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Optimizing Chemical Pre-Treatment Parameters to Enhance Quality in Dried Button Mushrooms: A Response Surface Methodology Approach

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Abstract

Browning is one of the main causes of quality losses in button mushroom. The pre-treatment of button mushroom was used to enhance the quality attributes during dehydration and storage. In this study, the pre-treatments are carried out optimize by using response surface methodology. The independent variables were taken as citric acid (0.23 to 0.57%), potassium metabisulphite (0.58 to 1.42%) and blanching time (2.3 to 5.7 min.). The response variables selected were rehydration ratio and visual colour. The optimized value of concentration of citric acid, concentration of potassium metabisulphite and blanching time were found to be 0.37%, 0.69% and 4.2 min. respectively with a desirability of 0.691. At these optimum conditions, the rehydration ration and visual colour were found to be 4.358 and 2.267 respectively. These optimized values of pre-treatment could be used for drying of button mushroom slices to get better quality attributes.

Keywords: Button mushroom, Pre-treatment, Response Surface Methodology, Optimization, Rehydration ratio, Visual colour

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Introduction

Button mushroom is considered as a next-generation healthy food supplements as they are low in fat, no cholesterol, high in protein with good biological value and identified as a food source to fight starvation in developing countries. It also contains a natural source of carbohydrates, unsaturated fatty acids, dietary fibres, vitamins and minerals and low in heavy metals [1]. Button mushroom is rich in bioactive compounds such as vitamins, minerals, polyphones and polysaccharides [2]. Button mushroom has a chemical composition of high content of P, Na, K, Ca, Mg, Na, Fe and Zn [3]. The fresh button mushroom contains 90-95% moisture, 1.8-2.1% crude protein, 1.5-3.3% fat (w.b.) [4]. The post-harvest losses of button mushrooms are up to 20-30% of total production [5]. The button mushroom is highly perishable and start deteriorating immediately within a day after harvest. Microbial, enzymatic and chemical reaction, discoloration, textural changes are the factors which lower its quality and thus reduce the consumer’s acceptance for fresh mushroom. The preservation of Agaricus bisporus is very essential due to its highly perishable nature. There are enormous physiological and morphological changes occur after harvest, which makes these mushrooms unacceptable for consumption.

Pre-treatments of fruits and vegetables prior to drying helps to reduce the undesirable changes in visual colour and texture. Pre-treatments of mushrooms before drying in one form or other viz, washing in water, potassium metabisulphite (KMS), sugar, salt either alone or in combination help in checking enzymatic browning, stabilizing colour, enhancing flavour retention and maintaining textural properties [6].

To prevent enzymatic and microbial deterioration, blanching is considered as one of the important unit operations during pre-treatment of button mushroom which helps to inactivates the enzymes. The polyphenol oxidase enzymes responsible for browning of button mushrooms. Solutions with potassium metabisulphite or citric acid prior to drying are frequently used for mushrooms to prevent enzymatic or non-enzymatic browning [7]. Citric acid, sodium metabisulphite, potassium metabisulphite, ascorbic acid, potassium carbonate, sodium hydroxide, sodium hydroxide, methyl and ethyl ester emulsions are commonly used for pre-treatments, enzymes inactivation and browning inhibition [8]. Several studies have been carried out to investigate the effect of pre-treatments prior to drying on the quality of dehydrated button mushroom.The water blanching for 3 min. was sufficient to inactivate the enzyme which causes browning during of mushrooms. Pre-treatment with 0.5 % citric acid solution on drying characteristics of button mushroom slices shows significant effects on the moisture removal from mushroom [9]. Blanching of mushroom for 1 minute was adequate to inactivate the enzymes [10]. The dehydrated mushrooms were given a blanching treatment of 0.5% potassium metabisulphite, 0.75% ethylene diamine tetra acetic acid (EDTA), 0.5% in citric acid and 0.5% ascorbic acid at 80ºC for 10 min. The mushroom samples dried after blanching in citric acid with salt solution and steeping in KMS with citric acid solution for 30 min. showed best colour and overall appearance than other pre-treated samples [11].

The blanching of A. bisporus and P. florida in boiling water for 1 min, treatment in 0.1% citric acid and 0.25% KMS for 15 min at room temperature shows lowest browning index [12]. The drying of white button mushrooms with pre-treatment of 0.5% KMS + 0.2% citric acid solution gave superior quality of dried mushrooms as compared to other pre-treatments [13].

The optimization of blanching treatment of button mushroom using response surface methodology gives the optimum values of citric acid, sodium metabisulphite and blanching time of 1.4 %, 1.4 % and 5.2 min [14]. The steeping of mushroom in sodium metabisulphite prior to drying had the lowest browning index, while those blanched in NaCl or citric acid had the highest browning index values [15]. The experiment for developing of mushroom powder with pre-treatment of 0.5% KMS + 0.2% citric acid for 30 minutes of steeping before drying helped to prevent from browning [16].

