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Effect of hot water dipping on quality and shelf-life of mature green Kagzi lime fruits during ambient storage

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Abstract
In view of using safer alternatives to harmful chemicals, our investigation aimed to examine the effect of hot water dipping as a pre-treatment on the quality and shelf-life of lime fruits stored under ambient conditions. Mature green Kagzi lime fruits were subjected to hot water dipping (HWD) at 40 °C, 45 °C and 50 °C for 2, 4, 6 and 8 min. After treatment fruits were packed in mesh bags (30.48 cm × 20.32 cm) and kept under ambient conditions (30±2 °C and 60-70% RH) for quality and shelf-life determination. The observations for PLW and juice yield were recorded till 12th day whereas the observations for mold incidence and overall spoilage were recorded till 16th day. The results revealed that hot water dipping and storage period had significant effect on PLW, juice yield, mold incidence and overall spoilage. Among all the HWD treatments, hot water dipping of lime fruits at 50 °C for 2 min was found to be the best in terms of quality retention (minimum PLW, maximum juice yield and minimum spoilage) and maximum shelf-life (15 days).

Keywords: Kagzi lime; Hot water dipping; Non-chemical postharvest treatment; Ambient storage; Shelf-life; Quality attributes

Introduction

Kagzi lime (*Citrus aurantifolia* Swingle) belongs to the family Rutaceae and is one of the most important tropical and subtropical fruits. Post-harvest losses of Kagzi lime still remains a matter of concern. Significant post-harvest losses can occur due to pathological breakdown (fungal rot), respiration (loss of sugars, acids, etc.) or transpiration (water loss), physiological disorders such as fruit softening and rind breakdown, low humidity in storage area etc. During the transportation, fruits also suffer huge losses due to improper handling and packing. Also, storing the limes at lower temperatures for longer duration in cold-storage facilities, suffer post-harvest losses due to chilling injury. Mahajan and Singh (2008) [15] have reported that around 25-40 per cent harvested fruits are lost before consumption due to faulty post-harvest handling and microbial attack after harvest.

At present, in order to deal with the postharvest losses of citrus, various chemicals such as imazalil, thiabendazole, pyrimethanil and fludioxonil are used (Ismail and Zhang, 2004; Smilanick *et al.*, 2005, 2006) [11, 31, 30]. However, excessive use of these chemicals accompanied with high costs, residues in plants, phytotoxic effects and development of resistance, has indeed left an adverse effect on human health and the environment (Paster and Bullerman, 1988; Bull *et al.*, 1997) [20, 5]. Moreover, the consumer demands for pesticide-free food necessitates the development of safer methods for bringing down overall qualitative and quantitative losses of citrus fruits.

Post-harvest heat treatments in the form of hot water dips, hot dry air, or vapour heat has attracted recent research interest as a promising alternative to replace or to reduce the use of toxic chemicals during storage (Barkai-Golan and Phillips, 1991; Lurie, 1998a, b; Fallik, 2004) [1, 13, 14, 6]. For insect control, vapour heat treatment has been mainly applied, while for both fungal and insect control, hot dry air has been employed (Lurie, 1998a, b) [13, 14]. Hot water is preferred for most applications since water is a more efficient heat transfer medium than air. Previous studies on citrus fruit indicated positive effects of heat treatment on storage stability and inhibition or reduction in pathogen development (Hatton and Cubbedge, 1983; Rodov *et al.*, 1995; Schirra and D'Hallewin, 1997; Schirra *et al.*, 1997; Gonzalez-

Aguilar *et al.*, 1997; Rodov *et al.*, 2000) [9, 25, 27, 28, 8, 24]. More recent reviews and experimental studies continue to confirm heat treatments — including hot-water dips and short hot-water brushing — as effective, residue-free options for maintaining quality and extending shelf life of citrus and other horticultural crops (Papoutsis *et al.*, 2019)[19], and recent region-specific and methodological studies have further explored feasibility, physiological responses and practical implementation of hot-water treatments (Strano *et al.*, 2022; Bhatta *et al.*, 2022) [32, 2].

Although heat-based postharvest techniques such as hot-water dips and brushing are well established as non-chemical alternatives for improving postharvest performance of citrus fruits, including maintenance of quality attributes and reduction of storage losses in lemons, oranges, and mandarins (Nafussi, 2001; Palou, 2013; Papoutsis *et al.*, 2019) [17, 18, 19]. the literature specifically evaluating hot-water dip treatments for Kagzi (acid) lime (*Citrus aurantifolia*) remains limited. Moreover, most studies involving hot-water treatments in citrus evaluate fruit quality and storage behavior under refrigerated or controlled-atmosphere conditions, while investigations conducted under ambient storage conditions are relatively scarce, despite their practical relevance in tropical and subtropical regions (Palou, 2013; Papoutsis *et al.*, 2019) [18, 19]. Existing postharvest studies on Kagzi lime predominantly emphasize coatings, oil emulsions, growth regulators, irradiation, or packaging interventions to enhance storage life (Verma & Dashora, 2000; Bisen, 2008) [34, 3], but do not report a systematic evaluation of hot-water dip time-temperature combinations with respect to quality retention and shelf-life under ambient storage. Therefore, focused research on hot-water dipping of Kagzi lime followed by ambient storage is necessary to develop chemical-free postharvest handling strategies applicable to low-infrastructure marketing systems.

