

Postharvest Quality of 'Galaxy' Apple Fruit in Response to Kaolin-Based Particle Film Application

M. Ergun¹

ABSTRACT

Kaolin-based film as Surround WP[®] was applied to 'Galaxy' apple trees to evaluate its effects on postharvest fruit quality. Following harvest, the Surround WP[®] on the fruit skin was either wiped off, or left unwiped, then, the fruits from these treatments along with fruits from non-Surround WP[®]-treated trees as the control were stored at 6°C for 100 days. Surround WP[®] film application reduced weight loss ratios during the period of storage while unaffected firmness loss, sunburn index, starch conversion, and pH values. After 70 days of cold storage, fruits treated with Surround WP[®] film showed less diminution in soluble solids and titratable acidity. A taste panel identified minor quality differences between fruits coated with and without the film. Fruits coated with the film had the highest appearance rating, but also exhibited the lowest smoothness rating due to film residue. This study indicates that Surround WP[®] may be safely used for 'Galaxy' apples before harvest for retaining postharvest quality during cold storage.

Keywords: *Malus domestica*, Sensory evaluation, Soluble solids, Surround WP[®], Titratable acidity.

INTRODUCTION

Due to shading and interference with stomatal activity, plant productivity is greatly reduced by dusts and particles (Glenn *et al.*, 2001). Some particles having film properties have been, nevertheless, found to increase plant productivity by decreasing foliage temperature and reducing heat loads (Glenn *et al.*, 2001). Having a negligible effect on the environment, being an efficient and cost-effective way to lower heat stress of plants grown under stressful temperatures, kaolin has emerged as the most important film resource for plants. This non-toxic film resource, mainly used against agricultural pests, has been used for reflecting radiation, especially UV wavelengths, reaching the surfaces of leaves and fruits (Glenn *et al.*, 2005). Apple trees and fruit, similar to most fruits, benefit from the application of kaolin (Glenn *et al.*, 2001;

Glenn *et al.*, 2005; Glenn and Puterka, 2007). The use of kaolin particles to apple trees can form a protective barrier that not only suppresses some pest and fungal development (Glenn *et al.*, 1999; Thomas *et al.*, 2004) but also provides some physiological benefits, such as reducing heat stress on leaves and increasing carbon assimilation, which results in higher fruit yield and better coloration (Glenn *et al.*, 2001; Thomas *et al.*, 2004; Glenn and Puterka, 2007). Moreover, kaolin reduces solar injury on apple fruit skin (Glenn *et al.*, 2002) by reflecting the shorter wavelengths (Gindaba and Wand, 2005).

Kaolin-based particle film also provides some physiological benefits to various horticultural crops. For example, kaolin particle has been reported to increase water use efficiency in tomato plants (Rao, 1985), cause a reduction in leaf temperature of peach tree while having no adverse effects

¹ Bingol University, Faculty of Agriculture, Department of Horticulture, Bingol, Turkey. e-mail: muharrem.ergun@yahoo.com



on fruit yield and quality (Glenn *et al.*, 1999), increase photosynthesis and water use efficiency in grapefruit (Jifon and Syvertsen, 2001), and reduce severity of sunburn damage in pomegranate fruit (Weerakkody *et al.*, 2010).

Few kaolin-based sunscreens such as Surround WP[®], Parasol[®] and Anti-stress 500[®], are commercially available worldwide. Surround WP[®] has become the most widely known and accepted kaolin-based sunscreen. Kaolin mineral particle, a hydrated alumino-silicate (Al₄Si₄O₁₀(OH)₈), in Surround WP[®] has homogenous, sprayable and non-corrosive characteristics (Thomas *et al.*, 2004). Surround WP[®] allows transmission of photosynthetically-active radiation by creating a white barrier on crops (Thomas *et al.*, 2004). Surround WP[®] also defends plants against certain pests that often become agitated by the kaolin mineral particle.

Recently, 'Galaxy' apples, a genetic mutation of the 'Tenroy' cultivar (trade name Stark[®] Royal Gala; Canadian Food Inspection Agency, 2010), showed sunburn incidences located at the Fruit Research Station of Kahramanmaras Sutcu Imam University within the Kahramanmaras city. As a result, practical approaches were investigated to reduce or prevent sunburn. The present study evaluates the effects of Surround WP[®] on postharvest quality and sensory attributes of fruit from 'Galaxy' apple trees stored at 6°C for over 3 months.

