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ORIGINAL ARTICLE

Effect of skin coatings on prolonging shelf life of kagzi lime fruits (*Citrus aurantifolia* Swingle)

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Abstract An experiment was conducted to assess the influence of chemical and oil coatings on storage life of kagzi lime fruits. Fruits were harvested at physiological light green mature stage and treated with different concentrations of chemicals viz., $Cacl_2$ and $KMnO_4$ and edible coatings viz., (coconut oil, mustard oil, sesamum oil, castor oil and liquid paraffin wax). After treatment, fruits were kept at ambient condition (25–30 °C, 60–70% RH) till 18 days and analyzed for various physical and chemical parameters like PLW, marketable fruits retained, TSS, acidity, ascorbic acid, juice content and also organoleptic values. The results revealed that edible oil emulsion coating particularly coconut oil had significantly ($p \leq 0.05$) effect on reduction of the physiological loss in weight (9.67%) and maximum marketable fruits retained (70%), total soluble solids (8.43%), ascorbic acid (49.93 mg/100 ml juice), acidity (1.52%) and juice content (42.34%) of fruits. Similarly, application of this oil emulsion coating acceptable for sensory quality parameters such as appearance, flavour, taste, external colour and no incidence of moulds & their growth up to 18 days of storage.

Keywords Kagzi lime · Oil coatings · Shelf life · Emulsion · Storage

Introduction

In India, lime is grown in tropical and subtropical regions occupying an area of 31, 6,050 ha with an annual production of 2.57 lakh MT (NHB 2010). Kagzi lime is the leading cultivar of lime, which is predominantly grown in Madhya Pradesh. It being a non climacteric fruits harvested, when it is matured stage. Although the fruit has a fairly good shelf life, yet enhancement of its shelf life may prove beneficial for its utilization during the off-season when prices are very high. Enhancing the shelf life of fruits is the only remedy to fulfill the demand of market during off- season also. Like any other fruits kagzi lime is perishable in nature, around 25–40% harvested fruits are lost before consumption due to faulty post harvest handling and microbial attack after harvest (Mahajan and Singh 2008). After the fruit have been harvested at optimum maturity the important post harvest need is the retention of quality for longer period as possible so that, it can be marketed for extended period. The post harvest losses can be minimized by extension of shelf life through checking the rate of transpiration and respiration, microbial infection and protecting membranes from disorganization (Bisen and Pandey 2008).

The foresaid objectives can be achieved to some extent by use of growth regulators, edible coating, wax emulsion, storage at low temperature, use of fungicide, calcium treatment, silver nitrate, chemical application, oil coating, irradiation and different types of packing material as post harvest treatment (Bisen et al. 2008; Chahal and Bal 2003). But even with the availability of modern technologies the percentage of post harvest losses of fruit is still high. These facilities are not generally with in the reach of a majority of growers because most of the farmer in India is small and marginal they are not able to effort the costly post harvest treatments as well as lack of knowledge about these techniques among growers. Therefore, alternative low cost technologies need to be standardized for reducing post harvest losses. These techniques should be easily available,

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economically viable and feasible in term of health point of view of human being (Pandey et al. 2010).

Among the different methods used to extend the shelf life alternative of low cost technology i.e. the application of edible coating (oil, wax, chemical) to fruit has received attention word wide as these coating are maintaining quality even under ordinary storage condition. Keeping these in views, the present investigation was conducted for comparative study to find out suitable skin coating emulsions on prolonging shelf life of winter kagzi lime fruits.

Materials and methods

The fresh, physiological light green mature and uniform size of lime fruits were procured from the fruit research station, Imalia, Department of Horticulture, JNKVV, Jabalpur. The fruits were washed and graded by density gradation method to select fruits having uniform maturity and only water sinker fruits were used for storage studies. The fruits were treated with chemical coatings i.e. control (T_1), $Cacl_2$ 1% (T_2), $Cacl_2$ 2% (T_3), $KMnO_4$ 1% (T_4), $KMnO_4$ 2% (T_5) , oil coatings i.e. liquid paraffin wax 100% (T_6), mustard oil 100% (T_7), coconut oil 100% (T_8), castor oil 100% (T_9) and sesamum oil 100% (T_{10}). The observations on various physico-chemical attributes and organoleptic values of lime fruits were taken on same day of harvest and after 6, 12 & 18 days of storage at ambient conditions (25–30 °C and 60–70% RH). The physiological loss in weight (PLW) of the fruits was calculated on initial weight basis and expressed in percent. The TSS of fruit was measured with the help of Zeiss Hand Refractometer of 0–32° Brix range. The acidity, sugar and vitamin 'C' contents were determined as per the method of AOAC (2002). The sensory quality parameters such as appearance, taste, flavour and texture of each sample was evaluated by a semi trained panel of 5 judges using the 9–point Hedonic rating scale (Amerrine et al. 1965).