In view of the above considerations, the present investigation was undertaken to evaluate the effect of hot water dipping as a pre-treatment on the quality and shelf-life of Kagzi lime fruits stored under ambient conditions.

Materials and methods

Mature green Kagzi lime (*Citrus aurantifolia* Swingle) fruits were procured from the farm of Department of Horticulture, Anand Agricultural University, Anand. Soon after harvest, the fruits were brought to the laboratory, pre-cooled under fan for half an hour and only good fruits were chosen for study. The selected fruits were then washed with running water, disinfected using 50 ppm chlorinated water, rinsed with potable water and dried to remove the surface moisture by placing under fan. Such fruits were used for imposing the treatments.

The lime fruits were subjected to hot water treatment in an autoclave (Mfr.: Nova Instruments Pvt. Ltd., Ahmedabad, Gujarat) while keeping the lid open. Once the desirable temperature was achieved, fruits were dipped in hot water. On dipping, there was little dip in temperature. The process time was recorded only after desirable temperature was achieved. Lime fruits were subjected to hot water dipping (HWD) at 40 °C, 45 °C and 50 °C for 2, 4, 6 and 8 min. On completion of treatment, the fruits were removed from the autoclave tank and allowed to dry under fan for few minutes. Fruits weighing about 500 g per treatment per replication were taken for determination of the physiological loss in weight (PLW) and juice yield and a separate lot of fruits weighing about 500 g per treatment per replication were taken for determination of spoilage (mold incidence and overall spoilage). The fruits were then packed in mesh bags (30.48 cm × 20.32 cm) and kept under ambient conditions (30±2 °C and 60-70% RH) for quality and shelf-life determination (based on overall spoilage). The observations were recorded at 4 days of interval till 12th day for PLW and juice yield (not continued further due to higher spoilage) whereas the observations were recorded till 16th day for mold incidence and overall spoilage.

PLW

For determining PLW, the fruits were weighed initially and after each storage interval and the loss in weight was calculated by following expression:

$$\text{PLW (\%)} = (\text{Initial weight} - \text{Final weight}) \div \text{Initial weight} \times 100 \quad (1)$$

Juice yield

The lime fruits were cut into two pieces and the juice was extracted by hand juice squeezer and strained through stainless steel sieve. The amount of juice was measured and percentage of juice yield was calculated on the basis of weight. Following expression was used for calculating juice yield:

$$\text{Juice yield (\%)} = \frac{\text{Juice weight}}{\text{Fruit weight}} \times 100 \quad (2)$$

Mold incidence

Mold incidence was recorded by visually observing the number of fruits affected by molds and expressed in percentage (Bisen *et al.*, 2012; García *et al.*, 2016) [4, 7]. Following expression was used to determine mold incidence:

$$\text{Mold incidence (\%)} = \frac{\text{Number of fruits affected by mold}}{\text{Total number of fruits}} \times 100 \quad (3)$$

Overall spoilage

Overall spoilage of fruits were judged on the basis of visual observation and expressed as percentage over total number of fruits (Reddy *et al.*, 2008) [22]. Overall spoilage of fruits was calculated by following expression:

$$\text{Overall spoilage (\%)} = \frac{\text{Number of fruits spoiled}}{\text{Total number of fruits}} \times 100 \quad (4)$$

Shelf-life

The shelf life of fruits was determined by recording the number of days the fruits remained in good condition during storage. The stage wherein more than 50 percent of the stored fruits became unfit for consumption was considered as end of shelf life (Sudheer, 2014) [33].

Statistical analysis

Data obtained from three replications were analyzed using a factorial CRD at a 5% level of significance with in-house tested statistical software at the Department of Agricultural Statistics, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India.

Results and Discussion

PLW

The data on the effect of hot water dipping on PLW of lime fruits during ambient storage are presented in Table 1. The results revealed that PLW was significantly affected by the treatments. The data also reflected significant differences due to storage period and interaction between HWD treatments and storage period. As the storage period was prolonged from day 4 to day 12, PLW increased for all the treatments. Weight loss mainly occurs due to water loss by transpiration and loss of carbon reserves due to respiration (Zagory and Kader, 1988) [36]. It was observed that among all the HWD treatments, the lowest mean values of PLW were recorded for HWD at 50 °C for 2 min on all observation days. On the other hand, the data showed highest mean values of PLW on all observation days for control.