MATERIALS AND METHODS

Plant Material and Trial Location

Three-year old apple trees, cultivar 'Galaxy', were selected as test trees. The trial was conducted at the Fruit Research Station of Kahramanmaras Sutcu Imam University within the Kahramanmaras city limit at 37° 36' 08" N latitude, 36° 56' 59" E longitude, at an elevation of 572 m above sea level, which has a terrestrial Mediterranean climate (the average annual temperature, total rainfall and the relative humidity are approximately 17°C, 850 mm and 65%, respectively). The weather data during the trial is presented in Table 1.

Kaolin-based Film Application

Kaolin-based film, Surround WP[®] (Engelhard, Corp., Iselin, N.J., USA), was suspended in water then applied as a spray to the 'Galaxy' apple trees (2.5 kg l⁻¹). The trees were sprayed 3 times before harvest, with 2-week intervals between each application. The Surround WP[®] suspension was sprayed on the trees using a tractor. Twenty five trees were randomly selected for both the non-treated (control) and Surround WP[®] treatment.

Fruit Harvest and Storage

Fruit was harvested from the treated and non-treated trees by hand at the optimum

Table 1. Weather data for the trial location, Kahramanmaras, TR.

Month*	Avg. Temp. (°C)	Max. Temp. (°C)	Min. Temp. (°C)	Total Precip. (mm)	Avg. RH (%)
Previous year					
June	27.40	35.30	20.50	-	42.40
Jul	28.60	35.90	22.90	0.10	46.80
August	30.20	38.60	23.70	-	43.30
The year when the trial was conducted					
June	25.95	32.38	20.58	0.21	41.73
July	27.20	31.00	25.66	-	44.80
August	28.56	32.27	23.06	-	45.19

*Only June, July, and August are given since most fruit development occurs during the summer.

maturity stage based on colour and soluble solids concentration (ca.16%). Apples treated with Surround WP[®] were divided into two groups. Fruit in the first group were wiped gently with a soft paper tissue to remove kaolin particles (SurrWiped treatment), while fruit from the second group were not wiped (Surround treatment). The fruit that were not sprayed with Surround WP[®] suspension in the orchard were used as the control during storage. Fruit from all 3 treatments were stored at 6°C for 100 days.

Quality Analyses

Ten fruits per treatment were evaluated for quality analyses. To estimate weight loss ratios (%), ten fruits were weighed every 20 days during storage. Flesh firmness was measured on opposing sides of peeled fruits using a penetrometer (N.O.W., FHR-5) fitted with an 11-mm-diameter tip. Fruit juice was extracted and its soluble solids contents (SSC) was measured using a hand-held refractometer (N1, Atago Co. Tokyo, Japan), and pH of the fruit juice was quantified using a digital pH meter. Titratable acidity (TA) was conducted by titrating 6 ml of the fruit juice with 0.1 N NaOH to an end point of pH 8.2 and expressed as percent malic acid equivalents. Starch conversion rates (%) were calculated using the starch conversion chart for 'Gala' apple (University of Massachusetts Cooperative Extension, Fruit Program Gala Chart) where 1= 10%, 2= 20%, 3= 30%, 4= 40%, 5= 50%, 6= 60%, 7 = 70%, 8= 80%, 9= 90%, and 10= 100%. Sunburn indexes were graded on a scale of 1 to 6, where 1 to 4 indicates sunburn browning intensity and 5 to 6 sunburn necrosis (Schrader *et al.* 2003).

Sensory Analysis

At the end of the storage period, fruits were removed from cold storage and placed in the evaluation area and allowed to equilibrate to room temperature. Approximately 100 fruits

per treatment were drawn randomly from the pooled samples, which were selected on the basis of colour, size, and absence of blemishes and diseases/decays. The fruits were then wiped with a slightly-moistened paper towel and prepared for the panellists, which consisted of 12 females and 7 males who received a brief introduction before the analysis. Nine fruits (3 fruits per treatment) were served to the panellists. The panellists were asked if a difference existed among the treatments and, if so, rank them according to Difference Ranking Taste (Table 2). The sensory attributes assessed in the study were physical (appearance, odour, touch resistance and smoothness); textural (firmness, crispness, juiciness and mealiness) and sensory (aroma and flavour, off-apple aroma and flavour, sweet flavour, puckeriness and sour flavour). At the end of the test, the panellists were asked to choose the most preferable treatment.

Statistical Analysis

A total of 310 fruits per treatment were employed in the present study. There were 11 cardboard boxes in the cold room 10 of which held 30 fruit and 1 box contained 10 fruits for weight loss measurements. The cardboard boxes were arranged in a completely randomized design. Data were analyzed using ANOVA in SAS (release 8.1, SAS Institute, Cary, NC, USA) and treatment means were compared using the LSD test ($P \leq 0.05$).

