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Anti-Sap Chemicals Reduce Sapburn Injury and Improve Fruit Quality in Commercial Mango Cultivars

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ABSTRACT

Sapburn injury of mango fruit is a serious problem as it reduces the cosmetic appeal and downgrade fruit. For the sapburn management in commercial cultivars (cvs) of Pakistan, physiologically mature fruits of cvs Sindhri and Chaunsa were harvested along with 4-5 cm pedicel. Immediately after de-stemming, fruits were treated with one of the potential chemical solutions: calcium hydroxide [$Ca(OH)_2$], Tween-80, sodium carboximethyl cellulose (CMC), lauryl sulfate sodium (LS), detergents and vegetable oil. The fruits after treatments were air dried and packed in cardboard boxes, transported to the laboratory and stored (14°C & RH 85%) for 7 and 14 days in case of cv Sindhri and cv Chaunsa, respectively. Fruits de-stemmed under calcium hydroxide showed better results against sapburn injury followed by Tween-80 in both the cvs. In the follow-up study, the best chemicals in experiment 1 along with alum were tested on cv Chaunsa to confirm the results. This time fruits after treatments were subjected to two different storage conditions (25°C & RH 56% & 14°C & RH 85%). Data on sapburn injury recorded after 24, 48 and 72 h, showed almost similar pattern at both the temperatures. De-stemming under $Ca(OH)_2$ gave 95% sapburn injury control at both temperatures. High TSS levels were observed in fruits de-stemmed under $Ca(OH)_2$ at 25°C. At this temperature total sugars were maximum in fruits treated with simple water (30.80%), while in stored fruits, maximum total sugars (26.70%) were noted with alum treatment. Total carotenoids were maximum in fruits de-stemmed under $Ca(OH)_2$, at both storage temperatures. In crux, $Ca(OH)_2$ was the best treatment in reducing sapburn injury and improving fruit quality at both the temperatures.

Key Words: Anti-sap chemicals; De-stemming; Calcium hydroxide; Carotenoids; Sugars; Taste; Firmness

INTRODUCTION

Mango is the second largest fruit crop produced in Pakistan, and with an annual production of 1.7 million tonnes, it ranks fifth in the world after India, China, Mexico and Thailand (Anonymous, 2005). However, the local mango industry is facing a number of problems including insect pest and disease attack (Mahmood & Gill, 2002; Ishaq *et al.*, 2004) and postharvest issues. One such problem that mango producers and exporters are facing is sapburn injuries resulting in poor quality fruits (Bosquez *et al.*, 2000). A resinous material (sap) exuded out as a result of de-stemming, which is somewhat milky at first and causes brownish-black to black streaks or blotches on the mango skin due to its acidic nature (Campbell, 1992). It becomes pale-yellow and transparent when dried and contains mangiferen, resinous acid, mangiferic acid and the resinol, mangiferol (Morton, 1987). The mango sap can be separated into two distinct fractions: oil and a protein-polysaccharide fraction. Injury occurs wherever the oil fraction makes contact with and enters into the mango skin via the lenticels. A major component of this oil fraction is terpinolene, which gives characteristic symptoms of sapburn injury when applied to the fruit skin (O'Hare & Prasad, 1991). The distinct symptoms appear a few hours later or as the ripening progress. Overtime, areas of skin damaged by sap may develop fungal or bacterial lesions due to its carbohydrate contents, increasing chances of mechanical injury to fruit (Negi *et al.*, 2002). The extent of sapburn injury may vary from cultivar to cultivar, harvesting conditions, growing regions, age of trees, season of harvest and maturity of fruit (Lim & Kuppelweiser, 1993).

To avoid this problem different techniques have been used including, de-sapping on the ground or on special de-sapping racks or trays, or on conveyor belts or machines (Ledger, 1991; Meurant, 1991). Various chemicals have also been tested to control the problem of sapburn injury including sodium carboximethyl cellulose (CMC), lauryl sulphate sodium (LS), calcium hydroxide solutions and dabbing with vegetable oil, waxes and powder, de-sapping in commercial detergent, Chlorsan, agral, alum (Landrigan *et al.,* 1991; Baker, 1991). These chemicals have been tested singularly or in various combinations, for controlling sapburn injuries in different varieties of mango. However, their effects on mango fruit quality have not been studied in details. In the past, there has been no study for sapburn management in commercial mango cvs. of Pakistan. Therefore, the need for sapburn management was felt by the local mango industry to improve the cosmetic fruit quality and export premium quality mangoes to the international markets. Since the mango sap is acidic in nature, it was assumed that destemming of fruit in a basic solution will

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neutralize the exuded acidic contents of sap, reducing the chances of injury to fruit skin. The main objectives of this study were to evaluate some of the potential anti-sap chemicals for sapburn reduction and their effects on mango fruit quality.

MATERIALS AND METHODS

Uniform fruit of two commercial mango cvs Sindhri and Chaunsa at physiological maturity were harvested along with 4-5 cm fruit stalk from a commercial orchard located in district Multan (Latitude 30.10' N; longitude 71'.36 E), Punjab province, Pakistan. Immediately after harvest fruits were treated with one of the chemicals (Table I).

