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ENHANCEMENT OF FRUIT QUALITY OF TABLE GRAPES (*VITIS VINIFERA* L.) CV. "PERLETTE" BY POSTHARVEST TREATMENT OF VARIOUS GRAS CHEMICALS

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Abstract

Being a non-climacteric fruit, table grape face huge postharvest losses. Some adverse effects of chemicals used for maintaining postharvest quality of table grapes necessitated the find for some safe and natural chemical to replace those uncertain ones like sulfur dioxide. Present study was conducted to evaluate the effects of various GRAS (Generally Recognize as Safe) chemicals on postharvest quality of table grapes cv. "Perlette" during 28 days of storage at 1 ± 1 °C and 90-95 RH. Different concentrations of GRAS chemicals were applied i.e. ethanol (30%, 40%, 50%), potassium metabisulfite (50ppm, 100ppm, 150ppm), egg yolk oil (2%, 3%, 4%) and hot water dip at 55 °C (3 min, 5 min, 8 min). After every week, three replicates of each treatment were evaluated for weight loss, disease incidence, fruit shatter, color, pH, titratable acidity, sugars, ascorbic acid and total soluble solid contents. Sensory analysis was done at the end of cold storage to check the organoleptic acceptability of the fruit for appearance, sweetness, taste, crispiness, aroma and flavor. Findings showed that all treatments significantly ($p<0.05$) reduced postharvest weight loss, fruit color, disease incidence, fruit drop and maintained titratable acidity, ascorbic acid and total soluble solid content throughout the storage as compared to control except egg yolk oil treatments. GRAS chemicals did not have any significant effect on fruit juice, sugar contents and pH value.

Key words: Postharvest, Food additive, Shelf life, Food preservation, Perlette.

Introduction

Table grape (*Vitis vinifera* L.) has a significant share in world fruit industry, including dried and fresh fruits. While supremacy of the countries is on dried fruits, fresh exports have been recently increased as well (Ceylan *et al.,* 2018). Table grape is considered as highly perishable among non-climacteric fruits (Guerra *et al.,* 2016). Many physiological, pathological and physical factors cause lowering the shelf life of table grapes (Thanaboripat, 2011). Main causes of the decreased postharvest quality of table grapes include fungal attack, water loss, fruit drop, rachis dehydration, skin browning and stem discoloration (Vial *et al.,* 2005; Li *et al.,* 2015., Takma & Korel, 2017; Khashi u Rahman *et al*., 2019). The most common method used on commercial scale to maintain postharvest life of table grape is the use of SO_2 (Kou *et al.*, 2009). However, many problems like discoloration, bleaching, rachis browning and cracking in barriers are associated with use of this chemical (Zoffoli *et al.*, 2008; Kou *et al.*, 2009; Marandi *et al.*, 2010; Wei *et al.*, 2018). These understandings constrained the search for some safe alternatives as substitute for SO_2 (Sivakumar & Bautista-Baños, 2014; Ahmed *et al*., 2018). The shelf life of grapes can be improved by postharvest treatment of various GRAS (Generally recognize as Safe) chemicals (Takma & Korel, 2017).

Ethanol is a safe chemical and it can be used with food (Anon., 2003). It is naturally occurring regular food additive and possesses high antimicrobial properties (Wang *et al*., 2015). Previously, many studies have been evaluated on postharvest use of ethanol in many fruits (Margosan *et al*., 1997; Janisiewicz & Korsten, 2002; Bai *et al*., 2011; Dao & Dantigny, 2011; Wang *et al.*, 2011; Vardar *et al*., 2012; Jin *et al*., 2013; AbdEl wahab & Rashid, 2013; Mu *et al*., 2017). Ethanol has also been used to overcome fungal attack and to enhance shelf life of table grapes (Smilanick *et al*., 1995; Lichter *et al*., 2002-2003; Karabulut *et al.*, 2003-2004-2005; Gabler *et al.*, 2004-2005; Chervin *et al.*, 2005-2009; Lurie *et al.,* 2006; Romanazzi *et al.,* 2007; Candir *et al.,* 2012; Elwahab *et al.,* 2014). These works have proved that the activity of ethanol significantly kills spores of different fungi and maintain quality of table grapes. Treatment of 30% ethanol significantly killed conidia of *Botrytis cinerea* (Lichter *et al.,* 2002; Karabulut *et al.,* 2005; Elwahab *et al.,* 2014), while 50% ethanol gradually reduced population of *Escheria coli* and successfully maintained postharvest quality of fruit (into *et al.*, 2006). Immersion of table grapes in 35% ethanol solution for one minute before storage significantly arrested *Botrytis cinerea* during storage (Gabler *et al.*, 2005). According to Lichter *et al*., (2006), use of <60% ethanol concentration is completely safe.

Potassium metabisulfite (PMBS) has been categorized as a GRAS chemical by US Food and Drug Administration (FDA, 2018). It is a food and wine additive and yielder of sulfur dioxide. Mostly, it is used as growth preventive against microorganisms and to maintain quality and color of wine, because it acts as a potent antioxidant (Alonso *et al.,* 2015). In recent years, some investigations have been made to illustrate effectiveness of PMBS to control decay and to maintain postharvest quality during cold storage of some fruits (Kumar *et al*., 2012; Quintero Ruiz *et al*., 2012; Sharma *et al*., 2013; Durrani *et al.*, 2014; Foralosso *et al.*, 2014; Khattak *et al.*, 2014; Kuang *et al.*, 2014). Potassium and sugars have a strong correlation in the grape fruit which indicates that potassium works as osmoticum in skin cells as sugars do in flesh of fruit (Blanch *et al.*, 2014). PMBS (1000ppm) significantly inhibited microbial growth in mango pulp during storage of 90 days (Akhtar *et al.*, 2010). Due to acidic characteristics of PMBS, it significantly suppresses growth of *Brettanomyces*

