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A Study on Enhancing Shelf-Life of Paddystraw Mushrooms Grown in Odisha by Bio-Chitosan Treatment

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Abstract
A rise in the number of vegans calls for a diet high in protein, and paddy straw mushrooms appear to be one of these cultures' super foods. Vitamin D and other vital nutrients that reduce oxidative stress and other chronic diseases are abundant in fresh mushrooms. To increase their shelf life, these super foods are treated with calcium chloride, sulphur dioxide, and MAP during shipping. Additionally, edible thin chemical coatings that shield it from moisture, oxygen, and germs outside contribute to its harmful impacts on the human population. Therefore, extending the shelf life of mushrooms by preserving them with natural plant compounds seems like an intriguing field. Eco-friendly methods utilising chitosan have been researched for the past few decades, yet in the areas of Odisha, farmers are suffering from significant losses due to the shelf-life extension of Paddystraw mushrooms. This might be caused by the state's several, diverse climate zones. In the current study, we looked at how local Paddystraw mushrooms could have a distinctive identity in the fiercely competitive market by having their shelf-life extended by a commercial grade chitosan along with arrange of temperature and time.
Key words: Chitosan Concentration, Oxidative Stress, Chemical Coating, Diversified Climatic Zones

1. Introduction

Muscle foods, like fish and meat, play a key function in maximum people's every day eating regimen because of their attractive sensory characteristics and dietary benefits which encompass excessive stage of pleasant protein, nutrients and minerals[1].Contrarily, muscle foods lack in vitamin C, dietary fibre, antioxidants, and calcium[2]. The necessity for a tropical or subtropical temperature, the paddy straw mushroom's quick pace of growth, its straightforward culture method, and consumer acceptability are only a few of its benefits. The acceptability of these mushrooms is comparable to that of the widely used white button mushrooms because they have an excellent combination of all characteristics, including flavour, fragrance, delicacy, high protein, vitamin, and mineral content[3, 4].

Due to its excellent nutritional and medicinal value, the consumption and demand of mushrooms have significantly increased in recent years, and this trend is expected to continue [5].Its short shelf life is caused by its microbial activity, enzymatic activity, high moisture content, respiration rate, and water loss after harvest in ambient settings [6]. These traits make the paddy straw mushroom less desirable, which also lowers the mushroom's market value.

Due to the world's growing population and decreasing per capita arable land, as well as increased industrialization and urbanization, climatic change, and consumer demand for high-

quality functional foods, secondary agriculture and innovative crops like mushrooms became increasingly significant [7].

But when it comes to using vertical space to aid with issues regarding food quality, health, and environmental sustainability, mushrooms offer a chance and a useful component. This implies that everyone always has physical, social, and financial access to an adequate supply of food that is safe and satisfies their dietary requirements for an active and healthy life as well as their dietary preferences.

To fulfil the changing dietary needs and to add more protein to our diets, we must boost both mushroom production and consumption. The paddy straw mushroom has high fibre content (11.1 percent). In addition to the various vitamins, its low sugar, low calorie, and high fibre nature offers an additional benefit. It has unique properties that allow it to treat a variety of illnesses, including ulcers, diabetes, and heart disease.

Mushrooms provide large amounts of the nutrients protein, energy, vitamins, and minerals. There have been several attempts to increase the shelf life of these mushrooms, but treatment with chitosan and maintaining a temperature range have both been successful. We previously described in detail the opinions of individuals from various regions regarding the quality and packing effectiveness of Paddystraw mushrooms, which motivated us to work on extending the shelf life of this delectable kind [8].Lots of researchers have worked on chitosan to extend the shelf life but in Odisha it has not been tried in mushrooms and this is the reason why we selected Bio chitosan as the element to use for shelf life extension. Researchers have been made by taking Electrolysed water to improve the post harvest self life [14] but we have taken chitosan into it as it is found to be more effective in the past.

