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Effects of Moisture Contents and Storage Temperatures on the Physical, Chemical and Microbiological Qualities of Non-Sulfitted Dried Apricots

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ABSTRACT
This study was conducted to determine the changes in the physicochemical and microbiological qualities of the non-sulfited sun dried apricots (NSDAs) at three different moisture contents (MCs, 13.7, 23.5 and 27.0%) and at four different storage temperatures (4, 10, 20, and 30 °C) for 12 months in bulk and packaged samples. NSDAs were subjected to physical (moisture, water activity, pH and reflectance colour values), chemical (browning formation, β-carotene, and acidity), and microbial (counts for total aerobic mesophilic and psycrofilic bacteria, yeast and mould, xerofilic mould and yeast, osmophilic yeast, lactic acid bacteria, *Enterobacteriaceae*, *Staphylococcus-Micrococcus* spp.) analyses at one-month time intervals. Results indicated that while the fastest brown colour formation occurred in the samples containing 23.5% MC and stored at 30 °C, the browning decelerated below 10 °C. No significant change was observed in β-carotene contents of NSDAs during storage ($P>0.05$). After rehydration, osmophilic yeast count of NSDAs increased by 2.5 log colony-forming units (cfu/g). Significant reductions were observed in the microbial loads of the samples at 23.5 and 27.0% MCs with the decreasing water activity ($P<0.05$) during storage and increasing storage temperatures. However, yeast and mould counts exceeded 5.0 log cfu/g of the samples containing 27.0% MC after 2-months storage at 20 °C. Overall, we suggest that MC and storage temperature for NSDAs should be below 23.5% and 20 °C to achieve high microbial and physicochemical qualities for a year, respectively.

Keywords: Dried apricots, Colour, Water activity, Browning index, β-carotene content, Yeast and mould counts

1. Introduction

Sulfur dioxide (SO_2) treatment of apricots before drying not only prevents enzymatic and non-enzymatic browning, but also prevents microbial spoilage during drying and storage. Aside from these valuable benefits, the adverse health effects of SO_2 have been well-documented for asthmatic patients (Rose 2007). For the last decade, because of increasing consumer demand towards minimally processed and additive free products, NSDAs (Non-sulfited dried apricots) have become more prominent. However, compared to sulfited apricots, NSDAs are more susceptible to chemical and microbial deteriorations during storage at very high MC (over 34%) (Alagöz et al. 2015).

The Codex Alimentarius (Codex Alimentarius Commission 2019) requires that maximum MC of untreated sun-dried apricot should not exceed 20%, while this limit is 22% for Turkish standard (TS 485 2019). Although the NSDAs are sun-dried until their MCs are generally reduced to 10.0–13.0% for long-term storage, dried apricots with high MC (over 25%) are more desirable because of their soft mouth-feel (Davis et al. 1973; Asma 2007). Dried apricots with 25% MC have been preferred due to their softer and tender texture (Davis et al. 1973). NSDAs are rehydrated before marketing because of consumer demand for higher moisture containing dried products (Davis et al. 1973). However, NSDAs at high MCs are susceptible to microbial deteriorations especially by yeasts and molds. Also, unlike golden yellow coloured-sulfited apricots, NSDAs colour become more brown due to the browning reactions take place during sun drying, and at high storage temperatures and/or for prolonged storages (Özkan et al. 2016).

The effects of factors such as MC (Sağırlı et al. 2008), drying temperatures (Ihns et al. 2011), sulfitting methods (Coşkun et al. 2013) and SO_2 content (Türkyılmaz et al. 2012) on the various quality parameters have been studied. On the contrary, there are only a few studies on NSDAs. Alagöz et al. (2015) investigated the effects of various sorbic acid levels (488–1087 mg/kg) on the chemical and microbial qualities of NSDAs (27.2–34.3% MCs) stored at 5–30 °C. Elmacı et al. (2008) studied the chemical and sensory quality changes of modified atmosphere packaged NSDAs (17.5% MC) during storage at 5–25 °C.

However, no information is available concerning the effect of low and intermediate MCs (13.7–27.0%) on the physicochemical and microbial properties of NSDAs stored in bulk and packaged. Therefore, considering both Codex Alimentarius and TS 485 limit for MC, the aim of the present study was to investigate the changes in MCs, water activity (a_w), brown color, reflectance surface color, β-carotene content, total mesophilic aerobic, psychrophilic aerobic bacteria, total yeast and molds, xerophilic yeast-mould, osmophilic yeast, lactic acid bacteria, *Staphylococcus-Micrococcus* spp and *Enterobacteriaceae* NSDAs with various MCs (13.7, 23.5 and 27.0%) during 12 months-storage at various temperatures (4, 10, 20 and 30 °C).

2. Material and Methods

2.1. Materials

Apricots (*Prunus armeniaca* L., var. *Hacıhaliloğlu*) that contained no preservatives were supplied by Malatya Apricot Research Foundation.

Chemical and Reagents. β-carotene was purchased from Sigma-Aldrich Co. (St. Louis, MO, USA) and HPLC grade liquid chromatography reagents, culture media, and all other analytical grade chemicals and reagents were obtained from Merck Co. (Darmstad, Germany). Aluminum phosphide was obtained from Platin Kimya, Inc (Istanbul, Turkey). Fresh apricots (*Prunus armeniaca* L., var. *Hacıhaliloğlu*) were supplied by Malatya Apricot Research Foundation.

2.2. Drying and fumigation

Fresh apricots (*Prunus armeniaca* L., var. *Hacıhaliloğlu*) were sun-dried for 6 days in Malatya. At the 3rd day of drying, semi-dried apricots were hand-squeezed to remove the pits and then continued for sun-drying for three 3 more days. NSDAs samples (120 kg) were put in a closable container and then left in a temperature-controlled room at 20 °C for one month so that they could equilibrate for MC. Then, the damaged ones, excessively soft and hard, and light and dark coloured dried apricots were removed. NSDAs were loosely put in crates and then fumigated to eliminate the insects and larvae present, using 2 tablets (6 g/each) containing aluminium phosphide (57%, w/w each) (Tamtoxin, Platin Kimya, İstanbul, Turkey) for each m^3 space in a confined room at room temperature for 3 days. A flow diagram of processing and storage of NSDAs is shown in Figure 1.

2.3. Rehydration

The rehydration of dried apricots was carried out on a conveyor system equipped with spray washing system using tap water at 20 °C. After rehydration, NSDAs were held in plastic storage crates at ambient temperature for 4 days for the absorption of moisture on the surface of dried apricots. To increase the MC from 13.7% to the targeted MCs (23.5 and 27.0%), rehydration was carried out in two and three steps respectively, to avoid skin peeling of the apricots. Finally, rehydrated apricots were transferred into closable plastic containers to equilibrate the respective MCs at 20 °C for 2 weeks. Following the rehydration, moisture analysis was carried out to monitor the final MC. As stated before, a part of NSDAs was kept at 13.7% to mimic the MC (10.0–13.0%) of NSDAs for long-term commercial bulk storage (Asma 2007), while MCs of 23.5 and 27.0% were mimic the commercially marketed packaged NSDAs, although these two MCs were above the both Codex Alimentarius and TS 485 limits.