bruxellensis in various wines (du Toit *et al*., 2005; Conterno *et al*., 2006; Barata *et al*., 2008; Agnolucci *et al*., 2010; Portugal *et al*., 2014). The mixing of some ingredients, like essential oils, into the polymer matrices can remarkably boost some physiochemical and antimicrobial properties (Sánchez-González *et al*., 2009-2010). Recent studies have proved minimizing decay rate of table grapes by postharvest treatment of various essential oils (Tripathi *et al*., 2008; Abdolahi *et al*., 2010; Abdollahi *et al*., 2012, Sánchez-González *et al*., 2011; Salimi *et al*., 2013; de Oliveira *et al*., 2014; Servili *et al*., 2017). Olive oil, a commercially used essential oil, is rich in monounsaturated fatty acid contents (56.3-86.5%), phenolic substances and tocopherols, which act as antioxidants (Pereda *et al*., 2014). Recent studies have demonstrated that olive oil could also be potentially used as food additive for food preservation (Bubonja-Sonje *et al*., 2011; Azaizeh *et al*., 2012; Endo *et al*., 2014). Hen egg yolk contains superoxide dismutase (a family of antioxidant enzymes), which protect fatty acids from peroxdative damage in olive oil (Wawrzykowski & Kankofer, 2014). So, the addition of egg yolk in olive oil could enhance its performance and minimize unpleasant flavor, rancid odor and discoloration of olive oil caused by oxidation of fatty acids.

Hot water treatment (HWT) was first reported to control citrus postharvest decay (Fawcett, 1922). Its application on table grapes is well documented (Karabulut *et al.,* 2004; Kou *et al.*, 2007; Candir *et al.*, 2011; Sabir & Sabir, 2013; Wu *et al.*, 2015). Karabulut *et al*., (2003) suggested a temperature about 50°C is an effective temperature for HWT of table grapes. Postharvest effectiveness of ethanol and HWT on table grapes have been studied already but a perfect treatment is still unknown. However, to the best of our knowledge, information on the use and effects of post-harvest application of egg yolk oil (EYO) and PMBS on the quality and storage behavior of grapes has not yet been systematically documented. Therefore, the aims of our study were to find effectiveness of postharvest application of EYO and PMBS and to find the most suitable treatments of ethanol and hot water to maintain postharvest quality and to improve shelf life of table grapes during cold storage. Furthermore, this study was supposed to discover an alternative of SO2 for long time preservation and storage of table grapes to fulfill consumer's need.

Materials and Methods

Preparation of egg yolk oil: Egg yolk was extracted from typical hen egg (50 grams). Egg yolk was blended in 10 ml water for 5 minutes using electric blender. 10 ml olive oil was added in aliquot mixture and was shaken well for another 5 minutes. Thus, solution of egg yolk oil was ready to be used for next 24 hours. Aqueous solution of egg yolk oil (v/v) was prepared of indicated concentrations for immersion of grape bunches.

Plant material and treatments: Table grapes cv. Perlette, which is sensitive to postharvest decay (Lichter *et al.*, 2002) was obtained from a commercial vineyard "Rawat fruit farm, Rawat", Pakistan. Harvested grapes were washed with water in order to remove field contamination. All treatments except HWTs were applied as described by Lichter *et al.,* (2002). Grape bunches (500 grams/treatment) immersed in specified concentration (v/v) of GRAS chemical at ambient temperature (25 ± 2°C). HWTs were performed in electric hot water bath (10L capacity Thermostatic Bath Model DK2-2). Grape bunches were dipped at 55ºC for indicated time. Bath temperature was constantly maintained within ± 0.5ºC during each treatment. The bunches were immediately allowed to dry on paper towel for 10-20 minutes at room temperature. Data for different parameters was recorded on day of harvesting and remaining fruits were packed in cartons after application of all the treatments and stored in cold storage (1±1°C and 90% RH) for four weeks.

Quality evaluation: To evaluate the postharvest quality, samples were analyzed with various postharvest quality parameters at an interval of one week. Percentage of weight loss was calculated using following formula:

$$\text{Weight loss (\%)} = \frac{\text{Fruit weight at harvest} - \text{Fruit weight at storage interval}}{\text{Fruit weight at harvest}} \times 100$$

Grape bunches were shattered manually for one minute constantly in kraft paper bag and number of shattered fruits was counted to estimate fruit drop at each sampling date. After every week all diseased fruits were removed and counted. Fruit color was determined using CIE L* a* b* color space with Konica Minolta Chromameter (CR-300). Bunches were assessed at the equatorial region from opposite sides. Grape juice was obtained from 50 gram fruit per replicate for the assessment of total soluble contents (TSS) and titratable acidity (TA). Hand refractometer was used to determine the TSS content while percentage of TA was assessed using the method followed by Candir *et al*., (2011). Ascorbic acid (vitamin C) contents were measured using method described by Hans (1992). Spectrophotometer (sp-3000 plus) was used to measure the absorbance of supernatant at 243nm.

Sensory evaluation: A panel consisting of 10 members investigated the change in organoleptic quality of fruit. The panelists were asked to evaluate the overall quality of fruit in terms of appearance, crispiness, sweetness, taste, aroma and flavor during the analysis. A grading scale was devised for the panelist as: 1=excellent, 2=very good, 3=good, 4=not acceptable and 5=bad. Members were advised to clean their mouth, chew the random fruit and grad using grading scale from 1 to 5.

Statistical analysis: Experiment was carried out according to Factorial Complete Randomized Design (CRD). The differences between treatments were analyzed by ANOVA using Statisix 8.1 (Analytical software, 2005). LSD test was used at 5% level of significance to compare mean values as recommended by Chase & Brown (1997).

Results

The results indicated that most of the GRAS chemicals significantly helped in maintaining postharvest quality of grapes during cold storage.