In case of cut + dip method first the fruit pedicles were cut back and sap was allowed to exude on the fruit skin for 2-3 min, then dipped in a chemical solution for 45-60 sec, while for dip + cut method, first the fruits were dipped in a solution, then pedicles were cut back and fruits were held in solution for 45 to 60 sec. On the other hand the fruits for control treatment were taken from the lot which were harvested by the traditional or local farmer technique. After giving treatments the fruits were air dried and packed in corrugated boxes. In the first experiment (Table I), all the treated fruits were transported to the laboratory and stored (14 ± 2°C & 85 ± 5% RH) for 7 days and 14 days for cvs Sindhri and Chaunsa, respectively. While in the second experiment (Table II), half of the treated fruits were stored for 14 days and other half were placed at ambient temperature (25 ± 2°C & 56 ± 5% RH).

Sapburn injury score. Sapburn injury score was recorded after 24, 48 and 72 h during storage and damage was scored from 0 to 4 depending on the injury level [0= no injury, 1= very mild (injury area <1 cm^2), 2= mild (injury area >1<2 cm^2), 3= moderate (injury area >2< 4 cm^2), 4= severe (injury area >4 cm^2)] (Brown *et al*., 1986).

Physico-chemical Characteristics and Organoleptic Evaluation

Physical characteristics. After storage fruit were allowed to ripe at room temperature (25±1°C). Data on fruit firmness and visual colour was collected daily by manual observations (Maqbool, 2006). Firmness was rated as; 5: hard; 4: sprung; 3: slightly soft; 2: eating soft; and 1: over ripe. Similarly fruit colour was scored as; 1: 100% green – 0% yellow; 2: 75% green- 25% yellow; 3: 50% green- 50% yellow; 4: 25% green-75% yellow; 5: 0% green- 100% yellow.

Chemical characteristics. Each fruit was peeled off with a stainless steel knife. The juice was extracted from representative sample and homogenized in a blender to study the following chemical characteristics.

Total soluble solids (TSS) were determined using Atago RX 5000 Digital Refractometer (Atago, Japan). A drop of juice was extracted and placed on clean prism of Refractometer and the lid was closed. Reading was taken directly from the scale at room temperature (AOAC, 1990). Total titratable acidity was determined by methods given by Hortwitz (1960). To estimate the sugars in juice of each sample, the method described by Hortwitz (1960) was used. Total carotenoids were estimated following the method of Lalel *et al.* (2003) and were expressed as $mg.g^{-1}$ of β-carotene equivalent from a standard curve of β-carotene.

Table I. Chemical compounds and handling method for two mango cultivars

Cultivar/ Treatments	Chemical	Handling method	Conc. (%)
Sindhri			
T_1	Simple water	cut+dip	-
T_2	Detergent pre-treatment	dip+cut	0.04
T_3	Sodium Carboximethyl Cellulose (CMC)	dip+cut	1.0
T_4	Lauryl Sulfate Sodium (LS)	dip+cut	0.1
T_5	CMC + LS	dip+cut	1.0+0.1
T_6	Vegetable oil	dabbing	1.0
T_7	Tween-80	cut+dip	1.0
T_8	De-stemming under $Ca(OH)_2$	-	1.0
Chaunsa			
T_1	Control	-	-
T_2	Simple water	cut+dip	-
T_3	Detergent pre-treatment	dip+cut	0.04
T_4	Sodium Carboximethyl Cellulose (CMC)	dip+cut	1.0
T_5	Lauryl Sulfate Sodium (LS)	dip+cut	0.1
T_6	CMC + LS		1.0+0.1
T_7	Tween-80	cut+dip	1.0
T_8	De-stemming under $Ca(OH)_2$	-	1.0
T_9	Calcium hydroxide	cut+dip	1.0
T_{10}	CMC + LS + Lime	cut+dip	0.5+0.05+1.0
T_{11}	Tween-20	cut+dip	1.0

Table II. Chemical compounds and handling method for cv Chaunsa

Treatments	Chemical	Handling method	Conc. (%)
T_1	Control	-	-
T_2	Simple water	cut+dip	-
T_3	Tween-80	dip+cut	1.0
T_4	De-stemming under $Ca(OH)_2$	-	1.0
T_5	Alum	cut+dip	1.0

Organoleptic evaluation. Organoleptic evaluation of the fruit for taste and aroma was done using the Hedonic scale suggested by Peryam and Pilgrim (1957). Ten judges were employed in the panel who were asked to score the parameters (taste & aroma) using the 9 point Hedonic scale: 9 being like extremely and 1 dislike extremely.

Experimental design and statistical analysis. Both the experiments were conducted in Completely Randomized Design (CRD) with three replications. The data were analyzed statistically by ANOVA using GenStat®-UK and Least Significant Difference (LSD) test was used to compare differences between treatments at 95% confidence level of each variable (Steel & Torrie, 1980).

