International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-3, February 2019

Optimization of Freeze Drying of Oyster Mushroom and Composition of Extruded Snack Incorporated with Oyster Mushroom Flour Using Response Surface Methodology

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Abstract: ***Mushroom is a highly perishable product, so various methods were developed for the preservation and storage of it. In our study the optimizing conditions for the freeze drying of oyster mushroom and incorporating this oyster mushroom flour in addition with either the rice flour or corn flour to develop an extruded product. For obtaining the optimizing conditions Central Composite Design is employed that comes under the Response Surface Methodology. With coefficient of determination R^2, the significant regression models are describing the changes on the physical characters, with respect to the independent variables that were established. For the freeze drying the parameters of the processing conditions are varied like for temperature of -30 ºC to -50ºC and time from 27 to 35 hrs. The independent variables that had an effect on the processing conditions are colour, particle density and porosity. The optimum processing conditions obtained according to Response surface methodology for freeze drying are -40ºC at 31 hrs. In the development of extruded product incorporated with the oyster mushroom flour to that of the corn flour or rice flour the compositions are varied from 5 to 20%. The response variables that had an impact due to the varying composition in raw material where speed, pressure and temperature. The optimum percent of oyster mushroom flour to that of the corn flour or rice flour are 10 and 12.5 respectively.***

Index Terms: ***Oyster mushroom, freeze drying, extruded product, colour, particle density, porosity, speed, temperature and pressure.***

I. INTRODUCTION

Mushrooms are rich in lysine and tryptophan which are proteins. In mushrooms carbohydrates are about 4.5 to 5%, instead of starch they are present in the forms of chitin, glycogen and hemicellulose. It is rich in an essential fatty acid that is linoleic acid, but has a very low fat content of 0.3%. They are rich in Vitamin C and also a good source of Vitamin B complex having niacin, pantothenic acid, thiamine, biotin and riboflavin. Even Vitamin $B_{12}$and folic acid are present in mushrooms, while they are mostly absent in the other vegetables. These are a good source of micro and macro nutrients mainly iron and potassium (Mehta et al., 2011). They are also used for medical resources (Aida et al., 2009). These mushrooms has a delicate texture and have high moisture content hence, they are highly perishable and cant be stored in ambient condition for more than 24 hrs (Lal and Sharma, 1994; Gothandapani et al., 1997). Within 48 hrs of harvest, they are usually processed as the fresh mushrooms have a high rate of respiration, which results in off flavour development, rapid deterioration in quality, discolouration and loss in texture (Bano and Singh, 1972). To extend their shelf life, many methods like freezing, dehydration, pickling and canning are used (Bano et al., 1998; Singh and Bano, 1997). Some studies on mushrooms have been carried out for storing them for longer periods and for retaining the colour. It was found that 3 to 5 mints of hot water blanching is better to that of 4 to 5 mints steam blanching by the inactivation of catalase and peroxidase, for retaining colour (Pruthi et al., 1984). For the blanched mushrooms the steeping solution has salt, sugar, ascorbic acid, citric acid and KMs having concentration of 5, 1, 0.5, 0.3 and 0.1 per cent respectively, for storing the mushrooms for a longer period (Singh., 1997).

Studies were conducted for the standardisation and optimization of Muttom Manchurian where physico-chemical and microbial properties of Optimised fresh and freeze dried Mutton Manchurianwere carried using Response Surface Methodology and Evaluation (Reddy et al., 2013). The optimization for the extrusion process having base material as Lali flour and rice flour mixture is done by Response Surface Methodology (Choudhary et al., 2001). Research work on ready to eat extruded snack having garlic incorporated was developed and evaluated (Haritha et al., 2014). It was reported that good appearance and colour was obtained by frozen products when *Agaricus bisporus L*treated by blanching for 20 sec in hot water and freezing in KMS at 3000-5000 rpm and storing it for 90 days at -20ºC (Czapski and Szudygu, 2000). *Pleurotus Ostreatus* mushrooms are froze using liquid CO_2 at -70ºC and was observed that they could be stored for 90 days under refrigeration condition (Kondratowicz and Dajanowska, 2000). Process conditions were obtained using Response Surface Methodology and Rotational Central Composite Design to develop a snack having by-products of soybean and rice (Coutinho et al., 2013). A procedure that is best used for developing a best possible product in a batch is known as optimization and measuring the response or opinion about the preference on the product of the consumers is known as sensory evaluation (Sidel and Stone, 1983). In the development of a product there are many tools used.