2. Raw material & Experimental :

Common cultivated fresh Mushrooms (*V. volvacea*) were collected from a commercial market of Bhubaneswar city of Odisha. Any diseased and rough mushrooms were discarded. The average weights of individual mushrooms were 28 grams with the cap embedding the body. The mushrooms were washed properly and surface-sterilised by immersion in a 0.1-g NaClO/100 mL for 1 min and at room temperature air-dried for 30 minutes. Then these were immersed in the solutions containing 0.5, 1.0 and 2.0 g chitosan/100 ml for 1 min (Bangalore fine chemical, Bangalore, India) which were prepared with a pH value of 6.0. Chitosan solutions were prepared from high-viscosity chitosan flakes (37% deacetylation) and practical grade “chitosan” from plant-based source (Inlife Pharma, Hyderabad, India) by slurring the flakes in 2% water. The slurry was combined with an equal volume of 2% malic acid solution, and the “chitosan” dispersed with homogenizer (Model Lab India Instruments, Mumbai). The dispersion was heated to 60^0C with stirring, and filtered through filter paper (Whatman No. 541, supplied by Nice Chemicals, Mumbai) under suction to remove a small amount of the insoluble materials. The untreated (no chitosan) was referred here as controlled samples. After being air-dried at room temperature for another 30 min, the mushrooms were placed into 0.02-mm-thick polyethylene films bag from local market of Bhubaneswar and then stored at 4^0C for progressive assessments. The control and chitosan-treated Paddystraw mushroom samples were stored for 0, 1,3, 5, 7 and 10 days at 4^0C and analysed for weight Loss and Browning Index (BI) [10] was measured from dual beam visible spectrophotometer with computer colour

matching system (Model Premier colorscan 5100 A). For each treatment, three measurements were repeated and averaged out.

3. Methodology:

Though many researchers already demonstrated the usefulness of chitosan, it has not been tried for the state of Odisha for giving clarity in increasing self-life with such diversified climate [11, 13]. So, we tried to investigate with a minimal experimental set-up with response surface methodology followed by regression analysis. The primary aim was to know the best combination of chitosan concentration, time and temperature to achieve the minimum weight loss and minimum browning of Paddystraw mushrooms. The contour plots in the response surface methodology indicated the range of concentration of chitosan, temperature and time to keep the browning and weight loss minimum.

4. Results and Discussion:

The regression analysis was carried out in SPSS to see the individual and mixing effects of input variables such as concentration of chitosan, time and temperature.

4.1.Regression Analysis: Tables 1-3 were found out for the regression analysis of Weight loss versus Concentration, Temperature and Time

Table-1: Analysis of Variance

Source	DF	Adj SS	A djMS	F-Value	P-Value
Regression	7	7112.80	1016.11	197.31	0.000
Conc	1	232.65	232.65	45.18	0.000
Temp	1	45.68	45.68	8.87	0.018
Time	1	35.01	35.01	6.80	0.031
Conc*Temp	1	42.88	42.88	8.33	0.020
Conc*time	1	28.40	28.40	5.51	0.047
Temp*time	1	21.93	21.93	4.26	0.073
Conc*Temp*time	1	22.25	22.25	4.32	0.071
Error	8	41.20	5.15		
Lack-of-Fit	6	36.53	6.09	2.61	0.303
Pure Error	2	4.67	2.33		
Total	**15**	7154.00			

Table-2: R value, R squared value and adjusted R squared value and predicted R squared value

S	R-sq	R-sq(adj)	R-sq(pred)
2.26933	99.42%	98.92%	96.33%

Table-3: Coefficients for weight loss

Term	Coef	SECoef	T-Value	P-Value	VIF
Conc	101.9	15.2	6.72	0.000	27.69
Temp	1.389	0.466	2.98	0.018	235.44
Time	3.12	1.20	2.61	0.031	356.61
Conc*Temp	-7.23	2.51	-2.89	0.020	280.77

Conc*Time	-14.75	6.28	-2.35	0.047	404.50
Temp*Time	-0.208	0.101	-2.06	0.073	928.12
Conc*Temp*Time	1.073	0.516	2.08	0.071	1000.49

4.2.Regression Equation:

Wt. Loss =101.9 Conc + 1.389 Temp + 3.12 Time - 7.23 Conc*Temp - 14.75 Conc*Time- 0.208 Temp*Time + 1.073 Conc*Temp*Time.

Wt. Loss:R^2 = 99.42: An excellent fit was obtained here which showed that the Concentration plays a significant role. In addition, their interactions did not show any significant contribution to the model. The predicted values were denoted in table no. 4 and the coefficients were given in table no. 3.

