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Optimization of Tomato Fruit Color after Simulated Transport Using Response Surface Methodology (RSM)

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Abstract Color is the initial parameter visible to the consumer in choosing a horticultural product including tomatoes, because the color is a determinant of the level of maturity and freshness of the product. The presence of vibration during the transportation process of tomato fruit can affect change in color of tomatoes. Optimization is used in this study in order to obtain optimum quality of tomato fruits after simulation transport. Optimization by using Response Surface Methodology (RSM) methods Central Composite Design (CCD) with two independent variables are the vibration frequencies (3 Hz, 6Hz, and 9Hz) and the duration of vibration (90, 120, and 150 minutes) as well as the color of tomatoes as a response. The optimum conditions obtained in the vibration frequency of 2,38 Hz and transport simulation time 89,44 minutes with optimum color quality value of tomatoes is the brightness (L*) 32,9994, a* value 13,6425, and b* value 24,1323 with a value of desirability that 0,955.

Keywords Vibration, Color of tomato, Optimization, RSM

1. Introduction

Damages that occur early in the post-harvest tomatoes are usually caused by the activities of packaging and transportation. Tomato fruit will be subjected to pressure and vibration during transport takes place that tomatoes are susceptible to injuries. During transportation, piles of tomatoes in the wooden box will be under pressure and vibration caused by several factors, such as the condition of the road is not flat, mileage, the packing process, and the speed of the vehicle (Mukti, 2013). Tomatoes excessive packaging results in tomato injuries, especially on the bottom of the pile because the tomatoes withstand considerable burden for a long time during transport. Meanwhile, when the package contents too little, this will cause conflicting pieces that are thrown due to vibrations that occur, causing friction between the fruit and the fruit friction with the packaging (Kusumah, 2007).

The size of the frequency, amplitude and duration of vibration during transport, as well as high and piles of fruit load, are factors that also greatly affect tomato fruit damage. Where the higher and the greater burden of the mechanical damage that occurs the greater. Damage due to vibration causing changes in fruit generally in the range of 3-7 Hz vibration frequency. (Marcondes and Sing, 1989). Damage to tomato fruit caused by the effect of vibration during transport sometimes can not be seen directly on the outside of the fruit, but the damage will accelerate the respiration rate of the fruit, so the fruit rapid ripening and decay process (Pantastico, 1989). Damage in tomatoes affect the quality, which can cause deterioration in quality such as discoloration on the fruit.

Maturation in tomatoes is indicated by color changes of the skin of tomatoes, where the color will be red tomatoes. Color is the initial parameters are visible to the consumer in choosing a horticultural products including tomatoes, because of the color as a determinant of the level of maturity and freshness of the product.

Response surface methodology (RSM) was used in this study to obtain the optimal conditions of the transport process, so as to produce quality tomato fruit in terms of optimum colors that match the desires of consumers. Optimization using response surface methodology (RSM) in which the experiment was designed using a central composite design (CCD).

2. Materials and Methods

Materials

Materials used are servo varieties of fresh tomatoes with physiological maturity level and size (weight) is relatively uniform with a yellowish red color. Equipment used consists of digital scales, wooden boxes, colorimeter, and circuit simulator vibration. Tomato fruit arranged in a wooden box and then simulated transport using vibrating table.

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Design and Data Analysis

Optimization of transport using central composite design (CCD) with two factors and each consists of three levels, namely the frequency of vibration (X_1) consist of 3 Hz, 6Hz, 9 Hz and a vibration (X_2) consists of 90, 120, 150 minutes which is the independent variable and the color of tomatoes is the dependent variable (Y). By Montgomery (2001), using the model of central composite design (CCD) with the design of 2^k factorial (k = 2) so that the design is 2^2, which were obtained by the value of α ($2^{k/4}$) = 1,41421 (star point), and the center point (n_c) or middle value (0.0) is repeated 5 times, it will get 13 combined treatment. Data analysis was performed using software Design Expert 7.0.0.

3. Results and Discussion

By using an instrument to objectively determine the color value, it can be seen the value of L*, a*, and b* of tomatoes. L* value declare the brightness level of the fruit measured, a* value indicating red color of tomatoes, and b* values indicate yellow color of tomatoes.

