MECHANISED CLEANING AND SANITIZATION TECHNIQUES FOR WATERMELON EXPORTATION: IMPROVE SHELF LIFE WHILE MAINTAINING QUALITY

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ABSTRACT

Watermelon holds significant commercial potential in Malaysia, with substantial cultivation and export volumes. Phytosanitary requirements mandate the removal of soil or weed contamination from watermelon surfaces before export, prompting concerns about potential cross-contamination during manual cleaning. Furthermore, due to its huge size and weight, the risk of physical injury to the fruit, and operator during cleaning and sanitising process can increase if it is handled manually. Therefore, a machine was designed to mechanized the cleaning and sanitising process. The machine, featuring a chlorine-treated water cleaning chamber and a drying mechanism, with capacity of around 100 fruits/hour. It eliminates the need for air drying before packaging. Therefore, reducing both time and space requirements. The aim of the study is to evaluates the developed machine's performance against manual methods. Results show that the machine effectively preserves watermelon quality by preventing physical harm, minimizing bruising, and reducing fungal infections compared to manual cleaning. Compositional analysis indicates no significant differences between treated and untreated watermelons after five weeks of storage, affirming the machine's efficacy in maintaining internal quality. In conclusion, the developed machine offers practical solutions to enhance post-harvest handling and reduce losses in watermelon supply chains. Its use of chlorine water during cleaning extends watermelon shelf life up to the fifth week, promising positive impacts on industry sustainability and food security.

Keywords: watermelon, cleaning machine, sanitation, storage life

INTRODUCTION

Watermelon, scientifically labelled as Citrullus lanatus, holds a significant position among Malaysia's fruit crops, displaying promising commercial potential. Rich in bioactive compounds like carotenoids, phenolics, flavonoids, amino acids, and vitamins, watermelon offers substantial health benefits (Sabeetha *et* al, 2017, Ridwan *et* al., 2018). According to Fruit Crop Statistics Malaysia, the cultivated area for watermelon in 2021 is 8,489 thousand hectares, with a production of almost 136 thousand metric tonnes. Standing at a figure of 43.1 thousand metric tonnes, watermelon is the fruit that has the largest export volume in

2021 (Department of Statistics Malaysia 2022). Japan, China, Singapore, and the Middle East are among the main markets for watermelon exports.

Obtaining a phytosanitary certificate from the Department of Agriculture is a mandatory step for watermelon exportation. One of the main requirements is that the fruit's surface must be free of soil or weed contamination. A field survey conducted with a watermelon exporting company indicates that the prevalent method involves wiping the fruit's surface with a damp towel to remove debris. However, there are concerns regarding potential cross-contamination arising from this practice. Past research has highlighted microbial contamination as a significant factor contributing to post-harvest losses (Richards and Beuchat, 2005).

Efforts to extend watermelon shelf life and maintain quality are crucial for industry stakeholders. Post-harvest losses, estimated at 32% in Malaysia, significantly impact on the food security and nutrition for watermelon industry (Suhana *et* al., 2022). Addressing food security concerns necessitates optimizing post-harvest techniques, particularly during collection and distribution. Although various anti-microbial treatments exist, their impact on quality and shelf life requires further exploration. Previous studies have indicated that immersing watermelons in water treated with sanitation solutions like sodium hypochlorite, acidified sodium chlorite, and acidified calcium sulphate has the potential to prolong shelf life by reducing microbial contaminants (Nur Azlin et al. 2022; Svoboda et al. 2016; Fan et al. 2009). Watermelons typically boast a three-week shelf life when stored at optimal conditions but are susceptible to shorter lifespans at ambient temperatures (Cantwell *et* al., 2002).

Manual cleaning and sanitation of watermelons are a labour-intensive task, poses risks of physical damage, especially given their substantial size and weight. Based on a survey conducted during visits to watermelon exporters, it was observed that watermelons intended for the export market vary in weight from 4 to 12 kg per fruit. The risk of physical damage to the fruit is heightened when handled manually during the cleaning process, given its substantial size and weight. To meet the rising global demand for watermelons, a specialized cleaning and sanitation machine tailored for the export market has been developed. Evaluating its performance against manual cleaning methods involves assessing parameters like overall appearance, weight loss, flesh colour, rind firmness, and chemical composition over a five-week storage period at ambient conditions.

