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Optimization and Modelling of the Shelf Life of Mango (Mangifera Indica) in Hydro-Cooling Coated with Antimicrobial Extract

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ABSTRACT:

Short-lived fruits like Mango (*Mangifera indica*) are to be subjected to cooling after reaping to increase their storage life. Hydro cooling method is found to achieve faster heat transfer. In the current study, Response surface methodology was used to search for the foremost storage conditions of the hydro-cooling system to extend the shelf life of mango coated with antimicrobial extract (Neem leaf extract). The cooling rate was most affected by cooling chamber temperature (13℃,16℃ and 22℃), fruit size (0.11, 0.13 and 0.17 m) and water flow rate (0.83 l/hr, 1.16 l/hr and 4.16 l/hr). The most suitable conditions to store mango fruits under hydro cooling were determined as cooling chamber temperature (13℃), fruit size (0.11 m) and water flow rate (4.16 l/hr). The shelf life for mango was prolonged to 32 days. Percentage Loss in Weight for the control sample was 9.38% within 8 days of storage whereas for the cooled sample it was 4.19- 8.26 % for 32 days of storage also, Total Soluble Solids was 16.33 -24.00℃Brix the for control and cooled sample it was 16.33-25.00℃Brix for 8 and 32 days of storage. Time taken for Cooling was 55, 45 and 40 mins for 0.17m, 0.13m, and 0.11m size fruits respectively.

Keywords: Hydrocooling, Total Soluble Solids (TSS), Percentage Loss in Weight (PLW).

INTRODUCTION:

Cooling is essential for perishables such as fruits after harvest to prolong their storage life with good keeping quality. In Hydrocooling the fruit is cooled by immersing them in cold water/ice or by subjecting them to a spray of cold water. Due to the higher heat transfer rate hydro cooling is three times faster than other cooling techniques (Delgado & Wen Sun, 2001). Hydro cooling is a fast-cooling technique, the time required to cool different fruits to desired core temperature changes with the physical or thermal properties (Teruel *et al*. 2004). Tropical fruit such as Mango (*Mangifera indica)*, has importance commercially. Kesar

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mangoes were cooled at 12 to 16℃ and shelf life was increased by 15 days but, cooling at 8˚ C showed chilling injury (Kapse *et al*.,1997). Cooling followed by low-temperature storage can help in storing fruits for a longer duration (Chepngeno *et al*.,2015). Hatton *et al*.,1965 studied that temperature more than 15.5°C is good for mango for ripening, while temperatures below 12.7°C were more suitable for storage. Alphonso mango was stored at 10°C ;85% and 30°C; 60% RH and it was found that low-temperature storage can extend the shelf life of the fruit up to 35 days (Salles and Travarcs.,1999). In the current study effect of precoating and hydro cooling on shelf life and physio-chemical properties of mango was studied.

MATERIALS AND METHODS:

2.1. Preparation of Antimicrobial (Neem Leaf) extract and coating:

For neem leaf extract dried leaves were chopped and grinded to fine powder. 100 ml of distilled water and 100 g of leaf powder was mixed and kept overnight. This resulted in 100% (E_1) concentration of every plant extract (Shrestha *et al*.,2018). The fruits were dipped in the solution for 7mins for uniform coating.

2.2. Hydrocooling Chamber:

The Hydro cooling system consists of two thermocol box having equal dimensions such as height - 40 cm, length - 60 cm, width - 46cm and capacity - 35 litre. Under the upper reservoir two showers were attached, two identical overhead showers made up of steel. The dimensions of showers are 30cm×13cm×10cm(L×W×H). Showers were having conical shaped outlet nozzles made of plastic. Upper thermocol box acts as water reservoir to which showers were fixed at the base and bottom thermocol box acts as a precooling chamber in which commodity placed for cooling as shown in figure 6. Upper box with showers was placed on the supporting stands and pre cooling chamber placed exactly below the reservoir.

2.3. Time - Temperature Relationship of fruit during Cooling:

The core temperature of the fruit samples was determined till desired core temperature was attained using a thermocouple also, the total time required to cool the fruit.

2.4. Percentage loss in Weight (PLW):

Fruits were weighed and the beginning of storage and at regular intervals during storage. The average percentage loss in weight was calculated using:

$PLW\ (\%) = [(W_i - W_1)/W_i] \times 100$

where W_i is the fruit weight at the beginning of storage and W_1 is the weight of fruit measured during storage. (Ravikumar *et al*., 2018).