Manuscript published on 28 February 2019.
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For food product development an effect method that can be employed is the Response Surface Methodology which is one among the statistical experimental methods (Hu, 1999).

II. MATERIALS AND METHODS

Materials

Oyster mushroom, corn flour and rice flour. Oyster mushroom flour which is obtained by freeze drying oyster mushroom and by grinding it.

Methodology

In Design Expert Software the methodology to be followed is to choose the Central composite design in the Response surface methodology. Then set the factors which are independent variables and response activity which are dependant variables. Then apply it in the Design Expert Software Version 11.

Optimization of freeze drying of Oyster mushroom

Freeze drying of oyster mushroom, optimization is done by having independent variables as temperature and time, and response activity as colour, particle density and porosity.

Formulation and processing of extruded snack having oyster mushroom flour

Extruded snack having oyster mushroom flour, formulation and processing is done by having independent variables as percent of oyster mushroom flour in corn flour and percent of oyster mushroom flour in rice flour, and response activity as Speed, pressure and temperature.

III. EXPERIMENTAL DESIGN

Optimization of freeze drying of Oyster mushroom

In the freeze drying of oyster mushroom the two independent variables are temperature and time which has a great combined effect on the final product. This was employed with the Central Composite design having the base on quadratic model. These independent variables that is temperature and time are coded as A, B which are responsible for the freeze drying. For these chosen variables in the table 1, the central composite design was executed having a number of 13 combinations with 3 replicates. Freeze dried oyster mushroom was measured for the dependant variable that is the colour (Y1), partial density (Y2) and porosity (Y3). Response function, where dependant variables are expressed individually as the function of independent variables. For each factor variances was observed using polynomial function and are presented as follows:

$$Y1 = 87.10123 - 0.132766A - 0.000259B$$

$$Y2 = 4.60178 + 0.022932A - 0.192518B - 0.001812AB - 0.000395A^2 + 0.002063bB^2$$

$$Y3 = 116.79881 - 0.293089A - 2.47439B + 0.001250AB - 0.003037A^2 + 0.038828B^2$$

Table 1: Response surface methodology's experimental design matrix for the freeze drying of oyster mushrooms

Std	Run	Factor 1 A:Temperature Degree Celcious	Factor 2 B:Time Hours	Response 1 Colour	Response 2 Particle Density g/cm3	Response 3 Porosity %
6	1	-25.8579	31	90.12	1.23	81.2
7	2	-40	25.3431	92.46	1.34	84.2
2	3	-30	27	90.89	1.32	83.9
3	4	-50	35	93.46	1.42	83.4
1	5	-50	27	93.78	1.22	84.1
9	6	-40	31	92.62	1.29	82.8
5	7	-54.1421	31	94.01	1.26	81.7
8	8	-40	36.6569	92.44	1.44	82.4
4	9	-30	35	91.23	1.23	83.4
12	10	-40	31	91.99	1.43	83.6
10	11	-40	31	92.34	1.22	82.1
11	12	-40	31	92.7	1.28	82.6
13	13	-40	31	93.21	1.35	82.5

Formulation and processing of extruded snack having oyster mushroom flour

In the development of extruded snack incorporated with oyster mushroomflour the two independent variables are percent of oyster mushroom flour in corn flour and percent of oyster mushroom flour in rice flour which has a great combined effect on the final product. This was employed with the Central Composite design having the base on quadratic model. These independent variables that is percent of oyster mushroom flour in corn flour and percent of oyster mushroom flour in rice flour are coded as A, B which are responsible for the end product. For these chosen variables in the table 2, the central composite design was executed having a number of 13 combinations with 3 replicates. Extruded snack having oyster mushroom flour was measured for the dependant variable that is the speed (Y1), pressure (Y2) and temperature (Y3). Response function, where dependant variables are expressed individually as the function of independent variables. For each factor variances was observed using polynomial function and are presented as follows:

$$Y1 = 298.61538 - 0.032956A - 0.156972B$$

$$Y2 = 6.28583 - 0.057255A - 0.057492B + 0.004889AB$$

$$Y3 = 160.38462 + 0.390349A - 4.74001B$$

Table 2: Response surface methodology's experimental design matrix for the development of extruded snack with oyster mushroom flour

