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CONSEQUENCES OF NAA, BA AND GA3 TREATMENT IN EARLY FRUIT DEVELOPMENT PHASE ON POSTHARVEST PROPERTIES OF APRICOT CV. NS4

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ABSTRACT

The effects of plant growth regulators (PGRs) including representative compounds from the group of cytokinins, auxins and gibberellins, on fruit quality and postharvest properties during 15 days of cold storage and 3 days of shelf life were compared. Apricots, cv. NS4, were treated with 1-naphthaleneacetic acid (NAA; 10 and 20 mg L^{-1}), 6-benzyladenine (BA; 50 and 100 mg L^{-1}) and gibberellin (GA3; 200 mg L^{-1}) 14 and 21 days after full bloom. Application of PGRs resulted in increase of ash, total soluble solids and decrease of water content in fruit, while the color of fruits was characterized with lighter skin and with more intensive color changes during postharvest period. BA decreased the content of majority of cations, while higher dosage of this compound resulted in the lowest fruit firmness. Application of NAA and GA3 increased of Ca and Mg content and resulted in the most expressed water loss. Titrable acidity and pH were not affected by any applied treatments.

Key words: apricot fruit, plant growth regulators, storage, shelf life, postharvest quality

INTRODUCTION

Phytohormones, with different roles in plant growth regulation are being synthetized at different stages of fruit development resulting in regulation of fruit development process [Ji et al. 2021]. Exogenous application of natural or synthetic phytohormones as plant growth regulators (PGRs) in fruit production disrupts a normal sequence of phytohormones synthesis resulting in alteration in fruit yield, quality and shelf life [Dias 2019].

In agricultural practice PGRs are commonly used for improvement of fruit set, regulation of fruit retention, control of plant and organ size, as well as improvement of fruit quality and its yield [Nickell 1994]. Application of PGR as a part of production practice could change, or even reverse naturally occurring ripening processes, leading either to improvement or deterioration of fruit quality [Abdel-Gawad and Romani 1974]. Gibberellic acid was proven to delay flower induction and control fruit set and regulate thinning [Abdel-Mohsen and Kamel 2015, Devrari et al. 2017]. Both, synthetic auxins (naphthaleneacetic acid, naphthaleneacetamide) [Son 2004, Taghipour et al. 2011,

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Devrari et al. 2017] and cytokinin (benzyladenine) [Abdel-Mohsen and Kamel 2015] were proven to control fruit set.

Application of PGRs was extensively investigated in production of diverse fruits including apricot. Experiments involving application of PGRs on apricots fruit quality at harvest are abundantly presented in academic literature regarding application of auxin [Son 2004, Stern et al. 2007, Taghipour et al. 2011, Devrari et al. 2017, Roussos et al. 2021], gibberellin [Abdel-Mohsen and Kamel 2015, Devrari et al. 2017] and cytokinin [Canli et al. 2014, Abdel-Mohsen and Kamel 2015, Roussos et al. 2021]. However, studies regrading postharvest behavior of treated fruit after PGRs application are quite scarce. There are several reports regarding postharvest changes of apricot fruits treated with GA3 [Abdel-Gawad and Romani 1974, Lal et al. 2011] and BA [Abdel-Gawad and Romani 1974] at ambient temperature. Regarding the effects of PGR on apricot fruit postharvest behavior after cold storage, there are just a few reports including effects of NAA [Mesa et al. 2012] and GA3 [Dagar et al. 2012] while, up to now, to our best knowledge, no results were published about influence of treatment with NAA, GA3 or BA on shelf life of apricots after cold storage.

In this study effects of commonly used auxin (NAA), cytokinin (BA) and gibberellin (GA3), applied during early stages of fruit development on difference in fruit quality and chemical composition at harvest and after cold storage and shelf life were compared with the aim to capture and emphasize the common effects of application of used PGRs on apricot fruit quality and postharvest behavior.

MATERIALS AND METHODS

Apricots (*Prunus armeniaca* L.) cv. NS4 were grown in experimental orchard at Rimski Šančevi, Serbia (45°19'N and 19°50'E, 86 m a.s.l.), equipped with drip irrigation system and anti-hail nets, established in 2012 with density of 1250 trees per ha. Apricot trees were treated with 10 mg L^{-1} and 20 mg L^{-1} of 1-naphthaleneacetic acid (NAA10 and NAA20, respectively), 50 mg L^{-1} and 100 mg L^{-1} of 6-benzyladenine (BA50 and BA100, respectively) and 200 mg L^{-1} of gibberellin A3 (GA3) two times: when fruits reached diameter of 5 mm (14 days after full bloom) and of 10 mm (21 days after full bloom). Each treatment was applied at six single randomly distributed trees. Fruits were harvested in commercial ripening stage (I_{ad} 0.4–0.8), using DA meter (TR-Turoni, Forlì, Italy) for determination of fruit ripening stage

Fruits were divided in three lots. First lot was used for analysis, while the other two were stored in cooling chamber (1 ±1°C) for 15 days in wooden crates 50 × 30 × 8 cm. After cold storage, one lot was used for analysis while the other was exposed to 3 days of shelf life at room temperature.