In general, the hot water dipping caused reduction in the loss of weight of lime fruits. This may be attributed to the melting of fruit epicuticular waxes which then covers and seals the stomata and cracks on the fruit surface. This sealing of natural openings and cracks reduces the weight loss. Moreover, the hot water treatments also affect ethylene evolution (Schirrra and D'Hallewin, 1997; Porat *et al.*, 2000, Ilic *et al.*, 2001 and Fallik, 2004) [27, 21, 10, 6]. Decreased weight loss due to hot water dipping for Valencia oranges and grapefruit (Mohamed *et al.*, 2002) [16] and Kumquat & 'Marsh' grapefruit (Rodov *et al.*, 1995) [25] have been reported. Similar reductions in physiological loss in weight following hot water or heat-based treatments have also been documented in recent studies and reviews on citrus and other horticultural commodities, where heat treatment was shown to reduce transpiration losses and delay senescence during storage (Papoutsis *et al.*, 2019; Strano *et al.*, 2022) [19, 32].

The effect of hot water temperature on PLW of lime fruits on 12th day of ambient storage is shown in Fig 1a. It was observed that as the hot water temperature was increased from 40 to 45 °C, there was a notable reduction in PLW of lime fruits for HWD times of 2, 4, 6 and 8 min. On further increasing the hot water temperature from 45 to 50 °C, the highest reduction in PLW from 18.83% to 12.42% was observed for 2 min of HWD time. The decrease in PLW with an increase in temperature might be due to reduced moisture losses due to sealing of natural opening and cracks as discussed earlier. The effect of HWD time on PLW of lime fruits on 12th day of ambient storage is shown in Fig 1b. It was observed that as the HWD time was increased from 2 to 8 min, there was a gradual decrease in PLW of lime fruits treated at 40 and 45 °C. This may be attributed to the sealing of natural openings and cracks which might have caused reduced transpiration losses. However, when the fruits were treated at 50 °C, a notable rise was observed in PLW from 12.42 to 16.48% as the HWD time was increased from 2 to 4 min. On further increasing the HWD time, PLW increased gradually till 6 min followed by a slight reduction till 8 min. This may be attributed to the damage to the skin at higher temperature and higher heating time which might have caused increased moisture losses. Valencia oranges hot water dipped at 45 °C for 42 min became firmer, whereas the fruit at 53 °C for 12 min showed increased weight loss and decreased firmness (Williams *et al.*, 1994)[35].

Table 1: Effect of hot water dipping on PLW of lime fruits during ambient storage

HWD treatments	PLW (%) during ambient storage on		
	Day 4	Day 8	Day 12
Control	10.62	21.51	27.94
40 °C for 2 min	8.49	17.58	21.40
40 °C for 4 min	8.12	17.16	20.64
40 °C for 6 min	7.66	16.73	20.36
40 °C for 8 min	7.32	16.43	19.87
45 °C for 2 min	6.89	15.55	18.83
45 °C for 4 min	6.60	15.23	18.23
45 °C for 6 min	6.36	14.82	17.87
45 °C for 8 min	6.18	14.35	17.33
50 °C for 2 min	4.48	10.25	12.42
50 °C for 4 min	4.92	12.73	16.48
50 °C for 6 min	5.26	13.07	16.98
50 °C for 8 min	5.77	13.51	16.61
Mean	6.82	15.30	18.84
	SEm±		CD (at 5%)
Treatments (T)	0.195		0.549
Storage period (S)	0.094		0.264
Interaction (T × S)	0.338		0.950

Juice yield

The data on the effect of hot water dipping on juice yield from stored lime fruits are presented in Table 2. The results revealed that juice yield was significantly affected by the treatments. The data also reflected significant differences due to storage period. However, the effect of interaction between HWD treatments and storage period was non-significant.

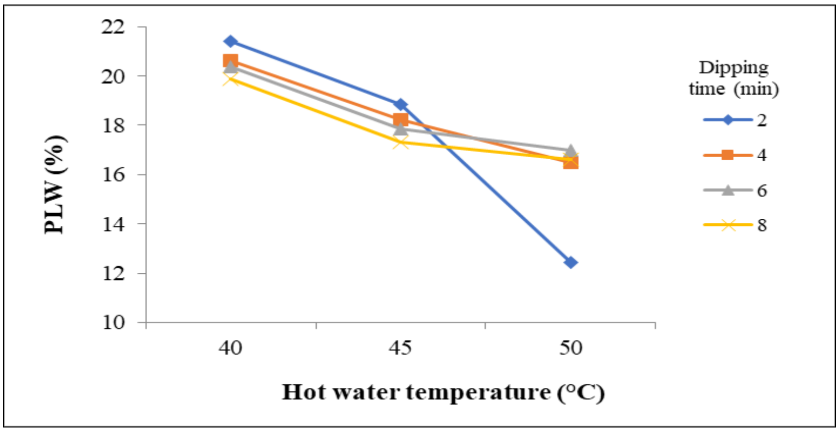

Fig 1a: Effect of hot water temperature on PLW of lime fruits on 12th day of ambient storage

