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Abstract: The kinetics of carotenoid and color degradation, furosine formation and antioxidant activity were investigated in apricot fruits during convective heating at 50, 60 and 70°C. Degradation of carotenoids and color, expressed as total color difference (TCD), followed a first and zero order kinetic, respectively. The activation energy (Ea) for carotenoids degradation ranged from 73.7 kJ/mol for 13-cis-β-carotene to 120.7 kJ/mol for lutein, being about 91 kJ/mol for β-carotene. Violaxanthin and anteraxanthin were the most susceptible to thermal treatment. The furosine evolution was fitted at zero order kinetic model. The Ea for furosine formation was found to be 83.3 kJ/mol and the Q10 (temperature coefficient) varied from 1.59 to 4.14 at the temperature ranges 50-60°C and 60-70°C, respectively.

Dear Editor-in-Chief: A. Sant"Ana**,**

We submit the original paper "Kinetics of carotenoids degradation and furosine formation in dried apricots (*Prunus armeniaca* L.)",

by A. Fratianni, S. Niro, M.C. Messia, L. Cinquanta, G. Panfili, D. Albanese, M. Di Matteo;

for publication in *"Food Research International", Special Issue on "Carotenoids in food and health"*

This study aimed at investigating the kinetics of color and carotenoid degradation and furosine formation, together with antioxidant activity, in apricot fruits, during convective heating.

We hope this paper is of sufficient interest and is worth of publication in: Special Issue on "Carotenoids in food and health"

Yours faithfully,

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Highlights Fratianni et al.

Kinetics of carotenoids degradation in dried apricots were evaluated

The activation energy E_a for carotenoids was 97 kJ/mol, higher than color evolution.

Violaxanthin and anteraxanthin were the most susceptible to thermal treatment

Q_{10} values of furosine ranged from 1.59 to 4.14 at 50-60°C and 60-70°C, respectively

Kinetics of carotenoids degradation and furosine formation in dried apricots (*Prunus armeniaca* L.)

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Abstract

The kinetics of carotenoid and color degradation, furosine formation and antioxidant activity were investigated in apricot fruits during convective heating at 50, 60 and 70°C. Degradation of carotenoids and color, expressed as total color difference (TCD), followed a first and zero order kinetic, respectively. The activation energy (Ea) for carotenoids degradation ranged from 73.7 kJ/mol for 13-cis-β-carotene to 120.7 kJ/mol for lutein, being about 91 kJ/mol for β-carotene. Violaxanthin and anteraxanthin were the most susceptible to thermal treatment. The furosine evolution was fitted at zero order kinetic model. The Ea for furosine formation was found to be 83.3 kJ/mol and the Q_{10} (temperature coefficient) varied from 1.59 to 4.14 at the temperature ranges 50-60°C and 60-70°C, respectively.

Keywords: Apricot; Carotenoids; Color; Drying; Furosine; Kinetics.

1. Introduction

Apricots are a good source of carotenoid compounds, which are beneficial for human health. Carotenoids are responsible for the color of a wide variety of foods and color is an important attribute, which significantly affects the consumer perception. Carotenoids are important, from a nutritional point of view, because some of them have provitamin A activity (Simpson & Chichester, 1981). Moreover, they are beneficial to human health, being scavengers of reactive species and thus showing antioxidant activity (Krinsky, 2001), protecting humans from serious disorders such as skin disorders, cardiovascular disease, several forms of cancer and age-related diseases of the eye (Melèndez-Martínez, Vicario, & Heredia, 2004). Color and carotenoid evolution are used as quality markers for several food products and processing (Fratianni, Irano, Panfili, & Acquistucci 2005; Fratianni, Cinquanta, & Panfili, 2010; Fratianni, Di Criscio, Mignogna, & Panfili, 2012; Fratianni, Giuzio, Di Criscio, Flagella, & Panfili, 2013a; Fratianni, Albanese, Mignogna, Cinquanta, Panfili, & Di Matteo, 2013b). The main pigment of apricot is β-carotene, the major important source of vitamin A, accounting for more than 50% of the total carotenoid content (Fratianni et al., 2013b; Kurz, Carle, & Schieber, 2008; Sass-Kiss, Kiss, Milotay, Kerek, & Toth-Markus 2005). Degradation of carotenoids and color, together with their antioxidant activity is a common phenomenon during the thermal treatment that have been developed to extend the shelf life of fruit, vegetables and their products (Demiray, Tulek, & Yilmaz, 2013; Fratianni et al., 2010; Fratianni et al., 2013b, Yemiş, Bakkabaşi, Artik, 2012, Kamiloglu, Toydemir, Boyacioglu, Beekwilder, Hall, & Capanoglu, 2016; Saxena, Maity, Raju, and Bawa, 2012). Being highly unsaturated, carotenoids are very prone to oxidation, which causes color loss. Moreover, depending on different factors (food matrix, food structure and composition, pH, heat, oxygen tension, presence of other antioxidants) (Penicaud, Achir, Dhuique-Mayer, Dornier, & Bohuon, 2011) carotenoids are expected to undergo two types of changes: degradation and isomerization. Thermal treatment induces variable losses, depending on its severity

and length (Fratianni, et al. 2010, 2013b; Gama & De Sylos, 2007) and leads to structural modifications such as cis-isomerization (Schieber & Reinhold, 2005). The thermal lability of carotenoids is also influenced by their chemical structure. Thus, carotenoid esters showed an increased stability compared to the corresponding non-esterified carotenoids (Schweiggert, Kurz, Schieber, & Carle, 2007). The carotenoids and β-carotene degradation during thermal treatment has been reported mainly as first-order kinetics and seldom as zero-order kinetics (Demiray et al., 2013; Di Scala & Crapiste, 2008; Saxena, et al., 2012). Quantitative kinetic models describing carotenoid and color changes as a function of process parameters are valuable tools for process optimization. Other process indicator that usually takes place during thermal processing of food is the Maillard reaction and the evaluation of the initial steps provides useful information for processing control. The formation of the "Amadori compounds" that takes place during the early stage of the Maillard reaction is considered as the key factor. To date the furosine assay, which is specific for ε-N-deoxy-ketosyllysine (Amadori compound), remains the most sensitive and most accepted method for determining the extent of "early" Maillard reactions (Rufían-Henares, García-Villanova, & Guerra-Hernández, 2008). It is one of the most commonly used markers for evaluating the raw materials, the type and conditions of heat treatment, and the storage conditions (Acquistucci, Panfili, & Marconi, 1996; Caboni, Boselli, Messia, Velazco, Fratianni, Panfili, & Marconi, 2005; Marconi, Panfili, & Acquistucci, 1997; Marconi, E. Caboni, Messia, & Panfili, 2002). Furosine (2-furoylmethyl-lysine) was the main 2-furoylmethyl derivative observed in dried apricot samples (Sanz, del Castillo, Corzo, & Olano, 2001) and in different vegetable and vegetable products, where the drying process can cause the non-enzymatic condensation of carbonyl and amino groups of sugars and protein (amino acids), leading to the browning of the product (Cardelle-Cobas, Moreno, Corzo, Olano, & Villamiel, 2005; Mendoza, Olano & Villamiel, 2002). The main objective of this study was to investigate the kinetic of carotenoid and color degradation together with the furosine

evolution, in order to use them as quality markers of thermal damage of dried apricots. In addition, the evolution of the antioxidant activity of both lipophilic and hydrophilic compounds was evaluated.