The different pre-treatments were carried out on ten levels of citric acids (0.25, 0.50, 0.75, 1, 1.25, 1.50, 1.75, 2, 2.5 %) for the optimization of button mushroom browning inhibition using response surface methodology and their results obtained the optimized value of citric acid (1.5%) and drying time (7 hours) for inhibit the browning in mushroom during drying [17]. Experiment carried out on oyster mushroom with pre-treatment of citric acid (0.5%), potassium metabisulphite (0.25%) and blanching time of 1, 2 and 5 min. at a boiling temperature of 90, 80 and 70°C. Results revealed that citric acid (0.5%), blanching time 2 min. with temperature 80°C shows lowest browning [18]. Pre-treatment of button mushrooms samples with 0.5 % on KMS solution showed more attractive using hot air oven with other treated samples [19]. Based on the above literature, the present study was conducted with the aim to the optimize the pre-treatment parameters of button mushroom to enhance its quality attributes.

Materials and Methods

Raw Material and Sample Preparation

Fresh button mushrooms (*Agaricus bisporus*) were obtained from local market of Ranchi and kept in cold storage at 4 to 5ºC. Prior to experiment, button mushroom was thoroughly washed in running tap water to remove the dirt and graded by size to eliminate the variations in respect to exposed surface area. Slices of desired thickness were obtained by carefully cutting the button mushrooms with a sharp knife. The slice thickness was maintained by using the digital vernier calliper. Citric acid and potassium metabisulphite were used during blanching. The experiments were carried out in Food Process Engineering Laboratory, College of Agricultural Engineering, Ranchi. The different concentrations of citric acid and potassium metabisulphite were used for pre-treatments.

Determination of moisture content

The moisture content of the fresh button mushroom was determined by oven drying method. The fresh samples were kept in a hot air oven at 100 ± 5 ºC for 24 h. For determination of initial moisture content of the button mushroom, three replications were kept in oven. The moisture content of button mushroom (w. b.) was calculated using the following formula [20]:

$$\boldsymbol{M.C.}\%\ (\boldsymbol{w.b.}) = \frac{\boldsymbol{w_2 - w_3}}{\boldsymbol{w_2 - w_1}} \times \mathbf{100} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Were, $\boldsymbol{w_1}$= Weight of the moisture dish, $\boldsymbol{w_2}$= Weight of the moisture dish along with fresh sample, $\boldsymbol{w_3}$ = Weight of the moisture dish along with the dried sample.

Experimental plan and design

Response surface methodology was applied to determine the relative effect of pre-treatment experiments of button mushroom. The independent variables taken for pre-treatment were concentration of citric acid, concentration of potassium metabisulphite and blanching time while the responses rehydration ratio and visual colour was selected. The independent variables and their levels were selected on the basis of data, available in published literature. According to the Central Composite Rotatable Design (CCRD), twenty experimental data were designed for conducting pre-treatment experiments of button mushroom samples. Three variables and five levels of each variable were taken for experimental design. The CCRD was used for experimental design. Levels of independent variables are coded using the following equations [21]:

$$x_i = \frac{\varepsilon_i - central value}{interval between successive levels} \dots\dots\dots\dots\dots (2)$$

Were, $x_i =$ Coded value of the independent variable, $\varepsilon_i =$ Actual value of the factor

Second order polynomial equations were developed using the dependent parameters (rehydration ratio, visual colour) and independent variables (concentration of citric acid, concentration of potassium metabisulphite and blanching time) for optimization [22]. The second order polynomial equation is given as:

$$Y_k = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{33} x_3^2 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 \dots\dots (3)$$

Were, Y_k= Response, β_{ijk}= Coefficients (i = 1, j = 2, k = 3), x_{ijk}= Coded independent variables (i = 1, j = 2, k = 3)

The independent variables, coded variables and their levels are presented in **Table 1**. The level combinations for a 3-factor CCRD are presented in **Table 2**.

Table 1 Levels of independent variables for optimization of pre-drying treatment of button mushroom

Variables	**Symbol**	**Level**				
		-1.682	**-1**	**0**	**1**	**1.682**
Concentration of Citric acid (%)	C_1	0.23	0.3	0.4	0.5	0.57
Concentration of Potassium metabisulphite (%)	C_2	0.58	0.75	1	1.25	1.42
Blanching time (min)	T_b	2.3	3	4	5	5.7

Table 2 Five levels three factors experimental design for optimization of pre-drying treatment conditions of button mushroom

