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Process Optimization of Hand Operated Machine for Coating of Apples using Carboxymethyl Cellulose

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Abstract **– Mechanization is the primary need in the field of agriculture for the purpose to maintain the quality of food products and hence reducing food waste. Edible coatings are best suited methods for shelf-life extension of fruits and vegetables, but with less availability of machines, the process is time consuming and laborious. Edible coatings are non-hazardous and consumable for human beings that results in resistance to metabolic and respiration activity of produces. Box Behnken Design was used for optimizing the developed machine parameters to coat the horticultural produce. During the experimentation, the effect of three parameters having three levels i.e., dipping time (2-6 s), dryer air velocity (0-30 m/s), and reduced drying time (3-7 min) was studied on machine coating efficiency and colour difference of apple fruits. A second-order model was developed for predicting responses and to study the effect of individual parameters and their interactions on the responses. Results revealed that machine coating efficiency and colour difference were found to be affected by dryer air velocity and reduced drying time. Maximum coating efficiency (93%) of hand operated coating machine were found at 4.26 s dipping time, 0.27 m/s dryer air velocity and 3.26 min reduced drying time whereas the minimum colour difference was found to be 14.6 at 0 m/s dryer air velocity, 3 min reduced drying time and 4 s dipping time. A storage study for 10 weeks was conducted and results showed decreased 7.5% weight loss, 9.49% firmness and increased 1.65% colour change of the machine coated apple fruits during the storage period.**

Keywords **– Coating Machine, Apple, Carboxymethyl Cellulose, Response Surface Methodology.**

I. INTRODUCTION

Horticultural produces, the most common crops cultivated worldwide, contains a variety of nutrients including vitamins, minerals and antioxidants. These crops are considered as the foundation of a healthy diet due to the presence of a variety of nutrients and provide several health benefits to the human being when consumed regularly. The total production of the fruit crop in the world is estimated to be around 656 million metric tons and that for vegetables is about 794 million metric tons each year [1]. Fruits comprise vitamins, proteins, minerals and dietary fibers and are perishable. Fruits and vegetable production of India is 86 million metric tons (12%) and 169 million metric tons (21%) respectively, India has ranked second in fruits and vegetable production in the world after China [2]. Global quantitative fruits and vegetable losses are about 40-50%, out of which more than 30% of fruits and vegetables are rendered unfit for consumption due to spoilage after harvesting and being referred to as post-harvest losses [3]. Post-harvest losses of horticulture produce lead to damage in the circular economy for developing and developed countries.

To reduce horticultural produce losses, edible coatings have been used by researchers for extending the shelf-life of horticulture produce [4]. Polysaccharide based coating material is most commonly used for edible coating of horticulture produces [5]. Coatings are pre-formed independent structures that wrap or cover horticulture produce. These are either applied to horticultural produce or formed directly on produce that is intended to be protected. Edible coatings are applied in liquid form on horticultural produce to be coated, ordinarily by immersing the produce in a solution of structural matrix forming substances such as carbohydrate, protein, lipid, or different compositions of it [6].

Edible coating of horticultural produce is still carried out manually worldwide due to high-cost machines for coating purposes. In most of the regions, there is no facility for edible coating of produces that leads to deterioration of horticultural produce in huge quantity and quality [7]. The manual way of the edible coating on the horticultural produce results in an increase in time and cost of coating. Manual coating leads to increased loss of coating and uncoated area due to a bunch of products in a single run. Coating methods (dipping, panning, and spraying) are used for the application of the edible coating solution on the horticultural produce. Presently, spraying coating machines are available in the market worldwide. Spraying coating machines have several drawbacks i.e. non-uniform coating, uncoated area, high capital cost, and labor cost [8].

The operating condition of the coating machine is one of the important factors which considerably affect the machine coating efficiency and capacity. The optimization of coating machine parameters to obtain the desired result was important. Thus, the objective of this study was to optimize the different operating machines parameters to obtain the desired results including coating efficiency and colour difference.

