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RESEARCH ARTICLE

TESTING OF TURMERIC SLICER FOR POTATO SLICING.

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Abstract

The turmeric slicer developed by All India Co-ordianted Research Project on Post Harvest Engineering and Technology was tested for slicing of potato. The machine/process parameters were optimized for better slicing efficiency. Cutting cum slicing machines was developed to meet the requirement of small scale entrepreneurs and also the farmers who are interested to set up their own rural level low capacity processing plant with low initial investment for preparation of processed products. Slicing machine have centrifugal action and consists of hollow drum with beaters, stationary blade and a rotor plate. Capacity of machine, breakage percentage and slicing efficiency were studied for potato.The performance of the developed turmeric slicer was found to satisfactory and the machine was found to be techno-economically feasible for the entrepreneur. The slicing efficiency, damage percentage and capacity of the machine for slicing of ginger were found to be 94.69%, 4.58% and 250 kg/h, respectively.

Introduction and objectives:-

India is the second largest vegetable producer, producing 99.4 million tones of different vegetables. India produced 41555 thousand tones of potato from 1973 thousand ha area during the year 2013-14 (*Source*: Horticulture Statistics Division, DAC&FW.). Potato processing involves cleaning/washing, slicing and drying. Cutting/slicing of potato is necessary in order to achieve fast drying for preparation of potato chips. Although the mechanical slicers are available in market but these are very costly and are beyond the limit of small entrepreneur. Therefore, the project was proposed to test the turmeric slicer developed by All India Co-ordinated Research Project on Post Harvest Engineering and Technology for slicing of potato.

Materials and methods:-

Turmeric cutting cum slicing machine:-

The All India Coordinated Research Project on Post Harvest Engineering and Technology developed power operated turmeric cutting cum slicing machine as shown in Plate 1. The machine consists of the feeding unit, slicing mechanism, driving mechanism, frame and the housing. Centrifugal action principle with fix SS blade is adopted. The material fed through hopper is subjected to centrifugal force and strikes on the stationary SS blade fixed on the casing. The machine cuts the turmeric rhizomes into slices of desired thickness (1.5 to 5 mm). The slices are collected through outlet provided below the blade.

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Plate 1:- Turmeric slicer

Testing of turmeric slicer for slicing of potato:-

Tests were carried out to evaluate the performance of the developed turmeric slicing/cutting machine for slicing of potato. Potatoes were purchased from local market of Akola. Before testing machine, physical properties of potato were measured. The clearance between casing plate and fixed cutting stainless steel blade was adjusted to get slices of desired thickness. The potatoes and ginger were fed through hopper into the machine at constant feed rate of 200 and 100 kg/h. The fed material is thrown forcefully by three stainless steel (SS) blades fixed to the hollow rotating drum by centrifugal action against the stationary SS cutting blade and get sliced/cut into desired thickness. The slicing was longitudinal. Whole slices and damaged slices were separated and weighed. The cutting efficiency was assumed to be affected by rotor speed (S) and slice thickness (T). The experimental design of independent parameters are shown in Table 1. This table shows the coded and decoded independent variables and their levels.

Table 1:- Levels of independent variables for potato.

Independent variables	Symbols		Levels	
	Coded	**Decoded**	**Coded**	**Decoded**
Rotor speed, rpm	x_1	X1	2	500
			1	450
			0	400
			-1	350
			-2	300
Slice thickness, mm	x_2	X2	2	3.5
			1	3.0
			0	2.5
			-1	2.0
			-2	1.5

Dependent variables:-

Cutting/slicing efficiency, %

Damage, %

The performance of the machine was evaluated by using the following formulae.

Cutting Efficiency (CE):-

$$Cutting\ efficiency\ (CE) = \frac{\mathrm{W} - WD}{W} \mathrm{X100}$$

Where W = Weight of all slices

Wd = Weight of damaged slices

Per cent Damage (PD):-

$$\text{Per cent damage} = \frac{WD}{W} \times 100$$

Response surface methodology was applied to the experimental data, using Design expert version 9 (Statease Inc. Minneapolis USA Trial version 2015). Sixteen trials were performed as enumerated in Table 2.