Weight loss: It is obvious from Fig. 1 that fruit weight declined during storage irrespective of treatments applied. However, the treatments significantly reduced the losses in fruit weight except EYO during storage (Table 1). HWT at 55 °C for 3 min significantly reduced loss in weight as compared to higher dip periods (5 and 8 min), while grape bunches dipped in 50% ethanol reduced comparatively lesser weight loss than the other two concentrations (30 and 40%).Similar pattern was showed by PMBS; grape bunches treated with 150 ppm PMBS reduced weight loss as compared to other two doses (50 and 100 ppm). EYO (2 and 3%) also helped in reducing weight loss but no significant difference was observed in grapes treated with 4% EYO and untreated grapes up to four weeks of storage. From the data in Table 1, it is clear that the highest loss in weight was observed in 4% EYO treatment (10.28%) and control (10.23%), while minimum loss in fruit weight was noted in the bunches dipped in hot water for 3min (6.97%) followed by 5min (7.17%).

Fruit drop: Results presented in Table 1 showed that all treatments significantly controlled fruit drop during controlled atmosphere 1 ±1°C and 90–95% RH. Minimum number of fruit drop (11.07/bunch) was counted in HWT at 55°C for 8 min followed by hot water treated bunches at 55°C for 5 min (11.27/bunch), whereas maximum fruit drop was observed in untreated bunches (16.93/bunch) after four weeks of cold storage. Ethanol treatments also proved beneficial for pedicel strength of fruit. Ethanol concentration of 50% showed better results after above mentioned HWTs as compared to lower concentrations of 40% and 30% respectively. Number of fruits drop (13.13/bunch) found in 50 ppm PMBS treated grapes was lower than other two concentrations of PMBS. Effect of EYO treatments to control fruit was statistically significant but it did not prove as much efficient as other treatments.

Disease affected fruits: Concerning results against this parameter, similar effects of GRAS chemicals were observed as in fruit drop parameter. Minimum numbers of disease affected fruits (15.67/bunch) were counted in HWT at 55°C for 8 min followed by hot water treated bunches at 55°C for 5 min (16.33/bunch), whereas maximum disease attack was noticed in grapes treated with 4% EYO (24.00/bunch), 3% EYO (23.08) and untreated samples (22.50/bunch) respectively after 4 weeks of cold storage (Table 1). Ethanol treatments also proved beneficial to control postharvest disease attack. Higher concentration of ethanol (50%) helped in controlling postharvest diseases more effectively as compared to its low concentrations (40%, 30%). Same trend was noticed in PMBS treated samples. Grapes treated with 150ppm PMBS showed minimum number of diseased fruits(18/bunch), while maximum number (19.17/bunch) were found in 50ppm PMBS treated bunches.

Table 1. Effect of GRAS chemicals on different postharvest quality parameters of table grapes cv. "Perlette" during cold storage.

Treatments	Weight loss (%)	Disease affected fruits	Fruit drop	Titratable acidity (%)	TSS (°Brix)	Ascorbic acid	Color		
							L*	a*	b*
Control	10.230 A	22.50 B	16.93 A	0.720 F	16.60 A	1.864 F	49.63 A	7.44 D	23.65 ABC
Ethanol (30%)	9.017 B	17.92 EF	13.73 FG	0.847 BCD	15.47 D	2.577 C	46.07 CD	7.06 CD	21.66 D
Ethanol (40%)	7.883 D	17.50 F	12.60 H	0.900 AB	16.13 BC	2.651 B	46.19 CD	7.00 C	21.54 D
Ethanol (50%)	7.167 F	17.42 F	12.53 H	0.86 BC	15.53 D	3.001 A	45.54 CD	6.87 BC	21.66 D
PMBS (50ppm)	8.017 D	19.17 D	13.13 GH	0.849 BCD	16.40 ABC	2.552 C	45.10 D	6.91 BC	22.73 BCD
PMBS (100ppm)	7.567 E	18.42 DE	13.87 EF	0.845 BCD	16.27 ABC	2.293 D	45.12 D	6.89 BC	21.60 D
PMBS (150ppm)	7.500 E	18.00 EF	14.4 DE	0.824 CD	16.33 ABC	2.311 D	45.53 CD	6.57 B	22.13 CD
EYO (2%)	8.567 C	21.42 C	14.60 D	0.755 AF	16.53 AB	1.886 F	44.02 D	5.66 A	22.05 D
EYO (3%)	8.550 C	23.08 B	15.40 C	0.806 DE	16.53 AB	1.955 E	45.10 D	5.60 A	21.91 D
EYO (4%)	10.283 A	24.00 A	16.07 B	0.734 F	16.40 ABC	2.272 D	44.47 D	5.62 A	21.33 D
HWT (55°C for 3 min)	6.967 G	16.58 G	14.20 DEF	0.818 D	16.07 C	2.574 C	47.52 ABC	7.26 CD	24.74 A
HWT (55°C for 5 min)	7.167 F	16.33 GH	11.27 I	0.815 DE	16.00 C	2.567 C	47.40 BC	7.41 D	23.75 AB
HWT (55°C for 8 min)	7.283 F	15.67 H	11.07 I	0.811 DE	16.07 C	2.599 BC	48.46 AB	7.12 CD	25.18 A

Means within a column not sharing same letter are significantly different by the LSD test at $\rho \leq 0.05$

Color: Grapes were harvested with L* value of 49.50, a* value of -8.92 and b* value of 23.39. Controlled samples maintained their brightness while all other treated grapes showed slight darkness (lower L* value) after four weeks of storage (Table 1). The greenness of fruits was lightly changed to redness (increase in a* value) in all samples after four weeks of storage. Samples treated with EYO showed significant redness (higher a* value) than all other treated and untreated samples observed. Yellow color of fruit decreased (lower b* value) with the storage intervals although grapes treated with hot water significantly improved yellowness after cold storage.

Titratable acidity: Titratable acidity decreased in all treated and untreated samples during cold storage, whilst the treated samples significantly maintained acidity as compared to untreated samples. Maximum acidity (0.90%) was measured in grapes treated with 50% ethanol while minimum acidity (0.72%) was obtained in control after storage period (Table 1). Non significant results were found in 4% EYO treated grapes when compared to control.