2. Materials and methods

2.1 Materials

Fresh, fully ripe apricots var. *Pellecchiella (Prunus armeniaca L.*) were obtained from the local farmer (Napoli, Italy). About 900 g apricots were halved and pitted. The apricots had a spherical shape with a diameter of about 6.0 cm and a thickness (halved apricot) of about 1.2 cm. One half was subjected to the drying treatment (HA), while the other half was used as time zero control and was immediately stored at −20°C. Every couple was labeled for the following identification. Apricots were dried in a hot-air convective HA and oven at 50°C (HA50), 60°C (HA60) and 70°C (HA70). All experiments were performed in triplicate. Drying tests were performed in a hot-air convective oven (Zanussi FCV/E6L3, Zanussi Professional, Pordenone, Italy), with an air speed of 2.3 m/s. Drying was stopped, until a final content of relative moisture equal to about 20% was reached. After sampling, apricots were freeze dried by using a freeze dryer Genesis 25SES (VirTis Co., Gardiner, NY).

2.2. Furosine determination

Furosine content was determined by HPLC, according to Resmini, Pellegrino, and Battelli (1990). A sample amount, corresponding to about 30-70 mg of protein, was hydrolyzed under nitrogen with 8 ml of 8 N HCl at 110 °C for 23 h. Afterwards, the hydrolyzate (0.5 ml) was purified on a Sep-Pak C18 cartridge (Waters), diluted and analyzed by HPLC (Waters), equipped with an Alltech furosine-dedicated column (250 x 4.6 mm) (Alltech, Derfield, IL, USA). Furosine standard was purchased from Neosystem Laboratoire (Strasbourg, France).

2.3. Color measurement

Color of fresh and HA samples was measured, at regular time intervals, by using a tri-stimulus colorimeter CR-200 Chromometer (Minolta, Japan) having an aperture size of 10 mm. Hunter values (L*, a*, b*) were monitored on the surface of fresh and dried samples; nine set of data were obtained from the three replicates with three measurements for each replicate (Albanese, Cinquanta, & Di Matteo, 2007). Color parameters were L* value (lightness), b* value (yellowness and blueness) and a* value (redness and greenness). The total color difference (TCD), was used to express the overall color change during the thermal process and was calculated by using the Eq. 1 as in Saxena et al. (2012):

$$[(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2]^{1/2} \quad (1)$$

where L, a, b are the values at time t; L_0, a_0, b_0 are the values at time zero.

2.4. Carotenoid extraction and determination

Carotenoids were extracted according to the method reported by Panfili, Fratianni, and Irano (2004) and Fratianni et al. (2013b, 2015) with slight modifications: 0.5 g of freeze dried apricots was saponified under nitrogen in a screw capped tube by adding 5 mL of ethanolic pyrogallol (60 g/L) as antioxidant, 3 mL of ethanol (95%), 1 mL of sodium chloride (10 g/L), and 2 mL of potassium hydroxide (600 g/L). The tubes were placed in a 70°C water bath and mixed every 5–10 min during saponification. After alkaline digestion at 70°C for 45 min, the tubes were cooled in an ice bath and 15 mL of sodium chloride (10 g/L) were added. The suspension was then extracted with 15 mL portions of n-hexane/ ethyl acetate (9:1, v/v) until it became colorless. Recovery tests made on samples and pure standards showed that the used saponification procedure did not cause isomerization/degradation of the investigated carotenoids (Fratianni et al., 2010; Panfili et al., 2004). The organic layers, containing

carotenoids, were collected and evaporated to dryness; the dry residue was dissolved in methanol:MTBE (50:50 v/v) and an aliquot of the carotenoid extract (25 µl) was separated, as in Mouly, Gaydou, and Corsetti (1999), by a reverse-phase HPLC system. A HPLC Dionex (Sunnyvale, CA) analytical system consisting of a P680 solvent delivery system and a 25 µl injector loop (Rheodyne, Cotati) was used. Separation was performed by a YMC (Hampsted, NC, USA) stainless steel column (250×4.6 mm i.d.), packed with 5 µm silica spheres that were chemically bonded with C30 material, at a flow rate of 1 mL/min. The mobile phase was methanol:MTBE:water (v/v/v). The eluted compounds were monitored by a photo-diode array detector (Dionex, Sunnyvale) set at 430 nm. Data were stored and processed by a Dionex Chromeleon Version 6.6 chromatography system (Sunnyvale, CA).

2.5. Carotenoid identification and quantification

Antheraxanthin, lutein, zeaxanthin, β-cryptoxanthin, 9-cis-β-carotene, 13-cis-β-carotene and β-carotene were identified on the basis of diode array spectral characteristics, retention times, and relative elution order, compared with known commercially available standards. Violaxanthin, antheraxanthin, α-carotene, 9-cis-β- carotene, and 13-cis-β-carotene standards were purchased from CaroteNature (Lupsingen, Switzerland); lutein, zeaxanthin, and β-cryptoxanthin were from Extrasynthese (Z.I. Lyon-Nord, Genay, France), all-trans-β-carotene was from Sigma Chemicals (St. Luis, MO, USA). Purity for all standards was above 95% (as certified by the suppliers), except for zeaxanthin, which was 90% pure. All carotenoid standards were spectrophotometrically quantified and diluted in methanol:acetone (2:1, v/v) to give a final concentration of 25 µg/ml. The concentration range was 5– 25 µg/ml for every carotenoid standard. Identified carotenoids were quantified using calibration curves of respective standard solutions. Total carotenoids were expressed as a sum of single quantified carotenoids.

2.6. ABTS assay

The ABTS (2,2-Azino-bis (3-ethylbenzothiazoline-6-sulfonicacid) diammonium salt) antioxidant activity was determined using $ABTS^{*+}$ radical cation decolorization assay (Re, Pellegrini, Proteggente, Pannala, Yang, & Rice-Evans, 1999). Proper dilutions of the lipophilic extracts for carotenoid analysis were added to 1 mL of diluted $ABTS^{*+}$ solution; the mixture was vortexed and the absorbance was read after 1 min. The disappearance of $ABTS^{*+}$ was determined by measuring the decrease of absorbance at 734 nm for 20 min. The percentage inhibition of absorbance was calculated and plotted as a function of concentration. The blank was run with ethanol and the standard curve was prepared using 0-22 nmoles Trolox. Results were analyzed by reference to trolox and expressed as micromolar trolox equivalent antioxidant capacity (micromoles Trolox/g db). Each analysis was performed in triplicate.