Statistical analysis The treatments were replicated 3 times and experiment was laid in a completely randomized design and results analysed statistically (Cochran and Cox 1957). Thirty fruits were taken for each treatment in each replication.

Results and discussion

PLW

PLW of fruit, in general, increased with the advancement in storage period, rather slowly in the beginning, but at a faster pace as the storage period advanced. The post harvest treatments significantly ($p \leq 0.05$) reduce the physiological weight loss of lime fruits. Fruits coated with pure coconut oil recorded minimum (3.7, 5.5 and 9.6%) physiological weight loss after 6, 12 and 18 days of storage (Table 1). Coconut oil coating proved to be significantly superior over control and all other treatment followed by castor oil coating and liquid paraffin wax. Thomas et al. (2005) found that waxing reduce weight loss and respiration rate during storage period. This may be due to antisenescence property present in pure coconut oil like slow storage break down associated with slow respiratory rate, transpiration rate and binding of the ethylene biosynthesis process. Coconut oil coating and castor oil coating closed the opening of stomata and lenticels thereby, reducing the transpiration and respiration rate and also reduce microbial activity (Das and Medhi 1996). Rate of transpiration and respiration reduces, which increases

Table 1 Effect of different post harvest treatments on the physical parameters of kagzi lime fruits

Treatments	PLW, %			Marketable fruits retained, %			Marketable fruits over control, %		
	6D	12D	18D	6D	12D	18D	6D	12D	18D
T_1	10.7	15.1	24.0	86.6	70.3	31.8	–	–	–
T_2	8.0	12.5	30.9	99.9	85.0	59.0	13.3	14.6	8.0
T_3	7.4	14.3	21.8	93.3	88.8	54.5	6.6	18.5	16.0
T_4	9.5	15.3	35.3	90.0	77.7	22.7	3.3	7.4	−20.0
T_5	12.4	15.0	29.1	86.6	74.0	18.3	0.0	3.7	−12.0
T_6	5.7	9.9	14.3	100	85.1	54.5	13.3	14.8	4.0
T_7	15.3	17.3	36.0	100	92.5	45.4	13.3	22.2	4.0
T_8	3.7	5.5	9.6	100	96.5	70.1	13.3	25.9	24.0
T_9	5.5	10.3	14.4	100	88.8	68.1	13.3	18.5	16.0
T_{10}	13.5	16.3	38.7	100	72.0	21.2	13.3	11.1	−39.0
SEm±	0.10	0.02	0.65	0.17	0.26	0.45	0.89	0.13	1.63
CD at 5%	0.32	0.06	1.92	0.52	0.77	0.16	0.25	0.39	4.81

T_1=Control, T_2=$Cacl_2$ 1%, T_3=$Cacl_2$ 2%, T_4=$KMnO_4$ 1%, T_5=$KMnO_4$ 2%, T_6=Liquid paraffin, T_7=Mustard oil, T_8=Coconut oil, T9=Castor oil, T_{10}=Sesamum oil, n=3

D days after treatment, *PLW* physiological loss in weight

Marketable fruits retained at 0D: 100%

ultimately more retention of moisture in the fruit due to minimum, physiological weight loss. Similar findings were noted by Pandey et al. (2010) and Jagadeesh et al. (2001) in guava fruits.

Whereas, highest (15.3, 17.3 and 36.0%) physiological weight loss was recorded under pure mustard oil coating followed by sesamum oil at 6, 12 and 18 days of storage. The pure mustard oil coating increases the respiratory rate and ethylene production is the possible cause to increase the physiological weight loss of the fruit. Bisen et al. (2008) reported that mustard oil emulsion increased the weight loss and decreased the firmness of kagzi lime fruits.

