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Optimization of Ethanol and Potassium Sorbate Treatment for Minimizing Postharvest Losses in Onion Bulbs (*Allium Cepa* L. cv. *Sukhsagar*)

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Abstract

Response surface methodology (RSM) was used to optimize treatment combination of ethanol and potassium sorbate for minimizing physiological loss in weight (PL_W) and rotting of onion bulbs during storage. Based on Central composite rotatable design (CCRD), PL_W and rotting percent as responses, 13 treatment combinations were selected involving four factorial points, four axial points and five central points. Optimum treatment combination of model generated by RSM was ethanol (71.08 percent; v/v) and potassium sorbate (0.76 percent; w/v). It was observed that this combination of ethanol and potassium sorbate had significantly reduced PL_W and rotting percent (8.57 and 1.38 percentage, respectively) during storage up to 90 days. Two-tailed t-test (assuming unequal variances) statistics ($P<0.05$) showed no significant difference between RSM-predicted and experimental values of the two responses. Hence, optimum treatment combination generated using CCRD/RSM was validated and confirmed from this study.

Keywords: Onion, shelf-life, PL_W, rotting, optimization, ethanol, potassium sorbate.

1. Introduction

Onion, scientifically known as Allium cepa L., is a member of class Liliaceae and family Alliaceae, widely distributed and grown in tropical, sub-tropical and temperate climatic zones (Fritsch and Friesen, 2002). It is a biennial crop (Bohanec, 2003), and in

India it is grown twice (Rabi and Kharif season) in a year due to its wide consumer demand (NHRDF, 2009). Besides its culinary values, onion provides variety of health promoting compounds (Slimestad et al, 2007). However, productivity of onion bulbs in India is comparatively very low (16.41 tons/ha), particularly due to disease associated during its cultivation and postharvest processing, handling and storage system (NHRDF, 2009). Therefore, good storage techniques become essential. The main purpose of onion bulb storage is to maintain reasonably stable price throughout the year whilst maintaining the product quality during extended shelf-life period (Chope et al, 2005). So far as extension of shelf-life is concerned, Qadir et al (2007) has reported the delay of sprouting, rooting and decay with ethanol vapour treatment on bulbs (cv. Tazan and Lyomante) during storage for three months. Karabulut et al (2005) achieved an effective control of postharvest disease of grapes with pre-storage treatment of ethanol in combination with potassium sorbate.

On the other hand, controlled atmosphere, cold storage, storage at ambient temperature with controlled relative humidity, pre-harvest and postharvest application of costly chemicals have been reported to control losses of bulbs due to sprouting, rooting and rotting during storage in temperate climate (Gubb and MacTavish, 2002; Downes et al, 2009). However, these methods of onion storage are costly and therefore, are not sustainable at commercial level. Hence, cheap alternative approaches for storage becomes inevitable. In view of the above, the objective of this study was fixed to evaluate the effect of ethanol in combination with potassium sorbate on PL_W and rotting of bulbs during storage, and to achieve the above objective, optimization and generation of regression model for treatment effect was carried out with CCRD and RSM, respectively (Senanayake and Shahidi, 2002; Zahid et al, 2011).

2. Materials and Methods

CCRD was used to generate experimental trials based on combination of different concentrations of factors (ethanol and potassium sorbate), and its responses (PL_W and rotting percentage) were studied. The effect of factors on responses was reported using RSM. Onion bulbs of cv. Sukhsagar with uniform size (55± 10 mm diameter) were procured from a commercial supplier and sorted for use as experimental material. For giving treatment to the bulbs for extending shelf-life, a hand sprayer with a fine nozzle was used. Mixture of different concentrations of ethanol and potassium sorbate were sprayed (three kg onion per treatment) until entire surface area of bulbs was wet. Thereafter, the bulbs were air dried and placed in cartons and stored at room temperature (30 ± 2 ^{0}C) in the dark for 90 days. Relative humidity in the storage room ranged from 73±2 % during the period of experimentation.