II. Material and Methods

Apple fruit is a widely produced and highly perishable fruit worldwide. The experiments were conducted for the performance evaluation of coating machine on the apple fruits of variety (*Malus Domestica*), and polythene bags (LDPE) were purchased from the local market of Pantnagar, Dist. U.S. Nagar (Uttarakhand). Apple fruits were graded manually in Development Lab, Postharvest Process and Food Engineering Department, G.B.P.U.A & T, Pantnagar. The graded sample having 45-47 g of weight was used for the whole experimentation. BBD (Box–Behnken design) was used for three level factorial design with three levels of each, to decide the combination of each variable in each experiment. To determine a relationship between independent and dependent variables, the data collected were subjected to regression analysis done using Design Expert software 10.0.1. Each response was represented by a mathematical equation that correlates the response surfaces. The response was then expressed as second-order polynomial Eq. 1 reported by [9].

$$Y = \beta_o + \sum_{i=1}^{n} \beta_i X_i + \sum_{i=1}^{n} \beta_{ii} X_i^n + \sum_{i=1}^{n} \sum_{j=i=1}^{n} \beta_{ii} X_i X_j \quad (1)$$

Where,

β_o, β_i, β_{ii}, β_{ii} = Regression coefficients.

X_i and X_j = Independent variables (where, i = 1, 2,....n and j = 1, 2,…n).

n = Number of independent variables (n=3).

Y= Responses.

The levels of the parameters and experimental plan are reported in Tables 1 and 2, respectively. The details of the variable selection are as follows:

Dipping Time

Dipping time was selected for the experimentation was according to the minimum and maximum time requir-

-ed for the apple fruit to be coated. Trial runs were conducted to establish the levels of speed. The overall acceptable range of parameters was decided from 2 to 6 s.

Reduced Drying Time

The levels of drying time reduction were selected as per the maximum drying time required of coating solution over the apple fruit using machine and minimum drying time required of coating solution using the incubator dryer. An overall acceptable range of parameters was decided from 3 to 7 min.

Dryer Air Velocity

It was found using trials that air velocity had a significant effect on independent variables for edible coated apple fruits. The overall permissible range of parameters for the present study was selected based on preliminary trials and the range was selected from 0 to 30 m/s.

Experimental Procedure

A 30-liter edible coating solution was prepared using CMC (carboxymethyl cellulose) (1 %) and glycerol (1%) with 30 lit distilled water. The procedure for the preparation of edible coating solution for apple fruits. All the machine parameters were set and the samples were fed in the hopper and the machine was operated for coating of apple fruits. The coating solution for edible coating of apple fruits was prepared using carboxymethyl cellulose (30 g) and 30 L of distilled water were mixed using stirring of solution at 85 °C for 15 mins at hot plate. After stirring of solution 30 ml of glycerol were added to increase the plasticizing property of the solution. After the addition of the plasticizer, the solution was mixed using a magnetic starrier. The solution was kept in a hot water bath at 70 °C for 20 mins.

Then the solution was kept in the cold water bath at room temperature for 20 mins. After preparation of the solution, the apple fruits were coated using the coating machine which is shown in Figure 1. The solution was coated on the apple fruit using a coating machine which works on the dipping method of coating as shown in Figure 2. Drying of coating solution was done using incubator dryer at 27 °C, and air velocity was optimized using Design Expert software 10.0.1. Dried samples of apple fruit were used for the performance evaluation of the coating machine. Responses results have shown in Table 2.

Response Measurement Technique

Following edible coating machine parameters were calculated as the dependent variable of the experiment and optimization of process parameters for performance evaluation of coating machine [10]. Experimental values of responses for Box-Behnken Design (BBD) are shown in Table 2.

Machine Coating Efficiency

Machine coating efficiency of the hand operated coating machine for horticultural produce was evaluated using the formula Eq. 2.

$$\eta_m = 1 - \frac{W_{dc}}{W_n} \qquad (2)$$

W_{dc}= Weight Difference of coated and uncoated horticultural produce.

W_n = Weight of coating material at ambient conditions.

