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Research Article

EFFECT OF DRYING ON GINGER PASTE AND OPTIMIZATION OF EVALUATED QUALITY PARAMETERS OF DRIED GINGER PASTE

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ABSTRACT
The ginger is one of the oldest known major spices indigenous to India. It is widely used around the world in food as spice and is a common condiment for a variety of compounded foods and beverages. A major problem encountered during processing of ginger is blackening or darkening of color due to oxidation of phenolase enzyme activity. During thermal processing of ginger considerable amount pungent flavor loss as well as nutrient loss occurs. Due to conventional thermal processing significant product quality damage may occurs due to slow conduction and convection heat transfer and therefore shelf life of the food products may deteriorate. On the other hand, through non thermal technology, heating occurs in the form of internal energy generation within the material and shelf life of processed foods is comparable to that of canned and sterile, aseptically processed products. The present investigation was planned to study the drying and quality characteristics of ginger paste during tray drying treatment with the view keeping in mind to reduce quality losses during preparation. Paste was thermally processed at 40, 50 or 60^{o}C, respectively. The quality of dried ginger paste was investigated in terms of pH and color. Independent variables selected for the study were temperature, thickness and citric acid treatment. The optimum values of independent variables in terms of temperature, thickness and pre-treatment in citric acid for pH and color was found as 40^{o}C, 4mm and 1.5 g/l respectively.

Keywords: *Drying; Food Quality; Ginger Paste; Tray Dryer; pH; Colour; Thermal Processing*

INTRODUCTION
Ginger is a tropical species native to South East Asia. It belongs to the family zingiberaceae botanically known as *'Zingiber officinale* Rose'. It's the most popular hot spice in the world. The useful part of this plant is the underground rhizomes. It is also called as *Adrak, Ada, Adraka, Allamu, Sunth* etc. in various Indian local languages. India from time immemorial is the "home of spices" producing almost all the spices of the world. India alone contributes 25-30% of total world trade in spices. There are over 80 spices grown in different parts of the world out of which 50 spices are grown in India (Schweiggert *et al*., 2007). Ginger, in its fresh as well as dried form has been used both as a medicine and as a spice in several countries.

The total production of ginger in the world in 2009-10 was 1683.00 thousand tons with the total acreage of 310.43 thousand ha. China, India, Nepal and Thailand are the major producers of ginger in the world, having production of 396.60 thousand tons, 385.33 thousand tons, 210.79 thousand tons and 172.68 thousand tons respectively (FAO, 2012). India and Indonesia have the largest area under cultivation. India has 149.10 thousand hector area under ginger cultivation contributing 36 percent of the total world production with productivity of 4.70. The total production of ginger in India is 702 thousand tons per year in 2010-11 (NHB Database, 2012)**.** The production of ginger in Uttarakhand was 18,000 tons and area under cultivation was 2,000 ha in the year 2007-08 (Anonymous, 2010)**.** Though ginger is grown throughout in India, Kerala is the maximum ginger producing state (about 70% of ginger production) (Purseglove *et al.,* 1981).

Ginger is mostly used in curries and in perception of curry powder, ginger bread, confectionary, ginger ale, table souse, ginger candy, preserved ginger, ginger pickling and in the manufacturing of certain soft drinks like cordials, ginger cocktails, carbonated drinks, ginger beer, ginger wine etc. Ginger can also be used for manufacture of ginger oil, oleoresin, essence etc. (Paruthi, 1998). Further ginger possesses all the three antioxidant, antimicrobial and anti-inflammatory properties (Salzer, 1982; Lee *et al.*, 1986; Ziauddin *et al.*, 1995b; Zang *et al*, 1996).

Fresh spices are perishable in nature and the causes of spoilage are improper handling, growth of spoilage microorganisms, action of naturally occurring enzymes and chemical reaction during storage. The post-harvest losses of ginger (20-30% for fruits and vegetables) could be considerably reduced if processed immediately after the harvest.