RESULTS

Experiment 1: Effect of Different Chemicals on Sapburn Injury and Fruit Quality

Sapburn injury development in relation to time after harvest. In this experiment data on sapburn injury

Table III. Sapburn injury development in relation to time after harvest

Treatment	Mean injury score (cv Sindhri)	Mean injury score (cv Chausna)
T_1	1.50NS	2.10c
T_2	1.67NS	2.35b
T_3	1.72NS	2.40a

Any two means not sharing a common letter are significantly different ($P \leq 0.05$). NS = Non-Significant
Time interval [T_1: 24 hrs; T_2: 48 hrs; T_3: 72 hrs]

Table IV. Sapburn injury development, treatments x time interaction in two mango cultivars (experiment 1)

Cultivar/ Treatments	Time 1 (24hrs)	Time 2 (48hrs)	Time 3 (72hrs)
Sindhri			
T_1	1.40	1.40	1.40
T_2	2.10	2.20	2.30
T_3	2.46	2.73	2.80
T_4	2.96	3.20	3.33
T_5	2.03	2.33	2.33
T_6	0.40	0.87	0.90
T_7	0.43	0.47	0.50
T_8	0.16	0.17	0.17
($p \leq 0.05$)	NS	NS	NS
Chaunsa			
T_1	4.00	4.00	4.00
T_2	1.92	2.59	2.67
T_3	3.80	4.00	4.00
T_4	1.60	2.06	2.33
T_5	3.13	3.17	3.20
T_6	0.33	0.60	0.60
T_7	0.33	0.67	0.80
T_8	0.27	0.27	0.27
T_9	3.40	3.17	3.60
T_{10}	2.80	2.87	2.93
T_{11}	1.47	2.00	2.00
($P \leq 0.05$)	NS	NS	NS

NS = Non-Significant
Treatments [T_1: Control; T_2: Simple water; T_3: Detergent pre-treatment; T_4: CMC; T_5: LS; T_6: CMC + LS; T_7: Tween-80; T_8: De-stemming under $Ca(OH)_2$; T_9: Calcium hydroxide; T_{10}: CMC + LS + Lime; T_{11}: Tween-20]

development was recorded 24, 48 and 72 h after storage. The statistical analysis of data showed non-significant difference in cv Sindhri, while in case of cv Chaunsa there was significant difference among different treatments (Table III). In cv Chaunsa the maximum injury was developed after 72 h (2.40) of sap contact, but most of the injury was developed after 24 h (2.10) and there was a little increase in injury after 48 h (2.35) during storage. The interaction between treatments and time showed non-significant results in both the cvs Sindhri and Chaunsa (Table IV).

Effect of chemical compounds on sapburn injury control. The results regarding reduction of sapburn injury after 72 h during storage illustrated that de-stemming under Ca $(OH)_2$ was found significantly superior to all other treatments (0.16) followed by vegetable oil (0.72), while Lauryl Sulphate Sodium (LS) (3.16) proved to be the least effective treatment in reducing sapburn injury in mango cv Sindhri, compared to simple water (1.40) (Fig. 1). The fruits treated with Tween-80 (0.46) also showed significant results

Fig. 1. Effect of different chemicals on sapburn injury in mango cvs Sindhri. ± SE
[T_1: Simple water; T_2: Detergent pre-treatment; T_3: CMC; T_4: LS; T_5: CMC + LS; T_6: Vegetable oil; T_7: Tween-80; T_8: De-stemming under $Ca(OH)_2$]

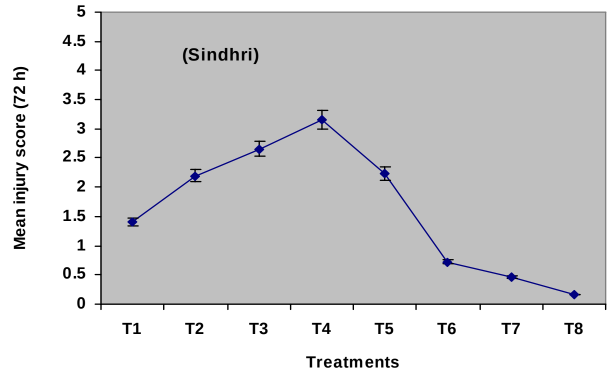


Fig. 2. Effect of different chemicals on sapburn injury in mango cv Chaunsa. ± SE
[T_1: Control; T_2: Simple water; T_3: Detergent pre-treatment; T_4: CMC; T_5: LS; T_6: CMC + LS; T_7: Tween-80; T_8: De-stemming under $Ca(OH)_2$; T_9: Calcium hydroxide; T_{10}: CMC + LS + Lime; T_{11}: Tween-20]

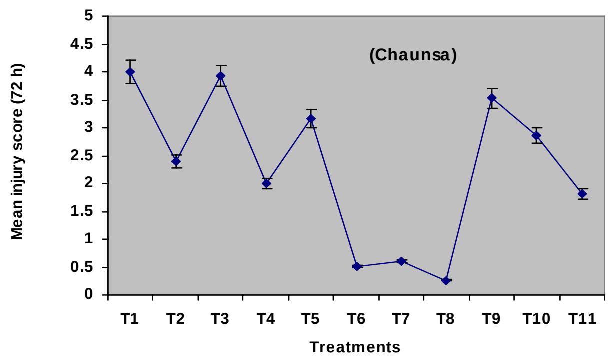
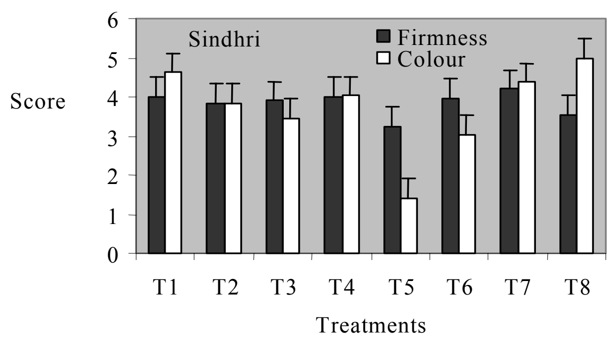