Change in Colour

Colour plays a very important role in the quality evaluation of the coating machine. A digital camera (Sony 7.2 megapixels) was used to capture the image of the sample. The brightness coordinate L* is used to assess the whiteness value of a color, which ranges from black at 0 to perfect white at 100. The chromaticity coordinates a* determines green when negative and red when positive and the chromaticity coordinate b* measures yellow when positive and blue when negative [11]. The ΔE^*, a*, and b* are used to express colour degradation/change value as a single numerical value. The ΔE^* is defined as the magnitude of total colour differences and is calculated from Eq. 3. The lightness (L), a, and b values were obtained from the Histogram window of Adobe Photoshop CS 5 software. The following equations were used to calculate colour indices such as L*, a* and b*. The measurement of change in colour (ΔE^*) of coated apple fruits.

$$L^* = \frac{Lightness}{255} \times 100$$

$$a^* = \frac{240 \times a}{255} - 120$$

$$b^* = \frac{240 \times b}{255} - 120$$

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (3)$$

Where,

ΔE^* = Distance matrix (colour difference).

$\Delta L^* = L^*_{standard} - L^*_{sample}$,

$\Delta a^* = a^*_{standard} - a^*_{sample}$,

$\Delta b^* = b^*_{standard} - b^*_{sample}$

Standard and sample represent fresh and machine coated fruit, respectively (Fresh apple fruit is the control sample and its ΔE^* value was 0.008832).

ΔL^* represents lightness/darkness.

Δa^* represents the red and green axis.

Δb^* represents the yellow and blue axis.

Weight Loss, Colour Difference and Firmness for Storage Study

Weight loss of the apple fruits during storage study for 10 weeks was conducted using weighing balance, at each week of time the weight of the apple fruit was recorded and weight loss calculated. Colour difference (control and coated) of the apple fruits was measured using HunterLab Colour Flex EZ, 45°/0° colour spectrophotometer (Hunter Associates Laboratory, Inc., Reston, VA, USA). The firmness of the apple fruits was conducted using Texture Analyzer Model TA-XT2i, Stable Micro Systems, Goldalming, Surrey, UK [12].

Table 1. Independent process variables.

Independent Parameters	Levels	Coded and Actual Values		
		-1	0	1

Independent Parameters	Levels	Coded and Actual Values		
Dryer air velocity (X_1, m/s)	3	0	15	30
Reduced drying time (X_2, min)	3	3	5	7
Dipping time (X_3, s)	3	2	4	6

** and * indicates maximum and minimum values.

III. Results and Discussion

Machine Performance

Performance of the hand operated coating machine was conducted on the apple fruit Figure 1 (a) and (b) show the hand operated coating machine for horticultural produce to experimentation. The model developed for each data of response such as machine efficiency (%) and change in colour of coated apple fruit was then examined for significance and lack-of-fit, while response surface graphs were plotted after removal of the non-significant terms. The experimental data were analyzed by employing multiple regression techniques to develop response functions and variable parameters optimized for the best outputs.

(a) (b)

Fig. 1. (a) and (b) represents uncoated and coated apple fruit using machine.

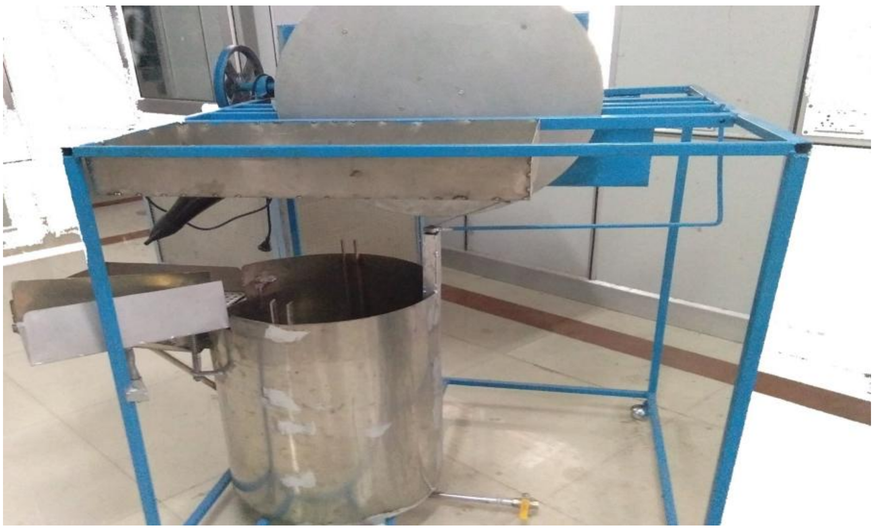

Fig. 2. Hand operated edible coating machine used for experimentation.