Observations were recorded on the physical parameters namely, PL_W and rotting percentage at the end of the storage period of 90 days. For recording PL_W, weight of the bulbs was recorded at the end of 90 days after storage (DAS) using an electronic balance (having least count of 0.1 g). The cumulative loss in weight of bulbs were calculated and expressed in percentage using the formula given below (Koraddi and Devendrappa, 2011):

$$\text{PLW (\%)} = \frac{(\text{Initial weight} - \text{Final weight})}{\text{Initial weight}} \times 100$$

Observations were also recorded on rotting percentage at the end of 90 DAS. It was calculated by the following formula given below (Kukanoor, 2005):

$$\text{Rotting (\%)} = \frac{\text{Weight of rotted bulbs}}{\text{Initial weight of bulbs}} \times 100$$

2.1 Experimental design for determination of optimum combination of ethanol and potassium sorbate

A five-level with two variables Central composite rotatable design was used in the present study. The design required 13 experiments including four factorial points, four axial points, and five replications at the central point. Five replications of the central point provided sufficient degrees of freedom for estimating the experimental error. In CCRD, low actual value and high actual value of ethanol (50-75%) and potassium sorbate (0.5-1%) was fixed based on preliminary trials made. The factors and their levels in the experimental design are shown in Table 1. The statistical analysis of the data was performed using Design-Expert 7.0 (Stat-Ease, Inc., Trial version) and the results are shown in Tables 2. The second-order quadratic regression equation of the following form developed for PL_W and rotting percentage is given below:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2 \qquad (1)$$

Where, Y is predicted response, β_0 is a constant, β_1 and β_2 represents regression coefficient of linear terms, β_{11} and β_{22} represents, regression coefficient of quadratic terms and β_{12} represents regression coefficient of interaction terms, and x_1 and x_2 are the coded values of an independent variables i.e. PL_W and rotting percent respectively.

Table 1: Central composite rotatable design (CCRD) for the factors (actual and coded levels).

Run#	Independent Variables			
	Actual level		Coded level	
	Ethanol (%)	Potasium sorbate (%)	x1	x2
1	75.00	0.50	+1	-1
2	75.00	1.00	+1	+1
3	50.00	1.00	-1	+1
4	50.00	0.50	-1	-1
5	80.18	0.75	+1.414	0
6	62.50	1.10	0	+1.414
7	44.82	0.75	-1.414	0

8	62.50	0.40	0	-1.414
9	62.50	0.75	0	0
10	62.50	0.75	0	0
11	62.50	0.75	0	0
12	62.50	0.75	0	0
13	62.50	0.75	0	0

3. Results and Discussion

3.1 Model fitting and statistical analysis of response

The experimental responses with respect to variation of two factors were evaluated by generating the best model equation for the particular response. The quadratic models were chosen for both the responses, as it gave higher precision which are presented in the equations given below with respect to coded factors. Therefore, the simplified second-order regression equations for PL_W and rotting percent in terms of coded factors were determined with the following equation:

$$Y_1 = +9.05 - 1.14x_1 - 0.66x_2 + 0.66x_1^2 + 0.71x_2^2 + 0.55x_1x_2 \quad (2)$$

$$Y_2 = +1.55 - 0.67x_1 - 0.34x_2 + 0.62x_1^2 + 0.70x_2^2 + 0.22x_1x_2 \quad (3)$$

where, independent variables x_1 and x_2 are ethanol (v/v with water) and potassium sorbate (w/v with water), respectively, and Responses Y_1 and Y_2 are responses in terms of PL_W (%) and rotting (%) at the end of 90 DAS respectively. The model significance (F and *P*-value), determination coefficient (R^2), coefficient of variation (C.V %), and lack of fit criteria were used to judge the goodness of fitted model. Factor with most significant effect in regression equation for PL_W (%) was the linear term of ethanol (x_1), followed by quadratic term of potassium sorbate (x_2^2), linear term of potassium sorbate (x_2), and quadratic term of ethanol (x_1^2), respectively. Their respective *P*-value proved that they are highly significant ($P < 0.01$). These suggested that ethanol (x_1) have more direct relationship with PL_W percent than potassium sorbate (x_2). In regression equation for rotting (%), the linear term of ethanol (x_1), followed by quadratic term of potassium sorbate (x_2^2) was most significant ($P < 0.01$) factor. Unlike, regression equation for PL_W (%), quadratic term of ethanol (x_1^2) was found to be more significant factor over linear term of potassium sorbate (x_2) in regression equation for rotting (%). This suggested that quadratic term of potassium sorbate is more related to rotting than linear term of potassium sorbate. However, interactive terms (x_1x_2) of regression equation for PL_W (%) is more significant at 0.01 level, than interactive terms of regression equation for rotting (%), which is significant at 0.05 level. Regression model obtained from CCRD was found to be highly significant ($P < 0.0001$) for PL_W and rotting with coefficient of determination, R^2 of 0.978 and 0.980, respectively. The large F-values (PL_W percent 63.11, rotting percent 71.14) and small *P*-value ($P < 0.01$) suggested that the models were statistically significant at 0.01 level