Marketable fruits retained and over control

The shelf life of 100 percentage marketable fruit was retained till 6 day after treatment under pure coconut oil, sesamum oil and liquid paraffin wax followed by $Cacl_2$ 1% (99.9%) without affecting fruit quality as evidenced by physico-chemical composition, colour, aroma and taste of the fruits, while 86.6% marketable fruits were retained under control up to 6 day of storage (Table 1). The result corroborate with finding of Dashora and Shaffat (1988) they reported that wax emulsion proved to be the most appropriate post harvest treatment from the view point of reduction of rotting, loss of weight and maintenance of quality of mosambi. When the storage period was enhanced up to 18 days, the maximum (70.1%) marketable fruits were retained under pure coconut oil. Maximum retention of marketable fruits under coconut oil coating might be owing to slow degradation of chlorophyll and decreased enzymatic acidity which are responsible for delay in ripening, it may be due to reduce the rate of water loss and lesser availability of oxygen with in the fruit which slow down the rate of ripening of fruits. Delay the ripening by oil and wax coating was reported by Dhemre and Waskar (2003) in mango fruits. Similar results were also obtained by Mahajan et al. (2005) is kinnow fruits. On the other hand minimum (18.3%) marketable fruits retained under $KMnO_4$ 2% followed by (21.2%) sesamum oil coating at 18 days of storage. After 12 days of storage this might be due to skin injury because viscosity is very high in hundred percent pure mustard oil. Which cause maximum retention of oil on the surface of fruit and more oil percentage in the stomatal pore space of cell wall and chlorophyll and increase enzymatic activity, which resulted in tissue softening, browning and over ripening under pure sesamum oil coated fruits. However, after 18 days of storage the height (24.0%) retention of marketable fruits over control was in coconut oil coating. Similarly, Thomas et al. (2005) reported that coating retard ethylene emission and enhance texture as compared to control and 30% less weight loss than control. Whereas, sesamum oil coating showed minimum (−39.0%) marketable fruits over control, it gave negative response. Similar observations were made by Mahajan et al. (2010) in pear fruits.

TSS

In coated fruits, TSS content increased slowly and steadily up to 18 days of storage. The maximum (9.3%) TSS was recorded under mustard oil coating followed by control and sesamum oil at each day of storage period. These results corroborate with the finding of Sindhu and Singhrot (1996). They reported that in sesamum oil TSS increase with increasing period of storage. The increase in TSS up to 18 days may be attributed to the hydrolysis of acid and deposition of polysaccharide with advancement of storage period reported by Omayma et al. (2010) in guava. Fruits treated with coconut oil recorded minimum (8.4%) increase in TSS followed by (8.5%) liquid paraffin wax (Table 2).

Table 2 Effect of different post harvest treatments on the chemical parameters of kagzi lime fruits

Treatments	TSS, %			Acidity ,%			Ascorbic acid, mg/100 ml of juice		
	6D	12D	18D	6D	12D	18D	6D	12D	18D
T_1	8.6	8.8	9.1	1.2	1.3	1.4	32.6	36.2	39.4
T_2	8.5	8.5	9.0	1.2	1.3	1.4	32.0	38.3	40.0
T_3	8.3	8.6	8.7	1.1	1.3	1.4	31.2	39.2	45.0
T_4	8.4	8.6	8.8	1.2	1.3	1.4	33.7	37.9	43.1
T_5	8.3	8.5	8.9	1.2	1.3	1.4	35.4	38.6	44.0
T_6	7.9	8.2	8.4	1.2	1.3	1.4	37.1	40.4	46.5
T_7	8.7	8.9	9.3	1.2	1.3	1.4	36.9	37.2	39.5
T_8	7.8	8.1	8.4	1.4	1.5	1.6	38.9	43.2	49.9
T_9	7.9	8.1	8.4	1.3	1.4	1.5	38.0	42.9	47.2
T_{10}	8.5	8.7	9.1	1.0	1.2	1.3	30.4	39.1	40.1
SEm±	0.05	0.06	0.12	0.10	0.08	0.04	0.20	0.69	0.12
CD at 5%	0.15	0.16	0.36	0.31	0.24	0.14	0.59	2.06	0.35

T_1–T_{10}: as in Table 1. n=3, D: as in Table 1, *TSS* total soluble solids, TSS at 0D: 8.2, Acidity at 0D: 0.98%, Ascorbic acid at 0D: 28.64 mg/100 ml of juice

This was probably due to less concentration of juice as a result of dehydration because coating with coconut oil sealed the opening of pore/stomata and controlled the dehydration process of fruits (Kulkarni et al. 2010).