3.6 TSS: TSS content measured before treatments was 14.72 °Brix. During the storage, a significant increase occurred in all samples. Grapes treated with 30% concentration of ethanol showed least increase in TSS content (15.47 °Brix) while untreated grapes were measured with maximum TSS content (16.60 °Brix) at the end of cold storage (Table 1). Other treatments also showed significantly lower TSS values as compared to control. Increasing trend of TSS content with the passage of time in EYO treated grapes was at par with the untreated bunches.

Sugars and pH: Results against sugars showed that effect of these GRAS chemicals on sugar contents was non-significant although reducing sugars (glucose and fructose) and non-reducing sugars both increased during four weeks of low temperature storage (Data not showed). Concerning our findings of pH of the samples, it remained stable and non-significant to control during four weeks of cold storage (Data not showed).

Ascorbic acid: All treatments significantly maintained ascorbic acid (AA) contents except 2% EYO. Grapes were stored at AA contents of 3.46 mg/100g FW. After four weeks of storage, maximum AA value (3.00mg/100g FW) was measured in 50% ethanol treated sample while minimum AA value (1.86 mg/100g FW) found in untreated sample (Table 1).

Discussion

Most of the weight loss occurred up to second week and was more obvious in control and EYO treated samples (Fig. 1). Magnitude of water loss tended to slow down after second week, which could be possibly related to reduction of water driving force arising with long storage (Sabir & Sabir, 2013). Water loss from grapes was due to water gradient between the internal environment of the fruit and external environment. In the conditions when there was very less gradient between the external and internal environment, no notable water loss occurred from fruit and vice versa (Sánchez-González *et al.*, 2011). Our results are in accordance with different previous studies that endorse that ethanol (35-50%) and hot water treatment at 55°C significantly reduce weight loss of table grapes during cold storage (Karabulut *et al.*, 2004; Candir *et al.*, 2011; Elwahab *et al.*, 2014). Restrictive effect of hot water on ethylene biosynthesis inhibited the ripening process of fruits during storage (Lurie, 1998), which most probably slowed down the metabolic activities in fruit tissues and respiration rate, hence, slowed down the weight loss (Cefola *et al.*, 2011; Sabir & Sabir, 2013). In present study, HWTs efficiently reduced diseased incidence followed by ethanol and PMBS treatments. It was observed that damaged tissues stimulate high oxygen uptake (Kou *et al.*, 2007). Hence, respiration rate could be highest in untreated and egg yolk oil treated grapes where maximum disease incidence was noticed. Higher weight loss in EYO treated grapes could be because of large surface area due to fungus attachment with fruit tissues. Another reason for higher water loss in higher EYO treatments could be damaged epidermal tissues by pathogen attack. In HWTs, weight loss of fruit was correlated with period of immersion in hot water. Increase in immersion period increased weight loss. This is evident from findings of Smock (1977) who stated that high temperature is the cause of high weight loss and this could be because of excessive damage caused by stress by high temperature for longer interval of time.

Effects of ethanol and HWTs against microbial attack and fruit shatter were found highly significant (Fig. 2). Our study corroborates with several previous findings that shows that hot water treatment and ethanol synergistically inhibited germination of many postharvest pathogens, including *Botrytis cinerea* (Lydakis & Aked, 2003; Gabler *et al.*, 2004) and *Escherichia coli* (Pinto *et al.*, 2006), which effectively reduced gray mold (Gabler *et al.*, 2005; Lurie *et al.*, 2006; Romanazzi *et al.*, 2007) and fruit shatter (Elwahab *et al.*, 2014) of table grapes during cold storage. In accordance with our findings, Karabulut *et al*., (2004) stated that HWT of table grapes at more than 50°C significantly reduced decaying rate of one month cold stored grapes. Similarly, Gabler *et al*., (2005) reported that HWT higher than 50°C significantly reduced gray mold incidence in table grapes during cold storage. Although, HWT with more than 50°C could effectively control decaying rate but it could inure the fruit (Gabler *et al.*, 2005), but in present study hot water did not have any negative effect on grapes. The primary site of action of both ethanol and hot water is mitochondrial membrane (Cabeca-Silva *et al.*, 1982). The main reason of lesser decay rate in hot water treated grapes could be because heat treatment induce fruit defense mechanism (Schirra *et al.*, 2000). Heat treatment maintained many protective enzymes, pathogenesis-related proteins, accumulation of phytoalexins and lignin-like materials, causing the treated bunches to become more resistant to subsequent infections (Sabir & Sabir, 2013). Ethanol dip created a layer of toxicity on fruit skin which most likely killed spores and retarded further mycelial development (Lichter *et al.*, 2003). Apparently, the mode of action of ethanol is direct on bacteria that adhered to fruit skin. It is important to acknowledge that ethanol has another mode of action which is related to wash-off effect of organic debris and dust. This organic matter may contain insect remains or the organic matter which may cause foci of fungal or bacterial development (Pinto *et al.*, 2006). PMBS noticeably decreased the decay rate of stored grapes as compared to EYO treatments and control (Fig. 2). Previously, PMBS is reported in controlling three major postharvest fungal

diseases (*Botryodiplo diatheobromae, Colletotrichum gloeosporioides* and *Gliocephalotrichum microchlamydosporum*) of Rambutan fruit (Sivakumar *et al.*, 2002). The inhibitory activity of PMBS was in accordance with previous results of PMBS against lactic acid bacteria in wine (Rojo-Bezares *et al.*, 2007). Portugal *et al*., (2014) stated that PMBS proved highly anti-microbial active at lower pH value. This increased activity was in accordance with the acid character of PMBS, which during storage yielded more active and higher amount of SO_2 molecules. SO_2 is well known as anti-microbial and grape preservative (Karabulut *et al.*, 2005). PMBS acted as effective antioxidant and antifungal agent (Sivakumar *et al.*, 2000). PMBS treated samples at low temperature significantly showed less decay and fruit drop than control because its stability could have been retained in low-O_2 environment. After third week of storage, fungus was observed on EYO treated and control bunches which was noticeably higher at the end of forth week storage (Fig. 2). Most possible reason could be that olive oil and egg yolk created high humidity in environment which lead to fungal incidence in compact bunches of Perlette grapes. To the date no study have been evaluated on postharvest EYO application so exact reason of fungal growth on EYO treated samples could not be understood and needs further research.

