

Postharvest quality of 'Granny Smith' apple grown under photo-selective red net

Utjecaj crvene foto selektivne mreže na kakvoću ploda jabuke 'Granny Smith' nakon čuvanja u hladnjači i života na polici

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ABSTRACT

The present study was conducted with aim to test the effect of red photo-selective nets (Agritech S.r.l., Eboly, Italy) on 'Granny Smith' apple postharvest quality. The fruits have been harvested on optimal harvest date from orchard near city of Zadar where red photo-selective nets were used. Afterwards fruits were stored in regular air storage at 0°C for 4 months and then kept for 7 days at room temperature (shelf life). After harvest, cold storage and shelf life fruits grown under red net had significantly lower total soluble solid (SSC) content. After cold storage, superficial scald index and share of fruits with strong and very strong superficial scald severity were significantly higher in fruits grown under red net while for share of fruits with low superficial scald severity situation was opposite. After shelf life, fruits grown under red net had significantly higher titratable acidity (TA), but lower weight loss and SSC/TA ratio. It can be concluded that, due to greater susceptibility to superficial scald, prevention measures (optimal harvest time, 1-MCP and CA storage) should be applied when red photo-selective net is used on superficial scald-susceptible apple varieties.

Keywords: apple, fruit quality, photo-selective nets, postharvest, superficial scald

SAŽETAK

Cilj ovog istraživanja je utvrditi utjecaj crvene fotoselektivne mreže (Agritech S.r.l., Eboli, Italija) na kakvoću plodova jabuke 'Granny Smith' nakon skladištenja i života na polici. Plodovi su ubrani u optimalnom roku u voćnjaku lociranom pokraj Zadra, Hrvatska gdje je korištena crvena fotoselektivna mreža. Nakon berbe plodovi su tijekom 4 mjeseca skladišteni u običnoj hladnjači pri 0°C te potom 7 dana na sobnoj temperaturi (život na polici). Plodovi uzgajani ispod crvene mreže su nakon berbe, skladištenja u hladnjači i života na polici imali signifikantno manji sadržaj topljive suhe tvari. Nakon završetka skladištenja u hladnjači indeks površinskog scalda te udio plodova sa jakim i iznimno jakim simptomima površinskog scalda je bio signifikantno veći na plodovima uzgojenima ispod crvene mreže, dok je za udio plodova sa blagim simptomima površinskog scalda situacija bila suprotna. Nakon života na polici plodovi uzgojeni ispod crvene mreže su imali signifikantno veću titracijsku kiselost, ali manji kalo i omjer topljive suhe tvari i titracijske kiselosti. Može se zaključiti da zbog veće osjetljivosti na površinski scald preventivne mjere (optimalan rok berbe, 1-MCP i čuvanje u kontroliranoj atmosferi) trebaju biti primijenjene kada se crvena fotoselektivna mreža koristi na sortama jabuke osjetljivima na površinski scald.

Ključne riječi: čuvanje plodova, foto-selektivne mreže, jabuka, kakvoća plodova, površinski scald

INTRODUCTION

Nets have long history of application in agriculture as for protecting the crop against wind, hail, excessive solar radiation, birds etc (Bosco et al., 2015). Since last decade, the traditional netting has been improvised and emerged as an innovative and eco-friendly technology in form of the photo-selective nets in modern fruit production. Photo-selective (coloured) netting is an emerging agro-technical concept, by which the netting is used to modify the quality of the transmitted light, in addition to its basic protective function (Basile et al., 2012). The photo-selective nets are made up of translucent threads that selectively screen out defined spectral bands of the light transmitted through them, in the UV and/or visible spectral ranges, concomitantly with transforming direct light into scattered/diffused light (Basile et al., 2012). In addition to their usual and traditional usage, in recent times they are also studied as protection against different pest problems on different crops (Sauphanor et al., 2012). Since it is a new technology hence there is limited information available regarding its effect on harvest and especially on postharvest fruit quality.

In previous research studies (Brkljača et al., 2016; Vuković et al., 2017.) it was determined that red nets have satisfactory effect on harvested apple, peach and nectarine fruit quality. The present work is hence an extension of previous studies with aim to test the effect of red photo-selective nets (Agritenax, Italy) on 'Granny Smith' apples postharvest quality.

