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Comparative Evaluation of Tomato Washing Using Treated and Untreated Water: Effects on Cleaning Efficiency, Microbial Reduction, and Quality Attributes

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Abstract

Efficient washing of fresh tomatoes is essential to reduce surface contaminants and microbial load while maintaining product quality. The present study compared the effectiveness of hand washing using untreated potable water and treated water containing 100 ppm sodium hypochlorite on the washing performance and quality attributes of tomatoes. Washing trials were conducted at retention times of 1, 2, and 3 minutes under ambient conditions. Mechanical washing efficiency, microbial washing efficiency, bruise index, and colour attributes (L*, a*, and b*) were evaluated.

The results showed that washing efficiency and microbial reduction increased significantly ($p \leq 0.05$) with an increase in retention time for both treatments. However, tomatoes washed with treated water exhibited significantly higher mechanical and microbial washing efficiencies compared to those washed with untreated water. The highest performance was achieved at a 3-minute retention time using 100 ppm chlorine-treated water, resulting in 87% mechanical washing efficiency and 88% microbial washing efficiency. The bruise index remained low (0.6) and was not significantly affected ($p > 0.05$) by the washing treatments, indicating minimal physical damage. Colour index values demonstrated improved colour retention in tomatoes washed with treated water.

Overall, the study concludes that hand washing with 100 ppm chlorine-treated water for a retention time of 3 minutes is an effective, safe, and economical method for improving the cleanliness and microbial safety of tomatoes without compromising quality. The findings provide practical insights for small-scale handling and post-harvest sanitation of fresh produce.

Keywords: Washing efficiency, Microbial washing efficiency, sodium hypochlorite, bruise index

1.0 Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most widely consumed horticultural crops worldwide due to its high nutritional value, versatility in culinary use, and economic importance. However, tomatoes are highly perishable and are often contaminated with soil, organic matter, and microorganisms during harvesting, handling, transportation, and marketing. Inadequate washing practices can lead to the persistence of pathogenic and spoilage microorganisms on the fruit surface, posing potential risks to consumer health and reducing market quality (Beuchat, 1998; Parish et al., 2003).

Washing is a critical post-harvest operation aimed at removing adhering dirt, pesticide residues, and microbial contaminants from fresh produce. Traditional washing with untreated potable water is commonly practiced at the farm and small-scale handling levels; however, it has been reported to be less effective in reducing microbial load and may even contribute to cross-contamination if wash water quality is not maintained (Gil et al., 2009). Consequently, the use of chemical sanitizers in wash water has been widely recommended to enhance microbial safety.

Among various sanitizing agents, chlorine-based compounds, particularly sodium hypochlorite, are extensively used in fresh produce washing due to their low cost, ease of application, and broad-spectrum antimicrobial activity. Previous studies have demonstrated that chlorine concentrations in the range of 50–200 ppm are effective in reducing microbial populations on fruits and vegetables without adversely affecting product quality when applied under controlled conditions (Sapers, 2001; Allende & Artés, 2003). Nevertheless, excessive concentration or prolonged exposure may lead to quality deterioration, emphasizing the need to optimize treatment conditions.

Retention time during washing is another important factor influencing washing efficiency and product quality. Increased contact time can improve soil removal and microbial inactivation; however, it may also increase the risk of mechanical damage such as bruising, particularly in soft fruits like tomatoes (Mohsenin, 1986). Therefore, a balance must be achieved between washing efficiency and quality preservation. Despite extensive studies on chemical sanitization, limited information is available on the comparative performance of treated and untreated water under simple hand-washing conditions commonly adopted by small-scale handlers and local markets. Therefore, the present study was undertaken to compare the effectiveness of hand washing of tomatoes using untreated potable water and treated water containing 100 ppm sodium hypochlorite at different retention times. The study specifically evaluated mechanical washing efficiency, microbial washing efficiency, bruise index, and colour attributes in order to identify an optimum washing condition that ensures both microbial safety and quality retention.

2.0 **Materials and Methods**

2.1 Field Survey

A field survey was carried out to understand the existing handling and washing practices adopted by local vegetable growers, traders, and small-scale processors shown in fig 2.1. The survey revealed that most farmers rely on manual washing methods, which involve rinsing vegetables in open containers or under running tap water. These practices were often labour-intensive, time-consuming, and inconsistent in terms of hygiene and microbial safety. Respondents reported challenges such as high labour cost, water wastage, and inadequate removal of soil, pesticide residues, and microbial contaminants.

Fig 2.1 The actual washing practices of vegetables on the field.

3.2 Raw Materials

The selected farm vegetables like tomatoes were procured directly from field (local language called as *wadi*) located at Amravati and were used for washing purpose.

