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EFFECTS OF BAGGING ON FRUIT DEVELOPMENT AND QUALITY IN 'KANZI' APPLES

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Abstract

Bagging is a widely used horticultural practice to modify the microenvironment surrounding developing fruit, with the goal of improving fruit quality and reducing external damage. This study investigates the effects of bagging on the growth, development, and quality of 'Kanzi' apples (Malus domestica Borkh.). Waxed paper bags were applied at early developmental stages, and their impact on fruit size, weight, skin coloration, firmness, and biochemical composition were assessed at harvest. The findings indicate that bagging significantly influenced fruit development, leading to reduced exposure to sunlight and enhanced protection against pests and environmental stressors. While bagging improved skin coloration uniformity it slightly delayed fruit maturity. Non-bagged fruits developed an attractive red colour while bagging suppressed the yellow/red colour development leading to a lower content of total phenolic and flavonoid content. Fruit damage caused by cracking was increased in bagged fruits.

***Key words**: firmness, flavonoids, fruit cracking, phenolic compounds TSS.*

INTRODUCTION

The Nicoter Kanzi apple (*Malus domestica* Borkh. 'Kanzi') is a premium apple cultivar renowned for its unique blend of sweetness and tangy flavor, achieved through the hybridization of two well-established apple varieties, such as 'Gala' and 'Braeburn' (Brown & Maloney, 2009). Developed in Belgium in 2004, the 'Kanzi' apple has rapidly gained popularity in global markets due to its exceptional taste, appealing appearance, and extended shelf life (Schouten et al., 2016). 'Kanzi' apples are distinguished by their vibrant red-over-yellow skin, offering an eye-catching glossy finish. The fruit boasts a firm, crunchy texture with a well-balanced sweetness and acidity, making it ideal for both fresh consumption and culinary applications. Its dense flesh retains moisture and crispness longer than many other varieties, contributing to its commercial value (Gwanpua et al., 2016; Damarla et al., 2022). Beyond its sensory appeal, the 'Kanzi' apple holds significant economic importance in the global fruit market (Sestras & Sestras, 2003). Its robust post-harvest qualities, including long storage potential and resistance to bruising, make it a preferred choice for international distribution (Tijskens et al., 2018; Wood et al., 2025). Additionally, 'Kanzi' apples contain essential nutrients, such as dietary fiber, vitamins (particularly vitamin C), and antioxidants, which contribute to consumer health (Serni et al., 2020).

Research into the 'Kanzi' apple continues to explore its agronomic performance, pest and disease resistance, and adaptability to different climatic conditions.

Despite their commercial success, 'Kanzi' apples face several cultivation challenges, particularly in the context of climate change. Fluctuations in temperature, irregular rainfall, and increased pest pressure have led to concerns about fruit quality and yield consistency (Bacelar et al., 2024). Extreme weather conditions can result in sunburn, skin cracking, and delayed maturation, all of which negatively impact market value. One potential solution to mitigate these challenges is fruit bagging, a practice where individual fruits are enclosed in protective bags during growth.

The bagging technique for various fruits was first introduced in Japan in the 20th century for pears and grapes. Nowadays, fruit bagging technique is widely used especially in Asian countries (Japan, China, and Korea), as well as in Australia and the USA. This method helps to protect fruits from environmental factors, primarily light and pathogens, along with stresses related to temperature, humidity, and air movement, by creating a physical barrier around the fruit.

Essentially, bagging involves enclosing young fruits in a food bag, secured to the fruit stalk with a ribbon or clamp. Fruit bagging has been shown to reduce sunburn, protect against pests, and improve skin finish in other apple varieties (Sharma et al., 2014a). In addition, bagging can create a microclimate around the fruit, helping to maintain consistent temperature and humidity levels, which is crucial under changing climatic conditions (Rajan et al., 2020). There are no studies of bagging effects on 'Kanzi' apples. Therefore, the main purpose of this research was to investigate the effects of fruit bagging in 'Kanzi' apples to improve fruit quality and reduce external damage.