MATERIALS AND METHODS

Pre-harvest part of the research work was established at apple orchard near city of Zadar, Croatia in April on the apple (*Malus domestica* Borkh.) cv. 'Granny Smith' grafted on M9 rootstock. The apples were raised as slender spindles with a spacing of 3.4 m × 1.3 m. The experiment consisted of two treatments: the trees covered with red nets (Agritech S.r.l., Eboly, Italy) with mesh size of 2.4 × 4.8 mm and uncovered as control. For each treatment there were three repetitions, and each repetition consisted of 10 fruits from three fruit trees. Fruits were

harvested on optimal harvest date on 04th September, that was determined by usual measurements for harvest date prediction: fruit firmness, total soluble solids (SSC), starch degradation level and maturity index.

The post-harvest part of research was conducted at Department of Pomology, Unit of Horticulture and Landscape Architecture, Faculty of Agriculture, University of Zagreb, Croatia. Fruits were stored in regular air storage at 0°C for 4 months, then kept for 7 days at room temperature (shelf life). Fruits were analysed after harvest, cold storage and shelf life. Quality parameters that were analysed in all phases were: fruit mass, fruit firmness, SSC, titratable acidity (TA) and SSC/TA ratio. Starch degradation level and maturity index was determined after harvest while fruit weight loss was measured after cold storage and shelf life period. Superficial scald index, share of fruit with no superficial scald symptoms, share of fruit with low, medium, strong and very strong superficial scald symptoms were determined after cold storage. Due to complete development of superficial scald symptoms on apple surface on all samples it was not determined after shelf life.

From each repetition 10 fruits were analysed (30 fruits per treatment). The average value of fruit mass and fruit weight loss was calculated using a digital analytical balance (OHAUS Adventurer AX2202, Ohaus Corporation Parsippani, NJ, USA) with accuracy of 0.01 g and was expressed in g and % (respectively). The starch degradation level was scored using a 10-point CTIFL scale (Centre Technique Interprofessionnel des fruits et Legumes, Paris, France). The firmness was measured using PCE PTR-200 (PCE Instruments, Jupiter/Palm Beach, USA) fitted with 11 mm diameter plunger and expressed in kg·cm⁻². Measurements regarding firmness were taken at four equatorial positions on each fruit at 90°. The SSC was measured with a hand digital refractometer (Atago, PAL-1, Tokyo, Japan) and expressed as °Brix. TA was determined by titration method with 0.1 N NaOH and expressed as % of malic acid. The SSC/TA ratio was calculated from the corresponding values of SSC and TA for each fruit. Maturity index (Streif) was calculated as the

quotient of [firmness/(SSC · starch index)] (Streif, 1996). Share of fruits with no superficial scald symptoms and share of fruits with low, medium, strong and very strong superficial scald symptoms were determined according to seizure of superficial scald symptoms on apple surface as: 0 %, >0 and ≤25 %, >25 and ≤50 %, > 50 and ≤75 %, >75 and ≤100 % (respectively). Scald index was calculated from the corresponding above stated values.

Data were analysed using analysis of variance (ANOVA) and F-test using SAS statistical software ver. 9.4 (SAS Institute, NC). F-test was used since there were only two experimental treatments (control and red net) and it was sufficient for determination of statistical difference.

RESULTS AND DISCUSSION

The data presented in Table 1. show the influence of the application of red net on fruit quality parameters of harvested apple cv. 'Granny Smith'. SSC content was significantly higher ($P < 0.05$) in fruits grown without net or control. Regarding fruit mass, starch degradation level, fruit firmness, TA, SSC/TA ratio and maturity index no significant differences were recorded between treatments. According to Manja and Aoun (2019) indicators of internal fruit quality (such as firmness, ripeness, sugar content, and acidity) seemed to be less affected by nets compared to external indicators, which corresponds to the most of obtained results in this research. Results on SSC contents are in accordance with Amarante et al. (2011) for apple cv. 'Gala' grown under white nets. However, in the same study authors reported no significant difference for cv. 'Fuji'. Brkljača et al. (2016) found no significant differences in SSC on apple cv. 'Cripps Pink' between control, red and white

nets. However, control had statistically highest value. According to Amarante et al. (2011), lower flesh firmness and SSC at commercial maturity of fruits under nets may be due to the decrease of structural (cell wall and middle lamellae components) and storage carbohydrates in fruit under shading conditions. In this study, a non-significant trend can be seen that fruits from red net tend to have higher fruit mass than fruits from control. In available literature there are conflicted reports about fruit mass and still it is a matter of discussion. Bosco et al. (2015) reported that apple cvs. 'Royal Gala' and 'Fuji Suprema' had significantly lower fruit mass of fruits grown under black anti-hail net than in control. Whereas, Amarante et al. (2011) reported that apple cvs. 'Gala' and 'Fuji' grown under white net had significantly higher fruit mass.