3.3 Evaluated parameters

3.3.1 Mechanical washing efficiency

A known mass of the washed vegetable sample was rinsed thoroughly with 500 mL of distilled water, and the wash water was collected in a glass beaker. The collected water was then evaporated using a water bath, after which the beaker was dried in a hot air oven at 130 °C for 1 hour. The final mass of the beaker was recorded to determine the amount of soil and suspended matter removed during washing. The same procedure was followed for 100 g of unwashed vegetables in order to quantify the initial soil content prior to washing.

Mechanical washing efficiency can be calculated as

$$\eta = \frac{Wuw - Ww}{Wuw} \text{x } 100 \quad \text{... (i)}$$

Where,

Wuw – Weight of soil present in 100 g of unwashed vegetable, g, and

Ww – Weight of soil present in 100 g of washed vegetable, g

η - Mechanical washing efficiency, %

3.3.2 Microbial washing efficiency

Microbial washing efficiency refers to the effectiveness of washing process in terms removing or inactivating microorganisms. The microbial washing efficiency was then calculated using the formula given by Sehgal *et al*., (2007).

$$\eta MLW = \frac{IML\text{-}FML}{IML} \text{x } 100 \quad \text{… (ii)}$$

Where,

I_{ML} – Initial microbial load, cfu/g^{-1}, and

F_{ML} – Final microbial load, cfu/g^{-1}

η_{MLW}– Microbial washing efficiency, %

3.3.3 Bruise index

Bruise index is a visual damage grading technique. According to Moden *et al*., (1989), “about 10% of the washed samples were examined for surface damage, which was classified by severity (scrape, cut, breakage) and quantified using a predetermined scaling factor”.

Bruise index = $0.5 (S_1)+1 (S_2)+1.5 (S_3)+3(S_4)+8(S_5)+2(S_6)$ … (iii)

Where,

S_1 = Scraping or surface abrasion (no depth)

S_2 = Scraping depth between 0 to 5 mm

S_3 = Scraping depth between 5.1 to 10 mm

S_4 = Scraping depth between 10.1 to 20 mm

S_5 = Scraping depth > 20 mm and

S_6 = Broken tip 25 mm in diameter or larger

Bruise index is important factors in quality control, loss reduction and product grading in food industry.

3.3.4 Determination of colour

The colour of tomato samples was recorded before and after washing using a chroma meter fitted with an 8 mm measuring head, which was calibrated against a standard white plate prior to each use. Colour values were measured on the Hunter L*, a*, b* scale, where L* indicates lightness (0 = black, 100 = white), a* ranges from green (−) to red (+), and b* from blue (−) to yellow (+). The obtained L*, a*, and b* values were further converted into hue angle (h°) and chroma (C*) to describe colour type and intensity. Measurements were taken at three different points on each sample, and the mean values were used for analysis.

4.0 Results and discussion

4.1 Performance of Traditional Method of Washing of Tomato

Tomato was directly bought from field like spinach and carrot. Tomato was round shape and had tight but soft skin.

4.1.1 Performance of traditional method (hand washing) with untreated water

Prior to washing, hands and mesh equipment were sanitized to minimize the risk of cross-contamination. Tomatoes were placed in a colander and washed under running potable water at ambient temperature, with gentle manual rubbing to remove adhering soil and surface contaminants. After washing, the samples were air-dried at room temperature to remove excess moisture and then packed in 40 µm zip-lock polyethylene bags. All treatments were performed in triplicate, and the mean values of the observations are presented in Table 4.1

Fig 4.1 Washing of tomato by hand

Table 4.1 presented the effect of hand washing on tomatoes in terms of mechanical and microbial washing efficiency, bruise index, and colour index. The mechanical washing efficiency was recorded as 78%, 82.5%, and 86% at washing durations of 1, 2, and 3 minutes, respectively, while the corresponding microbial washing efficiencies were 74%, 79%, and 83%. The minimum bruise index (0.5) was observed at a washing duration of 1 minute. A slight increase in bruise index was noted with increasing washing time, with values of 0.5, 0.5, and 0.6 at 1, 2, and 3 minutes, respectively. The highest mechanical (86%) and microbial (83%) washing efficiencies were achieved at a retention time of 3 minutes, with a bruise index of 0.6.

An increasing trend in colour index values (L*, a*, and b*) was observed with an increase in washing duration. However, when the washing time was extended beyond 3 minutes (from 4 to 6 minutes), no significant changes in colour index values were recorded.