4.3. Response surface explanation for safe zone of Weight loss:

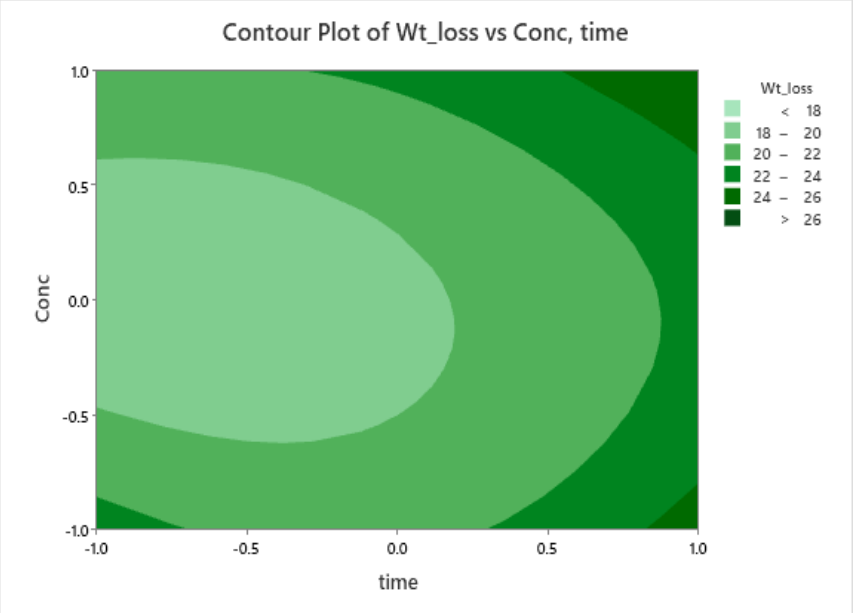

Fig-1: Contour plot of Weight loss Vs. Concentration and Time

The safe zone of weight loss as per the analysis [12] remains below 18% (Fig-1). The range of concentration of chitosan remains in between -0.5 - 0.5 and time ranges between 3 to 7 minutes. Here the role played by concentration of chitosan is remarkable.

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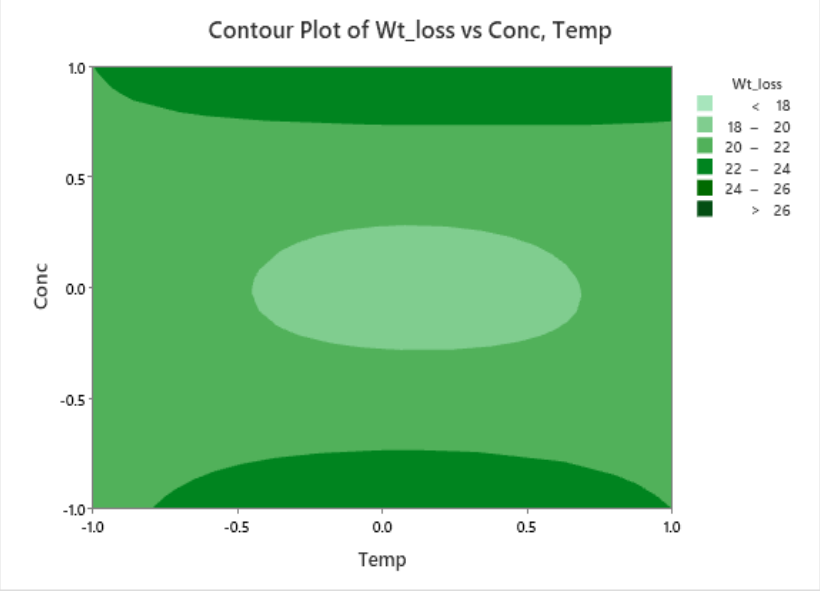

Fig-2: Contour plot of Weight loss Vs. Concentration and Temperature

Weight loss remains below 18% in the safe zone mentioned in the contour plate(Fig-2). The range of concentration of chitosan remains at 0.2M and temperature range remains between 12.5^0 to 20^0 C. Here both the elements are equally significant for the minimum weight loss and those are concentration of chitosan and temperature.