Table 2:- Experimental layout for two variables and five levels response surface analysis for potato slicing.

Treatment	**Rotor speed, rpm**	**Slice thickness, mm**	**Rotor speed, rpm**	**Slice thickness, mm**
	Coded independent variables		**Decoded independent variables**	
	x_1	x_2	X_1	X_2
1	2	2	500	3.5
2	-1	-1	350	2
3	-1	-1	350	2
4	2	2	500	3.5
5	-2	-2	300	1.5
6	-2	-2	300	1.5
7	2	2	500	3.5
8	2	2	500	3.5
9	1	1	450	3
10	2	2	500	3.5
11	-2	-2	300	1.5
12	0	0	400	2.5
13	0	0	400	2.5
14	0	0	400	2.5
15	0	0	400	2.5
16	0	0	400	2.5

As per 2 variable 5 level model, 16 trials were performed as enumerated in Table 3 for obtaining the slicing efficiency and per cent damage responses for each treatment. All these trials were conducted with 500 g sample size and data for slicing efficiency and per cent damage was reported. To avoid bias, 16 runs were performed in a random order. The decision for the range and centre points of the variables was taken through preliminary trials as described by Pokharkar (1994), Chowdhury*et al.* (2000), Ravindra and Chattopadhyay (2000), Jain (2007), Singh *et al.* (2008), Ranmode (2009) and Borkar (2011).

Results and Discussion:-

Potato slicing:-

Physical properties:-

Some physical properties of potatoes used for study are given in Table 3. The average of 10 observations are given.

Table 3:- Physical properties of potato.

Sr. No.	**Physical property**	**Range**
1.	Major dimensions, mm	
	Length	77.23
	Width	53.90
	Thickness	40.95
2.	Geometric Mean diameter (mm)	54.35
3.	Sphericity	0.72
4.	Bulk Density (g/cm^3)	0.61
5.	Angle of repose, ^{o}	57.52

Testing of turmeric slicer for slicing of potatoes:-

Effect of input parameters on slicing efficiency for potato:-

The slicing efficiency was observed to be ranging from 84.72 to 95.27% depending upon the slicing treatments. The minimum slicing efficiency was found for treatment having the combination of rotor speed of 500 rpm, slice thickness of 3.5 mm. The maximum slicing efficiency was observed in case of treatment having the combination of rotor speed of 350 rpm, slice thickness of 2.5 mm.

The analysis of variance (ANOVA) was made for the experimental data and the significance of rotor speed and slice thickness as well as their interactions on slicing efficiency was analyzed. The response surface quadratic model was fitted to the experimental data and statistical significance of linear, interaction and quadratic effects were analyzed for slicing efficiency response (Table 4). It revealed that the model was highly significant at 1 % level of significance.

Table 4:- ANOVA for effect of slicing variables on slicing efficiency.

Source	**Df**	**Sum of Square**	**Mean sum of square**	**F Value**	**p-value Prob>Fig**	
Model	91.99	3	30.66	11.35	0.0008	significant
A-Rotor speed	30.36	1	30.36	11.24	0.0058	
B-Slice thickness	64.58	1	64.58	23.91	0.0004	
A^2	11.81	1	11.81	4.37	0.0585	
Residual	32.41	12	2.70			
Lack of Fit	26.63	7	3.80	3.29	0.1044	*not significant*
Pure Error	5.79	5	1.16			
Cor Total	124.41	15				

Std. Dev.	1.64		R-Squared	0.96
Mean	91.27		Adj R-Squared	0.6743
C.V. %	1.80		Pred R-Squared	0.5618
PRESS	54.51		Adeq Precision	12.046

The results showed that among linear effects, slice thickness had significant effect on slicing efficiency ($P<0.01$) at 1 % level of significance followed by rotor speed. Quadratic effect of rotor speed had significant effect on slicing efficiency ($P<0.01$) at 1 % level of significance. The existence of quadratic terms of rotor speed indicates the curvy linear nature of response surface. It indicates that increasing the value of variable initially increases the response up to certain level of variable however further increase in the level of variable decreases the value of response.