RESULTS AND DISCUSSION

Quality Assessments

Fruits from each treatment lost weight throughout the storage period (Figure 1-A). The percentage of cumulative weight loss increased to 2.44% with Surround, 3.13% with the Control and 3.24% with SurrWiped by the end of the storage period. Starting from day 15, both SurrWiped and Control showed statistically higher weight loss ratio

**Table 2.** Definitions of sensory attributes assessed in the study.

Physical	
Appearance	-All the visible characteristics of a fruit
Odor	-Sensation due to stimulation of the olfactory receptors in the nasal cavity by volatile material from a fruit
Touch resistance	-A fruit moderate resistance when force is applied by touch
Smoothness	-Degree of a fruit peel smoothness as measured by touch
Textural	
Firmness	-A fruit exhibiting moderate resistance when force is applied in the mouth
Crispness	-Force required to for the first bite plus the noise resulting from this bite
Juiciness	-Amount of liquid released on mastication
Mealiness	-A starch-like sensation in the mouth
Flavor related	
Typical apple aroma and flavor	-Typical apple aroma and flavor released during chewing
Off-apple aroma and flavor	-Off-apple aroma and flavor released during chewing
Sweet flavor	-The relative degree of or intensity of sweet sensation upon chewing
Puckeriness	-The relative degree of or intensity of puckering sensation upon chewing
Sour flavor	-The relative degree of or intensity of sour sensation upon chewing

compared to surround treatment. Surround WP[®] has a very small particle size of about 1.0 µm in diameter (Glenn, Puterka 2007). This size of particle can partially block stomata and lenticels resulting in reduced water stress (Soundara Rajan *et al.*, 1981), which in the present study resulted in lower weight loss of ‘Galaxy’ apple fruit coated with Surround WP[®].

Fruit firmness of every treatment gradually decreased during storage, with losses reaching 17–18% of their initial firmness values after 100 days of storage (Figure 1-B). The initial firmness values were 2.23, 2.19 and 2.19 kg force for Control, SurrWiped and Surround, respectively. No marked difference was observed in fruit firmness from Control, SurrWiped or Surround before and during the storage period.

Fruits from each treatment showed sunburn incidences before storage. The initial index values were 0.7 (SurrWiped and Surround) and 1.10 (Control) (Figure 1-C). Sunburn index values somewhat increased during storage, climbing to 1.20 (Surround), 1.50 (Control) and 1.90 (SurrWiped). None of the treatments showed any statistical differences in the sunburn index during the storage period. Reducing/preventing

sunburn damage, caused by heat and solar radiation when fruit skin temperature exceeds 45°C (Glenn *et al.*, 2002; Shinomiya *et al.*, 2005; Iamsub *et al.*, 2009), is the most ameliorative effect of Surround WP[®] on apple fruit (Glenn *et al.*, 2001; Glenn *et al.*, 2005; Glenn and Peturka, 2007). Sunburn, either at harvest or during storage, was not a problem for ‘Galaxy’ apple grown under the conditions of this trial, where only a small degree of sunburn index was recorded on fruits irrespective of Surround WP[®] treatment. The reduced level of sunburn was probably due to cooler temperatures compared to the previous year’s temperatures (Table 1), which may have led to statistical differences becoming insignificant.

Fruits SSC slightly declined from 20.33% to 16.20% for Control, from 21.40% to 16.32% for SurrWiped and from 20.75% to 18.44% for Surround over time (Figure 2-A), implying that small amounts of soluble solids were used during respiration and/or other catabolic processes. The reduction rate for SSC, however, was lower in Surround compared to the other treatments, causing a significant difference after 70 days. The delay mechanism for the loss of SSC in fruits coated with Surround WP[®] is not fully