MATERIAL AND METHODS

Machine Description

The machine consists of a cleaning chamber, a drying chamber, a roller conveyor, motors for both the conveyor and rotating mechanism within the cleaning and drying chambers, a water tank, a water pump, a filtration system, and two air tanks, all controlled by PLC programming. The watermelons are automatically transported to the cleaning chamber by the roller conveyor. Inside the cleaning chamber, a 250 ppm sodium hypochlorite solution is sprayed on the watermelons, efficiently cleaning and sanitising them at the same time. Additionally, a brushing mechanism within the chamber facilitates a brushing motion to remove dirt, sand, and other residues from the watermelon surfaces. Subsequently, the watermelons are conveyed to the drying chamber, In the drying, where compressed air is used to dry the surfaces of the cleaned fruits, allowing for immediate packing after cleaning. During the cleaning and drying process, the watermelons are rotated by a motor to ensure that all surfaces are thoroughly cleaned, sanitised, and dried.

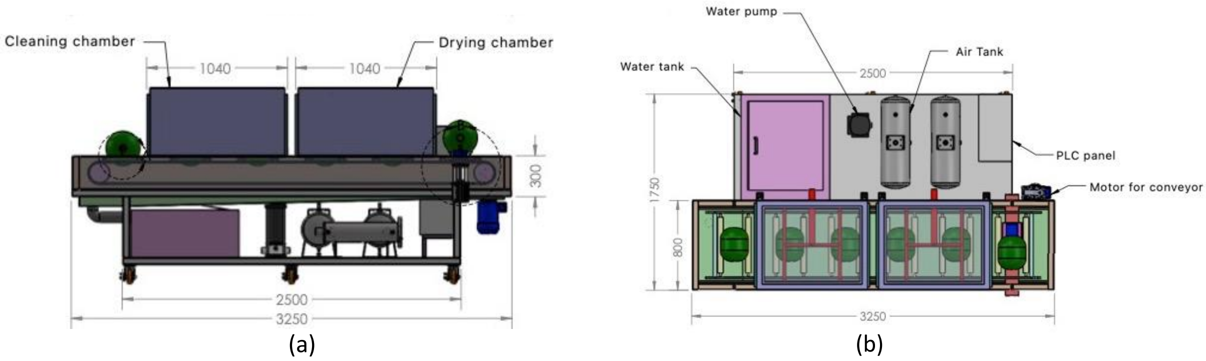

Figure 1: Schematic diagram of watermelon cleaning machine. (a) Front view; (b) Top view

Performance Evaluation

The assessment compared the efficiency of the watermelon cleaning machine, manual cleaning, and untreated watermelon, focusing on the time required to clean 100 fruits and the impact on fruit quality. To evaluate fruit quality, watermelon samples were divided into three treatment groups: (i) Cleaned, sanitized, and dried using the machine; (ii) Manually cleaned and sanitized by soaking in 250 ppm sodium hypochlorite, then air-dried for 30 minutes; and (iii) Untreated as a control. Following treatment, the watermelons were packed in clean corrugated fiberboard (CFD) boxes and stored in a controlled room at 27°C for five weeks to simulate market conditions for transit and sale.

Fruit Quality Assessment

Weekly assessments were conducted to track changes in quality, both visually and physiochemically. Visual appearance was evaluated subjectively by scoring individual fruits for skin bruising, flesh bruising, fungal infection,and overall acceptability ratings. Weight loss, endocarp firmness and mesocarp colour, as well as compositional characteristics such as soluble solids content

(SSC), total titratable acidity (TTA), ascorbic acid content (AAC), juice content, and moisture content, were all measured to monitor quality changes during storage.
Weight loss (% fresh weight basis) was calculated by comparing initial and subsequent weights after storage using Equation 1:

$$Weight\ loss\ (\%) = \frac{Initial\ fruit\ weight\ (g) - final\ fruit\ weight(g)}{Initial\ fruit\ weight(g)}\ x\ 100 \quad (1)$$

Endocarp firmness was measured at three points on each fruit using a texture analyzer (TA.xt.Plus, Stable Micro System) with a flat stainless steel cylindrical probe (P2N). Surface color was determined using a reflectance colorimeter (Minolta Chroma Meter, CR400). The SSC was measured with a digital refractometer (ATAGO RX-5000).

TTA was determined using an automatic titrator (Model 888 Titrando; Metrohm, Switzerland). 5 mL of juice was diluted with 50 mL of water and titrated with 0.1 M NaOH to achieve a pH of 8.1. The result is expressed as a percentage of malic acid. Meanwhile, AAC was determined through titration with 2,6- dichlorophenolindophenol until a faint pink colour persists which represents the endpoint.