2.7. DPPH assay

The antioxidant activity of the hydrophilic extract was measured with the DPPH assay as in Albanese, Cinquanta, Cuccurullo, and Di Matteo (2013).

2.8. Kinetic Parameters

The evolution of TCD, single carotenoids and total carotenoids (TCAR) during HA at 50, 60 and 70°C, was modeled by Eqs. 2–3 for a zero and first-order reaction, respectively:

$$C = C_0 \pm k_0 t \qquad (2)$$

$$ln\ C = ln\ C_0 \pm k_1 t \qquad (3)$$

where C is the concentration (%) at time t; C_0, the concentration (%) at time zero; k_0, the zero order rate constant (h^{-1}); k_1, the first-order rate constant (h^{-1}); t, the drying time (h). The efficacy of fitted model was determined by the highest correlation coefficient (R^2).

Temperature dependence of carotenoid and TCD degradation and furosine formation was determined by the Arrhenius equation (Eq. 4) and Q_{10} value (Eq. 5):

$$k = k_0 \times e^{[-Ea/RT]} \quad (4)$$

where E_a, the activation energy (kcal/mol); k, the rate constant; k_0, the pre-exponential factor; R, the universal gas constant (8.314 J/(mol. K), T, the absolute temperature (K).

$$Q_{10} = k_2/k_1^{\,10/T2-T1} \quad (5)$$

where k_2 is the rate constant of the furosine formation and TCD and carotenoid degradation at T2 temperature; k_1 is the constant rate of the furosine formation and TCD and carotenoid degradation at T1 temperature.

2.9. Statistical analysis

Drying tests, for all temperatures, were performed in triplicate. Data reported are means and standard deviations calculated from three replicates. The analysis of variance (ANOVA) was applied to the data. The least significant differences were obtained using an LSD test ($P < 0.05$). Statistical analysis was performed using an SPSS version 13.0 for Windows (SPSS, Inc., Chicago, IL, USA).

3. Results and discussion

3.1. Drying curves

In the early stages of convective drying sensible heating dominates while, in the later stages, the progressive reduction in the evaporation rates was responsible for the lower drying rates. When the internal resistance to the transport of liquid water to the surface increases, thereby lowering the drying rate, the falling rate period occurs. Hence, internal diffusion may be assumed as the mechanism responsible for water loss during the drying process. At lower drying temperatures (50 °C) a more uniform moisture distribution exists, which allows the sample to continue to shrink until the last stages of drying, ending after about 25 hours, with a low porosity (Fig. 1). On the contrary, at highest air temperatures (70°C) the drying process lasts about 10 hours, but case hardening of the surface may occur and the volume of the sample becomes fixed at an earlier stage, inducing less shrinkage and a more intensive pore formation (Bonazzi & Dumoulin, 2011).

3.2. Furosine evolution

The Maillard reaction is strongly influenced by the temperature and the moisture content of the food during drying (Labuza, & Saltmarch, 1991). In addition, also the reducing sugars play an important role in the furosine formation in some groups of vegetables (Rufían-Henares et al., 2008). Furosine values were determined at 2 h, at the middle and to the end of drying. The furosine evolution was fitted at zero order kinetic model (Fig. 2). During drying, furosine values went from 2.4 to 28.1 mg/100g protein, from 3.6 to 40.1 mg/100g protein and from 4.4 to 70.4 mg/100g protein for HA50, HA60 and HA70, respectively. The Ea for furosine formation was found to be 83.3 kJ/mol and the Q_{10} values went from 1.59 to 4.14 at the temperature ranges 50-60°C and 60-70°C, respectively (Table 2). The parameter Q_{10} describes the temperature dependence of a reaction as the factor by which the reaction rate is changed when the temperature is increased by 10°C. It can be concluded that the browning increases markedly when the temperature increases from 60 to 70°C.

237 *3.3. Impact of thermal treatment on color parameters and carotenoids*

238 Carotenoid profiles in fresh apricot showed seven different identified compounds, in the following
239 elution order: (i) epoxycarotenoids: violaxanthin, antheraxanthin, (ii) hydroxycarotenoids: lutein,
240 zeaxanthin, β-cryptoxanthin and (iii) carotenes: 13-cis-β-carotene, all-trans-β-carotene and 9-cis-β-
241 carotene. Total carotenoid content in fresh fruits was 137.8 mg/kg db: the main compound was β-
242 carotene (65%), followed by β-cryptoxanthin (11%), 13-cis-β-carotene (9%), 9-cis-β-carotene (7%),
243 violaxanthin (5%), lutein (2%) and antheraxanthin (about 1%), according to Fratianni et al. (2013b).
244 The amount of the main representative identified carotenoids in fresh and HA dried apricots at the end
245 of the drying treatment are reported in Table 1. At the end of the drying treatments the total carotenoid
246 (TCAR) content significantly reduced to about 40% and 45% from fresh fruit at 50°C and 60°C,
247 respectively, while the extent of TCAR degradation increased at 70 °C, with about a 70% decrease. The
248 reduction observed for β-carotene was similar to that of total carotenoids. In a previous work (Fratianni
249 et al., 2013b) we observed a lower decrease in TCAR, about 20% for HA60 samples and 40% for
250 HA70 samples. Violaxanthin and anteraxanthin were the most susceptible to thermal treatment;
251 antheraxanthin, in particular, was found to significantly decrease ($P<0.05$) during the first hours of
252 drying and to disappear at the end of drying in all HA samples. The high susceptibility of 5,6-
253 epoxycarotenoids (violaxanthin and antheraxanthin) was also observed in previous works (Fratianni et
254 al., 2010; Fratianni et al., 2013b) and by other authors (Melèndez-Martínez, Britton, Vicario, &
255 Heredia, 2008), which found also their isomerization into their corresponding 5,8-epoxyderivatives,
256 however, this isomerization was not observed. Several studies report the decrease of trans β-carotene
257 and the concomitant increase in cis isomers in vegetables subjected to thermal processes (Penicaud et
258 al., 2011; Schieber & Reinhold, 2005). However, in our case no rising of cis isomers, 9-cis β-carotene
259 and 13-cis β-carotene, was found during drying treatment, indicating the predominance of a higher
260 degradation rate upon isomerization. The above reported different results could be due to the fact that