Drying is one of the most widely used methods of preservation of agricultural products by reducing water activity and microbial activity. The removal of moisture prevents the growth and reproduction of decay causing microorganisms minimizes the many of moisture induced deteriorating reactions. But drying of ginger has limited scope because the volatile oils and chemical components responsible for pungent flavors, especially gingerols and pigments are high heat sensitive (Baranowski, 1985). The loss of volatile oils from dehydrated ginger can be substantial and it has been reported that ground ginger can lose up to 50% of its volatile oils during 6 months of storage, depending upon the packaging material used (Richardson, 1967; Govindarajan, 1982). Therefore, there is an urgent need to explore alternate process for the preservation of ginger and to develop products based on these. Ginger paste is one such alternate product and can be stored for longer period without much alternation in fresh ginger rhizome and can also be considered as a minimally processed food (Baranowski, 1985; Ahmad and Shivhare, 2001 Ahmad *et al.,* 2002). Recently the market for spices paste has increased significantly mainly because of the success of fast food industries. Over the past few years, ginger paste is produced commercially in several combinations as ginger alone or with garlic/onion but discoloration and changes in flavor during storage are the major problems associates with ginger paste (Baranowski, 1985).

Furthermore, conventional processing of ginger which include washing, peeling, drying, grinding can cause several quality and hygiene problems (Legrand, 1986; Rejano *et al*., 1977). Conventional processing promotes the growth of bacteria and moulds and cause adverse effects of quality of product. Color is also the important attribute because it usually the first property the consumer observes. Various factors are responsible for the loss of color during the processing of food products.

These include mallard and enzymatic browning and process conditions, such as pH, packaging materials, duration and temperature of storage. Discoloration of ginger paste during preparation and storage has been recognized as major quality problem. Change in color during thermal processing could be used as a tool to evaluate the quality of ginger paste.

Therefore, it is the need to manufacture ginger paste which is of good quality, safe and can be stored for the longer time by thermal processing methods like tray drying.

Tray dryer is the most extensively used because of its simple and economic design. In a tray dryer, more products can be loaded as the trays are arranged at different levels. The food is spread out on trays at an acceptable thickness so that the product can be dried uniformly. Heating may be produced by hot air stream across the trays, conduction from heated trays, or radiation from heated surfaces. In a tray dryer, more products can be loaded as the trays are arranged at different levels. The key to the successful operation of the tray dryer is uniform airflow distribution over the trays. The tray dryer may be applied to a solar dryer or any conventional dryer that uses fossil fuel or electrical energy. Good airflow distribution will ensure the final moisture content of the dried products on the trays is uniform.

MATERIALS AND METHODS

Experiments were conducted to study the quality characteristics of drying of ginger paste. During the experiments the quality characteristics (i.e. pH and color) of ginger paste were evaluated. The process for making the ginger paste was standardized first. Independent variables and their ranges were finalized based on the observations and results obtained in preliminary experiments. Temperature, thickness and pre-treatment were taken as independent variables for the study. The pH and color were taken as dependent variables representing the product quality.

Raw Materials

Fresh, fully matured, yellowish colored ginger rhizomes without any defect on visual infection was procured from the local market of Pantnagar. The ginger was washed and peeled by hand peeler. The peeled ginger was then cut into slices. The peeled ginger was given the pre-treatment in citric acid for 10 hours.

Preparation of Ginger Paste

Ginger paste was prepared by grinding the ginger rhizomes in grinder with fruit to water ratio of 1:1 which is recommended by researchers. Then prepared ginger paste was treated in tray drying with different temperatures until the ginger paste was dried up to the equilibrium state. The enzymatic browning was prevented by pretreating ginger rhizomes in citric acid. Dried ginger paste samples with addition of citric acid treatment, at different temperatures were compared in terms of quality parameters (i.e. pH and color).

Sorting, Washing and Peeling

Ginger rhizomes were washed in cold water to remove soil and other foreign materials. For peeling, ginger were conditioned by dipping in water at room temperature for 15 minutes an dried in open air for one hour, this results in development of cracks on outer skin. The peel was manually removed with the help of a sharp stainless steel knife.