Machine Coating Efficiency

During the coating of apple fruit, machine coating efficiency ranged from 71% to 93%. The maximum efficiency of hand operated edible coating machine for apple fruit was 93% with a combination of dryer air velocity (0 m/s), reduced drying time (5 min) and dipping time (6s). At minimum dryer air velocity, machine efficiency was maximum due to less moisture diffusion of coating solution at fruit surface but drying time of coating solution on apple fruit was effectively reduced using incubator dryer. The spray coating of fruits and vegetables did not show good efficiency due to the poor surface distribution of spray droplets. Drop impact behavior is affected by the molecular structure of the food surface in the spray coating mechanism [13]. A highly viscous coating solution has resulted in the decreased spraying coating efficiency on the fruits and vegetables therefore dipping method of edible coating is generally adopted for higher efficiency [14].

Second order mathematical Eq. 1 was fitted into machine efficiency data to analyze the effect of dryer air velocity, drying time reduction and dipping time and other variables were kept constant. The response surface model was developed with values of R^2 (0.98) for machine coating efficiency having the least residual error (0.22) in the fitted second-order regression model. However, R^2_{adj} (0.96) value is relatively close to the model fitted into the experimental data. The coefficient of variation was found at 1.67% which shows minimum variability in data fitted in the model due to a lower value of standard deviation (0.014). The model of machine coating efficiency was found highly significant ($p<0.01$). Therefore, second order regression Eq. 4 was considered to be adequate for describing the effect of independent variables on machine coating efficiency for performance evaluation of coating machine. The effect of dryer air velocity on machine coating efficiency at optimum values of drying time reduction (3.26 min) and dipping time (4.92 s) is shown in Figure 3. Results have demonstrated that by increasing the dryer air velocity from 0 m/s to 30 m/s, machine coating efficiency also decreases by 15.21% as shown in Figure 3 because the increase in the air velocity shrinkage effect was reported due to intense water diffusion coefficients [15].

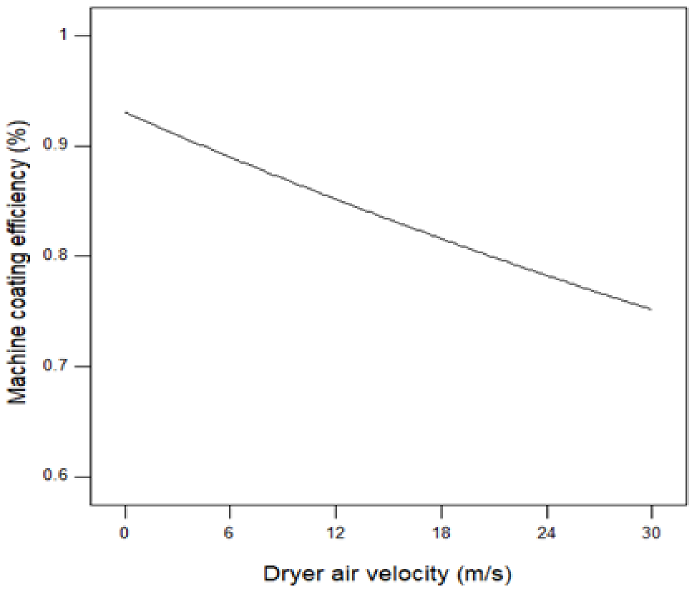

Fig. 3. Effect of dryer air velocity on machine coating efficiency.