Fruit drop was efficiently controlled by hot water dip for 8 min, 5min and 50% ethanol treatments respectively (Fig. 3). This could be due to inhibition of ethylene biosynthesis by heat treatments (Lurie *et al.*, 1998). It seems that HWTs suppressed activation of enzymes like cellulose and polygalacturonase in abscission zone (Deng *et al.*, 2007). Dehydrated brown pedicel of fruit was observed in all EYO treated bunches and control. Dehydration was likely due to higher water loss from the tissues because of faster respiration. Ethanol and PMBS treatments also significantly reduced number of fruit drop. Findings of present study corroborate with the results of Elwahab *et al*., (2014) that ethanol treatment significantly reduces fruit drop percentage. Ethanol treated bunches showed decrease in weight loss (Fig. 3) because of low water loss which could be a possible reason of reduced dehydration rate in pedicels and ultimately low fruit drop.

GRAS chemicals slightly affected fruit color during four weeks of storage period. Major change in color was examined in EYO treated grapes which showed highest darkness and redness while hot water treated grapes improved in yellowness at the end of storage. Our results of ethanol treatments are in accordance with findings of Gabler *et al*., (2005) who stated that cool ethanol treatment did not change fruit color after one month of storage. Improvement in yellowness of hot water treated grapes could be due to heat components of treatments which caused anthocyanin's degradation due to increase in polyphenol oxidase activity (Patras *et al*., 2010).

Change in TSS, titratable acidity, and ascorbic acid contents of the grapes throughout the storage is given in Table 1.A treatment-dependent and significant increase in TSS contents was observed in all samples (Fig. 4). Such increment indicated progressive ripening of fruit during storage (Kader, 2002; Artés-Hernández *et al*., 2004; Sabir *et al*., 2010). Grape fruit store a large amount of organic acids in vacuoles, which are converted back to sugars leading to increase in TSS (Hui & Nip, 2006). Normal increase in concentration of solute due to water loss could be another reason of increment in TSS contents (Pretel *et al*., 2006; Rezaei & Vande Gheynst, 2010; Sabir *et al.*, 2011). Conversely, the least increase in TSS was detected in ethanol and hot water treated grapes (15.71 °Brix and 16.04 °Brix) respectively. Ethanol delays ripening process through its food preservative properties. The changes in TSS and effect of HWTs on grapes are well adjusted with findings of Saftner *et al*., (2002) and Sabir & Sabir (2013), where clear attenuate influence of high temperature on ripening was observed. It has already been reported by Lurie (1998) that the ripening is inhibited by heat treatment because of its restrictive effects on ethylene biosynthesis. Grape fruit remains metabolically active after detachment from vine and it reacts to internal and environmental factors for certain period of time. Main objective of postharvest strategies is to restrict the physio-chemical attributes of produce by retarding physiological activities (Rizzini *et al*., 2009). Among these activities, water loss is a principal problem, which is responsible for changes in metabolism and fruit composition as revealed in this study. Accordingly, untreated samples were measured with highest value of TSS mainly because of higher water loss and progressive ripening process.

All treatments significantly maintained AA contents except 2% EYO. Maximum AA contents were maintained by ethanol treatments (50% especially) followed by HWTs after storage period (Fig. 5). Elwahab *et al*., (2014) found little higher AA contents in 30% ethanol treated grapes after 6 weeks of cold storage. Titratable acidity decreased up to second week and then increased in all treated and untreated samples during cold storage (Fig. 6). As per findings, maximum acidity was found in grapes treated with three different ethanol concentrations followed by PMBS and HWTs. This could be because of reduction in metabolic conversion of organic acids into CO_2 and water as a result of reduction in rate of respiration (Elwahab *et al*., 2014). Minimum acidity was obtained in control followed by EYO treated bunches because of higher respiration rate and faster metabolic process.

Sugars and pH value of all treated and untreated samples remained almost same and changes were non-significant although slight reduction in pH value and increment in sugars was measured along with prolonged storage period up to second week (Data not showed). These results were in accordance with previous studies which stated that pH value of table grapes remained almost stable during prolonged storage (Artés-Hernández *et al*., 2004; Sanchez-Ballesta *et al*., 2006; Sabir & Sabir, 2013). Sugar level measured in treated and untreated grapes was same and there was no significant difference found after cold storage, although it increased with the passage of storage time in all the samples consistently. This increase could be because of conversation of starch into sugars (mainly glucose) during cold storage (Kunkes *et al*., 2008). Rusjan (2010) found increase in glucose and fructose contents due to water loss in 'Cardinal' grapes during storage.

Grapes treated with ethanol and hot water treatments were found 'excellent' in sweetness and 'very good' in appearance, taste, aroma and flavor while PMBS treated bunches were rated 'very good' in all sensory attributes (Fig. 7). Examination panel of sensory analysis marked grapes as 'not acceptable' which were treated with EYO treatments due to egg yolk smell, low sweetness, bad flavor and taste.