Experiment No.	**Concentration of Citric acid (%) [coded (actual)]**	**Concentration of Potassium metabisulphite (%) [coded (actual)]**	**Blanching Time (min.) [coded (actual)]**
1	-1 (0.3)	-1 (0.75)	-1 (3)
2	1 (0.5)	-1 (0.75)	-1 (3)
3	-1 (0.3)	1 (1.25)	-1 (3)
4	1 (0.5)	1 (1.25)	-1 (3)
5	-1 (0.3)	-1 (0.75)	1 (5)
6	1 (0.5)	-1 (0.75)	1 (5)
7	-1 (0.3)	1 (1.25)	1 (5)
8	1 (0.5)	1 (1.25)	1 (5)
9	-1.682 (0.23)	0 (1)	0 (4)
10	1.682 (0.57)	0 (1)	0 (4)
11	0 (0.4)	-1.682 (0.58)	0 (4)
12	0 (0.4)	1.682 (1.42)	0 (4)
13	0 (0.4)	0 (1)	-1.682 (2.3)
14	0 (0.4)	0 (1)	1.682 (5.7)
15	0 (0.4)	0 (1)	0 (4)
16	0 (0.4)	0 (1)	0 (4)
17	0 (0.4)	0 (1)	0 (4)
18	0 (0.4)	0 (1)	0 (4)
19	0 (0.4)	0 (1)	0 (4)
20	0 (0.4)	0 (1)	0 (4)

Experimental procedure

For all experiments, 100g samples of button mushroom slices were taken and samples were blanched in boiling water (100ºC) with different concentrations of citric acid, concentration of potassium metabisulphite and blanching times (Table 2). The drying was carried out in hot air oven using fixed air temperature of 55ºC. Before placing the samples in hot air oven, the oven was kept ON for half an hour to stabilize the temperature of the drying air to the pre-set drying air temperature. The samples were dried until it attained the constant weight.

Evaluation of response variables of button mushroom samples

The quality parameters such as rehydration ratio and visual colour were taken as quality attributes of treated button mushroom slices.

Calculation of rehydration ratio (RR)

The rehydration characteristic of a dried product is widely used as quality index. Rehydration ratio is defined as the ratio of weight of rehydrated samples to the dry weight of the sample. The rehydration ratio was calculated by using the following equation [23]:

$$\boldsymbol{RR = \frac{w_r}{w_d}} \ldots\ldots\ldots\ldots (4)$$

Were, $\boldsymbol{w_r}$ = Weight of the sample after rehydration, $\boldsymbol{w_d}$ = Weight of the sample before rehydration

The rehydration experiments were conducted for all dried samples of button mushroom. The dried sample (approx. 2g) was immersed in distilled boiling water (100°C) and were weighed at every 2 min. of intervals after draining the excess water until it attained the constant weight.

Determination of visual colour (VC)

Visual colour is the most common and important parameters in food applications as it is first priority in selection for consumer behaviors. The visual colour of dried samples were determined by conducting a sensory evaluation with a panel member of 10 untrained judges. The panelists were given a performa of 5-point Hedonic Scale for each sample [24]. The sensory parameters including visual colour was carefully selected after final decision. The mean of sensory score data given by panelists were recoded. The Hedonic Scale rating used are as follows:

Excellent: 1, Good: 2, Fair: 3, Poor: 4 and Very poor: 5

Statistical analysis

Analysis of variance (ANOVA) is used to test the model as a whole and individual terms in the model. The adequacies of the models were determined using model analysis, lack-of-fit test, R^2 (coefficient of determination), C.V (coefficient of variance) and Std. Dev. (Standard deviation) expressed as a percentage of mean. The lack-of-fit technique is used to check the models are adequate. It should be non-significant for the model to fit well in the experimental design. The R^2 is defined as the ratio of the explained variation to the total variation and is a measure of the degree of fit of the model. The goodness of fit was evaluated from regression analysis depends on the R^2 value. The higher R^2 value gives better in the goodness of fit. Regression analysis (RA) was conducted to examine the statistical significance of the model terms. The second order polynomial response surface model equation 3 was fitted to each of the response variable (Y_k) with the independent variables (x_1, x_2, x_3) for pre-treatment experiments.

Numerical optimization

Optimization is a combination of factor levels that simultaneously satisfy the requirement of each of the response and factor. Simultaneous optimization of multiple responses can be performed graphically or numerically. Numerical optimization of Design Expert software, version 13.0.5.0 (Stat. Ease Inc, Minneapolis, MN) was used for simultaneous optimization of the multiple responses. The desired goals for each variable and responses were chosen. The goals were either factors or responses. The possible goals were maximize, minimize, target, within range, none (for responses only). All the independent variables were kept within range while the dependent variables (responses) were either maximized or minimized. Desirability is an objective function that ranges from 0 (least desirable) to 1 (most desirable) of the limits at the goal. The numerical optimization helps to find out a point which maximizes the desirability function. In optimization of pre-drying treatments of button mushroom, rehydration ratio was kept maximum and visual colour was kept minimum. The values of independent parameters were kept within experimental range.