Std	Run	Factor 1 A:Oyster Mushr... %	Factor 2 B:Oyster Mushr... %	Response 1 Speed Kg/h	Response 2 Pressure bar	Response 3 Temperature Degree Ccelcious
8	1	12.5	23.1066	280	5.4	179
4	2	20	20	324	5.8	145
11	3	12.5	12.5	275	5.9	169
2	4	20	5	287	5	140
5	5	1.8934	12.5	293	5.1	143
9	6	12.5	12.5	289	5.8	153
13	7	12.5	12.5	325	5.7	155
12	8	12.5	12.5	317	5.6	154
7	9	12.5	1.8934	310	5.6	180
10	10	12.5	12.5	300	5.5	146
6	11	23.1066	12.5	289	5.9	167
3	12	5	20	298	5.7	176
1	13	5	5	295	6	178

IV. RESULTS AND DISCUSSIONS

Optimization of freeze drying of Oyster mushroom

STATISTICAL ANALYSIS

For different processing conditions the experimental value and the analysis of variance are estimated by these response variables which are colour, partial density and porosity. All the response variables were adequate and were characterized by the response surface model that was obtained. A satisfying value of R^2 was obtained for all the response activity. The R^2 values for the response variables that is colour, particle density and porosity are 0.913, 0.6634 and 0.5284 respectively. In this model, less relevant dependable variables explain the less behavioural variation when the R^2 value is smaller. Closer to unity if R^2 value is there then the actual model fits the empirical data.

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COLOUR

Variation in colour between the dried and the fresh sample determines the Total colour
difference. The samples that are freeze dried represented the hue having lowest yellowness, high lightness and saturation (Martinez – Soto et al., 2001).

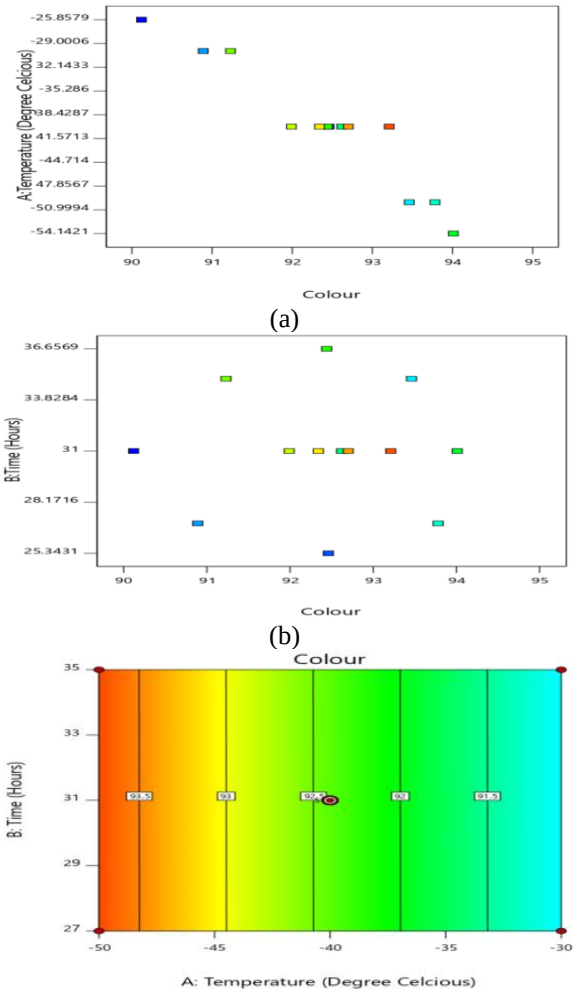
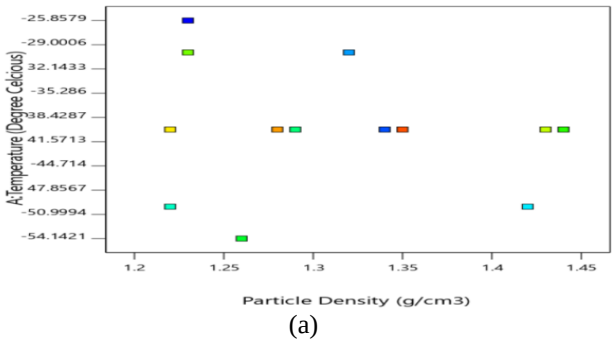


Figure 1: (a), (b) exhibits the relationship of colour with that of the operating conditions and (c) exhibits the relationship of colour with time and temperature