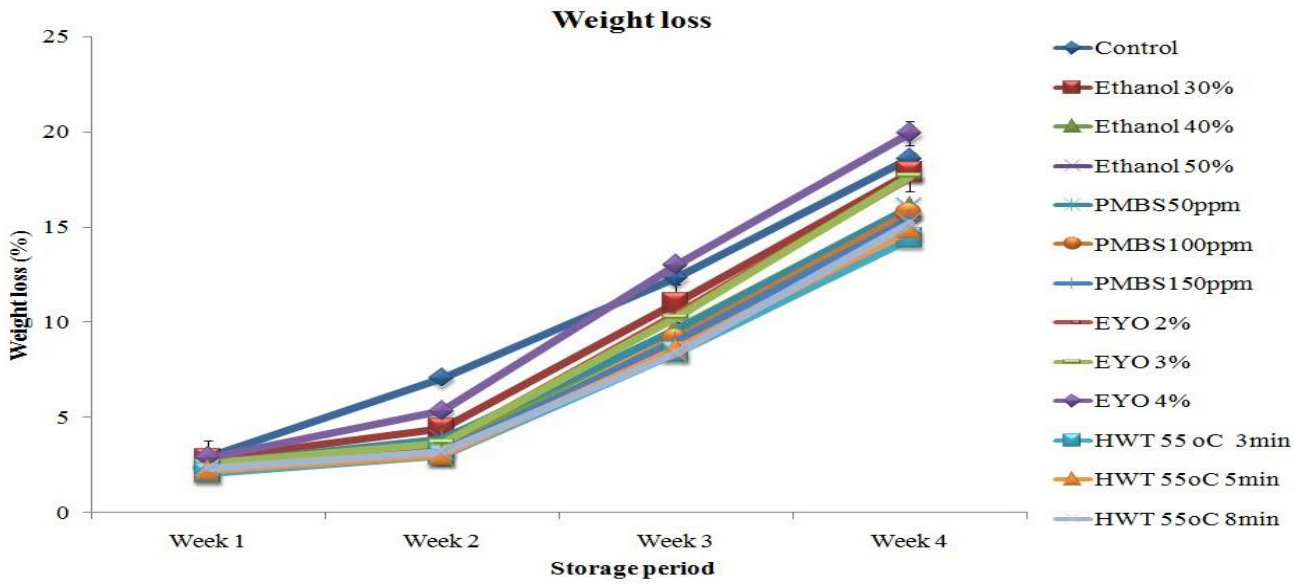

Fig. 1. Effect of GRAS chemicals on weight loss (%) of Perlette grapes during 4 weeks of cold storage.

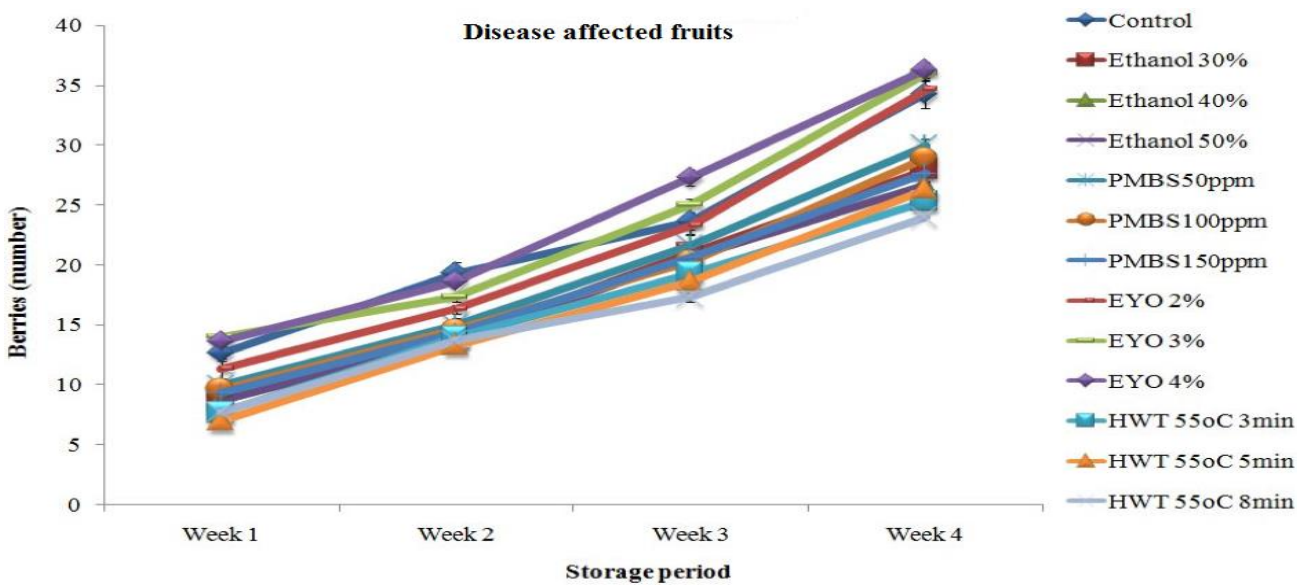

Fig. 2. Effect of GRAS chemicals on disease incidence (fruit /bunch) of Perlette grapes during 4 weeks of cold storage.

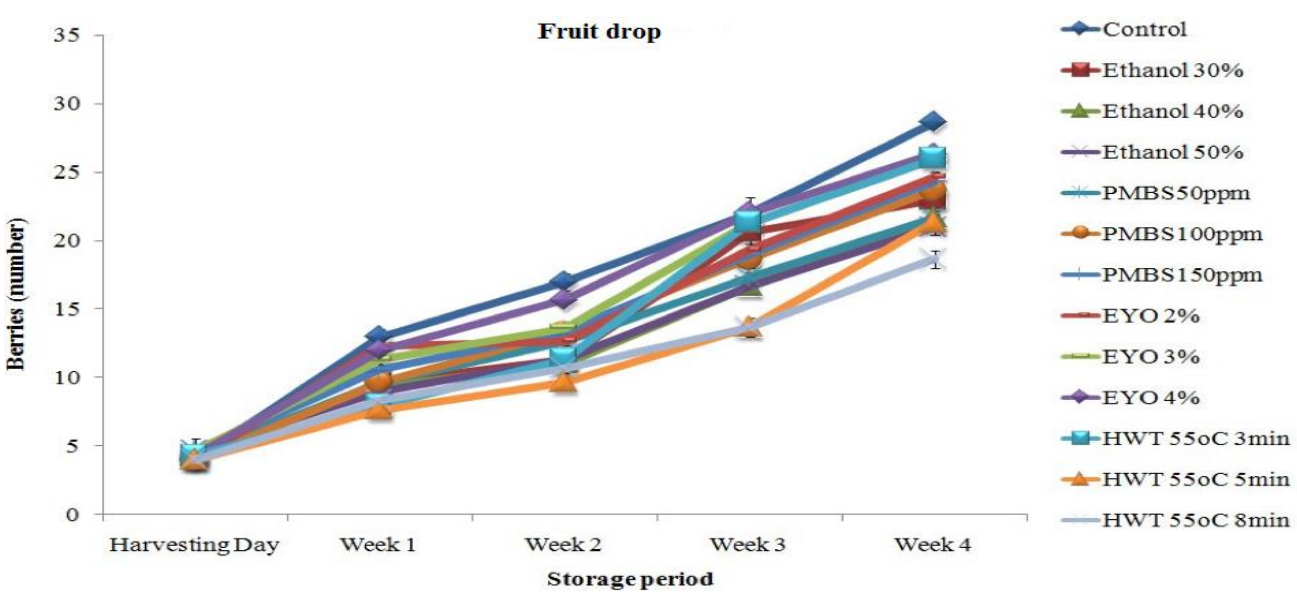

Fig. 3. Effect of GRAS chemicals on fruit drop (fruit /bunch) of Perlette grapes during 4 weeks of cold storage.