Analysis Response Brightness (L*)

From the results of data processing using the program Design Expert 7.0.0 Trial Version obtained a second order polynomial equations (quadratic) brightness of tomatoes:

$$Y = +31{,}29387 + 0{,}47799X_1 + 0{,}030710X_2 - 6{,}38889E\text{-}004X_1X_2 - 0{,}12164X_1^2 - 1{,}69167E\text{-}004X_2^2 \quad (1)$$

Table 1. Response Colors of Tomatoes after Simulated Transport

Run	Frequency (*Coded*)	Time (*Coded*)	Frequency (Hz)	Time (minute)	Color L*	a*	b*
1	0	-1,4142	6	77,57	31,77	14,17	22,83
2	0	1,41421	6	162,43	29,83	15,27	22,53
3	-1,4142	0	1,76	120	33,43	13,77	24,77
4	1,41421	0	10,24	120	24,40	19,67	17,17
5	-1	1	3	150	31,87	13,99	23,05
6	1	-1	9	90	25,83	18,13	18,60
7	1	1	9	150	25,44	18,20	18,37
8	-1	-1	3	90	32,03	13,80	23,30
9	0	0	6	120	30,16	15,07	22,00
10	0	0	6	120	31,03	14,77	21,70
11	0	0	6	120	30,55	14,20	22,57
12	0	0	6	120	31,47	14,13	21,47
13	0	0	6	120	29,65	13,63	22,40

Table 2. Summary of Responses ANOVA Tomato Fruit Color

Responses	Color L*	a*	b*
Prediction models	Quadratic	Quadratic	Quadratic
Model	0,0002	<0,0001	0,0002
A-Frequency	<0,0001	<0,0001	<0,0001
B-Time	0,207	0,2327	0,6438
AB	0,8946	0,9063	0,9884
A^2	0,0107	0,0003	0,0173
B^2	0,6462	0,2094	0,7672
Lack of fit	0,2739	0,7474	0,1305
Std. Dev.	0,84	0,49	0,66
Mean	29,8	15,29	21,6
C.V.%	2,81	3,21	3,06
PRESS	23,61	4,9	17,08
R-Squared	0,9485	0,9654	0,9474
Adj R-Squared	0,9117	0,9406	0,9098
Pred R-Squared	0,7522	0,8996	0,7068
Adeq Precision	15,785	19,027	15,827

Source: Data Processing DX 7.0.0
The significant level of 0.05

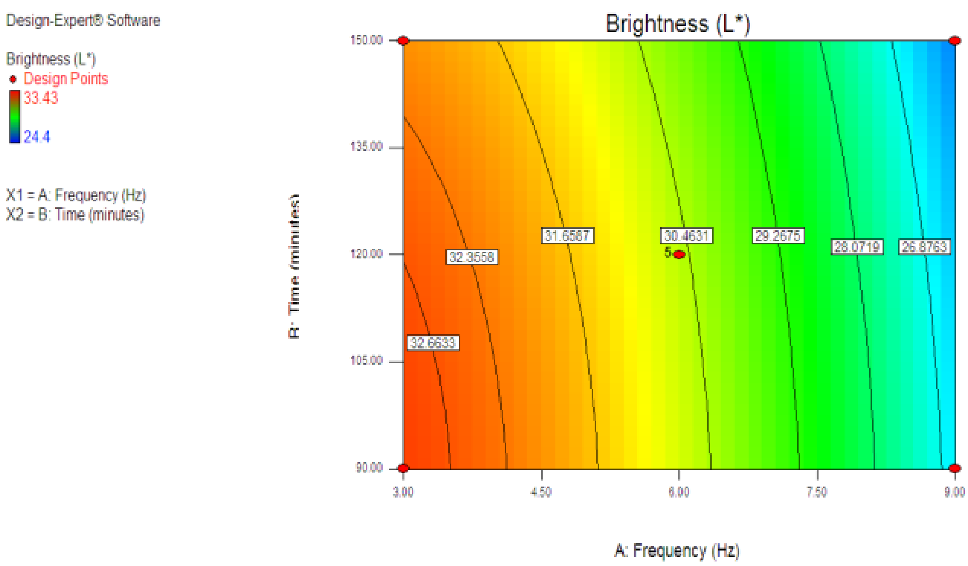
Only variable frequency (X_1) and quadratic frequency ($X_1{}^2$) have a significant impact on the response of the brightness of the tomatoes (Table 2). The higher the frequency of vibration, the smaller the tomato fruit brightness. Based on the calculation of the roots of the characteristic matrix B, we found that the root characteristics (eigen values of matrix) are λ_1= -1,09 and λ_2= -0,147. Eigen values obtained are both negative, so it can be concluded that the response surface produced a maximum (Aunudin, 2005). Response surface model can be seen in the following figure 1.