Respiration rate, color and texture were analyzed 12 h following the harvest as well as cold storage, when the fruits reached room temperature. For chemical analysis fruits were quartered and one quarter from each fruit was used for homogenization. Homogenized samples were frozen in thin layer in PA bags in dry ice and stored at –18°C until further analysis.

Respiration rate was determined on fruits sealed with multilayer foil in plastic container for 4 h at room temperature. Carbon dioxide (CO_2) content was analyzed using OXYBABY® 6.0 (WIT-Gasetechnik GmbH & Co KG T, Germany). Weight loss was determined at room temperature (24 ±2°C) and low relative humidity (60–70%). Measurements of fruit weight and respiration rate were performed at harvest, as well as after 15 days of cold storage, for 4 consecutive days.

Thermo-gravimetric analysis was used for determination of moisture and ash content (TGA 701, Leco, St. Joseph, MI, USA). Total soluble solids (TSS; %) were determined by digital refractometer ATR-ST plus (Schmidt + Haensch, Germany) on previously homogenized apricot samples at 20°C. Titrable acidity (TA) was determined by titrating of 10 mL of homogenized sample with 0.1 M NaOH and expressed as malic acid. pH was measured directly, using pH meter (AMT12, Amtast, USA).

Determination of K, Ca, Mg, Fe and Zn in sample prepared in microwave-assisted wet digestion (Milestone, Ethos 1, Italy) was performed by AAS (Varian, SPECTRAA 10).

Carotenoids were extracted from 2 g of homogenized sample dissolved in 20 mL of acetone, vortexed and centrifuged at 13,776 g (Centrifuge 5804R, Eppendorf, Germany), for 5 min and analyzed spectrophotometrically (CINTRA 303, GBC, Australia), by

measuring absorbance at 662, 645 and 470 nm. Carotenoid contents (mg/100 g of fresh weight) were calculated using molar extinction coefficients according to the formula:

$$\text{Carotene} = 1000\,A_{470} - 2.270\,(11.75\,A_{662} - 2.35\,A_{645}) - 81.4\,(18.61\,A_{645} - 3.96\,A_{662})/227$$

Extraction of phenols was carried out from 1 g of homogenized sample in two steps, the first step in 40 mL of methanol : water (50 : 50; v : v) and the second in 40 mL of acetone : water (70 : 30; v : v) incubated in both steps at orbital shaker PSU-10i (Boeco, Germany), for 60 min, and centrifuged at 13,776 g (Centrifuge 5804R, Eppendorf, Germany), for 5 min. Supernatants were combined and filled up to 50 mL with mixture methanol : aceton : water (25 : 35 : 40; v : v : v). Total phenols content (mg of gallic acid equivalent (GAE)/100 g) was analyzed spectrophotometrically (CINTRA 303, GBC, Australia) according to Folin-Ciocalteu method : 0.1 mL of extract, 7.9 mL of dH_2O and 0.5 mL of Folin-Ciocalteu reagent diluted with deionized water (1 : 1; v : v) were mixed and incubated for 5 min. Subsequently, 1.5 mL of 20% Na_2CO_3 solution was added to the mixture, and incubated for 30 min. Absorbance was recorded at 750 nm and calibration was obtained using gallic acid as the reference standard.

The color of apricot fruit was determined by CR-400 Chroma Meter (Konica-Minolta, Osaka, Japan) on 10 randomly selected apricot fruits, with two measurements on the opposite sides at equatorial region. Results were expressed in CIE L*a*b* color system, with L*; a*; b* representing lightness; intensity of red/green color and intensity of yellow/blue color, respectively. Color difference between two samples (ΔE) was calculated according to the formula:

$$\Delta E = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2}$$

Flesh firmness represented as the force (N) needed for penetration of 8 mm diameter stainless steel rounded cylinder probe to pre-set distance 3 mm, at penetration speed 10 mm s^{-1} and trigger force 25 g was analyzed using TA.XT Plus Texture Analyzer (Stable Micro Systems, England, UK). Penetration test was performed on 10 randomly chosen fruit from which small circle of skin was removed at its equatorial region, with a sharp peeler.