isomerization and degradation processes could depend also on the structure and cellular organization of carotenoids in the food matrix, water activity (Lavelli, Zanoni, & Zaniboni, 2007), pH, oxygen occurrence and the interactions with other antioxidants (Dragovic-Uzelac, Levaj, Mrkic, Bursac, & Boras, 2007, Penicaud et al., 2011). Degradation of carotenoid content was found to follow first-order reaction kinetics, as reported in Figs 3 and 4 for β-carotene and TCAR, respectively, where the negative slope shows the degradation of content as a function of time. As for visual color, with the increase in time and temperature the lightness (L* value) of all HA samples tended to decrease, while the b* value (yellowness) decreases at 60°C and 70°C (data not shown). The alteration in total color difference (TCD) was modeled using the Eq. 1. Zero order kinetic plots, showing the change of TCD in function of time, are reported in Fig. 5. At the end of drying the TCD increases from 0 to 7.6, 13.1 and 14.0 at 50, 60 and 70°C, respectively. Rate constants at different drying temperatures and Q_{10} values for single, total carotenoids (TCAR) and TCD are presented in Table 2. Q_{10} values for TCAR were similar at all the analyzed temperature ranges and close to those of TCD in the range 50-60°C. Q_{10} values for TCD were slightly lower in the range 60-70°C. From Q_{10} values for single carotenoids emerged that the most susceptible carotenoid to the temperature increase from 50 to 60°C was lutein. These data are in accordance with previous results (Fratianni, et al., 2010) where lutein, together with violaxanthin, was found to be the most sensitive carotenoid to temperature changes. The E_a for change in TCD was found to be about 67 kJ/mol. The E_a for the degradation process of carotenoids was observed in the range from 73.7 kJ/mol for 13-cis-β-carotene to 120.7 kJ/mol for lutein, being about 91 kJ/mol and 97 kJ/mol for β-carotene and TCAR, respectively. Several literature works show variable results, with a E_a range from 14 to 188 kJ/mol (Ahmed, Shivhare, & Sandhu, 2002; Penicaud et al., 2011; Saxena et al., 2012). The observed difference in susceptibility of carotenoid content to drying temperatures might be due to differences in processing, in type of fruit, degree of ageing and carotenoids composition. Moreover, the β-carotene reaction may be influenced by the presence of co-substrates, which can be found in different

285 concentration in food matrices (Penicaud et al., 2011). A good correlation, at all drying temperatures,
286 was found between the evolution of total carotenoid content and TCD ($r > 0.90$), of TDC and furosine ($r > 0.95$), and of total carotenoids and furosine ($r > 0.95$).
287
288

289 *3.4. Impact of thermal treatment on the antioxidant capacity*

290 The antioxidant activity of lipophilic extracts (ABTS assay) of fresh samples, was found to be about
291 1.7 μmol Trolox/g db, while that of hydrophilic extract (DPPH assay) was found to be about 13.5 (%
292 inhibition of DPPH $*$ mg^{-1} db^{-1}). Similar decreases ($P < 0.05$) in the antioxidant activity of hydrophilic
293 extracts and lipophilic ones were observed at the end of drying, being about 35-40%, at all the applied
294 temperatures, (Figs. 6A and 6B). In addition, the evolution of the antioxidant activity, with the
295 exception of HA50 samples at the middle of the drying process, was the same for both extracts, showing
296 a decrease until the middle of the drying time, followed by no further decreases until the end of the
297 process. Decreases in the antioxidant activities under drying conditions have been found by different
298 authors in several fruit and vegetable products (Duru, Karadeniz, & Erge, 2012; Kamiloglu et al., 2016;
299 Sogi, Siddiq, & Dolan, 2015). In some case, different results were observed for dried apricots, with an
300 increase in DPPH during processing, probably due to the formation of new compounds of antioxidant
301 activity or to the presence of interfering substances, such as sulphites (Igual, García-Martínez, Martín-
302 Esparza, Martínez-Navarrete, 2012).
303

304 **4. CONCLUSIONS**

305 On dependence of the applied drying temperatures, a statistically significant decrease of carotenoids,
306 visual color (TCD) and antioxidant activities, together with an increase of furosine, occurred.
307 Carotenoid degradation was adequately described by a first-order kinetic model, with activation energy

E_a of 97 kJ/mol, higher than that of TCD, which was about 67 kJ/mol. In particular, among carotenoids, the epoxycarotenoids violaxanthin and antheraxanthin confirmed to be adequate markers for the evaluation of drying process.

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454 **Figure legend**

455

456 **Fig.1.** Plots of the drying process of apricots at different temperatures. Squares, 50 °C; diamonds, 60
457 °C; triangles, 70 °C

458 **Fig.2.** Furosine evolution during apricot drying at different temperatures. Squares, 50 °C; diamonds, 60
459 °C; triangles, 70 °C

460 **Fig.3.** Kinetic plots of changes of β-carotene in apricots dried at different temperatures. Squares, 50 °C;
461 diamonds, 60 °C; triangles, 70 °C.

462 **Fig.4.** Kinetic plots of changes of total carotenoids (TCAR) in apricots dried at different temperatures.
463 Squares, 50 °C; diamonds, 60 °C; triangles, 70 °C.

464 **Fig.5.** Kinetic plots of changes of total color difference (TCD) in apricots dried at different
465 temperatures. Squares, 50 °C; diamonds, 60 °C; triangles, 70 °C.

466 **Fig.6.** Effect of apricot drying at different temperatures on the antioxidant activity (A) DPPH (B)
467 ABTS.

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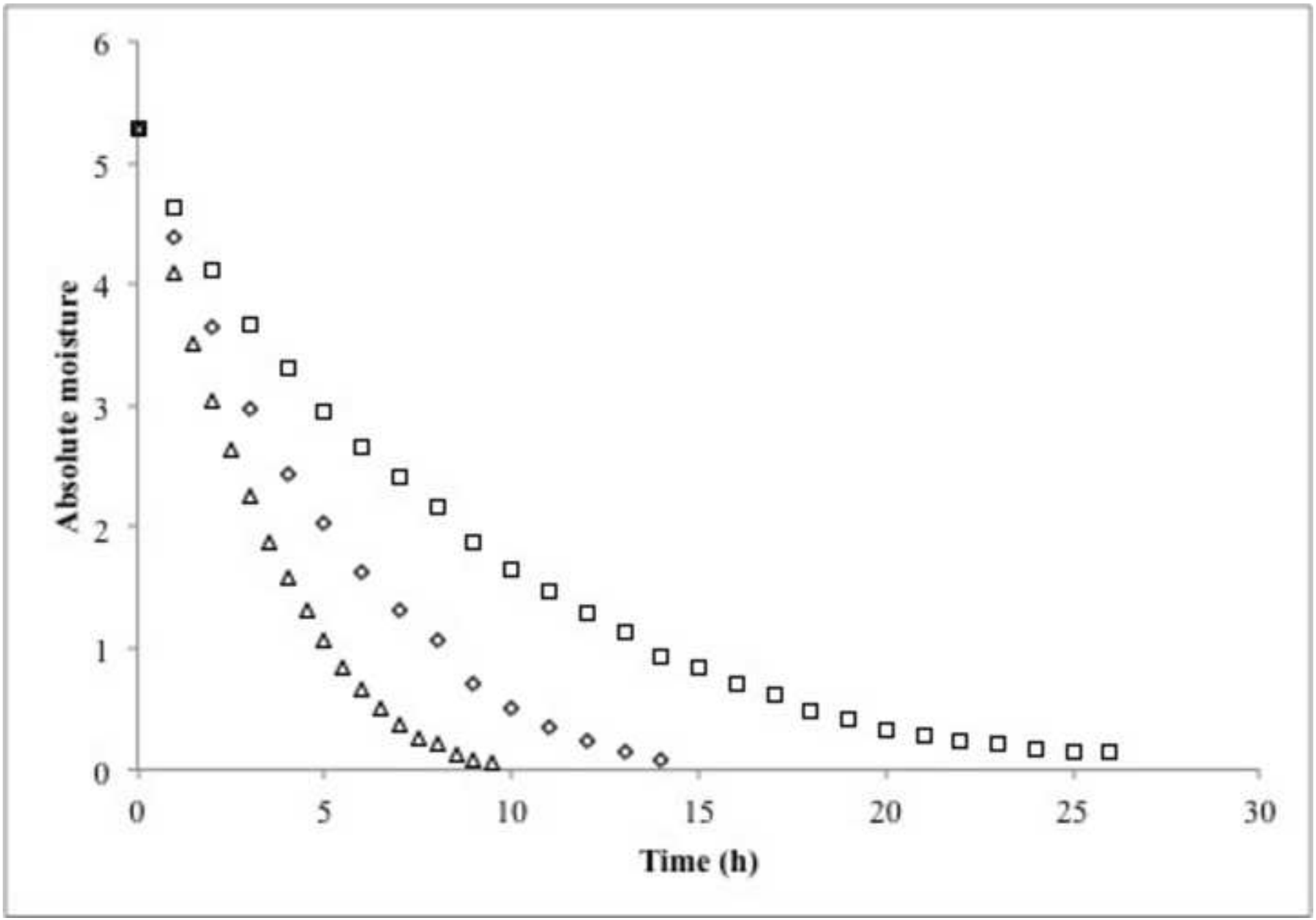

