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Evaluation of Milk Paneer Textural properties by Microwave Drying using Response Surface Methodology for Accelerated Drying

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ABSTRACT: The major goal of this research was to evaluate the texture of microwave-dried milk paneer cubes and to examine how the combination of microwave heating tempering time and hot air drying affected those attributes. The shelf life of paneer is a major constraint in its utilization. A paneer sample was made using a National Dairy Development Board-developed industrial paneer manufacturing procedure (NDDB). Response surface methodology was used in this study to optimise microwave heating and ambient tempering for accelerated drying of milk paneer. Drying can be one of the methods to increase shelf-life. Drying experiments were conducted at Optimization factors included paneer cube size (5-25mm), microwave power level (150-750W), heating time (2-10 min), tempering time (1-5 min), and responses such as hardness, springiness, cohesiveness, gumminess, and chewiness. Using Texture Analyzer (TA-XT-Plus) and Design Expert 13, the ideal parameters for a highly acceptable product with a cube size of 11.504 mm at a microwave power level of 350.442W, heating time of 5.587 min, and tempering time of 2.341 min revealed the 231.439 g Hardness, 0.774 mm springiness, 0.603 cohesiveness, 139.973 Nmm gumminess, and 105.917 N The experimental values under the microwave drying condition matched the outcome predicted by analysis of variance. It shows that the model is highly fit and that RSM was successful in maximizing the microwave power level, which has a significant and advantageous impact on drying rate. Texture is an important property of Paneer from the viewpoint of consumer acceptance and satisfaction.

Keywords: Paneer, Microwave drying, Texture, Response surface methodology (RSM).

INTRODUCTION

Paneer, a dairy product has a marble-white appearance, a spongy substance, and a close-knit texture. It also has a flavour that is sweetish-acidic and nutty (Chandan, 2007). Paneer contains a lot of fat, vitamins, and minerals including calcium and phosphorus. The heat-acid coagulated milk product known as paneer, also known as Indian soft cheese, is a rich source of high-quality animal fat, proteins, vitamins, and minerals including calcium and phosphorus. A high-quality block of paneer has a marble-white colour, a flavour that is sweet but somewhat acidic, a nutty scent, a spongy body, and a tightly woven and smooth texture. Paneer was required to meet standards (BIS, 1983) that specified a minimum of 50% fat and a maximum of 60% moisture in dry matter. One day at ambient temperature and six days in the refrigerator are the maximum storage times for paneer. Paneer is a crucial source of animal protein. Paneer has a biological value of between 80 and 86 percent because of its high protein content and easy digestion (Shrivastva and Goyal 2007). With increase in life expectation as well as standard of living, people now, not only require convenience but also anticipate health benefits from the foods (Gawad *et al.*, 2022). A major position is held by paneer, a classic milk product from India, as a base for the creation of numerous culinary creations. Buffalo milk is thought to be more suited than cow milk for creating paneer of high grade (Sachdeva *et al.*, 1985).

The term "texture" refers to the mix of characteristics that describe how a food's structure reacts to applied forces, with the three physiological senses involved being visual, kinesthetic, and auditory. Several researchers acknowledge the connection between the textural and structural characteristics of food (Stanley, 1976). Texture is the sensory and functional manifestation of the structural, mechanical and surface properties of foods detected through the senses of vision, hearing, touch and kinesthetic (Szczesniak, 2002). Food texture qualities can be assessed using instrumental (objective) measurement. The instrumental examination of food texture is faster and significantly less expensive than sensory evolution in terms of providing information about the product's qualities. In this study, the Texture Analyzer was used to measure hardness, springiness, cohesiveness, gumminess, and chewiness (TA-XT-Plus). While springiness, cohesiveness, and chewiness showed very minor variation compared to fresh paneer, hardness, adhesiveness, and resilience showed significant variance between fresh and rehydrated paneer. Controlling the variables that affect product texture is crucial for producing high-quality dairy products (Foegedinga *et al.,* 2003). When it comes to food harvesting, processing, packing, storage, and customer presentation, texture attributes are crucial. One of the textural features, such as hardness, is one of the most important criteria typically used to assess the freshness of fruits and vegetables (Konopacka and Plocharski 2004). Cohesiveness, springiness, gumminess, and adhesiveness are of prime importance for meat and meat products or gel products (Stejskal *et al.*, 2011; Akwetey and Knipe 2012; Taniwaki and Kohyama 2012; Chen and Opara 2013).

