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EALUATION OF TURMERIC SLICER FOR GINGER SLICING

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Summary: The turmeric slicer developed by All India Co-ordianted Research Project on Post Harvest Engineering and Technology was tested for slicing of ginger. The machine/process parameters were optimized for better slicing efficiency. Cutting cum slicing machine 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 ginger. 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 94.20%, 4.90% and 250 kg/h, respectively.

Keywords: Ginger, slicing, entrepreneur.

Introduction and objectives

India is the second largest vegetable producer, producing 99.4 million tones of different vegetables. India produced 655 thousand tones of ginger from 133 thousand ha area during the year 2013-14 (*Source*: Horticulture Statistics Division, DAC&FW.). Ginger processing involves cleaning/washing, slicing and drying. Cutting/slicing of ginger is necessary in order to achieve fast drying for preparation of ginger slices. 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 ginger.

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

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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.

Plate 1: PDKV Turmeric slicer

Testing of turmeric slicer for slicing of ginger

Tests were carried out to evaluate the performance of the developed turmeric slicing/cutting machine for slicing of ginger. Ginger were purchased from local market of Akola. Before testing machine, physical properties of ginger were measured. The clearance between casing plate and fixed cutting stainless steel blade was adjusted to get slices of desired thickness. The ginger were fed through hopper into the machine at constant feed rate of 250 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 ginger slicing

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

1. Cutting/slicing efficiency, %
2. Damage, %

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

1. Cutting Efficiency (CE)

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

Where W = Weight of all slices

Wd = Weight of damaged slices

2. Per cent Damage (PD)

3. 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 ginger 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

Physical properties

Physical properties of ginger used for study are given in Table 3. The average of 10 observations are given in this Table.

Table 3. Physical properties of ginger

Sr. No.	Physical property	Range
1.	Major dimensions, mm	
	Length	88.20
	Width	54.79
	Thickness	24.38
2.	Geometric Mean diameter (mm)	47.17
	Sphericity	0.59
3.	Bulk Density (g/cm^3)	0.37
4.	Angle of repose, ^{o}	53.80

Effect of input parameters on slicing efficiency for ginger

The slicing efficiency was observed to be ranging from 77.77 to 93.90% depending upon the slicing treatments. The minimum slicing efficiency was found for treatment having the combination of rotor speed of 400 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 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 cubic 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 treatment variables on slicing efficiency

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob> F	
Model	221.97	2	110.99	21.58	< 0.0001	Significant
A-Rotor speed	*69.22*	*1*	*69.22*	*13.46*	*0.0028*	
B-Slice thickness	*182.91*	*1*	*182.91*	*35.56*	*< 0.0001*	
Residual	66.87	13	5.14			
Lack of Fit	*51.42*	*8*	*6.43*	*2.08*	*0.2181*	*not significant*
Pure Error	*15.46*	*5*	*3.09*			
Cor Total	288.85	15				

Std. Dev.	1.68	R-Squared	0.8929
Mean	85.13	Adj R-Squared	0.8540
C.V. %	1.97	Pred R-Squared	0.7581
PRESS	69.87	Adeq Precision	16.385

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 0.89 for slicing treatment which indicated that the model could fit the data for slicing very well for all the two variables, i.e. of rotor speed and slice thickness.

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

Slicing efficiency, % = $85.92 - 11.32\, x_1 - 5.22\, x_2 - 1.17\, x_1^2 + 9.18\, x_1^3$ ….5

Where,

x_1 = rotor speed, rpm

x_2 = slice thickness, mm

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

Slicing efficiency, % = -461.94356– +4.38641 X_1- -5.22253 X_2- -0.011132 X_1^2 +9.17900E-006 X_1^3 ….6

Where,

X_1 = rotor speed, rpm

X_2 = slice thickness, mm

The effect of rotor speed and slice thickness on slicing efficiency for ginger 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 as slice thickness increased, slicing efficiency was increased initially. The slicing efficiency was found maximum at 2 mm slice thickness and as the slice thickness increased further, the slicing efficiency decreased.