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2.5. Total Soluble Solids:

By using a Hand Refractometer, the total soluble solids of the samples were recorded in ^{0}Brix.

2.6. Statistical Analysis:

All the experiments were designed using full factorial design (design expert version 13.0). There were 27 (3^3) treatment combinations in total. The different variables that affect the shelf life of the fruit were identified as fruit size(m), cooling chamber temperature (℃), and water flow rate (l/hr) as shown in Table 1.

Table 1: Experimental Factors.

Factor A	Factor B	Factor C
Cooling Chamber Temperature (℃)	**Fruit Size (m)**	**Water Flow Rate (l/hr)**
13	0.11	0.83
16	0.13	1.16
22	0.17	4.16

RESULTS AND DISCUSSIONS:

3.1. Time- Temperature Relationship

The main goal of the cooling process is to reduce the core temperature of the fruit to the desired storage temperature (10-15℃). At regular intervals, the core temperature of the fruit was recorded till it attained the desired temperature.

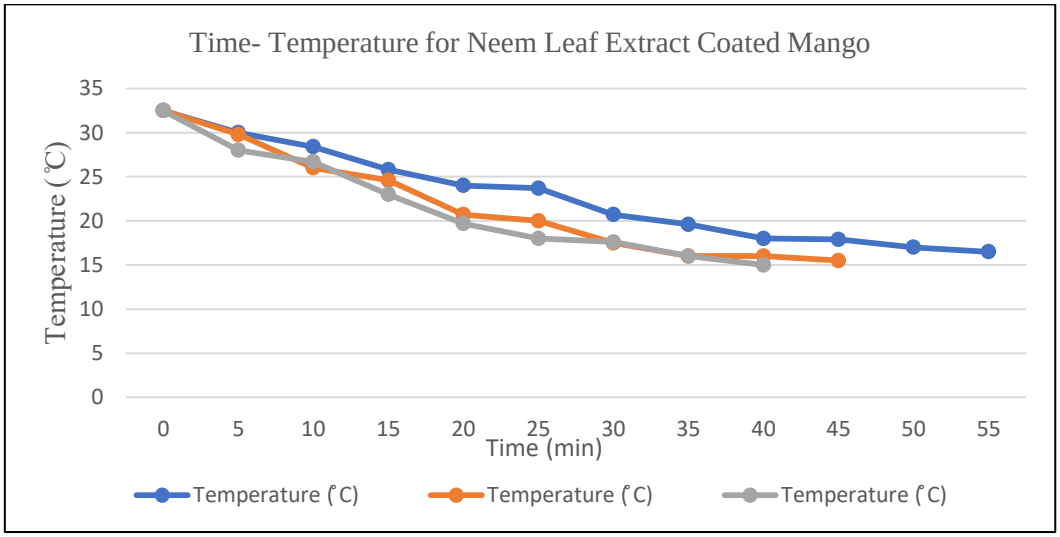

Figure 1: Time -Temperature Response of small, medium and large size Mango

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The above figure demonstrates the relationship between time and temperature of small, medium and large size fruit to attain the desired core temperature at the lowest storage temperature (13℃). A linear trend was observed for all-time temperature relations for different sized fruits. Small, medium, and large-sized fruits were cooled at 40, 45 and 55 mins i.e cooling time increased with an increase in the size of the fruit. A similar observation was made by Teruel *et al.*,2004. It was also, observed that there was not much effect of coating on temperature reduction.

3.2. Percentage Loss in Weight

Table 2: Percentage Loss in Weight of Mango

Fruit Size	Medium Temperature (℃)	PLW (%) (After 16 Days of storage)	PLW (%) (After 32 Days of storage)
Large	13	2.33 ±0.11	4.19±0.55
	16	2.68 ±0.11	Discarded
	22	2.47 ±0.14	Discarded
Medium	13	4.00±0.17	5.66±0.51
	16	2.14 ±0.18	Discarded
	22	2.93 ±0.08	Discarded
Small	13	3.00±0.00	7.16 ±0.74
	16	4.00±0.17	Discarded
	22	5.00±0.00	Discarded

PLW at 13 & 16℃ was notably reduced by hydro cooling as shown in Table 2; for the cooled sample PLW did not exceed 2-7.64% till 32 days but for the control sample PLW was as high as 9-13.0 % within 8 days of cooling. As the low temperature was maintained in hydro cooling there was a reduction in PLW; according to Hardenburg *et al.*,1990 high storage temperature causes a high respiration rate which leads to fruit weight loss. The result was on par with the observation made by Aly M. Ibrahim and El-Sayed. M. Qaoud (2019). It was also observed that PLW was more small-sized fruits hence shrivelling was observed towards the end of the storage period, whereas large-sized fruits had minimum PLW even at the end of 32 days. Reduced weight loss in the coated fruit can be due to the ability of the coating film to block all the pores which may have resulted in reduced transpiration