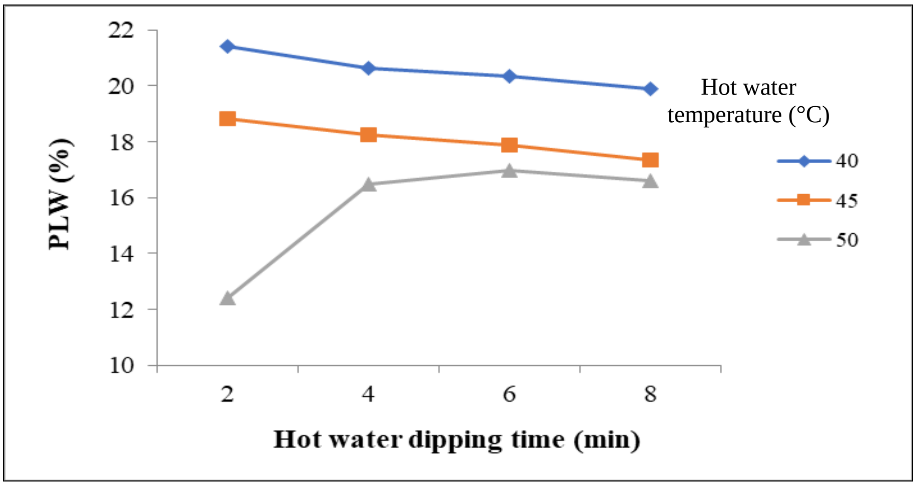

Fig 1b: Effect of hot water dipping time on PLW (%) of lime fruits on 12th day of ambient storage

As the storage period was prolonged from day 4 to day 12, there was a decrease in juice yield for all the treatments. It was observed that among all the HWD treatments, the highest mean values of juice yield were recorded for HWD at 50 °C for 2 min on all observation days of storage. On the other hand, the data showed the lowest mean values of juice yield on all observation days for control. Minimum weight loss from hot water dipped lime fruits at 50 °C for 2 min might be the possible reason for higher juice yield from lime fruits.

The effect of hot water temperature on juice yield of lime fruits on 12th day of ambient storage is shown in Fig 2a. As the hot water temperature was increased from 40 to 45 °C, juice yield increased for HWD time 2, 4, 6 and 8 min. On further increasing the hot water temperature from 45 to 50 °C, the juice yield from lime fruits increased from 38.41 to 48.33 for HWD time 2 min and this increase was the maximum as compared to 4, 6 and 8 min. This may be attributed to the loosening of the juice sacs with an increase in temperature.

The effect of HWD time on juice yield from lime fruits on 12th day of ambient storage is shown in Fig 2b. It was observed that as the HWD time was increased from 2 to 8 min, there was a gradual increase in juice yield for lime fruits treated at 40 and 45 °C. However, when the fruits were treated at 50 °C, a decreasing trend was observed in juice yield from 48.33 to 44.13% as the HWD time increased from 2 min to 4 min. On further increasing the HWD time till 8 min, a gradual decrease in juice yield was noticed. The decrease in juice content due to treatment and storage might be attributed to the higher weight loss as PLW and juice yield are closely related parameters.

Table 2: Effect of hot water dipping on juice yield from stored lime fruits

HWD treatments	Juice yield (%) during ambient storage on		
	Day 4	**Day 8**	**Day 12**
Control	41.79	34.26	28.40
40 °C for 2 min	46.18	38.19	33.75
40 °C for 4 min	46.24	40.06	35.97
40 °C for 6 min	46.39	41.15	36.78
40 °C for 8 min	46.73	41.92	37.82
45 °C for 2 min	47.68	43.38	38.41
45 °C for 4 min	48.22	44.19	39.01
45 °C for 6 min	49.02	44.35	40.20
45 °C for 8 min	49.81	44.84	41.88
50 °C for 2 min	54.37	51.54	48.33
50 °C for 4 min	52.09	47.68	44.13
50 °C for 6 min	51.11	46.57	43.54
50 °C for 8 min	50.06	45.88	42.50
Mean	48.44	43.38	39.29
	SEm±	CD (at 5%)	
Treatments (T)	0.938	2.640	
Storage period (S)	0.451	1.268	
Interaction (T × S)	1.625	NS	

NS: Non-significant

Mold incidence

The data on the effect of hot water dipping on mold incidence of lime fruits during ambient storage are presented in Table 3. The results revealed that mold incidence was significantly affected by the treatments. The data also reflected significant differences due to storage period. However, the effect of interaction between HWD treatments and storage period was non-significant. As the storage period was prolonged from day 4 to day 16, there was an increase in mold incidence for all the treatments. One of the major limiting factors for ambient storage of lime fruits is black mold and in our ambient storage study, the fruits were also affected by the same. Aspergillus rot covers the fruit with black mold and also affects the adjacent fruits, thereby contaminating the whole lot. The favourable temperature range is 25-40ºC and can cause rapid decay at 30-35ºC (Ladaniya, 2008) [12]. It was observed that among all the HWD treatments, the lowest mean values of mold incidence were recorded for HWD at 50 °C for 2 min on all observation days during storage. Controlling postharvest decay in various citrus fruits by hot water dips (2-3 min at 50-53 °C) were shown to be as effective and also much less expensive due to shorter treatment duration (Rodov *et al.*, 1993, 1995) [26, 25]. On the other hand, the data showed highest mean values of mold incidence on all observation days for control.