Statistical analysis

Significance of effects of PGRs application and storage and their interaction was determined using ANOVA. Difference between average values was tested with Duncan's multiple range test, while for respiration and ethylene Tukey's HSD test was used. Statistical calculations were performed using (TIBCO Statistica 14.0; Software Inc., 2020; available from: http://tibco.com).

RESULTS AND DISCUSSION

Respiration rate and weight loss

At harvest all fruits treated with PGRs were characterized with higher respiration rate in comparison to non-treated fruits (Fig. 1), for BA50 and NAA10 the difference was significant. After harvest fruit respiration rate slightly decreased remaining finally at rather constant level, while after cold storage it significantly increased throughout the shelf life (Fig. 1). After cold storage respiration rate of fruits treated with PGRs was somewhat lower in comparison to the non-treated control, for NAA10 and NAA20 the difference was significant. Present results suggest that respiration in apricot might be altered by application of PRGs.

Slight differences among the applied PGR treatments were noted also regarding weight loss (Fig. 1). At harvest, after 4 days of shelf life, only fruit treated with NAA20 had significantly lower weight loss compared to the control and other PGR treatments. The treatment with NAA, for both used concentrations, was characterized with significantly lower weight loss also after cold storage and shelf life when compared to control.

Fruit composition

Ash and mineral content were analyzed at harvest. In dependence of ripening stage and cultivar, ash content in apricot fruits can range from 1% up to 6.32% [Iordănescu et al. 2018]. Application of PGRs resulted in significant increase of ash content in comparison to the control fruit (Tab. 1). The highest ash content increase was recorded in fruit treated with NAA20, while the lowest, but still significant, in fruit treated