A second order mathematical model was developed which represents an empirical relationship between the response and independent variables in actual form. The equation in terms of actual factors can be used to make predictions about the machine coating efficiency. The predicted regression Eq. 4 of machine coating efficiency of coating machine is given below.

$$\text{Machine coating efficiency} = 0.84 - 0.0063X_1 + 0.039X_2 \quad (4)$$

Change in Colour

The experimental results of colour differences obtained were given in Table 2 with the combination of different independent variables. Second order mathematical Eq. 1 was fitted into colour difference data to analyze the effect of dryer air velocity, reduced drying time, dipping time. The adequacy of the model was checked using a numerical method employing the coefficient of determination (R^2) and R^2 adjusted. The response surface model was developed with values of R^2 (0.846) for colour difference having the least residual error (0.212) in the fitted second order regression model. However, R^2_{adj} (0.649) value is relatively close to the model fitted into the experimental data. The coefficient of variation was found at 11.7% which shows minimum variability in data fitted in the model. The model of colour difference was found highly significant ($p<0.05$). Therefore, second order regression Eq. (5) was considered to be adequate for describing the effect of independent variables on colour difference of coating machines.

Table 2. Experimental values of responses for BBD design.

Expt. No	Dryer Air Velocity (X_1, m/sec)	Reduced Drying Time (X_2, min)	Dipping Time (X_3, sec)	Machine Coating Efficiency	Colour Difference (ΔE^*)
1	0	7	4	0.91	17.1
2	0	5	6	0.93**	16.31
3	15	5	4	0.83	25.06
4	15	3	2	0.79	22.74
5	15	5	4	0.83	25.63
6	15	3	6	0.85	24.97
7	30	5	6	0.75	32.35**
8	15	7	2	0.76	27.79
9	15	7	6	0.80	20.8
10	15	5	4	0.81	19.9
11	0	5	2	0.91	18.89
12	30	3	4	0.73	24.86
13	15	5	4	0.84	20.63
14	15	5	4	0.83	24.43
15	30	7	4	0.72	23.71
16	30	5	2	0.71*	22.14
17	0	3	4	0.91	14.58*

** and * indicates maximum and minimum values.

Table 3. Regression analysis of machine coating efficiency and colour difference of coating machine.

Source of Variation	M.E (%)				ΔE			
	SS	DF	MS	p-value	SS	DF	MS	p-value
Model	9	0.077	0.00853	< 0.0001**	266.48	9	29.61	0.0339
	1	0.00344	0.00345	0.004**	163.62	1	163.62	0.0018**
	1	0.00111	0.00111	0.045*	0.63	1	0.63	0.7708
	1	0.000817	0.000818	0.074	1.03	1	1.03	0.7107
	1	0.000025	0.000025	0.725	3.37	1	3.37	0.5073
	1	0.0001	0.0001	0.487	40.90	1	40.90	0.0451*
	1	0.0001	0.0001	0.487	21.25	1	21.25	0.1227
	1	0.000221	0.000223	0.312	23.45	1	23.45	0.1077
	1	0.00132	0.00137	0.321	2.11	1	2.11	0.5976
	1	0.000442	0.00044	0.167	11.50	1	11.50	0.2377
Residual error	7	0.0013	0.000186		48.29	7	6.90	0.5010
Lack of fit	3	0.000825	0.000275	0.220	19.94	3	6.65	0.0339
Pure error	4	0.00048	0.00012		28.35	4	7.09	
Corrected total	0.078	16			314.76	16		
Standard deviation	0.014				2.63			
Coefficient of variance	1.67				11.69			
R-Squared	0.9833				0.8466			
Adjust R-Squared	0.9618				0.6494			
Adequate precision	21.724				8.022			

DF: Degree of freedom, S: Sum of Square, MS: Mean of Square, M.E machine coating efficiency, ΔE colour difference. **, * represents 1% and 5% level of significance. X1, X2, X3 are dryer air velocitiy, reduced drying time and dipping time respectively.

At linear level, from Table 4 it was observed that the dryer air velocity has a higher effect on colour difference as compared to the interactive effect of dryer air flow rate and dipping time based on significance results of both parameters ($p<0.01$), while no significant effect of reduced drying time and dipping time was found on the responses. At the interactive level, the effect (X_1X_3) was found to be significant at a 5% level of significance. The equation in terms of actual factors can be used to make predictions about the colour difference. Therefore, the non-significant terms were removed from the model and then Eqn. 5 has resulted in that describes only the effect of significant process variables on colour difference of coating machine. The equation is as follows:

Table 4. Colour difference values for the given storage period.