PARTICLE DENSITY

Freeze drying has a very minimal effect on the particle density as it directly sublimes to vapour from ice that is present in the sample, this causes minimal shrinkage as it protects the shape and primary structure (Krokida et al., 1998b



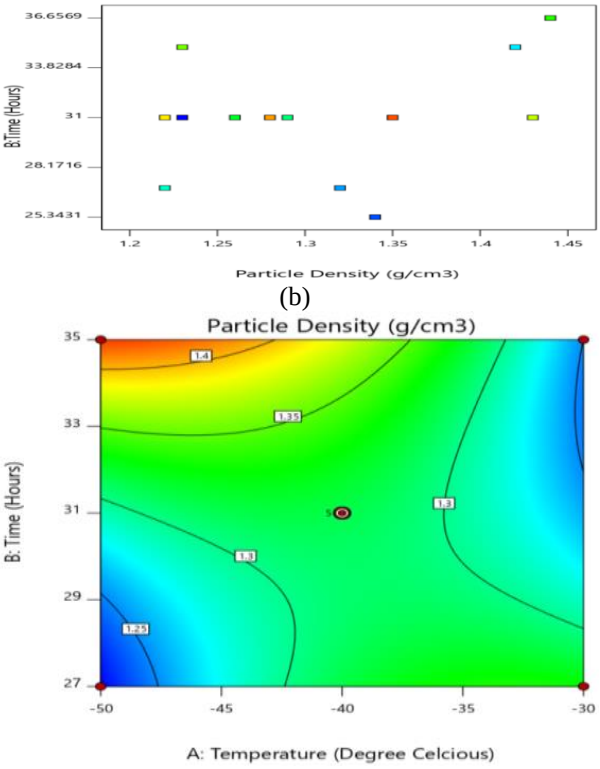
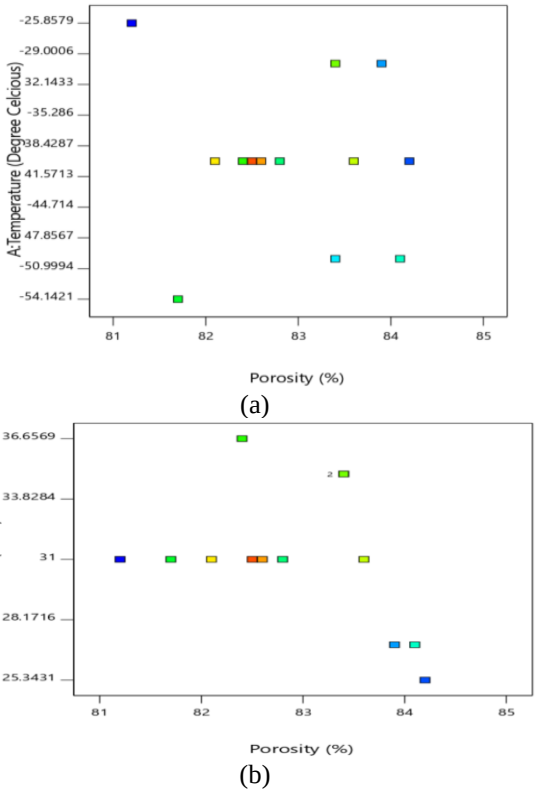


Figure 2: (a), (b) exhibits the relationship of particle density with that of the operating conditions and (c) exhibits the relationship of particle density with time and temperature

POROSITY

Freeze drying causes the highest porosity in mushrooms. A porous structure having a minimized shrinkage helps to improve water potential reconstitution.



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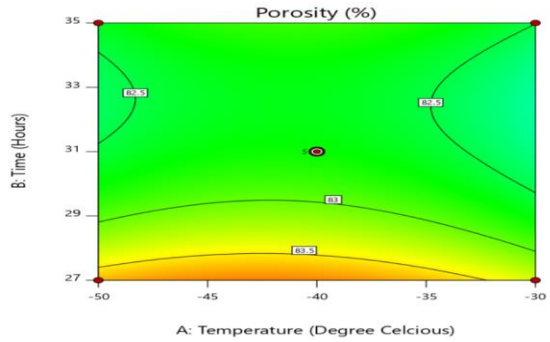


(c)

Figure 3: (a), (b) exhibits the relationship of porosity with that of the operating conditions and (c) exhibits the relationship of porosity with time and temperature

OPTIMIZATION

Freeze drying, the optimum conditions of the responses should be having a light colour, minimum particle density and maximum porosity. There are various combinations available to obtain light colour, minimum particle density and maximum porosity having different variables in different conditions. For the processing conditions the absolute combinations of response variables are -40ºC for 31 hrs respectively.