Fig. 3. Effect of different chemicals on fruit firmness and colour in cv Sindhri. ± SE
[T_1: Simple water; T_2: Detergent pre-treatment; T_3: CMC; T_4: LS; T_5: CMC + LS; T_6: Vegetable oil; T_7: Tween-80; T_8: De-stemming under $Ca(OH)_2$]



against sapburn injury as compared with detergent pre-treatment (2.20) and simple water (1.40) treated fruits. Wiping fruits with edible vegetable oil significantly reduced sapburn injury but it caused blotchiness. In case of cv Chaunsa the most effective treatment was de-stemming

Fig. 4. Effect of different chemicals on fruit firmness and colour in cv Chaunsa. ± SE

[T_1: Control; T_2: Simple water; T_3: Detergent pre-treatment; T_4: CMC; T_5: LS; T_6: CMC + LS; T_7: Tween-80; T_8: De-stemming under $Ca(OH)_2$; T_9: Calcium hydroxide; T_{10}: CMC + LS + Lime; T_{11}: Tween-20]

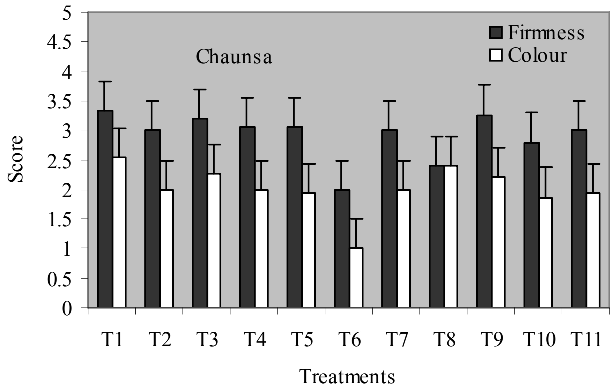


Fig. 5. Effect of different chemicals on taste and aroma in cvs Sindhri. ± SE

[T_1: Simple water; T_2: Detergent pre-treatment; T_3: CMC; T_4: LS; T_5: CMC + LS; T_6: Vegetable oil; T_7: Tween-80; T_8: De-stemming under $Ca(OH)_2$]

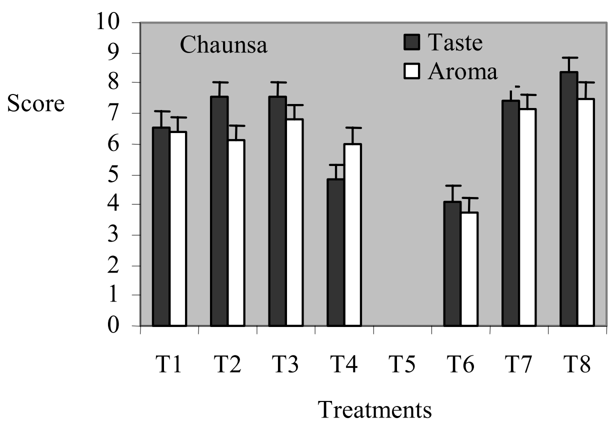
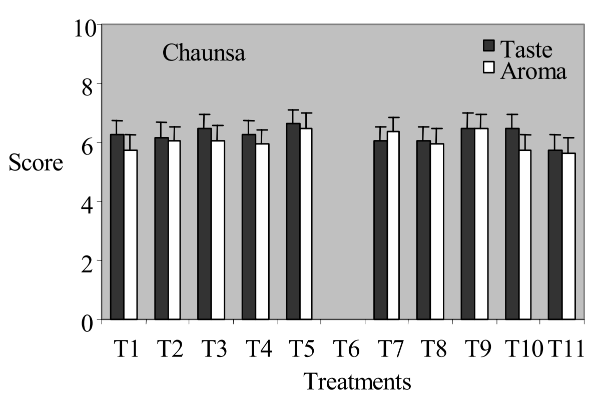


Fig. 6. Effect of different chemicals on taste and aroma in cv Chaunsa. ± SE

[T_1: Control; T_2: Simple water; T_3: Detergent pre-treatment; T_4: CMC; T_5: LS; T_6: CMC + LS; T_7: Tween-80; T_8: De-stemming under $Ca(OH)_2$; T_9: Calcium hydroxide; T_{10}: CMC + LS + Lime; T_{11}: Tween-20]



under $Ca(OH)_2$ (0.26) followed by CMC + LS (0.51) as compared with untreated control (4.0) after 72 h of sap

Table V. Effects on biochemical characteristics of two mango cultivars (experiment 1)