Week (s)	Control (ΔE)	Machine coated (ΔE)
1	17.36	16.95
2	16.76	16.94

Week (s)	Control (ΔE)	Machine coated (ΔE)
3	16.75	16.92
4	16.69	16.91
5	16.68	16.92
6	16.66	16.87
7	16.63	16.82
8	16.58	16.76
9	16.49	16.69
10	16.43	16.67

$$\text{Colour difference} = 22.46 + 4.52X_1 + 3.20X_1X_3 \qquad (5)$$

The combined effects of dryer air velocity and dipping time on colour difference at an optimum value of reduced drying time (3.26 min) are shown in Figure 4. Increasing the dipping time from 2 to 6 s significantly ($p<0.05$) affected the colour difference value from 16.9 to 15.6, because increasing the time for dipping also increases the coating protective layer thickness [21]. The dryer air velocity of the machine also affects the colour difference of the apple fruits as shown in Figure 4, this is due to shrinkage resulted from higher mass transfer coefficients at higher air velocity [16]. Colour change (ΔE) was found to be 4.05 after exposing the cut apple fruits in the air for 60 mins [17]. Decrease in dryer air velocity and increasing the dipping time leads to retention of the colour of the apple fruits as shown in Figure 4.

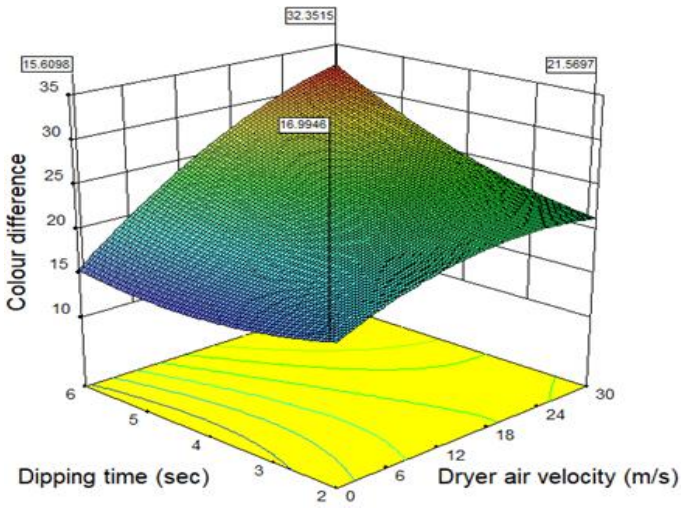

Fig. 4. Interactive effect of dryer air velocity and dipping time on the apple fruit.

IV. Effect of Machine Coating on the Quality of Apple Fruit During Storage

Storage study of the uncoated and coated apple fruit by machine was conducted for 10 weeks and three parameters were selected namely weight loss, firmness and colour change.

Colour Change

Changes in colour of the apple fruits were observed for 10 weeks. During the storage period of each week, L*, a* and b* values were recorded for control and machine coated samples of apple fruits. The value of ΔE is given in Table 4. When compared to the controlled conditions, the machine coated apple fruits reported less colour change, this is due to the formation of a coating layer on the surface of apple fruit [21]. The ΔE value of apple fruit increased from 16.7 to 16.9 after a storage period of 10 weeks [18].

Firmness

Firmness is known as one of the quality indicators of fruit and vegetables and is also used as the primary indication for handling, picking and grading of produce [19]. Firmness values of the apple fruit during the storage were recorded and resulted in 30.7 in control, whereas machine coated were found to be 9.49. Recorded values of firmness are shown in Figure 5 which shows the retention of firmness of apple fruits. The firmness value of the apple fruit was found to be decreased by 36.85 in controlled atmospheric conditions but in the present study, the firmness value was found to be decreased by only 9.16, because the edible coating reduces the fungal growth due to the antimicrobial effect [20].