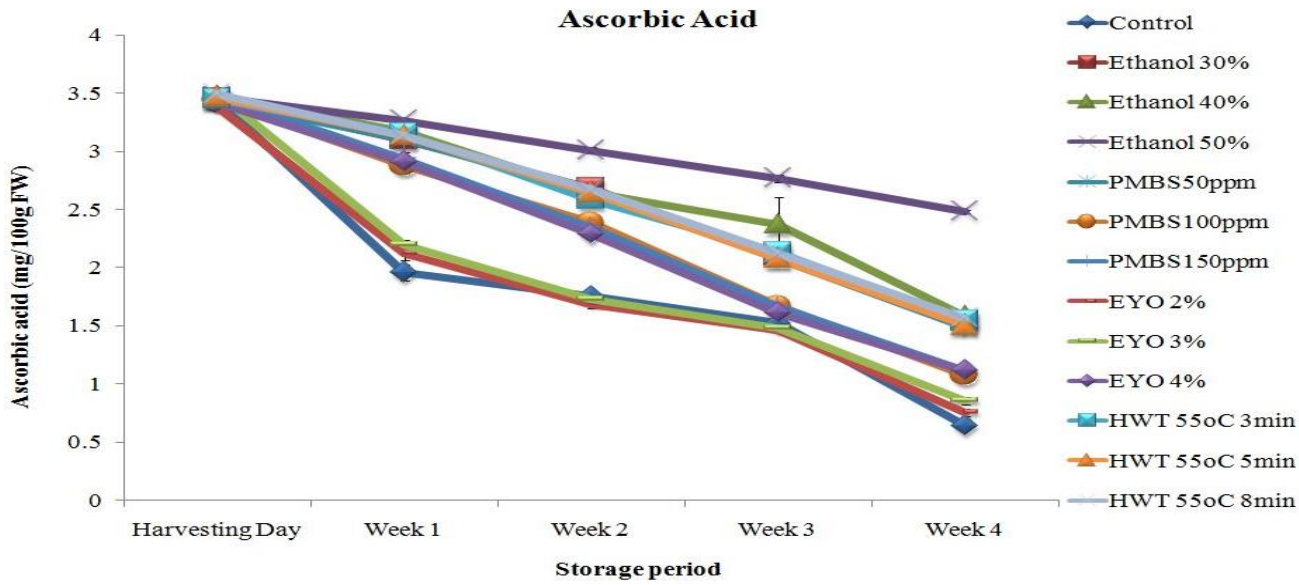

Fig. 5. Effect of GRAS chemicals on ascorbic acid contents (mg/100g FW) of Perlette grapes during 4 weeks of cold storage.

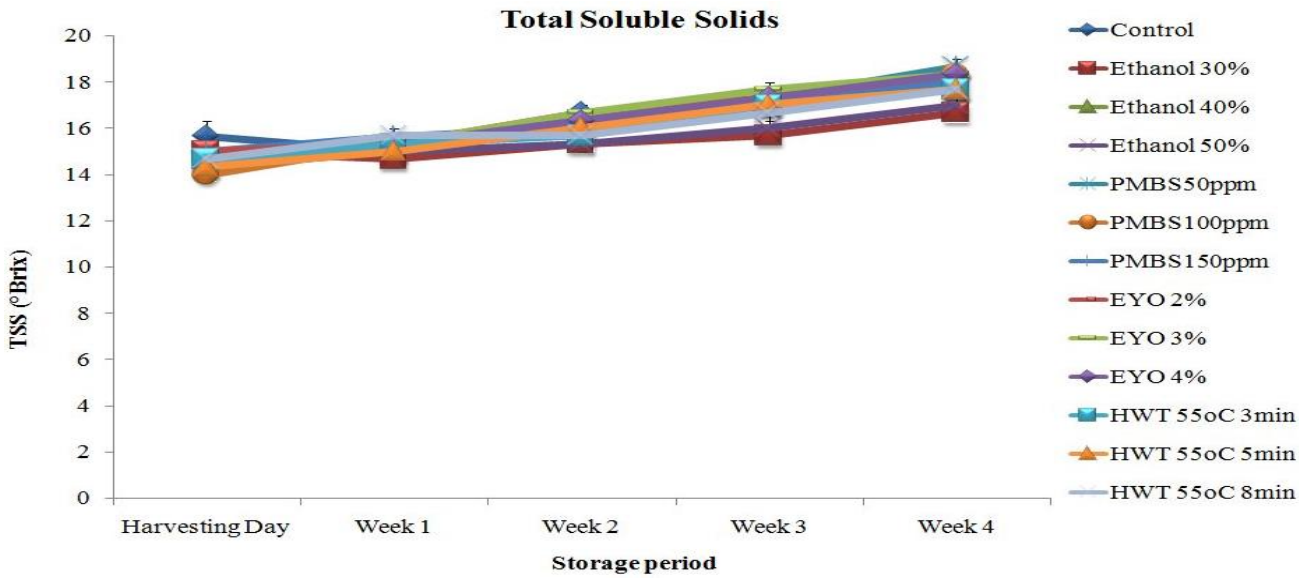

Fig. 4. Effect of GRAS chemicals on total soluble solids (Brix) of Perlette grapes during 4 weeks of cold storage.