Treatment	TSS (°Brix)	Acidity (%age)	T. Sugars (%age)	T. Carotenoids (μgg^{-1})
Sindhri				
T_1	15.73b	0.18e	9.89e	76.60b
T_2	14.65d	0.19d	11.10d	53.30d
T_3	14.42e	0.16f	12.47b	55.90cd
T_4	15.03c	0.17e	10.10d	78.30b
T_5	11.00g	0.19d	9.11f	37.20e
T_6	13.29f	0.33a	11.90c	60.30c
T_7	16.40a	0.23c	12.93a	87.00a
T_8	15.94b	0.28b	8.31g	56.6cd
Chaunsa				
T_1	24.09bcd	0.22bc	27.50b	73.40a
T_2	22.43d	0.29a	24.90c	55.90bcd
T_3	27.40a	0.22bc	25.55c	56.30bcd
T_4	27.59a	0.19e	22.15d	66.50ab
T_5	25.51b	0.19cd	20.73d	54.06bcd
T_6	19.34e	0.30a	16.38e	57.00bcd
T_7	23.92bcd	0.21bc	29.08a	63.40ab
T_8	23.58cd	0.19cd	24.61c	54.30bcd
T_9	23.68bcd	0.21bc	24.69c	61.30abc
T_{10}	24.34bc	0.20bcd	21.07d	47.10cd
T_{11}	23.89bcd	0.19cd	24.70c	43.60d

Any two means not sharing a common letter are significantly different ($p \leq 0.05$).

TSS: Total Soluble Solids, T. sugars: Total sugars, T. carotenoids: Total carotenoids

Treatments [T_1: Control; T_2: Simple water; T_3: Detergent pre-treatment; T_4: CMC; T_5: LS; T_6: CMC + LS; T_7: Tween-80; T_8: De-stemming under $Ca(OH)_2$; T_9: Calcium hydroxide; T_{10}: CMC + LS + Lime; T_{11}: Tween-20]

contact. Tween-80 (0.60) also reduced sapburn injury very efficiently but the fruits, which were first cut and then dipped in a solution of calcium hydroxide showed poor results (3.53) in controlling sapburn injury, while CMC in combination with LS and lime proved to be better (2.86) as compared with detergent treatment (4.0) (Fig. 2).

Effect of treatments on fruit firmness, colour and organoleptic characteristics. Statistically significant ($P \leq 0.05$) differences were found in fruits treated with different chemicals. In cv Sindhri it was observed that fruit de-stemmed under $Ca(OH)_2$ had better colour and firmness (Fig. 3), while in case of cv Chaunsa the colour development was maximum in untreated control fruits, while firmness was rated highest in CMC + LS treated fruits (Fig. 4). The fruits treated with CMC + LS remained hard and green even after three weeks of storage at room temperature and therefore, not presented for organoleptic evaluation. Taste and aroma score was maximum for the fruits, which were de-stemmed under Ca $(OH)_2$ in case of cv Sindhri (Fig. 5), while in cv Chaunsa the fruit treated with LS had maximum taste and aroma score (Fig. 6).

Effect of treatments on biochemical characteristics. Statistically significant ($P \leq 0.05$) differences among treatments for various biochemical parameters in cvs Sindhri as well as Chaunsa were observed (Table V). High levels of TSS were observed in fruits treated with Tween-80 (16.40°Brix) followed by fruit de-stemmed under lime (15.94°Brix), while lowest TSS level was found in

Table VI. Sapburn injury development in relation to time and temperature (cv. Chaunsa)

Treatments	Mean injury score
Storage time	
T_1	1.29NS
T_2	1.53NS
T_3	1.57NS
Storage temperature	
Temp 1	1.41NS
Temp 2	1.52NS

NS = Non-Significant ($P \leq 0.05$)
Time intervals [T_1: 24 hrs; T_2: 48 hrs; T_3: 72 hrs]
Storage Temperature and Humidity [T_1: 14°C & RH 85%; T_2: 25°C & RH 56%]

Table VII. Interactive effects of various factors in cv Chaunsa

Treatments	Time 1 (24hrs)	Time 2 (48hrs)	Time 3 (72hrs)
Treatments x time interaction			
T_1	4.00	4.00	4.00
T_2	0.76	1.00	1.13
T_3	1.00	1.56	1.66
T_4	0.00	0.00	0.00
T_5	0.70	1.06	1.06
	NS	NS	NS
Treatments x temperature interaction			
Treatment	***Temp 1***	***Temp 2***	
T_1	4.00	4.00	
T_2	1.00	0.93	
T_3	1.20	1.62	
T_4	0.00	0.00	
T_5	0.86	1.02	
($p \leq 0.05$)	NS	NS	
Time x temperature interaction			
Time	***Temp 1***	***Temp 2***	
T_1	1.24	1.35	
T_2	1.45	1.60	
T_3	1.55	1.60	
($P \leq 0.05$)	NS	NS	

NS = Non-Significant
Treatments [T_1: Control; T_2: Simple water; T_3: Tween-80; T_4: De-stemming under $Ca(OH)_2$ T_5: Alum]
Time intervals [T_1: 24 hrs; T_2: 48 hrs; T_3: 72 hrs]
Storage Temperature and Humidity [T_1: 14°C & RH 85%; T_2: 25°C & RH 56%]

Table VIII. Treatments x time x temperature interaction in cv Chaunsa

Treatments	Time 1 (24hrs)		Time 2 (48hrs)		Time 3 (72hrs)	
	Temp 1	Temp 2	Temp 1	Temp 2	Temp 1	Temp 2
T_1	4.00	4.00	4.00	4.00	4.00	4.00
T_2	0.73	0.80	1.00	1.00	1.26	1.00
T_3	0.73	1.26	1.33	1.80	1.53	1.80
T_4	0.00	0.00	0.00	0.00	0.00	0.00
T_5	0.73	0.66	0.93	1.20	0.93	1.20
($P \leq 0.05$)	NS	NS	NS	NS	NS	NS