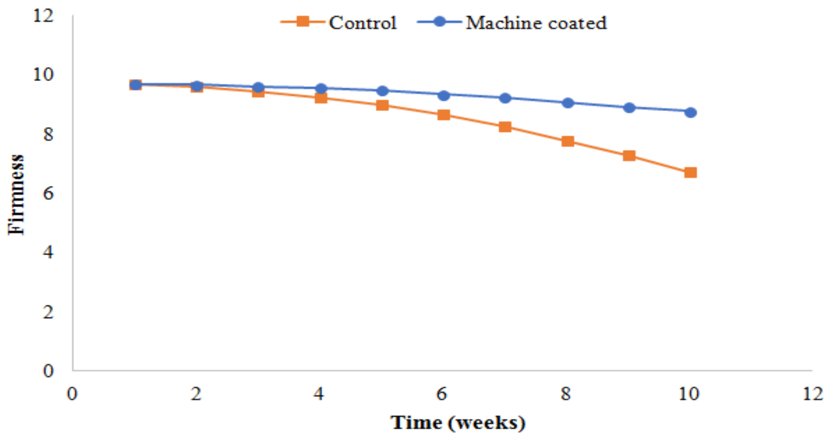

Fig. 5. Firmness values of the apple fruit during storage.

Weight Loss

Weight loss of fruits and vegetables leads to a reduction of the total mass in terms of moisture content and nutritional aspects. Storage study has resulted in the decrease in the weight loss after coating using coating machine whereas higher weight loss was depicted at control conditions as shown in Figure 6. The weight loss of control was reported as 13.2% whereas machine coated depicted a loss of 7.5% because coating reduces the respiration process and exerts the synergistic effect [21].

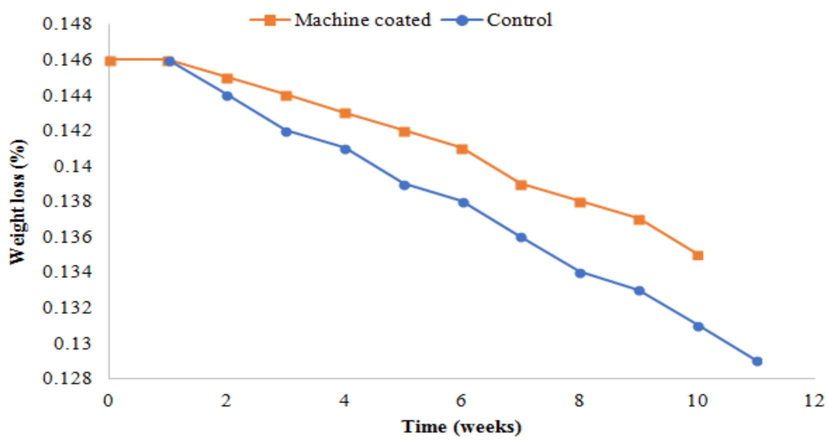

Fig. 6. Weight loss values of apple fruit during the storage period.

V. Conclusion

The hand operated coating machine for horticultural produce has a coating efficiency of 93% and colour difference maximum of 32.4. The maximum coating efficiency was found at dryer air velocity (0 m/s), reduced drying time (5 min) and dipping time (6 s). The machine coating efficiency was highly affected by the dipping time and dryer air velocity because of the increase in the coating layer thickness and shrinkage effect on the apple fruit respectively. Colour difference of the apple fruits was affected by the dryer air velocity and reduced drying time because air velocity increases the mass transfer from the apple fruits. From the results, it can be concluded that the machine has a potential alternative for the small-scale farmers worldwide for the edible coating of agricultural produces.