An important new technique for the thermal processing of food and dairy products is microwave heating. The friction between the water molecules inside the product is what causes instantaneous heating. Today, conventional thermal ovens have mostly been replaced by microwave ovens in the food processing and preservation industries. It is useful to process products with high and intermediate moisture content using this technique. Products with more moisture, fat, and sugar are more microwave-sensitive and heat up more quickly as a result. Microwave heating has a variety of advantages over traditional heating methods, including quick and thorough heating that produces foods of greater quality in terms of nutrition, taste, texture, and flavour, as well as enhanced productivity. Presently, there is a chance to use temperature sensors and microwave generators with precisely controlled input power, allowing one to exert control over the technological process (Marzec *et al.,* 2007). One of the most significant benefits of utilising microwaves for drying is the ability to control microwave power and temperature, which allows one to prevent thermal degradation of the studied material (Szarycz *et al.,* 2002).

In a microwave drying system, the microwave energy can produce internal heat that helps penetrate the interior layers and quickly adsorb the moisture from the sample. This energy is absorbed by the sample, which causes rapid water evaporation. This causes a flow of quickly evaporating vapours to move in the same direction as the moisture gradient (Dadali *et al.,* 2007; Soysal *et al.,* 2006; Wang *et al.,* 2007). The introduction of a microwave drying/heating technique which reduces drying time considerably and produces a high-quality end-product could offer a promising alternative and significant contribution to the processing industry (Soysal, 2004). During microwave drying, the vapour pressure increases as the material's moisture content approaches the boiling point, allowing the transport of moisture to the outside. Local pressure and temperature rise even while the moisture content of treated materials decreases and their loss factor rises (Bengtsson *et al.,* 1947; Odjo *et al.,* 2012). Additionally, the food ingredients that will be heated in the microwave must be put in microwave-safe containers, such as plastic (Attrey, 2017). According to the Food and Drug Administration (FDA), using the microwave in accordance with the provided instructions is perfectly safe (FDA, 2021).

A set of mathematical and statistical methods called the response-surface methodology (RSM) can be used to examine the effects of numerous unrelated inputs. RSM is a useful tool for analysing a wide range of input factors that affect the performance metric or quality characteristics of the product or investigative process. The main advantage of RSM was that it reduced the number of experimental trials needed to evaluate a variety of factors and their interactions (Zhong *et al.*, 2012). RSM was utilised in this work to explore the microwave heating and ambient tempering process optimization for the quick drying of milk paneer.

This study's objectives included creating models for paneer drying using the selected drying technique and examining the impacts of paneer cube size on drying time, microwave heating tempering duration, and hot air drying combined, on Textural qualities of rehydrated paneer cube.

MATERIAL AND METHODS

A. Material

In this research, fresh milk (buffalo milk) was used as the raw material for the preparation of paneer.

B. Sample preparation

For the manufacturing of paneer, the National Dairy Development Board developed a commercial paneer production procedure (NDDB). Using a plate heat exchanger, the milk is heated to 85°C, co-precipitated, pumped into a cheese vat, and then cooled to 75 °C. To coagulate the milk, a citric acid solution is added and well combined with the heated milk. The curd is allowed to sit quietly for ten to fifteen minutes. After the whey has been drained, the curd piles are placed inside cheese hoops made of muslin cloth and pressed for 10 to 15 minutes at a pressure of 3 kilograms per square centimeter. After the blocks were immersed in 4°C cold water for three hours to remove the whey, the paneer was cooled and firmed.