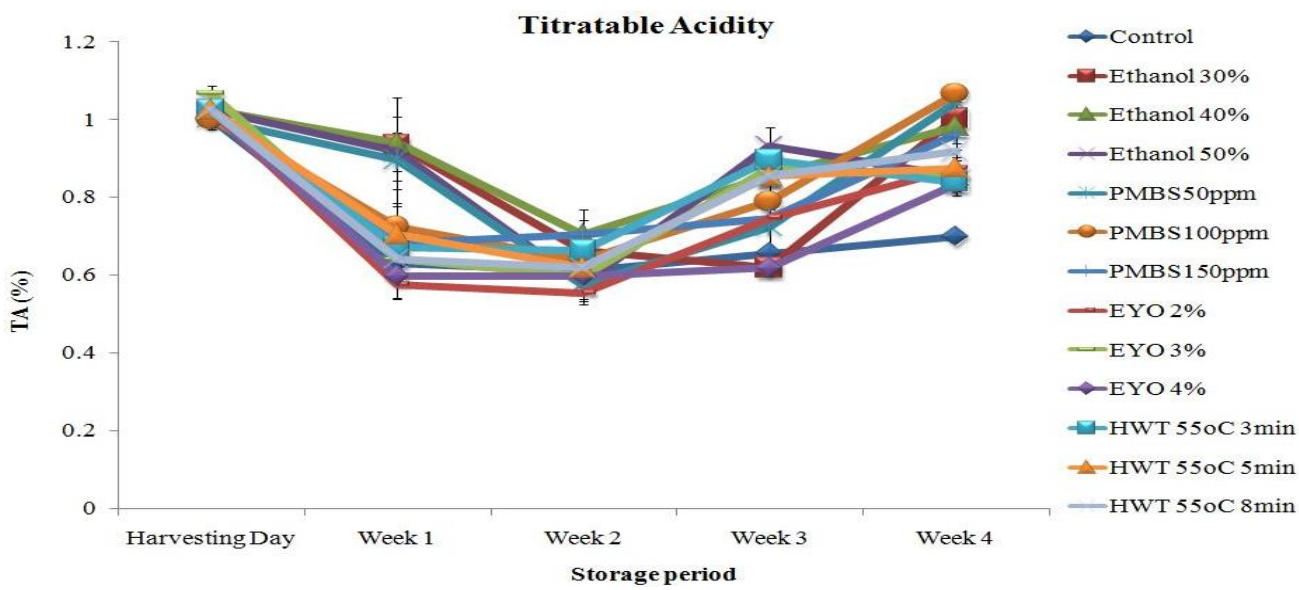

Fig. 6. Effect of GRAS chemicals on titratable acidity (%) of Perlette grapes during 4 weeks of cold storage.

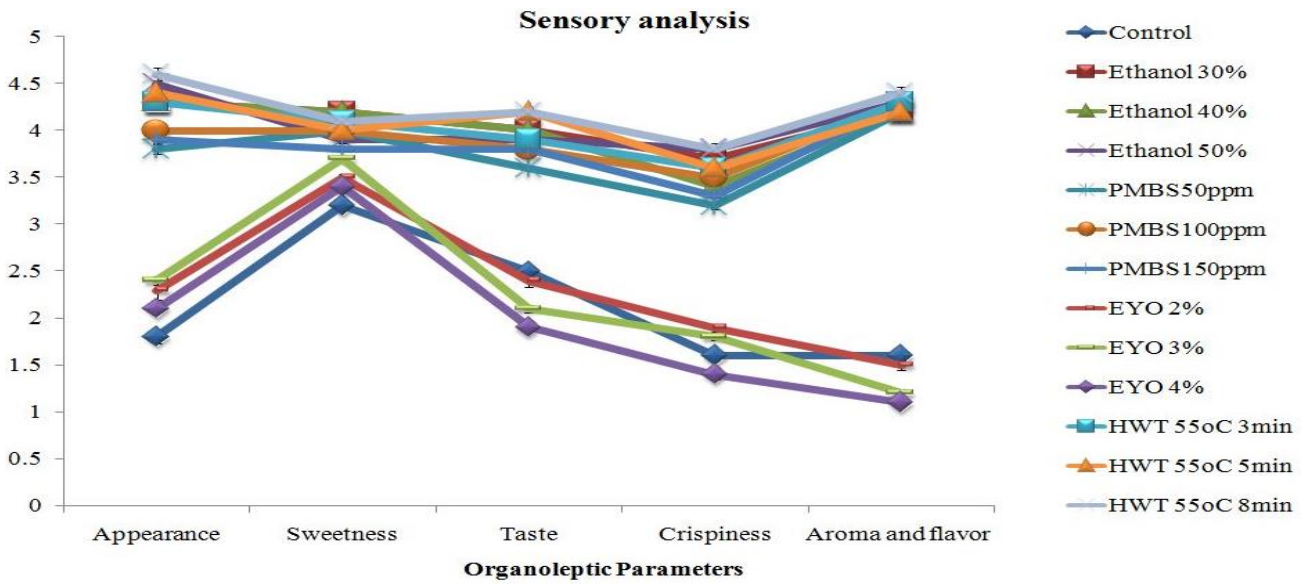

Fig. 7. Effect of GRAS chemicals on organoleptic quality of Perlette grapes during 4 weeks of cold storage.

Conclusion

Results from the present study showed that HWT at 55°C for 8 min was found highly effective in controlling postharvest disease incidence and decay rate while 50% ethanol maintained titratable acidity and ascorbic acid contents during storage. All treatments of hot water, ethanol and PMBS significantly enhanced postharvest quality of table grapes during 28 days of cold storage without any adverse effect. Concerning PMBS treatments, concentrations were low thus further study is needed to find its high efficiency in maintaining postharvest quality of table grapes at high concentrations. EYO treatments adversely affected grapes and were found unacceptable during organoleptic anlysis, thus it is recommended not to use in postharvest technology of table grapes.

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