The juice content (%) was obtained using the weight of squeezed juice recovered from 100 g of fruit sample. The juice content (%) was calculated using the following equation:

$$Juice\ content\ (\%) = \frac{Sample\ juice\ weight\ (g)}{100\ (g)}\ x\ 100 \quad (2)$$

The moisture content (%) was calculated by weighing the sample before and after drying in an oven. 10g of sample was dried in an oven at 60°C for three days.

$$Moisture\ content\ (\%) = \frac{Initial\ weight\ (g) - final\ weight(g)}{Initial\ weight(g)}\ x\ 100 \quad (3)$$

The experimental design employed a Completely Randomized Design (CRD) with three replications, subjected to analysis of variance (ANOVA), and means were differentiated using Duncan's Multiple Range Test (DMRT) at a 5% significance level. Statistical analyses were performed using SAS software version 9.4.

RESULTS AND DISCUSSION

Performance Evaluation

The findings displayed in Table 1 demonstrate that the developed machine exhibits greater consistency in speed compared to the manual method. Cleaning 100 fruits takes only 1 hour with the machine, while the manual method can range from 1 to 2 hours, indicating potential variability and prolonged cleaning durations, particularly for heavily soiled fruits from the farm. Furthermore, as both methods require the same number of operators, the machine enhances productivity without requiring extra manpower. Moreover, the manual cleaning process requires a 30-minute air-drying period before the fruits can be packed. In contrast, fruits cleaned with the developed machine can be immediately packed as its drying chamber ensures continuous drying post-cleaning. This not only reduces the drying time but also minimizes the space required for air drying.

Table 1. Comparison performance of developed machine with manual

Method	Cleaning times for 100 fruits	No. of operators
The developed machine	1 hours	2
Manual	1 – 2 hours	2

Fruit Quality Evaluation

Table 2 shown that the developed machine did not cause any physical harm to the watermelon. Conversely, manually washed fruits exhibited more prominent bruising effects after a storage period of three weeks. Fungal infections became apparent on the control group's fruits as early as three weeks (Figure 2), underscoring the importance of sanitation in extending the shelf life of watermelons. This observation aligns with a similar discovery reported by Svoboda et al. (2016) that sanitization can prolong the shelflife of melon. All watermelon samples stored at an ambient temperature of 27°C with a relative humidity of 75% consistently received scores surpassing 3 (Acceptable) for up to 5 weeks. Notably, fruits cleaned using the developed prototype received the highest overall acceptability score.

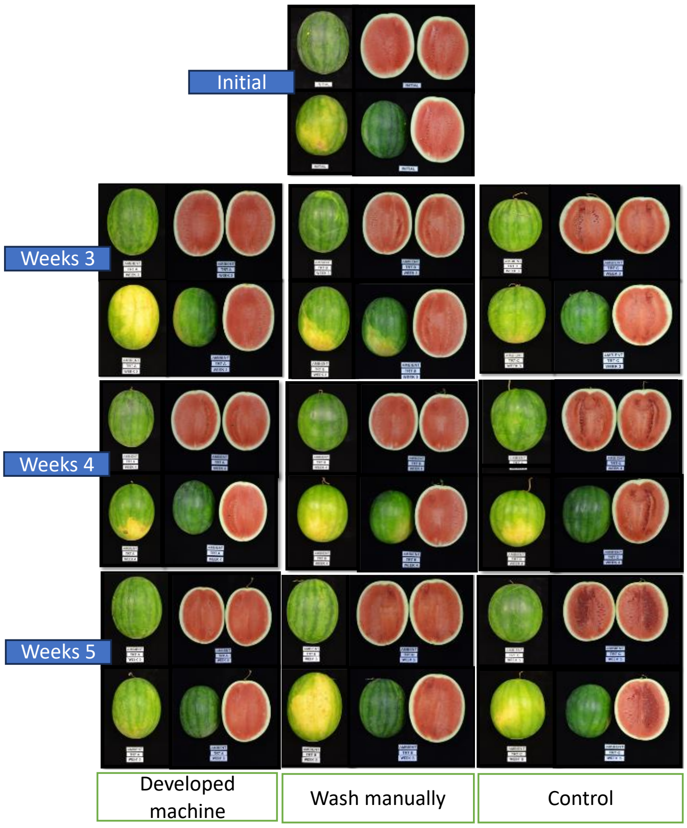

Figure 2: The visual quality of watermelon during 5-week storage period

Table 2. Effect of washing treatment on watermelon skin and flesh bruising, fungal infection and overall acceptability rating (score 1-5) during 5 weeks storage

