American-Eurasian J. Agric. & Environ. Sci., 23 (3): 122-130, 2023
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2023.122.130

Effect of Foliar Spray with Calcium, Potassium and chitosan Nanoparticles on storage ability and Quality of Strawberry

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Abstract: This study was carried out in a private farm located in Badr City, El Behaira Governorate, Egypt, during successive seasons of 2021/2022 and 2022/2023. The current study was conducted to assess the beneficial effect of foliar spray with calcium, potassium and chitosan nanoparticles at 80 ppm, bulk calcium (10g/l), bulk potassium (15g/l) and control treatment on strawberry cultivars (Festival, Fortuna, Sensation and Brilliance) to investigate their effect on postharvest quality, storability and shelf life of strawberry cultivars. The experiments included 24 treatments resulting from the interaction between four cultivars and six treatments. Data were recorded on fruit quality (Total Soluble Sugars (TSS), weight loss, fruit decay and general appearance) in all strawberry cultivars. Results showed that a significant difference among the studied cultivars for all measured fruit quality characters. In this respect, cultivar Sensation reflected the highest values of fruit quality parameters and storability with extended shelf life. on the contrary Brilliance cultivar obtained lowest values of fruit quality, Nano-chitosan treatment recorded the lowest value in weight loss, increased TSS value, highest score of general appearance and lowest decay value in both +16 days and 16 +2 days shelf life then Nano-potassium and Nano-calcium respectively. As for the interaction effect on fruit quality, data showed that the highest value was found in Sensation cultivar under Nano-chitosan treatment, while the lowest value was recorded to Brilliance cultivar under control treatment.

Key words: Strawberry · New cultivars · Chitosan · Calcium · Potassium Nanoparticles · Postharvest · Storability

INTRODUCTION

Strawberry is vegetable crop rich in vitamin C, vitamins A and B, potassium, calcium, magnesium, iron, sulfur and phosphorus. Egypt is among the great countries that produce strawberries. Regarding the produced amount of strawberry crop, Egypt is considered as the fourth largest producer in the world [1]. Fresh strawberries have a very limited post-harvest shelf-life and cannot be stored except briefly [2]. Crop yield and early harvests are of primary importance to the growers, while fruit quality is the most important to the consumers.

Zakaria *et al.,* [3] recorded that using Nano-calcium developed fruits quality and fruits storability. Among macronutrients nano fertilizers, Calcium (Ca) is one of the important macronutrients which is essential for the normal growth of plants. The controlled supply of Ca is a must to ensure such quality growth [4].

Potassium (K) has basic role in mitigation of biotic and abiotic stresses, also it is entered in many processes in plant such as transport, assimilation, storage in tissue protein synthesis, photosynthesis, activation of enzymes and nitrogen fixation, which effect on plant growth and yield components [4-6].

The effect of nano-fertilizers on Physical measurements, Melo *et al.,* [7] showed decreased the weight loss, decay percentage, microbiological growth and moisture loss of the strawberry and preserved the pH values, anthocyanin content, titratable acidity and sensory characteristics. Therefore, the use of chitosan edible coating containing nanoparticles can be a

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promising strategy to improve the post-harvest quality of strawberries. Hajirasouliha *et al.*, [8] observed the highest values of weight loss under the untreated control during the storage periods compared to chitosan nanoparticles treatment. Also, Ing *et al.*, [9] and Ma and Lim [10] found that the chitosan nanoparticles with high surface charge will interact more effectively with a negative charge of fungus.

Zakaria [11] recorded that Nano-chitosan foliar application improved fruits quality and fruits storability. Concerning the effect of Nano-particles on TSS percentage in fruits, The general increase of TSS of fruits has been recorded by Wahdan *et al*., [12] that the increase might be caused from the transformation of organic matter of fruits to soluble solids under enzymatic activities. These results are similar to this obtained by Yang *et al.*, [13] that TSS of strawberry fruits was decreased with prolongation of storage periods or shelf life in both seasons.

General appearance was affected by the chitosan coating which reduced respiration activity, thus delaying ripening and the progress of fruit decay due to senescence. Chitosan coatings delayed changes in weight loss, firmness and external color compared to untreated samples. Strawberries coated with 1.5% chitosan exhibited less weight loss and reduced darkening than those treated with 1% chitosan as found by Hernandez-Munoz *et al.*, [14]. Afifi [15] recorded that strawberry fruits, quality scores were based on fresh appearance, dehydration, darkening, calyx dryness and also founded by Atalla [16].