Response Analysis a* Value of Tomato

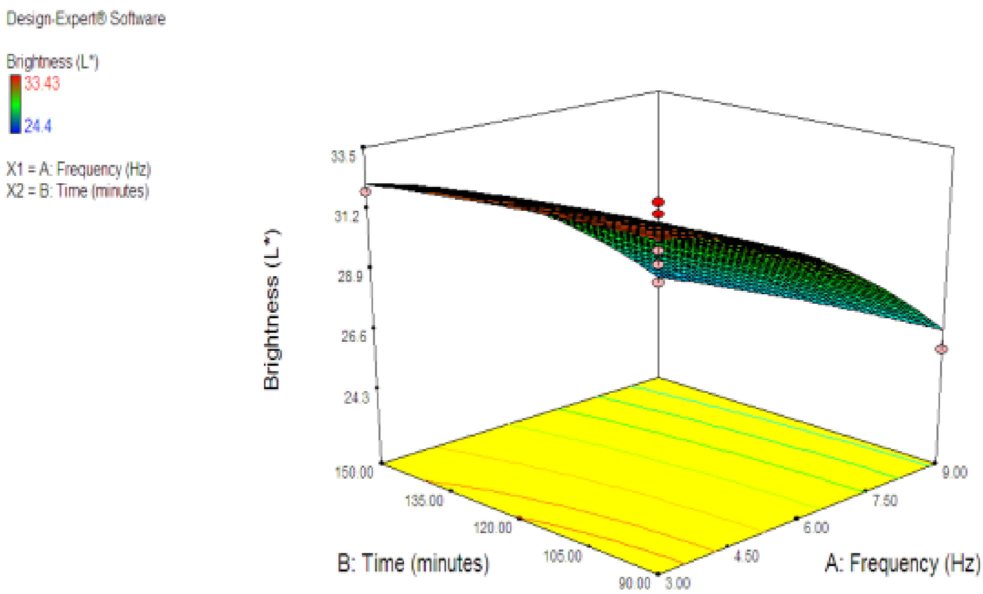
From the results of data processing using the program Design Expert 7.0.0 Trial Version obtained a second order polynomial equations (quadratic) a* value of tomatoes:

$$Y = +18{,}14122 - 0{,}93317X_1 - 0{,}059102X_2 - 3{,}33333E\text{-}004X_1X_2 + 0{,}13972X_1{}^2 + 2{,}86111E\text{-}004X_2{}^2 \quad (2)$$

Only variable frequency (X_1) and quadratic frequency ($X_1{}^2$) have a significant impact on the response of the a* value of tomatoes (Table 2). The higher the frequency of vibration, the more increased the a* value of tomatoes. Based on the calculation of the roots of the characteristic matrix B, we found that the root characteristics (eigen values of matrix) are λ_1= 0,255 and λ_2= 1,282. Eigen values obtained were both positive values, so it can be concluded that the response surface produced a minimum (Aunudin, 2005). Response surface model can be seen in the following figure 2.