(Myers et al. 2002). F-values and *P*-values enlisted in Table 2, indicates the significance of each regression coefficient. Predicted R^2 of 0.90 and 0.88 is in reasonable agreement with adjusted R^2 of 0.96 and 0.97 for PLW and rotting percent models, respectively (Joglekar and May, 1987). Coefficient of variation percent (CV) for PL_W percent (2.61), and rotting percent (7.11) was found to be less than 10%, which indicated better precision and reliability of the experiments conducted. The insignificant lack of fit value for the quadratic model (*P*= 0.3607 and *P*= 0.1022 for PL_W and rotting percent, respectively) suggested statistical acceptability of the regression model for screening experimental design to predict both the responses.

Table 2: Significance level of regression coefficient for response variables.

	PLW (%)				**Rotting (%)**			
Source	**Regression coefficient**	**S.E.**	**F-value**	**P-value**	**Regression coefficient**	**S.E.**	**F-value**	**P-value**
β0	+9.05*	0.12	63.11	<0.0001	+1.55*	0.07	71.14	<0.0001
Linear								
β 1	-1.14*	0.09	157.72	<0.0001	-0.67*	0.06	126.71	<0.0001
β 2	-0.66*	0.09	52.17	0.0002	-0.34*	0.06	32.73	0.0007
Quadratic								
β 11	+0.66*	0.09	46.18	0.0003	+0.62*	0.06	94.90	<0.0001
β 22	+0.71*	0.09	53.02	0.0002	+0.70*	0.06	119.20	<0.0001
Interaction								
β 12	+0.55*	0.13	17.88	0.0039	+0.22*	0.08	6.69	0.0361**
Lack of Fit			1.42	0.3607NS			4.13	0.1022NS
R2	0.978				0.980			
Adj. R2	0.963				0.967			
Pred. R2	0.904				0.889			
C.V. %	2.61				7.11			

Subscripts: 1=Ethanol; 2=Potassium sorbate; Adj= adjusted; Pred= predicted; C.V= coefficient of variation; S.E= standard error; *significant at 0.01 level. **significant at 0.05 level. ^{NS}=non-significant.

3.2 Effect of chemicals on PL_W and rotting percent at the end of storage study

The three dimensional response curve plots were generated using the regression equations to assess the effect of ethanol and potassium sorbate on the PL_W and rotting percent. The significance of each variables and its interaction were assessed by evaluating three-dimensional response plots described in Figure 1.