The quadratic response surface model data indicated the results as significant. The lack of fit was found to be non significant which indicates that the developed model was adequate for predicting the response. The coefficient of determination (R^2) was 0.9620 for slicing treatment which indicated that the model could fit the data for slicing activity very well for all the two variables, i.e. of rotor speed and slice thickness. The linear terms of both the parameters showed effect on slicing efficiency however the interaction terms were showing non-significant effect. The quadratic terms of rotor speed only showed significant effect.

The regression equation describing the effects of input parameters on slicing efficiency in terms of coded value of variables is given as

$$\text{Slicing efficiency} = +92.62-1.93x_1-3.02x_2-1.96x_1^2 \quad \ldots 1$$

x_1 = rotor speed, rpm

x_2 = slice thickness, mm

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

The regression equation describing the effects of input parameters on slicing efficiency in terms of actual value of variables is given as

Slicing efficiency = $+76.50099+0.13764X_1-3.02250\ X_2-1.96132E\text{-}004X_1^2$ …2

X_1 = rotor speed, rpm

X_2 = slice thickness, mm

The equation in terms of actual factors can be used to make predictions about the response forgiven levels of each factor. Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space.

The effect of rotor speed and slice thickness on slicing efficiency is as shown in Fig. 1. It could be observed that with increase in rotor speed, the slicing efficiency increased at a particular rotor speed and then decreased. It was observed that the slicing efficiency was found maximum at 2 mm slice thickness and as the slice thickness increased the slicing efficiency decreased.

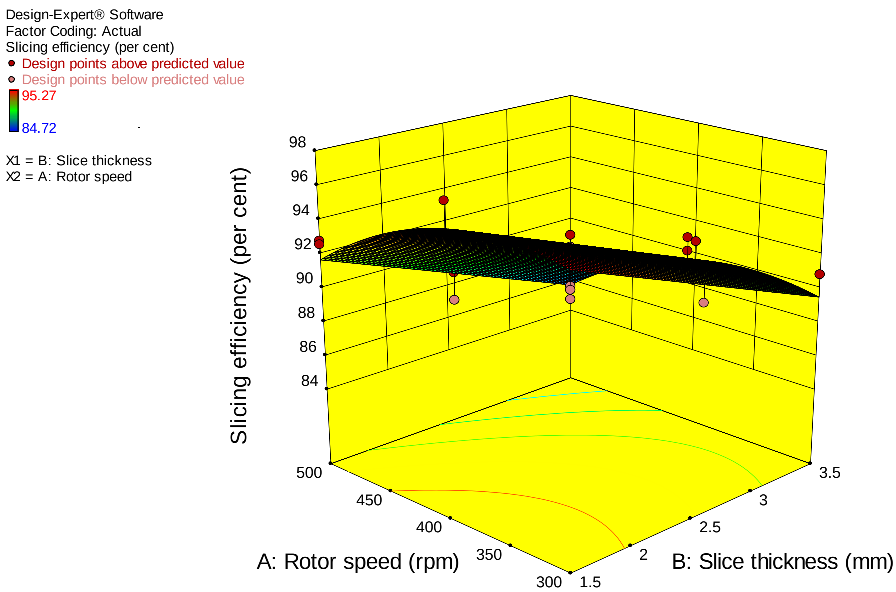

Fig. 1:- Effect of rotor speed and slice thickness on slicing efficiency of potato

Damage:-

Effect of slicing treatments on percent damage:-

The results regarding percent damage by using various slicing parameters are given in Table 5.

Table 5:- Effect of various levels of slicing parameters on percent damage.