(A)



(B)

Figure 1. Response Surface Curve Frequency and Vibration Time of the Response Brightness of Tomato Fruit Contour Plot (A) and 3D Graphics (B)

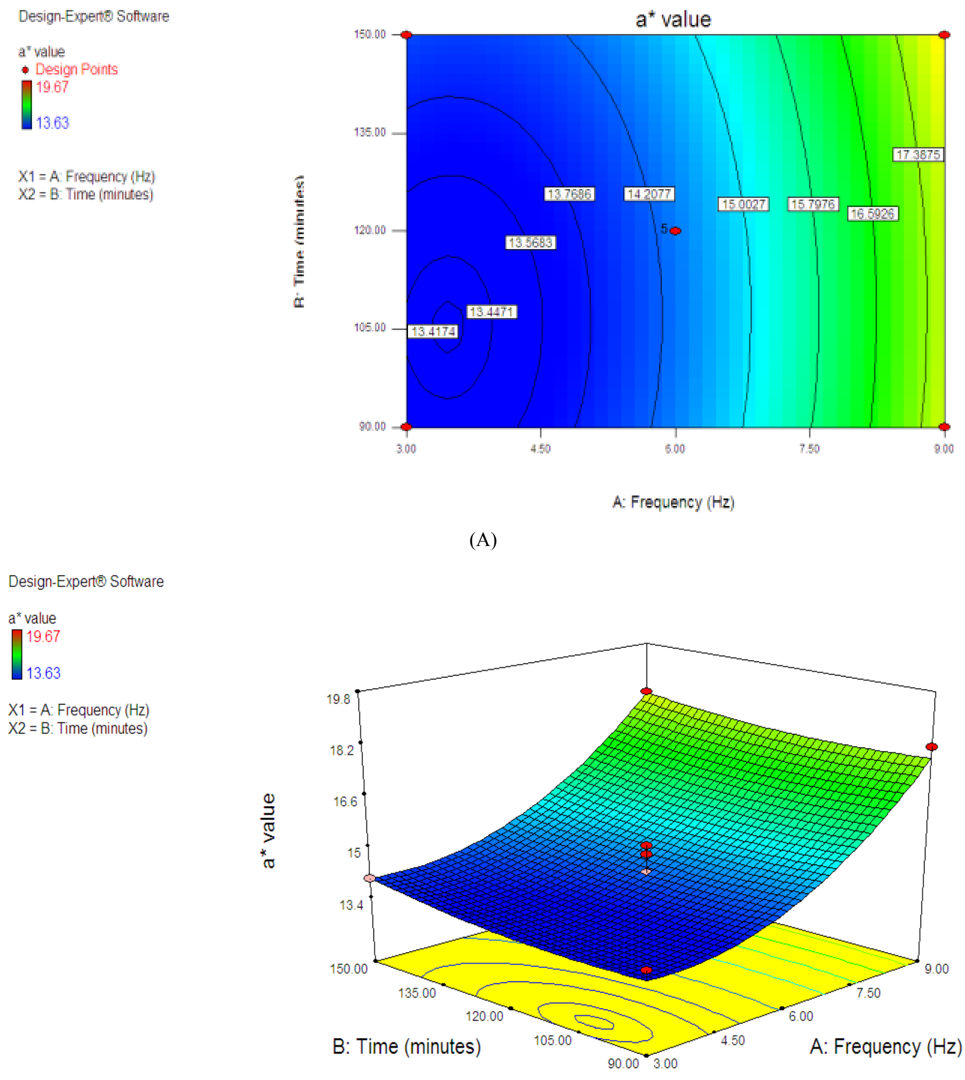


Figure 2. Response Surface Curve Frequency and Vibration Time of the Response a* Value of Tomato Fruit Contour Plot (A) and 3D Graphics (B)

Response Analysis b* Value of Tomato

From the results of data processing using the program Design Expert 7.0.0 Trial Version obtained a second order polynomial equations (quadratic) b* value of tomatoes:

$$Y = +25{,}67714 + 0{,}19167X_1 - 0{,}024701X_2 + 5{,}55556E\text{-}005X_1X_2 - 0{,}086417X_1^2 + 8{,}58333E\text{-}005X_2^2 \quad (3)$$

Only variable frequency (X_1) and quadratic frequency (X_1^2) have a significant impact on the response of the b* value of tomatoes (Table 2). The higher the frequency of vibration, the more decreased the b* value of tomato fruit. Based on the calculation of the roots of the characteristic matrix B, we found that the root characteristics (eigen values of matrix) are λ_1= 0,0766 and λ_2= -0,7844. Eigen values obtained different sign, so it can be concluded that the response surface generated in the form plana (saddle point) (Aunudin, 2005). Response surface model can be seen in the following figure 3.