Acidity

Acidity of lime fruit was increase with prolonging in storage period up to 18 days irrespective of treatments. The highest acidity (1.6%) was registered in pure coconut oil followed by (1.5%) castor oil coated fruits at 18 days of storage (Table 2). Similarly, Ghosh and Sen (1985) reported that in wax treated fruit their TSS and acidity where high. The maximum acidity after 6, 12 and 18 days of storage recorded in pure coconut oil followed by castor oil coating both these treatment are significantly ($p \leq 0.05$) superior to all other post harvest treatments. Sharma and Sandhooja (1991) reported similar results in kinnow fruits. The higher acidity of lime fruit was retained under pure coconut oil coating may be due to lesser availability of oxygen to fruit in later stages of storage. It appears that the organic acid, which participates in the respiratory process but it not oxidized therefore, their level remained high. Similarly, Jagadeesh et al. (2001) reported that wax emulsion proved best in improving shelf life of guava fruit than other treatment and acidity and TSS where high under waxol. The minimum acidity was observed in sesame oil coating at each stage of storage period which may be due to maximum utilization of acid in the metabolism or more use of organic acid during respiratory process.

Ascorbic acid

Fruit coated with pure coconut oil coating retain maximum ascorbic acid (49.9 mg/100 mg juice) at 18 days of storage which was significantly ($p \leq 0.05$) higher then control and all other treatments (Table 2). The maximum content of ascorbic acid may be due to metabolic changes and increasing percentage of acidity under pure coconut oil and liquid paraffin coating. Pure coconut oil and castor oil helped in reducing the rate of respiration and ripening which results in dissipation of ascorbic acid to dehydro ascorbic acid during storage. These findings are in conformation with El-Monem et al. (2003) in custard apple. The minimum (39.4 mg/100 ml juice) ascorbic acid content of fruit was recorded under control followed by (39.5 mg/100 ml juice) mustard oil and (40.1 mg/100 ml juice) sesamum oil coating was possibly due to rapid conversion of ascorbic acid in to dehydro ascorbic acid in to presence of enzymes ascorbinase in over ripen fruit those were having injured skin. The results corroborates with the finding of Bisen and Pandey (2008) and Jadhao et al. (2008) in Kagzi lime fruits.

Juice content

The maximum (42.3%) juice content recorded under pure coconut oil followed by (40.9%) castor oil and (40.4%) liquid paraffin wax coating at 18 days of storage (Table 3). It may be due to less water loss from surface of fruit were coating with oil and wax. Similarly, Bullar (1988) in Kagzi lime reported that highest percentage of juice retained by wax emulsion coated fruits. Dashora and Shaffat (1988) also reported similar result in mosambi fruits. Whereas, the minimum (29.1%) juice content recorded under those fruits treated with pure sesamum oil coating. This may be due to continues transpiration from the surface of the fruit as a result of more dehydration (Thomas et al. 2005).

Appearance

When the storage period was advanced up to 18 days, the appearance of fruit was affected adversely under all the treatments. The maximum appearance acceptability of fruits

Table 3 Effect of different post harvest treatments on the chemical parameters and sensory scores of kagzi lime fruits