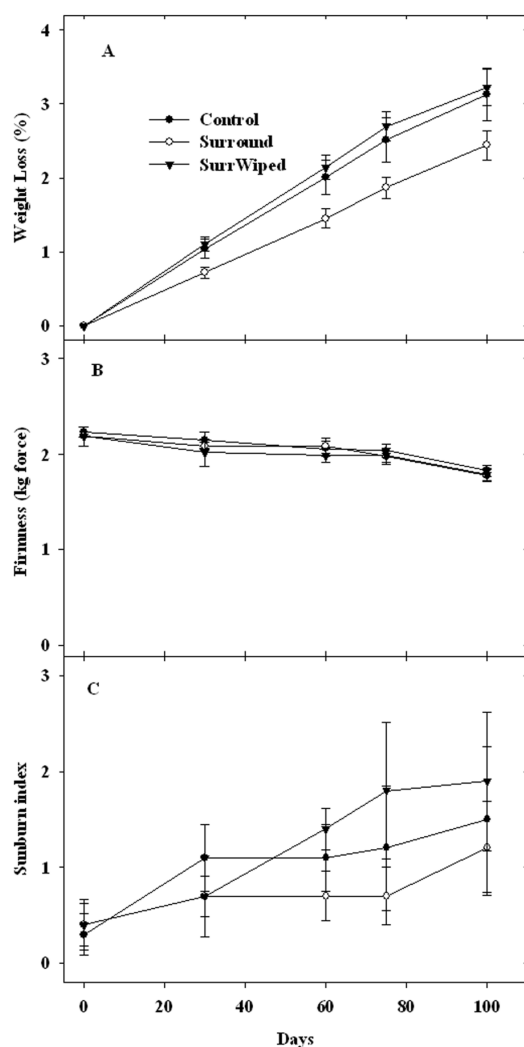


Figure 1. Changes in cumulative weight loss (%) (A), firmness (B) and sunburn index (C) of fruit from trees treated with Surround WP[®] film (Surround), from trees treated with Surround WP[®] but the film wiped off at the beginning of the storage (SurrWiped) and from control trees (Control) during storage. Vertical bars represent standard errors of the means (n= 10).

understood, however, it could be due to restricted gas exchange.

The percentage of starch conversion in fruits from all three treatments increased with storage duration, reaching nearly 100% by the end of the storage period (Figure 2-B). Similar results were observed by Schupp *et al.* (2002) on 'Fuji' and 'Honeycrisp', and by Gindaba

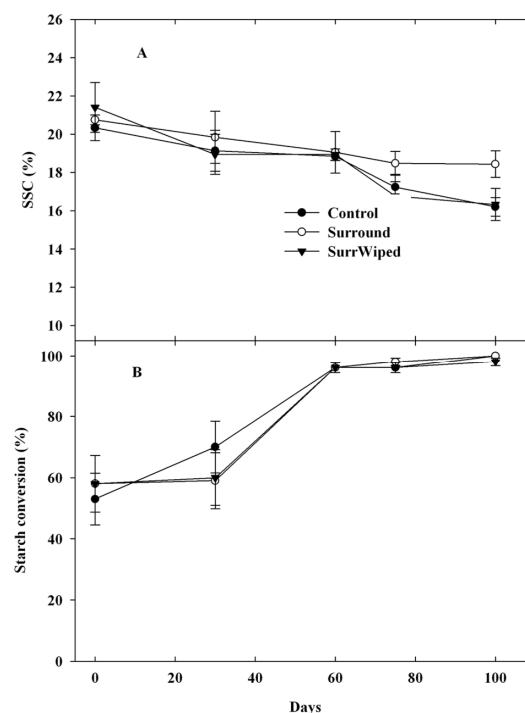


Figure 2. Changes in total soluble solids concentrations (SSC) (A) and starch conversion (B) of fruit from trees treated with Surround WP[®] film (Surround), from trees treated with Surround WP[®] but the film wiped off at the beginning of the storage (SurrWiped) and from control trees (Control) during storage. Vertical bars represent standard errors of the means (n= 10).

and Wand (2005) on 'Crisps' Pink' and 'Royal Gala' fruit. Percent starch conversion for the control rose from 53% to 100%, for SurrWiped from 58% to 100%, and for Surround from 58% to 98%, after 100 days at 6 °C. In the present study, there were no marked differences among the treatments throughout the cold storage period.

Initial TA values were similar for Control (0.33%), SurrWiped (0.33%) and Surround (0.34%) (Figure 3A). The values slightly declined with time, dropping to 0.17% for control, 0.15% for SurrWiped, and 0.25% for Surround by the end of the storage. After 100 days, Surround treatment demonstrated a lower TA value compared to SurrWiped and Control, generating a statistical difference among the treatments. TA and SSC results