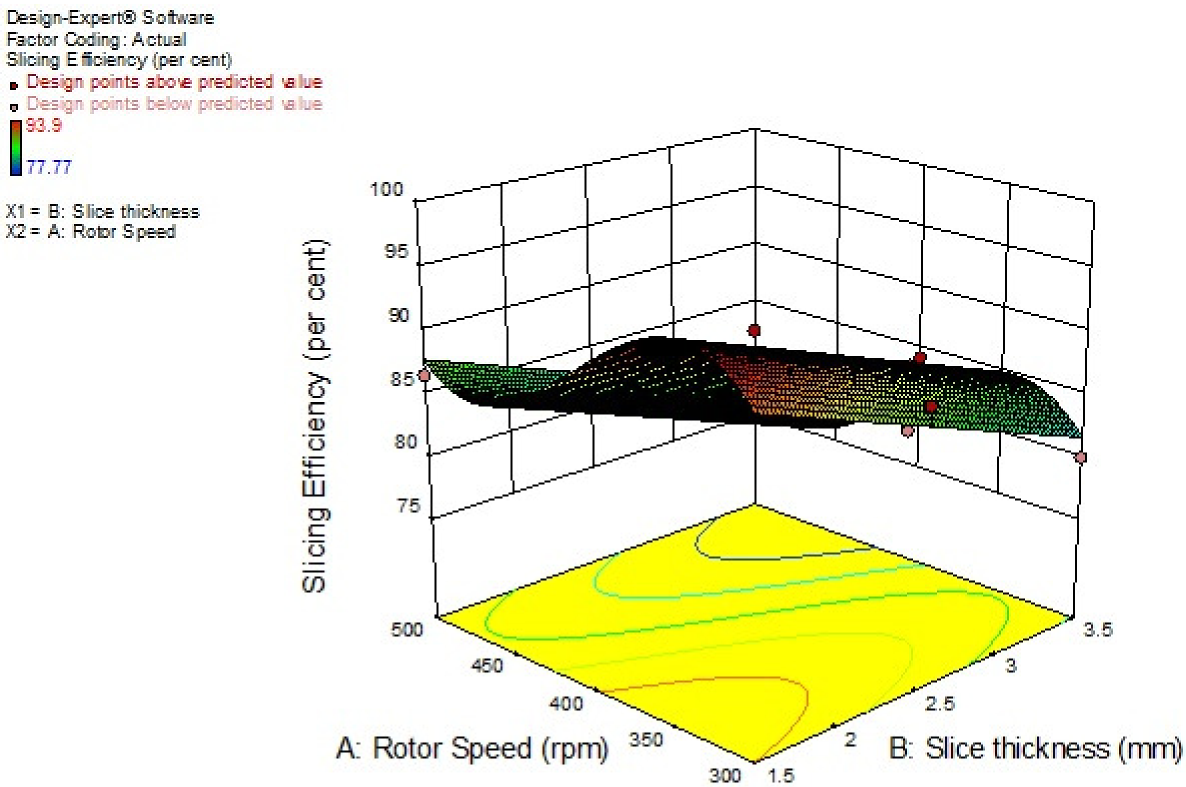

Fig. 1: Effect of rotor speed and slice thickness on slicing efficiency

Effect of slicing treatments on percent damage

The percent damage was observed to be ranging from 6.09 to 22.22 % 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.

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 percent damage was analysed (Table 5).

Table 5: ANOVA for effect of slicing treatment variables on percent damage for ginger

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob> F	
Model	257.99	4	64.50	22.92	< 0.0001	Significant
A-Rotor speed	51.79	1	51.79	18.40	0.0013	
B-Slice thickness	192.56	1	192.56	68.42	< 0.0001	
A^2	4.22	1	4.22	1.50	0.2464	
A^3	31.23	1	31.23	11.10	0.0067	
Residual	30.96	11	2.81			
Lack of Fit	15.50	6	2.58	0.84	0.5898	not significant
Pure Error	15.46	5	3.09			
Cor Total	288.95	15				

NS= Non significant S= Significant

Std. Dev.	1.68	R-Squared	0.8929
Mean	14.86	Adj R-Squared	0.8539
C.V. %	11.29	Pred R-Squared	0.7579
PRESS	69.96	Adeq Precision	16.379

The ANOVA in Table 5 revealed that the model was highly significant at 1 % level of significance. The results showed that among linear effects, slice thickness had significant effect on percent damage (P<0.01) at 1 % level of significance followed by rotor speed. Interaction was found significant. The quadratic effect of speed was 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 0.89 for slicing which indicated that the model could fit the data for activity very well for all the two variables, i.e. rotor speed and slice thickness.