Results and Discussion

The initial moisture content of button mushroom was found to be in the range of 85-95% (w.b). The experimental data of pre-drying treatment parameters with their responses are given in both in coded and actual form except responses (**Table 3**). The data obtained were optimized using response surface methodology.

Table 3 Experimental data of pre-drying treatment parameters with their responses

Experiment No.	Levels of variables			Responses	
	Citric acid (C_1, %) [coded (actual)]	Potassium Meta bisulphite (C_2, %) [coded (actual)]	Blanching Time (T_b, min.) [coded (actual)]	Rehydration ratio (RR)	Visual colour (VC)
1	-1 (0.3)	-1 (0.75)	-1 (3)	3.44	2.20
2	1 (0.5)	-1 (0.75)	-1 (3)	3.75	2.70
3	-1 (0.3)	1 (1.25)	-1 (3)	3.36	2.90
4	1 (0.5)	1 (1.25)	-1 (3)	3.98	3.10
5	-1 (0.3)	-1 (0.75)	1 (5)	3.41	1.92
6	1 (0.5)	-1 (0.75)	1 (5)	3.24	2.50
7	-1 (0.3)	1 (1.25)	1 (5)	3.32	3.20
8	1 (0.5)	1 (1.25)	1 (5)	3.28	3.15
9	-1.682 (0.23)	0 (1)	0 (4)	3.33	2.90
10	1.682 (0.57)	0 (1)	0 (4)	3.28	3.10
11	0 (0.4)	-1.682 (0.58)	0 (4)	3.31	1.90
12	0 (0.4)	1.682 (1.42)	0 (4)	4.21	2.20
13	0 (0.4)	0 (1)	-1.682 (2.3)	4.26	2.90
14	0 (0.4)	0 (1)	1.682 (5.7)	4.43	2.80
15	0 (0.4)	0 (1)	0 (4)	4.89	2.68
16	0 (0.4)	0 (1)	0 (4)	4.32	2.34
17	0 (0.4)	0 (1)	0 (4)	4.76	2.53
18	0 (0.4)	0 (1)	0 (4)	4.92	2.76
19	0 (0.4)	0 (1)	0 (4)	4.48	2.46
20	0 (0.4)	0 (1)	0 (4)	4.66	2.84

Table 4 Analysis of variance (ANOVA) for the effect of concentration of citric acid, concentration of potassium metabisulphite and blanching time on rehydration ratio

Square	Sum of Squares	df	Mean Square	F-value	P-value	
Model	6.40	9	0.7106	7.66	0.0019	significant
C_1	0.0296	1	0.0296	0.3192	0.5846	
C_2	0.1907	1	0.1907	2.05	0.1822	
T_b	0.0724	1	0.0724	0.7800	0.3979	
C_1C_2	0.0242	1	0.0242	0.2608	0.6206	
C_1T_b	0.1624	1	0.1624	1.75	0.2152	
C_2T_b	0.0050	1	0.0050	0.0539	0.8211	
C_1^2	4.23	1	4.23	45.61	< 0.0001	*
C_2^2	2.09	1	2.09	22.55	0.0008	*
T_b^2	0.4373	1	0.4373	4.71	0.0551	
Residual	0.9278	10	0.0928			
Lack of Fit	0.6501	5	0.1300	2.34	0.1861	Non- significant
Pure Error	0.2777	5	0.0555			
Std. Dev. 0.3046 Mean 3.93 CV% 7.75 R^2 0.87						
* Significant (at 5% level)						

Effect of process parameters on rehydration ratio

Analysis of variance (ANOVA) was developed to explore the effect of concentration of citric acid, concentration of potassium metabisulphite and blanching time on rehydration ratio which is shown in **Table 4**. From the Table 4, it is evident that the quadratic term of concentration of citric acid (C_1) and concentration of potassium metabisulphite (C_2,) were found to be significant due to P-value less than 0.05. Values greater than 0.10 indicated the model terms are not significant. The P-value of lack-of-fit (0.1861) was found to be non-significant which indicated that the developed model is adequate for predicting the rehydration ratio of button mushroom. From the Table 3, the rehydration ratio of button mushroom samples was found to be in the range of 2.24 to 4.92 respectively. Similar trends were reported by [25, 26].