Sr. No.	Rotor speed, rpm	Slice thickness, mm	Percent damage, %
1.	400	2.5	7.5
2.	300	2.5	8.42
3.	450	2	4.82
4.	400	3.5	9.03
5.	400	3.5	9.87
6.	500	2.5	11.25
7.	500	2.5	12.08
8.	400	2.5	9.79
9.	300	3.5	9.1
10.	350	2	4.72
11.	400	2.5	8.12
12.	350	3	7.17
13.	300	1.5	5.1
14.	500	3.5	15.27
15.	500	1.5	7.35
16.	500	1.5	7.14

From Table 5, it revealed that the percent damage was observed to be ranging from 4.72 to 15.27 % depending upon the slicing treatments. The minimum percent damage was found for treatment having the combination of rotor speed 350 rpm, slice thickness 2 mm. The maximum percent damage was observed in case of treatment having the combination of rotor speed 500 rpm, slice thickness 3.5 mm.

Table 6:- ANOVA for effect of slicing treatment variables on percent damage for potato.

Source	Df	Sum of Square	Mean sum of square	F Value	p-value Prob>F	
Model	99.07	4	24.77	16.24	0.0001	Significant
A-Rotor speed	*30.37*	*1*	*30.37*	*19.91*	*0.0010*	
B-Slice thickness	*60.88*	*1*	*60.88*	*39.92*	*< 0.0001*	
AB	*6.24*	*1*	*6.24*	*4.09*	*0.0680*	
A^2	*15.39*	*1*	*15.39*	*10.09*	*0.0088*	
Residual	16.77	11	1.52			
Lack of Fit	*13.25*	*6*	*2.21*	*3.13*	*0.1155*	*not significant*
Pure Error	*3.53*	*5*	*0.71*			
Cor Total	115.84	15				

Std. Dev.	1.64	R-Squared	0.9774
Mean	91.27	Adj R-Squared	0.8743
C.V. %	1.80	Pred R-Squared	0.7618

The ANOVA in Table6 revealed that the model was highly significant at 5 % level of significance. The results showed that among linear effects, slice thickness had significant effect on percent damage ($P<0.05$) at 5 % level of significance followed by rotor speed. All the interaction and quadratic effects of rotor speed were found significant for percent damage.

The lack of fit was non significant which indicates that the developed model was adequate for predicting the response. The coefficient of determination (R^2) was 0.9774 for slicing which indicated that the model could fit the data very well for all the variables.

The response surface equation was obtained for the model of second degree in terms of coded factors as under.

Percent damage, % = $7.13 + 1.94 x_1 + 2.95x_2 +1.13x_1x_2 +2.24 x_1^2$ ….3

Where,

x_1 = rotor speed, rpm

x_2 = slice thickness, mm

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying therelative impact of the factors by comparing the factor coefficients.

The response surface equation was obtained for the model of second degree in terms of actual factors as under.

Percent damage, % = $+39.12907-0.18806 X_1 -1.56678X_2 ++0.011300X_1X_2 +2.24 \quad X_1^2$

The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space.

Effect of rotor speed and slice thickness on percent damage:-

The effect of rotor speed and slice thickness on percent damage was determined as shown in Fig. 2. The percent damage was found decreasing as the rotor speed increased to some extent and then the damage was found increasing at higher rotor speed. The percent damage was found increased significantly as the thickness of slice increased.