In general, discoloration in tomatoes caused by metabolic reactions in fruit and with the frequency of vibration during transport simulation, it can speed up the metabolic processes so that the degradation of chlorophyll can not be suppressed (Kismaryanti, 2007).

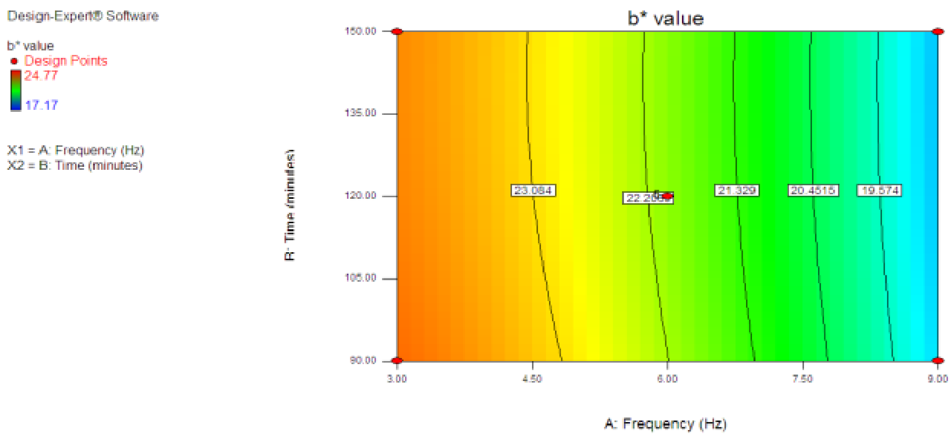
Response Optimization of Tomato Fruit Color

Criterion or objective function is used to determine the optimal conditions adapted to the constraints as presented below:

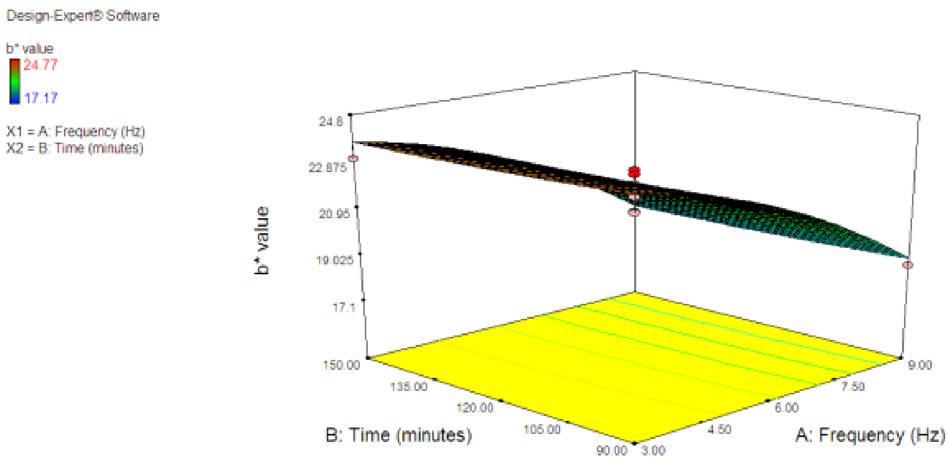
Table 3. Response Constraints for Optimization

Name	*Goal*	*Lower Limit*	*Upper Limit*
Frequency	is in range	1,76	10,24
Time	is in range	77,57	162,43
Brightness (L)*	Maximize	33,43	24,40
a value*	Minimize	19,67	13,63
b value*	Maximize	24,77	17,17

Source: Data Processing DX 7.0.0



(A)



(B)

Figure 3. Response Surface Curve Frequency and Vibration Time of the Response b* Value of Tomato Fruit Contour Plot (A) and 3D Graphics (B)

Table 4. Optimal Solutions

No	Frequency (Hz)	Time (minutes)	Brightness (L*)	a* Value	b* Value	*Desirability*	
1	2,38	89,44	32,9994	13,6425	24,1323	0,955	*selected*
2	2,39	88,55	32,999	13,6483	24,139	0,955	