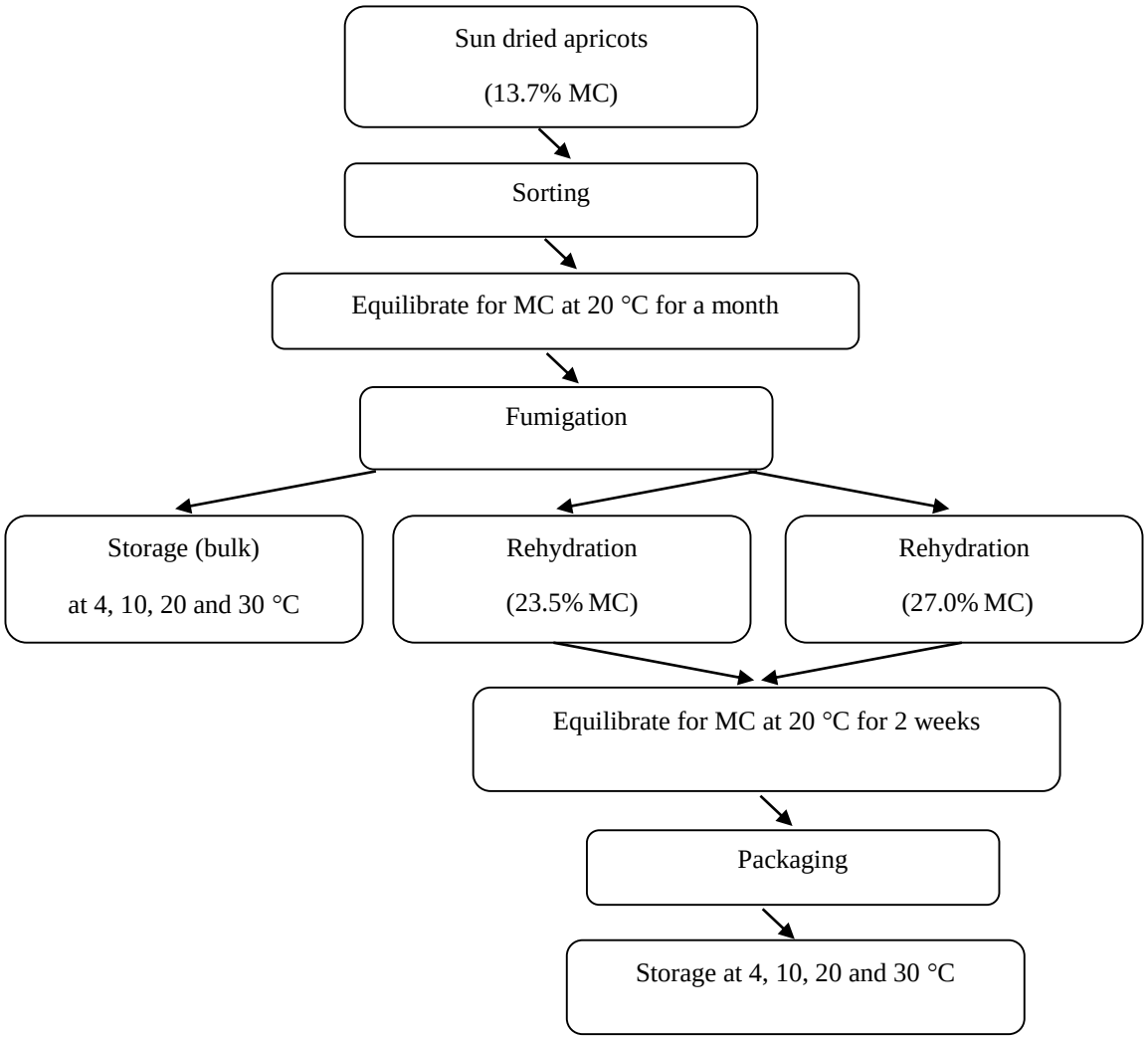

Figure 1- Flow diagram of the processing and storage of non-sulfitted dried apricots

2.4. Packaging and storage

For the packaged storage, 400-g samples at 23.5 and 27.0% MCs were placed in polystyrene trays (14 x 22 x 2.5 cm) which was then covered with PVC film (moisture permeability: 500 cm^3/cm^2.day and O_2 permeability: 20 000 dm^3 O_2/cm^2.day) to mimic consumer packaging. The PVC film was applied one layer and stretched moderately to minimize permeability change. For the bulk storage, a 10-kg sample at 13.7% MC was transferred into temperature controlled incubators (Sanyo MIR 153 and 253, Gunma, Japan) at 4, 10, 20 and 30 ºC ± 0.5 °C to mimic the commercial bulk storage conditions for a period of 12 months. For each sampling time, samples (2 packages) were randomly taken out of the storage for the various physical, chemical and microbiological analyses given below. To obtain a homogeneous sample, a-400 g sample was passed twice through a meat grinder (Tefal Maxi Power 1800 W, France) with 4 mm orifices.

2.5. Moisture Analyses, Water Activity, pH and Titratable Acidity

The MCs of NSDAs were determined using 5 g homogenized sample which was dried in a vacuum oven (Heraeus VT 6025, Hanau, Germany) at 70 °C ± 0.5 °C for 14 h with the AOAC 934.06 method (AOAC 2000). Moisture measurements were replicated four times. The MCs of the samples throughout storage was determined based on the weight changes of NSDAs due to moisture loss. Each time, 20 pieces of NSDAs for each storage temperature from the packaged and bulk stored samples were randomly picked and their weights were recorded. After weight measurements, the same 20-piece samples were immediately placed in the plastic bags which were then hot-sealed and returned to the respective incubators for the future moisture determinations. For the bulk-stored samples, these sub-samples were directly transferred in the incubators without any plastic bags.

The water activities of the homogenized NSDA samples were measured with a hygrometer (AquaLab 3, Decagon Devices, Pullman, USA) with an accuracy ± 0.003 at 25 °C. The pH of the samples was measured using a pH meter (WTW Inolab, Weilheim, Germany). The titratable acidity was measured by the method (942.15) given by AOAC (2000), and the results were expressed as "g anhydrous citric acid/100 g sample".

2.6. Browning measurement

Brown colour formation was determined by the method outlined by Baloch et al. (1973). Details of this analysis were given in Coşkun et al. (2013). Briefly, water soluble brown pigments were extracted with acetic acid containing formaldehyde and then the absorbances of supernatants were determined at 420 nm for brown colour and 600 nm for turbidity with a UV-VIS spectrophotometer (Thermo Spectronic Helios-α, Cambridge, England). Calculation of the browning was based on the difference between the absorbances at 600 and 420 nm. The browning value was expressed as "absorbance at 420 nm/g sample dried weight (DW)".

2.7. β-carotene analyses

2.7.1. Extraction

β-carotene was extracted by the method outlined in Sadler et al. (1990). A 10 g (±0.01 g) homogenized sample in 20 mL distilled water was rehydrated at +4 °C overnight and then homogenized at 13 500 rpm using a benchtop homogenizer (Heidolph SilentCrusher M, Schwabach, Germany) for 2 min. Calcium carbonate (0.2 g) as a neutralizing agent was added onto a-2 g homogenized sample in polypropylene centrifuge tube containing 25 mL extraction solvent (hexane:acetone:ethanol; 25:50:25, v/v/v). The tube was then agitated on an orbital shaker (Heidolph Unimax 2010, Schwabach, Germany) at 220 rpm until the residue became completely colourless (ca. 15 min). 5 mL distilled water was added onto the yellowish-orange extract which was then centrifuged at 9400 *g* at +4 °C for 15 min to separate the polar and nonpolar layers.