Therefore, the study aimed to investigate the effect of foliar spray with calcium and potassium nanoparticles on postharvest quality of some strawberry new cultivars.

MATERIALS AND METHODS

Location and Duration: Field experiment was carried out in a private farm located in Badr City, El Behaira Governorate, Egypt, during the two successive seasons of 2021/2022 and 2022/2023. The soil type was sandy. The preparation and characterization of calcium and potassium nanoparticles were carried out at Nanotech company and chitosan nanoparticles were carried out at Nano technology and advanced Materials Central Lab., Agricultural Research Center, Giza, Egypt. The concentration of Nano-Ca and Nano-K was 80 ppm solution, bulk calcium (10g/l), bulk potassium (15g/l) and control treatment on strawberry cultivars.

Plant Materials: Fresh strawberry transplants (Festival, Fortuna, Brilliance and Sensation) cultivars were used.

Planting dates were on the third and fourth week of September in the first and second seasons respectively as previously mentioned.

Fruit Quality: A random sample of thirty fruits from each experimental plot at ¾ color stage was randomly chosen in mid-January to determine the following properties for each cultivar:

Physical Measurements

Weight Loss Percentage: Was expressed as a percentage of weight loss relative to the initial weight as described in the equation by Lemoine *et al*., [17].

$$\text{Weight loss\%} = [(A-B)/ A] * 100$$

where: A= the initial weight, B= weight at inspection date.

Decay Percentage: Decayed fruits were counted and recorded by visual examination (decayed fruits included all injured or spoiled, resulting from microorganism's infections) percentage of decay was calculated in relation to the total initial weight of stored fruits [18].

$$\text{Decayed fruits\%} = (A/B)*100$$

where: A=weight of the decayed fruits at time of sampling.
B=weight of the initial.

General Appearance (Score): It was scored as described below according to Kader *et al*., [19]. It was recorded based on fresh appearance, fresh calyx, dryness or watery condition, decay, skin color and lightness or any visible deterioration. The scores were averaged to give score for the sample. 9=excellent, 7=good, 5=fair, 3=poor and 1=unsalable. Fruits rating (5) or below were considered unmarketable.

Chemical Measurements

Total Soluble Solids: Was determined by using digital refractometer (Abbe Leica model).

Statistical Analysis: The experiment was a Split Plot Design with three replications. Statistical analysis: all obtained data were statistically analyzed as the method of Data were statistically analyzed by two-way analysis of variance (ANOVA) using CoStat software (version 6.4,

CoHort Software, USA) according to the method described by Gomez and Gomez [20]. The differences among means at P ≤ 0.05 level of probability were determined by Duncan's multiple range test.

RESULTS AND DISCUSSION

Weight Loss: As for the effect of foliar application on weight loss after 16-days storage, data showed that the highest weight loss was found in Fortuna and Brilliance cultivars under control treatment, while the lowest weight loss was detected to Festival and Sensation cultivars treated with Nano-Chitosan treatment. The result agrees with those recorded by Zakaria [11] that chitosan nanoparticles succeeded in reducing weight loss percentage as well as delayed changes in the respiration rate compared with the control during the storage period. Data agree also with those of Melo *et al.,* [7] showed that decreased the weight loss, microbiological growth and moisture loss of the strawberry.

As for the effect of foliar application on weight loss after 16 days +2 day shelf life, data show that the highest weight loss % was found in Fortuna cultivar under control treatment while the lowest weight loss was detected to Sensation cultivar under Nano-Chitosan treatment. Also, highest value was recorded to Festival cultivar under control treatment, lowest value was obtained to Fortuna cultivar under control treatment. These results are similar to those obtained by Hajirasouliha *et al.,* [8] on chitosan nanoparticles treatment they observed that the highest values of weight loss were under the untreated control during the storage periods or shelf life in the two seasons.

General Appearance: As for the effect of foliar application on general appearance after 16 days' storage, data show that the highest general appearance was found in Sensation cultivar under Nano-chitosan treatment in the two seasons without significant differences, while the lowest general appearance score was detected to Brilliance cultivar under control treatment. The result agrees with those recorded by Hernandez-Munoz *et al.*, [14]; Atalla [16] and Afifi [15] on strawberry fruits, quality scores were based on fresh appearance, dehydration, darkening, calyx dryness and decay.