Table 4.1 Washing of tomato by hand

SN	Time (min)	Hand Washing Efficiency	Microbial Washing Efficiency	Bruise Index	Colour Index		
					L*	a*	b*
1	1 min	78%	74%	0.5	37	-19	7
2	2 min	82.5%	79%	0.5	37	-18	7
3	> 3 min	86%	83%	0.6	38	-18	9

4.2 Performance of traditional method (hand washing) with treated water

A dilute sodium hypochlorite solution was prepared by adding commercial bleach to water. Specifically, 1.66 mL of liquid NaOCl was diluted with water to obtain an active chlorine concentration of approximately 100 ppm. Tomatoes were submerged in the prepared solution and allowed to stand for 1 to 3 minutes at room temperature. After the dipping treatment, the tomatoes were thoroughly rinsed with clean water to remove any residual sodium hypochlorite. Each treatment was conducted in triplicate, and the mean values of the replications are presented in Table 4.2.

Table 4.2 Washing of tomato by Hand with treated water.

SN	Time (min)	hand Washing Efficiency	Microbial Washing Efficiency	Bruise Index	Colour Index		
					L*	a*	b*
1	1 min	81%	76%	0.5	37	-17	8
2	2 min	85%	82%	0.6	38	-18	9
3	> 3 min	87%	88%	0.6	38	-18	9

Table 4.2 presents the effect of retention time on mechanical and microbial washing efficiencies during hand washing of tomatoes with 100 ppm chlorine water. Mechanical washing efficiency increased significantly ($p \leq 0.05$) from 81% to 87% as retention time increased from 1 to 3 minutes, while microbial washing efficiency showed a statistically significant improvement ($p \leq 0.05$), increasing from 76% to 88%. This trend indicates that longer contact time between the produce surface and sanitizing solution enhances soil removal and microbial inactivation, as also reported by Beuchat (1998) and Gil et al. (2009).

A comparative evaluation of hand washing (Table 4.1) and hand washing with 100 ppm chlorine water treatment (Table 4.2) revealed a statistically significant increase ($p \leq 0.05$) in both mechanical and microbial washing efficiencies when chlorine was used. The optimum performance was observed at a 3-minute retention time, achieving 87% mechanical washing efficiency and 88% microbial washing efficiency, along with a bruise index of 0.6. Similar improvements in microbial reduction using chlorine-based sanitizers have been widely reported in fresh produce washing studies (Sapers, 2001; Parish et al., 2003).

Fig 4.2 and 4.3 further demonstrate that hand washing with 100 ppm chlorine water was significantly more effective ($p \leq 0.05$) than hand washing without chlorine. While mechanical and microbial washing efficiencies increased significantly, no statistically significant difference ($p > 0.05$) was observed in the bruise index between the treatments, indicating that chlorine application did not adversely affect the physical integrity of tomatoes. This finding is consistent with earlier studies reporting minimal mechanical damage at recommended chlorine concentrations (Allende & Artés, 2003).

With respect to colour attributes, the L*, a*, and b* values indicated better colour retention in tomatoes washed with 100 ppm chlorine solution. The improvement in colour parameters may be attributed to the effective removal of surface contaminants and reduced microbial activity, which helps maintain visual quality. Similar observations have been reported by Gil et al. (2009), who highlighted the role of proper sanitization in preserving the appearance and marketability of fresh produce.