MATERIALS AND METHODS

The current research has been carried out in a private high-density apple orchard located in Iaz, Sălaj County (47°06′48″N; 22°38′33″E) during 2023-2024. The trees were grafted onto M9 rootstocks, and the canopies were trained as spindle (Hrotkó et al., 2013). The apple trees were planted in 2011 at a distance of 3.5 m between the rows and 1 m between the trees within a row. Ten trees were randomly selected and monitored over a full annual growth cycle (n = 10). To determine the effect of fruit bagging on fruit development and quality, ten fruits from each tree at different positions were selected and bagged with brown paper bags (BPB) on the 22nd of May 2023, at 21 days after anthesis (DAA). Ten unbagged fruits from each tree were also selected and served as the control (Figure 1).

The fruits were harvested at commercial maturity stage in the 13th of November 2023.

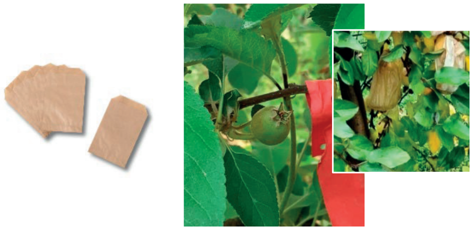

Figure 1. Brown paper bags used for fruit bagging

At harvest, the ten bagged and ten non-bagged fruits/tree were individually weighed and average fruit weight was calculated. Furthermore, other physical traits such as skin colour, fruit density, fruit firmness (Orosz-Tóth & Kincses, 2019; Sala et al., 2017) were determined and fruit cracking rate was calculated (Yang et al., 2009). Among the fruits' chemical properties, titratable acidity (TA) was assessed by titration (Nour et al., 2010) while total soluble solid content (TSS) was determined by using a hand-held refractometer. In addition, the pH and water content of the fruits were also analysed. The total phenolic content was determined according to the Folin-Ciocalteu colorimetric method and expressed as mg gallic acid equivalents per 100g of sample (Bunea et al., 2011). Total flavonoids were determined according to the aluminium chloride colorimetric assay and expressed as expressed on a fresh weight basis as mg catechin equivalents (CE) per 100 g of sample (Miliauskas et al., 2004).

The antioxidant activity of the apple extracts was determined through two methods: DPPH - the evaluation of the free radical-scavenging effect on the 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical according to the protocol described by Miliauskas et al. (2004) and De Ancos et al. (2002). An aliquot (0.1 ml) of apple extract was mixed with 3.9 ml of 100 mM DPPH methanol solution. The mixture was thoroughly vortexed and kept in the dark for 30 min. The absorbance was measured at 515 nm.

A blank sample containing the same amount of methanol and DPPH solution was prepared for the blank. A calibration curve was prepared using a standard solution of Trolox (ranging from 2 to 10 μM). The results were expressed on a fresh weight basis as mmol Trolox equivalents (TE)/100 g of sample. The measurements were carried out in triplicates. The ability of the apple samples against the radical anion ABTS+ was determined according to Arnao et al. (2001). ABTS radical cation (ABTS·+) solution was prepared by the reaction of 7 mM ABTS and 2.45 mM potassium persulphate, after incubation at 23°C in the dark for 12 h. The ABTS·+ solution was then diluted with 80% ethanol to obtain an absorbance of 0.700 ± 0.020 at 734 nm. Solution of ABTS·+ (3.9 ml; absorbance of 0.700 ± 0.005) was added to 0.1 ml of the test sample and mixed thoroughly. The reaction mixture was kept at 23ºC for 6 min and the absorbance was immediately measured at 734 nm. The samples were diluted with 80% ethanol. The blank consisted of 0.1 ml of 80% ethanol. The standard curve was obtained by using Trolox standard solution. The total antioxidant activity of apples was expressed as mmol Trolox equivalents (TE) per 100 g fresh weight (Surveswaran et al., 2007). The experiment was carried out in triplicate.
The data, collected have been subjected to statistical analyses using the ANOVA procedure of SPSS V.19 Statistical package. Differences between the means of bagged and control fruits through all the physical and chemical parameters studied were ascertained by Tukey's multiple range test at $p<0.05$.

RESULTS AND DISCUSSIONS

The results showed that fruit bagging affected significantly the colour of the fruit skin. The peel colour of apples plays a crucial role in consumer acceptance, as it serves as a key indicator of fruit quality, ripeness, and overall appeal. Apple peel colour is primarily determined by the concentration and distribution of pigments such as chlorophylls, carotenoids, and anthocyanins. These pigments not only influence aesthetic appeal but also provide insights into the fruit nutritional value and physiological state of the (Chen et al., 2019). The present study found that in comparison to non-bagged fruits, those covered with BPBs resulted in an intense yellow colour exhibiting almost a complete lack of red colouration of the apple peel. Non-bagged apples developed redder peel with more red colour intensity (Figure 2).