As for the effect of foliar application on general appearance after 16 day +2 day shelf life, data show that the highest general appearance was found in Sensation cultivar under Nano-chitosan treatment while the lowest general appearance score was detected to Brilliance cultivar under control treatment. The result agrees with those recorded by Atalla [16] and Afifi [15] that Nano-chitosan use could improve the fruit appearance as well as better preserving with overall compare with control treatment.

Table 1: The effect of foliar application on weight loss % of strawberry fruits stored for 16 days at 0C and RH 95% during 2021/2022 and 2022/2023 seasons.

	Variety				
Treatments	Festival	Fortuna	Sensation	Brilliance	Mean
	2021/2022				
Control	4.53de	5.85a	4.73d	5.45b	5.14A
Nano-Ca	2.56ij	4.51de	2.66ij	2.65ij	3.09D
Nano-K	2.85hi	3.65g	2.85hi	2.45j	2.95DE
Nano-CH	1.87k	3.05h	1.92k	4.52de	2.84E
Bulk-Ca	4.13f	5.13bc	4.14f	5.1bc	4.62B
Bulk-K	4.01fg	4.85cd	4.22ef	4.01fg	4.27C
Mean	3.32C	4.50A	3.42C	4.03B	
	2022/2023				
Control	4.9c	4.45e	4.46e	5.59a	4.85 A
Nano-Ca	2.53k	4.62de	2.54k	2.96ih	3.16 C
Nano-K	2.76ijk	2.6jk	2.8ij	2.87i	2.75D
Nano-CH	1.82l	3.15gh	1.83l	4.57de	2.84D
Bulk-Ca	4.1f	3.31g	4.1f	5.18b	4.17 B
Bulk-K	4.19f	4.74cd	4.09f	4.12f	4.28 B
Mean	3.38C	3.81B	3.3C	4.21A	

*Values with capital letters in the same column and the same row are not statistically different.

The same small letters for interaction are not statistically different, according to Duncan's multiple range test.

Control=without spraying, Nano-Ca= Calcium nanoparticles, Nano-K= potassium nanoparticles, Nano-CH= chitosan nanoparticles, Bulk-Ca= calcium, Bulk-K= potassium.

Table 2: The effect of foliar application on weight loss % of strawberry fruits stored for 16 days + 2 days shelf life at 7C and RH 95% during 2021/2022 and 2022/2023 seasons

	Variety				
Treatments	Festival	Fortuna	Sensation	Brilliance	Mean
	----------2021/2022----------				
Control	7.23a	7.13ab	5.96f	6.58d	6.72A
Nano-Ca	5.52g	5.42g	3.41jk	3.56ij	4.47D
Nano-K	3.68i	4.88h	3.58ij	3.28k	3.58E
Nano-CH	2.19m	3.59ij	2.78l	4.96h	3.38F
Bulk-Ca	6.92bc	6.76cd	5.31g	6.28e	6.31B
Bulk-K	4.92h	5.82f	5.8f	4.93h	5.36C
Mean	5.07B	5.60A	4.47D	4.93C	
	----------2022/2023----------				
Control	6.78b	7.78a	5.88d	6.35c	6.69A
Nano-Ca	4.14g	5.34e	3.43j	3.61hij	4.13D
Nano-K	3.88gh	3.78ih	3.52ij	3.48ij	3.66E
Nano-CH	2.82k	3.75ih	2.96k	5.19e	3.68E
Bulk-Ca	5.37e	5.24e	4.56f	5.71d	5.22B
Bulk-K	4.86f	5.86d	4.7f	4.82f	5.06C
Mean	4.64C	5.29A	4.17D	4.86B	

*Values with capital letters in the same column and the same row are not statistically different.

The same small letters for interaction are not statistically different, according to Duncan's multiple range test.

Control=without spraying, Nano-Ca= Calcium nanoparticles, Nano-K= potassium nanoparticles, Nano-CH= chitosan nanoparticles, Bulk-Ca= calcium, Bulk-K= potassium.