A second order polynomial equation 3 was fitted to experimental data (Table 4). The regression model obtained by using step-down regression method neglecting non-significant factors for rehydration ratio as a function of concentration of citric acid (C_1), concentration of potassium metabisulphite (C_2) and blanching time (T_b) is presented in equation 5. The regression equation 5 were developed for rehydration ratio in terms of concentration of citric acid, concentration of potassium metabisulphite and blanching time. The high value of coefficient of determination R^2 (0.87) indicated that the developed model is fit good for predicting the rehydration ratio.

$$RR = 4.68 + 0.0466*C_1 + 0.1182*C_2 - 0.0728*T_b + 0.0550*C_1C_2 - 0.1425*C_1T_b - 0.0250*C_2T_b - 0.5419*C_1^2 - 0.3810*C_2^2 - 0.1742*T_b^2 \quad \ldots\ldots(5)$$

The linear positive terms of equation 5 indicates that rehydration ratio increases with increase in concentration of citric acid and concentration of potassium metabisulphite but decreases in case of linear term of blanching time. The positive interaction terms of citric acid with potassium metabisulphite increase the value of rehydration ratio while other negative interaction terms reduce. The high values of all quadratic negative terms of these variables further reduced rehydration ratio. The 3d-model graph represents the relationship between independent variables with response variables obtained by response surface methodology. The effect of independent variables (C_1, C_2& T_b) on rehydration ratio using regression model is shown in **Figure 1** (a, b, c).

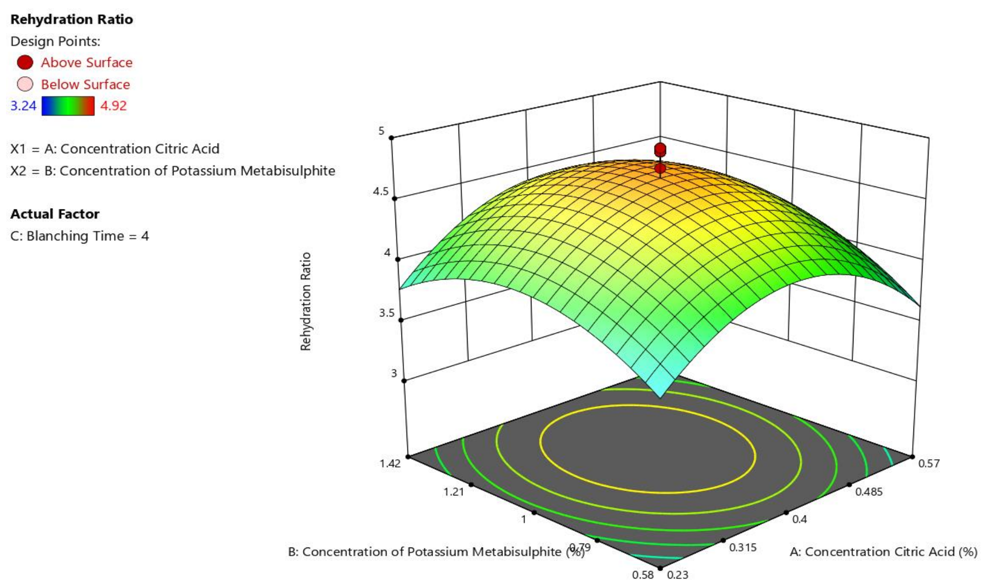

Figure 1 (a) Effect of concentration of citric acid and concentration of potassium metabisulphite on rehydration ratio

From Figure 1 (a), it is clear that rehydration ratio increases at early stages with increase in concentration of citric acid (C_1) and concentration of potassium metabisulphite (C_2). However, with increase in blanching time (T_b), Figure 1 (b & c) indicates that there is a slight increase in the value of rehydration ratio. Similar result was reported by [27]. This may be due to development of porous structure in mushroom tissues. The high F-value (45.61) of quadratic term of concentration of citric acid indicates that the effect of citric acid was most pronounced in comparison to effect of potassium metabisulphite and blanching time.

Effect of process parameters on visual colour

Analysis of variance (ANOVA) was developed to explore the effect of concentration of citric acid, concentration of potassium metabisulphite and blanching time on visual colour which is shown in **Table 5**. From the Table 5, it is evident that the linear term of concentration of potassium metabisulphite (C_2) and quadratic term of concentration of citric acid (C_1^2) and potassium metabisulphite (C_2^2) were found to be significant due to P-value less than 0.05. Values greater than 0.10 indicate the model terms are not significant. The P-value of lack-of-fit (0.2553) were found to be non-significant which indicated that the developed model is adequate for predicting the visual colour of button mushroom. From the Table 3, the visual colour of dehydrated button mushroom samples was found to be in the range of 1.9 to 3.15 respectively.