NS = Non-Significant
Treatments [T_1: Control; T_2: Simple water; T_3: Tween-80; T_4: De-stemming under $Ca(OH)_2$ T_5: Alum]
Storage Temperature and Humidity [T_1: 14°C & RH 85%; T_2: 25°C & RH 56%]
Time intervals [T_1: 24 hrs; T_2: 48 hrs; T_3: 72 hrs]

treatment CMC + LS (11.0°Brix) as compared with simple water (15.73°Brix) in cv Sindhri (Table V). In case of cv Chaunsa, de-stemming under $Ca(OH)_2$ showed a low TSS level (23.58°Brix), while fruit treated with CMC and detergent have high levels (27.59 & 27.40°Brix), respectively as compared with control (24.09°Brix) (Table V).

Titratable acidity was lowest in fruits treated with CMC (0.16%), followed by LS (0.17%) as compared to vegetable oil (0.33%) in cv Sindhri (Table V). As far as cv Chaunsa is concerned fruits treated with CMC + LS have highest levels of acidity (0.30%), while those treated with CMC had lowest levels (0.19%) as compared with control (0.22%) (Table V).

In cv Sindhri the total sugars were more in fruits treated with Tween-80 (12.93%), while lowest in fruits de-stemmed under $Ca(OH)_2$ (8.31%) as compared with simple water (9.89%) (Table V), while for cv Chaunsa fruit treated with Tween-80 had highest level of total sugar (29.08%) and fruits de-stemmed under $Ca(OH)_2$ had medium amount (24.61%) as compared with control (27.50%) (Table V).

Comparison of treatment means showed that maximum total carotenoids were observed in Tween-80 treated fruits (87.0 $\mu g\ g^{-1}$) followed by fruits treated with LS (78.3 $\mu g\ g^{-1}$), while the minimum amount was recorded in fruits treated with CMC + LS (37.2 $\mu g\ g^{-1}$) in case of cv Sindhri (Table V). For cv Chaunsa, the minimum amount of total carotenoids was observed in fruits treated with Tween-20 (43.6 $\mu g\ g^{-1}$), whereas the control fruits had maximum total carotenoids (73.40 $\mu g\ g^{-1}$) (Table V).

Experiment 2. Effect of Different Chemicals on Sap Burn Injury and Fruit Quality

Sapburn injury score. Data on sapburn injury score showed that de-stemming under $Ca(OH)_2$ proved to be the most effective treatment (Fig. 7), since fruits de-stemmed under $Ca(OH)_2$ recorded no injury (0.00). The fruits treated with alum also showed minimum injury score (0.94) as compared with control (4.00). Similarly, the fruits, which were dipped in simple water immediately after de-stemming also showed better results against sapburn injury (Fig. 7). The data regarding sapburn injury development at different times showed non-significant results (Table VI). It was observed that the maximum injury took place within first 24 h of sap contact however, it may continue non-significantly even after 72 h (Table VI). Similarly the results regarding means for temperatures (Table VI) and also their interactions (treatment x time, treatment x temperature, time x temperature & treatment x time x temperature) also showed non-significant results (Table VII & VIII).

Effect of treatments on fruit firmness, colour and organoleptic characteristics. The statistical analysis of data regarding fruit firmness and colour showed significant differences ($P \leq 0.05$) among treatments. The fruits which were treated with Tween-80 and de-stemmed under $Ca(OH)_2$ showed maximum firmness and colour score at both the temperatures (Fig 8 & 9). The results regarding taste and aroma showed non-significant difference among treatments at both the temperatures (Table IX).

Effect of treatments on biochemical characteristics. Non-

Fig. 7. Effect of different chemicals on sapburn injury in mango cv Chaunsa. ± SE

[T_1: Control; T_2: Simple water; T_3: Tween-80; T_4: De-stemming under $Ca(OH)_2$ T_5: Alum]

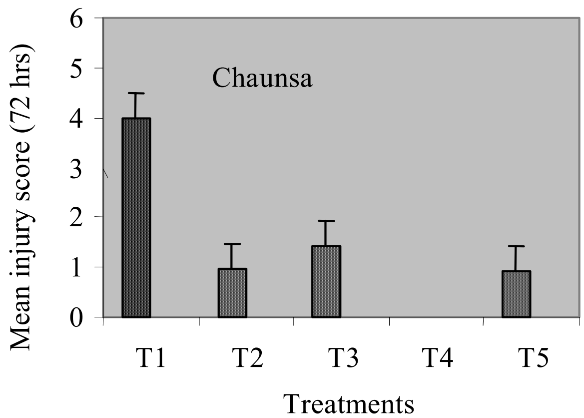


Fig. 8. Effect of different chemicals on fruit firmness and colour in cv Chaunsa at room temperature. ± SE

[T_1: Control; T_2: Simple water; T_3: Tween-80; T_4: De-stemming under $Ca(OH)_2$ T_5: Alum]