Pre-treatment with Citric Acid

Three solutions of 0.5 g/l, 1.0 g/l and 1.5 g/l (w/v) of citric acid were prepared and ginger rhizomes were treated in the solutions for 10 hours in different amount for preventing the enzymatic activity in ginger rhizomes.

Preparation of Paste

After removing the peels manually, peeled rhizomes were cut into small pieces using a sharp stainless steel knife. Chopped ginger was taken into the glass beaker and required amount of water (according to the experimental design) was added to the beaker.

Then, those known amount of chopped ginger and water were transferred to the jar of the grinder. Grinding was done to obtain ginger paste. 17 samples of ginger paste were prepared based on thickness (i.e. 2mm, 4mm and 6mm).

Table 2.1: Independent variables

Independent Variable	+1	0	-1
Temperature (^{o}C)	40	50	60
Thickness (mm)	2	4	6
Pre-treatment (g/l)	0.5	1.0	1.5

Preliminary Experiments

Preliminary experiments of drying of ginger paste were carried out based on the past research work. On the basis of preliminary experiments and reviewed study, the values for independent variables (i.e. temperature, thickness and citric acid pre-treatment) were finalized.

Drying of Ginger Paste

In order to choose appropriate range of temperature, previous research works were reviewed and chose three temperatures i.e. 40, 50 and 60^{o}C.

The objective was to dry ginger paste at three different temperatures up to equilibrium moisture content state. Four samples of 2mm thickness of ginger paste were dried at the temperature of 40^{o}C in tray drier up to constant moisture content. Same procedure was carried out for four samples of 6mm thickness of ginger paste at 60^{o}C and nine samples of 4mm thickness of ginger paste at 50^{o}C.

Design of Final Experiment

The drying behavior of system represents the process of tray drying while pH and colour represent product quality. The full factorial experimental design was adopted for given experiments and is summarized in table 3.4 while flow chart of experimental procedure is given in fig 2.1.

Dependent Variables
1. Color
2. pH

Experimental Procedure
Ginger paste with citric acid treatment was prepared under chosen experimental conditions. The details of experiment procedure are described below:
1. Washed and selected ginger rhizomes was peeled and cut into small pieces.
2. Pre-treatment of citric acid is given to ginger rhizomes in three different solutions of 0.5, 1.0 and 1.5 g/l.
3. Small ginger rhizomes pieces were ground into mixture to prepare ginger paste. Water was added in small ginger pieces before grinding in 1:1 ratio of ginger to water.
4. Prepared ginger paste was subject to tray drying treatment at different temperatures (i.e. 40, 50 and 60^{o}C) based on thickness of ginger paste sample (i.e. 2, 4, and 6mm).
5. Quality parameters (i.e. pH and colour) were determined for all samples by using standard equipment and methods.