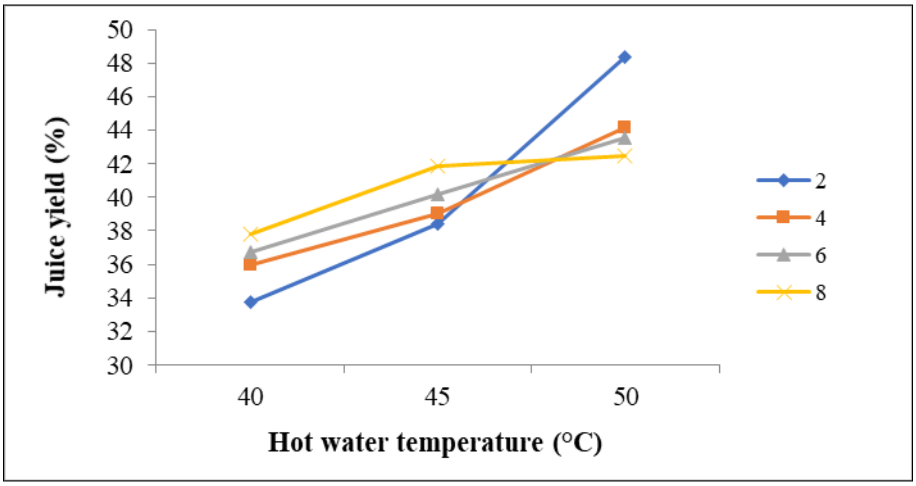

Fig 2a: Effect of hot water temperature on juice yield of lime fruits on 12th day of ambient storage

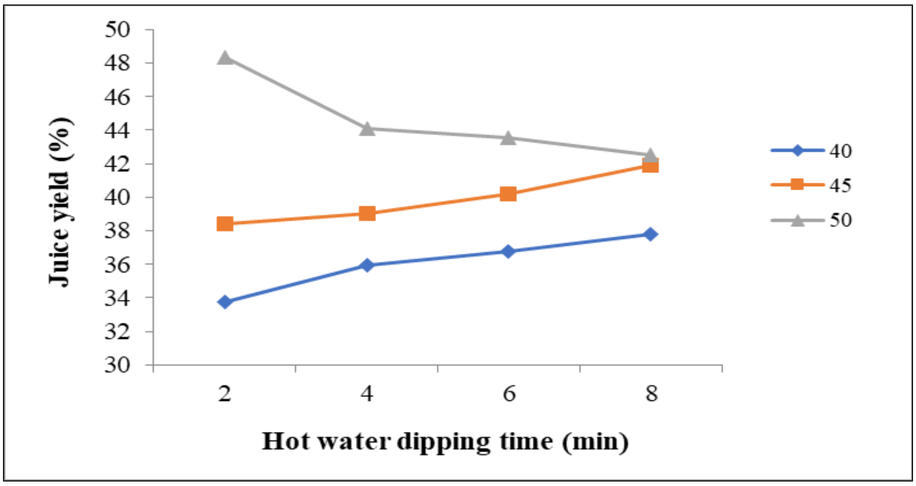

Fig 2b: Effect of hot water dipping time on juice yield of lime fruits on 12th day of ambient storage

The effect of hot water temperature on mold incidence of lime fruits on 12th day of ambient storage is shown in Fig 3a. As the hot water temperature was increased from 40 to 45 °C, a decreasing trend was observed in mold incidence for HWD times of 2, 4, 6 and 8 min. This decreasing trend continued from 45 °C to 50 °C for all HWD times, however, maximum drop (32.14 to 24.44%) was noticed for HWD time of 2 min. This can be attributed to the physical barrier created by lignin like compounds (Schirra *et al.*, 2000) [29] which might have caused more effective restriction to fungal attack at higher temperature.

The effect of HWD time on mold incidence of lime fruits on 12th day of ambient storage is shown in Fig 3b. It was observed that as the HWD time was increased from 2 to 4 min, mold incidence of lime fruits treated at 40 and 45 °C decreased. However, when the fruits were treated at 50 °C, an upward trend was observed in mold incidence from 24.44 to 28.03%. On further increasing the HWD time from 4 min to 8 min, a gradual decrease in mold incidence was noticed for 40 °C. However, in case of fruits treated at 45 °C and 50 °C, increasing trend in mold incidence was observed. Moreover, from 4 to 8 min of HWD time, the lime fruits treated at 50 °C, showed the maximum increase in mold incidence (28.03 to 32.54%). The occurrence of mold at 50 °C at higher heating times might be attributed to the peel damage. Ritenour *et al.* (2003) [23] reported that the grapefruit dipped in 62 °C water for 30 s developed only 5% stem-end rot after 82 d in storage, whereas increasing the treatment duration to 120 s caused significant peel scalding (100%) and increased stem-end rot incidence (23%).