Treatments	Juice content,%			Appearance			Flavour		
	6D	12D	18D	6D	12D	18D	6D	12D	18D
T_1	35.2	34.8	29.8	8.5	6.9	5.0	6.7	5.5	4.0
T_2	42.5	38.1	36.3	8.6	6.4	5.3	6.6	6.1	4.7
T_3	48.2	35.9	37.4	8.7	6.5	5.3	7.0	6.3	3.9
T_4	45.5	45.3	39.6	8.6	6.3	4.9	7.0	5.9	4.1
T_5	45.1	42.3	37.2	8.4	6.2	4.0	6.5	5.6	3.1
T_6	48.4	46.0	40.4	8.9	7.8	6.5	6.8	6.9	4.5
T_7	45.0	34.8	31.4	8.7	6.8	4.2	6.5	6.3	3.5
T_8	49.4	46.7	42.3	9	8.2	7.1	8.3	7.5	5.2
T_9	48.2	46.1	40.9	8.8	7.5	6.3	6.6	5.5	3.0
T_{10}	42.9	33.3	29.1	8.4	6.0	3.8	6.5	5.2	3.2
SEm±	2.88	1.05	0.06	–	–	–	–	–	–
CD at 5%	8.50	3.10	0.19	–	–	–	–	–	–

T_1–T_{10}: as in Table 1. n=5 panelists, D: as in Table 1, Juice content at 0D: 50.3%, Appearance at 0D: 8.3, Flavour at 0D: 9.0

(8.3, 9.0, 8.2 and 7.1) was retained after 0, 6, 12 and 18 of storage period, respectively under pure coconut oil without any objectionable change in appearance followed by liquid paraffin wax. Dhemre and Waskar (2003) reported that waxed fruit had the best appearance and less in weight loss. The acceptability of coconut oil coated fruit was more because the coating maintain the cosmetic appearance of fruits and hence their acceptability. This may also due to delay in ripening, uniform colour development in fruits under pure coconut oil coating in later period of storage. Similar results were reported by Mahajan et al. (2005) in kinnow fruits. These results also corroborated the findings of Singh et al. (1997) and Jagadeesh et al. (2001) in guava fruits. Whereas, minimum (3.8) consumer acceptability of fruit in term of appearance was observed under sesamum oil coating followed by (4.0) $KMnO_4$ 2% after 18 days of storage (Table 3). This may be due to development of dark brown brownish spot on skin and softening of tissue by skin injury.

Flavour

The maximum (8.3) organoleptic value for flavour of fruits was recorded under pure coconut oil coating after 6 days of storage but, as the storage period advance up to 12 and 18 days, respectively the flavour of fruits gradually deteriorate in all the treatments. The best organoleptic score for flavour was recorded under pure coconut oil followed by liquid paraffin wax coating under every stage of storage. It may be due to delay in ripening of fruit, which retain the flavour for longer period of time and release pleasant flavour in fruits. Similarly Singh et al. (1997) also reported that those fruits treated with the advancement of storage period. Whereas, the least value of flavour (6.5, 5.2 and 3.2) at 6, 12 and 18 days of storage, respectively were recorded under sesamum oil followed by castor oil coating (Table 3). Almost all the citrus species contain oil glands in skin of fruit, which release the specific flavour of citrus in natural way. Similarly in kagzi lime, the oil glands are concentrated and more in numbers which liberate the oil and release the flavour in the atmosphere. Sesamum oil coating causes skin injury, hence it damage the oil gland result in least value of flavour. Sharma and Sandhooja (1991) revealed that til oil 2% + Captaf 0.2% shows slight changes in flavor, aroma and texture of kinnow fruits.

Taste

The organoleptic value of taste decreases with the advancement of storage period in all treatments. However, the highest (6.3) value of taste was recorded in coconut oil coating after 18 days of storage followed by (5.1) $CaCl_2$ 1% on the basis of observation (Table 4). Retention of better taste is due to more acidity content under this treatment. Whereas, minimum consumer acceptability for taste of fruit juice noted in castor oil coating (3.8). It may due to anaerobic condition created by wax coating by sealing the pores of fruits and enhance the degradation of acidity while advanced the storability. Mc Guire (1997) reported that waxing reduce oxygen and content and caused CO_2 level to increase significantly. Waxed fruit retain better physical appearance but showed sharpest fall in organoleptic taste, similar results observed by Pandey et al. (2010) when guava fruit treated with wax.