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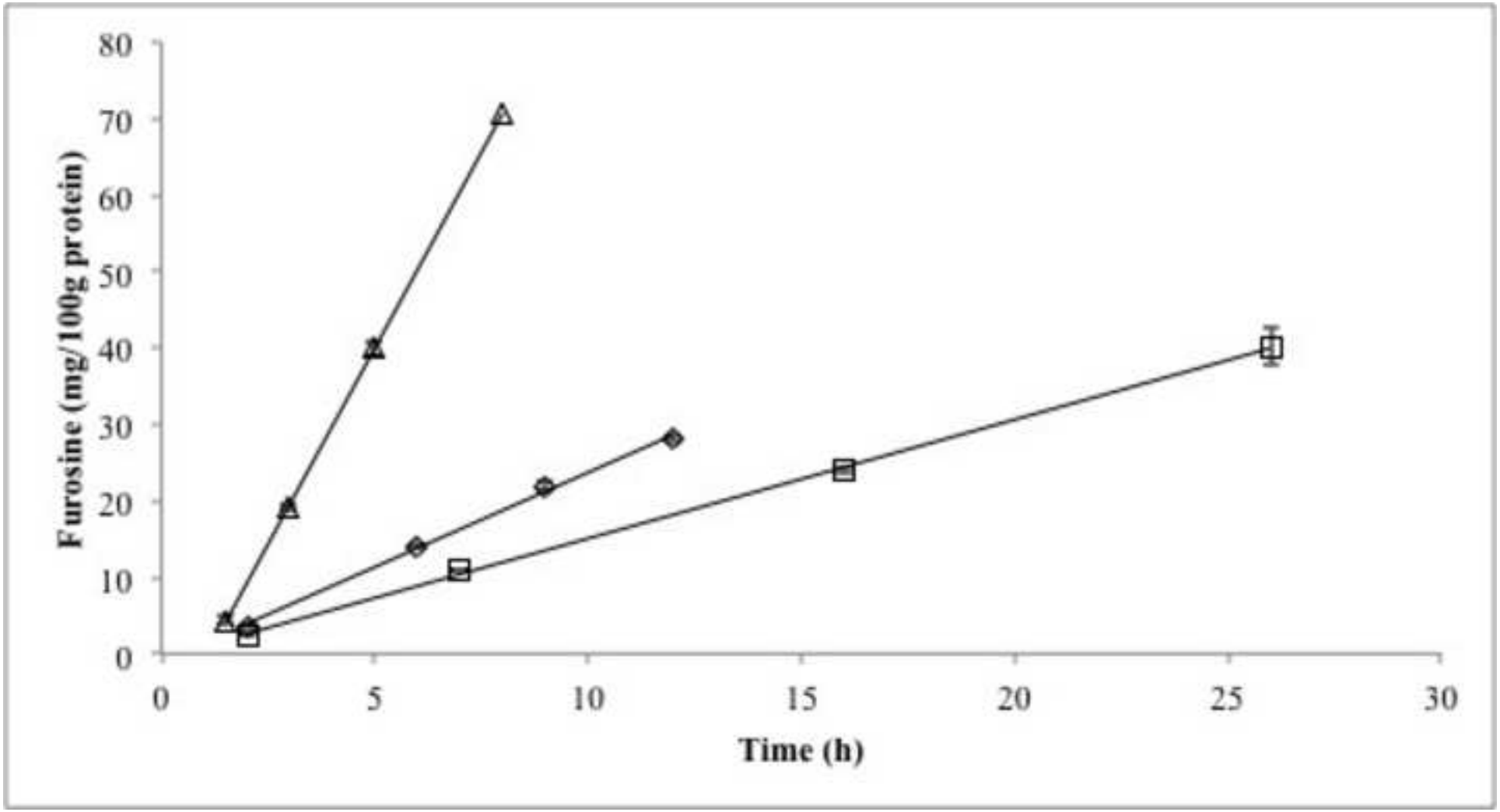