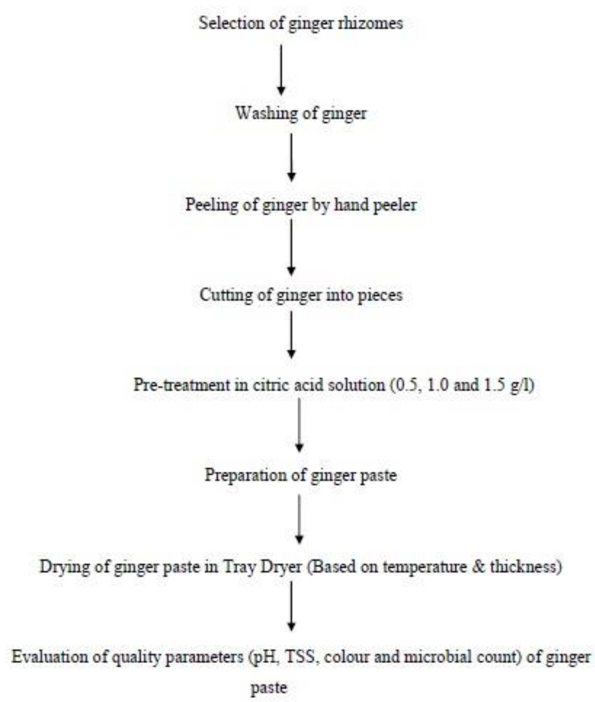

Figure 2.1: Flow Chart of Experimental Work

Measurement of Quality Parameters of Ginger Paste

Measurement of pH
The pH of ginger paste was determined by using a digital pH-meter with glass electrode. The accuracy of pH-meter was ±0.01. Before using the pH-meter, it was calibrated using distilled water. After that the electrode was inserted into the sample and reading was taken from the digital display.

Measurement of Colour
Colour of the sample was determined by combination of digital camera, computer and graphic software (Spyridon *et al.*, 2000). The L*a*b* values were calculated for determination of the colour of ginger paste. L* is the luminance of lightness component, which ranges from 0 to 100, and a* (from green to red) and b* (from blue to yellow) are the two chromatic components, which ranges from -120 to +120. Photographs of freshly prepared ginger paste were used as basis for determining the ‘L, a, b’ values in

Adobe Photoshop. The pixel value tool present in Adobe Photoshop software was positioned to 100 pixel for determining respective 'L, a, b' values. These 'L, a, b' values were used to calculate the required L*a*b* values by using formulas given below

$L^* = (\text{Lightness}/250) \times 100$

$a^* = (240a/255) - 120$

$b^* = (240b/255) - 120$

These L*a*b* values were used to calculate total colour difference ΔE^* values for all samples of ginger paste.

$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$

RESULTS AND DISCUSSION

The experiments were conducted in Processing Lab at Department of Post-Harvest Process and Food Engineering, College of Technology, G.B. Pant University of Agriculture and Technology, Pantnagar. The experiments were planned using the full factorial design considering the dependent and independent variables. Temperature, thickness and citric acid pre-treatment were taken as independent variables. The quality of ginger paste was determined in terms of pH and color as dependent variables.

The influence of various factors was analyzed using a statistical technique called Analysis of Variance (ANOVA) by Design Expert software. The ANOVA of response break down the total variance of response and indicated whether the influence of a particular factor is statistically significant or not. The significance of any factor is judged by comparing the corresponding F-value in the ANOVA table with the tabulated F-value. It can also be judged based on the computed p-value, which represents the probability that the effect of factor is non-significant. Hence a large p-value indicates that the effect of corresponding factor is non-significant. The result obtained in this study are presented and discussed in the following sections.

Statistical Analysis of Experimental Parameters of Ginger Paste

The quality of ginger paste was evaluated in terms of selected quality parameters namely, pH and colour. The tray drier dried ginger paste was evaluated and compared with different temperatures, thickness and citric acid treatment.

pH

As acidified food (pH>4.6) requires pasteurization, the pH of ginger paste was determined by using a digital pH-meter. The data of pH for different temperature, thickness and citric acid treated samples after tray drying have been noted in tabular form.

Effect of Temperature, Thickness and Citric Acid Treatment on pH of Ginger Paste

ANOVA of pH of ginger paste is given in Table 2.1 which shows that citric acid treatment and temperature affect the pH of ginger paste at 5% level of significance as calculated F value is greater than tabulated F for both the factors.

Table 3.1: ANOVA of pH of ginger paste

Source	Degree of freedom	Sum of square	Mean square	F-value
Model	9	1.58	0.18	94.81
Linear	3	1.475	0.492	264.52
Quadratic	3	0.069	0.023	12.36
Interactive	3	0.047	0.0158	8.49
Residual	7	0.013	0.00186	--
Lack of fit	3	0.005	0.00167	--
Cor total	16	1.60	--	--

Second model of regression model was developed from data using Design Expert software. This model analyses the effect of thickness, temperature and citric acid treatment on pH of ginger paste. pH data were fitted into second order mathematical model (equation 3.1). On regression analysis the model results in a coefficient of determination (R^2) of 0.9919, mean of 3.79, standard deviation of 0.043 and Adjusted R^2 of estimate 0.9814. Value of R^2 more than 0.9, implies that the equation fits very well to the experimental data.