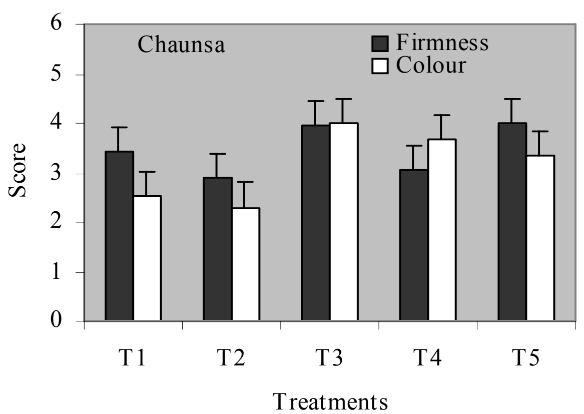
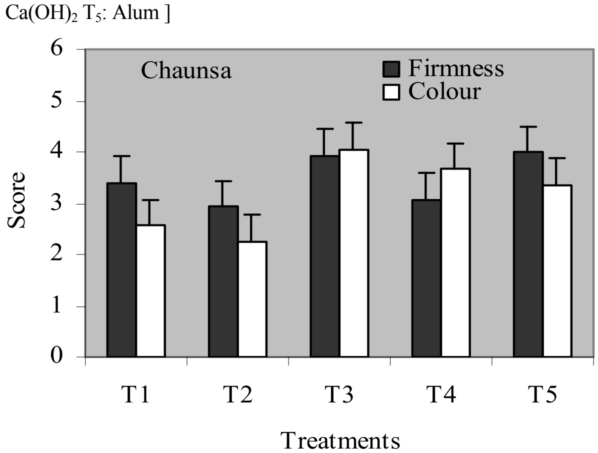


Fig. 9: Effect of different chemicals on fruit firmness and colour in cv Chaunsa during storage. ± SE

[T_1: Control; T_2: Simple water; T_3: Tween-80; T_4: De-stemming under $Ca(OH)_2$ T_5: Alum]



significant difference among treatments for various biochemical parameters was observed, except total sugars in

Table IX. Hedonic scale rating in cv Chaunsa

Treatments	Taste score	Aroma score
Room temperature		
T_1	6.75	6.83
T_2	6.99	6.83
T_3	5.60	5.24
T_4	6.03	6.08
T_5	6.96	6.83
($p \leq 0.05$)	NS	NS
Storage		
T_1	6.16	5.83
T_2	5.66	4.83
T_3	5.83	5.83
T_4	6.67	6.66
T_5	6.50	6.16
($P \leq 0.05$)	NS	NS

NS = Non-Significant

Treatments [T_1: Control; T_2: Simple water; T_3: Tween-80; T_4: De-stemming under $Ca(OH)_2$ T_5: Alum]

Table X. Effects on biochemical characteristics of cv Chaunsa

Treatment	TSS (°Brix)	Acidity (%age)	T. Sugars (%age)	T. Carotenoids ($\mu g g^{-1}$)
Room temperature				
T_1	25.98a	0.31a	27.40b	82.67a
T_2	26.38a	0.32a	30.80a	71.35a
T_3	26.71a	0.31a	27.85b	78.58a
T_4	27.60a	0.30a	26.65b	85.09a
T_5	26.03a	0.28a	23.90c	63.05a
Storage				
T_1	26.8a	0.40ab	22.43d	48.54c
T_2	25.4b	0.33b	23.75c	49.59b
T_3	27.3a	0.39ab	25.50b	64.52a
T_4	27.0a	0.43a	23.65c	69.43a
T_5	26.9a	0.37ab	26.70a	67.24a

Any two means not sharing a common letter are significantly different ($P \leq 0.05$).

TSS: Total Soluble Solids, T. sugars: Total sugars, T. carotenoids: Total carotenoids

Treatments [T_1: Control; T_2: Simple water; T_3: Tween-80; T_4: De-stemming under $Ca(OH)_2$ T_5: Alum]

cv Chaunsa at room temperature. Total sugars were maximum in fruits treated with simple water (30.80%) and minimum in fruits treated with alum (23.90%) as compared with untreated control (27.40%) (Table X).

On the other hand, during storage the biochemical parameters showed significant results ($P \leq 0.05$) among treatments (Table X). Maximum TSS level was found in fruits de-stemmed under $Ca(OH)_2$ (27.0%) while minimum level of TSS was observed in fruits treated with simple water (25.40°Brix) as compared with control (26.80%). Minimum titratable acidity was recorded in fruits treated with simple water (0.33%) followed by alum (0.37%) as compared with control (0.40%) (Table X). The amount of total sugars was recorded maximum in alum treated fruits (26.70%) as compared with control (22.43%). Total carotenoids were observed highest in fruits, which were de-stemmed under lime (69.43 $\mu g\ g^{-1}$) as compared with control (48.54 $\mu g\ g^{-1}$). The fruits treated with Tween-80 and alum resulted in total carotenoids contents of 64.52 $\mu g\ g^{-1}$ and 67.24 $\mu g\ g^{-1}$ respectively (Table X).