2.7.2. Preparation of sample for HPLC

The upper non-polar hexane layer (5 mL) containing β-carotene was pipetted to an amber coloured vial. The hexane was evaporated under a stream of nitrogen at 40 °C (Caliper TurboVap LV, Hopkinton, MA, U.S.A.). The resulting residue was dissolved in 200 µL tetrahydrofuran (THF) with 0.1 g/L buthylated hydroxytoluene (BHT) and then diluted with 1800 µL methanol. After filtration through a 0.22-µm polytetrafluoroethylene (PTFE) filter (Sartorious AG, Goettingen, Germany), the extract was immediately injected to HPLC.

2.7.3. Instrumentation and chromatography

For the separation and quantification of β-carotene, high performance liquid chromatography (HPLC, Agilent 1200 series, Waldbronn, Germany) with the following equipments were used: A binary pump, a photo diode array (PDA) detector, a thermostatted auto-sampler, a degasser and a thermostatted column compartment. Agilent 1200 series ChemStation rev.B.02.01 software was used to process the chromatographic data. Isocratic separation was carried out on a C_{30} (5 µm) column (250 x 4.6 mm) (Phenomenex, Inc, Los Angeles, CA, U.S.A.) with a C_{30} (5 µm) guard column (10 x 4.0 mm) (Phenomenex, Inc). Methanol:tert-buthylmethylether (65:35, v/v) solution containing 0.1 g/L BHT was the mobile phase. The flow rate was 1.0 mL/min, sample injection volume was 50 µl and column temperature was set at 30 °C. The detector was set at 450 nm. The other details are given in Türkyılmaz et al. (2013). The amount of β-carotene was calculated taking into account of recovery values (90–96%).

2.8. Surface Colour Measurement

The surface colour of NSDA samples were measured using a reflectance spectrophotometer (Minolta CM-3600d, Osaka, Japan). The measurements were recorded L* (Lightness), +a* (redness), +b* (yellowness), C* (Chroma), and h° (hue angle) colour coordinates. Browning Index (BI) and total colour changes (ΔE) were calculated using L*, a* and b* coordinates according to the following equations (Ihns et al. 2011):

$$BI = [100\ (x - 0.31)] / 0.17 \quad (1)$$

$$x = [a^* + 1.75L^*] / [5.645L^* + a^* - 3.012b^*] \quad (2)$$

$$\Delta E = [(\Delta a)^2 + (\Delta b)^2 + (\Delta L)^2]^{0.5} \quad (3)$$

2.9. Microbial analyses

The microbial analyses were carried out to evaluate the microbial contamination before and after fumigation, and after rehydration and packaging, and during storage of the NSDA samples. At each sampling day, three packages of samples were removed from the incubators and a 400-g sample was removed from the bulk stored NSDA samples. The NSDA samples were aseptically cut into halves to obtain a uniform subsample. Then, a-30 g subsample was aseptically weighed in a screw cap flask (500 mL). A 20 mL portion of 90 mL aliquot of sterile 0.1% (w/v) peptone water (PW) was added to the flask, which was left at room temperature for 15 min to prevent osmotic shock and revive the stressed microorganisms (Mackey 2000). Then, the

remaining 70 mL PW was added into the flask, which was agitated with an oscillating flask shaker (Griffin and George Ltd., UK) at half speed of the shaker's maximum speed for 1.5 min. Appropriate dilutions in PW were transferred to appropriate media for each microorganism according to APHA-directives (APHA 2002).

The microbial loads of for total mesophilic aerobic (TMAB) and psychrophilic aerobic bacteria (TPAB) were determined on plate count agar (PCA) plates by pour culture method, total yeast and molds (YM) on yeast extract glucose chloramphenicol (YGC) agar, xerophilic yeast-mould (XYM) on dichloran glycerol (DG-18) agar, osmophilic yeast (OSY) on malt yeast extract (MY-40G, osmofilic 40% glucose) agar, lactic acid bacteria (LAB) by spread culture method on de man, rogosa and sharpe (MRS) agar containing cycloheximide (100 μg/mL), *Staphylococcus-Micrococcus* spp (SM) on Baird-Parker (BP) agar (fortified with egg yolk tellurite) and *Enterobacteriaceae* (ENT) on violet red bile dextrose (VRBD) agar by pour plate method. The plates were then incubated at 28 °C for 48 h and 4 °C for 10 days for the detection of TMAB and TPAB, respectively, at 28 °C for 5–6 days for YM, XYM and OSY, at 30 °C for up to 3 days for LAB, at 37 °C for 48 h for SM and at 37 °C for 24 h for ENT. Suspected colonies for LAB, SM and ENT were confirmed with appropriate biochemical tests. All microbiological incubations were carried out in temperature-controlled incubators (Sanyo MIR 253).

2.10. Statistical analysis

Browning, β-carotene content, moisture, titration acidity, pH and microbial counts were the main variables. These variables were subjected to one-way analysis of variance (ANOVA) using the SPSS Statistics software, version 20 (IBM Statistics for Windows, Armonk, NY, USA). Statistical differences among means were determined using Duncan's multiple range tests at 5% significance level. Chemical analyses and microbiological counts were carried out twice analytical and biological triplicates, respectively.

3. Results and Discussion

3.1. Moisture content and a_w

Although the MC of NSDAs should not exceed to 20% for Codex Alimentarius and 22% for Turkish standard (TS 485), the MCs of the packaged NSDA samples were over the standards' limits. The reason for chosing higher MCs for NSDAs was due to mimic the MC of commercially marketed NSDAs. The MCs of the NSDA samples during storage at 4–30 ºC are presented in Table 1. The MCs of the NSDA samples stored at 20 and 30 ºC lost most of their MCs after 1-month storage. The decrease in MC of the NSDA samples during storage was parabolic at 20 and 30 ºC at all MCs (data not shown). For example, the samples packed in PVC film (containing 23.5 and 27.0% MC) lost 44 and 57% MCs after 1-month storage at 20 and 30 ºC, respectively. After 3-months storage, the MCs at all samples were similar and did not change much between 3- and 12-months storage at both temperatures. At the end of 1-year storage, MCs of the samples at 13.7, 23.5 and 27.0% MCs decreased by 47, 67 and 77% at 30 ºC, respectively. These observations clearly showed that most of the MCs were lost for the first 3-months storage at high temperatures (20 and 30 ºC). Moreover, the moisture loss was also higher at higher MCs, compared to lower MCs. Furthermore, as expected, storage at 30 ºC caused more moisture loss than that of 20 ºC.