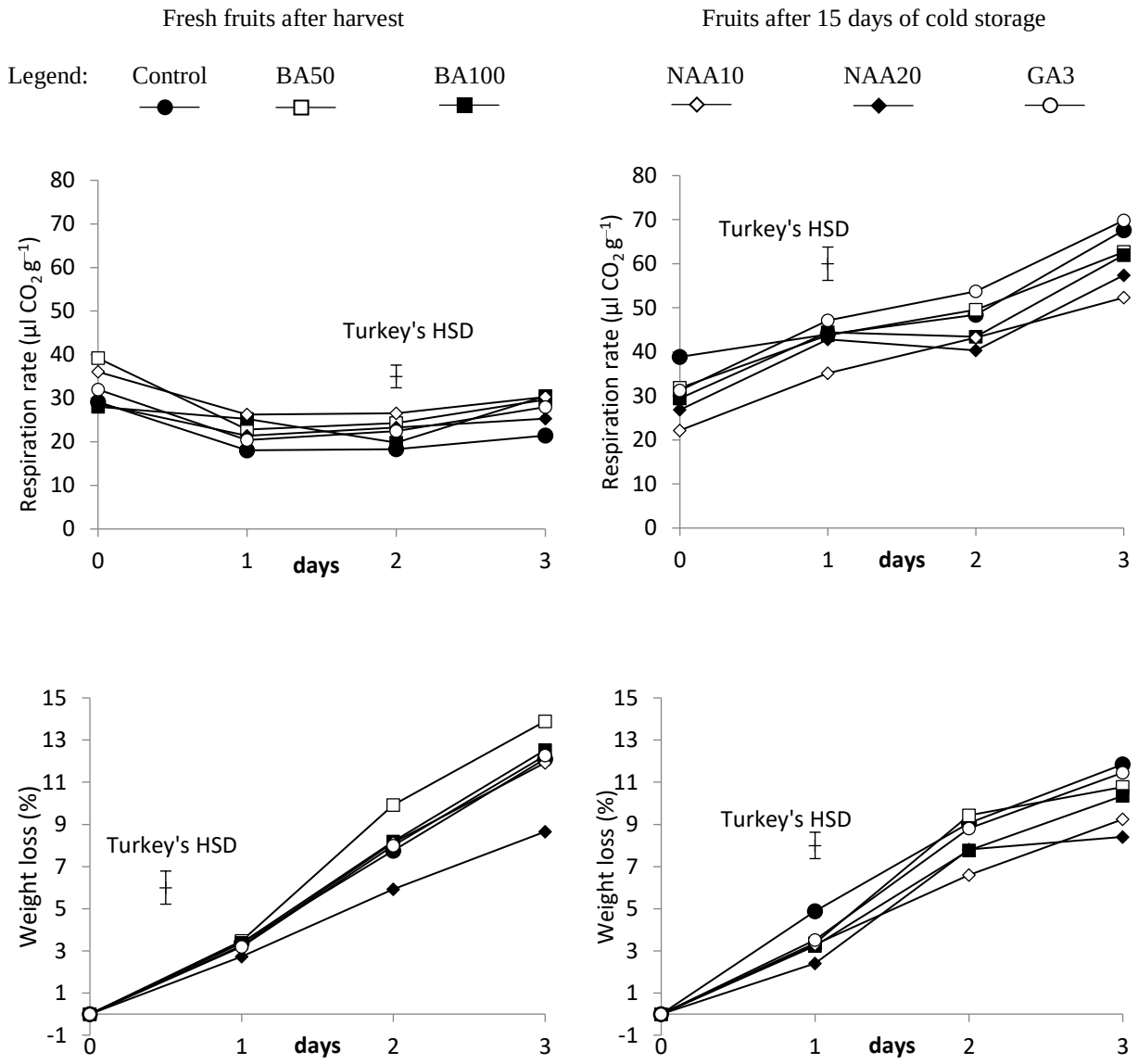

Fig. 1. Respiration rate and weight loss in apricot fruit after the harvest and 15 days of cold storage, followed during 4 consecutive days of shelf life

Table 1. Content of ash, K, Ca, Mg Fe and Zn in apricot fruit treated with PGRs

Treatment	Ash (%)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	Fe (mg/kg)	Zn (mg/kg)
Control	0.82^{d}	3041^{b}	123^{cd}	84.0^{b}	3.25	1.58^{a}
BA50	1.15^{c}	2891^{cd}	144^{c}	78.2^{c}	3.26	1.39^{bc}
BA100	1.25^{bc}	2970^{bc}	101^{d}	74.9^{d}	2.79	1.47^{b}
NAA10	1.22^{bc}	3253^{a}	193^{a}	93.7^{a}	3.41	1.32^{c}
NAA20	1.41^{a}	2998^{b}	152^{ab}	86.6^{b}	3.07	1.30^{c}
GA3	1.27^{b}	2829^{d}	140^{c}	72.3^{d}	3.69	1.58^{a}
Treatment	**	**	**	**	N.S.	**

** statistically significant at $p < 0.01$; N.S. – not significant; ^{abcd} statistically significant values are denoted with different letters ($p < 0.05$)

with BA50. The levels of individual minerals showed different trends depending on the applied treatment (Tab. 1). Only Fe content was not significantly influenced by PGR treatments, while in the case of all other minerals the influence was highly significant ($p < 0.01$). The content of Zn was significantly lower in fruit treated with BA and NAA regardless of applied concentration. Treatment with BA, regardless of concentration resulted in lower content of K and Mg, while both treatments with NAA resulted in significantly higher content of Ca and Mg. Application of GA3 resulted in lower K and Mg content. Similar to our findings, Iordănescu et al. [2018] noted a decrease in content of individual cations (K, Ca, Mg and Fe) along with an increase in total ash during fruit ripening.

Contents of water, soluble solids, acids, carotenoids and phenols were analyzed both after harvest and after cold storage and shelf life (Tab. 2). Treatment with PGRs exhibited significant effects on water content, carotenoids, total phenols ($p < 0.01$) and total soluble solids ($p < 0.05$) in apricot fruit. Storage as well as the interaction of treatments with PGRs and storage significantly influenced water content, total soluble solids, carotenoids and phenols ($p < 0.01$). In the case of titrable acidity and pH no significant changes were detected among the applied treatments (Tab. 2).

Content of water in apricots varies in dependence of cultivar and ripening stage from below 80% to almost 89% [Iordănescu et al. 2018]. Water content of harvested apricot fruits was at about the same level at harvest (85.1–85.7%) regardless of applied treatment with PGRs (Tab. 2) but the reduction of water content during cold storage and shelf life was evidently affected. NAA and GA3 resulted in more expressed reduction of water content in postharvest period. During shelf life, the most expressed loss of water was noted in fruits treated with GA3 followed by the treatment with NAA10. In fruits treated with BA, reduction of water content was comparable to the non-treated fruit.

Application of PGRs resulted in lower total soluble solids (TSS) content at harvest in comparison to non-treated fruit (Tab. 2). Oppositely to our findings, Taghipour et al. [2011] found no changes in TSS in apricot fruits when NAA was applied. Diverse influence of NAA on total soluble solids in apricot in dependence of concentration and cultivar was found by Son [2004], who reported that application of NAA in concentrations of 20 mg L^{-1} increased TSS in cv. Priana, while application of 10 mg L^{-1} NAA reduced TSS in cv. *Beliana*. During storage, no significant change in TSS observed in non-treated fruits while in the fruits treated with PGRs, TSS increased during cold storage with significant increase in the cases of application of NAA20 and GA3 (Tab. 2). At the end of cold storage the differences among TSS were not significant regardless of applied treatment. After application of NAA once or two times and cold storage of 20 days, Mesa et al. [2012] found no difference in TSS in apricot fruit. During shelf life, TSS significantly increased regardless of treatments. Particularly high values of TSS content, significantly higher than in non-treated fruits were recorded after shelf life in fruits treated with BA100 and with GA3 (Tab. 2).

