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Effects of various sulphuring methods and storage temperatures on the physical and chemical quality of dried apricots

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ABSTRACT

The effects of different sulphuring methods, i.e. sulphuring by "burning the elemental sulphites (BES)," "SO_2 gas from liquified SO_2 tank (SG)" and "dipping into sodium metabisulphite solution (DSM)" on the colour (brown colour formation and carotenoid degradation) and the loss of SO_2 in apricots from Hacıhaliloğlu and Kabaaşı varieties stored at 5, 20 and 30 °C for a year were investigated. There were significant effects of variety, sulphuring method and especially storage at 30 °C on the brown colour formation and loss of SO_2 ($P < 0.05$). As storage temperature–time increased, β-carotene content decreased. Sulphuring methods and variety did not show significant effect on β-carotene content ($P > 0.05$). The changes in L^*, b^* and C^* values were directly associated with β-carotene content and browning values. The most suitable method for all samples, except for Hacıhaliloğlu variety stored at 30 °C (BES), is SG, because the samples retained their attractive golden yellow colour during storage.

1. Introduction

Dietary carotenoids provide health benefits in decreasing the risk of some diseases, particularly certain cancer and eye disease (Krinsky & Jhonson, 2005). Therefore, there is an intense interest in apricots which contain high amount of β-carotene whose beneficial effects are due to its role as an antioxidant (Krinsky & Jhonson, 2005). Apricots are grown in many countries in the world. The major apricot producers are Turkey, Iran, Pakistan, Uzbekistan and Italy. Turkey produces approximately 20% of the world's fresh apricot (716000 metric tons, Mt) and 84% of the dried apricots (DAs) (98000 Mt) (FAOSTAT, 2011). The primary importer countries of Turkish DAs with a share of ca. 60% are the USA, England, Russia, Germany, France and Australia (Asma, 2011).

Apricots have a short harvest season and a limited time of storage even under suitable conditions (Ihns, Diamante, Savage, & Vanhanen, 2011). To supply the apricots to consumers during throughout the year, different preservation methods, i.e. freezing, canning (Ihns et al., 2011), drying without any treatment and drying after sulphuring, are commonly applied. Compared to DAs without any treatment, sulphured-DAs are much more preferred due to their characteristic golden yellow colour and taste. Sulphur dioxide (SO_2) could retard the β-carotene breakdown in DAs during drying and storage (Eheart & Sholes, 1945; Türkyılmaz, Tağı, & Özkan, 2013). Additionally, SO_2 provides both inhibition of the enzymatic browning during drying and protection from non-enzymatic browning reactions as well as prevention of microbial deterioration during drying and storage.

In Turkey, almost all of the commercial DA production is carried out in the city of Malatya, located in the south-eastern part of Turkey. In Malatya, Hacıhaliloğlu and Kabaaşı varieties are the main apricot varieties destined for drying. Among these two varieties, Hacıhaliloğlu cultivar is the most commonly grown cultivar in Malatya and is very suitable for drying due to its high soluble solid content (°Brix) which is between 24 and 28. In Malatya, 70% of the apricots destined for drying belong to this cultivar. The fruits are medium-sized; 25–35 g, oval-shaped, and skin and flesh colours are yellow. Fruit has a tendency to be red blushed. Flesh is firm-textured, low in water content, and very sweet and aromatic (Asma, 2011). Kabaaşı is the second most important cultivar for drying, which has larger fruit in size and weight (30–35 g), has

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sweet taste and is also more resistant to spring late frosts than the other apricot cultivars, especially Hacıhaliloğlu (Asma, 2011).

In Malatya, Hacıhaliloğlu and Kabaaşı cultivars have always been sulphured by BES due to the simplicity of its application. However, there are some disadvantages of this sulphuring method. The maximum limit of 2000 mg SO_2 per kg of DAs is accepted by most countries, including Turkey (Codex Alimentarius Commission, 1989). However, DAs sulphured by BES method often contain much higher or lower SO_2 content than the legal limits because many factors affect the sulphuring process (e.g. variety, temperature and SO_2 gas content in the sulphur house). In fact, McBean, Johnson, and Pitt (1964) reported that the apricots sulphured by BES could contain SO_2 from less than 1000 to over 6000 mg kg^{-1}. In BES method, elemental sulphites could not always burn completely due to insufficient oxygen in sulphur house. Moreover, temperature and SO_2 concentration in sulphur house could not be controlled by BES method. As a result, losses of time, labour and quality occur with the BES method.

In this study, the effects of three sulphuring methods, i.e. sulphuring by SG and DSM as well as BES, on the colour and loss of SO_2 in Hacıhaliloğlu and Kabaaşı varieties during storage at 5, 20 and 30 °C for a year were investigated. Meanwhile, the correlations between reflectance colour values, total colour changes (ΔE) and browning index with browning values and β-carotene contents of the DAs were also determined.

2. Materials and methods

2.1. Materials

Fresh apricots (*Prunus armenica* L., var. Hacıhaliloğlu and var. Kabaaşı) were provided by the Institute of Fruit Research Center at İnönü University, Malatya.

2.2. Sulphuring methods and sun-drying

Taking into consideration the maximum limit (2000 mg SO_2 per kg of DAs) set by Codex Alimentarius Commission (1989), the production of the samples containing SO_2 at 2000 mg kg^{-1} level by using three different sulphuring methods given below was intended (Table 1). However, since the processing parameters of the sulphuring methods were not known at the time of study and SO_2 absorption of each apricot was different, SO_2 concentrations of the samples were not accurately 2000 mg SO_2 per kg of DAs, but were close to this value.