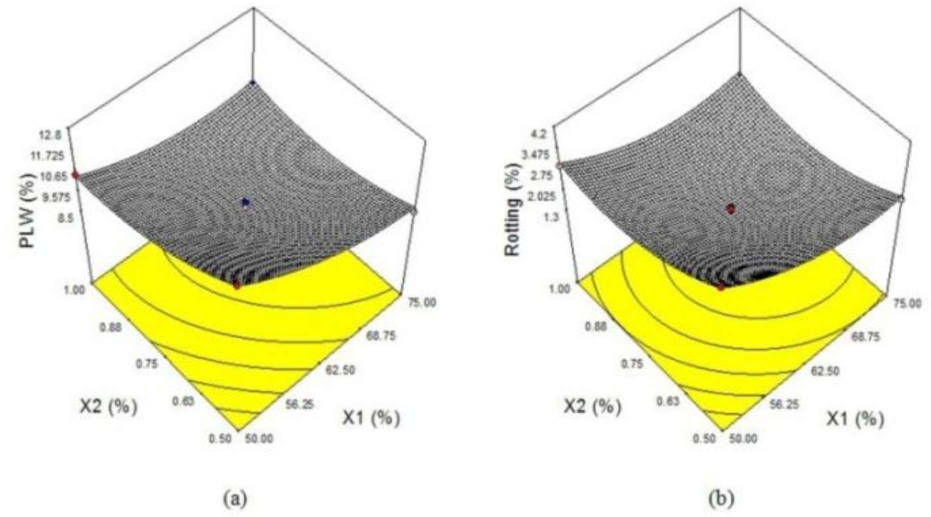

Figure 1: Surface plots showing variation in (a) PL_W and (b) Rotting with ethanol and potassium sorbate.

3.3 Optimization

For obtaining optimum combination of ethanol and potassium sorbate in reducing PL_W and rotting during storage, multiple response optimizations applying desirability approach in response surface methodology was done. According to the objective of the experiment, criteria for responses (PL_W and rotting percent) were minimized and factors were kept in range i.e. 50-75% for ethanol and 0.5-1.0% for potassium sorbate. As reported by Myers et al (2002) each response (Y_i) was converted into an individual desirability function (d_i) that varied over a range of $0 \leq d_i \leq 1$, and nature of responses were studied by using value of the desirability functions.

With these conditions set, 30 different solutions for numerical optimization were generated. Out of those, solution (71.08% ethanol; 0.76% potassium sorbate) with predicted score of 8.57% for PL_W and 1.38% for rotting was chosen based on above considerations and small variation between different solutions obtained. Therefore, the optimum combination of ethanol and potassium sorbate to reduce PL_W and rotting percent during storage was identified as ethanol (71.08 percent, v/v) and potassium sorbate (0.76 percent, w/v) having desirability index of 1.00, which is considered as satisfactorily good value. Hence, the treatment combination has been selected for further validation of the optimized combination obtained by the RSM. An overlay plot in Figure 2 was obtained from graphical optimization, showed the optimum concentrations of ethanol and potassium sorbate as 71% ethanol and 0.76% potassium sorbate with predicted value of responses as 8.57% and 1.38% for PL_W and rotting percentage, respectively. Hence, the predicted values of responses obtained from numerical and graphical optimization were closely situated.

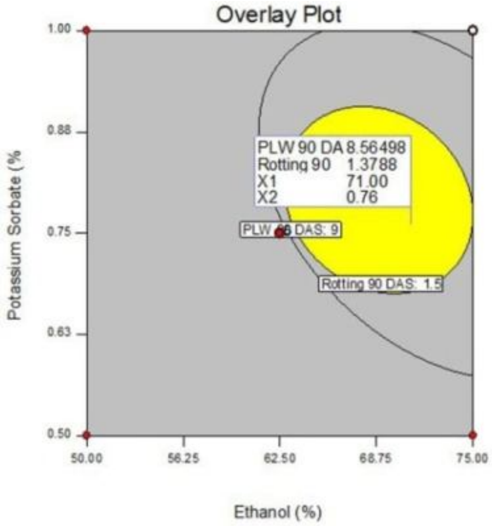

Figure 2: Overlay plot showing optimum region for responses of two treatments.

4. Model Verification

Model verification was done with additional three sets of experiments with obtained numerically optimized combination from CCRD/RSM model to obtain the actual values of responses (PL_W and rotting percent). The actual values of responses obtained after storage of 90 days in dark, at ambient room temperature is presented in Table 3. The predicted value suggested by the RSM model was 8.57 % for PL_W and 1.38 % for rotting. Two-tailed t-test (assuming unequal variances) statistics ($P<0.05$) was performed to find the difference between means of experimental and predicted values of PL_W and rotting percent values. From t-test it was found that means of experimental value and predicted value of responses (PL_W and rotting percentage) were not significantly different from each other. Hence, the results of validation parameters were satisfactory.

Table 3: Experimental values of responses 90 DAS of onion bulbs treated with optimized combination of ethanol and potassium sorbate.