Neither applied PGRs nor storage had significant impact on titrable acidity (TA) and pH level (Tab. 2). Similar to our findings, application of NAA [Taghipour et al. 2011] BA and gibberellins [Canli et al. 2014] did not result in differences in TA at harvest. However, according to available published results, different synthetic auxins managed to increase and decrease TA levels in apricot fruit [Stern et al. 2007]. Regardless of the applied treatment with PGRs, TA demonstrated decreasing trend during storage and shelf life, while pH increased during cold storage and decreased during shelf life (Tab. 2). Non-significant changes in TA during cold storage of apricot fruits were reported quite commonly, regardless of ripening stage [Ghasemnezhad et al. 2010] but in some cases significant reduction of this parameter and increasing trend of pH during cold storage was reported too [Nagy 2018]. Decreasing trend of TA [Fan et al. 2000] and pH [Ali et al. 2015] during storage at ambience temperature was also reported.

Carotenoid content at harvest was lower when BA was applied; while application of NAA increased the content of these pigments (Tab. 2). Carotenoids change, as a consequence of treatment with PGRs, seems to be cultivar depended. Roussos et al. [2021] found that application of synthetic auxin and cytokinin, in cv. Nafsika changed carotenoid level while the same treatment did not alter carotenoid level in cv. Niovi. During both, cold storage and shelf life increasing trend of carotenoid content was noted regardless of applied treatment but the significant difference was

Table 2. Influence of applied PGR treatments and storage duration on composition of apricot fruit

Treatment	Storage	Water content (%)	Total soluble solids (%)	Titrable acidity (g malic acid/100 g)	pH	Total carote-noids (mg/100 g FW)	Total phenols (mg/100 g FW)
Control	0	85.7^{a}	14.2^{def}	1.42	3.79	1.92^{bc}	40.4^{c}
	15	85.1^{ab}	13.8^{cde}	1.33	3.78	2.52^{ef}	50.6^{ef}
	15 + 3	83.7^{cd}	15.1^{fgh}	1.22	3.53	2.99^{fg}	49.7^{e}
BA50	0	85.6^{a}	12.5^{a}	1.32	3.46	1.34^{a}	34.1^{ab}
	15	85.1^{ab}	13.1^{abc}	1.27	3.87	2.41^{cde}	30.7^{a}
	15 + 3	83.4^{d}	15.1^{gh}	1.20	3.61	2.51^{ef}	36.6^{b}
BA100	0	85.7^{a}	13.1^{abc}	1.32	3.63	1.84^{b}	42.7^{cd}
	15	85.2^{ab}	14.0^{cde}	1.20	3.93	2.27^{bcde}	50.5^{ef}
	15 + 3	83.3^{d}	16.2^{i}	1.03	3.79	3.19^{g}	54.3^{fg}
NAA10	0	85.3^{ab}	13.2^{abc}	1.41	3.62	2.34^{bcde}	52.4^{efg}
	15	84.2^{bc}	13.6^{bcde}	1.25	3.92	2.99^{fg}	49.9^{e}
	15 + 3	81.7^{f}	15.7^{hi}	1.20	3.93	3.77^{h}	55.1^{g}
NAA20	0	85.1^{b}	12.6^{a}	1.33	3.68	2.22^{bcde}	43.2^{cd}
	15	84.7^{b}	13.7^{bcde}	1.22	3.93	2.23^{bcde}	41.5^{c}
	15 + 3	82.6^{e}	15.4^{h}	1.22	3.87	2.59^{ef}	41.2^{c}
GA3	0	85.5^{ab}	12.8^{ab}	1.38	3.70	1.93^{bc}	45.6^{d}
	15	84.6^{b}	14.4^{efg}	1.33	3.81	1.95^{bcd}	50.3^{ef}
	15 + 3	80.7^{g}	16.5^{i}	1.23	3.53	2.48^{def}	49.6^{e}
Treatment with PGRs		**	*	N.S.	N.S.	**	**
Storage		**	**	N.S.	N.S.	**	**
Treatment with PGRs × storage		**	**	N.S.	N.S.	**	**