The paneer was then cut into five sizes of paneer cubes measuring 5, 10, 15, 20 and 25 mm using a knife and thread. Each paneer cube sample that was to be dried weighed 50g.

C. Microwave Dried Paneer

Drying paneer cubes in five different sizes—5, 10, 15, 20, and 25 mm—was evaluated at five different microwave producing powers—150, 300, 450, 600, and 750 W duty cycles of the microwave oven's magnetron tube. Each sample of a paneer cube to be dried was chosen, weighing 50g, from the raw paneer. The paneer cubes were microwave dried for ten minutes, pausing every two minutes so that they could finish drying or tempered for five minutes outside. Moisture loss was estimated by weighing the plate on a digital scale. Each microwave generating power was used for three distinct drying tests. To establish the drying parameters, the values from these trials were averaged.

D. Experimental Design, Statistical Analysis and Optimization

Using quantitative information from an appropriate experimental design, RSM is a statistical technique that pinpoints the perfect conditions. The variables chosen for the microwave drying experiments were paneer cube size (A), microwave power level (B), microwave heating time (C), and tempering time (D). The variable values were selected based on early drying trials. 27 experiments were run using the central composite ratable design with five levels of each variable (CCRD). Table 1 lists the degree of variables in coded and actual units. A second-order polynomial equation was then used to fit the measured dependent variables (moisture content and bulk density) as a function of the independent variables. Response Surface Methodology (RSM), which looks at the relationship between a number of explanatory variables and one or more response variables, was used to analyses the experimental data using the trial program.

Table 1: Independent Variable and their levels used in the response surface design.

Independent Variables	Code	Levels				
		-2	-1	0	+1	+2
Paneer cube size (mm)	A	5	10	15	20	25
Microwave power level (W)	B	150	300	450	600	750
Heating time (min)	C	2	4	6	8	10
Tempering time (min)	D	1	2	3	4	5

According to Lee *et al.* (2000); Bezerra *et al.* (2008), regression analysis and analysis of variance (ANOVA) were used to fit the model represented by equation (1) to the experimental data and to assess the statistical significance of the model analysis, lack of fit test, and R2 (coefficient of determination) analysis.

$$Y_k = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum_{i=1}^{k-1} \sum_{j=i+1}^{k} \beta_{ij} X_i X_j \quad (1)$$

Where Y is the response (predicted moisture content and bulk density), β_i is the linear coefficient, β_{ii} is the quadratic coefficient, β_{ij} is the interaction effect, X_i and X_j are the independent variables in the form of coded values, and the $X_{i,}$ X_j and X_i^2 represent the interaction and quadratic term, respectively.

When points were omitted from the regression and model fluctuations could not be explained by random error, the lack-of-fit is a measurement of a model's inability to accurately reflect data in the experimental domain. If the probability value indicates a significant lack of fit, the response predictor is dropped. The ratio of the explained variance to the total variation is known as the R2 (coefficient of determination), which measures the degree of fit (Haber and Runyon 1977). The coefficient of variation displays the relative difference between the experimental data and the model prediction (CV). The response surface was created using Design Expert software, which also performed numerical optimization. It should be noted that the 3D figure was produced by changing the other two variables within the experimental range while holding one variable constant at the centre point. For graphical optimization, the simplified response model was depicted as three-dimensional (3D) surface plots (Weng *et al*., 2001).

E. Textural Properties Analysis

Texture Analyzer (Model TAXT2i, Exponent Stable Micro Systems, United Kingdom, Software Texture Expert) was used to perform Texture Profile Analysis (TPA) on paneer samples. Using the following settings, exceed version 7.1.6): load cell capacity 5 kg, return to start option, displacement 0.1-5.24 mm, pretest speed 5 mm/sec, test speed 0.01 mm/sec, and post test speed 2 mm/sec. Heavy duty platform (HDP/90) was employed to position the sample. The probe and texture analyzer were connected using the probe adapter. The AD/100 probe adapter was utilised in these studies to connect the probe to the machine. Throughout the investigations, a stainless steel cylindrical probe (P/5) with a 5 mm diameter was employed. Using the texture Expert Exceed software and adhering to the user documentation, real-time data collecting was completed (9). The data presented are the means of at least 5 measurements for each paneer cube's three replicates. In terms of hardness, springiness, cohesiveness, gumminess, and chewiness, the texture profile curve was interpreted.

