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Effects of Sulphurization Duration of Doses and Cold Storage on SO_2 Content of Dried Apricot Fruits of cv. 'Hacihaliloglu'

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Abstract

e study was carried out between 2004 and 2005 years in Malatya Fruit Research Institute. e fumigation of 1600, 1800 or 2000 g SO_2 were applied for 6, 8, 10, 12 and 24 hr a er harvest on dried 'Hacihaliloglu' apricot fruits. e loss of SO_2, product moisture (%), product temperature, acidity (%), pH and the colour of the apricot fruits were determined a er the drying processes on the wooden trays following the SO_2 fumigation and during storage periods. e results showed that the average level of the SO_2 in the dried apricots was found as 2000 ppm a er fumigation as requirement of European regulations. Dried apricot fruits had 2174 ppm of SO_2 in 2004 and 1586 ppm of SO_2 in 2005 at the beginning of storage and these amounts were decreased to 1284 and 1091 ppm at the end of 12 months of storage in normal atmospheric conditions. e loss of SO_2 amount in dried apricots was found to be directly proportional with the initial quantity of SO_2. When the level of SO_2 in dried apricots was decreased to 1500 ppm, the quality of the product was also decreased and the colour of dried apricots are darkened. As a result of this study, can be recommended that the dried apricots including 2000 ppm SO_2 should be marketed a er 6 months of storage.

Keywords: dried apricot, sulphurization, storage, 'Hacihaliloglu'

Introduction

Turkey accounted 20.8% of the world apricot production in 2009 with 660 thousand tons production amount. The country ranks first in the world both for dried apricot production and export. In 2009, 97.876 tonnes of dried apricot were exported and this brought in 276.2 million US dollars of foreign currency revenue to Turkey (Unal, 2010). The great majority of this production takes place in the city of Malatya (Altindag *et al*., 2006; Ercisli, 2009)

To preserve yellow color and prolonged shelf life of dried apricots, sulphurization is necessary. Sulphurization of apricots in Turkey first began in Malatya in 1910s and the first scientific researches on applying SO_2 to apricots were carried out in 1942 at Ankara University (Gokce, 1966). More recently consumers throughout the world prefer more natural products. In this context, the majority of the countries which Turkey exporting apricots requires limited SO_2 levels in the dried apricot product. SO_2 has been limited to 2000 ppm in the Turkish Food Codex.

In a study of improving apricot sulphurization technologies; it was stated that the amount of SO_2 gas to be filled in the sulphurizing room depends on potential leaks from the room, the type of the product, maturity of apricots at harvest, whether it was sulphurized in wooden trays or frames, how it was stowed, the circulation of the air inside the sulphurizing room, the ratio of air/product in the room, the oxygen level in room atmosphere, room temperature and the process duration (Pala *et al*,. 1993). Among them, maturity degree of the fruit, sulphur concentration and process duration are main factors for success and it was advised to carry out sulphurization on wooden trays (Gokce, 1966; Pala *et al.,* 1993).

The main purpose of this study was to ascertain the necessary conditions towards ensuring the 2000 ppm SO_2 content in dried apricots which had been established as a legal obligation in Turkey and many other countries. Another purpose of the study was to detect the change in the SO_2 loss under normal storage conditions.

Material and methods

Fresh fruits of 'Hacihaliloglu' cultivar, which constitute approximately 73-80% of apricot trees in Malatya, were used as material. The fruits of this cultivar are medium size with 25-30 g of weight, are oval shaped and symmetrical; their skin color was determined as L^*: 65.59, a^*: 79.54, b^* : 41.40 with a yellow flesh color and they tend to form red cheeks. They had a thin skin and their resistance to transportation was good. Texture of the fruit flesh was hard. The fruits contain little juice, were very sweet with aroma, their pH was 4.5-4.8, total soluble solid was 24-28% and total acidity was 0.20-0.40%. The shape of the seeds was oval; their weigh between 1.7-2.2 g with sweet taste and they were not attached to the fruit flesh. In Malatya, these fruits mature by the second week of July (Asma, 2000).