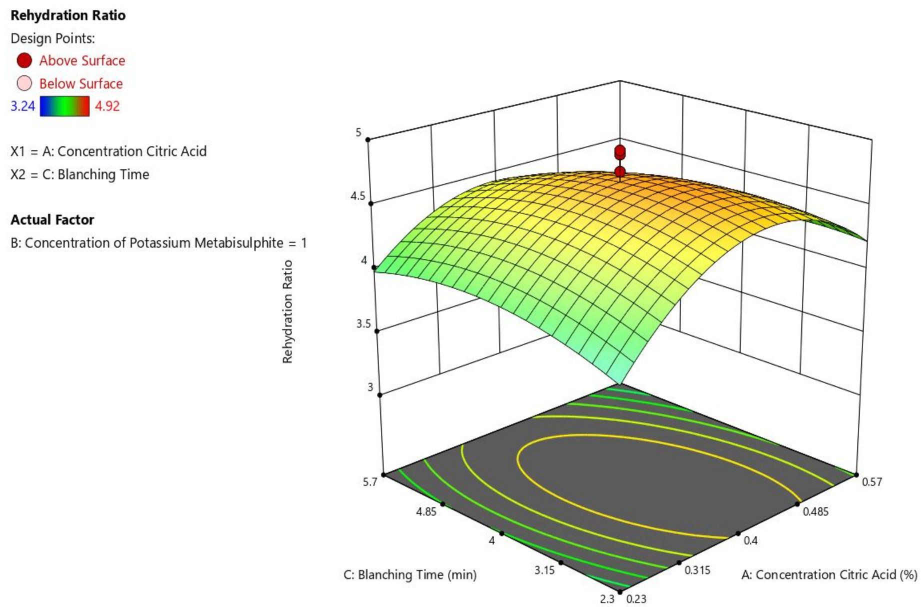

Figure 1 (b) Effect of concentration of citric acid and blanching time on rehydration ratio

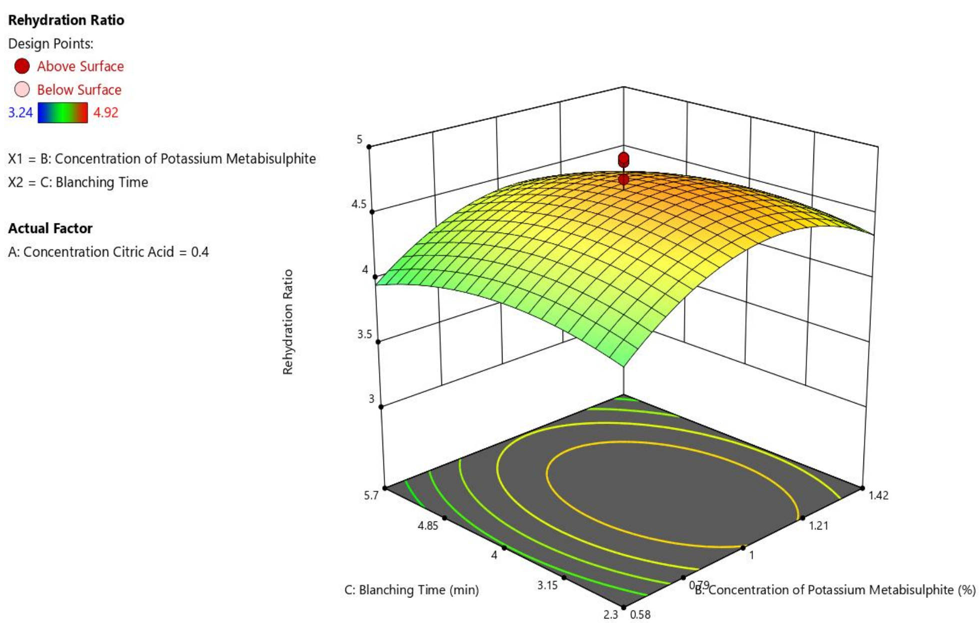

Figure 1 (c) Effect of concentration of potassium metabisulphite and blanching time on rehydration ratio

A second order polynomial equation3 was fitted to experimental data (Table 3). The regression model obtained by using step-down regression method neglecting non-significant factors for visual colour as a function of concentration of citric acid (C_1), concentration of potassium metabisulphite (C_2), blanching time (T_b) is presented in equation 6. The regression equation 6 were developed for visual colour in terms of concentration of citric acid, concentration of potassium metabisulphite and blanching time. The high value of coefficient of determination ($R^2 = 0.81$) indicated that the developed model is fit good for predicting the visual colour.

$$VC = 2.60 + 0.1147*C_1 + 0.2588*C_2 - 0.0218*T_b - 0.1163*C_1C_2 - 0.0213*C_1T_b + 0.1037*C_2T_b + 0.1563*C_1^2 - 0.1795*C_2^2 + 0.1033*T_b^2 \quad (6)$$

The linear positive terms of equation 6 indicates that visual colour increase with increase in linear terms of concentration of citric acid and concentration of potassium metabisulphite but decreases in case of linear negative terms of blanching time. The positive interaction terms of concentration of potassium metabisulphite with blanching time **(**C_2T_b) increases the value of visual colour while other negative interaction terms reduce. The high values of quadratic positive terms of concentration of citric acid (C_1^2) and blanching time (T_b^2) increases the visual colour while the concentration of potassium metabisulphite decreases the visual colour. The 3d-model graph represents the relationship between independent variables with response variables obtained by response surface methodology. The effect of independent variables (C_1, C_2& T_b) on visual colour using regression model is shown in **Figure 2 (a, b, c)**.

