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Efficacy of fungicides with edible coatings on quality of Nagpur mandarin fruits

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ABSTRACT

New postharvest fungicides (azoxystrobin and propiconazole) and edible coatings (shellac and stayfresh) were evaluated for the extension of shelf-life of Nagpur mandarin fruits. Freshly harvested fruits were washed thoroughly and treated with different combinations of fungicides and coating alone and in combination on a mechanized packing line. A set of fruits was also treated as control. The fruits were allowed to air dry, packed in CFB boxes and analyzed after 21 days of storage in ambient conditions (temp 25-30°C, RH 25-40%). Maximum juice recovery (42.52 ± 4.83%), total soluble solids (13.10 ± 0.85° Brix), and vitamin C (21.99 ± 0.43 mg/100ml) were recorded in SH10B and azoxystrobin coated fruits. Treated fruits retained gloss and acidity as compared to control. Minimum physiological loss in weight of 14.98 ± 2.59% was also found in SH10B and azoxystrobin coated fruits, while it was 26.48 ± 1.74% in untreated control. The minimum spoilage (3.17 ± 2.75%) was recorded in shellac SH10B and azoxystrobin coated fruits, followed by fruits with SH10 and azoxystrobin (4.40 ± 0.38%) coating. Shellac coating retained organoleptic characteristics of fruit and was found effective in combination with azoxystrobin fungicide in enhancing the shelf-life of Nagpur mandarin fruits.

Keywords: *Citrus reticulata* Blanco, Shellac coating, Azoxystrobin, Propiconazole.

INTRODUCTION

Citrus fruits known for its unique flavour are grown commercially all around the world in tropics and subtropic regions. India with a production of 12.04 million tonnes citrus fruits, occupies third position in the world. The commercial citrus fruits cultivated in India includes mandarins, Sweet orange, lime and lemon (Kumar *et al.*, 10). Among these species, mandarins are cultivated in 404'000 ha area with 4964'000 MT of production (NHB, 13). By comparing production of last three years, it has increased by 11.85%. Nagpur mandarin (*Citrus reticulata* Blanco) is famous for a unique flavour and presence of secondary metabolites, bioactive-compounds, contributing a key role in maintaining human health and nutrition (Kumar *et al*., 11).

Despite the increase in the production of Nagpur mandarin fruits, the post –harvest losses are still very high (20-25%). The major post harvest fungal pathogens attacking citrus fruits are *Penicillium digitatum* Sacc. (responsible for green mould) and *Penicillium italicum* Welmer (responsible for blue mould) (Singh *et al*., 17). In the past years, imazalil, thiabendazole (TBZ) and o-phenyl-phenate (SOPP) were registered for the use to control the postharvest citrus decay. The technologies presently used today to reduce postharvest losses are not sufficient to meet out the satisfactory results. Its use often led to development of resistant pathogen populations (Kanetis *et al*., 8). Existing technology has certain drawback viz. expensive, large space, in shipments during transportation and difficult to maintain temperature internally. Hence, appropriate post-harvest technologies needs to be found out. The use of edible coatings in extending shelf –life of fruits is an emerging one.

Food Safety and Standards Authority of India (FSSAI, New Delhi) have granted the use of carnauba wax and shellac wax, bee wax in fresh fruit coatings at a level not exceeding good manufacturing practices. These fall under category of reduced risk fungicides as classified by U. S. Environmental Protection Agency and are recently been also used in United States for citrus decay control (Kanetis *et al*., 8; EPA, 5). The Maximum Residue Levels (MRLs) of 3mg/kg for appropriate use of azoxystrobin is set by the Australian Pesticides and Veterinary Medicines Authority (APVMA, 2). Shellac is non-toxic, biodegradable, tasteless, eco-friendly and physiologically harmless. Therefore, it is regarded as Generally Recognized as Safe (GRAS) substance by FDA. Shellac based formulations coated on the fruit increases the resistance towards diffusing of different gases. This reduces internal O_2 level and increases CO_2 concentration. Increased CO_2 retards and slows down respiration rate, yellowing and de-formation occurring during ripening process.

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The present study was undertaken with an aim to find out the effectiveness of new postharvest fungicides alone or in combination with edible coatings in quality retention and extension of shelf-life of Nagpur mandarin fruits under ambient storage conditions.