Sulphurizing room with 2.5 x 2.5 x 2.2 m dimensions, which was constructed with the support of Aegean Exporters' Association, and sulphurization trays with 190 x 100 cm dimensions, were used in sulphurization studies (Fig. 1).

Fig. 1. A typical sulphurization room

Storage studies were conducted in the storage room that meets producer conditions with 6 x 6 x 3 m dimensions located in the Malatya Fruit Research Institute. Ascertaining of the apricot's market price was predicated with the records of Malatya Commodity Exchange.

The fruits were first evaluated according to their maturity criteria and those meeting these criteria were harvested. Placed upon wooden trays in the standard sulphurization room (Fig. 2), the apricots were subjected to SO_2 fumigation for different durations and doses. In the first year, one tons of fresh apricots were kept in the sulphurization room by burning 800, 1000, 1500, 1600, 1800 and 2000 g of SO_2 for 6, 8, 10, 12 and 12+12 hours. In the second year, the applications that deviated ± 400 ppm from the 2000 ppm level in the first process were eliminated and sulphur doses of 1500, 1600 and 1800 g were used. Apricots obtained at the end of the application that contained 1586 ppm and 2174 ppm SO_2 were selected and taken to be stored in open mass in a normal storage conditions without refrigerator (average temperatures are quite low and annual range 4-13°C) for 12 months. Temperature and moisture values of the storage place were recorded at the time of storing. Additionally; SO_2 levels, total acidity, pH, moisture analysis and color change analyses were carried out for every month by taking samples from the stored apricots. Thus, changes in these parameters were tracked on a monthly basis. At the same time, the market price of the product was tracked for one year to determine the price of the stored apricots.

Fig. 2. Apricots on wooden trays in sulphurization room

Results and discussion

Sulphurization studies

In the preliminary test carried out in 2004, the first year of the study, the doses and durations were determined for the second year study. In these tests, the amount of sulphurized apricots and the volume of the sulphurizing room were kept constant whereas doses and durations were changed (Tab. 1).

First year 800, 1000, 1600, 1800 and 2000 g of sulphur were burnt two times for durations ranging between 6 to 12+12 hours. The obtained results were given in Tab. 1. For per tons of apricots; when 800 and 1000 g of sulphur were burnt for 6 hours, apricot fruits had 1207 to 1499 ppm SO_2; when 1600 g were applied for 8 hours, apricots having 2245.5 ppm SO_2 were obtained. With regard to the burning of 1800 g of dose for 8 to 10 hours, the best results were gained by the application of 1800 g of dose for 10 hours. As a result of 8 and 10 hour, approximately 2059.5 ppm SO_2 was detected in dried apricots. In the application of 2000 g of sulphur, it was firstly detected that 2000 g of sulphur did not completely burn due to lack of oxygen in the 13.5 m^3 sulphurizing room (2.5 x 2.5 x 2.2). As a solution, 2000 g dose was applied two times in 1000 g pieces for 12 hours. It was detected that in this dose sulphur content in the dried apricot exceeds approximately 2500 ppm. It should also be taken into consideration that this dose caused a waste of time. On the other hand, 2000 g of sulphur was burnt at one time in 25.7 m^3 sulphurizing room and sulphur content in these products was found to be 2551 ppm.

In the second year of the study, applications resulted with 2000±400 ppm SO_2 for the apricots were eliminated and 1500, 1600 and 1800 g SO_2 doses were applied for three times on apricot fruits in this year and the results were given in Tab. 1. As the result of the studies, it was determined that 1500 g dose was not adequate to obtain 2000 ppm SO_2 in dried apricot whereas 8 and 12-hour applications of 1600 g dose as well as 10 and 12-hour applications of the 1800 g dose were appropriate to obtain 2000 ppm of SO_2 content in dried apricots.