DISCUSSION

Sapburn injury and its control. In the present study, mango cv Sindhri had much lower incidence of sapburn injuries as compared with cv Chaunsa, which is consistent with our previous study (Maqbool, 2006). The difference in sapburn injury between cvs Chaunsa and Sindhri can be attributed to two reasons, (1) high sap causticity of cv Chaunsa as compared to cv Sindhri, (2) absence of prominent lenticels on the skin of Sindhri, while prevalence of prominent lenticels in cv Chaunsa. Previous study has provided evidence that different terpenoids may cause varying degree of damage to mango skin and that the chemical consistency of sap can vary between cultivars (Loveys *et al*., 1992). Similarly, the lenticels density also appeared to have a modifying effect on injury, as damage occurred, where sap flowed over lenticels (O'Hare & Prasad, 1991; Robinson *et al*., 1993).

In the series of experiments, de-stemming under $Ca(OH)_2$ and Tween-80 proved superior to other chemicals in reducing sap burn injury. Calcium hydroxide is a colourless crystal or white powder. It is a strong base with a pH 12.4 and is widely used as an inexpensive alkali, often as a suspension in water (milk of lime). It is commonly used to reduce soil acidity and as a cheap alkali in many industrial processes (Anonymous, 2006). Although, the phenomenon of calcium hydroxide reduced injury is not clear, it is possible that it might have neutralized the effect of sap, which is strongly acidic (pH = 4.3) (John *et al*., 2003) and provided a safety to the mango skin, which is very sensitive to caustic nature of sap. Previously it is reported that 1% lime solution gave good results against sapburn injury (Holmes & Ledger, 1992). Similarly, Twen-80 acts as a detergent and provided a physical coating that prevented entry of at least some sap as earlier reported (Lim & Kuppelweiser, 1993). Other chemicals like CMC and LS had no significant control against sapburn injury in both Chaunsa and Sindhri cvs but earlier reports suggest that these chemicals were considered better in cvs Haden and Tommy Atkins (Bosquez *et al*., 2000), it might be due to the chemical consistency of sap that can vary between cultivars (Loveys *et al*., 1992) or the lenticels density that also had a significant effect on sapburn severity (Robinson *et al*., 1993). The dabbing with vegetable oil was more efficacious in controlling sapburn injury; however it caused blotchiness and induced off-flavour. It might be due to the blockage of lenticels, which led to anaerobic respiration and ultimately resulted in poor quality of the fruits. Similar results were also reported in a previous study (Lim & Kuppelweiser, 1993). They found that dabbing with vegetable oil or dipping in DC Tron oil at 100-1000 μL/l was more efficacious than similar dosages of Agral 60, Ethokem, Crop life, Codacide and 1% Chlorsan, however the fruits treated with vegetable oil had poor colour development and produced off-flavour during storage.

After storage at both the temperatures (14 ± 2°C; 85 ± 5% RH & 25 ± 2°C; 56 ± 5% RH), the 1% alum solution also proved to be the effective treatment against sapburn injury, which coagulated sap during the dipping process (Brown *et al*., 1986).

Chemical treatments and their effects on fruit quality. Sensory attributes like colour and firmness were also good in fruits de-stemmed under $Ca(OH)_2$ in both the cvs Sindhri and Chaunsa. Fruit colour and firmness were enhanced by using $Ca(OH)_2$ which expressed the potential of $Ca(OH)_2$ for further studies to be used as commercial treatment against sapburn injuries. The better fruit firmness with $Ca(OH)_2$ treatment could be linked to the role of calcium in stability of cell wall (Roe & Bruemmer, 1981) as the 60% of the total cell calcium is found in the cell wall (Tobias *et al*., 1993) therefore, fruit softening has been attributed to changes that occur in pectin substances cementing the cell wall, which are characterized by the solubilization of these substances in the middle lamella (Roe & Bruemmer, 1981).

On the other hand, fruits treated with CMC + LS had poor colour development and remained hard and green as at the time of harvesting. It is reported that CMC has a capacity to form a film that works as a barrier and prevents fruit skin from direct contact of sap (Bosquez *et al*., 2000). So it might be the reason that as CMC + LS had stopped the ripening process by blocking the lenticels therefore, no colour change took place (Tamjinda *et al*., 1992) and fruit got fermented during storage (Hoa *et al*., 2002).

High levels of TSS and more sugar contents were found in fruit treated with Tween-20, Tween-80 and fruit de-stemmed under $Ca(OH)_2$ in both the cultivars. Since TSS and sugars are normally increased as the ripening process progresses, it shows that these treatments may have accelerated the fruit ripening process. A relationship between high calcium content and ethylene production has been suggested in melon (Madrid *et al*., 2004), so it could be assumed that de-stemming fruit in calcium hydroxide may have induced ethylene resulting in accelerated ripening. This possibility is further strengthened by the high total carotenoids in fruit treated with calcium hydroxide. Total carotenoids content usually increases as fruit ripening process is advanced and the increase in carotenoids content has a direct relation with the apparent fruit skin colour, in which the major part is β-carotene, which is the colouring agent (Chaudhary, 2006). Hence, $Ca(OH)_2$ treatment enhanced total carotenoids resulting in improved fruit colour development of mango.

CONCLUSION

The results indicate that a better sapburn control can be achieved by using specific anti-sap chemicals as they provide a protection by neutralizing the effects of sap or preventing the entry of sap via the lenticels of the fruit skin. For the purpose, Tween-80 and de-stemming under $Ca(OH)_2$ proved to be the best anti-sap chemicals. These chemicals not only protected fruits from sapburn injury but also improved the overall fruit quality.

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