2.2.1. Sulphuring by "burning elemental sulphites" (BES)

Fresh apricots that are in uniform size and free of physical damage were selected before sulphuring process. After sorting for sound fruits, fresh fruits (20 kg) were placed in plastic crates (90 × 180 cm) in single layer and the crates were stacked on top of each other in the sulphur house. Then, the elemental sulphur was burned and the gate of sulphur house was closed. The amount of elemental sulphur burned was 1.8 kg ton^{-1} and the apricots were exposed to the fumes of SO_2 in sulphur house for 12 h.

2.2.2. Sulphuring with "SO_2 gas from liquified SO_2 tank" (SG)

Similar to BES method, after sorting for sound fruits, fresh fruits (20 kg) were placed in plastic crates (90 × 180 cm) in single layer and the crates were stacked on top of each other in the sulphur house. Then, the apricots were sulphured by SG. The amount of SO_2 gas given to sulphur house was controlled by measuring the reduction in the weight of the liquified SO_2 tank on a steelyard. After target level (1–1.5 kg) of SO_2 was given to sulphur house, valve of the tank was closed. The apricots were exposed to the fumes of SO_2 in sulphur house for 3.5 h. In this method, a fan was used to ensure homogenous distribution of SO_2 gas in sulphur house, while a heater was used to accelerate the SO_2 absorption by the apricots.

2.2.3. Sulphuring by "dipping into sodium metabisulphite ($Na_2S_2O_5$) solution" (DSM)

In this method, the apricots (13 kg) were dipped to the $Na_2S_2O_5$ solution for 35 min. For the preparation of $Na_2S_2O_5$ solution, 3 kg of $Na_2S_2O_5$ was dissolved in 25 L water.

2.3. Drying

After sulphuring, the sulphured apricots in plastic crates in single layer were removed from the sulphur house and placed under direct sunlight. On the 3th day of drying, the pits were removed by squeezing the fruit by hand. At the end of 6 days of sun-drying, the drying process was terminated.

2.4. Sampling

The sulphured and sun-dried apricots were brought to Ankara University Food Engineering Department where all storage studies as well as physical and chemical analyses were carried out. The samples sulphured by different sulphuring methods were left in enclosed containers at 20 ± 0.5 °C for 2 weeks to equilibrate moisture content.

A 1-kg of the apricot samples were placed in each plastic bag made of polyethylene [gas permeability 7.5 dm^3 O_2 $(cm^2\ day)^{-1}$; water vapour permeability 15 g H_2O $(m^2\ 24\ h)^{-1}$]. The bags were then hot sealed and placed to carton package with a capacity of 2 kg. The selection of the package materials was made by taking into account of the package materials used by the packing houses in Malatya.

Table 1
Some physical and chemical properties of the dried apricot samples sulphured by three different methods before storage.

Properties	BES[a]		SG[b]		DSM[c]	
	Hacıhaliloğlu	Kabaaşı	Hacıhaliloğlu	Kabaaşı	Hacıhaliloğlu	Kabaaşı
Moisture (%)	22.58 ± 0.02Aa[d]	19.01 ± 0.00Ab	22.27 ± 0.10Aa	17.34 ± 0.29Bb	21.27 ± 0.03Ba	15.41 ± 0.23Cb
a_w (water activity)	0.69 ± 0.00Aa	0.62 ± 0.01Ab	0.68 ± 0.00ABa	0.60 ± 0.00Bb	0.66 ± 0.01Ba	0.56 ± 0.00Cb
pH	4.28 ± 0.04Ba	3.81 ± 0.03Bb	4.15 ± 0.02Ca	3.77 ± 0.04Bb	4.86 ± 0.02Aa	4.60 ± 0.02Ab
Titratable acidity (g 100 g^{-1} dry weight)	1.73 ± 0.05Ab	2.04 ± 0.12Aa	1.79 ± 0.08Ab	2.06 ± 0.10Aa	1.21 ± 0.07Bb	1.76 ± 0.05Ba
SO_2 content (mg kg^{-1})	2364 ± 20.2Bb	2609 ± 33.0Aa	2573 ± 17.3Aa	2218 ± 19.7Bb	1703 ± 27.6Ca	1456 ± 31.0Cb
Browning value (A_{420} g^{-1} dry weight)	0.27 ± 0.01Ba	0.24 ± 0.00Bb	0.25 ± 0.01Ba	0.21 ± 0.04Bb	0.37 ± 0.01Aa	0.28 ± 0.00Ab
β-Carotene content (mg 100 g^{-1} dry weight)	31.3 ± 1.02ABa	28.1 ± 0.94ABb	30.0 ± 1.01Ba	26.4 ± 1.11Bb	33.3 ± 0.9Aa	30.8 ± 1.27Ab

a–b: values with different letters within lines indicate significant difference between varieties (Duncan test, $P < 0.05$).
[a] BES : sulphuring by "burning the elemental sulphites".
[b] SG : sulphuring by "SO_2 gas from liquified SO_2 tank".
[c] DSM: sulphuring by "dipping into sodium metabisulphite solution".
[d] A–C: values with different letters within lines indicate significant difference between sulphuring methods (Duncan test, $P < 0.05$).