Tab. 1. The effects of sulphure application duration and doses on SO_2 content in dried apricot cv. 'Hacihaliloglu' (2004 and 2005)

2004					2005				
Apricot amount (ton)	Time (hr)	Sulphur (g)	Room volume (m^3)	SO_2 in apricot (ppm)	Apricot amount (ton)	Time (hr)	Sulphur (g)	Room volume (m^3)	SO_2 in apricot (ppm)
1	6	800	13.5	1195	1	12	1500	13.5	1889
1	6	800	13.5	1220	1	12	1500	13.5	1710
1	6	1000	13.5	1568	1	12	1500	13.5	1771
1	6	1000	13.5	1430	1	8	1600	13.5	1923
1	8	1600	13.5	2100	1	8	1600	13.5	2088
1	8	1600	13.5	2391	1	8	1600	13.5	2000
1	12	1600	13.5	2480	1	12	1600	13.5	2063
1	12	1600	13.5	2460	1	12	1600	13.5	2242
1	8	1800	13.5	1772	1	12	1600	13.5	2158
1	8	1800	13.5	1710	1	8	1800	13.5	1995
1	10	1800	13.5	1850	1	8	1800	13.5	1996
1	10	1800	13.5	2269	1	8	1800	13.5	2012
1	12+12	2000	13.5	2481	1	12	1800	13.5	2125
1	12+12	2000	13.5	2550	1	12	1800	13.5	2216
1	12	2000	25.7	2526	1	12	1800	13.5	2065
1	12	2000	25.7	2576					

Storage Studies

In the first year of the study, dried apricot fruits including 2174 ppm SO_2 were stored in normal storage as described before. The monthly change of sulphur content in these apricots was given in Tab. 2. At the end of 12 months, it was detected that a loss of 890 ppm SO_2 took place in these stored apricots. The sulphur loss did not follow a steady rate in months and the loss in hot months increased up to two folds compared to cold months. The greatest losses were recorded in August and September (Tab. 2).

During the storage study carried out in the second year, sulphurized and dried apricot samples including 1586 ppm SO_2 were taken into the storage in order to determine the SO_2 level when the product starts to have brown color. At the end of one year storage, a loss of 395 ppm SO_2 took place in this product and the monthly changes were given in Tab. 3.

In this experiment it was detected that partial brown coloring started in the 10% portion of the product which had 1500 ppm SO_2 content. Since the fully matured head parts of the fruits have low SO_2 intake, the brown coloring started especially at these points. When the sulphur content was reduced to 1300-1400 ppm, brown colorings were observed in approximately 20-30% portion of the fruits. When SO_2 content was reduced further to 800 ppm, 80-90% of the fruits became completely brown and 10% of the fruits were observed to show black coloring (Fig. 3).

During the storage study of the second year; changes in temperature, moisture and temperature of storage room were similar to the study conducted in the first year; however, there was also less SO_2 loss in the second year. The main reason for this was the lower SO_2 content of the apricot which was stored in the second year. Whereas

Tab. 2. Monthly changes of storage conditions and some parameters in the dried apricot stored in 2004

Months	SO_2 (ppm)	SO_2 loss (%)	Storage temperature (°C)	Product temperature (°C)	Storage room moisture (%)	Product moisture (%)
August	2174	0.0	27.2	25.7	35	14
September	2052	5.6	23.5	17.7	37.5	14
October	1952	10.2	19.8	17.6	39.2	14
November	1878	13.6	13.5	10.7	46.0	15
December	1813	16.6	6.7	3.8	56.5	15
January	1758	19.1	3.3	2.2	63.5	15
February	1689	22.3	1.9	-0.6	58.0	16
March	1607	26.1	8.7	7.5	50.0	16
April	1529	29.7	23.5	19.2	32.0	16
May	1440	33.8	24.5	23.9	25.5	15
June	1374	36.8	26.5	23.0	24.0	15
July	1284	40.9	23.3	22.0	24.5	15