Table 5 Analysis of variance (ANOVA) for the effect of concentration of citric acid, concentration of potassium metabisulphite and blanching time on visual colour

Square	Sum of Squares	df	Mean Square	F-value	P-value	
Model	2.37	9	0.2631	5.06	0.0092	significant
C_1	0.1797	1	0.1797	3.45	0.0928	
C_2	0.9148	1	0.9148	17.58	0.0019	*
T_b	0.0065	1	0.0065	0.1251	0.7309	
C_1C_2	0.1081	1	0.1081	2.08	0.1801	
C_1T_b	0.0036	1	0.0036	0.0694	0.7975	
C_2T_b	0.0861	1	0.0861	1.65	0.2273	
C_1^2	0.3523	1	0.3523	6.77	0.0264	*
C_2^2	0.4645	1	0.4645	8.93	0.0136	*
T_b^2	0.1538	1	0.1538	2.96	0.1163	
Residual	0.5204	10	0.0520			
Lack of Fit	0.3388	5	0.0678	1.86	0.2553	Non-significant
Pure Error	0.1817	5	0.0363			
Std. Dev. 0.2281	Mean 2.65		CV% 8.60	R^2 0.81		

* Significant (at 5% level)

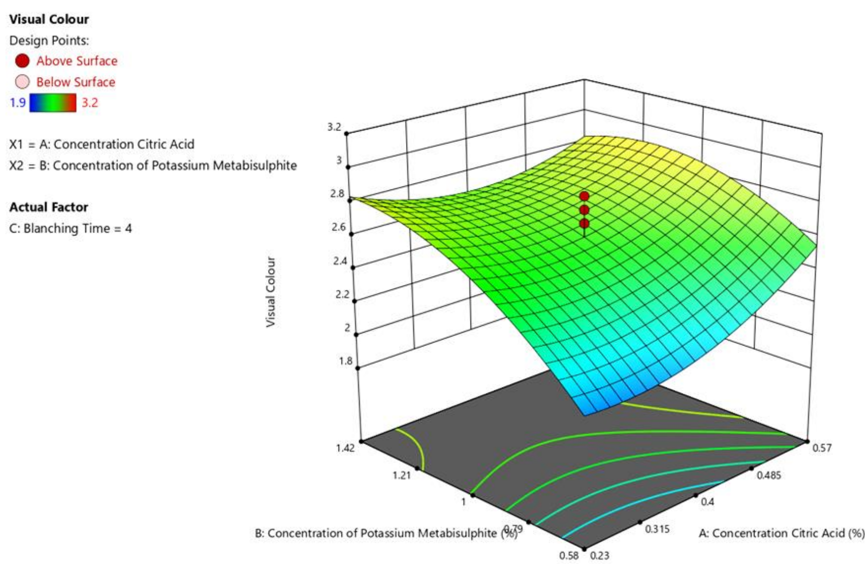

Figure 2 (a) Effect of concentration of citric acid and concentration of potassium metabisulphite on visual colour

From Figure 2 (a), it is clear that visual colour increases with increase in concentration of citric acid (C_1) and concentration of potassium metabisulphite (C_2). The significant increase was also observed with concentration of citric acid (C_1) and concentration of potassium metabisulphite (C_2) as shown in Figure 2 (b, c). This was due to the increased concentration of citric acid and potassium metabisulphite used during blanching treatment which helped in preserving the colour. There is a slight increase in the value of visual colour with increase in blanching time and concentration of potassium metabisulphite as shown in Figure 2 (c). This increase in visual colour could be synergistic effect of blanching time and concentration of potassium metabisulphite. Similar result was reported by [28]. The high F-value (17.58) of linear term of concentration of potassium metabisulphite indicates that the effect of potassium metabisulphite was more in comparison to concentration of citric acid (C_1) and blanching time (T_b).