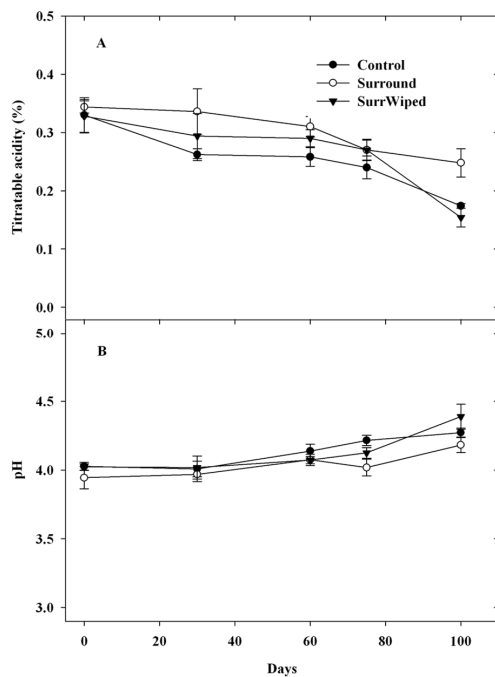


Figure 3. Changes in titratable acidity (A) and pH (B) of fruit from trees treated with Surround WP[®] film (Surround), from trees treated with Surround WP[®] but the film wiped off at the beginning of the storage (SurrWiped) and from control trees (Control) during storage. Vertical bars represent standard errors of the means (n= 10).

followed a similar trend, showing a slight decrease with time and higher values for fruit coated with Surround WP[®]. The mechanism responsible for the soluble solids is most likely the reason for this delay in titratable acidity during the last quarter of the storage period.

Initial pH values were 4.03 for Control, 4.02 for SurrWiped, and 3.94 for Surround (Figure 3-B). The values gradually increased with storage duration, reaching 4.24 for Control, 4.39 for SurrWiped and 4.18 for Surround by the end of the storage period. No marked differences were recorded among the treatments during the period of cold storage.

'Fuji' and 'Honeycrisp' apple cultivars grown in New York and Idaho showed similar results to our trial in response to Surround WP[®] treatment in firmness, soluble solids and starch conversion, with no differences at harvest (Schupp *et al.*, 2002). Additionally,

Surround WP[®] did not affect soluble solids, starch conversion or firmness in 'Crisps' Pink and 'Royal Gala' apple at harvest (Gindaba and Wand 2005). However, 'Fuji' apples treated with Surround WP[®] displayed increased soluble solids and 'Camoe' apples treated with Surround WP[®] showed an increase in both soluble solids and starch index, which could be caused by reduced canopy temperature and increased stomatal conductance resulting in more carbon assimilation. (Glenn *et al.*, 2001; 2003; 2005).

Weight loss ratio, sunburn index and pH values were slightly higher in SurrWiped fruits than the control by the end of storage. This phenomenon could be due to plant stress caused by application of Surround WP[®]. Fruit wiping and, thus, removal of Surround WP[®] could have enabled the fruit to return to a more physiologically active state leading to increased respiration and, therefore, higher weight loss ratio, sunburn index, and pH in SurrWiped fruits.

Sensory Analysis

Among the physical attributes evaluated, only appearance and touch resistance showed statistical difference among the treatments (Table 3). Appearance of fruits treated with Surround was rated as the most preferable, followed by SurrWiped and Control, which were rated similarly. According to the rating, Control fruits had smoother fruit skin surface compared to Surround and SurrWiped fruits. Neither touch resistance nor odour showed significant differences among the treatments. As shown in Table 3, there were no differences in any textural attributes between the treatments. The flavour descriptors, similar to the physical ones, were insignificantly rated among the treatments (Table 3).

Fruits treated with Surround WP[®] at the orchard had the best appearance throughout storage (Table 3). The ameliorative effects on appearance, especially colour, were also observed in 'Red Chief Delicious' (Glenn *et*

Table 3. Sensory profiles of fruits from trees treated with Surround WP® film (Surround), from trees treated with Surround WP® but the film wiped off before storage (SurrWiped) and from untreated trees (Control) after 100 days at 6°C.

Treatments	Physical attributes				
	Appearance (1-3)*	Touch resistance (1-3)	Smoothness (1-3)	Odor (1-3)	
Control	2.32a**	1.53a	1.94a	2.20a	
Surround	1.42b	2.16b	1.82a	1.73a	
SurrWiped	2.26a	2.47b	2.31a	2.13a	
	Textural attributes				
	Firmness (1-3)	Crispness (1-3)	Juiciness (1-3)	Mealiness (1-3)	
Control	2.00a	2.00a	2.18a	2.26a	
Surround	1.89a	1.88a	2.29a	1.88a	
SurrWiped	1.89a	1.94a	1.88a	2.05a	
	Flavor related attributes				
	Typical apple aroma and flavor (1-3)	Non-apple aroma and flavor (1-3)	Sweetness (1-3)	Puckeriness (1-3)	Sourness (1-3)
Control	2.05a	1.67a	2.05a	2.07a	2.14a
Surround	2.16a	2.08a	1.84a	2.13a	2.21a
SurrWiped	1.95a	2.17a	1.95a	2.13a	1.71a

* Ranking indicates the most preferable (1) to the least preferable (3).