3.3. Total Soluble Solids

TSS increased with an increase in the storage period and temperature as shown in figs 2 to 4. TSS was about 24.00-24.66 at 22℃ after 24 days of storage and about 23.00-25.00 at 13℃

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after 32 days; whereas for control, it was 24.00,24.00 and 24.52 at 13, 16 and 22℃ within 8 days of storage respectively. Azene *et al*., 2014 and Youssef *et al*., 2012 claimed that due to synthesis of starch into sugars TSS increases in climatric fruits during ripening.

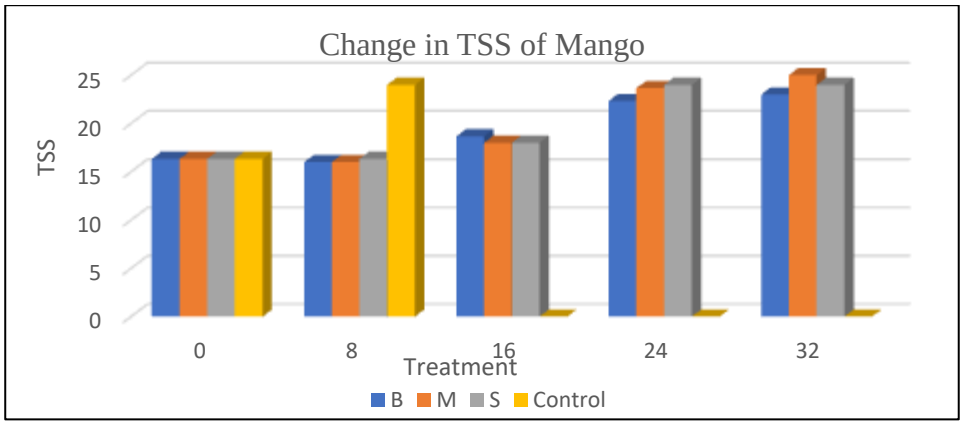

Figure 2: Total Soluble Solids of different sized Mango at 13℃

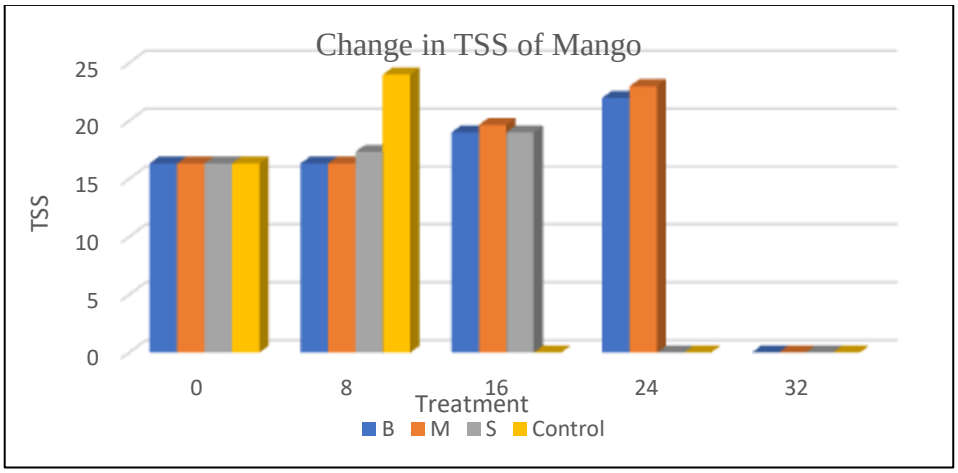

Figure 3: Total Soluble Solids of different sized Mango at 16℃

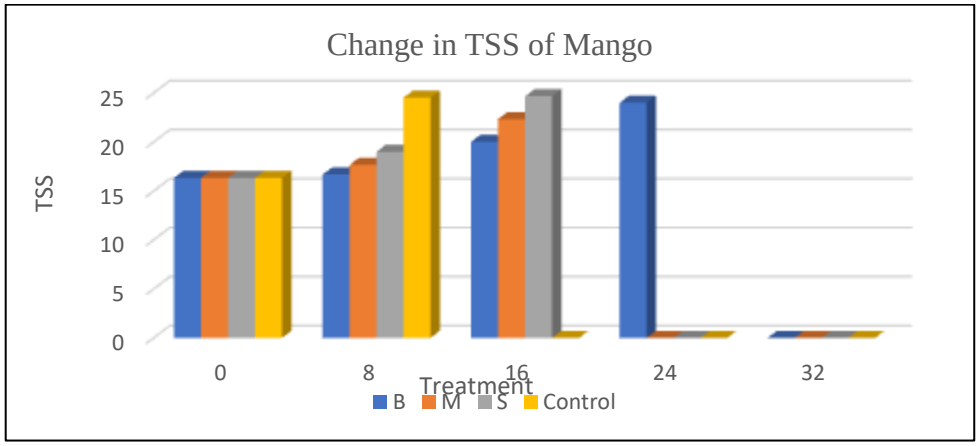

Figure 4: Total Soluble Solids of different sized Mango at 22℃

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3.4. Modelling of Storage conditions

The factors that affect the shelf of mango when subjected to hydro-cooling were Fruit Size(m), Cooling Chamber Temperature (˚ C), and Cooling medium Flow Rate (l/hr). The combinations are shown in Table 4.

Table 3: Shelf life of Stored Mango as a function of Cooling Chamber temperature, Fruit Size and Medium Flow Rate during Hydro Cooling

Run	A: Cooling Chamber temp (°C)	B: Fruit Size (m)	C: Flow Rate (l/hr)	Shelf life (Days)
1	16	0.17	0.83	9
2	13	0.13	4.16	30
3	13	0.17	0.83	20
4	22	0.13	0.83	7
5	16	0.11	1.16	15
6	16	0.13	4.16	18
7	13	0.11	1.16	28
8	22	0.13	4.16	9
9	13	0.13	0.83	22
10	22	0.11	0.83	8
11	16	0.17	4.16	16
12	22	0.13	1.16	8
13	16	0.11	0.83	10
14	13	0.13	1.16	27
15	16	0.11	4.16	19
16	16	0.13	0.83	9
17	22	0.17	4.16	7
18	22	0.17	1.16	8
19	16	0.17	1.16	12
20	22	0.11	1.16	9
21	13	0.11	4.16	32
22	22	0.17	0.83	7
23	13	0.11	0.83	24
24	13	0.17	1.16	25
25	16	0.13	1.16	13
26	22	0.11	4.16	12
27	13	0.17	4.16	22

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3.4.1. Final Model Equation and its Analysis