The data presented in Table 2 show the influence of the application of red nets on fruit quality parameters of apple cv. 'Granny Smith' after cold storage. SSC content was significantly higher ($P < 0.05$) in fruits grown without net than under red net. These results are in accordance with the findings obtained by Amarante et al. (2011) for cv. 'Gala', but for cv. 'Fuji' results were opposite. Superficial scald index was significantly higher ($P < 0.05$) in fruits grown under the red net than those from control trees. The influence of red net on severity of superficial scald symptoms is presented in Figure 1. Fruit grown without net had significantly higher share of fruits with low superficial scald severity symptoms ($P < 0.05$) after cold storage. Share of fruits with strong and very strong superficial scald severity symptoms were significantly higher ($P < 0.05$) in fruits grown under the red net. However, despite the non-significant difference, share of healthy fruit tend to be higher in fruits grown without

Table 1. Fruit quality parameters of harvested apples grown under red net and in control

Treatment	Fruit mass (g)	Starch (1-10 CTIFL)	Fruit firmness ($\text{kg} \cdot \text{cm}^{-2}$)	SSC ($^{\circ}\text{Brix}$)	TA (as % of malic)	SSC/TA	Maturity index (Streif)
Red net	180.69 ± 24.82 ^a	5.33 ± 1.84 ^a	8.63 ± 0.66 ^a	11.93 ± 0.66 ^a	0.82 ± 0.10 ^a	14.86 ± 2.18 ^a	0.15 ± 0.06 ^a
Control	167.39 ± 27.04 ^a	5.73 ± 1.33 ^a	8.74 ± 0.63 ^a	12.63 ± 0.59 ^b	0.82 ± 0.06 ^a	15.40 ± 1.19 ^a	0.13 ± 0.03 ^a

¹ All numbers present average value ± standard deviation

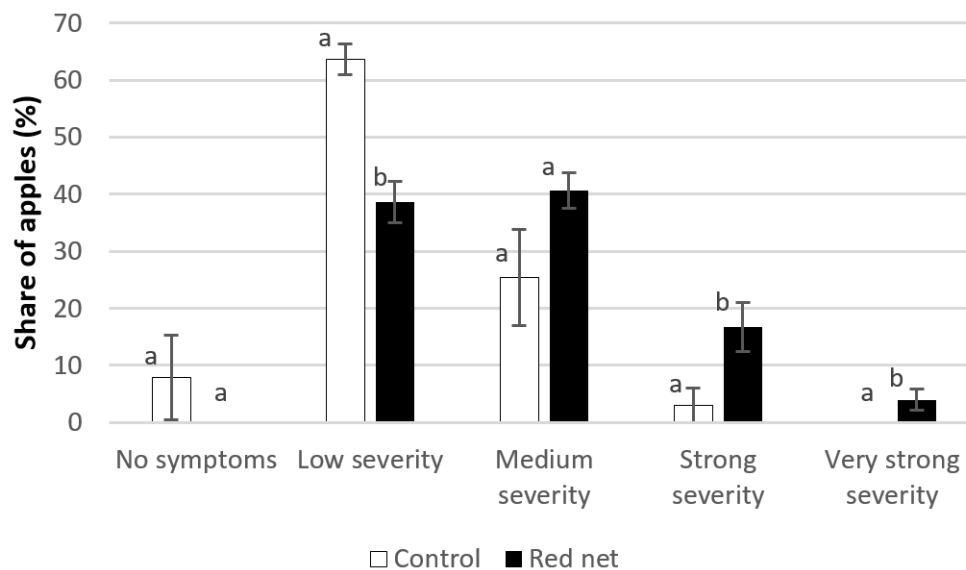
² Values marked by same letter within the same parameter don't have significant difference according to Student's t-test with $P < 0.05$