Table 1-Moisture contents (%) of NSDAs stored at various temperatures for 1 year

		MCs after 1 year of storage			
MCs prior to storage (%)	*Time (months)*	*4 ºC*	*10 ºC*	*20 ºC*	*30 ºC*
13.7	1	17.7	16.1	12.2	10.6
	2	20.7	16.8	11.1	09.0
	3	21.5	18.4	10.2	08.2
	4	18.9	20.6	10.0	07.6
	6	14.0	21.9	11.7	07.3
	9	11.5	12.3	12.3	06.7
	12	11.3	25.4	09.7	07.0
23.5	1	23.1	22.3	16.5	13.2
	2	22.8	21.2	13.9	10.8
	3	22.5	20.7	12.4	09.7
	4	20.6	21.0	11.9	09.0
	6	13.5	21.9	12.8	08.5
	9	10.6	12.9	13.1	07.8
	12	10.2	18.0	11.0	07.7
27.5	1	26.5	25.1	18.1	11.7
	2	26.2	23.3	14.0	09.1
	3	26.0	22.1	12.1	08.0
	4	24.1	21.7	11.4	07.4
	6	16.5	22.1	12.2	06.9
	9	13.5	12.0	12.5	06.2
	12	13.1	17.5	10.3	06.3

The a_w values of the samples at 23.5 and 27.0% MCs were initially 0.675 and 0.696, respectively. These a_w values are in the range of a_w optimums (aw=0.60–0.70) for Maillard reactions. This will be discussed in detail in "3.2. Brown colour formation" section. The a_w values of the samples could not have been measured at 30 ºC because the samples lost most of their moisture after 1-month storage and this made impossible the samples to pass through the grinder. Moreover, a_w values of the sample stored in bulk (13.7% MC) could also have not been measured at 20 ºC due to the very low MC.

Similar to MCs, the a_w of NSDAs also decreased sharply after 1-month storage and this high decrease also continued up to 3-months storage at 20 and 30 °C. This showed that most of the moisture loss occurred during the first 3-months storage at these temperatures as a result of the loss of free water. The highest reductions in both MC and a_w values were observed in the samples stored at 30°C. The samples packaged in PVC films (at 23.5 and 27.0% MCs) could not have kept their initial MC even after 1-month storage at 30 °C. The results indicated that PVC packaging material, which is widely used for dried apricot packaging in Turkey, is not suitable for the rehydrated dried apricots stored at 30 °C.

3.2. Brown colour formation

At the beginning of storage, the absorbance values measured for brown colour at 420 nm in NSDAs ranged from 3.52 to 4.99 A_{420}/g DW, depending on MCs. The acceptable colour for sulfite-treated dried apricots was defined by Nury et al. (1960) as the time where the absorbance values at 440 nm reached to 0.3 (Davis et al. 1973). However, there has been no such absorbance value defined for NSDAs. Therefore, in the present study, only the changes in in the brown colour measured at 420 nm of the NSDA samples were compared throughout the storage. Below 10°C, no significant changes were detected for the brown colour values of the samples throughout the storage period ($P>0.05$); therefore, no kinetic parameter was calculated below 10 ºC. However, above 10 °C, significant increase in brown colour formation was observed as the storage temperature increased from 10 to 20 and 30 °C at all MCs ($P<0.05$) (Table 2). For instance, the brown colour formation for the sample containing 23.5% moisture after 12-months storage at 20 and 30 °C increased by 51 and 80%, respectively.

Table 2- *k* values for the formation of brown colour, ΔE, pH and titratable acidity in NSDA samples during storage at 20 and 30 °C

Temperature (°C)	*Initial MC (%)*	*Formation of brown colour (1/month)*	*ΔE (colour units/month)*	*pH (pH units/month)*	*Titratable acidity (g/[100g DW month])*
20	13.7	0.0598 (0.8820)[a]	0.2902 (0.9233)	–0.0140 (0.8922)	0.0276 (0.8642)
30		0.1483 (0.9533)	0.3694 (0.9310)	–0.0220 (0.8272)	0.0562 (0.9126)
20	23.5	0.0643 (0.9219)	0.1928 (0.9502)	–0.0135 (0.7316)	0.0320 (0.9480)
30		0.1568 (0.9446)	0.3402 (0.8060)	–0.0179 (0.9534)	0.0412 (0.9075)
20	27.0	0.0332 (0.8929)	0.2204 (0.7500)	–0.0098 (0.8803)	0.0477 (0.8309)
30		0.1338 (0.9025)	0.3091 (0.7978)	–0.0137 (0.8399)	0.0558 (0.8555)

[a]: Numbers in parentheses are the coefficient of determination (n=2).

The brown colour formation in NSDA samples at 13.7–27.0% MCs at 20 and 30 °C was fitted to a first-order reaction kinetic model. Investigation of determination coefficients (R^2) values at these temperatures revealed a little higher value for zero-order than for the first-order reaction rate constants. However, zero-order reaction model for brown colour formation in NSDAs would not be possible because MCs in the NSDAs changed not in a constant amount during the 12-months storage period. Therefore, brown-colour formation in NSDAs would not fit zero-order reaction kinetic model. Most studies in sulfite-dried apricots during storage showed that brown colour formation was fitted to a first-order reaction model (Sadler et al. 1990; Sağırlı et al. 2008; Türkyılmaz et al. 2012).

The increase in *k* value for NSDAs stored at 20 °C (0.0643/month) and 30 °C (0.1568 /month) at 23.5% MC clearly showed that brown colour formation was highly dependent on storage temperature. Similarly, Sağırlı et al. (2008) found *k* values as 0.0488 and 0.2411/month for brown colour formation in sulfitted (1458 mg/kg) dried apricots stored at 20 and 30 °C at 36.6% MC, respectively. In another study with lower MC (18.9–24.5%), Türkyılmaz et al. (2012) reported *k* values for sulfitted (188–3864 mg/kg) dried apricots stored at 20 and 30 °C as 0.0193 and 0.0553/month, respectively. The *k* values for brown colour formation increased by 1.5 times increasing the storage temperature from 10 to 20 °C than from 20 to 30 °C. Moreover, increasing the temperature form 20 to 30 °C caused the rate of brown colour formation to increase 4.81 and 7.53 times at 13.7 and 27% MCs, respectively. Studies on sulfited and non-sulfitted dried apricots showed that storage temperature over 20 °C caused significant increase in brown colour formation (Türkyılmaz et al. 2012; Coşkun et al. 2013; Alagöz et al. 2015). The results from the present study and above studies clearly indicated that the storage temperature should be lower than 20 °C in order to control the brown colour formation in dried apricots. To show the effects of the temperature change on brown colour formation, Q_{10} values were calculated, which were 2.36 at 10–20 °C and 3.49 at 20–30 °C. Higher Q_{10} value showed that increase in temperature at 20–30 °C had more effect on brown colour formation than at 10–20 °C.

The MCs also had significant effects on brown colour formation in NSDAs. As expected, the highest brown colour formation was observed in the NSDA samples containing 23.5% MC (a_w=0.675) at both 20 and 30 °C, which corresponds to intermediate MC. As known, the non-enzymatic Maillard browning reactions occur fastest at the intermediate MC, which corresponds to a_w=0.6–0.7 (Beveridge & Harrison 1984). The samples containing 13.7% MC had higher brown colour compared to those containing 27% MC at especially 20 °C. Increasing MC from 13.7 to 23.5% caused 10% decrease in the *k* value for brown colour formation in NSDAs stored at 30 °C, while 7.7% decrease increasing MC from 23.5 to 27%.