Figure 2. Peel coloration of non-bagged and bagged 'Kanzi' apples

It is assumable that the effects of bagging are associated with solar radiation and temperature regarding fruit pigment production (Saure, 1990). However, the current findings indicate that bagging induced light deprivation which led to limited pigment production resulting in paler fruit (Sharma et al., 2014b). Furthermore, bagging increased humidity and altered temperature conditions compared to non-bagged fruits. These environmental changes can further suppress pigment formation, affecting the overall intensity and uniformity of apple peel colour (Feng et al., 2014).
Regarding fruit size, the results suggest that fruit bagging slightly impacted the size of 'Kanzi' apples as well. The average fruit length of bagged apples was slightly bigger (66.16±1.78 mm) as compared to the control (60.47±2.96 mm), but the average size of the apples was not significantly different between the treatments (Table 1).

Table 1. Effects of fruit bagging on 'Kanzi' apple fruit size

	Fruit length (mm)	Fruit width (mm)	Fruit thickness (mm)	Average
Non-bagged	60.47±2.96	78.07±1.19	75.00±1.23	71.18±4.79 a
Bagged	66.16±1.78	75.86±1.02	74.17±0.89	72.06±3.41 a

*same lowercase letters indicate no significant differences between the bagging treatments at $p < 0.05$ according to Tukey's multiple range test.

These differences in fruit size can be explained by the altered light exposure, temperature, humidity and gas exchange, due bagging which can modify cell expansion and overall fruit growth (Sharma et al., 2014a).
These results are consistent with the findings reported by Tran et al. (2015) in pitaya fruits. Other reports proved that bagging had no effect on fruit size in other fruits either such as pears (Amarante et al., 2002), peach (Jia et al., 2005) and mangoes (Hofman et al., 1997).
The influence of fruit bagging on fruit weight, fruit density, fruit firmness and fruit cracking rate are displayed in Table 2.

Table 2. Effects of fruit bagging on fruit weight, density, firmness and cracking rate in 'Kanzi' apple

	Fruit weight (g)	Fruit density (g/cm^3)	Fruit firmness (kgf/cm^2)	Fruit cracking rate (%)
Non-bagged	192.03±6.66 a	0.92±0.05 a	2.98±0.06 a	11.20±2.89 a
Bagged	200.74±8.82 a	0.87±0.05 a	2.83±0.09 a	43.8±9.33 b

*different lowercase letters indicate significant differences between the bagging treatments within the same fruit characteristic at $p < 0.05$ according to Tukey's multiple range test.

After fruit colour, fruit firmness is another important quality parameter which indicates external fruit quality and post-harvest handling (Shewa et al., 2022). In the present study, there were no significant differences detected in terms of fruit firmness, fruit weight and fruit density among the treatments (Table 2). Previous research results obtained due fruit bagging show inconsistent effects of fruit firmness. For example, fruit bagging amplified fruit softening in apples 'Red Fuji' appled (Chen et al., 2017), red pitaya (Tran et al., 2015), pears (Hudina et al., 2011; Amarante et al., 2002) and pomegranate (Asrey et al., 2020), but reduced slightly in guava (Abbasi et al., 2014) and 'Fuyu' persimmon (Katagiri et al., 2000). In the case of 'Kanzi' apples, less firm fruits might be the results of lower light penetration, higher light absorbance and temperature that resulted from the BPB having darker colour and no holes (Yang et al., 2009).
Fruit cracking is a physiological disorder that affects the quality and marketability of apples. A few studies demonstrated that incidences of fruit cracking can be reduced by bagging (Son & Lee, 2008; Oosthuizen, 1989). However, our study showed that the fruit cracking rate was more than 3-fold higher (43.8±9.33%) in the bagged apples than those without cover (11.20±2.89%). This phenomenon might be explained by type of the bagging material which has different physicochemical characteristics such as light transmittance, vapour permeability and heat conductance, and consequently generate differential effects on microenvironment and quality of fruit. The formation of cracks or fissures on the fruit surface are caused in general by imbalances in fruit water uptake, cuticle elasticity, and cell wall integrity (Knoche & Lang, 2017). In recent years, fruit bagging has been employed as a horticultural practice for various reasons. However, bagging can inadvertently influence the incidence of fruit cracking due to microclimatic changes around the developing fruit (Amarante et al., 2002). Bagging alters the fruit's immediate environment by increasing relative humidity and reducing temperature fluctuations. Elevated humidity can enhance cuticle hydration, reducing its mechanical strength and increasing susceptibility to cracking (Knoche & Grimm, 2008; Legay et al., 2015). Furthermore, during peak growth stages, rapid cell enlargement can exert mechanical stress on the fruit surface. In bagged apples, limited transpiration may