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

Percent damage, % = $14.07 + 11.32\ x_1 + 5.22\ x_2 + 1.17\ x_1^2 - 9.18\ x_1^3$ … 7

Where,

x_1 = rotor speed (rpm)

x_2 = slice thickness, mm

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

Percent damage, % = $+562.13926 + -4.38791\ X_1 + +5.22401\ X_2 ++0.011135\ X_1^2 -9.18177\ X_1^3$ … 8

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.

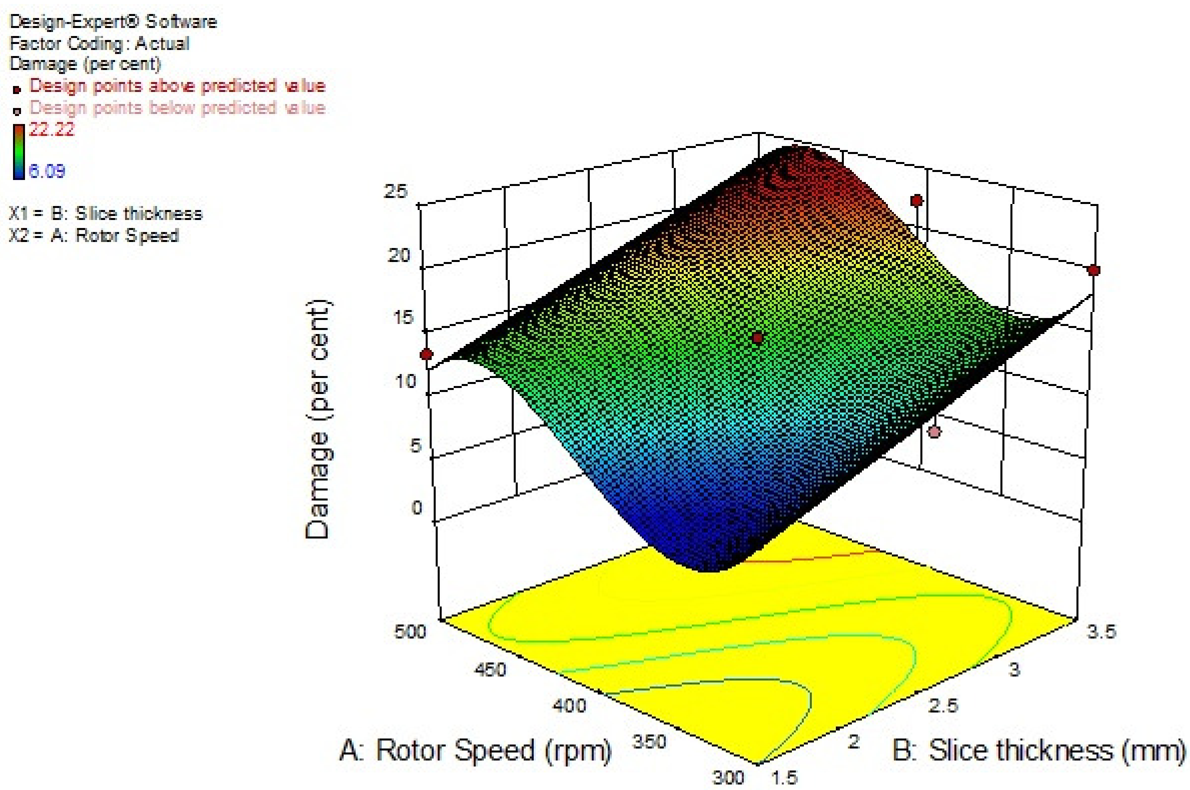

Fig. 2. Effect of rotor speed and slice thickness on percent damage

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 6 as well as Fig. 3.