MATERIALS AND METHODS

Fruits of Nagpur Mandarin of uniform size and shape were harvested and collected from mature trees during February 2017 from orchard located in Nagpur, Maharashtra, India. The collected fruits were washed thoroughly in running tap water to remove the dirt and any dust practices adhered to it. They were dried under natural air for a period of about 20-30 minutes and used further for shellac coating. The shellac coatings (SH10 and SH10B) were provided by Indian Institute of Natural Resins and Gums, Namkum, Ranchi, Jharkhand, India., while stayfresh coating and fungicides namely Amistar (Azoxystrobin 23% SC) and Tilt (Propiconazole 25%) were procured from – Syngenta, India. The standard of ascorbic acid was procured from Sigma-Aldrich (Mumbai India) and other chemicals used in carrying out the study were of analytical grade.

Nagpur mandarin fruits were first disinfected with 1000 ppm of sodium hypochlorite solution, washed with water and coated with formulations of shellac (SH10, SH10B), stayfresh along with fungicides Amistar and Tilt containing active ingredient azoxystrobin and propiconazole respectively. The coating was carried out on a mechanized packaging line developed at ICAR-Central Citrus Research Institute (ICAR-CCRI), Nagpur, Maharashtra, India. Among the treatments, T1 and T2 fruits were coated with shellac formulations SH10 and SH10B, respectively without any fungicidal treatment. However, in the treatments T3 to T6, fruits were treated with 1000 ppm each of azoxystrobin and propiconazole along with shellac-based formulations. T7 and T8 fruit were treated with stayfresh (6%) with azoxystrobin or propiconazole (1000 ppm) and T9 treated fruits were kept without any treatment (Control). These coating was done by spraying with nozzle wax applicator machine present on the roller of mechanized packaging line. After coating, these treated fruits were packed in CFB boxes in polyethylene linear having 0.5% ventilation and stored under ambient conditions (temp 25-30°C, RH 25-40%) for 21 days and each replication was having 25 fruits..

The physiological and biochemical response and sensory attributes of fruits with respect to different formulations was studied. Physiological loss in weight (PLW) was calculated by taking weight of fruits initially and after 21 days of storage (Ladaniya, 12; Chouhan *et al*., 4). Juice recovery (Ladaniya, 12) was calculated by dividing weight of juice by fruit. Spoilage rate in percentage (%) was recorded by dividing no. of rotten fruits by total no. of fruits. Degree of glossy appearance of the fruit was measured using gloss meter (Optics Technology, Delhi-110 034, India) calibrated with a standard surface. The gloss results were reported in GU. Total soluble solids (TSS) was determined using hand refractometer of DR6000 series (A. Kruss Optronic, Germany) thermostat based at 25°C and having a range of 0-95^0 brix. Titratable acidity was carried as per method given by Ranganna (14). Titratable acidity was measured by titrametric method using 0.1N NaOH and phenolphthalein as an indicator. The results were expressed in percentage (%). The ascorbic acid content was evaluated by titration method using 2, 6-dichlorophenol indophenol dye and expressed in mg AA/100 ml of juice (Ranganna, 14).

Sensory evaluation of fruits was performed by trained panellists. The 9- point hedonic scale was used to carry out sensory evaluation (Ranganna, 14). Overall acceptability score was calculated as average of the whole sensory attributes. The values determined of all parameters were reported in mean ± standard deviation to verify statistical significance. The probability values of $P < 0.01$ were considered as statistically significant. An analysis of variance (ANOVA) and a multiple range test Tukey's HSD test was carried out using SSCNARS portal.

RESULTS AND DISCUSSION

The physiological loss in weight was evaluated and is regarded as one of the factor for fruit freshness determination. Water loss due to high respiration, production of ethylene and other metabolic reactions leads to softening of fruit flesh, ripening and senescence (Kumar and Sethi, 9). Minimum physiological loss in weight (PLW) was observed in shellac formulation SH10B with azoxystrobin fungicide (14.98 ± 2.59%) followed by SH10B with propiconazole fungicide (16.91 ± 0.91%) after 21 days of storage as compared with unwaxed fruits (26.48 ± 1.74%). Coating reduced the loss in weight by acting as Modified Atmosphere Packinging (MAP) and thus reduces the respiration and transpiration rate from fruit surface lenticles. On the other hand, higher rate of weight loss in control (unwaxed fruits) was due to higher temperatures leading to moisture loss and increased respiration rate (Kumar and Sethi, 9). Similar type of results were reported by Giri *et al*. (6); Singh *et al*. (16) in different varieties of fruits.