References

[1] Ionut, D., Camelia, M., and Nicoleta, M.S. Evolution of fruit production worldwide. Agricultural Management/ Lucrari Stiintifice Seria I, Management Agricol, 2017:19(3).
[2] Das K. (2020). Role of organic and environment friendly post-harvest management of organically grown horticultural produces. Int J Chem Stud, 8, 1553-6.
[3] Augustin M A, Sanguansri L, Fox E M, Cobiac, L, Cole M.B. Recovery of wasted fruit and vegetables for improving sustainable diets. Trends in Food Science & Technology 2020; 95, 75-85.
[4] Tahir H E, Xiaobo Z, Mahunu G K, Arslan M, Abdalhai M, Zhihua L. Recent developments in gum edible coating applications for fruits and vegetables preservation: A review. Carbohydrate polymers, 2019; 224, 115141.
[5] Nesic A, Cabrera-Barjas G, Dimitrijević-Branković S, Davidović S, Radovanović N, Delattre C. Prospect of polysaccharide-based materials as advanced food packaging. Molecules 2020; 25 (1), 135.
[6] Yousuf B, Qadri O S, Srivastava A K. Recent developments in shelf-life extension of fresh-cut fruits and vegetables by application of different edible coatings: A review. LWT-Food Science and Technology 2017.
[7] Riva S.C., Opara U.O., Fawole O.A. Recent developments on postharvest application of edible coatings on stone fruit: A review. Scientia Horticulturae, 2020; 262, 109074.
[8] Suhag R., Kumar N, Petkoska A.T., Upadhyay A. Film formation and deposition methods of edible coating on food products: A review. Food Res. Int 2020; 136, 109582.
[9] Market trend in beverage industry. [weblink: Market trend in beverage industry | Food & Drink Industry Magazine (ifttrade.com)]. [Visited on 7 June, 2021].
[10] A Tripathi, S Kumar, KS Kumar, A Rawson. Effect of ultrasonication process on the physical properties of three different honey varieties. Indian Journal of Pure & Applied Biosciences 2020; 8(6): 667-674.
[11] Design, development and performance evaluation of hand operated coating machine for horticultural produce. [weblink: https://krishikosh.egranth.ac.in/handle/1/5810092833]. [visited on 3 July, 2021].
[12] De Jesus Ornelas-Paz J., Quintana-Gallegos B.M., Escalante-Minakata P, Reyes-Hernandez J., Perez-Martínez J.D., Rios-Velasco C., Ruiz-Cruz S. Relationship between the firmness of golden delicious apples and the physicochemical characteristics of the fruits and their pectin during development and ripening. Journal of food science and technology 2018; 55(1), 33-41.
[13] Andrade R, Skurtys O, Osorio F. Drop impact behavior on food using spray coating: Fundamentals and applications. Food research international 2013; 54(1), 397-405.
[14] Kumar S. Design, development and performance evaluation of hand operated coating machine for horticultural produce (Doctoral dissertation, GB Pant University of Agriculture and Technology, Pantnagar-263145 (Utarakhand)).
[15] Garcia C.C., Caetano L.C., de Souza Silva K., Mauro M.A. Influence of edible coating on the drying and quality of papaya (Carica papaya). Food and bioprocess technology 2014; 7(10), 2828-2839.
[16] Performance Evaluation of hand operated coating Machine for rheological parameters. [weblink: View article (google.com)]. [visited on 2 July, 2021].
[17] Shrestha L, Kulig B, Moscetti R, Massantini R, Pawelzik E, Hensel O, Sturm B. Optimisation of physical and chemical treatments to control browning development and enzymatic activity on fresh-cut apple slices. Foods, 2020; 9 (1), 76.
[18] Ganai S A, Ahsan H, Wani I A, Lone A A, Mir S A, Wani S M. Colour changes during storage of apple cv. Red delicious-influence of harvest dates, precooling, calcium chloride and waxing. International Food Research Journal 2015; 22(1), 196.
[19] Konopacka D, Plocharski W J. Effect of storage conditions on the relationship between apple firmness and texture acceptability. Postharvest Biology and Technology, 2004; 32(2), 205-211.
[20] Zambrano-Zaragoza M.L., Quintanar-Guerrero D., Del Real A., González-Reza R.M., Cornejo-Villegas M A, Gutiérrez-Cortez E. Effect of nano-edible coating based on beeswax solid lipid nanoparticles on strawberry's preservation. Coatings, 2020; 10(3), 253.
[21] Soares N.M, Fernandes T.A., Vicente A.A. Effect of variables on the thickness of an edible coating applied on frozen fish-establishment of the concept of safe dipping time. Journal of Food Engineering, 2016; 171, 111-118.

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