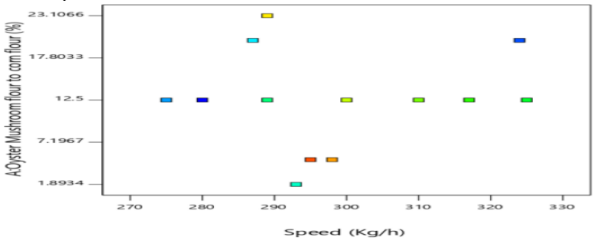
Formulation and processing of extruded snack having oyster mushroom flour

STATISTICAL ANALYSIS

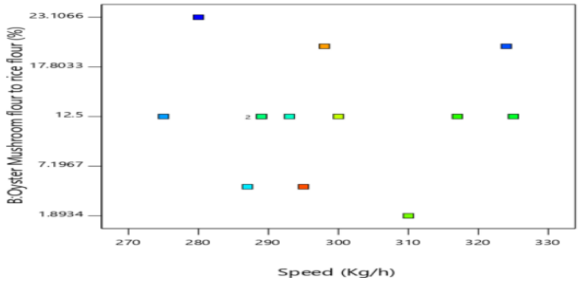
For different composition of ingredients the experimental value and the analysis of variance are estimated by these response variables which are speed, pressure and temperature. All the response variables were adequate and were characterized by the response surface model that was obtained. An acceptable value of R^2 was obtained for all the response activity. The R^2 values for the response variables that is speed, pressure and temperature are 0.4521, 0.2872 and 0.1269 respectively.

SPEED

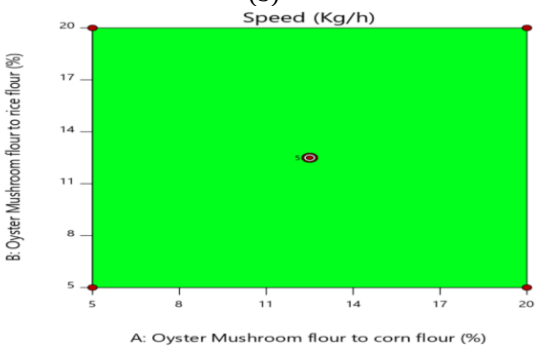
The speed at which the flour is mixed along with the solution to form a dough plays an important role in the production of the extruded snack. When the screw speed is increased along with a decrease in the feed rate causes the degree of fill to reduce having torque at low level (Guha et al., 2003).



(a)



(b)

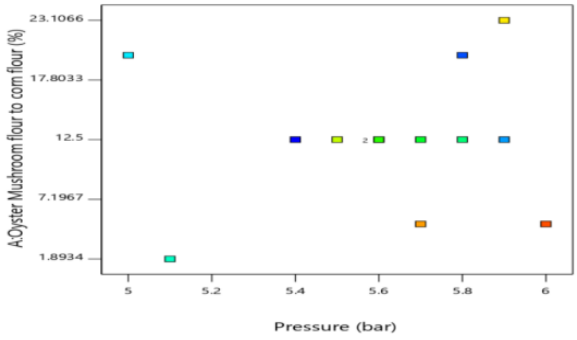


(c)

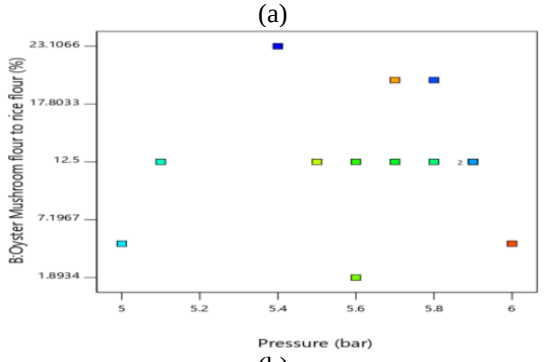
Figure 4: (a), (b) exhibits the relationship of speed with that of the composition of the raw material and (c) exhibits the relationship of speed with Percent of oyster mushroom flour added to that of rice flour and corn flour

PRESSURE

Positive influence of pressure is mainly due to the feed composition and the moisture content of the feed. The moisture absorption varies between the corn flour and that of the rice flour.