3.3. Changes in β-carotene content

The sample chromatogram for carotenoid composition of NSDA sample is presented in Figure 2. β-carotene was the predominant carotenoid in all NSDA samples. Similar composition was also found for the same cultivar (Hacihaliloğlu) in the studies carried out in our laboratory (Sağırlı et al. 2008; Türkyılmaz et al. 2012; Coşkun et al. 2013; Alagöz et al. 2015). β-carotene content in NSDA samples at the beginning of the storage-ranged from 6.5 to 12.8 mg/100 g DW, while 4.7–12.4 mg/100 g DW after 12-months storage. The storage time and temperature had no significant effect on the β-carotene contents of the samples at 13.7, 23.5 and 27.0% MCs during storage at 4–30 °C (P>0.05). Similarly, Alagöz et al. (2015) found that storage at 30 °C for 10 months did not affect the β-carotene content of sorbic acid treated dried apricots (P>0.05). On the contrary, Elmacı et al. (2008) reported that increasing storage time and temperature decreased the β-carotene content of NSDAs during 12-months storage. The decrease observed in β-carotene content might have been due to the higher a_w of the samples during storage. As known, one of the degradation patterns of β-carotene is the enzymatic oxidation which is catalyzed by the enzyme lipoxygenase, showing the optimum activity a_w>0.85 (Berry et al. 1996).

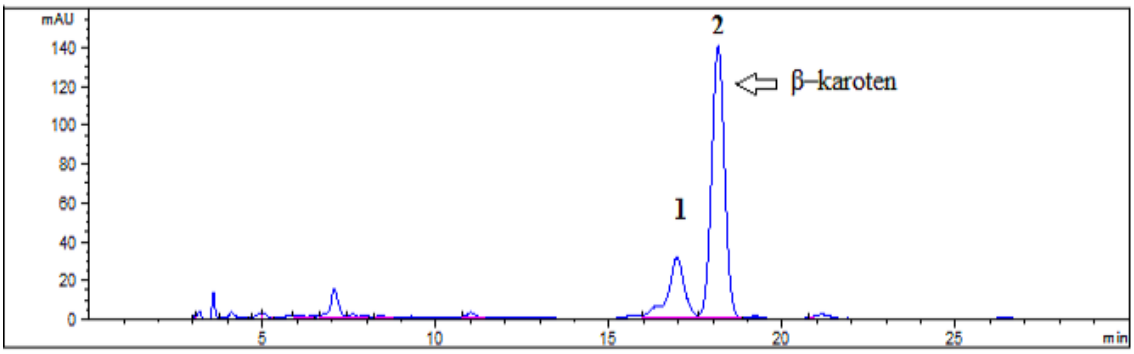

Figure 2- Carotenoid profile of NSDA sample containing 13.7% moisture at the beginning of storage

3.4. Changes in surface colour

For the dried fruits whose MC is not very low, reflectance color measurements, along with browning and carotenoid measurements, can be used to monitor the changes in the color of NSDAs throughout the storage. Results from surface color measurements are presented in Table 2. Both MC and storage temperature affected the reflectance colour values of NSDA samples. Changes in reflectance colour values were found insignificant ($P>0.05$) in the samples stored at low temperatures (4 and 10 °C). On the contrary, L* values decreased by 2.5–2.7 units in the samples at 13.7% MC, 1.8–2.0 units at 23.5% MC and 0.9–1.7 units at 27.0% MC after 12-months storage at 20 and 30 °C, respectively. Much higher decreases (3.7 and 7.4 units) were reported for L* values of the NSDA samples containing 34.0% MC and 488 mg/kg sorbic acid after 10-months storage at 20 and 30 °C, respectively (Alagöz et al. 2015). Studies showed that MCs of dried fuits had tremendeous effects on the reflectance color measurements. For example, Özkan et al. (2003) showed that increasing MC from 15.0 to 30.0% caused significant changes in L*, a*, b*, C* and h^o color values ($P<0.05$). L* value was used as a browning index in many dried fruits, such as raisins (Aguilera et al. 1987), dried figs (Piga et al. 2004) and dried pears (Joubert et al. 2001). In addition to L* value, Browning Index (BI), which was calculated from L*, a* and b* values, has also been used to evaluate brown colour formation (Castañón et al. 1999; Chutintrasri & Noomhorm 2007). Strong negative correlations between BI and browning values (A_{420}/g DW) were found in in the samples containing at 23.5% MC ($r= –0.8575$) and 27.0% MC ($r= –0.9258$) at 30 °C during 12-month storage. This result was in an agreement with the finding of Alagöz et al. (2015) who found a strong negative logarithmic correlation ($r=0.896–0.996$) between BI and browning values of sorbic acid treated dried apricots at 20 and 30 °C. These high correlations indicated that measuring the reflectance colour values of dried apricots may be a good alternative to the spectrophotometric lenghty brown color measurements. As expected, increasing the storage temperature decreased the BI values of the samples, indicating the increase in brown color formation (Table 3).

Table 3- Changes in the reflectance colour values[a] of NSDAs during storage at 20 and 30°C

Temperature (°C)	*Initial MC (%)*	*Time (month)*	*L**	*a**	*b**	*C**	*h°*	*ΔE*	*BI*
20	13.7	0	25.76±2.35 [a]	4.82±1.59 [a]	9.12±2.07 [a]	10.37±2.35	62.30±6.54	–	56.08
		12	23.19±2.17 [b]	4.65±1.65 [a]	6.85±1.63 [b]	8.36±1.98	56.28±8.39	3.43	48.59
30		0	27.30±2.29 [a]	5.40±1.67 [a]	10.42±2.41 [a]	11.79±2.68	62.59±6.08	–	61.06
		12	24.55±1.90 [b]	4.10±1.81 [a]	6.96±2.16 [a]	8.16±2.51	59.85±6.49	4.61	44.56
20	23.5	0	26.26±2.06 [a]	5.84±2.25 [a]	8.83±3.07 [a]	10.65±3.61	56.62±6.87	–	55.98
		12	24.98±2.54 [b]	5.77±2.12 [b]	8.16±2.50 [a]	10.35±3.07	56.90±7.61	1.45	55.20
30		0	25.66±2.55 [a]	6.00±2.25 [a]	9.10±2.71 [a]	10.97±3.29	56.82±7.03	–	59.52
		12	23.66±1.90 [b]	2.95±0.92 [b]	6.26±2.15 [b]	6.96±2.20	64.18±6.95	4.62	38.95
20	27.0	0	26.43±2.34 [a]	7.08±2.45 [a]	9.58±3.17 [a]	11.98±3.79	53.20±6.38	–	63.11
		12	25.54±1.83 [b]	4.86±1.70 [b]	7.34±2.64 [b]	8.87±2.96	56.25±6.91	3.28	46.76
30		0	24.32±1.66 [a]	5.58±1.28 [a]	7.98±2.14 [a]	9.77±2.35	54.62±5.13	–	55.30
		12	22.63±1.37 [b]	2.87±0.92 [b]	5.73±1.93 [b]	6.45±1.99	62.54±7.11	3.91	37.60

[a]: Colour values are expressed as mean ± standard deviation (n=30). The letters indicated for the means which are at the begining and end of the storage in the same column with different lower case superscripts are significantly different (P<0.05).