promote faster growth, amplifying the risk of cracking (Schrader et al., 2003).
With respect to the chemical characteristics of the 'Kanzi' apples under study, the results revealed that fruit bagging increased slightly the TSS content of the fruits and reduced acidity and water content (Table 3). While fruit bagging is commonly associated with a reduction in TSS due to light deprivation (Ma et al., 2018a), several studies report cases where TSS levels increase in bagged apples. This paradoxical outcome is influenced by specific physiological and environment. With lower water content of the fruits, the concentration of sugars increases leading to a higher TSS content (Wang et al., 2024; Srivastava et al., 2023). In addition, fruit bagging alters carbon partitioning by reducing photooxidative stress, allowing more efficient sugar metabolism (Sharma et al., 2014a). Furthermore, bagging may delay fruit ripening slightly, allowing the fruit to mature longer on the tree. Extended maturation increases sugar accumulation, contributing to higher TSS (Wang et al., 2013).

Table 3. Effects of fruit bagging on 'Kanzi' apple chemical characteristics

	TSS (°Brix)	TA (%)	TSS/TA	pH	Water content (%)
Non-bagged	15.2±1.15 a	0.48±0.02 a	31.67±13.21 a	3.39±0.76 a	84.66±11.01 a
Bagged	16.2±0.89 a	0.54±0.03 b	30.00±10.09 a	3.82±0.83 b	83.83±9.86 a

*different lowercase letters indicate significant differences between the bagging treatments within the same fruit characteristic at $p < 0.05$ according to Tukey's multiple range test.

The colour of apple peel is not only a visual attribute; it is a multifaceted quality parameter linked to consumer perception, ripeness but most importantly nutritional content (Pontesegger et al., 2023). However, a rich, vibrant peel colour may subconsciously influence consumers' decisions suggesting that the fruit is healthier and richer in nutrients (Boyer & Liu, 2004). The pigments responsible for apple peel colour, such as anthocyanins (red) and carotenoids (yellow-orange), are not only aesthetic but are also closely associated with the phenolic compounds and flavonoid content of the apple fruits, which are linked further to the fruit's antioxidant activity (Zhang et al., 2012; Wang et al., 2022).
The results of this study proved that the colour intensity of fruits was strongly related to their total phenolic and flavonoid content. Therefore, the results showed that fruit bagging had a negative impact on fruit coloration and reduced the accumulation of phenolic and flavonoid content. The phenolic content of the non-bagged 'Kanzi' apple fruits was significantly higher (83.5±2.1 mg GAE/100 g FW) than those covered with BPBs (53.21±1.99 mg GAE/100 g FW) as presented in Figure 3. However, there are no previous studies which investigate the influence of bagging on the quality parameters of 'Kanzi' apples, a few previous studies reported similar values for the total phenolic content. For example, Preti & Tarola (2021) investigated both ancient and commercial apple varieties and reported a polyphenol content of 12.38 mg/100 g in 'Kanzi' apple pulp, and 43.45 mg/100 g FW in the apple peel. Furthermore, Mitić et al. (2013) in their study analyzed 15 apple cultivars which exhibited considerable differences regarding the total phenolic content ranging from 72.80 mg GAE/100 g FW ('Braeburn') to 217.37 mg GAE/100 g FW in 'Kozara' apples. Other previous findings also indicate the suppressive effect of bagging on total phenolic and flavonoid content in fruits, such as loquat (Xu et al., 2010) and red Chinese sand pear (Huang et al., 2009).