Table 3: Effect of hot water dipping on mold incidence of lime fruits during ambient storage

HWD treatments	Mold incidence (%) during ambient storage on			
	Day 4	Day 8	Day 12	Day 16
Control	29.70	40.60	54.27	64.96
40 °C for 2 min	22.53	30.04	42.49	54.95
40 °C for 4 min	17.86	25.00	36.90	47.62
40 °C for 6 min	16.72	24.07	35.84	45.23
40 °C for 8 min	15.02	24.91	35.16	45.05
45 °C for 2 min	11.79	20.68	32.14	39.49
45 °C for 4 min	11.77	19.28	31.23	38.22
45 °C for 6 min	10.90	19.02	32.69	37.82
45 °C for 8 min	10.10	18.22	33.27	38.61
50 °C for 2 min	4.44	11.11	24.44	28.89
50 °C for 4 min	7.01	14.02	28.03	32.48
50 °C for 6 min	11.27	18.10	31.90	38.57
50 °C for 8 min	11.59	18.73	32.54	39.68
Mean	13.90	21.83	34.69	42.43
	SEm±		CD (at 5%)	
Treatments (T)	1.324		3.713	
Storage period (S)	0.734		2.059	
Interaction (T × S)	2.648		NS	

NS: Non-significant

Overall spoilage

The data on the effect of hot water dipping on overall spoilage of lime fruits during ambient storage are presented in Table 4. The results revealed that overall spoilage was significantly affected by the treatments. The data also reflected significant differences due to storage period. However, the effect of interaction between treatments and storage period was non-significant.

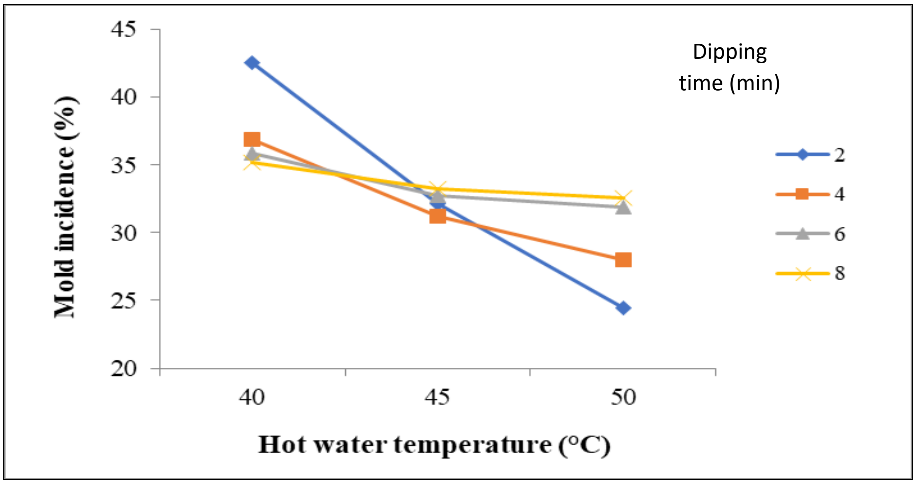

Fig 3a: Effect of hot water temperature on mold incidence of lime fruits on 12th day of storage

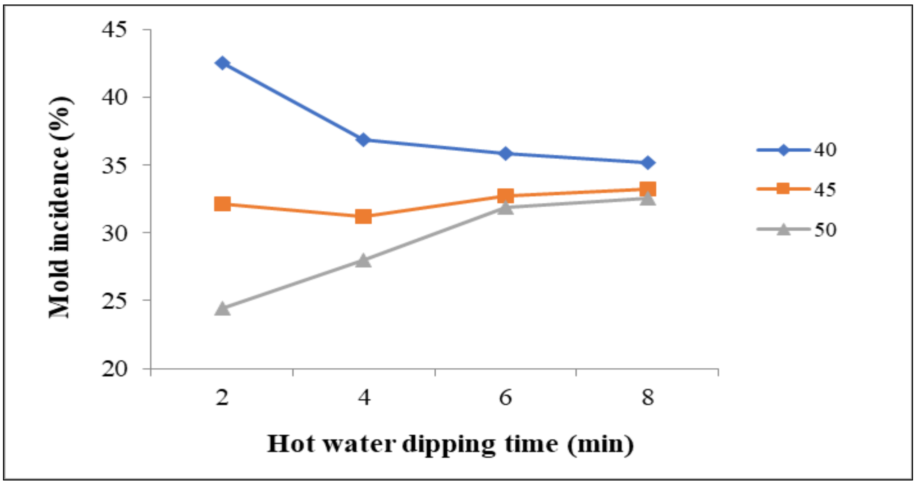

Fig 3b: Effect of hot water dipping time on mold incidence of lime fruits on 12th day of storage

The overall spoilage of lime fruits stored under ambient conditions included spoilage due to mold and also due to shrivelling which affects the appearance of lime fruits and in turn affects the marketability to greater extent. As the storage period was prolonged from day 4 to day 16, there was an increase in overall spoilage for all the hot water dipping treatments. This may be attributed to the loss of moisture and mold attack which is responsible for causing an increase in spoilage over a period of time. It was observed that among all the HWD treatments, the lowest mean values of overall spoilage were recorded for HWD at 50 °C for 2 min on all observation days. On the other hand, the data showed highest mean values of overall spoilage on all observation days for control.