Table 3: The effect of foliar application on general appearance of strawberry fruits stored for 16 days at 0C and RH 95% during 2021/2022 and 2022/2023 seasons

	Variety				
Treatments	Festival	Fortuna	Sensation	Brilliance	Mean
	----------2021/2022----------				
Control	3.67cde	2.33de	3.67cde	3de	3.16C
Nano-Ca	7ab	5.67abcd	7ab	6.33abc	6.50AB
Nano-K	7.67ab	7ab	7.67ab	8.33a	7.66A
Nano-CH	8.33a	7.67ab	8.33a	7ab	7.83A
Bulk-Ca	5bcde	5bcde	5.67abcd	5bcde	5.16B
Bulk-K	5.67abcd	5.67abcd	6.33abc	5.67abcd	5.83B
Mean	6.22A	5.55A	6.44A	5.88A	
	----------2022/2023----------				
Control	4.33cd	3.67d	4.33cd	3.67d	4.00C
Nano-Ca	6.33abcd	6.33abcd	7abc	6.33abcd	6.50AB
Nano-K	7.67ab	7.67ab	7.67ab	6.33abcd	7.33A
Nano-CH	7.67ab	7.67ab	8.33a	7abc	7.66A
Bulk-Ca	5bcd	5.67abcd	5bcd	4.33cd	5.00C
Bulk-K	5bcd	5bcd	5.67abcd	5.67abcd	5.33BC
Mean	6.00A	6.00A	6.33A	5.55A	

*Values with capital letters in the same column and the same row are not statistically different.

The same small letters for interaction are not statistically different, according to Duncan's multiple range test.

Control=without spraying, Nano-Ca= Calcium nanoparticles, Nano-K= potassium nanoparticles, Nano-CH= chitosan nanoparticles, Bulk-Ca= calcium, Bulk-K= potassium.

Table 4: The effect of foliar application on general appearance of strawberry fruits stored for 16 days + 2 days shelf life at 7C and RH 95% during 2021/2022 and 2022/2023 seasons

	Variety				
Treatments	Festival	Fortuna	Sensation	Brilliance	Mean
	2021/2022				
Control	3e	2.33e	3.33e	2.33e	2.50E
Nano-Ca	6.33abcd	5bcde	6.33abcd	5bcde	5.66BC
Nano-K	7abc	6.33abcd	7abc	6.33abcd	6.66AB
Nano-CH	7.67ab	7.67ab	8.33a	7abc	7.66A
Bulk-Ca	3.67de	3.67de	4.33cde	3e	3.66DE
Bulk-K	4.33cde	4.33cde	5bcde	3.67de	4.33CD
Mean	5.33A	4.88A	5.55A	4.55A	
	2022/2023				
Control	2.33e	2.33e	3de	2.33e	2.50E
Nano-Ca	6.33abc	5abcde	6.33abc	5.67abcd	5.83BC
Nano-K	7ab	6.33abcd	6.33abc	6.33abc	6.33AB
Nano-CH	7.67a	7ab	7.67a	7ab	7.33A
Bulk-Ca	4.33bcde	3.66cde	4.33bcde	3de	3.83DE
Bulk-K	5abcde	4.33bcde	5abcde	4.33bcde	4.66CD
Mean	5.44A	4.66A	5.44A	4.77A	

*Values with capital letters in the same column and the same row are not statistically different.

The same small letters for interaction are not statistically different, according to Duncan's multiple range test.

Control=without spraying, Nano-Ca= Calcium nanoparticles, Nano-K= potassium nanoparticles, Nano-CH= chitosan nanoparticles, Bulk-Ca= calcium, Bulk-K= potassium.

Table 5: The effect of foliar application on decay percentage of strawberry fruits stored for 16 days at 0C and RH 95% during 2021/2022 and 2022/2023 seasons.

	Variety				
Treatments	Festival	Fortuna	Sensation	Brilliance	Mean
	2021/2022				
Control	27.33b	28.83ab	27.68b	29.68a	28.38A
Nano-Ca	0j	0j	0j	13.14gh	3.28D
Nano-K	0j	2.86i	0j	0j	0.71E
Nano-CH	0j	0j	0j	2.68i	0.67E
Bulk-Ca	13.14gh	18.04d	15.66ef	20.04c	16.72B
Bulk-K	12.33h	16.6de	14.68fg	18.14d	15.43C
Mean	8.79D	11.05B	9.67C	13.94A	
	2022/2023				
Control	28.68b	29.14b	28.33b	30.14a	29.07A
Nano-Ca	0j	0j	0j	12.33h	3.08D
Nano-K	0j	3.14i	0j	0j	0.78E
Nano-CH	0j	0j	0j	2.33i	0.58E
Bulk-Ca	13.86j	19.14e	15.6f	22.31c	17.61B
Bulk-K	11.47h	18.68e	13.86g	20.83d	16.21C
Mean	9.00D	11.68B	9.55C	14.65A	

*Values with capital letters in the same column and the same row are not statistically different.