The shelf life of fruits can be increased by storing them under appropriate storage conditions. According to Meir *et al*.,1995 a model should be rejected if the result showed significance in the LOF test. The **Model F-value** of 211.2 implies the model is significant. A P-value less than 0.05 indicate model terms are significant. Hence, A, B, C, AC, A^2 and C^2 are significant model terms as shown in Table 4.

Table 4 ANOVA for the experiments performed.

Source	**Sum of Squares**	**df**	**Mean Square**	**F Value**	**p-value Prob > F**	**Significant/ Non-Significant**
Model	1606.37	6	267.7	211.2	< 0.0001	Significant
A: Chamber temp (ºC)	1289.3	1	1289.3	1017.2	< 0.0001	Significant
B: Fruit Size (m)	25.03	1	25.03	19.75	< 0.0001	Significant
C: Flow Rate (l/hr)	150.50	1	150.50	118.74	0.0001	Significant
AC	26.79	1	26.79	21.14	0.0002	Significant
A^2	266.57	1	266.57	210.31	0.0011	Significant
C^2	33.29	1	33.29	26.26	0.0060	Significant

Std Dev	1.12	R-Squared	0.9852
Mean	15.53	Adj R-Squared	0.9805
C.V %	7.24	Pred R-Squared	0.9708
PRESS	43.80	Adeq Precision	46.68

The Predicted $R^2$of 0.9708 is in reasonable agreement with the Adjusted R^2 of 0.9805; i.e. the difference is less than 0.2. Adeq precision greater than 4 is desirable and 46.682 indicates an adequate signal. This model can be used to furthur research.

Final equation:

Shelf Life =+16.63-9.42 * A-1.21* B-2.99 * C-1.41 * A * C+7.81* A2 -7.27* C2.

3.4.2. Optimization of Storage conditions

Fig. 5 describes the relationship between all the selected factors and shelf life for small, medium and large-size fruits in a 3-D plot. The best combination of various independent variables such as chamber temperature, fruit size and water flow rate for storage of mango in

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the hydro-cooling technique is the smallest fruit (0.11 m), least chamber temperature (13˚C) and highest Water flow rate (4.16 l/hr) required to attain longest shelf life of 32 days.