Tab. 3. Monthly changes in some parameters in the dried apricot stored in 2005

Months	SO_2 (ppm)	SO_2 loss (%)	Storage temperature (°C)	Product temperature (°C)	Storage room moisture (%)	Product moisture (%)
August	1586	0.0	26.5	24.2	32.0	15
September	1495	5.7	22.4	23.0	23.6	15
October	1449	8.6	18.4	19.3	26.8	15
November	1381	12.9	9.5	11.0	47.5	16
December	1351	14.8	1.4	2.4	49.3	16
January	1325	16.5	0.4	-0.5	50.0	16
February	1290	18.7	2.5	3.0	54.3	15
March	1265	20.2	7.0	7.7	47.0	15
April	1247	21.4	15.4	15.2	42.0	15
May	1229	22.5	15.2	15.6	48.0	15
June	1212	23.6	18.1	18.2	44.0	15
July	1191	24.9	22.2	21.5	33.0	16

Tab. 4. Monthly changes of some physical and chemical properties in stored dried apricot

Months	pH	Titratable acidity (%)	L*	a*	b*	a*/b*
August	5.50	1.85	37.48	10,51	21.38	0.49
September	5.49	1.71	37.68	8,92	19.07	0.47
October	5.14	1.61	36.30	8.57	18.06	0.47
November	5.35	1.54	34.38	8.45	17.19	0.49
December	5.21	1.63	34.55	9.00	17.50	0.51
January	5.24	1.69	35.26	7.97	17.11	0.47
February	5.18	1.70	36.58	8.49	17.28	0.49
March	5.17	1.68	36.19	8.25	17.86	0.46
April	5.27	1.63	35.12	8.30	18.10	0.45
May	5.20	1.62	34.57	8.87	17.01	0.52
June	5.13	1.64	34.98	9.03	16.70	0.53
July	5.20	1.68	35.04	9.70	17.34	0.55

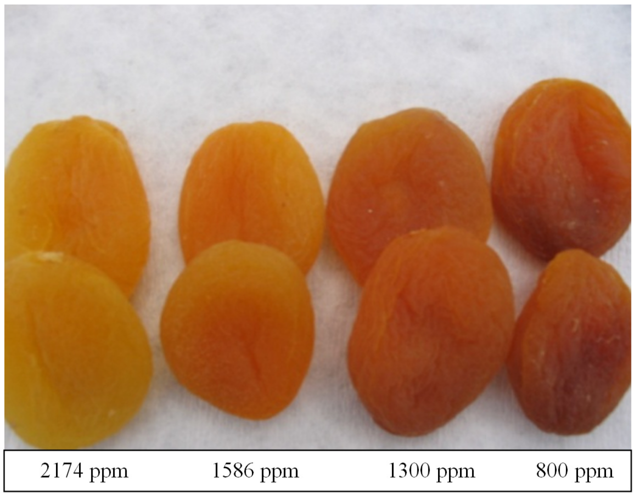

Fig. 3. Relationships between sulphure content and browning of dried apricot

apricots with 2174 ppm SO_2 content were stored in the first year, those with 1586 ppm SO_2 content were stored in the second year. The amount of absorbed SO_2 does not stay constant during the storage and its amount gradually decreases in accordance with the conditions during the material's storage (Stadman *et al.,* 1946). The main reason for the SO_2 loss in dried apricot throughout the storage is change of SO_2 to sulphate (SO_4^{-2}) due to oxidization (Davis *et al.,* 1973).

The results obtained from the present study were in accordance with the previous studies. In the study of researching mass storage capabilities of dried apricot fruits, it was reported that the absorbed SO_2 content was expected to decrease during storage depending on the temperature (Karacali and Sen, 2002; Mahmutoglu *et al*., 1996). A study conducted on apricots which were stored after sulphurizing showed a 360 ppm (11%) decrease in cold storage, 855 ppm decrease (25%) in normal storage following a 9 months period in the first year whereas it showed a 39 ppm (3%) decrease in cold storage and 468 ppm (34%) decrease in normal storage in the second year. The low temperature in the cold storage was effective in preserving the SO_2 content of the product (Karacali *et al.,* 2003). In another study reported the SO_2 loss in sulphurized apricot after 18 months of storage as 45-50% in normal storage and 25% loss in cold storage conditions (Ozturk, 2003). Similar statements were also made by Bolin and Jackson (1985).