Independent Trials	a Experimental Values of PLW (%) 90 DAS	b Experimental Values of Rotting (%) 90 DAS
Trial 1	8.25 ± 0.11	1.42 ± 0.01
Trial 2	8.68 ± 0.15	1.40 ± 0.05
Trial 3	9.15 ± 0.08	1.39 ± 0.02

[a, b] values expressed as mean ± S.E., significant at 0.05 level.

5. Conclusion

In this study, response surface methodology has been used to minimize two major postharvest losses of onion bulbs during storage (PL_W and rotting percent) as a function of pre-storage ethanol and potassium sorbate treatment. The optimum combination of ethanol and potassium sorbate was found to be 71.08 % (v/v) and 0.76 % (w/v), respectively. Under this optimum combination, the predicted and actual values of PL_W and rotting percent were found to be in close agreement and also were not significantly different from each other.

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References

[1] B Bohanec, M Jakše and M J Havey (2003), Genetic analyses of gynogenetic haploid production in onion, *J. Am. Soc. Hort. Sci.*, 128, pp. 571-574.

[2] G A Chope, L A Terry and P J White (2005), Effect of controlled atmosphere storage on abscisic acid concentration and other biochemical attributes of onion bulbs, *Postharvest Biol. Technol.*, 39, pp. 233-242.

[3] K Downes, G A Chope and A L Terry (2009), Postharvest application of ethylene and 1-methylcyclopropene either before or after curing affects onion (*Allium cepa* L.) bulb quality during long term cold storage, *Postharvest Biol. Technol.*, 55, pp. 36-44.

[4] M Fritsch and N Friesen (2002), Evolution, domestication and taxonomy, In *Allium Crop Science: Recent Advances* (H D Rabinowitch & L Currah, Eds), CABI Publishing, Wallingford, pp. 5-30.

[5] I R Gubb and H S MacTavish (2002), Onion pre- and postharvest considerations, In *Allium Crop Science: Recent Advances* (H D Rabinowitch & L Currah, Eds), CABI Publishing, Wallingford, pp. 233-265.

[6] A M Jogelkar and A T May (1987), Product excellence through design of experiments, *Cereal Food World*, 32, pp. 857-868.

[7] O A Karabulut, G Romanazzi, Smilanick JL, A Lichter (2005), Postharvest ethanol and potassium sorbate treatments of table grapes to control gray mould, *Postharvest Biol. Technol.*, 37, pp. 129-134.

[8] V V Koraddi and S Devendrappa (2011), Analysis of physiological loss of weight of vegetables under refrigerated conditions, *Int. J. Farm Sci.*, 1, pp. 61-68.

[9] L Kukanoor (2005), Postharvest studies in Onion cv. N-53. PhD Thesis, University of Agricultural Sciences, Dharwad, India.
[10] R Myers, D C Montgomery and C M A Cook (2002), Response surface methodology: process and products optimization using designed experiments, Wiley, USA, pp. 9-45.
[11] NHRDF (2009), Area and production data, National Horticultural Research and Development Foundation, Available at: www.nhrdf.com. Accessed 14 April 2013.
[12] A Qadir, F Hashinaga and R M Karim (2007), Effect of pre-storage treatment with ethanol and CO_2 on onion dormancy, *J. Bio-Science*, 15, pp. 55-62.
[13] S P J N Senanayake and F Shahidi (2002), Lipase-catalyzed incorporation of docosahexaenoic acid (DHA) into borage oil: optimization using response surface methodology, *Food Chemistry,* 77, pp. 115-23.
[14] R Slimestad, T Fossen and M I Vågen (2007), Onions: A source of unique dietary flavonoids, *J. Agric. Food Chem.,* 55, pp. 10067-10080.
[15] A Zahid, C S Cheow, A R Norizzah, M S Halimahton, M S Adi, A W Noorakmar and I Ruzaina (2005), Optimization of process conditions for the application of edible coating emulsion on guava (*Psidium guajava*) using response surface methodology. *Proc. Intl. Conf. Biotechnol. Food Sci. (IPCBEE)*, IACSIT press Singapore, 7, pp. 61-65.