The effect of hot water temperature on overall spoilage of lime fruits on 12th day of ambient storage is shown in Fig 4a. As the hot water temperature was increased from 40 to 45 °C, a downward trend was observed in overall spoilage for HWD times of 2, 4, 6 and 8 min. From 45 to 50 °C, the reduction in overall spoilage continued for all HWD times except for 8 min which showed a slight increase in mean value. Moreover, it was noticed that the decrease in overall spoilage was the maximum (44.27 to 35.56%) for HWD time of 2 min. The reduction in spoilage with an increase in HWD temperature may be attributed to the physical barrier created by lignin like compounds (Schirra *et al.*, 2000)[29] which might have caused more effective restriction to fungal attack and also might have reduced moisture losses.

The effect of HWD time on overall spoilage of lime fruits on 12th day of ambient storage is shown in Fig 4b. It was observed that as the HWD time was increased from 2 to 4 min, overall spoilage of lime fruits treated at 40 °C decreased. However, when the fruits were treated at 45 and 50 °C, an upward trend was observed in overall spoilage. On further increasing the HWD time from 4 to 8 min, a gradual decrease in overall spoilage was noticed for 40 °C. However, an upward trend in overall spoilage continued for fruits treated at 45 and 50 °C. Moreover, from 4 to 8 min of HWD time, the lime fruits treated at 50 °C, showed maximum increase in overall spoilage (41.71 to 46.51%). This may be attributed to the peel damage which might have caused higher weight loss and mold growth.

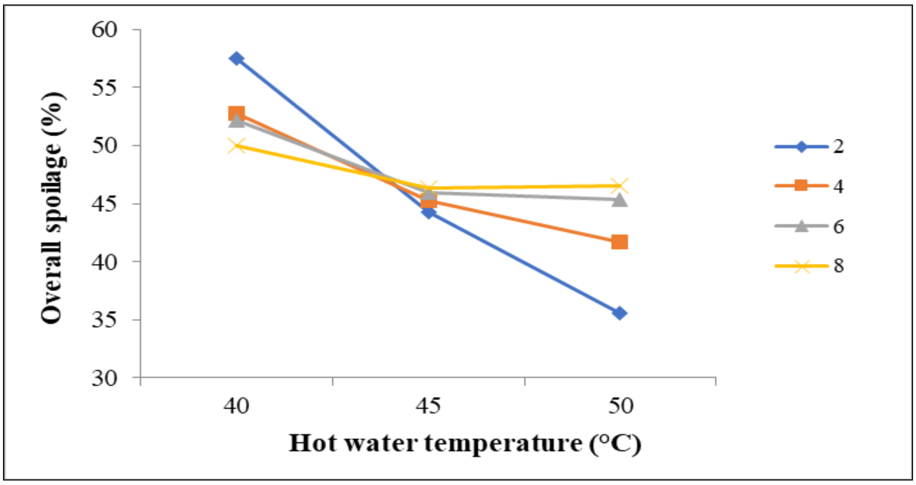

Fig 4a: Effect of hot water temperature on overall spoilage of lime fruits on 12th day of ambient storage

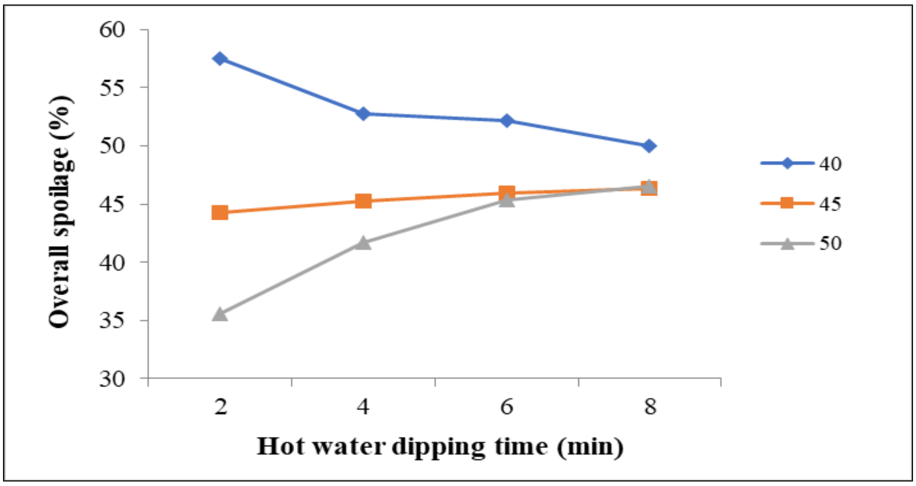

Fig 4b: Effect of hot water dipping time on overall spoilage of lime fruits on 12th day of ambient storage

Table 4: Effect of hot water dipping on overall spoilage of lime fruits during ambient storage