RESULT AND DISCUSSION

A. Response surface analysis of Hardness

Hardness is the maximal peak force during the initial compression cycle or the force necessary to cut through food with the front teeth. Samples with a gentle texture required less force, whereas samples with a firm texture required more force. Hardness is the amount of pressure that must be applied to a food item in order to create deformation, such as between the tongue and teeth or between the teeth and mouth (Caine *et al.,* 2003). The greatest force on the deformation curve served as the hardness indicator (Marzec *et al.,* 2007). Hardness may rise as a result of the rising temperature. For all sizes, paneer's hardness increased as temperature rose. The relationship between paneer's hardness and moisture content is inverse (Desai *et al.,* 1991). During experiment the hardness of all microwave dried paneer cube ranged for 5mm paneer cube from 229 to 512gm, for 10mm 203 to 392. 5 gm, for 15 mm 177.9 to 213.5 gm, for 20mm 145 to 156 gm and for 25 mm 138 to 92.3 gm with microwave power levels, heating time and tempering time. The multiple regression models for predicting the hardness showed regression coefficient (R^2) 0.9988 and non-significant F-value of 13.97 as lack of fit. The significant quadratic model was established P-value of< 0.0001 The response surface 3D graph for hardness (Fig. 1) shows the interactive effect of microwave power, heating time, Tempering time.

Table 2: Analysis of the variance (ANOVA) for response surface quadratic model for hardness.

Source of Variation	Sum of squares	Degree of freedom	Mean square	F-Value	P Value
Residual	0.1231	12	0.0103		
Lack of fit	0.1214	10	0.0121	13.97	0.0686 Non significant
Pure error	0.0017	2	0.0009		
Cor total	104.11	26			
R^2= 0.9988, R(adj.)= 0.9974, R(pred.)= 0.9932, Adeq. Precision=107.254, C.V. % = 0.7102%					

The multiple regression equation representing the effect of processing parameter on hardness in coded values is given by following second-order model:

$$\text{Hardness} = +13.89 - 2.02\times A + 0.2993\times B + 0.0608\times C + 0.0013\times D - 0.1996\times AB - 0.0337\times AC + 0.0135\times AD - 0.0280\times BC - 0.0034\times BD + 0.0035\times CD + 0.3331\times A^2 + 0.0514\times B^2 + 0.0164\times C^2 + 0.0147\times D^2 \quad \ldots(2)$$

Equation 2 represent the negative coefficient of the order term of Paneer cube size (A) and interaction term AB, AC, BC and BD indicated the decrease in hardness with increasing these variables.

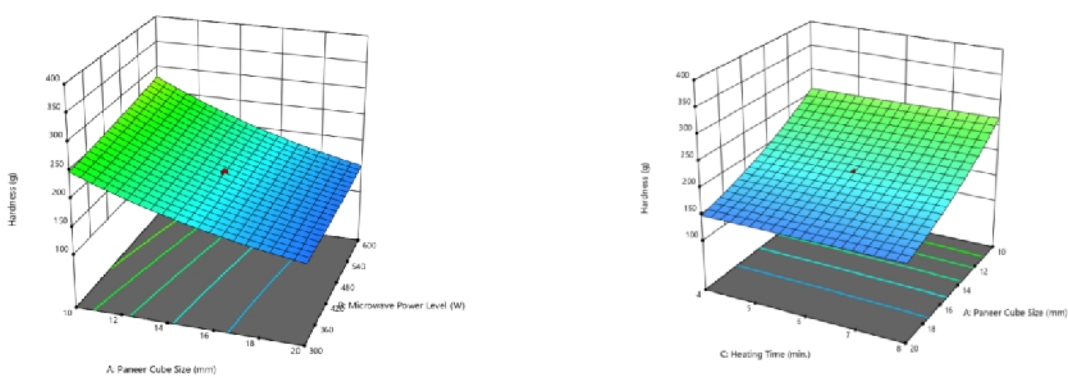

Fig. 1 (a,b). Impact of Paneer cube size, Heating time and power levels upon Hardness.