* statistically significant at $p < 0.05$; ** statistically significant at $p < 0.01$; N.S. – not significant
^{abcdef} statistically significant values are denoted with different letters ($p < 0.05$)

confirmed only for non-treated and fruit treated with BA50 and NAA10 during cold storage and BA100 and NAA10 during shelf life. After storage, fruit treated with NAA10 had significantly higher carotenoid content compared to other treatments and control (Tab. 2). Increase of these pigments is a common trend during cold storage of apricots regardless of applied treatments, as demonstrated for different treatments: with ethylene blocking substances (Aminoethoxyvinylglycine and 1-methylcyclopropene), $CaCl_2$ or combination of mentioned compounds [Nagy 2018]. However, increase of carotenoids during cold storage is characteristic of apricots harvested in earlier maturity stages [Fan et al. 2018], while for fruits harvested at commercial maturity stage Ezzat et al. [2017] reported no change in carotenoid content, while Egea et al. [2007] claimed an increase of carotenoids during shelf life of apricots previously stored at low temperature.

Total phenol content at harvest was similar in non-treated and fruits treated with BA100 and NAA20. Apricots treated with BA50 had lower, while fruit treated NAA10 and GA3 had significantly higher total phenol content in comparison to non-treated fruit (Tab. 2). Similarly to our results, Devrari et al. [2017] reported increase of total phenols in apricot fruit as a consequence of GA3 treatment and combined NAA and GA3 treatments, but there are also results stating absence of phenols content as consequence of PGRs

treatment [Roussos 2021]. Investigation including 12 genotypes of apricot conducted by Leccese et al. [2012] pointed out that phenol content level in apricot fruit depends on production year. During storage and shelf life, total phenol content increased in control fruit and fruit treated with BA100 and GA3, while in fruit treated with BA50, NAA10 and NAA20 did not change. Only fruit treated with BA50 and NAA10 significantly changed phenol content during shelf life compared to its content after cold storage (Tab. 2). Increase of total phenol content in apricots during initial phases and its subsequent decrease to initial level was reported by a number of authors [Fan et al. 2018, Leccese et al. 2012], but the incidence of reduction of total phenols during cold storage was reported too [Ezzat et al. 2017]. Conditions of cold storage are very important from the standpoint of total phenol content. During first 14 days apricot fruit stored at 4–6°C significantly increased total phenols if compared to fruit stored at 0–1°C or at near freezing point [Cui et al. 2019].

Physical properties

Treatment with PGRs influenced significantly fruit lightness (L*), intensity of yellow tone (b*), ($p < 0.01$) and fruit flesh firmness ($p < 0.05$), but not the hue (h) and intensity of red tone (a*). Changes of all color properties and fruit firmness were significantly influenced by fruit storage, while interactions between PGR treatments and storage were not significant (Tab. 3).

Apricot fruit firmness is property that is the most limiting considering postharvest handling. At harvest, besides fruit treated with BA100, which was characterized with significantly lower flesh firmness, there was no other significant difference between treatments (Fig. 2). Interestingly, at harvest fruit treated with BA100 also had the lowest Ca content (Tab. 1), and connection of fruit firmness and Ca is well documented [Tzoutzoukou and Bouranis 1997]. Application of synthetic auxin and the combination of synthetic auxin and cytokinin reduced flesh firmness in apricot cv. Nafiska, but in cv. Niovi only the combination of mentioned compounds had the same effect, while synthetic cytokinin increased flesh firmness in cv. Nafiska [Roussos et al. 2021]. These results suggest that the effect of PGRs on apricot fruit flesh firmness is cultivar depended. Also, flesh firmness depends on specific auxin compound applied, so in research published by Stern et al. [2007], 2,4-dichlorophenoxypropionic acid reduced flesh firmness, while 3,5,6-trichloro-2-pyridyloxyacetic acid, 2,4,5-trichlorophenoxypropionic acid did not significantly influenced flesh firmness in cv. Canino apricot fruit. Contrary to our results, Devrari et al. [2017] found increased firmness in apricot fruit treated with GA3 (10 and 15 mg L^{-1}) and with combination of GA3 and NAA, while application of NAA (10 and 15 mg L^{-1}), similarly to our results, did not significantly change apricot fruit firmness.