The same small letters for interaction are not statistically different, according to Duncan's multiple range test.

Control=without spraying, Nano-Ca= Calcium nanoparticles, Nano-K= potassium nanoparticles, Nano-CH= chitosan nanoparticles, Bulk-Ca= calcium, Bulk-K= potassium.

Table 6: The effect of foliar application on decay percentage of strawberry fruits stored for 16 days + 2 days shelf life at 7C and RH 95% during 2021/2022 and 2022/2023 seasons

	Variety				
Treatments	Festival	Fortuna	Sensation	Brilliance	Mean
	2021/2022				
Control	31.6b	32.86ab	32.23ab	33.86a	32.63A
Nano-Ca	0k	0k	0k	15.68fg	3.96D
Nano-K	0k	3.04j	0k	0k	0.76F
Nano-CH	0k	0k	0k	10.73i	2.68E
Bulk-Ca	14.52gh	20.04d	17.23ef	23.86c	18.91B
Bulk-K	13.43h	18.86de	16.45f	20.49d	17.30C
Mean	9.92D	12.46B	10.98C	17.46A	
	2022/2023				
Control	32.67b	33.14b	33.12b	36.45a	33.84A
Nano-Ca	0l	0l	0l	14.04hi	3.51D
Nano-K	0l	3.86k	0l	0l	0.96F
Nano-CH	0l	0l	0l	10.43j	2.60E
Bulk-Ca	15.04gh	23.14d	17.45f	25.68c	20.32B
Bulk-K	13.23i	20.86e	15.23g	23.14d	18.11C
Mean	10.15D	13.50B	10.96C	18.29A	

*Values with capital letters in the same column and the same row are not statistically different.

The same small letters for interaction are not statistically different, according to Duncan's multiple range test.

Control=without spraying, Nano-Ca= Calcium nanoparticles, Nano-K= potassium nanoparticles, Nano-CH= chitosan nanoparticles, Bulk-Ca= calcium, Bulk-K= potassium.

Table 7: The effect of foliar application on total soluble solids (TSS%) of strawberry fruits stored for 16 days at 0°C and RH 95% during 2021/2022 and 2022/2023 seasons.

	Variety				
Treatments	Festival	Fortuna	Sensation	Brilliance	Mean
	2021/2022				
Control	7.5hij	7.28ij	8.26fg	6.18l	7.30D
Nano-Ca	9.17cde	8.9def	9.26bcd	6.96jk	8.57B
Nano-K	9.48bcd	9.23bcd	9.84abc	8.46efg	9.25A
Nano-CH	9.93ab	9.74abc	10.42a	7.23ij	9.33A
Bulk-Ca	8.26fg	7.96fgh	9.28bd	6.47kl	7.99C
Bulk-K	8.36fg	8.18fgh	9.43bcd	6.83jkl	8.20BC
Mean	8.78B	8.54B	9.41A	7.02C	
	2022/2023				
Control	7.83jk	7.4kl	9.14fghi	6.86l	7.80D
Nano-Ca	9.86bcdef	10.06abcde	9.74cdefg	6.96l	9.15B
Nano-K	8.94ghi	10.30abc	10.23abcd	7.58kl	9.25B
Nano-CH	10.41abc	10.77a	10.57ab	7.12kl	9.17A
Bulk-Ca	8.46ij	9.64cdefg	9.36efgh	7.1kl	8.64C
Bulk-K	8.78hi	9.16fghi	9.43defgh	7.43kl	8.70C
Mean	9.04B	9.55A	9.74A	7.17C	

*Values with capital letters in the same column and the same row are not statistically different.

The same small letters for interaction are not statistically different, according to Duncan's multiple range test.

Control=without spraying, Nano-Ca= Calcium nanoparticles, Nano-K= potassium nanoparticles, Nano-CH= chitosan nanoparticles, Bulk-Ca= calcium, Bulk-K= potassium.