B. Response surface analysis of Cohesiveness

The sample's degree of deformation before rupturing as a result of molar biting the amount of deformation a material may undergo before breaking. Cohesiveness declined as temperature rose. When the temperature was high, it was higher; when the paneer's size increased, it was lower. Possible causes include moisture loss and protein changes, which have a major impact on certain textural properties. During the experiment the cohesiveness of all fresh paneer cubes ranged from 0.740 to 0.412 and for rehydrated paneer cube ranged from 0.766 to 0.247. The multiple regression models for predicting the cohesiveness showed regression coefficient (R^2) 9996 and a non-significant F-value of 17.82 as lack of fit. The significant quadratic model was established at probability P-value of <0.0001. The response surface 3D graph for cohesiveness (Fig. 2) shows the interactive effect of Paneer cube size, microwave power levels, heating time and tempering time. The multiple regression equation representing the effect of processing parameter on cohesiveness in coded values is given by following second-order model:

Table 3: Analysis of the variance (ANOVA) for response surface quadratic model for cohesiveness.

Source of Variation	Sum of squares	Degree of freedom	Mean square	F-Value	P Value
Residual	0.1105	12	0.0098		
Lack of fit	0.0980	10	0.0087	17.82	0.0543 Non significant
Pure error	0.0012				
Cor total	189.33				
R^2=0.9996, R(adj.)=0.9991, R(pred.)= 0.9976, Adeq. Precision=183.1815, C.V.% = 0.7827%					

Cohesiveness = $+0.5130-0.1323\times A+0.0131\times B+0.0040\times C-0.0025\times D+0.0040+0.0061\times AB+0.0002\times AC-0.0002\times AD-0.0006\times BC + 0.0003\times BD + 0.0002\times CD - 0.0032\times A^2 + 0.0030\times B^2 - 0.0135\times C^2 + 0.0008\times D^2$ ...(3)

The negative coefficient of the first order terms of A, D, interaction term, and quadratic term in equation 3 indicated that cohesiveness decreased with an increase in these variables, while the positive coefficient of the first order terms of B, C, interaction term, and quadratic term resulted in an increase in the cohesiveness of rehydrated paneer with an increase in these variables.

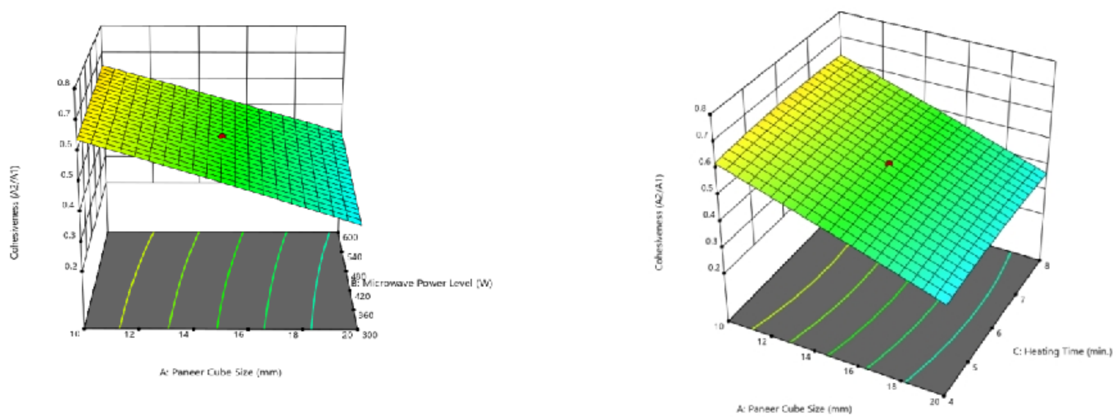

Fig. 2 (a, b). Impact of Paneer cube size, Heating time and power levels upon cohesiveness.

