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ORIGINAL ARTICLE

Anthocyanin changes in Hot Air drying of Strawberry

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ABSTRACT
Quality of dried crop is dependent on physical and biochemical changes in crop during drying process. The aim of this research was investigation the effect of drying parameters including slices thickness (3, 6 and 9mm), drying time (8, 9 and 10h) and temperature (62, 68and 74°C) on moisture and anthocyanin content of strawberry fruit. The fruit slices were dried in a cabinet air dryer. The measured properties of strawberry were significantly influenced by drying parameters. The moisture and anthocyanin content decreased with increasing the time and temperature as well as decreasing thickness of slices.
***Keywords**: Strawberry, drying, moisture content, anthocyanin.*

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INTRODUCTION

Strawberry fruit (*Fragaria ananassa*), a member of rose family, is a popular fruit grown in Iran and many other countries. In Iran, strawberry is generally produced in western part of country, especially Kurdistan province, with an annual fresh production of 40000 tons [14]. Due to respiration rate, softening and microbial spoilage of strawberry, this fruit has a short shelf-life, and usually about 30 to 40 percent of fresh fruit is corrupted, so trying to reduce these losses is necessary. On the other hand this fruit is highly seasonal and is available only in particular time of the year. Preservation of it can prevent the huge wastage and make that available in the off-season at remunerative price [7].
Drying is one of the oldest methods of food preservation and represents a very important aspect of food processing. Hot air drying is a food processing operation in which water is removed from a product by the action of heat in a dryer in which a stream of hot air is passed through the product in such a way so as to transfer heat and remove water from it. By moisture elimination, microbial spoilage and biochemical and physical deteriorative processes are slowed or almost stopped and the consequent decrease in weight and very often of volume, reduces storage, packing and transport associated costs [13].
Some physical and chemical properties are changed by this drying technique. Physical changes include discoloration of tissues, shrinking and deformation, migration of water soluble compounds, and Chemical changes include, loss of heat-sensitive products including vitamins and other nutrients, unfavorable reactions between components as well as enzymatic inactivation [9, 13].
A careful selection of drying operating conditions and evaluation of heat-damage to products is a very important issue in food processing and quality assurance practice [11].
Few studies have been published on deferent method of drying for strawberry, such as infrared drying [8], convective drying [2], freeze drying [12], and solar drying [7].
Strawberry is a good source of natural antioxidants and exhibits a high level of antioxidant capacity against free radical species [17]. The bene ts of these high antioxidant activity fruit include reduction of carcinogens in humans [2], protection against tumor development [10] and reversal of age-related effects on memory [1]. Anthocyanins are typically present at high levels in strawberries and are thought to

signi cantly contribute to the total antioxidative activity of this fruit [16]. Also the red color of strawberry is mainly due to the presence of anthocyanins. Total anthocyanin content, can vary among cultivars [4], and will change with any changes in fruit and treatments, such as oxygen treatment [18], cool storage [4], carbon dioxide treatment [9].
Thus, it is useful to determine the concentration of these compounds in fruits and the effect of the changes in drying parameters on the stability of pigments and other phenolic compounds. However there is not any study on changes of anthocyanin content of Kurdistan variety strawberry in hot air drying of that.
In this study, the effects of hot air drying parameters including temperature, time and thickness of slices on moisture content and anthocyanin changes of strawberry (Kurdistan variety) were determined.

MATERIAL AND METHODS

Sample preparation
Strawberry fruits were obtained from a local market in Sanandaj, Iran, and transported to laboratory (Islamic Azad University, Sanandaj, Iran) within 1 h. then they were sorted to eliminate unripe or damaged fruits, and selected for uniform color and size, and finally sliced into circular discs of 3, 5, 7 mm thicknesses using a mechanical slicer.
Drying experiments
In this study, the effects of air temperature (at 62, 68and 74 ˚C), slice thickness (3, 6 and 9mm) and drying time (8, 9 and 10 h) on moisture and anthocyanin content of strawberry slices were studied. Slices were dried in a cabinet air dryer. For each test, the dryer was started 30min before experiments in order to reach steady-state.
Moisture content measurement
The initial and final moisture content of samples were determined by using hot air oven method in 75 ˚C for 24 h according to following equation [14]:

$$MC = 100 \quad \frac{(W+W_1)-W_2}{W} \qquad (1)$$

Where W is net weight of sample taken (g), W_1 ia weight of dish (g), and W_2 is weight of dish plus oven dried sample (g).
Anthocyanin content measurement
For considering the changes of anthocyanin content of strawberry fruits, the Beer's law was used. The Beer's law is the linear relationship between absorbance and concentration of an absorbing species. When working in concentration units of molarity, this law is written as [15]:

$$A = \varepsilon CL \qquad (2)$$

Where A is the measured absorbance, ε is the wavelength-dependent molar absorptivity coefficient (m^2/mol), L is the path length (m), and c is the analyze concentration (mg/100g).
A strawberry sample (2g) was ground with 20ml of methanol in 1% Hcl, using a homogenizer, and centrifuged at 2000 rpm for 15 min. anthocyanin content was estimated as pelargonidin 3-glucoside at 510 nm in spectrophotometer, using a molar absortivity coefficient of 36000 [4].
Data analysis
All obtained data were subjected to the operations of ANOVA (analysis of variance) and treatment means were compared with Duncan's multiple range test at $P \leq 0.05$. The statistical operations were accomplished using SAS software version 9.1 (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