ΔE (total change in colour) value is another useful indicator which is used to show the colour change in dried fruits. ΔE of the NSDA samples increased with increasing storage temperature, which indicated that higher colour deterioration occurred at high storage temperatures (Table 2). The change in colour might be due to pigment degradation, browning reaction or both during drying and storage. The changes in ΔE values were fitted to zero-order kinetic model, which was in agreement with the former studies (Barreiro et al. 1997; Chutintrasri & Noomhorm 2007). The highest *k* values for the change in ΔE (0.3091–0.3694 colour units/month) of all NSDA samples were determined at 30 °C. Furthermore, the colour deterioration occurred faster in bulk samples than the samples stored in PVC packages at all temperatures. The results showed that the colour properties of NSDAs were affected by both storage temperature and packaging conditions during storage.

3.5 Changes in microbial counts

After fumigation of NSDAs, no live insects were observed in the samples during 12-months storage. The effect of fumigation on the microbial flora of NSDAs was also determined. Before fumigation, TMAB, TPAB, YM, XYM, OSY, LAB, ENT, and SM counts were 3.93 (±0.07) and 2.75 (±0.20), 2.09 (±0.03), 2.65 (±0.11), <0.60, <0.60, <0.60 and <1.60 log cfu/g, respectively. The microbial counts after fumigation are presented at "month 0" column in Table 4. Results of counts for OSY, LAB, ENT, and SM were not given in Table 4 because they were generally below detection limit. Compared to the microbial of loads of the samples before (given above) and after fumigation (month 0 in Table 4) the number TAMB and TAPB decreased slightly by 0.4 and 0.3 log cfu/g (P>0.05), respectively, whereas LAB count significantly increased from <0.60 log cfu/g to <1.30 log cfu/g (P<0.05). However, no significant changes in YM, XYM, OSY, ENT, and SM were found (P>0.05). Similarly, Alagöz et al. (2015) reported that counts for TMAB and TPAB were unchanged, and the YM counts declined by 0.6 log cfu/g after fumigation. Overall, the fumigation process had no effect on the number of YM, XYM, but increased the number of LAB and slightly decreased that of TMAB and TPAB.

Following fumigation, a part of the samples was rehydrated from the NSDAs (13.7% MC) to 23.5 and 27.0% MC. After rehydration, initial numbers of each microbial groups for the samples at 23.5 and 27% MCs are presented at "month 0" columns in Table 4. When compared to the initial counts of the sample at 13.7% MC, TAMB counts increased by 0.84 and 1.01 log cfu/g in the samples at 23.5 and 27.0% MCs (Table 4), respectively (P<0.05). While the number of OSY was below the detection limit

before rehydration, the number increased by 1.99 and 1.91 log cfu/g for the samples at 23.5 and 27.0% MCs, respectively ($P<0.05$). However, rehydration did not increase the numbers of TAPB, YM, OSY, XYM, LAB, SM and ENT ($P>0.05$). Alagöz et al. (2015) reported that the number of YM decreased by 0.7 log cfu/g after rehydration of the samples to 27.2% MC while YM increased by 0.7 log cfu/g for the samples with 34.1% MC. Results of the present study indicated that a_w values (0.67–0.69) for the rehydrated NSDAs at 23.5 and 27.0% MCs were appropriate for the growth of TAMB and OSY.

Generally, counts of the sample at 13.7% MC for TAMB and TAPB, YM, XM, and OSY were not affected by the storage temperatures. During 12-months storage, almost no changes in microbial counts were observed for all storage temperatures and the microbial groups. Although very slight increases and decreases ($P>0.05$) in the counts were observed, they are negligible in practice. However, the number of TAMB and TAPB in the sample at 23.5% MC decreased during storage at all temperatures ($P<0.05$). Despite the fluctuation of the bacterial counts between month 4–9, the decrease in the number of TAMB and TAPB were in the range of 1.20–0.75 and 0.91–1.01 log cfu/g for the storage temperatures between 4–30 °C and 4–10 °C during 12-months storage period (Table 4). Similarly, the number of TAMB in the sample at 27.0% MC decreased ($P<0.05$) after 12 months for all the storage temperatures (Table 4). Also, the number of TAPB decreased by 0.96 and 1.02 log cfu/g after 12 months at 4 and 10 °C, respectively ($P<0.05$). The decrease in bacterial counts for the samples at 23.5 and 27.0% MCs could be explained by the greater decrease in MC and a_w with increasing storage temperature. Significant reduction in TAMB counts with decreasing a_w during 12 months in bulk stored sulfitted dried apricots (SDA) at 5–30 °C was reported by Türkyılmaz et al. (2013). However, Alagöz et al. (2015) reported that TAMB decreased slightly, while a_w values did not change during the 10-months storage of packaged SDAs at 4–30 °C.

While YM and XYM counts did not change in the sample at 13.7% MC during the storage at all temperatures, they decreased in the sample at 23.5 and 27.0% MCs in the same storage conditions ($P<0.05$). The YM and XYM counts for the sample at 23.5% MC were similar to the initial values and decreased after 3-months storage at 4 °C, ($P<0.05$). The YM and XYM counts of the stored samples at 10, 20 and 30 °C significantly decreased ($P<0.05$) after the 3rd, 2nd and 1st month, respectively while they remained constant for the samples stored at 4 °C.

As seen in Table 4, YM count for the sample at 27.0% MC increased to 6 and 4 log cfu/g level after the 2nd and 1st month of storage at 20 and 30 °C, respectively, exceeding the legal limit. YM counts for the sample at 27.0% MC did not change significantly until the 6th month at 4 and 10 °C ($P>0.05$), and then they decreased (1.2 log cfu/g) after 12-months storage ($P<0.05$). Reduction in YM counts with increasing storage temperatures (20 and 30 °C) increased as seen in Table 4. Interestingly, YM and XYM followed a similar pattern in that they increased rapidly in numbers during the first 2-months storage at 20 and 30 °C. After 2 months, sharp decreases of the counts for the samples at 27.0% MC were observed. Counts for YM and XYM were in the range between 3.85–2.53 and 3.77–2.5 log cfu/g, compared to that in the following 3rd month, at 20 and 30 ºC, respectively. Microbial growth is expected to increase with increasing storage temperature. However, in our study, microbial growth was low or limited as the moisture loss increased with increasing temperature and storage time.

OSY-counts in the 13.7% MC stored at all temperatures remained below the detection level (<0.60 log cfu/g) throughout 12-months storage. On the contrary, OSY-counts remained almost constant (except month 4) and remained below the detection level after 9th month at 4 and 10 °C, and after 6 and 2 months at 20 and 30 °C, respectively. In these samples, increase in microbial reduction due to increase in storage temperature was observed. A similar trend in OSY-counts for the sample at 27.0% MC to that of the sample at 23.5% MC was also observed. Counts for OSY followed similar pattern to that of YM and XYM increased to 6.49 log cfu/g level after 2-months storage at 20 °C for the sample at 27.0% MC. After 2 months, a sharp reduction was observed for the counts of YM, XYM, and OSY. This trend might be related to the sharp decrease of the MC from 27% (a_w= 0.69) to 9.1% (a_w= 0.55) in the first 2-months storage. In the following months, MC remained at between 8.0–6.3% until the end of the storage.