C. Response surface analysis of Springiness (mm)

How much of a product, after partial compression (without failure) between the tongue and palate or teeth, returns to its original size or shape? After the deformation force is removed, the sample's height rebounds between the first and second compressions. While the springiness values drop as the temperature rises. With the coded values and natural values of independent variables, the following relationship was discovered after the deformation force is removed, the sample's height rebounds between the first and second compressions. While the springiness values drop as the temperature rises. With the coded values and natural values of independent variables, the following relationship was discovered:

Springiness = $+0.7750+0.0183\times A-0.0133\times B-0.0044\times C+0.0029\times D-0.0043\times AB-0.006\times AC+0.0004\times AD+0.0001\times BC-0.0002\times BD+0.0001\times CD-0.0035\times A^2-0.0015\times B^2-0.0103\times C^2-0.0017\times D^2$ ...(4)

The negative coefficient of the first order term of B, C, interaction term, and quadratic term in equation 4 indicated that springiness decreased with an increase in these variables, while the positive coefficient of the first order term of A, D, interaction term, and quadratic term resulted in an increase in the springiness of rehydrated paneer with an increase in these variables.

Table 4: Analysis of the variance (ANOVA) for response surface quadratic model for springiness.

Source of Variation	**Sum of squares**	**Degree of freedom**	**Mean square**	**F-Value**	**P Value**
Residual	0.0001	12	0.0000		
Lack of fit	0.0001	10	0.0000	14.54	0.0428
Pure error	0.0021				
Cor total	0.0158	26			
R^2= 9907, R(adj.) = 0.9798, R(pred.)= 0.9467, Adeq. Precision= 29.777, C.V.% = 0.4612					

A high R^2 indicates that the variation could be accounted for by the data satisfactorily fitting the model. The coefficient of variation (CV) of less than 10 indicated that the model was reproducible. The model F-value 91.08, implied that the model was significant. Adequate precision measures the signal-to-noise ratio. A ratio greater than 4 is desirable (Myers and Montgomery 2002). For the proposed model, this value was 29.777 a very good signal-to-noise ratio. All these statistical parameters show the reliability of the model.

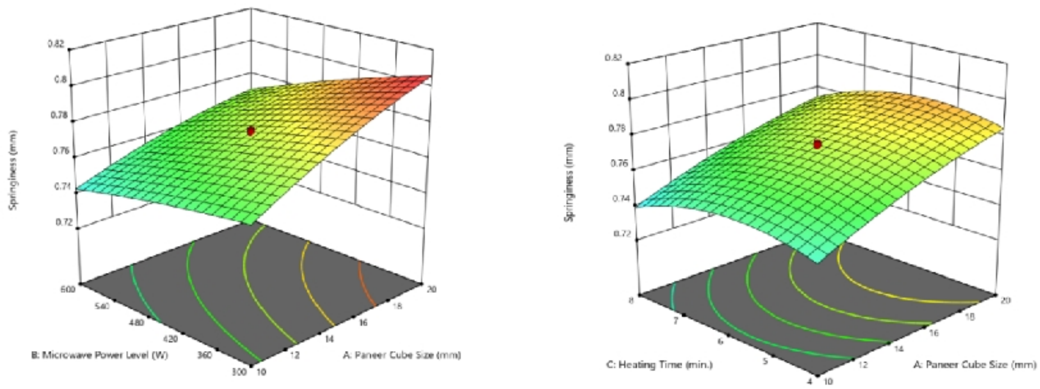

Fig. 3. (a, b). Impact of Paneer cube size, Heating time and power levels upon springiness.