(a)



(b)

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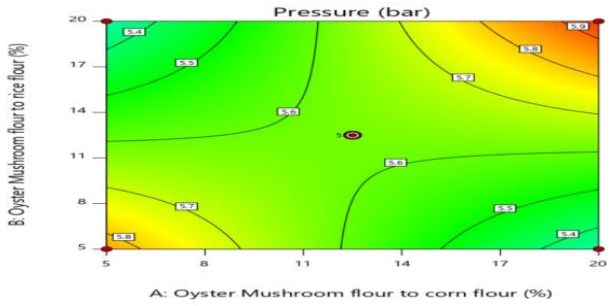
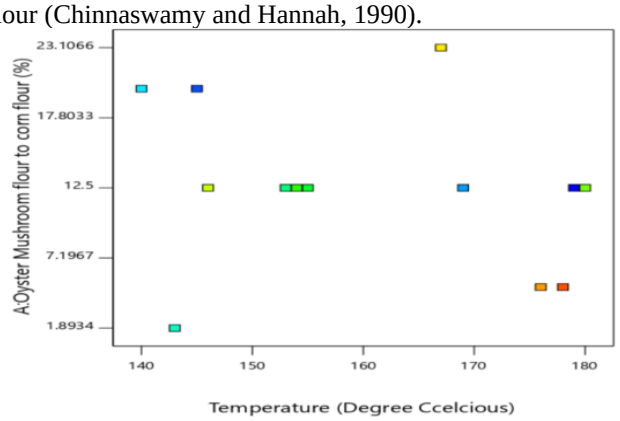


(c)

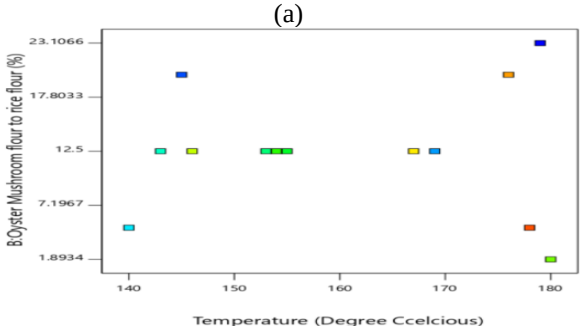
Figure 5: (a), (b) exhibits the relationship of pressure with that of the composition of the raw material and (c) exhibits the relationship of pressure with Percent of oyster mushroom flour added to that of rice flour and corn flour

TEMPERATURE

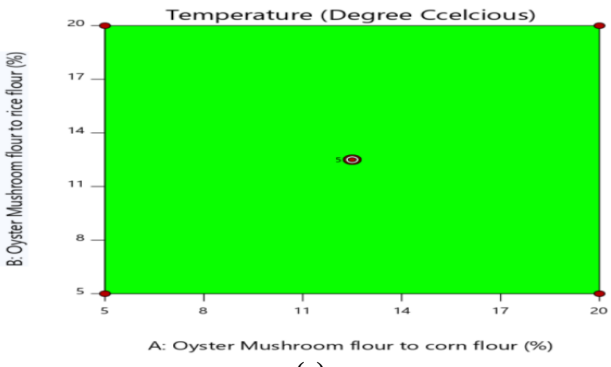
At low temperature the elastic forces will be dominant along with that of low moisture content. High temperatures are required for the rice based snack than that of the corn flour (Chinnaswamy and Hannah, 1990).



(a)



(b)



(c)

Figure 6: (a), (b) exhibits the relationship of temperature with that of the composition of the raw material and (c) exhibits the relationship of temperature with Percent of oyster mushroom flour added to that of rice flour and corn flour

V. OPTIMIZATION

Extrusion, the optimum conditions of the responses should be having a minimal speed, pressure and temperature and it varies for the composition of the products that are fed into the extruder. There are various combinations available to obtain minimal speed, pressure and temperature having different variables in different conditions. The evaluated compositions of the percent of oyster mushroom flour in corn flour and in rice flour are 10 and 12.5 respectively.

VI. CONCLUSION

For the freeze drying of the oyster mushrooms different processing conditions like time and temperature were varied to obtain the responses in the colour, particle density and porosity. For the development of the extruded snack, the composition of the oyster mushroom flour to that of the corn flour and the rice flour were varied having response variables as the speed, pressure and temperature. In order to obtain the favourable processing conditions and for the composition of the flour this response surface methodology was employed.

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