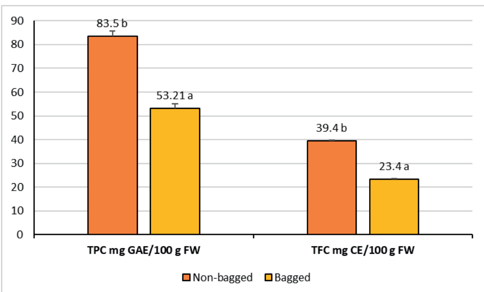

Figure 3. Effects of fruit bagging on total phenolic and flavonoid content of 'Kanzi' apples

Other researchers have found that apples with intense red peel coloration have higher concentrations of anthocyanins, a class of flavonoids known for their strong antioxidant properties (Boyer & Liu, 2004).
These compounds act as scavengers of free radicals, helping to reduce oxidative stress in the human body. Other studies have also shown a positive correlation between the intensity of red colour in apple peels and the total phenolic content (González-Talice et al., 2013). Flavonoids, especially quercetin and kaempferol, are another important class of compounds found in apple peel. (Zhang et al., 2020). These flavonoids contribute to both the coloration of the fruit and its antioxidant activity. Apples with a dark red peel, are typically rich in anthocyanins, and have been shown to exhibit higher antioxidant activity, which is directly related to their flavonoid content (Kunradi et al., 2009). The results of this study are in agreement with this statement and showed a significantly higher total flavonoids content in non-bagged apples (39.4±0.33 mg CE/100 g FW) with red coloured peels than those covered with BPBs (23.4±0.22 mg CE/100 g FW). Similar results were reported by other authors suggesting similar amounts of flavonoids accumulated in apples. Mitić et al. (2013) who investigated the total phenolics, flavonoids and antioxidant activity of 15 apple cultivars, reported a total flavonoid content ranging from 37.2±0.4 mg CE/100 g FW to 112±3 mg CE/100 g FW among the cultivars, out of which 'Gala' (42.0±0.5 mg CE/100 g FW) and 'Braeburn' (37.2±0.4 mg CE/100 g FW) cultivars displayed very similar flavonoid content to the current results. These similarities might be attributed to their genetic background, and biochemical composition.
Apple consumption has been widely linked to a reduced risk of degenerative diseases, including cancer and cardiovascular diseases (Boyer & Liu, 2004; Hyson, 2011). This protective effect is primarily attributed to the high levels of polyphenols and antioxidants found in apples, which play a crucial role in mitigating oxidative stress by scavenging oxygen free radicals in the human body (Lee et al., 2003). These bioactive compounds, including flavonoids and phenolic acids, are known to contribute significantly to the overall antioxidant capacity of apples. Despite the fact that apples also contain ascorbic acid also known as vitamin C, research suggests that it accounts for less than 0.4% of the fruit's total antioxidant activity, underscoring the importance of phenolic compounds as the primary contributors to antioxidant activity (Wolfe et al., 2003). In this regard, the antioxidant activity of non-bagged and bagged 'Kanzi' apples were determined using DPPH radical scavenging activity and ABTS radical cation scavenging activity. The antioxidant activity of non-bagged and bagged apple fruits is presented in Figure 4.
The DPPH Assay involves a stable DPPH radical that accepts an electron or hydrogen atom from antioxidants and works primarily in non-polar or organic solvents (e.g., methanol or ethanol), favoring lipophilic antioxidants such as carotenoids and certain phenolic acids (Mishra et al., 2012).

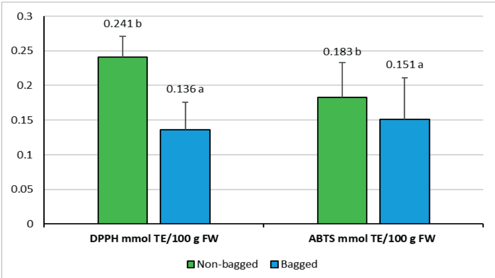

Figure 4. Effects of fruit bagging on the antioxidant activity of 'Kanzi' apples

ABTS assay uses the ABTS•+ radical cation, generated by oxidation with potassium persulfate, which reacts with both hydrophilic and lipophilic antioxidants. It operates in aqueous and organic solvents, making it more suitable for hydrophilic antioxidants like flavonoids, ascorbic acid, and phenolic acids (Re et al., 1999). The results obtained corelate fairly with previous findings reported by Mitić et al. (2013) and Preti and Tarola (2021) and further confirm the strong antioxidant activity of 'Kanzi' apples.