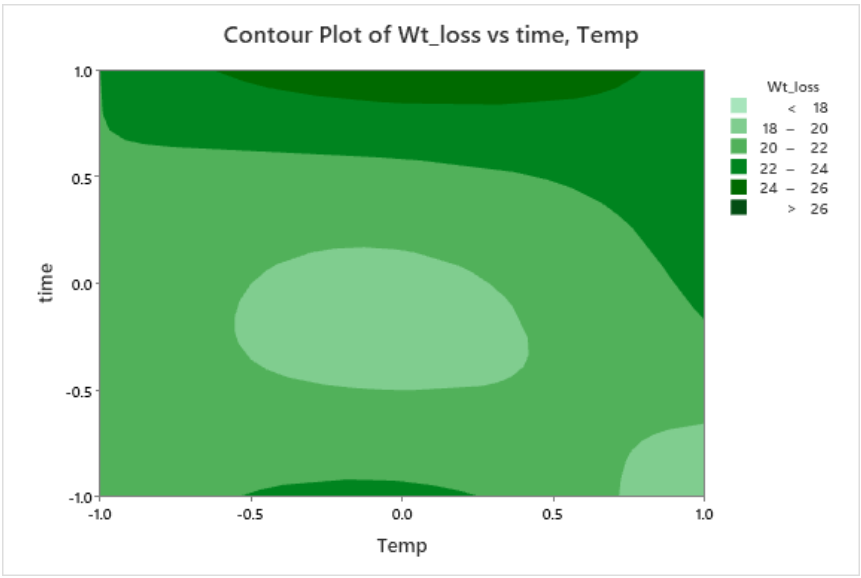

Fig-3: Contour plot of Weight loss Vs. Time and Temperature

From Fig-3 contour plot, it is pretty clear that weight loss will be minimal with the temperature range of 12.5^0 to 20^0 C. It is the best area to be chosen for work as it shows the suitability for the work.

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Table-4: (Predicted weight loss and Predicted Browning**)**

Chit.Conc	Temp	Time	Wt.loss	Browning	FITS1 (Wt.Loss)	FITS2 (Browning)	Model	Coef1 Wt_loss	Coef2 Browning
0.15	15	3	23	15	20.48	15.41	Conc	101.93	61.07
0.15	15	15	25	17	22.96	18.48	Temp	1.39	1.28
0.25	15	3	22	14	20.23	12.81	Time	3.12	2.64
0.25	15	15	26	17	24.34	17.68	Conc*Temp	-7.23	-6.10
0.15	10	7	21	18	21.43	15.82	Conc*time	-14.75	-12.44
0.15	30	7	22	20	20.93	18.27	Temp*time	-0.21	-0.17
0.25	10	7	22	14	21.58	13.62	Conc*Temp*time	1.07	0.93
0.25	30	7	23	18	21.65	16.87			
0.2	10	3	20	16	20.54	13.63			
0.2	30	3	18	15	19.79	15.54			
0.2	10	15	22	20	23.44	16.90			
0.2	30	15	23	22	24.29	21.63			
0.2	15	7	20	12	21.45	15.44			
0.2	15	7	18	13	21.45	15.44			
0.2	15	7	21	12	21.45	15.44			

*4.3.Regression Analysis***:** Tables 5-7 were found out for the regression analysis of Browning versus Concentration, Temperature and Time

Table-5: Analysis of Variance

Source	**DF**	**AdjSS**	**AdjMS**	**F-Value**	**P-Value**
Regression	7	4006.45	572.349	78.20	0.000
Conc	1	83.51	83.513	11.41	0.010
Temp	1	38.87	38.869	5.31	0.050
Time	1	25.04	25.041	3.42	0.102
Conc*Temp	1	30.56	30.562	4.18	0.075
Conc*time	1	20.20	20.204	2.76	0.135
Temp*time	1	15.36	15.360	2.10	0.185
Conc*Temp*time	1	16.68	16.677	2.28	0.170
Error	8	58.55	7.319		
Lack-of-Fit	6	57.89	9.648	28.94	0.034
Pure Error	2	0.67	0.333		
Total	15	4065.00			