External colour

Fruit coated with pure coconut oil, liquid paraffin wax and castor oil are able to maintain natural light green colour up to 18 days of storage, which has consumer acceptability in marketable (Table 4). This is due to retardation of senescence process, slowed metabolic as well as enzymatic reaction activities and less degradation in the colour pigment (Chlorophyll) which slower the change with

Table 4 Effect of different post harvest treatments on the sensory scores and incidence of moulds of kagzi lime fruits

Treatments	Taste			External colour			Fruits affected by moulds,%		
	6D	12D	18D	6D	12D	18D	12D	18D	Moulds occurred on the surface of lime fruits
T_1	7.5	6.8	4.2	YG+LG	LY+LG	YG+LB	7.00	15.0	*Penicillium italicum,*
T_2	8.3	7.8	5.1	LY+LG	DY+LG	YB+DY	0.00	0.00	
T_3	7.5	6.6	4.8	LY+DG	DG+YG	YB+YG	0.00	3.00	
T_4	7.1	6.7	4.9	DG+YG	LG+LY	LB+YG	0.00	4.00	*Aspergillus spp.,*
T_5	7.5	6.7	4.1	DG+LY	LG+LY	LB+LY	0.00	2.00	
T_6	7.0	6.5	5.0	DG+LG	LG+YG	LY+LG	0.00	0.00	
T_7	7.2	6.9	4.8	YG+LY	LG+LB	DY+DB	0.00	32.0	*Alternaria citri*
T_8	8.8	8.4	6.3	LG+DG	LG+DG	LY+DG	0.00	0.00	
T_9	6.7	6.3	3.8	LG+DG	LY+DG	LG+LY	0.00	1.00	
T_{10}	7.8	7.1	4.0	LY+DG	LB+YG	DB+LY	4.00	39.0	

T_1–T_{10}: as in Table 1. n=5 panelists, D: as in Table 1, *YG* yellowish green, *LG* light green, *LY* light yellow, *LG* light green, *DG* dark green, *LB* light brown, *YB* yellowish brown, *DB* dark brown, *DY* dark yellow, Taste at 0D: 9.0, External colour at 0D: Light green, Fruits affected by moulds at 6D: 0%

mustard oil and sesamum oil showed dark brown external colour at 18 days of storage. It may be due to skin injury caused by higher concentration of pure oil coating which further caused tissue softening and deflection of colour pigments leading to change in external colour of fruits. Similar finding was also made by Dalal et al. (1987) in baramasi lemon reported that maximum physiological weight loss, low firmness and some differences in appearance, texture, flavour and colour of fruit was observed under mustard oil emulsion.

Incidence of moulds

All the treatments delayed the appearance of moulds and their growth which appeared after 18 days of storage (except in liquid paraffin wax and coconut oil) as compared to control in which the incidence took place after 12 days of storage. Dhaka et al. (2001) observed that 8% wax emulsion had the lowest spoilage incidence. Similarly Choudhary et al. (2003) reported that minimum spoilage was recorded in fruit treated with wax emulsion. The colonies of *Penicillium italicum, Aspergillus spp.* and *Alternaria citri* were seen on the surface of fruits. The maximum (39%) fruits were affected by mould under pure sesamum oil followed by mustard oil coating (Table 4). Whereas, no incidence was seen on fruits coated with coconut oil and liquid paraffin. This was due to the reason that coating (coconut oil and liquid paraffin) sealed the opening on the surface of the fruit there by preventing incidence of moulds. Dashora and Shaffat (1988) reported that wax coating inhibit fruit rot of mosambi during storage. Similar result was also obtained by Chandra (1995) in guava fruit. It may be due to skin injury caused by this oil because of its higher concentration. Skin injury results in degradation of cell wall as well as it increase the ethylene production and respiration rate .Which results in decaying and rotting of fruits and consequently occurrence of the pathogens. These are in conformity with results of Singh and Singh (2002) in kinnow fruits.

Conclusion

The physical and chemical parameters of fruits were significantly and positively influenced by coconut oil coating upto 18 days of storage at ambient condition (25–30 °C and 60–70% RH). Hence, coating of lime fruits with pure coconut oil is useful for extending their shelf life and effective in stabilizing the market demand. Whereas, sesamum oil and mustard oil coating exhibited lesser post harvest life due to appearance of brownish spots on the surface of fruit ultimately, which deteriorated the physico-chemical composition of the fruit. In case of occurrence of microbial population on surface of fruits, it was observed that pure coconut oil coating delay the appearance of moulds upto 18 days of storage, while untreated fruits were affected by moulds after 12 days of storage.

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