Shellac coating SH10B significantly reduced the spoilage of Nagpur fruits under ambient storage conditions. Waxed coated fruits Shellac SH10B with fungicide azoxystrobin resulted the minimum

spoilage (3.17 ± 2.75%), while it was maximum (34.78 ± 13.05%) in control fruits. Low rate of spoilage in coated fruits was due to delay in senescence. Similar observations were also observed by Singh *et al*. (17) while studying the effect of shellac-based formulations on Kinnow mandarin fruits. In the studies of Kaplan (7), rotting of fruit by fungi was also reduced by shellac-based formulations and emulsion of stayfresh wax in citrus fruits.

Gloss of the fruits was estimated which varied from 1.97 ± 0.01GU to 3.60 ± 1.04GU (Table1). Glossiness was seen more in coated fruits as compared with uncoated fruits. Gloss is related to weight loss of fruits. Coating imparts gloss which induces reduction in weight loss and also improves consumer acceptance. These results are in accordance with those obtained by Singh *et al*. (16) and Kaplan (7).

In the present study, it was observed that wax coated Nagpur mandarin fruits had more juice content than uncoated control fruits (Figure 1). Among all treatments, maximum recovery of juice was recorded in T_4 (42.52 ± 4.83%) followed by T_7 (40.21 ± 0.47%) and T_6 (39.90 ± 2.56%). Control

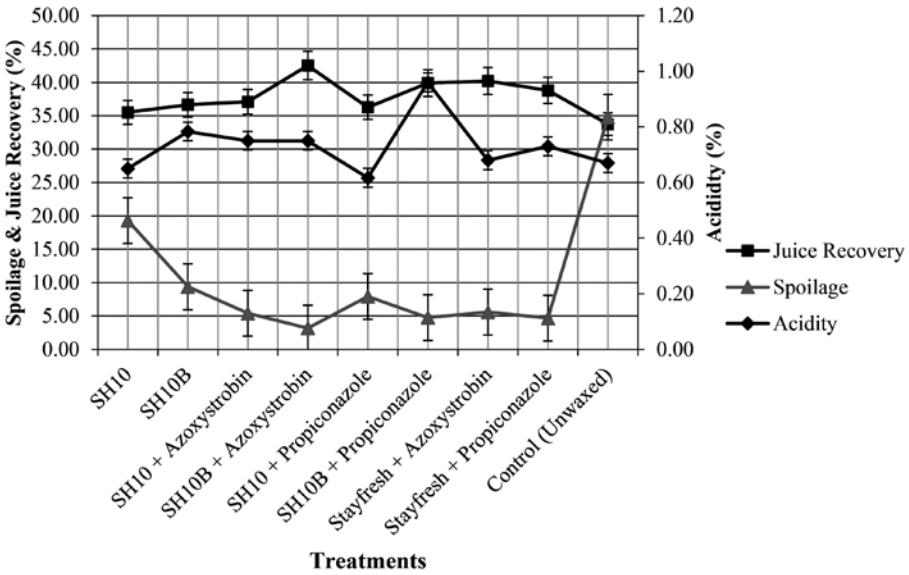

Fig. 1. Spoilage, juice recovery and acidity of treated Nagpur mandarin fruits after 21 days of storage in ambient conditions.

Table 1. Physiological loss in weight and gloss of treated Nagpur mandarin fruits after 21 days of storage in ambient conditions.

Sr. No.	Treatments	Physiological Loss in Weight (PLW) (%)	Gloss (GU)
1	SH10	19.51^{ab} ± 0.62	3.60^{a} ± 1.04
2	SH10B	17.49^{b} ± 1.37	2.58^{ab} ± 0.44
3	SH10 + Azoxystrobin	16.46^{b} ± 3.68	3.14^{ab} ± 0.52
4	SH10B + Azoxystrobin	14.98^{b} ± 2.59	2.68^{ab} ± 0.39
5	SH10 + Propiconazole	17.32^{b} ± 2.06	3.15^{ab} ± 0.26
6	SH10B + Propiconazole	16.91^{b} ± 0.91	2.89^{ab} ± 0.17
7	Stayfresh + Azoxystrobin	17.79^{b} ± 0.61	2.65^{ab} ± 0.27
8	Stayfresh + Propiconazole	18.45^{b} ± 3.13	2.95^{ab} ± 0.14
9	Control (Unwaxed)	26.48^{a} ± 1.74	1.97^{b} ± 0.10
Tukey's HSD at 1%		7.4787	1.6074