Characteristics	Week	The developed Machine	Wash manually	Control
Skin bruising	0	-	-	-
	3	-	+	+
	4	-	+	+
	5	-	-	+
Flesh bruising	0	-	-	-
	3	-	++	-
	4	+	+	++
	5	+	++	+
Fungal infection	0	-	-	-
	3	-	+	+
	4	-	-	-
	5	-	-	-
Overall acceptability ratings	0	5	5	5
	3	4.7	3.7	4.0
	4	4.0	3.0	3.3
	5	3.7	3.0	3.3

Abbreviations: Score of symptoms based on each fruit (n=3): negative=no trace; +=slightly affected; ++=moderately affected; +++=badly affected; Overall acceptability ratings: 5=Excellent, 4=Good, 3=Acceptable, 2=Poor, 1=Very poor

The quality assessment data revealed no significant differences in the internal color, endocarp firmness, and weight loss of watermelons stored for five weeks at 27°C (refer to Table 3). The average weight loss percentage was 2.2%, which falls within an acceptable range for watermelons stored over a five-week period. Previously, Nur Azlin et al. (2021) reported that sanitation using 250 ppm sodium hypochlorite had no significant effect on the color, endocarp firmness and weight loss of watermelons up to the fourth week. Table 3 demonstrates that the use of the machine for cleaning and sanitizing will not affect the internal quality of the watermelon similar to manual method.

Table 3. Watermelon internal colour, endocarp firmness and weight loss after 5 weeks storage at 27°C.

Main effect / Treatment	L*	Hue* angle	Chroma*	Endocarp firmness[x] (N)	Weight loss (%)
Developed system	38.92a[z]	40.87a	28.91a	65.84a	2.26a
Wash manually	38.15a	40.39a	28.44a	69.39a	2.02a
Control	38.40a	39.19a	30.90a	69.43a	2.36a
Significance	ns[y]	ns	ns	ns	ns

[z]Means in each column for the with the same letter are not significantly different according to Duncan's Multiple Range test at $p \leq 0.05$.
[y]ns=not statistically different, *, **=statistically different at $p \leq 0.05$, $p \leq 0.01$, respectively.
[x]As determined by the bioyield point.

Table 4 presents the composition data of watermelon contents after 5 weeks of storage at 27°C. No significant differences were found in readings of soluble solids content, total titratable acidity, ascorbic acid content, juice content, and moisture content between treated watermelons and the control group. Therefore, the cleaning and sanitation process using the developed machine did not affect the internal quality of the fruits throughout the five-week storage period.

Table 4. Compositional data for watermelon after 5 weeks storage at 27 °C.

Main effect / Treatment	Total soluble solids (%)	Total titratible acidity (%)	Ascorbic acid content (mg/100g)	Juice content	Moisture content (%)
Developed system	6.67a[z]	0.06a	5.96a	77.94a	91.10a
Wash manually	6.43a	0.06a	6.34a	78.96a	90.62a
Control	6.73a	0.08a	7.59a	79.28a	89.73a
Significance	ns[y]	ns	ns	ns	ns

[z]Means in each column with the same letter are not significantly different according to Duncan's Multiple Range test at $p \leq 0.05$.
[y]ns=not statistically different, *, **=statistically different at $p \leq 0.05$, $p \leq 0.01$, respectively, from ANOVA.

CONCLUSION

In summary, the study highlights the effectiveness of the developed machine in preserving the physical integrity and extending the shelf life of watermelons. The result demonstrated that the developed machine did not cause any physical harm to the fruit, contrasting with manually washed fruits which exhibited more pronounced bruising effects after three weeks of storage. Additionally, the appearance of fungal infections on the control group's fruits at the same time frame underscores the critical role of sanitation in prolonging watermelon shelf life. Moreover, the compositional data showing that no significant differences in key parameters between treated watermelons and the control group after five weeks of storage. This underscores that the cleaning and sanitation process using the developed machine did not compromise the internal quality of the fruits throughout the storage duration. Overall, these findings demonstrate that the developed machine's positive impact on post-harvest handling, coupled with its ability to maintain fruit quality, positions it as a valuable asset in the agricultural sector, offering practical solutions to enhance efficiency and reduce losses in watermelon supply chains. Notably, the use of chlorine water at a concentration of 250 ppm during the cleaning process extends the shelf life of watermelons up to the fifth week.

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