HWD Treatments	Overall spoilage (%) during ambient storage on			
	Day 4	Day 8	Day 12	Day 16
Control	35.04	43.38	67.52	94.66
40 °C for 2 min	27.47	32.60	57.51	87.55
40 °C for 4 min	22.62	27.78	52.78	77.38
40 °C for 6 min	21.50	28.67	52.21	78.50

40 °C for 8 min	22.53	27.47	50.00	77.47
45 °C for 2 min	18.46	23.25	44.27	71.97
45 °C for 4 min	16.90	21.50	45.23	71.33
45 °C for 6 min	16.24	21.79	45.94	73.08
45 °C for 8 min	15.45	20.79	46.34	74.45
50 °C for 2 min	8.89	15.56	35.56	62.22
50 °C for 4 min	11.79	18.46	41.71	67.52
50 °C for 6 min	16.03	20.48	45.40	72.70
50 °C for 8 min	16.35	20.95	46.51	74.44
Mean	19.17	24.82	48.54	75.64
	SEm±		CD (at 5%)	
Treatments (T)	1.027		2.880	
Storage period (S)	0.570		1.598	
Interaction (T × S)	2.054		NS	

NS: Non-significant

Shelf-life

The untreated and hot water dipped lime fruits were stored in mesh bags and shelf-life was determined for ambient conditions of storage (30±2 °C and 60-70% RH). The shelf-life recorded for untreated and hot water dipped lime fruits is depicted in Fig 5. Among all the HWD treatments, the highest shelf-life of lime fruits was recorded for HWD at 50 °C for 2 min (15 days). On the other hand, the lowest shelf-life of lime fruits was recorded for control i.e., 9 days.

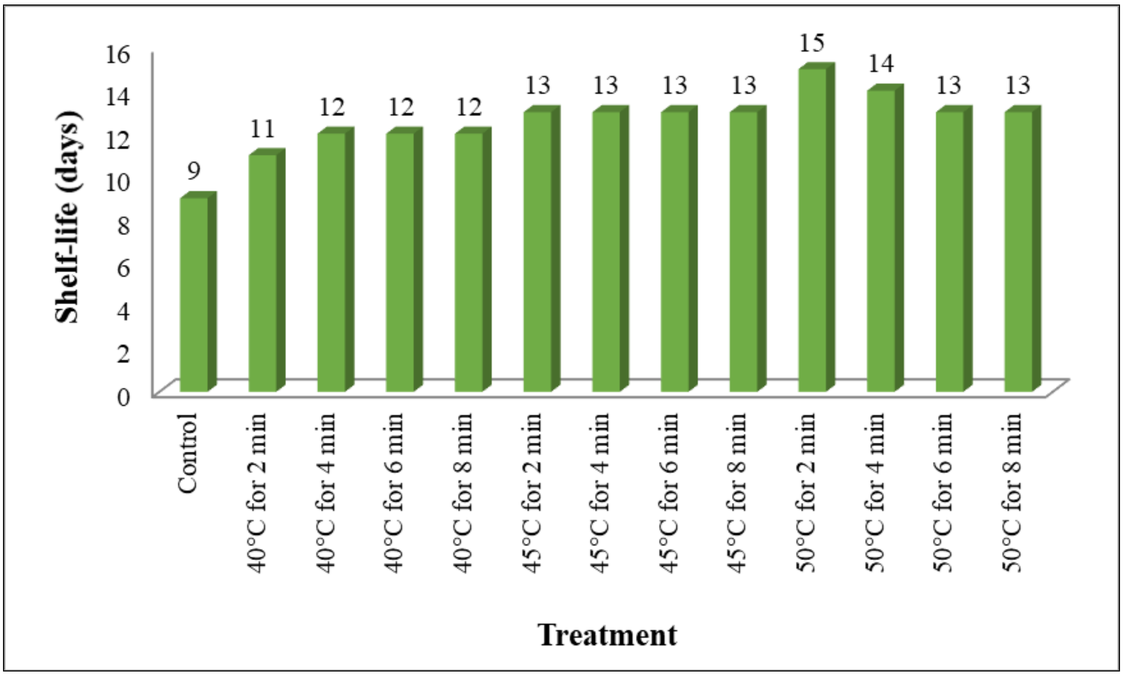

Fig 5: Effect of hot water dipping on shelf-life of lime fruits during ambient storage

Conclusion

The fruits subjected to hot water dipping (HWD) recorded lower values of physiological loss in weight (PLW), higher values of juice yield, lower values of spoilage and better shelf-life as compared to the untreated fruits. Among all the HWD treatments, hot water dipping of lime fruits at 50 °C for 2 min was found to be the best in terms of quality retention (minimum PLW, maximum juice yield and minimum spoilage) and maximum shelf-life (15 days). Therefore, we conclude that without using any harmful chemical, hot water dipped (50 °C for 2 min) lime fruits can be stored safely in mesh bags (30.48 cm × 20.32 cm) under ambient conditions (30±2 °C and 60-70% RH) for 15 days.

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