Due to the large dataset resulted from the analyzed fruit traits, a principal component analysis (PCA), a multivariate technique was employed to compare the bagged and non-

nagged fruits through specific fruit quality traits, including morphological characteristics, textural attributes and chemical compounds of the ‘Kanzi’ apples (Figure 5).
The result of the PCA analysis highlighted that fruit weight and fruit size are positively correlated and primarily contribute to Component 1. Furthermore, it was revealed that the water content of the fruits (%) is moderately associated with fruit size, indicating that larger fruits may have higher water content.
TPC and TFC contents were clustered together with a strong contribution to Component 2, indicating that phenolic and flavonoid contents behave similarly but independently of fruit size or water content. Variables further from the origin, such as TPC and fruit weight, explain more of the variance in the dataset. Higher

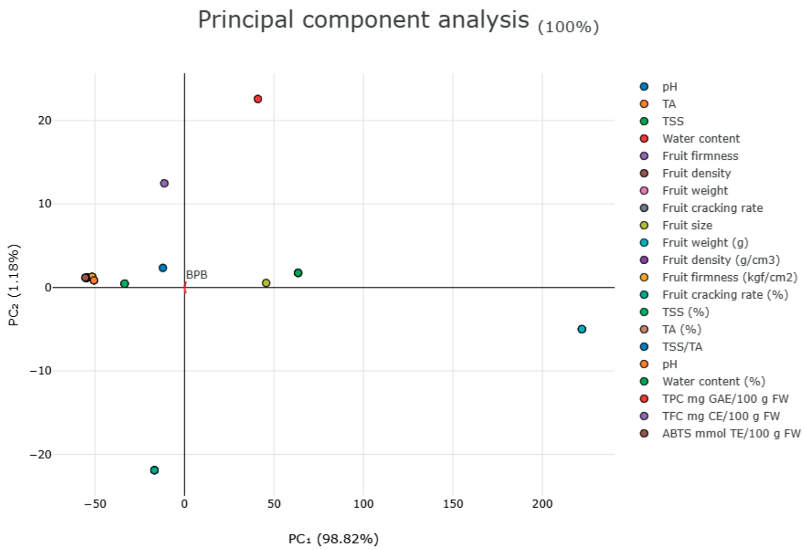

Figure 5. Principal component analysis (PCA) for the types of bagging treatment applied and the fruits traits analyzed in ‘Kanzi’ apples

phenolic and flavonoid content is independent of fruit size but may reflect other fruit quality traits.
TSS to TA Ratio and TA (%) are located near the origin, which suggest a minimal influence on both components.
The fruit cracking rate (%) is located in the lower left quadrant, negatively correlated with most other variables. This suggests that higher cracking rates are associated with smaller fruit size and lower water content. This relation might be explained by the fact that bagging can create a microclimate that traps heat and humidity especially when the bags do not allow air circulation (Ali et al., 2021). This promotes skin softening and weakens the epidermis, predisposing it to crack. In addition, sudden changes in temperature can exacerbate fruit cracking. During hot days, the fruit inside the bag warms quickly, promoting cell expansion. If followed by a sudden cooling (e.g., evening or rain), the rapid shrinkage can cause skin splitting (La Spada et al., 2024). Furthermore, certain apple cultivars, including ‘Kanzi’ and other high-turgor varieties, are more prone to cracking due to their genetic tendency toward high internal pressure. In these cases, bagging exacerbates this susceptibility by intensifying moisture retention (Knoche and Grimm, 2008)

CONCLUSIONS

In summary, the current study demonstrated that bagging can protect apples from environmental damage, but it poses a challenge by suppressing fruit coloration, particularly anthocyanin accumulation and further the phenolic and flavonoid content of the apples and ultimately the antioxidant capacity. In order to balance protection and appearance, strategic bagging techniques, including material choice and timing, are essential. The timing of bag removal could significantly influence these outcomes. Since the exposure of fruits to light/UV accelerate colour development, the removal of the bag before fruit ripening should allow the fruits to regain red coloration of the skin. The same phenomenon of colour induction occurs also in non-red apple varieties (Ma et al., 2018b) and even peaches (Zhao et al., 2017). It has been demonstrated that red-coloration was re-acquired after bag removal and UV treatment.

Understanding the underlying mechanisms allows growers to optimize bagging practices for improved fruit quality.

Choosing breathable, UV-resistant bags with good ventilation holes could help to obtain higher fruit quality.

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