Source: Data Processing DX 7.0.0

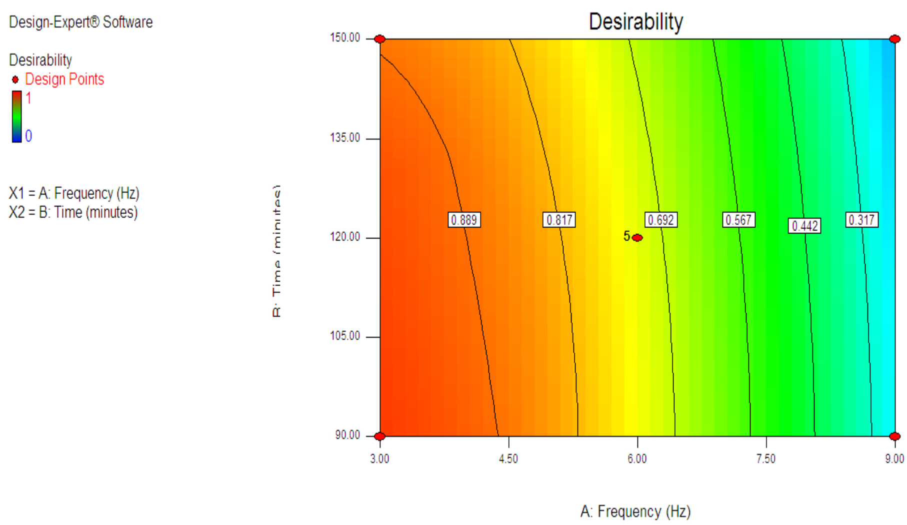
Response optimization results are presented in the form of contour plots and three-dimensional form below:

Based on the contour plot and the resulting three-dimensional shapes in Figure 4, we obtained two composition formulas that were considered to provide optimum solutions which can be seen in the following table:

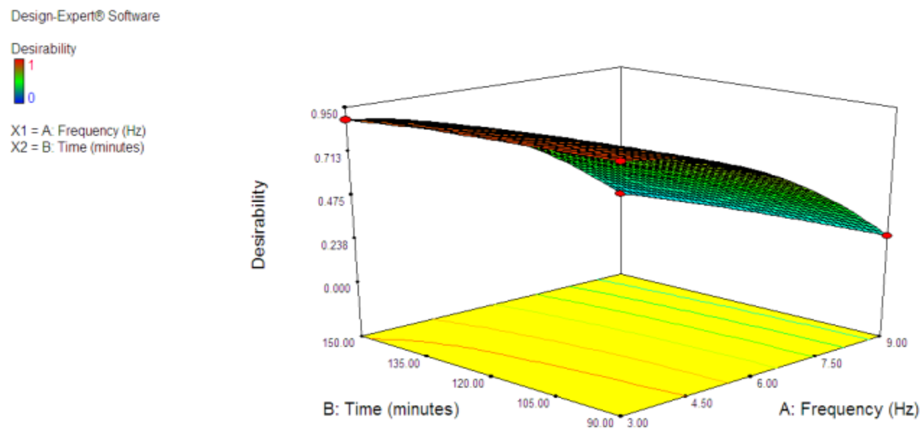
Of the two optimum solutions offered, the program suggests the solution chosen is indicated on the first no, corresponding to a vibration frequency of 2,38 Hz a length of time of 89,44 minutes, with the optimal response to the brightness value of 32,9994, a a* value of tomatoes of 13,6425, and b* tomatoes value of 24,1323 with a large enough value of desirability that 0,955. Desirability value that can be achieved with a value of 0.955 indicates that formula will produce quality tomatoes have optimum color characteristics and according to the wishes or consumer criteria of 95,5%.

4. Conclusions

From the results of optimization using response surface methodology (RSM) methods using central composite design (CCD) model with DX 7.0.0 software, we obtained as optimum variables: vibration frequency 2,38 Hz transport simulation time 89,44 minutes, with optimum color quality values of tomatoes like brightness (L*) 32,9994, a* value (red tomato color) 13,6425, and b* value (yellow tomato color) 24,1323, with a desirability value of 0,955.



(A)



(B)

Figure 4. Surface Curve Effect of Frequency and Vibration Time to Response Tomato Fruit Color Countour Plot desirability (A) and 3D (B)

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