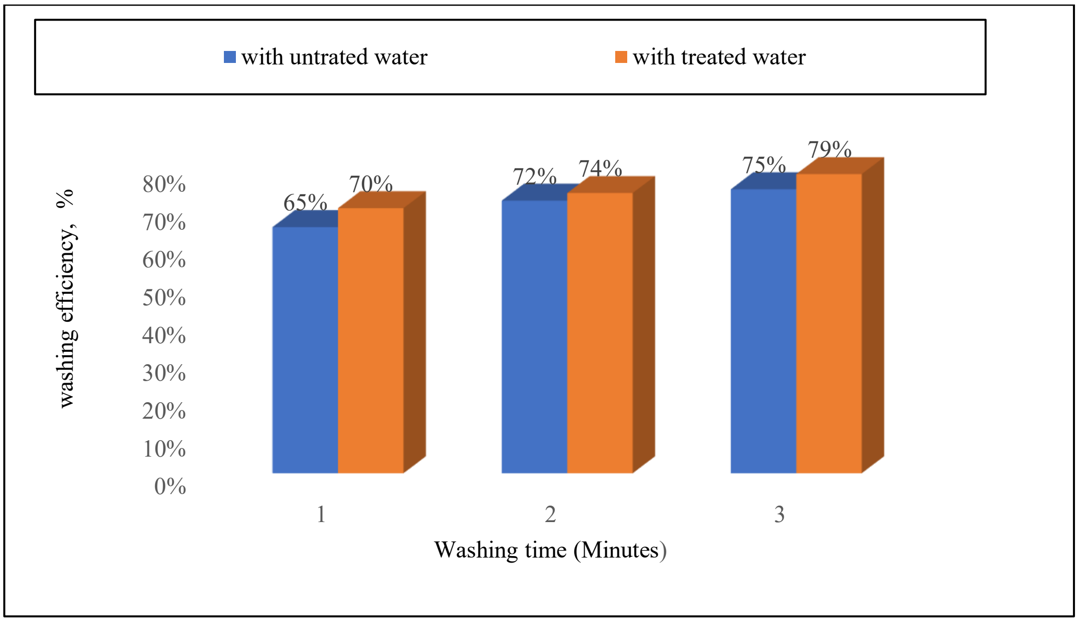

Fig 4.2 Effect of washing time on washing efficiency of tomato in traditional washing method

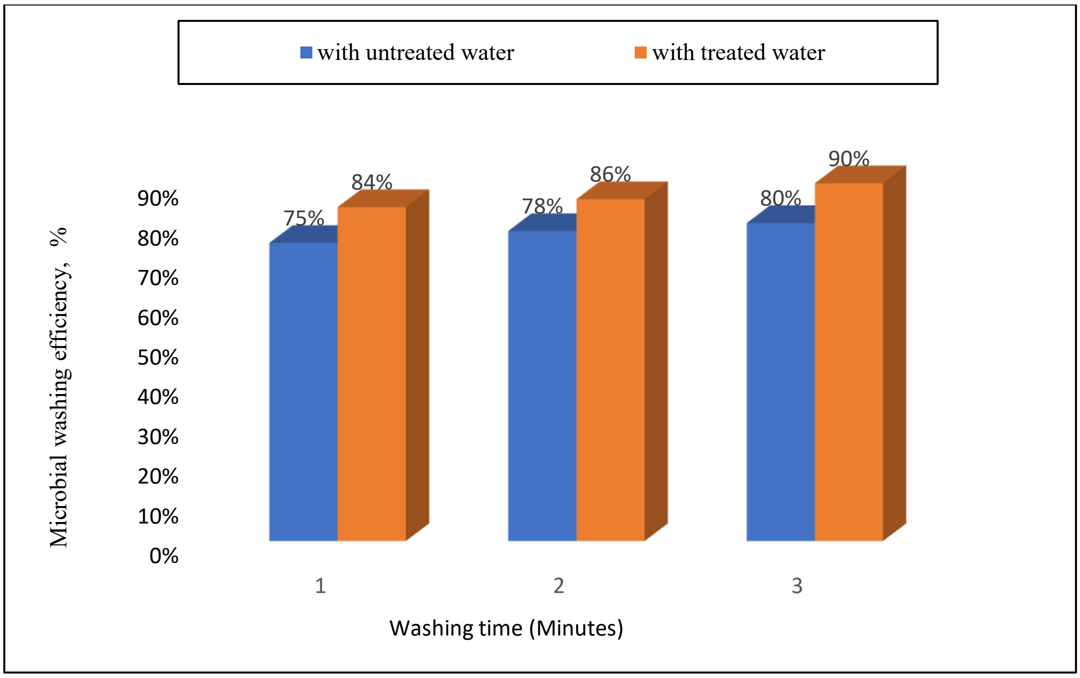

Fig 4.3 Effect of washing time on microbial washing efficiency of tomato in traditional washing method

The present study demonstrated that hand washing of tomatoes using a 100 ppm sodium hypochlorite solution significantly improved both mechanical and microbial washing efficiencies compared to hand washing with potable water alone. An increase in retention time from 1 to 3 minutes resulted in a statistically significant enhancement ($p \leq 0.05$) in washing performance, with the optimum results achieved at a 3-minute duration. At this condition, mechanical washing efficiency of 87% and microbial washing efficiency of 88% were recorded, while maintaining a low bruise index (0.6), indicating minimal mechanical damage to the fruit. The application of chlorine did not exert a significant adverse effect ($p > 0.05$) on the bruise index, confirming that the recommended concentration and exposure time are safe for maintaining the physical integrity of tomatoes. In addition, colour attributes (L*, a*, and b*) showed improved retention under chlorine treatment, reflecting better visual and market quality.

Overall, hand washing with 100 ppm chlorine water for a retention time of 3 minutes can be considered an effective and practical method for enhancing cleaning efficiency and microbial safety of tomatoes without compromising quality. The findings provide useful technical guidance for small-scale handlers and post-harvest operations seeking to improve produce sanitation using simple and economical washing practices.

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