D. Response surface analysis of Gumminess

Energy required to disintegrate a semi-solid food into a state ready for swallowing. It is the amount of energy required to masticate a sample to the point where it is ready to swallow a product of hardness and cohesiveness. Gumminess was almost constant at different temperatures. It did, however, increase with temperature. The multiple regression models for predicting Gumminess showed a regression coefficient (R^2) 0.9992 and a non significant F-value of 1044.70 as a lack of fit. At a probability P-value of 0.0001, the significant quadratic model was established. The response surface 3D graph for gumminess (Fig. 4-8) shows the interactive effect of paneer cube size, microwave power levels, heating time, and tempering time.

Table 5: Analysis of the variance (ANOVA) for response surface quadratic model for gumminess.

Source of Variation	Sum of squares	Degree of freedom	Mean square	F-Value	P Value
Residual	72.14	12	6.01		
Lack of fit	71.39	10	7.14	19.22	0.0504
Pure error	0.7428	2	0.3714		
Cor total	8798.25	26			
R^2= 0.9992, R(adj.)= 0.9982, R(pred.)= 0.9953, Adeq. Precision= 125.437, C.v.% = 2.18%					

The multiple regression equation representing the effect of processing parameter on cohesiveness in coded values is given by following second-order model:

$$\text{Gumminess} = + 99.01 - 57.31\times A + 7.96\times B + 1.99\times C - 0.5446\times D - 4.32\times AB - 0.9504\times AC + 0.4106\times AD - 0.6523\times BC + 0.0992\times BD + 0.0894\times CD + 16.15\times A^2 + 0.1948\times B^2 - 0.6619\times C^2 - 0.5599\times D^2 \quad \ldots(5)$$

The negative coefficient of the first order term of A, D , interaction term and quadratic term equation 5 indicated that gumminess decreases with increase of these variables while positive coefficient of the first order term of B, C, interaction term and quadratic term resulted in increase in gumminess of rehydrated paneer with increase in these variable.

E. Surface analysis of chewiness

Response Number of chews (at 1 chew/sec) needed to masticate the sample to a consistency suitable for swallowing. It is the energy required to masticate a sample to a state ready for swallowing. It is product of hardness, cohesiveness and springiness. Chewiness increased with increase in temperature. Higher chewiness was observed at higher temperatures. The multiple regression models for predicting the chewiness showed regression coefficient The Model F-value of 1934.60 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. (R^2) 0. 9998 and a non-significant F-value of 14.14 as lack of fit. The significant quadratic model was established at probability P-value of <0.0001 The response surface 3D graph for chewiness (Fig. 5) show the interactive effect of Paneer cube size, microwave power levels, heating time and tempering time.

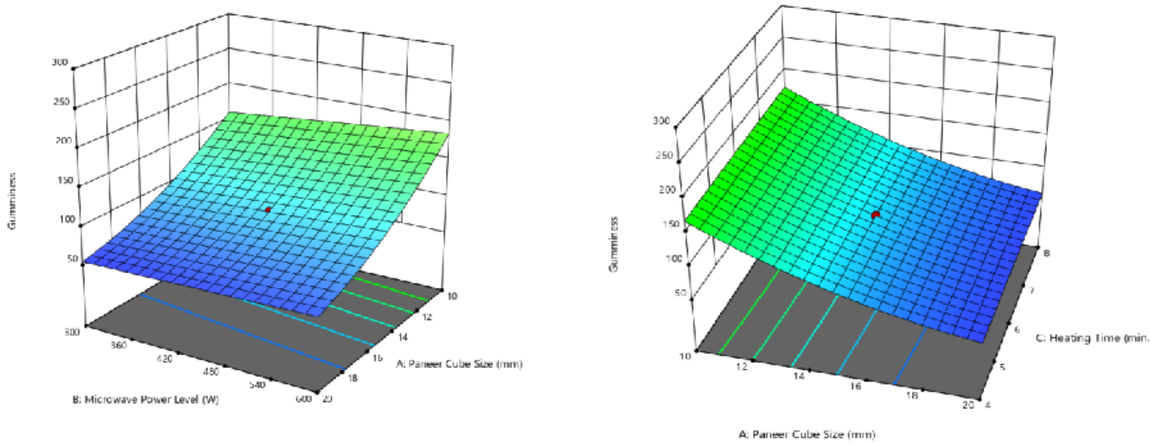

Fig. 4 (a,b). Impact of Paneer cube size, Heating time and power levels upon Gumminess.