Table 6: Optimized variables and their responses for slicing of ginger

Variable	Optimized values	Responses	Predicted values
Rotor speed, rpm	338.22 ≈340	Slicing efficiency, %	95.21
Slice thickness, mm	1.55≈1.5	Per cent damage, %	4.77
R^2	0.89		

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

Validity of the model

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 at optimum input parameters. The average values of three experiments are given in Table 7. The observed values of slicing efficiency and percent damage were found to be 94.20 % and 4.90%. It could reveal that the experimental values were very close to the predicted values which confirmed the optimum conditions (Table 7).

Table 7: Predicted and experimental values of responses at optimum level of different variables for ginger slicing

Sr. No.	Responses	Predicted values	Experimental values (± SD)	C.V.
1	Slicing efficiency, %	95.21	94.20 (± 1.60)	2.66
2	Percent damage, %	4.77	4.90 (± 0.68)	9.28

* Figures in parenthesis represent standard deviation

The superimposed contours for response and their intersection zone for maximum slicing efficiency (Fig. 6) indicated the range of optimum values of process variables.

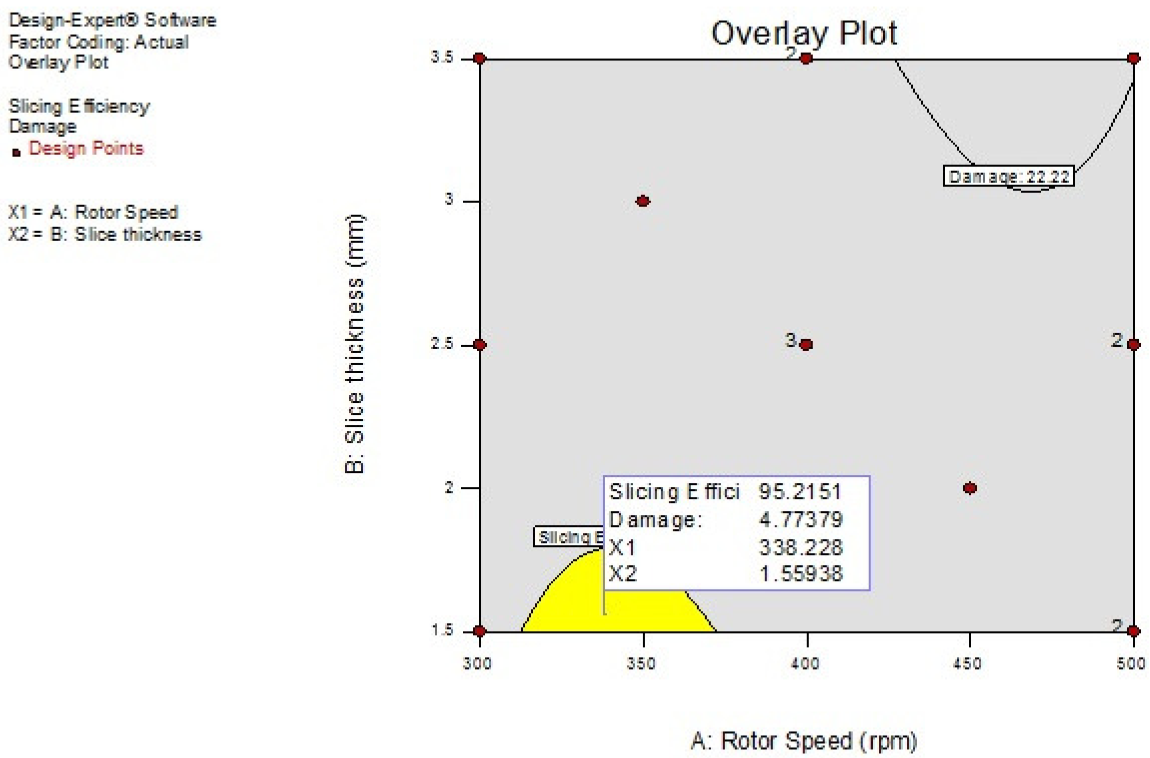

Fig. 3: Effect of rotor speed and slice thickness on ginger slicing efficiency and percent damage

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 ginger with 94.20 % slicing efficiency. It was found techno economically feasible for an entrepreneur.

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