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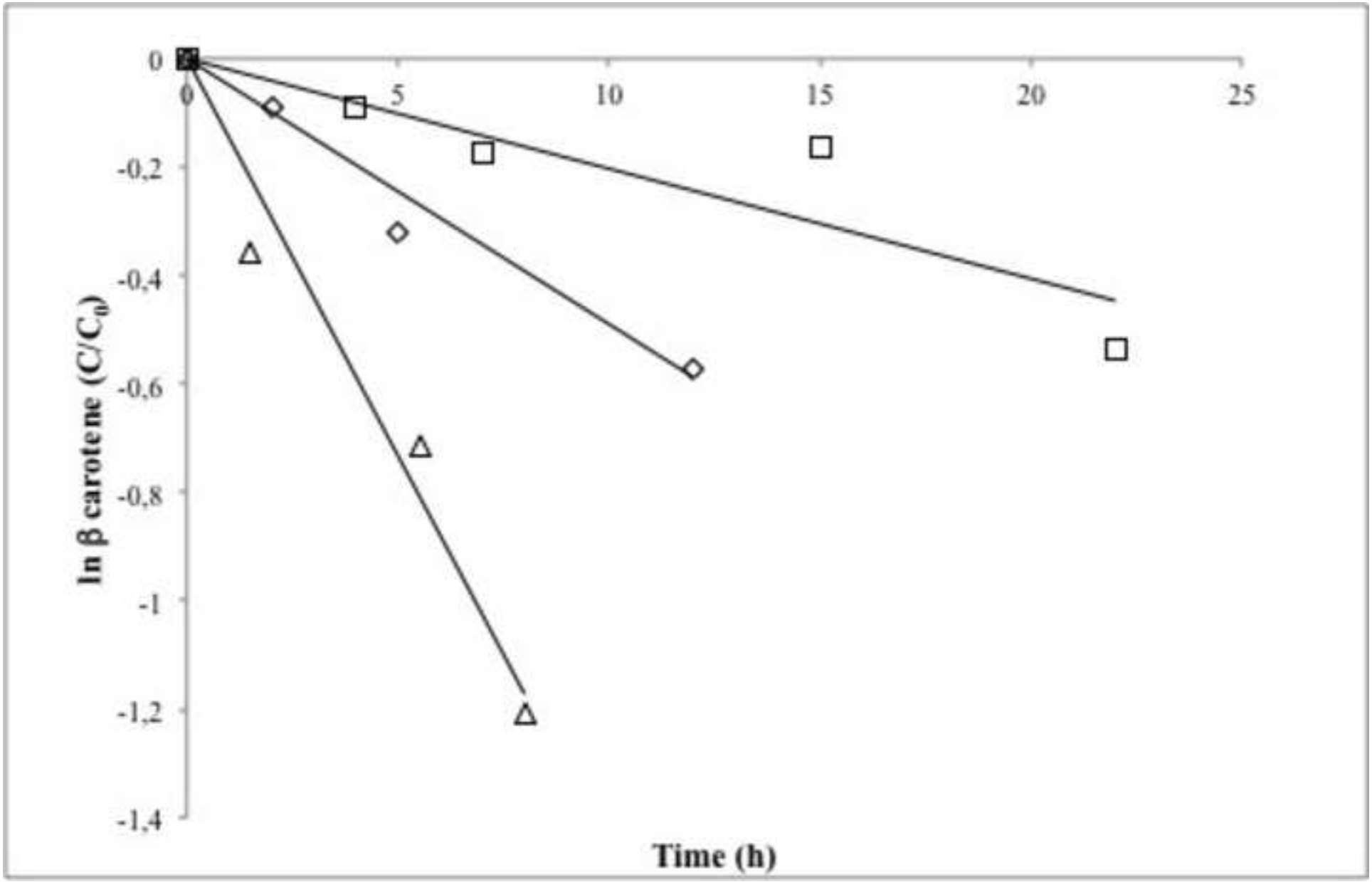

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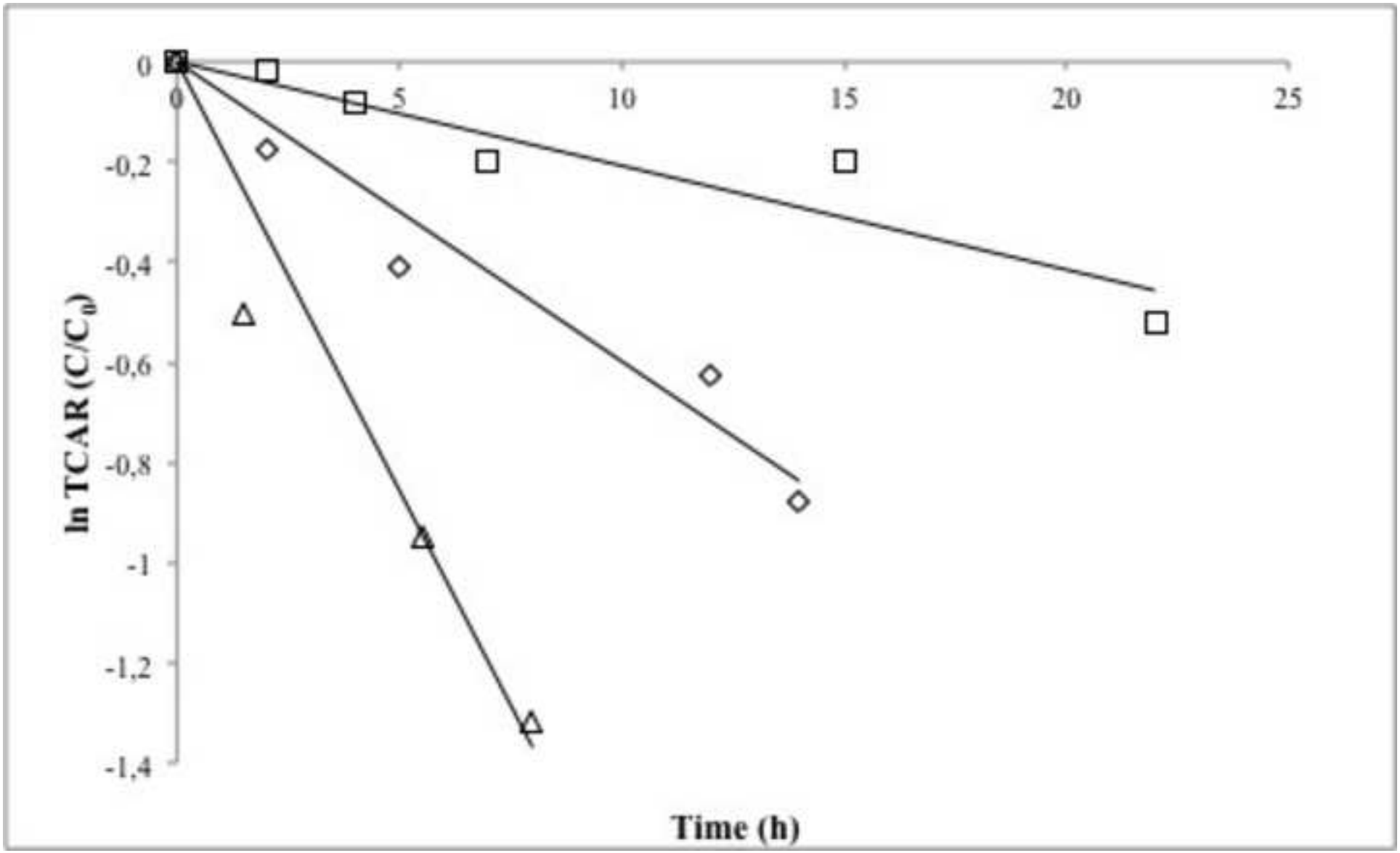