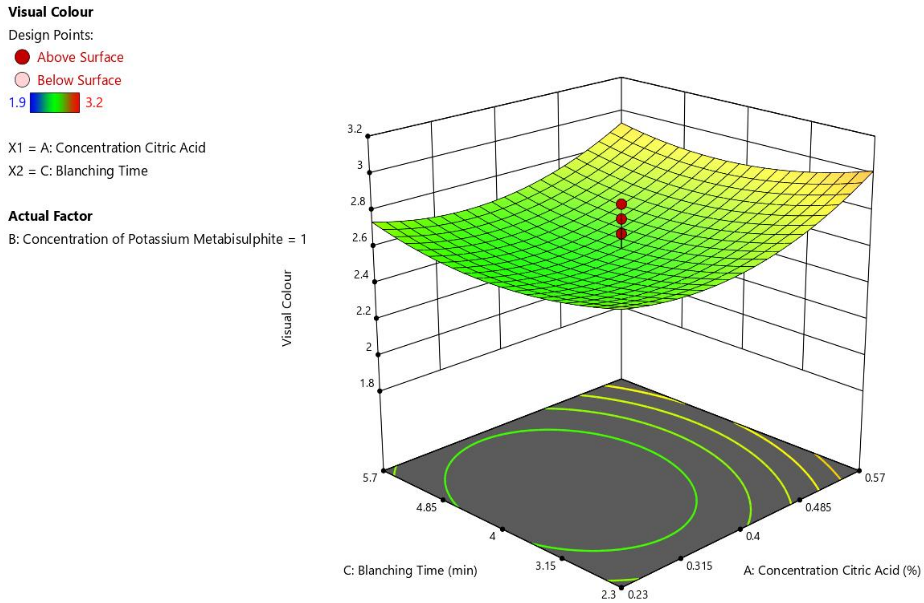

Figure 2 (b) Effect of concentration of citric acid and blanching time on visual colour

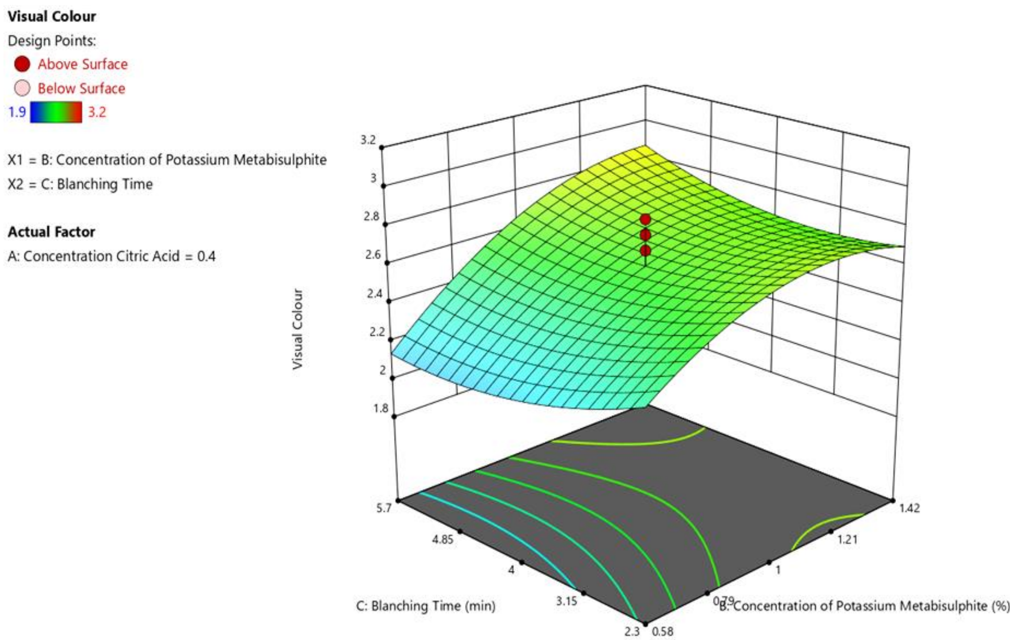

Figure 2 (c) Effect of concentration of potassium metabisulphite and blanching time on visual colour

Numerical optimization of process parameter of pre-treatment of button mushroom

The numerical multi response optimization was used for the optimization of concentration of citric acid, concentration of potassium metabisulphite and blanching time of the pre-drying treatment conditions of button mushroom samples. The response variables selected for optimization were rehydration ratio and visual colour. Design Expert software was used to get the optimum values of concentration of citric acid, concentration of potassium metabisulphite and blanching time. The optimization condition was achieved by maximizing the rehydration ratio and minimizing visual colour. Similar numerical optimization techniques were used by [29].

The optimum values of concentration of citric acid, concentration of potassium metabisulphite and blanching time obtained by numerical optimization were found to be 0.371 %, 0.688 % and 4.241 min. respectively at desirability value of 0.691. At this optimum condition, the value of rehydration ratio and visual colour were found to be 4.358 and 2.267 respectively. The final optimum values of process parameters were taken as concentration of citric acid (0.37 %), concentration of potassium metabisulphite (0.69 %) and blanching time (4.2 min.). These optimum values were can be used for further blanching treatment of button mushroom for dehydration to get better quality attributes.

Conclusions

Pre-treatment of button mushroom is an essential unit operation before dehydration to get desired quality attributes. In this study, optimization of pre-treatment parameters of button mushroom was carried out using response surface methodology. The treatment parameters taken for study were citric acid, potassium metabisulphite and response variables were rehydration ratio and visual colour. The optimum values of concentration of citric acid, concentration of potassium metabisulphite and blanching were found to be 0.37 %, 0.69% and 4.2 min. respectively at a desirability of 0.691. Under this optimum condition, the rehydration ratio and visual colour were found to be 4.358 and 2.267 respectively. This optimum condition of pre-treatment could be utilized for dehydration of button mushroom with better quality attributes.

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