Table-6: Model Summary

S	R-sq	R-sq (adj)	R-sq (pred)
2.70543	98.56%	97.30%	95.32%

Table-7: Coefficients for browning

Term	Coef	SECoef	T-Value	P-Value	VIF
Conc	61.1	18.1	3.38	0.010	27.69
Temp	1.281	0.556	2.30	0.050	235.44
Time	2.64	1.43	1.85	0.102	356.61
Conc*Temp	-6.10	2.99	-2.04	0.075	280.77
Conc*Time	-12.44	7.49	-1.66	0.135	404.50
Temp*Time	-0.174	0.120	-1.45	0.185	928.12
Conc*Temp*Time	0.929	0.616	1.51	0.170	1000.49

4.5. Regression Equation:

Browning = 61.1* Conc + 1.281* Temp + 2.64 Time - 6.10 Conc*Temp - 12.44 Conc*Time - 0.174 Temp*Time + 0.929 Conc*Temp*Time

Browning: R^2=98.42 which is found to be an excellent fit. Here concentration of Chitosan plays a significant role and their interaction did not show any significant contribution to the model. The predicted values are given and the coefficients are given in Table-4 and Table-7 respectively.

The coded values assigned were given below in table no.8

Table-8: Assignment of value of Concentration, Time and temperature

Concentration	Time	Temperature
0	0	0
0.2	7	15
-1	-1	-1
0.15	3	10
1	1	1
0.25	15	30

4.6. Response surface explanation for safe zone of Browning

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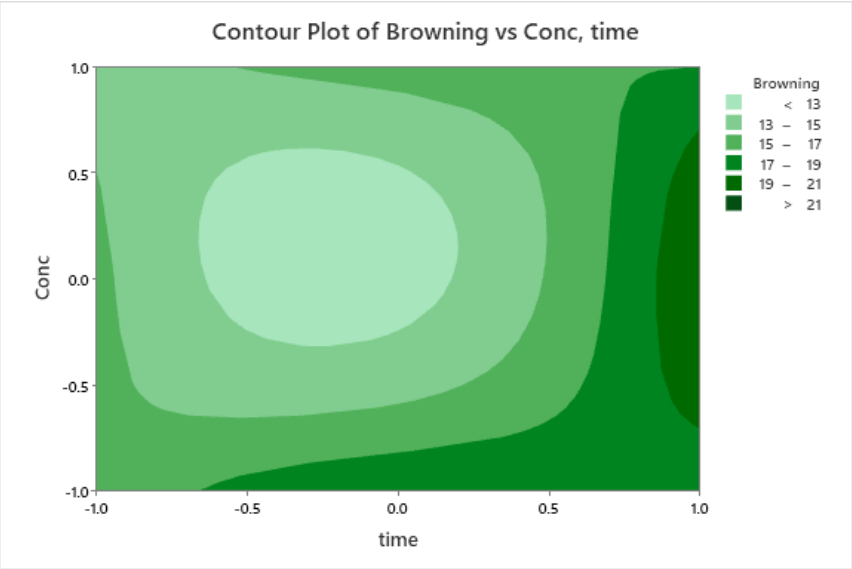

Fig-4: Contour plot of Browning Vs. Time and Concentration

Figure-4 indicates the contour plot of Browning versus Time and Concentration. Browning is found to be very less in 0.2 M concentration for7 minutes (less than 13%). So this combination can be taken into confidence for proceed with the process as both are equally significant.