Cold storage significantly reduced flesh firmness in the cases of all treatments with PGRs as well as in non-treated fruits, compared to its initial values at harvest. After storage, non-treated apricots had the least expressed decrease in flesh firmness. Fruit treated with both concentration of NAA and with GA3 exhibited similar loss of firmness to non-treated fruit, while fruit treated with BA100 had the most expressed decrease. Shelf life at room temperature caused further decrease of flesh firmness. Regardless of treatment with PGRs, at the end of cold storage and shelf life, there was no significant difference in flesh firmness of apricot fruits (Fig. 2). Mesa et al. [2012] observed similar reduction of firmness in apricot fruit treated once or twice with NAA after 20 days of cold storage. Same authors

Table 3. Influence of treatments with PGRs, storage and their interaction on apricot physical properties: flesh firmness and color

	Flesh firmness (N)	L*	a*	b*	h
Treatment with PGRs	*	**	N.S.	**	N.S.
Storage	**	**	**	*	**
Treatment with PGRs × storage	N.S.	N.S.	N.S.	N.S.	N.S.

* statistically significant at $p < 0.05$; ** statistically significant at $p < 0.01$; N.S. – not significant

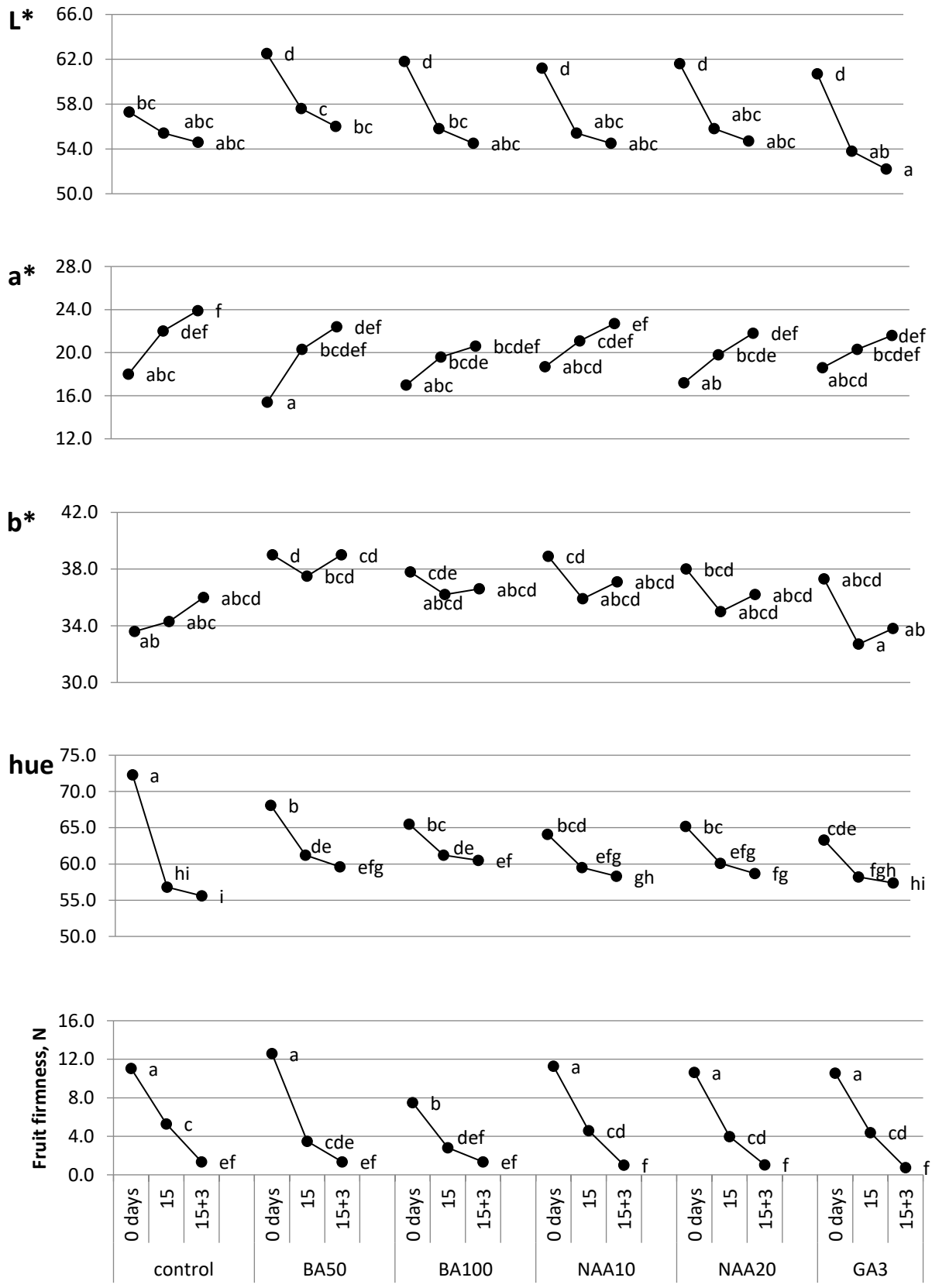

Fig. 2. Physical properties of apricot fruits at harvest, after cold storage and shelf life