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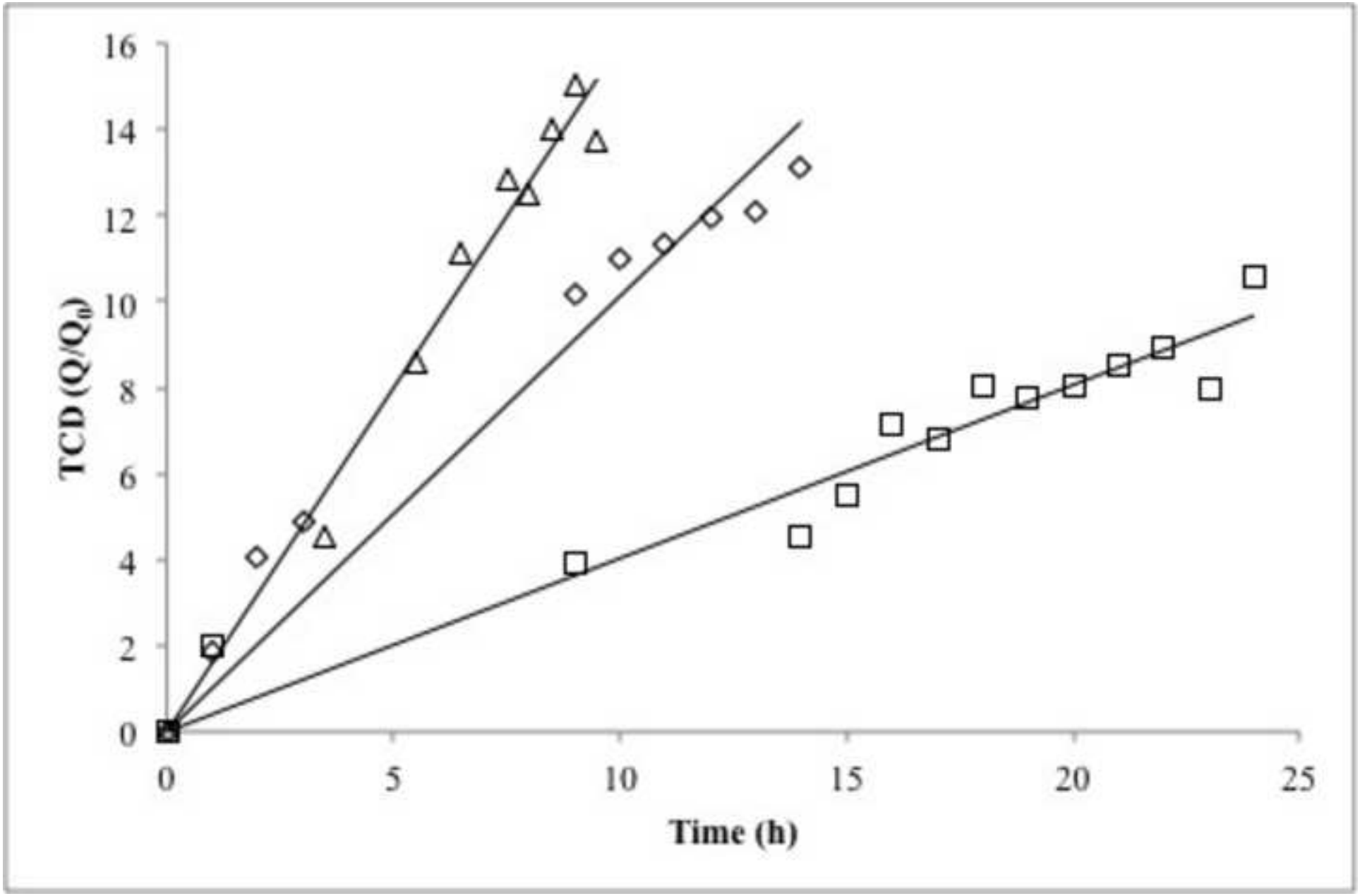

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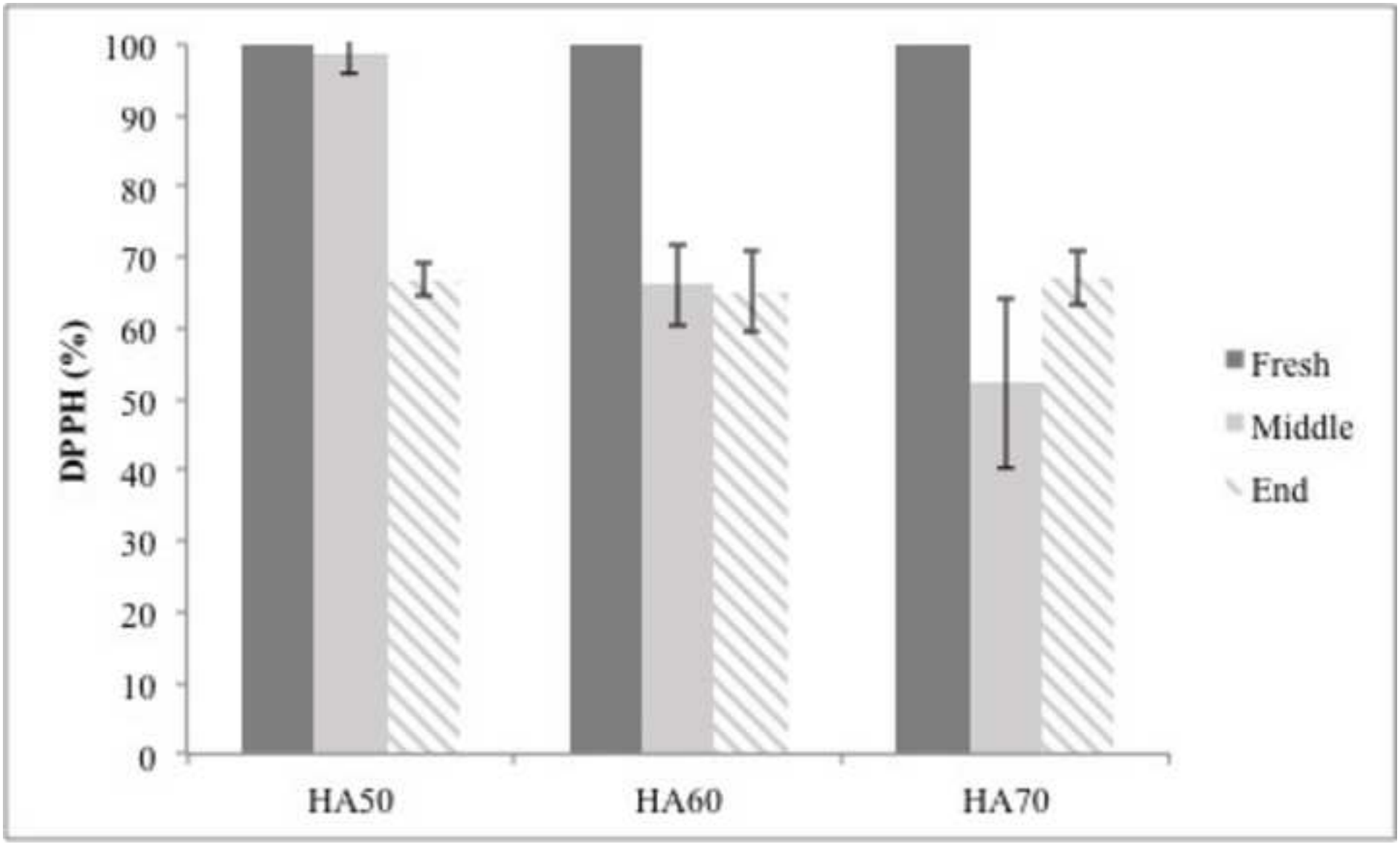