Table 3.2: Results of regression analysis of pH

Factor	Coefficient	P (%)
Model	3.82	0.01*
X_1	0.050	1.35**
X_2	0.025	14.48
X_3	- 0.43	0.01*
X_1 X_2	- 0.075	1.03**
X_1 X_3	- 0.025	28.40
X_2 X_3	0.075	1.03**
X_1^2	0.027	23.17
X_2^2	0.027	23.17
X_3^2	- 0.12	0.06*
R^2 (%)	99.19	--

, ** and * significant at 1%, 5% and 10% level of significance*

$$Y = 3.82 + 0.05\ X_1 + 0.025\ X_2 - 0.43\ X_3 - 0.075\ X_1 X_2 - 0.025\ X_1 X_3 + 0.075\ X_2 X_3 + 0.027\ X_1^2 + 0.027\ X_2^2 - 0.12\ X_3^2 \qquad \ldots\ldots\ldots\ldots\ldots(3.1)$$

Where,
X_1 = Temperature
X_2 = Thickness
X_3 = Citric acid treatment
Y = pH

Positive coefficients at linear level in the regression equation indicate an increase in response with increase in level of the parameter and vice versa. Negative quadratic terms conclude that maximum value of response is at the center point while positive quadratic terms have a minimum response. Similarly, negative interactions suggest that the level of one of the variables can be increased while that of other decreased.

This model gives the relationship of pH of ginger paste with various independent variables like temperature, thickness and citric acid pre-treatment.

Colour

The colour was measured in terms of Hunter L*, a* and b* values. L* represents the lightness or darkness of the object and it is measured on a scale of 0-100. L* values of 100 represents white and L* of 0 represents black. Hunter a* represents redness (+) or greenness (-). Hunter b* represents yellowness (+) or blueness (-). The colour of ginger paste under the influence of various treatments was determined by L*, a* and b* values described as follows:

$L^* = (L/250) \times 100$
$a^* = (240a/255) - 120$
$b^* = (240b/255) - 120$

These values were used to calculate ΔE* for all the samples of ginger paste by using following expression:

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

Where,
$\Delta L^* = L^* - L_f$
$\Delta a^* = a^* - a_f$
$\Delta b^* = b^* - b_f$

L*, a* and b* are the colour coordinates of the sample and L_f, a_f and b_f are the colour coordinates of the fresh sample (Francis and Clydesdale, 1975).

Table 3.3: Results of analysis of pH and colour (Δ*E)**

Std.	Temperature (*C)	Thickness (mm)	Pretreatment (g/I)	pH value	Colour (Δ*E**)
1	50	2	1.5	3.2	12.14
2	60	4	1.5	3.3	13.95
3	50	4	1	3.8	12.45
4	50	6	0.5	4.1	12.94
5	60	6	1	3.9	13.96
6	50	4	1	3.9	12.55
7	40	2	1	3.7	10.72
8	50	4	1	3.8	12.77
9	60	2	1	4.0	13.47
10	40	4	1.5	3.3	10.91
11	50	6	1.5	3.4	12.77
12	50	4	1	3.8	12.77
13	50	4	1	3.8	12.62
14	40	6	1	3.9	11.24
15	50	2	0.5	4.2	12.46
16	40	4	0.5	4.1	11.53
17	60	4	0.5	4.2	13.99

Effect of Temperature, Thickness and Citric Acid Treatment on Colour of Ginger Paste

Table 3.4 shows the ANOVA for ΔE* value of ginger paste indicates that all the three variables i.e. temperature, thickness and citric acid pre-treatment had significant effect on ΔE* values of ginger paste at 1% level of significant. Table 3.4 also shows that all the combinations of interaction significantly affect the ΔE* value of ginger paste. It is concluded from the table that ΔE* value is highly dependent on all the independent variables.