** Different letters in the same column represent significant differences.

al. 2001); in ‘Empire’, ‘Gala’ and ‘Camoe’ (Glenn *et al.*, 2005); and in ‘Granny Smith’ and ‘Royal Gala’ (Wand *et al.*, 2006) apples. The mechanism of this phenomenon is not clear, however, Glenn *et al.* (2001) speculated that this might be partially due to temperature reduction of the fruit surface while attached to the tree. In contrast to our data, Surround WP® caused a reduction in red colour development in ‘Fuji’ and ‘Honeycrisp’ (Schupp *et al.*, 2002), and ‘Crsips’ Pink’ and ‘Royal Gala’ (Gindaba and Wand 2005) apples. Schupp *et al.* (2002) suggested that, under less stressful temperatures (< 30°C), Surround WP® could reduce light reaching the leaf surface, resulting in less CO₂ assimilation and, consequently, less pigmentation.

Fruits treated with Surround WP® had a rough surface texture in the present study even after wiping and washing (Table 3). The same problem was reported by Schupp *et al.* (2002) on ‘Fuji’ and ‘Honeycrisp’ apple cultivars and by Melgarejo *et al.* (2004) on ‘Mollar de Elche’ pomegranate cultivar. The difficulty of removing

Surround WP® is probably the most important and primary issue to be solved. Treatment with Surround WP® can leave residue, especially in the basin of the apple fruit cavity that is difficult to remove.

Neither textural nor flavour attributes of ‘Galaxy’ apple were affected by Surround WP® treatment (Table 3). Similar results were observed by Glenn *et al.* (2005) on ‘Empire’ apples. This indicates Surround WP® does not negatively affect the eating quality of ‘Galaxy’ apple fruit.

CONCLUSIONS

From the data presented here we conclude that Surround WP® film is effective in decreasing weight loss, delaying the reduction of soluble solids and titratable acidity, and impeding change of appearance in ‘Galaxy’ apple fruit during cold storage. Since Surround WP® has no adverse effects on plants or the environment, it could easily and safely be applied to ‘Galaxy’ apples for maintaining quality during cold storage.



Proper environmental conditions and time of application interactions need to be established by region and season before making a definitive recommendation.

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کیفیت پس از برداشت میوه سیب "گالاکسی" در پاسخ به کاربرد لایه پوششی از ذرات کاؤلین

م. ارگون

چکیده

در این تحقیق، اثر پاشیدن ماده ای پوششی از جنس کاؤلین با نام تجاری $\text{Surround WP}^{\text{®}}$ روی درختان سیب "گالاکسی" در کیفیت میوه پس از برداشت بررسی شد. بعد از چیدن میوه، پوشش مزبور از روی آنها یا پاک شد و یا دست نخورده باقی گذاشته شد و میوه های این تیمارها با تیمار شاهد که ماده پوششی به درختان آن پاشیده نشده بود در حرارت ۶ درجه سانتیگراد به مدت ۱۰۰ روز انبار شدند. پاشش $\text{Surround WP}^{\text{®}}$ نسبت کاهش وزن در مدت انبار داری را کم کرد بدون آنکه روی افت سفتی، نمایه آفتاب سوختگی، تبدیل نشاسته، و pH میوه اثری بگذارد. با گذشت ۷۰ روز در سردخانه، میوه های با پوشش مزبور کاهش کمتری در مقدار مواد جامد محلول و اسیدیته کل نشان دادند. شرکت کنندگان در آزمون کیفیت، تفاوت اندکی در کیفیت میوه های با و بدون پوشش تشخیص دادند. میوه های پوششدار بالاترین مرتبه را از نظر وضع ظاهری داشتند ولی به لحاظ صاف بودن پوست میوه، به علت وجود باقیمانه های پوشش مزبور، در پایین ترین رتبه بودند. این مطالعه نشان می دهد که به منظور حفظ کیفیت میوه سیب "گالاکسی" در سرد خانه می توان ماده $\text{Surround WP}^{\text{®}}$ را قبل از برداشت روی درختان پاشید.