Table 4- Microbial counts* of the NSDAs at various MCs during storage

Microbial count (log cfu/g)*	*MC** (%)*	*Storage temp. (ºC)*	*Storage period (months)*							
			0	*1*	*2*	*3*	*4*	*6*	*9*	*12*
TMAB		4°C	3.56 ^{bc}	3.88 ^{a}	3.63 ^{ab}	3.41 ^{bc}	3.45 ^{bc}	3.32 ^{cd}	2.86 ^{e}	3.40 ^{d}
		10°C	3.56 ^{b}	4.70 ^{a}	3.28 ^{b}	3.43 ^{b}	3.56 ^{b}	3.53 ^{b}	3.42 ^{b}	3.45 ^{b}
		20°C	3.56 ^{cd}	4.04 ^{ab}	3.20 ^{a}	3.51 ^{cd}	3.60 ^{bc}	3.50 ^{cd}	3.21 ^{d}	3.28 ^{cd}
		30°C	3.56 ^{a}	3.63 ^{a}	3.56 ^{a}	3.88 ^{a}	3.70 ^{a}	3.83 ^{a}	4.32 ^{a}	3.71 ^{a}
TPAB		4°C	2.48 ^{cd}	1.79 ^{e}	1.51 ^{f}	2.59 ^{c}	2.35 ^{d}	3.34 ^{b}	4.00 ^{a}	2.34 ^{d}
		10°C	2.48 ^{b}	2.08 ^{cd}	2.41 ^{bc}	2.32 ^{b}	2.53 ^{b}	3.50 ^{a}	3.56 ^{a}	2.08 ^{d}
YM	13.7	4°C	2.23 ^{cd}	2.90 ^{b}	4.93 ^{a}	2.88 ^{b}	2.25 ^{c}	2.33 ^{c}	1.99 ^{d}	2.10 ^{cd}
	(NP)	10°C	2.23 ^{cd}	3.21 ^{a}	2.78 ^{b}	2.27 ^{cd}	2.01 ^{de}	2.35 ^{c}	2.00 ^{e}	2.14 ^{de}
		20°C	2.23 ^{ab}	2.04 ^{b}	2.40 ^{a}	2.00 ^{cd}	2.33 ^{a}	2.33 ^{a}	1.63 ^{c}	1.46 ^{c}
		30°C	2.23 ^{b}	2.31 ^{b}	2.28 ^{a}	2.28 ^{b}	2.10 ^{b}	2.10 ^{bc}	1.99 ^{c}	1.98 ^{c}
XYM		4°C	2.65 ^{b}	2.60 ^{b}	4.94 ^{a}	2.78 ^{b}	2.31 ^{c}	2.22 ^{c}	1.01 ^{d}	2.20 ^{c}
		10°C	2.26 ^{c}	3.17 ^{a}	2.81 ^{b}	2.14 ^{cd}	1.99 ^{d}	2.30 ^{c}	2.01 ^{cd}	2.11 ^{cd}
		20°C	2.26 ^{b}	2.04 ^{bc}	2.64 ^{b}	2.02 ^{bc}	2.21 ^{bc}	3.68 ^{a}	1.74 ^{c}	1.40 ^{c}
		30°C	2.26 ^{a}	2.34 ^{a}	2.34 ^{a}	2.34 ^{a}	2.09 ^{ab}	2.23 ^{a}	1.91 ^{b}	2.08 ^{ab}
TMAB		4°C	4.40 ^{bc}	4.31 ^{bc}	3.54 ^{d}	4.02 ^{c}	4.82 ^{a}	4.59 ^{ab}	3.43 ^{e}	3.20 ^{d}
		10°C	4.40 ^{a}	3.55 ^{bc}	3.81 ^{b}	3.55 ^{bc}	3.45 ^{bc}	3.52 ^{bc}	4.03 ^{bc}	3.25 ^{c}
		20°C	4.40 ^{b}	3.58 ^{bc}	3.59 ^{b}	3.36 ^{bc}	3.28 ^{bc}	5.13 ^{a}	2.50 ^{bc}	3.49 ^{bc}
		30°C	4.40 ^{a}	3.88 ^{b}	3.33 ^{c}	4.41 ^{a}	3.32 ^{c}	3.37 ^{c}	3.43 ^{c}	3.65 ^{bc}
TPAB		4°C	2.67 ^{cd}	2.52 ^{cd}	2.21 ^{de}	2.06 ^{ef}	3.06 ^{c}	4.41 ^{a}	3.55 ^{b}	1.76 ^{f}
		10°C	2.67 ^{c}	2.25 ^{de}	1.91 ^{e}	1.91 ^{de}	2.52 ^{cd}	3.63 ^{b}	4.12 ^{a}	1.66 ^{e}
YM	23.5	4°C	2.29 ^{b}	2.81 ^{a}	2.49 ^{ab}	1.95 ^{c}	1.79 ^{cd}	1.45 ^{e}	1.92 ^{c}	1.61 ^{de}
	(P)	10°C	2.29 ^{a}	2.31 ^{a}	4.64 ^{a}	1.40 ^{c}	1.90 ^{b}	1.08 ^{d}	0.60 ^{c}	1.00 ^{d}
		20°C	2.29 ^{ab}	2.64 ^{a}	1.92 ^{bc}	1.48 ^{c}	2.53 ^{ab}	1.41 ^{c}	1.04 ^{cd}	0.60 ^{d}
		30°C	2.29 ^{a}	1.04 ^{b}	1.11 ^{b}	1.08 ^{b}	1.00 ^{bc}	0.95 ^{bcd}	0.70 ^{d}	0.70 ^{cd}
XYM		4°C	2.39 ^{b}	2.89 ^{a}	2.58 ^{ab}	2.08 ^{c}	1.81 ^{cd}	1.52 ^{cd}	2.00 ^{c}	1.41 ^{d}
		10°C	2.39 ^{a}	2.36 ^{a}	4.65 ^{a}	1.38 ^{c}	1.71 ^{b}	1.18 ^{cd}	0.60 ^{d}	0.95 ^{d}
		20°C	2.39 ^{ab}	2.52 ^{a}	2.04 ^{b}	1.53 ^{b}	2.38 ^{ab}	1.30 ^{c}	1.15 ^{c}	0.78 ^{d}
		30°C	2.39 ^{a}	0.90 ^{b}	1.04 ^{b}	1.11 ^{b}	0.95 ^{bc}	0.78 ^{c}	0.85 ^{bc}	1.11 ^{b}
TMAB		4°C	4.57 ^{a}	3.84 ^{b}	3.52 ^{c}	3.48 ^{c}	3.92 ^{b}	3.34 ^{c}	3.47 ^{c}	3.43 ^{c}
		10°C	4.57 ^{a}	4.10 ^{b}	3.58 ^{cd}	3.79 ^{c}	3.21 ^{d}	3.79 ^{d}	2.59 ^{e}	3.47 ^{cd}
		20°C	4.57 ^{b}	4.04 ^{b}	4.07 ^{b}	3.74 ^{b}	3.78 ^{b}	5.13 ^{c}	3.38 ^{c}	4.10 ^{b}
		30°C	4.57 ^{a}	4.08 ^{b}	3.33 ^{cd}	3.25 ^{d}	3.49 ^{cd}	3.37 ^{cd}	3.85 ^{bc}	3.44 ^{cd}
TPAB		4°C	2.66 ^{b}	2.53 ^{b}	1.95 ^{d}	2.14 ^{c}	2.86 ^{b}	2.14 ^{a}	3.55 ^{a}	1.70 ^{d}
		10°C	2.66 ^{bc}	2.05 ^{de}	1.93 ^{ef}	3.19 ^{cd}	2.42 ^{cd}	3.19 ^{ab}	2.77 ^{a}	1.64 ^{f}
YM	27.0	4°C	2.42 ^{a}	2.56 ^{a}	2.14 ^{bc}	2.59 ^{a}	2.21 ^{b}	2.59 ^{a}	2.00 ^{c}	1.20 ^{e}
	(P)	10°C	2.42 ^{a}	2.18 ^{a}	2.13 ^{a}	2.12 ^{a}	1.82 ^{b}	2.12 ^{a}	0.78 ^{c}	1.23 ^{c}
		20°C	2.42 ^{bc}	5.25 ^{a}	6.23 ^{a}	2.38 ^{bc}	3.43 ^{b}	2.38 ^{bc}	1.20 ^{c}	0.95 ^{c}
		30°C	2.42 ^{b}	4.05 ^{a}	3.37 ^{a}	0.84 ^{c}	0.78 ^{c}	0.85 ^{c}	0.70 ^{c}	<0.60 ^{c}
XYM		4°C	2.44 ^{a}	2.63 ^{a}	2.07 ^{bc}	2.53 ^{a}	2.14 ^{bc}	1.57 ^{c}	2.00 ^{bc}	1.18 ^{c}
		10°C	2.44 ^{a}	2.21 ^{a}	2.16 ^{a}	2.23 ^{a}	1.79 ^{b}	1.84 ^{b}	0.95 ^{c}	1.18 ^{bc}
		20°C	2.44 ^{bc}	5.19 ^{a}	5.96 ^{a}	2.19 ^{bc}	3.35 ^{b}	1.36 ^{c}	1.23 ^{c}	1.11 ^{c}
		30°C	2.44 ^{c}	4.01 ^{a}	3.10 ^{b}	<0.60 ^{d}	0.78 ^{d}	0.70 ^{d}	0.60 ^{d}	0.84 ^{d}