Analysis of data showed that the effects of slice thickness, temperature and time of drying on moisture content were significant ($P \leq 0.01$). Decreasing in thickness as well as increasing in temperature and time, decreased the moisture content of strawberry. Otherwise 3mm in thickness, 74˚ C in temperature and 10h in drying time, resulted the lowest rate of moisture content, 11.501%, 11.064% and 12.483%, respectively (Tables 1and 2). Similarly in an experiment conducted by Doymaz (2008), the effect of thickness and drying temperature on drying kinetic of strawberry was studied and a significant decrease in moisture was recorded by increasing the temperature and decreasing the thickness of slices. The required time for reduction moisture from 93.2% to 20% in 50, 55 and 65˚C was reported 1620, 1320 and 900 min, respectively. He also reported that the required time for whole fruit is 125% more than half.
Anthocyanin content of strawberry was statistically influenced by the temperature of dryer and thickness of strawberry slices, whereas the effect of drying time on anthocyanin content was not significant (Table 1).
With increasing the thickness of slices from 3 to 7mm, the amount of anthocyanin content was reduced from 20.265 to 18.62 mg/100g. Also application of 62˚C temperature resulted highest rate (20.573

mg/100g) of anthocyanin content which was about 14 percent higher than the recorded of that for 65°C (18.003 mg/100g). However there was no significant difference between 62 and 65°C temperature regarding anthocyanin content (Table 2). Similarly in an experiment conducted by Morales et al. (2014), the effect of drying temperature on anthocyanin content of strawberry was studied. They reported anthocyanin decreases equal to 37%, 50%, 52% and 55% for 60, 70, 80 and 90°C, respectively.
The best-fitting regression equation (Fig. 1) between moisture content and anthocyanin content showed that there is a high correlation (R^2=0.914) between them.

Table 1. Analysis of variance of dried strawberry characteristics affected by thickness, temperature and time

Source of variation	DF	mean squares	
		moisture content	anthocyanin content
Thick	2	263.293**	19.134*
Temp	2	203.205**	44.796**
Time	2	52.778**	10.569ns
Thick*temp	4	3.219**	1.426ns
Thick*time	4	0.145ns	0.57ns
temp*time	4	0.312ns	7.83ns
Thick*temp*time	8	4.534ns	1.716ns
Error	54	0.176	4.377
cv (%)		3.006755	10.81737

ns, * and **: Non significant and significant at 5 and 1% levels of probability, respectively.

Table 2. Main effects of thickness, temperature and time on moisture and anthocyanin content of strawberry

	moisture content (%)	anthocyanin content (mg/100g)
Thick		
7 (mm)	17.457 a	20.265 a
5 (mm)	12.85 b	19.134 ab
3 (mm)	11.501 c	18.62 b
temp		
62 (c)	16.53 a	20.573 a
68 (c)	14.214 b	19.442 a
74 (c)	11.064 c	18.003 b
time		
8 (h)	15.272 a	19.751 a
9 (h)	14.053 b	19.648 a
10 (h)	12.483 c	18.62 a

Values in each group of a column with the same letters are not significantly different at P ≤ 0.05 according to Duncan's multiple range test

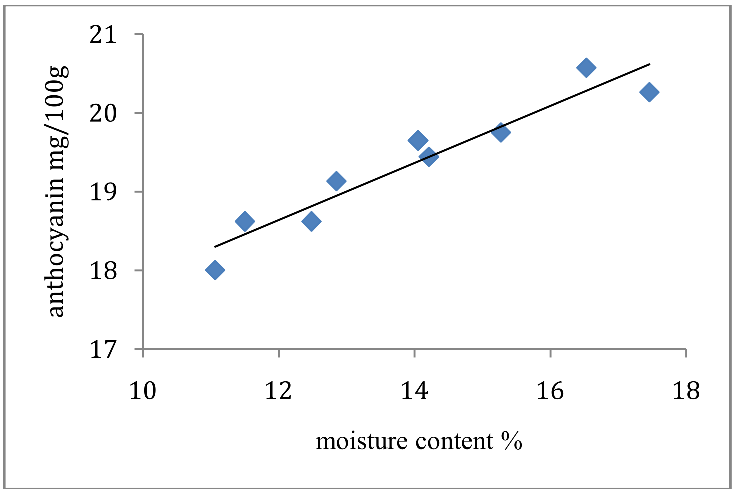

Fig. 1. Correlation between moisture and anthocyanin content of dried strawberry

CONCLUSION
Moisture and anthocyanin content of strawberry as a function of slice thickness, time and temperature were obtained experimentally. The measured moisture of strawberry was significantly influenced by drying parameters. Decreasing in thickness as well as increasing in temperature and time, decreased the moisture content of strawberry. Also the effect of thickness and temperature on anthocyanin content was significant. The anthocyanin content of fruit decreased with increasing the temperature and thickness of slices

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