In the measurements, product temperature and storage temperature did not show a significant difference, only a difference of 2-3°C were observed (Tab. 2 and 3). Even though storage moisture changed with the air moisture, it did not quite affect the product moisture. During storage pH is decreased and titration acidity increased slowly (Tab. 4). Karacali *et al*. (2003), on the other hand, report that the titratable acidity of apricot fruit increases especially rapidly towards the end of storage period and that total acidity of normal stored fruits turned out to be higher than cold stored fruits.

The most significant change during the storage was observed on b* and a*/b* color values. As a result of the SO_2 loss in the apricot; the b* value indicating yellow color of the fruit, decreased from 21.14 to 17.34 and the fruit color tended to become red or brown. In the study con-

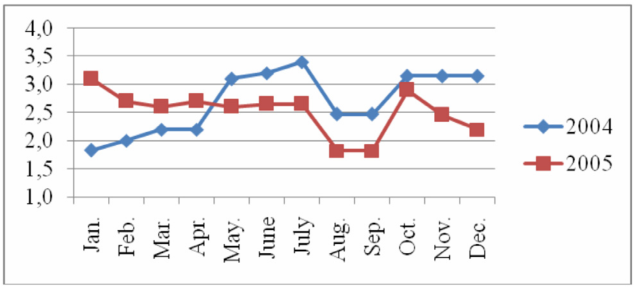

Fig. 4. Monthly changes in the second class dried apricot prices between 2004-2005 (US$)

ducted by Karacali *et al*. (2003), this change in the b* value was also emphasized. The increase of a*/b* value shows that the yellow color of the fruit is diminishing and dark red color is rising. Previously, L*, a*, b* and a*/b* values in 2000 ppm sulphurized 'Hacihaliloglu' apricot were measured as 39.92, 6.00, 19.76 and 0.29, respectively (Ozturk, 2003).

In another study conducted in Malatya and its surrounding areas, colors of 15 cultivars of dried apricots were measured as per CIE L*, a*, b* system; L* value ranged between 25.97 - 42.58, a* value ranged between 7.24 - 18.53 and b* value between 9.49 - 28.79. In the same study, surface color values of the 'Hacihaliloglu' apricots including 1600 ppm SO_2, the most widely dried apricot in Malatya, were ascertained as 38.14 for L* value, 7.24 for a* value and 23.26 for b* value (Akca *et al.*, 1999).

Determining the market price

The market price of the dried apricot was determined in accordance with the records of Malatya Commodity Exchange. Whereas the dried apricot was sold for 1.83 US$ per kg dried fruits in the market in January 2004, it increased to 3.20 US$ in June due to the late frosts of spring. The price decreased to 2.47 US$ in August and September and then increased back to 3.15 US$ between October and January. In February and March, prices started to fall. The fact that the late frosts of spring did not happen caused the price fall down to 1,82 US$ in August and September in the next year (Fig. 4). In both years, prices tended to fall in August and September and increase in October and November. Therefore, as long as no extraordinary developments take place, selling the stored apricots in October and November would be beneficial for the producers.

Conclusions

In order to obtain the more quality dried apricots containing 2000 ppm of sulphur, the amount of sulphur to be burnt should be between 1600-1800 g per tons of dried apricots. The sulphurization room should be 250 x 250 x 220 cm dimensions for one ton of apricot. At least 40% of the sulphurization room's volume should be left empty. Apricots should be placed in the room with wooden trays in a single line. When conditions were met, optimum sulphurization duration was determined as 8 hours. A partial decrease in the pH of stored apricots and an increase in % titration acidity in connection to this was observed. b* and a*/b* levels also changed in connection with the sulphur dioxide loss. It has been concluded that the most appropriate period for the producers to market their products from the highest price was the September-October period.

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