Table 8: The effect of foliar application on total soluble solids % of strawberry fruits stored for 16 days + 2 days shelf life at 7C and RH 95% during 2021/2022 and 2022/2023 seasons

	Variety				
Treatments	Festival	Fortuna	Sensation	Brilliance	Mean
	2021/2022				
Control	7.03gh	7.1gh	7.83f	6.00j	6.99D
Nano-Ca	9.07cd	8.63de	9.14bcd	6.73ih	8.39B
Nano-K	9.17bcd	8.93cd	9.46abc	8.13ef	8.92A
Nano-CH	9.76ab	9.23bcd	10.13a	7.03gh	9.04A
Bulk-Ca	7.98ef	7.66fg	8.94cd	6.2ij	7.69C
Bulk-K	8.11ef	7.9f	9.23bcd	6.63ijh	7.96C
Mean	8.51B	8.24B	9.12A	6.78C	
	2022/2023				
Control	7.53ij	7.11jk	8.84efgh	6.57k	7.50D
Nano-Ca	9.57bcde	9.86abcd	9.44cde	6.61k	8.86B
Nano-K	8.62fgh	10.1abc	9.96abc	7.16jk	8.96B
Nano-CH	10.1abc	10.54a	10.24ab	6.94jk	9.45A
Bulk-Ca	8.1hi	9.41cdef	9.13defg	6.78jk	8.35C
Bulk-K	8.5gh	8.97efg	9.1defg	7.13jk	8.42C
Mean	8.73B	9.32A	9.45A	6.86C	

*Values with capital letters in the same column and the same row are not statistically different.

The same small letters for interaction are not statistically different, according to Duncan's multiple range test.

Control=without spraying, Nano-Ca= Calcium nanoparticles, Nano-K= potassium nanoparticles, Nano-CH= chitosan nanoparticles, Bulk-Ca= calcium, Bulk-K= potassium.

Decay Percentage: As for the effect of foliar application on decay % after 16 days storage, data show that the highest decay % was found in Brilliance cultivar under control treatment while the lowest decay % was detected to Festival cultivar under Nano-chitosan treatments without significant differences with Nano-potassium treatment. The results are similar to those obtained by Hajirasouliha *et al.*, [8] for chitosan nanoparticles. Melo *et al.,* [7] showed decreased the weight loss, microbiological growth and moisture loss of the strawberry.

As for the effect of foliar application on decay % after 16 days + 2 day shelf life, data show that the highest decay % was found in Brilliance cultivar under control treatment while the lowest decay % was detected to Festival cultivar under Nano-potassium treatment. The result agrees with those recorded by Ma and Lim [10] and Ing *et al.*, [9] that the chitosan nanoparticles with high surface charge will interact more effectively with a negative charge of fungus.

Total Soluble Solids: As for the effect of foliar application on total soluble solids % after 16 days storage, data showed that the highest interaction of the total soluble solids % was found in Sensation cultivar under Nano-chitosan treatment with non-significant differences with Nano-potassium treatment in the first season, concerning the cultivars effect the lowest total soluble solids % was detected to Brilliance cultivar under the control treatment. The result agrees with those recorded by Yang *et al.,* [13] and Zakaria [11] that TSS of strawberry fruits was decreased with prolongation of storage periods or shelf life in both seasons.

As for the effect of foliar application on Total soluble solids % after 16 days +2 day shelf life, data show that the highest Total soluble solids % was found in Sensation cultivar under Nano-chitosan treatment in the first season Fortuna cultivar under Nano-chitosan treatment in the second season without significant differences with first season results. As for cultivar effect, the lowest Total soluble solids % was detected to Brilliance cultivar under control treatment. The result agrees with those recorded by Zakaria [11] the interaction between preharvest treatments and storage periods was significant during storage or shelf life. Wahdan *et al*., [12] found that the increase in TSS might be caused from the transformation of organic matter of fruits to soluble solids under enzymatic activities.

CONCLUSION

The study concludes that using 80ppm of chitosan nanoparticles as foliar application on strawberry plants (Fortuna, Festival and Sensation cultivars) to preserve quality and storability of fruits with good appearance and preventing decay.in addition to maintaining TSS and total sugars concentration after 20 days at 0c plus 2 days at 7c shelf life. And also, using 80 ppm of potassium nanoparticles as foliar application on strawberry plants cultivar Brilliance also gave good appearance and preventing decay.in addition to maintaining TSS and total sugars concentration after 20 days at 0c plus 2 days at 7c shelf life.

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