Table 3.4: ANOVA of ΔE* value of ginger paste

Source	Degree of freedom	Sum of square	Mean square	F-value
Model	9	16.07	1.79	150.47
Linear	3	15.77	15.77	1314.167
Quadratic	3	0.21	0.21	17.5
Interactive	3	0.08985	0.08985	7.4875
Residual	7	0.083	0.012	--
Lack of fit	3	0.004975	0.001658	--
Cor Total	16	16.15	--	--

For analyzing the effect of temperature, thickness and citric acid pre-treatment on colour value of ginger paste the second order regression model was developed for various combinations of temperature, thickness and citric acid pre-treatment. Values of ΔE* were fitted into second order mathematical model. On regression analysis the model results in a coefficient of determination (R^2) of 0.9949, mean of 12.54, standard deviation of 0.11and adjusted R^2 of 0.9882. Equation 3.2 gives the ΔE* colour values of ginger paste at different temperature, thickness and citric acid pre-treatment.

Table 3.5: Results of regression analysis of colour of ginger paste

Factor	Coefficient	P (%)
Model	12.63	0.01*
X_1	1.37	0.01*
X_2	0.27	0.02*
X_3	-0.14	0.73*
$X_1 X_2$	-0.0075	89.43
$X_1 X_3$	0.14	3.24**
$X_2 X_3$	0.038	51.33
X_1^2	-0.13	4.01**
X_2^2	-0.15	2.49**
X_3^2	0.097	11.19
R^2 (%)	99.49	--

, ** and * significant at 1%, 5% and 10% level of significance*

$Y = 12.63 + 1.37 X_1 + 0.27 X_2 – 0.14 X_3 – 0.0075 X_1 X_2 + 0.14 X_1 X_3 + 0.038 X_2 X_3 - 0.13 X_1^2 - 0.15 X_2^2 + 0.097 X_3^2$ …………(3.2)

Where,
X_1 = Temperature
X_2 = Thickness
X_3 = Citric acid treatment
Y = Colour

Optimization of Processing Parameters of Ginger Paste

Optimization of pH of Ginger Paste

For optimum values of pH of ginger paste, it should be in range of pH values.

$Y = 3.82 + 0.05 X_1 + 0.025 X_2 – 0.43 X_3 – 0.075 X_1 X_2 – 0.025 X_1 X_3 + 0.075 X_2 X_3 + 0.027 X_1^2 + 0.027 X_2^2 – 0.12 X_3^2$

Significant Model

$Y = 3.82 + 0.05 X_1 – 0.43 X_3 – 0.075 X_1 X_2 + 0.075 X_2 X_3 – 0.12 X_3^2$

For X_1, $X_2 = 0, X_3 = 1$
For X_3, $X_1 = -1, X_2 = 0$
For $X_1 X_2$, $X_3 = 1$
For $X_2 X_3$, $X_1 = -1$

The values of X_1, X_2 and X_3 were obtained as 40°C, 4mm and 1.5 g/l respectively. Hence the optimum conditions of temperature, thickness and citric acid pre-treatment for in range pH of ginger paste were obtained as 40°C, 4mm and 1.5 g/l respectively.

Optimization of Colour of Ginger Paste

The optimization values to obtain minimum ΔE* value of ginger paste under different levels of temperature, thickness and citric acid pre-treatment were calculated with respect to each parameter.

$Y = 12.63 + 1.37 X_1 + 0.27 X_2 – 0.14 X_3 – 0.0075 X_1 X_2 + 0.14 X_1 X_3 + 0.038 X_2 X_3 - 0.13 X_1^2 - 0.15 X_2^2 + 0.097 X_3^2$

Significant Model

$Y = 12.63 + 1.37 X_1 + 0.27 X_2 – 0.14 X_3 + 0.14 X_1 X_3 - 0.13 X_1^2 - 0.15 X_2^2$

For X_1, $X_2 = 0, X_3 = 1$
For X_2, $X_1 = -1, X_3 = 1$
For X_3, $X_1 = -1, X_2 = 0$
For $X_1 X_3$, $X_2 = 0$

Graphical Analysis of Experimental Parameters of Ginger Paste

One of the objectives of study was to get the optimized conditions for good quality ginger paste at best levels of temperature, thickness and citric acid pre-treatment. The optimized condition could be a single point or a range of points in which all the possible combinations would yield good quality ginger paste. The optimization for given processing was carried out using Design Expert software.