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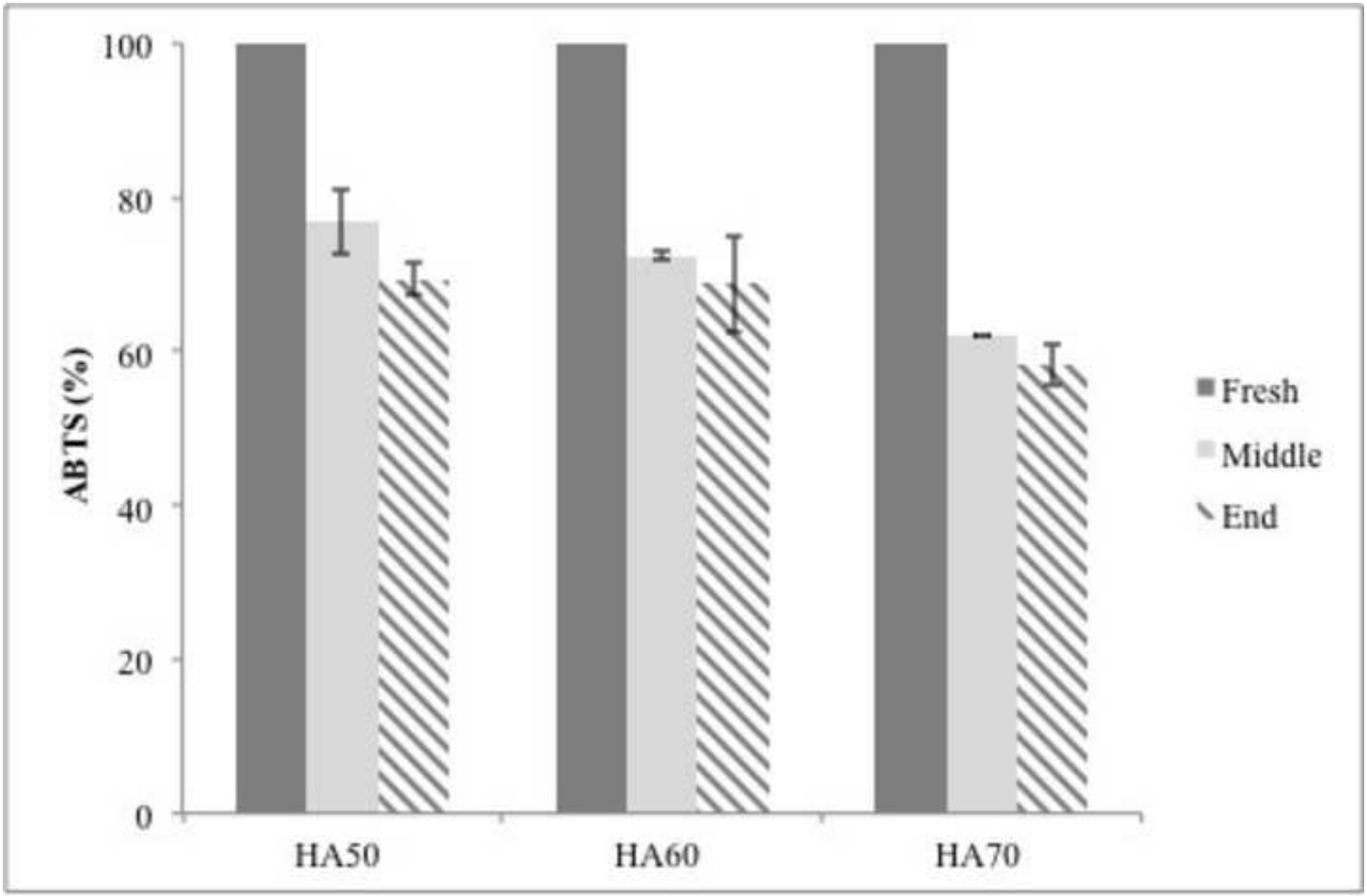

Table 1.
Main carotenoid composition and content (μg/100 g db) in fresh and HA dried apricots at the end of the drying treatment at different temperatures (mean of 3 determinations).

Compound	Fresh	End of treatment*		
		50°C	60°C	70°C
Violaxanthin[§]	674.5[a]	16.6[b]	0.0	0.0
Anteraxanthin	122.3 [a]	0.0	0.0	0.0
Lutein	311.7 [a]	187.0[b]	155.8[c]	0.0
β-criptoxanthin	1457.1[a]	1129.0[b]	852.2[c]	413.1[d]
13-cis-β-carotene	1221.3[a]	791.2[b]	817.2[b]	470.0[c]
β-carotene	9011.2[a]	5270.1[b]	6029.2[c]	3468.1[d]
9-cis-β-carotene	984.1 [a]	577.8[b]	361.9[c]	219.2[d]
Totals	13782.2 [a]	7971.7[b]	8216.3[c]	4570.4[d]

* 22 h for 50°C; 12 h for 60°C; 8 h for 70°C.

[§] Different letters in the same raw indicate a significant difference ($P < 0.05$).

Table 2.

Rate constants, activation energy (E_a) and Q_{10} values of carotenoid, TCD formation and furosine evolution during apricot drying at different temperatures.

	Rate constant (min^{-1})	R^2	Rate constant (min^{-1})	R^2	Rate constant (min^{-1})	R^2	E_a (kJ/mol)	Q_{10}	
	50°C		60°C		70°C			50-60°C	60-70°C
Carotenoids									
Violaxanthin	0.0812	0.939	0.1570	0.956	nd	--	nd	1.93	nd
Anteraxanthin	0.0490	0.916	0.1591	0.841	0.3174	0.861	86.20	3.24	2.02
Lutein	0.0170	0.883	0.1237	0.901	0.2312	0.958	120.74	7.27	1.86
β-criptoxanthin	0.0146	0.859	0.0575	0.826	0.1697	0.895	120.61	3.93	2.95
9-cis-β-carotene	0.0213	0.820	0.0895	0.898	0,1872	0.980	100.34	4.20	2.09
13-cis-β-carotene	0.0247	0.876	0.0350	0.815	0.1237	0.940	73.72	1.41	3.53
β-carotene	0.0203	0.84	0.0490	0.908	0.1465	0.965	90.85	2.41	2.98
TCAR*	0.0208	0.892	0.0598	0.934	0.1710	0.933	96.95	2.88	2.86
*TCD***	0.3770	0.913	1.0124	0.941	1.5978	0.974	66.70	2.69	1.58
Furosine	1.5560	0.999	2.4731	0.997	10.247	0.999	83.30	1.59	4.14

*Total carotenoids.

** Total color difference.

*Graphical Abstract

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