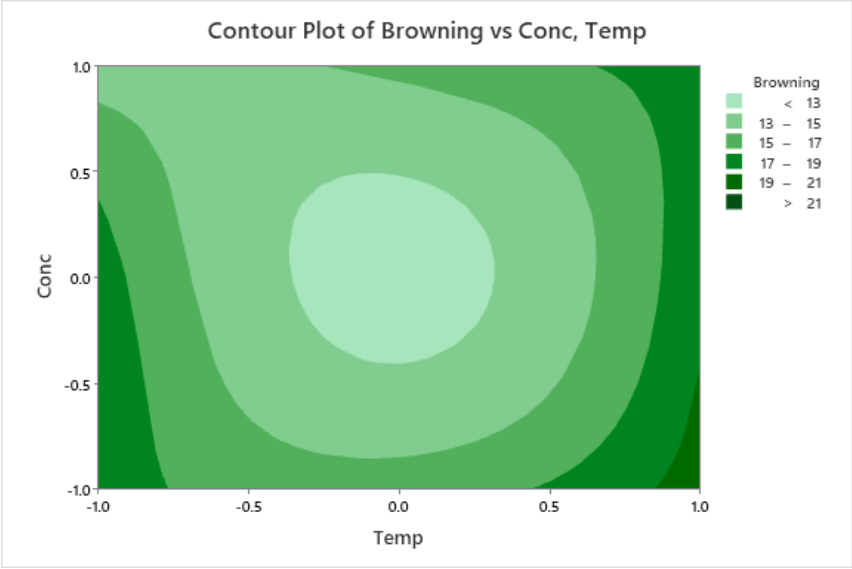

Fig-5: Contour plot of Browning Vs. Conc. and Temperature

In Fig-5 it is conclusive that browning is found to be less in 0.2M concentration with the temperature range of 12.5^0 to 20^0 centigrade. This gives ample encouragement to the farmers and researchers to go for this combination for minimal browning in Paddystraw mushrooms.

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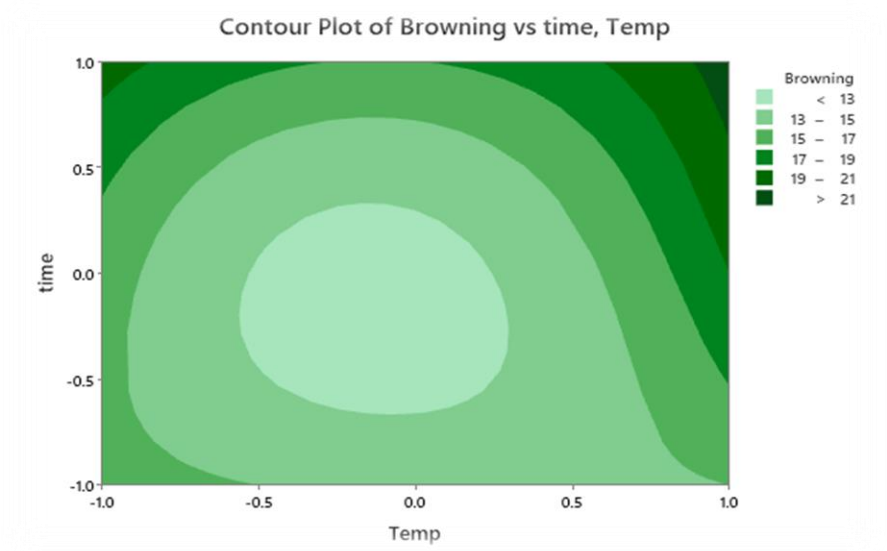

Fig-6: Contour plot of Browning Vs. Time and Temperature

Temperature is more dominant in case of weight loss (p=0.01) than browning (0.018) from the contour plot (Fig-6). So we are encouraged to take this combination of time (5-10 minutes) and temperature range of 12.5^0 to 15^0C.