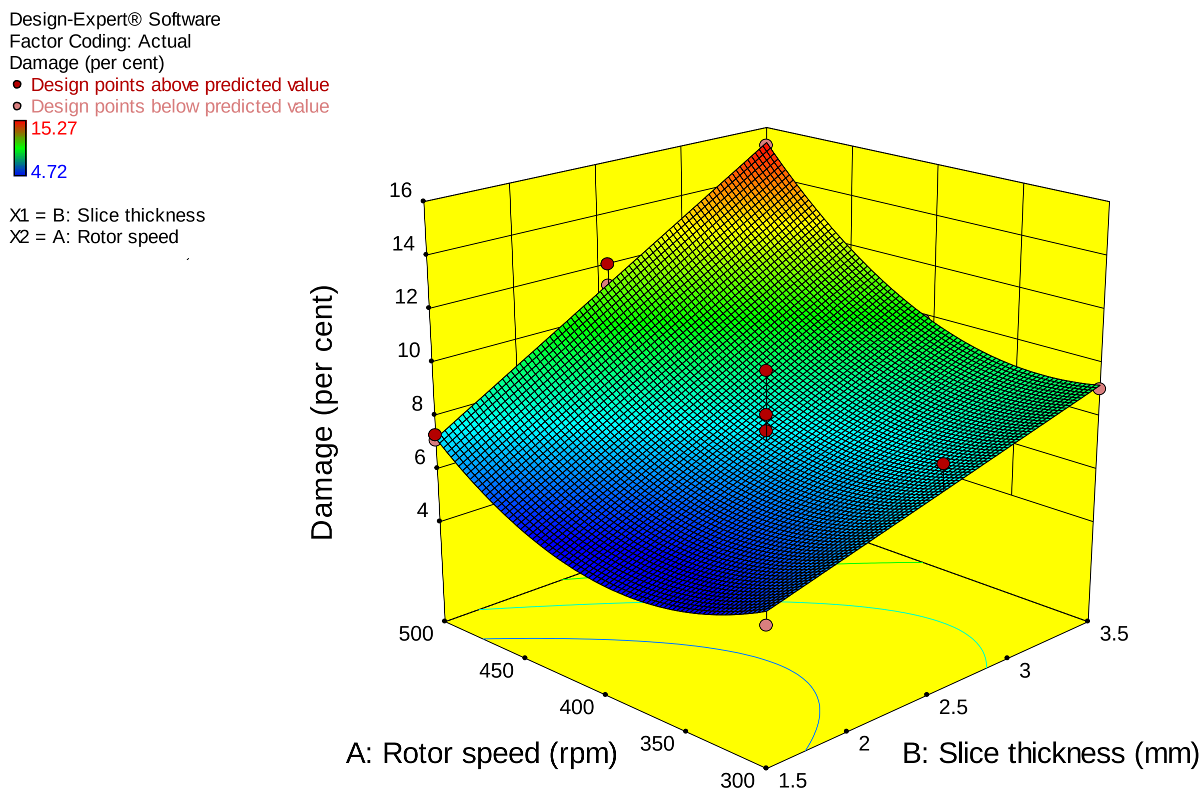

Fig. 2:- Effect of rotor speed and slice thickness on percent damage.

The optimization criteria for different process variables and responses for slicing efficiency are given in Table 7.

Table 7:- Optimization criteria for different process variables and responses for slicing efficiency of potato.

Constraints						
Variable	**Goal**	**Lower Limit**	**Upper Limit**	**Lower Weight**	**Upper Weight**	**Importance**
A:Rotor speed	is in range	300	500	1	1	3
B:Slice thickness	is in range	1.5	3.5	1	1	3
Slicing efficiency	maximize	84.72	95.27	1	1	3
Damage	minimize	4.72	15.27	1	1	3

Optimization of slicing treatment variables:-

Software Design Expert version 9.0.3.1 was used for the optimization of responses. A stationary point at which the slope of the response surface was zero in all the direction was calculated by partially differentiating the model with respect to each variable, equating these derivatives to zero and simultaneously solving the resulting equations. The optimum values for different variables and their predicted responses thus obtained are given in Table 8 as well as Fig. 3.

Table 8:- Optimized variables and their predicted responses for slicing of potato

Variable	Optimized values	Responses	Predicted values
Rotor speed, rpm	415.382	Slicing efficiency, %	95.272
Slice thickness, mm	1.509	Per cent damage, %	4.386

The optimum values of different variables for slicing were found within the range considered in the study.

Verification of the Model for slicing of potato:-

The performance of this model was also verified by conducting an experiment for the validation. In order to validate the optimum conditions of slicing treatment variables, the experiments were conducted at optimum input parameters derived conditions. The average values of three experiments are given in Table 9. The observed values of slicing efficiency and percent damage were found to be 94.69 % and 4.58%. It could reveal that the experimental values were very close to the predicted values which confirmed the optimum conditions (Table 9).