*: Counts are expressed as mean (n=3), log cfu/g: colony forming unit, **: Moisture content, NP: bulk storage (non-packaged), P: packaged. TMAB: Total Mesophilic Aerobic Bacteria, TPAB: Total Psychrophilic Aerobic Bacteria, YM: Yeast-Mould, XYM: Xerophilic Yeast-Mould. $^{a-f}$ Values with different letters within same row indicate significant difference (Duncan test, $P< 0.05$). <0.60 log cfu/g values indicate that microbial count are below detection limits.

The initial number (1.30 log cfu/g) of LAB in the sample 13.7% MC decreased at the beginning (10 and 20 ºC) and after 1-month storage (4 and 30 ºC) and remained below the detection limit throughout the storage, which might be due to the low MC of the sample. However, the LAB-counts for the samples at 23.5 and 27.0% MCs decreased gradually and faster due to higher moisture loss of NSDAs with the increasing storage temperatures, and later remained below the detection level for the rest of the storage period. On the contrary to the LAB counts of the present study, Alagöz et al. (2015) reported no detectable LAB (<0.6 log cfu/g) in both sorbic acid treated and untreated dried apricots before and after storage. This difference may be due to higher initial LAB loads of the NSDAs, which were 1.3 log cfu/g for the sample at 13.7% MC, and 2.5–2.7 for the samples at 23.5 and 27.0% MCs, respectively, in the present study.

ENT and SM counts, which can be considered as the index for the level of hygiene during production and microbial quality of the product (Jay 2000), were below the detection limit (<0.60 log cfu/g) and no growth was detected prior to and during 12-months storage in all samples and storage temperatures. Similar findings were reported by Sağırlı et al. (2008) and Alagöz et al. (2015) in high moisture dried apricots containing SO_2 and sorbic acid, respectively. In general, as the a_w values of the NSDA

samples decreased with storage time, significant reductions ($P<0.05$) were observed in microbial loads of the samples at 23.5 and 27.0% MCs for all the storage temperatures studied.

According to FDA (2013), the maximum limit of YM counts for dried fruits should not exceed 3 log cfu/g (1 and 2 log cfu/g for yeasts and molds, respectively). In the present study, the YM count for the samples at 13.7 and 23.5% MCs were below the legal limits; therefore, rehydrated NSDAs containing up to 23.5% moisture were acceptable for consumption during storage at 4–30 °C. However, after 1-month storage at 20 and 30 °C, the YM counts of NSDAs containing 27.0% moisture exceeded the permitted legal limits (3 log cfu/g). Alagöz et al. (2015) observed visible yeast and mold colonies on the surface of NSDAs containing no preservative (34.3% MC) after 1-month storage at 20 and 30 °C. In the present study, none of the samples yielded visible colonies. In addition to YM count, OSY count in rehydrated sample (27.0% MC) exceeded to the legal limit of 4 log cfu/g after 1-month storage at 20 and 30 °C. Similarly, XYM counts of the same sample group were above 5 and 4 log cfu/g after 1-month storage at 20 and 30 °C, respectively. These findings suggested that rehydrated NSDAs above 23.0% MC has the potential to be spoiled mostly by osmophilic yeast and xerophilic yeast-molds during the storage at 20 and 30 °C.

3.6 pH and titratable acidity

The initial pH values of NSDAs were found between 5.12 and 5.21, while the initial titratable acidity values ranged between 1.12–1.53 g/100 g DW. Almost no changes in the pH and titratable acidity values were observed in NSDA samples stored at 4 and 10 °C. On the other hand, significant increases were observed in the titratable acidity of the NSDAs stored at 20 and 30 °C ($P<0.05$). The decreases in pH and increases in titratable acidity values of the samples stored at 20 and 30 °C were fitted to zero-order kinetic model. Increasing storage temperature from 20 to 30 °C caused 1.3–1.5 times faster decrease in the pH values, while titratable acidity of values increased 1.2–2 times. The increase in titratable acidity of the samples during higher MC and at 30 °C would be attributable to the increase in microbial counts. This could be easily understood from the very high correlations ($r=0.960–0.991$) between titratable acidity and microbial counts. Similar results were reported by Türkyılmaz et al. (2012) who found that titratable acidity values of sulfitted dried apricots (2899 mg SO_2/kg) showed an increase with the increase of the storage temperature from 10 to 30 °C.

4. Conclusions

Physicochemical and microbial qualities of NSDAs were affected by both MC and storage temperature. Colour deterioration in NSDAs occurred because of browning reactions during the storage. The browning of NSDAs occurred at a much faster rate above 20 °C. Below 10 °C, brown colour formation was limited. The increase in MC from 13.7 to 23.5% substantially accelerated brown colour formation. On the contrary, increasing MC from 23.5 to 27.0% decreased brown colour formation. These findings clearly showed that the fastest brown colour formation occurred at the intermediate MC (23.5%) samples, indicating the non-enzymatic Maillard browning. The content of β-carotene did not change during storage at all temperature. In general, significant decreases were found in microbial loads and a_w values of NSDA samples during storage with the increasing storage temperature. However, among the microorganisms tested, only the number of yeast and mould exceeded permitted limits in the samples at 27.0% MC after 2-months storage at 20 °C. The results suggest that the NSDAs over 23.5% MC need to be stored below 20 °C to preserve their microbial and physicochemical quality.

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