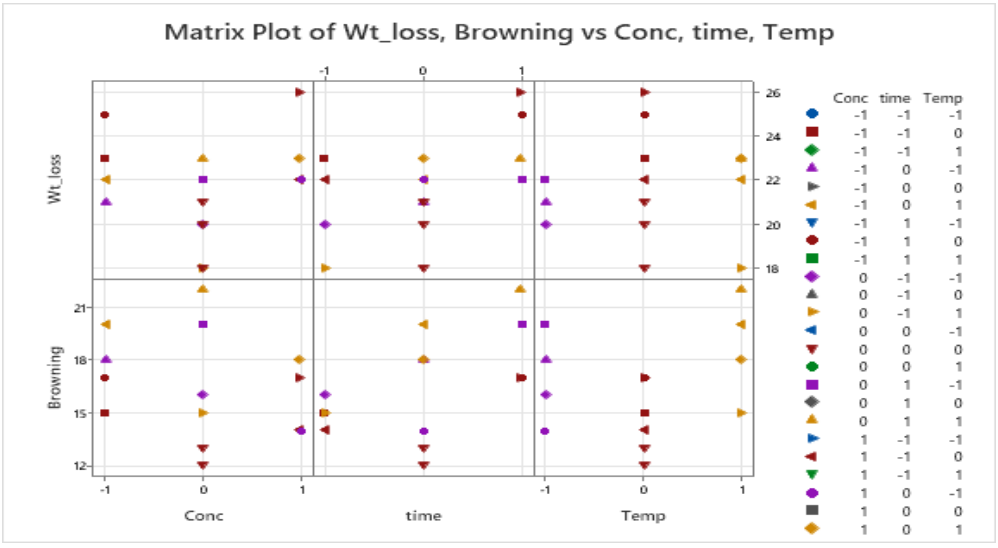

Fig-7: Matrix Plot of Weight loss and Browning Vs. Concentration, Time and Temperature

In Fig-7, the matrix plot shows maximum weight loss at concentration (1), Time (1), and Temperature (0) and maximum browning occurred at concentration (0), Time (1), Temperature (1).Optimum Condition ranges are found clearly from the Fig-7 regarding least browning and least weight loss.

4.7. Browning: At concentration level (0) i.e. 0.2 M, time (0) i.e. 7 min and temperature (0), i.e. 15^0 C. Browning of the mushrooms is an indication of deterioration which makes the attractive mushrooms very dull and non-hygienic which results in the reduction of market price.Ithas to be minimized to benefit the seller in making good amount of profit and simultaneously makes the customers pleased with the colour, texture and weight.

According to the matrix plot of weight loss, browning versus concentration, time and temperature, the browning of paddy straw mushrooms is least at 0.2% chitosan concentration for 7 minutes at 15^0 C. All other combinations did not produce such less browning that is why the aforementioned combination is an optimum one for storing these delicious mushrooms.

4.8. Weight loss: At Concentration level (0) i.e. 0.2 M, time (-1 to 0) i.e. 3-7 min & Temp (0), i.e. 15^0 C.

Weight of the mushrooms at the time of production should be same or negligible amount of loss can be managed. But if the weight will reduce at a larger rate then it will be a threat for the producer as well as the seller to deal with this problem. So the weight loss is a major factor to be considered at the producer's as well as at the seller's end.

We found from the contour plot that the weight loss is least at 0.2% concentration of chitosan for 3 to 7 minutes at 15^0C. It is considered to be an ideal combination to apply for these mushrooms to keep the weight loss minimum

However, the deterioration effects are prominent when Weight loss is maximum at Concentration level (+1) i.e. 0.25 M, time +1 i.e. 15 min & Temp (0), i.e. 15 degree centigrade and we experience more Browning: at Conc. level (0) i.e., 0.2 M, time (+1) i.e., 15 min & Temp (0), i.e. 15-30^0C.

The deterioration i.e. weight loss is found to be maximum and the effects are prominent at 0.25 concentration of chitosan(+1) in 15minutes(+1) of incubation time at 15 degree centigrade(0) and browning is found to be very disappointed and disastrous at 0.2 concentration(0) with incubation time 15 minutes(+1) at 15-30^0C.

Annotation: * Indicates multiplication (X)

5. Conclusion:

The current investigation showed the best chitosan treatment parameters that ensure the long shelf life of paddy mushrooms grown in Odisha. The chitosan concentration, temperature, and time have a significant impact on weight loss and browning. By using statistical analysis to find the best combinations of temperature, time, and chitosan concentration, the shelf life of the delectable tropical paddy-straw mushrooms was increased to a tolerable level while minimising weight loss and browning. Our tables and matrix display make the minimum and maximum weight loss and browning evident. The appropriate ranges to choose and continue with were revealed using the response surface methodology. Here, temperature is more important than chitosan concentration in the case of weight loss, while temperature is more important than chitosan concentration in the case of mushroom browning. According to our response surface explanations, the safe range for weight loss was less than 18% and browning was less than 13%.This study aimed to assist mushroom growers with their post-harvest procedures, as well as vendors in reducing waste before placing mushrooms in consumers' bags. On a national level, it will not only aid in reducing waste but also enable farmers to comprehend that tropical mushrooms may be stored using rational techniques like those we employed in this study.

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