Table 6: Analysis of the variance (ANOVA) for response surface quadratic model for chewiness.

Source of Variation	Sum of squares	Degree of freedom	Mean square	F-Value	P Value
Residual	20.16	12	1.68		
Lack of fit	19.88	10	1.99	14.14	0.0678
Pure error	0.2811	2	0.1406		
Cor total	45516.16	26			
R^2= 0.9998, R(adj.)= 0.9995, R(pred.)= 0.9987, Adeq. Precision= 245.458, C.V.% = 1.44					

The multiple regression equation representing the effect of processing parameter on chewiness in coded values is given by following second-order model:

$$\text{Chewiness} = +\ 76.73 - 41.51\times A + 5.21\times B + 0.7290\times C - 0.1020\times D - 2.94\times AB - 0.5563\times AC + 0.2627\times AD - 0.4743\times BC + 0.0354\times BD + 0.0297\times CD + 10.66\times A^2 - 0.6751\times B^2 - 1.12\times C^2 - 0.4194\times D^2 \quad \ldots(6)$$

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients. The negative coefficient of the first order term of A, D , interaction term and quadratic term equation 6 indicated that chewiness decreases with increase of these variables while positive coefficient of the first order term of B, C, interaction term and quadratic term resulted in increase in chewiness of rehydrated paneer with increase in these variable.

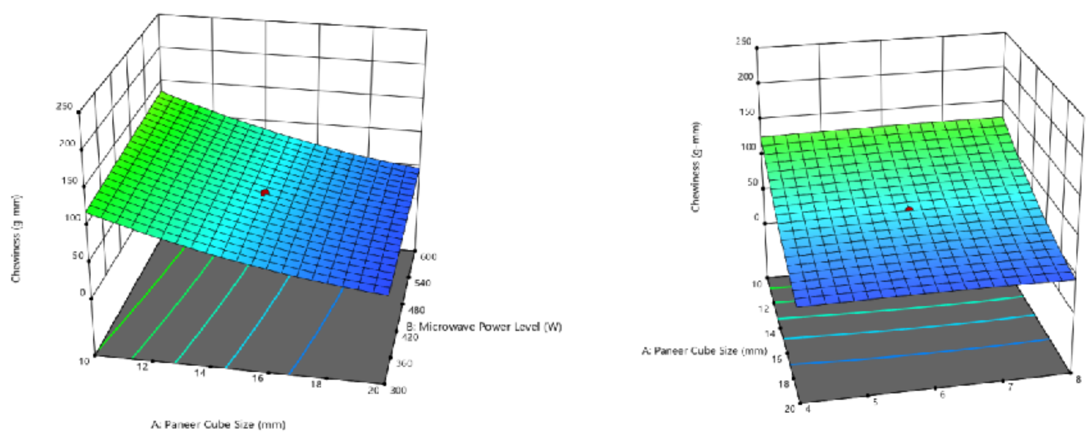

Fig. 5 (a, b). Impact of Paneer cube size duration, Heating time and power levels upon chewiness.

CONCLUSION

The RSM is utilized to optimize the process conditions for the textural properties of paneer cubes: hardness, cohesiveness, gumminess, springiness, and chewiness. The ANOVA of the determination coefficient implies the regression model is adequate. Based on the analysis and regression model, the results indicate the microwave power, paneer cube size, heating time, and tempering time are identified to be 350.442, 5.587 min, and 2.341 min, presented with an experimental 231.439 g hardness, 0.774 mm springiness, 0.603 cohesiveness, 139.973 Nmm gumminess, and 105.917 Nmm chewiness.

FUTURE SCOPE

To study the storability of dried paneer and the study on puffing characteristics should also be done.

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Conflict of Interest. None.

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