Table 2. Fruit quality parameters of apples grown under red net and in control after 4 months of regular air storage at 0°C

Treatment	Weight loss (%)	Fruit firmness (kg · cm ⁻²)	SSC (°Brix)	TA (as % of malic)	SSC/TA	Superficial scald index
Red net	3.68 ± 0.68 ^a	5.87 ± 0.59 ^a	13.77 ± 0.63 ^a	0.60 ± 0.06 ^a	23.00 ± 1.58 ^a	2.86 ± 0.04 ^a
Control	3.94 ± 0.93 ^a	6.02 ± 0.65 ^a	14.47 ± 0.53 ^b	0.61 ± 0.06 ^a	23.75 ± 2.52 ^a	2.23 ± 0.15 ^b

¹ All numbers present average value ± standard deviation

² Values marked by same letter within the same parameter don't have significant difference according to Student's t-test with P<0.05



¹ Vertical bars present standard deviation

² Values marked by same letter within the same parameter don't have significant difference according to Student's t-test with P<0.05

Figure 1. Share of apples grown under red net and in control after 4 months of regular air storage at 0°C without and with low, medium, strong and very strong superficial scald severity symptoms

net while share of fruits with medium superficial scald symptoms tend to be higher in fruits grown under the red net. From these results it is evident that photo-selective red net increases sensitivity of apple cv. 'Granny Smith' on superficial scald. According to Lurie and Watkins (2012) scald is an expression of damage and death within the surface layers of cells in localized region and it usually develops after fruits have been removed from cold storage. It is reported that varieties vary greatly in susceptibility to scald, and that apple cv. 'Granny Smith' is susceptible (Emongor et al., 1994; Tsantili et al., 2007). Since occurrence of scald is more prevalent on earlier than later harvested fruit (Wilkinson and Fidler, 1973; Wang and Dilley, 1999), the higher susceptibility of fruit grown under red net can be due to delayed fruit ripening. Delayed fruit ripening is indicated by non-significant trend of starch degradation level and maturity index of

harvested fruits (Table 1.) and significantly higher TA after shelf life of fruits grown under red net (Table 3).

The data presented in Table 3 show the influence of the red photo-selective net on fruit quality parameters of apple cv. 'Granny Smith' after shelf life. Weight loss, SSC content (P<0.05) and SSC/TA ratio (P<0.05) were significantly higher in fruits grown without net. However, TA was significantly higher (P<0.05) in fruits grown under red nets than in control. In this study, TA became significantly higher in fruits grown under red nets only after shelf life, while Amarante et al. (2011) reported opposite trend regarding cv. 'Fuji'. Where, fruits grown under white nets had significantly higher TA after harvest while during cold storage and shelf life that difference was lost.

Table 3. Fruit quality parameters of apples grown under red net and in control after 7 days of shelf life at room temperature

Treatment	Weight loss (%)	Fruit firmness (kg · cm ⁻²)	SSC (°Brix)	TA (as % of malic)	SSC/TA
Red net	1.01 ± 0.22 ^a	4.63 ± 0.73 ^a	14.1 ± 0.49 ^a	0.65 ± 0.04 ^a	21.93 ± 2.26 ^a
Control	1.15 ± 0.17 ^b	5.28 ± 1.13 ^a	14.8 ± 0.53 ^b	0.56 ± 0.06 ^b	26.67 ± 2.33 ^b

¹ All numbers present average value ± standard deviation

² Values marked by same letter within the same parameter don't have significant difference according to Student's t-test with P<0.05

CONCLUSION

While assessing effect of photo-selective nets on fruit quality it must be taken in account that one of the main reasons for usage of photo-selective nets is to alleviate negative shade properties of nets by smaller light quantity reduction, enhancement of light scattering (levels of diffuse light) and light quality modification. In this study red net in most cases did not have negative effect on most postharvest quality parameters, except for SSC and superficial scald. However SSC was influenced by pre-harvest conditions and in some cases the effect of red net was even positive (weight loss after shelf life). Significant risk of the occurrence of superficial scald must be taken into account when red net is used on superficial scald-susceptible apple varieties. Therefore, in order to minimize this risk prevention measures (optimal harvest time, 1-MCP and CA storage) should be applied.

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