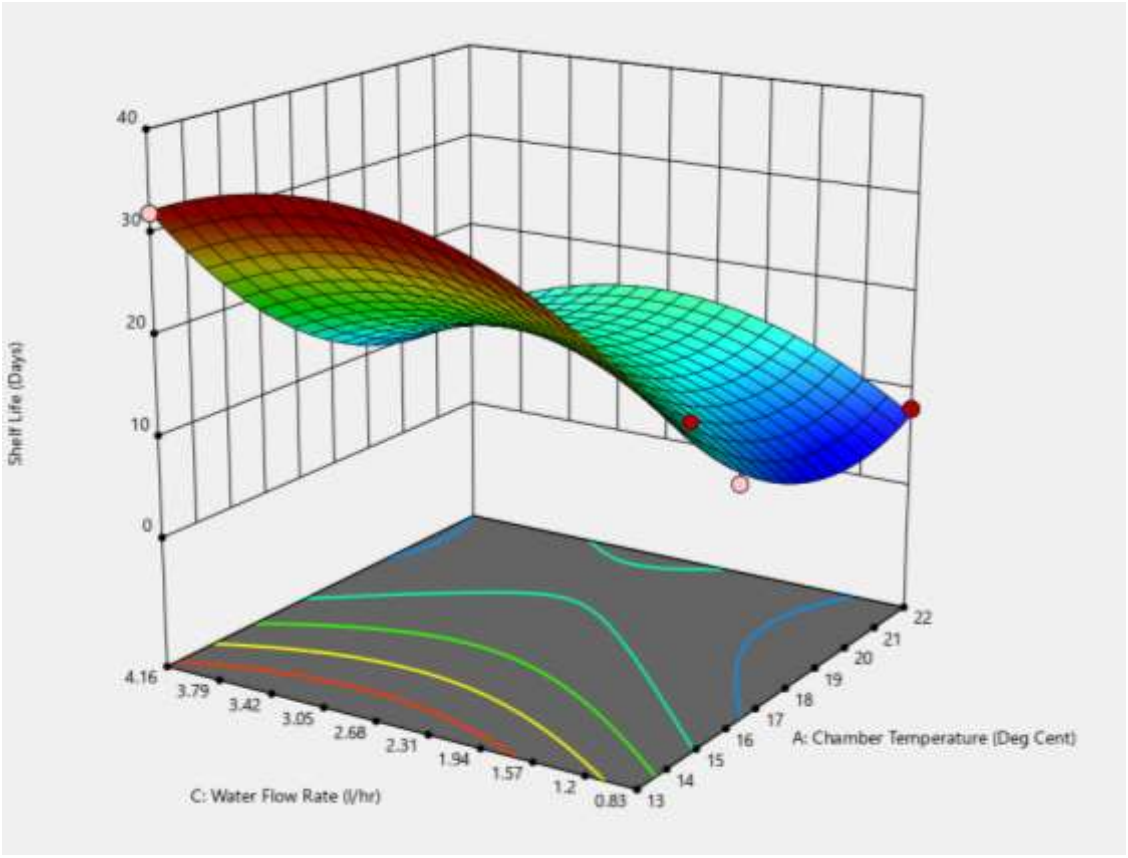

Figure 5: Relationship Between Chamber Temperature, Fruit Size, water flow rate and Shelf Life for Different Sized Fruits

CONCLUSIONS:

Mango with antimicrobial coating stored in the hydro-cooling chamber was stored for 32 days, whereas control (without antimicrobial coating) stayed fresh only for 3-8 days. Time taken for cooling smallest to largest sized mango fruit was 40, 45 and 55 mins for 0.11m, 0.13m and 0.17 m size fruits respectively. The best storage conditions according to modelling were found to be for smallest fruit size (0.11 m), least cooling chamber temperature (13˚C) and highest water flow rate (4.16 l/hr) among all the treatments. Loss in Weight of the fruit was found to be maximum for the control sample 9-13.0 % within 8 days of cooling, whereas for the cooled fruit sample after 32 days weight loss did not exceed 2-7.64%. TSS was maximum for mangoes stored at 22℃ and then at 16℃ and finally at 13℃. TSS was about 24.00-24.66 at 22℃ after 24 days of storage and about 23.00-25.00 at 13℃ after 32 days whereas for control it was 24.52 at 13, 16 and 22℃ within 8 days of storage. Hydro cooling and antimicrobial coating can be an alternate method to extend the shelf of mangoes.

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