Data presented are in means ± standard deviation (n=3)

Statistical note: Means (n=3) within a column followed by different letters are significantly different at P < 0.01 according to the Tukey HSD multiple range test

*Means with superscripts having the same letter are not significantly different

fruits had only 33.73 ± 2.84% of juice which also experienced the greater moisture loss under ambient conditions due to relatively higher temperature with lower relative humidity. Coatings act as a barrier and prevent loss of moisture from fruit (Ahmad *et al*., 1). Bisen and Pandey (3) reported similar results while working with Kagzi lime.

The organic acids are regarded as the substrate consumed by respiration during storage interval (Kumar and Sethi, 9). The acidity of shellac coated and uncoated fruits are presented in Figure 1. The treatments failed to influence the content of titratabale acids statistically, however, it ranged from 0.62 ± 0.18% to 0.78 ± 0.15% and 0.67 ± 0.25% in coated and uncoated fruits, respectively. The coating of fruits reduced the metabolic reactions and also inhibited rate of respiration useful in slowing down the process of oxidation of organic acid and thus explain the higher content in waxed fruits as compared to unwaxed fruits (Ahmad *et al*., 1). The similar results were also reported by Bisen and Pandey (3).

Vitamin C (ascorbic acid) content of shellac coated Nagpur mandarin fruits ranged from 19.25 ± 0.80 mg/100ml to 21.99 ± 0.43 mg/100ml. Stayfresh emulsion coated fruits had 20.76 ± 1.87 mg/100ml vitamin C content, while it was 19.08 ± 0.80 mg/100ml when coated along with azoxystrobin and propiconazole fungicides (Figure. 2). The control fruits had the lowest content 18.03 ± 0.31 mg/100 ml. Waxed coated fruits had higher content of vitamin C due to less oxidation of ascorbic acid leading to lower respiration rate (Singh *et al*., 17).

The total soluble solids (TSS) content as influenced by various tretaments are presented in Figure 2. The TSS content in Nagpur mandarin coated fruits ranged from 11.50 ± 0.44°Brix to 13.47 ± 0.31°Brix, and was found to be highest (13.47 ± 0.31°Brix) in fruits coated with SH10B with azoxystrobin fungicide. The control (unwaxed) fruits recorded 11.47 ± 0.35°Brix of TSS. It was reported that TSS of fruits was consumed during storage period due to respiration process and was found higher in shellac coated fruits of pear as compared to control ones (Kumar and Sethi, 9). Slightly contradictory results have been reported by Singh *et al*. (17) and Ahmad *et al*. (1) while carrying out study with kinnow mandarin fruits.

The sensory characteristics analysed of treated Nagpur mandarin fruits are depicted in Figure 3. Among all treatments, the fruits coated with SH10B along with azoxystrobin had better fruit characteristics in terms of flavour (8.14), firmness (7.35), shining (5.46) and shrivelling (2.75) as compared with other treatments when assessed on a 9-point hedonic scale. Shellac coated fruits without any fungicide treatment had lower scale in these sensory attributes, which might be due to formation of ethanol caused due to anaerobiosis (Chauhan *et al*., 4). Ahmad *et al*. (1) reported that waxing imparts beneficial effect without any unpleasant taste and thus helps in maintaining the fruit quality. The findings in the present study also corroborate with Singh *et al*. (15) carried out similar type of study. Wax coated fruits without fungicide also shrivelled