Table 9:- Predicted and experimental values of responses at optimum level of different variables

Sr. No.	Responses	Predicted values	*Experimental values (± SD)	C.V.
1	Slicing efficiency, %	95.27	94.69 (± 1.04)	1.80
2	Percent damage, %	4.38	4.58 (± 0.39)	9.45

* Figures in parenthesis represent standard deviation

The superimposed contours for response and their intersection for maximum slicing efficiency (Fig. 3) indicated the range of optimum values of process variables.

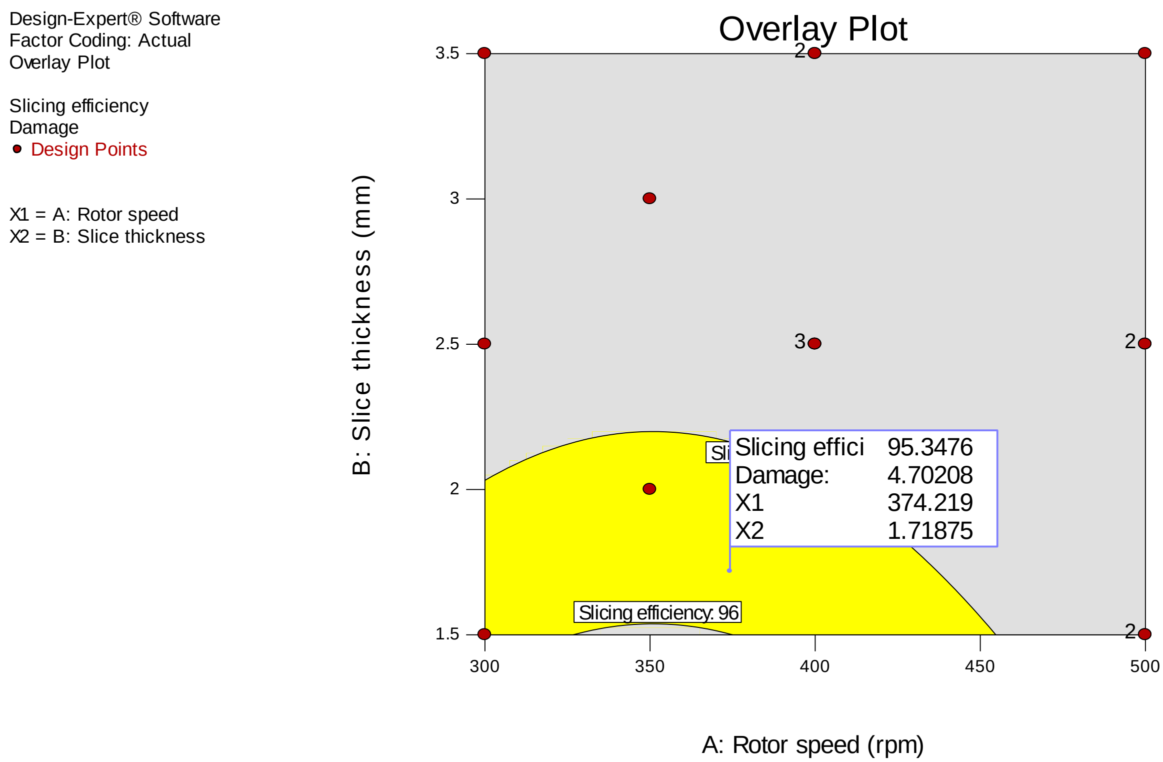

Fig. 3:- Superimposed contours for slicing efficiency and percent damage potato slicing

The cost of machine is Rs. 60,000/-. The gadget is technically feasible and economically viable with annual net profit of Rs. 44,283/-, break even point of 34.07 %, cost of processing of 0.25 Rs./kg and employment generation of 120 mandays/year.

Conclusion:-

The performance of developed turmeric slicer was found to be satisfactory for slicing of potato with 94.69 % slicing efficiency and it was found techno economically feasible for an entrepreneur.

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