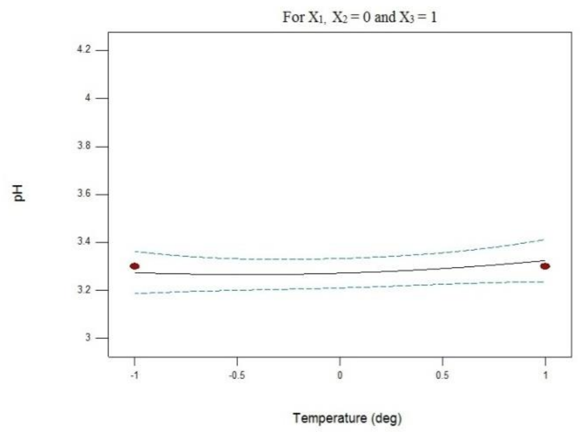

Figure 3.1: Effect of temperature (X_1) on pH at optimum points

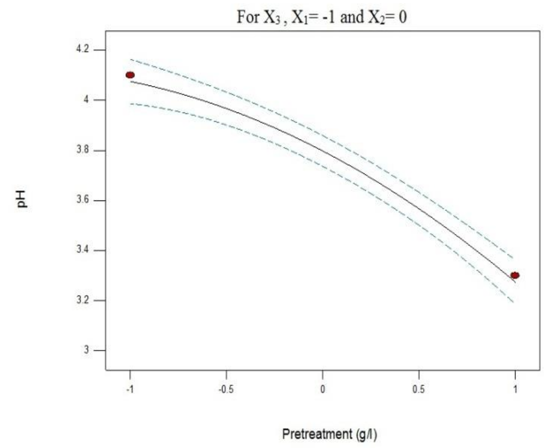

Figure 3.2: Effect of pre-treatment of citric acid (X_3) on pH at optimum points

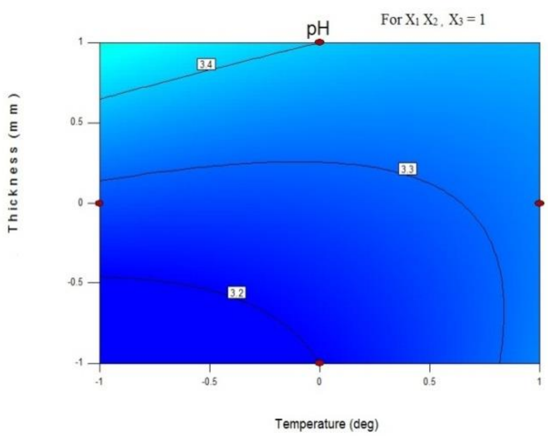

Figure 3.3: Effect of temperature (X_1) and thickness (X_2) on pH at optimum points

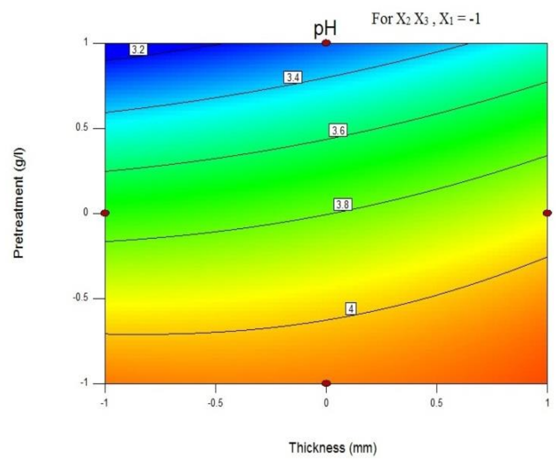

Figure 3.4: Effect of pre-treatment (X_3) and thickness (X_2) on pH at optimum points