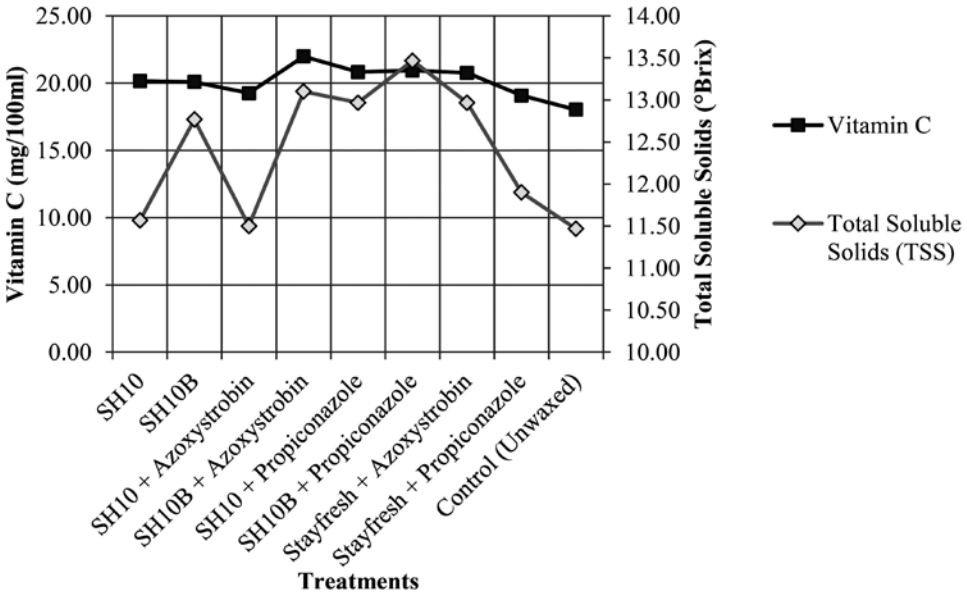

Fig. 2. Vitamin C and total soluble solids (TSS) content of treated Nagpur mandarin fruits after 21 days of storage in ambient conditions.

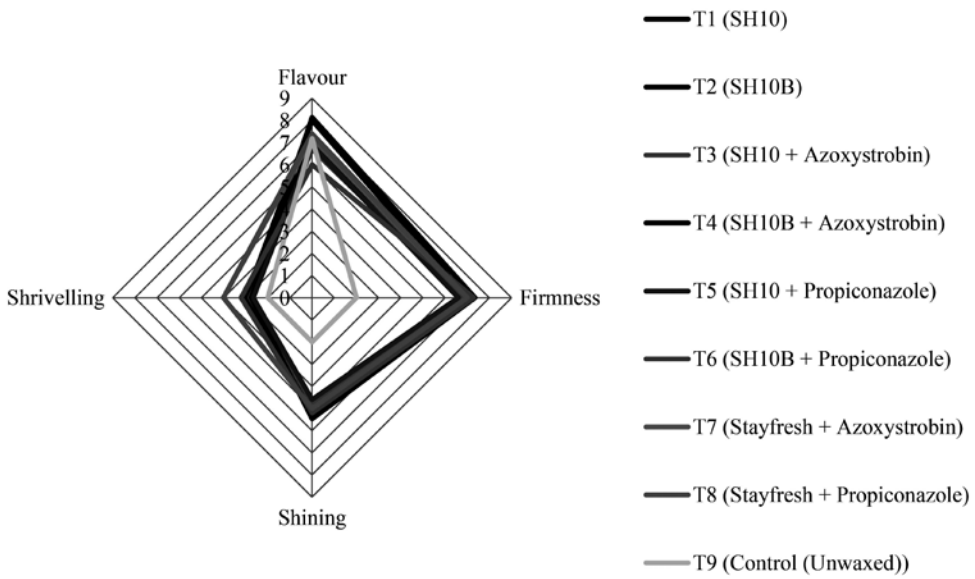

Fig. 3. Sensory evaluation of treated Nagpur mandarin fruits after 21 days of storage in ambient conditions.

and showed symptoms of white blushing on the skin surface of the fruits in the present study. On the other hand, Shellac coated fruits with fungicides treatment did not show such symptoms. Similar results were also observed by Chauhan *et al*. (4) while studying the effect of shellac coating in shelf life extension of tomatoes.

The results of this investigation showed that shellac formulations coated fruits retained fruit quality attributes along with organoleptic properties after 21 days of storage in ambient conditions. Among all treatments, shellac coating SH10B with azoxystrobin was found to be the most suitable edible coating in extending the shelf-life of Nagpur mandarin fruits and can prove an eco-friendly, cost effective and non-hazardous technology effective in storage and transport of fresh fruit from its cultivation site to distant markets and ultimately to consumers.

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AUTHORS' CONTRIBUTION

Conceptualization, Investigation, Writing—original draft, review and editing (Kumar, D); Project administration, Supervision (Ladaniya, M. S.); Resources (Kumar, S.); Formal analysis, Software statistical analysis, Data curation, (Gurjar, M.).

DECLARATION

The authors declare no conflict of interest.

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