L* – lightness; a* – intensity of red/green; b* – intensity of yellow/blue color; C*– chroma; h – hue

Table 4. Color difference (ΔE) between treatments and during storage and shelf life

	Differences at harvest in comparison to control	Differences after storage in comparison to fresh fruit of the same treatment	
		15 days cold storage	15 + 3 days shelf life
Control	0	4.52	6.95
BA50	7.86	7.04	9.53
BA100	6.19	6.71	8.22
NAA10	6.57	6.99	8.08
NAA20	6.17	7.05	8.53
GA3	5.03	8.42	9.66

observed that combined treatment with NAA and prohexadion-Ca reduced the loss of flesh firmness, while after 40 days of cold storage no difference was observed between the control and treated fruit.

Regarding fruit skin color (Fig. 2) all applied treatments resulted in significantly higher skin lightness (L*) versus the control, at harvest, but among the treatments no significant differences was noted. Regardless of applied PGR treatment, the intensity of red tone (a*) was at the same level at harvest, while the intensity of yellow tone (b*) was significantly higher in treated fruits in comparison to non-treated control. Hue values (h) were significantly lower at harvest in the case of all fruits treated with PGRs in comparison to non-treated apricots. Contrary to our results, application of synthetic auxin and cytokinin did not change L* in apricot fruit after harvest, while h was changed only in one of two cultivars investigated [Roussos et al. 2021]. Similarly to our results Stern et al. [2007] did not find difference in a* of fruit flesh and peel after application of natural and synthetic auxins. During cold storage, L* significantly decreased, while a* increased indicating that fruit color became darker with more expressed red tone. In non-treated fruits b* increased during cold storage and shelf life pointing out that fruits became also more intensively yellow. Oppositely, in fruits treated with PGRs intensity of yellow color (b*) decreased after cold storage, but after shelf life somewhat increased again, and in the case of BA50 returned to its initial value from the harvest. The decrease of h value was noted in all cases with more expressed decrease in the case of non-treated fruit in comparison to all applied treatments with PGRs. Similarly to our results, after 14 days of storage, L* decreased and a* increased in peel after storage at 2°C and shelf life of 2 days at 20°C [Fan et al. 2021]. In apricot, cv. Xiaobai stored at 4°C for 14 days, L* and b* increased, while a* did not change [Cui et al. 2020].

Color differences (ΔE) between treatments and between fruit at harvest and after storage and shelf life are presented in Table 4. All applied treatments with PGRs resulted in apparent differences in color of fruit skin with the most expressed difference in the case of BA50, and the least expressed in the case of GA3. The changes of color during both, cold storage and shelf life were in the case of fruit treated with PGRs more expressed, resulting in higher color difference values in comparison to the control fruit.

CONCLUSIONS

Effects of commonly used auxin (NAA), cytokinin (BA) and gibberellin (GA3), applied during early stages of fruit development on difference in fruit quality and chemical composition at harvest and after cold storage and shelf life were investigated.

Regardless of applied PGRs, apricots had higher ash and lower total soluble solids, but titrable acidity and pH were not changed. Significantly higher lightness (L*), intensity of yellow color (b*) and lower hue resulted in apparent difference in color of skin of fruits treated with PGRs in comparison to non-treated fruits. Content of micro and macro elements and carotenoids

in fruits varied in dependence of used PGR: fruits treated with auxin (NAA) were characterized with lower Zn and higher Ca, Mg and carotenoid contents, fruits treated with cytokinin (BA) with lower Zn, K, Mg and carotenoid contents, while in apricots treated with gibberellin (GA3) had lower K and Mg contents. Specific property of apricot treated with higher concentration of cytokinine (BA) was less firm flesh in harvested fruits.

Respiration rate was differently affected by application of PGRs in fruits at harvest and in fruits after cold storage. Treated apricots had higher respiration rate at harvest and mainly lower respiration rate after cold storage, particularly in the case of auxin (NAA), which also resulted in lower weight loss, both at harvest and after cold storage. All applied PGRs caused more expressed increase of total soluble solids in fruits during cold storage versus non-treated apricots. Oppositely, fruit flesh firmness in postharvest period decreased more prominently in the case of treated fruits, but without significant differences after cold storage and shelf life. Changes in skin color in postharvest period were more expressed in treated fruits, but increase of intensity of yellow color (b*) typically characterized treated fruits regardless of used PGR. Specific property in the postharvest period characterizing NAA- and GA3-treated fruits was more expressed reduction of water content, while GA3 and BA100 resulted in significantly higher total soluble solids in fruits after shelf life.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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