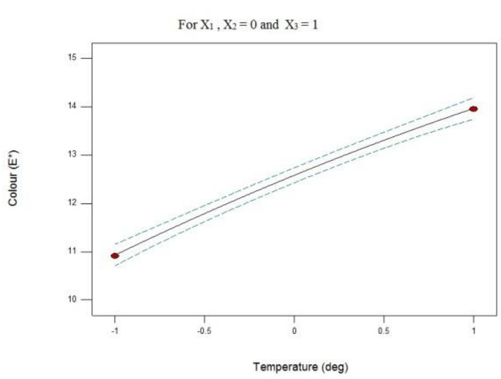

Figure 3.5: Effect of temperature (X_1) on colour at optimum points

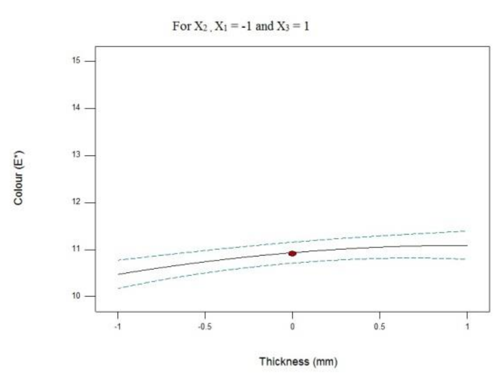

Figure 3.6: Effect of thickness (X_2) on colour at optimum points

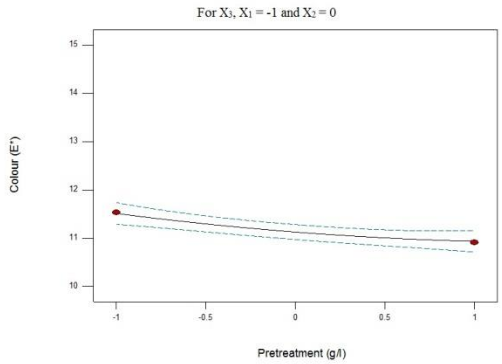

Figure 3.7: Effect of pre-treatment (X_3) on colour at optimum points

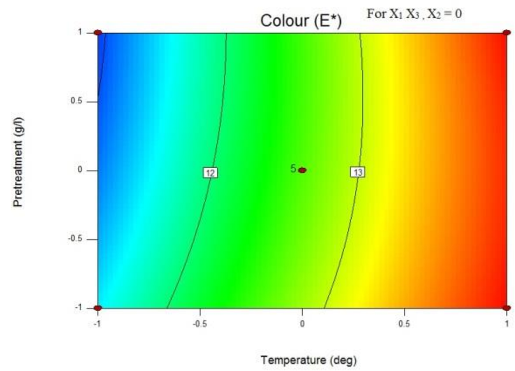

Figure 3.8: Effect of temperature (X_1) and pre-treatment (X_3) on colour at optimum points

Conclusion

The present investigation was planned to study the drying and quality characteristics of ginger paste during tray drying treatment with the view keeping in mind to reduce quality losses during preparation. The quality of dried ginger paste was investigated in terms of pH and colour. The full factorial design experiment was used to analyze the responses. The full factorial design experiment was used to analyze the responses.

On the basis of experimental data and analysis the following observations were made.

The effect of temperature and pre-treatment of citric acid for ginger paste was evaluated. It was found that as temperature increased, pH of the ginger paste was slightly decreased and then became constant and after that the pH of ginger paste slightly increased due to increment in temperature.

It was found that time of heating of ginger paste decreased significantly with increasing temperature and decreasing the thickness of ginger paste. All the quality parameters (i.e. pH and colour) were influenced by independent variables significantly.

The optimum values of temperature, thickness of ginger paste and pre-treatment of citric acid were 40^{o}C, 4 mm and 1.5 g/l for the study of ginger paste. Tray drying can be suitably used for production of acceptable yellowish coloured ginger paste.Tray drying keeps the pH of ginger paste well within the acceptable range and the value of colour of ginger paste maximized for the samples.

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