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Sachin Kumar
Assistant Professor, Department of Post-Harvest Process and Food Engineering, College of Technology, GBPUAT Pantnagar, Udham Singh Nagar, Uttarakhand, India

Anil Kumar
JRO, Department of Food Science and Technology, GBPUAT Pantnagar, Udham Singh Nagar, Uttarakhand

Dr. PK Omre
Professor and Head, Post-Harvest Process and Food Engineering, College of Technology, GBPUAT Pantnagar, Udham Singh Nagar, Uttarakhand

Khan Chan
Associate Professor, Department of Agricultural Engg, Nagaland University, Dimapur Campus, Lumami, Nagaland, India

Iftikhar Alam
Ph.D., Scholar, Department of Post-Harvest Process and Food Engineering, College of Technology, GBPUAT Pantnagar, Udham Singh Nagar, Uttarakhand, India

Corresponding Author:
Sachin Kumar
Assistant Professor, Department of Post-Harvest Process and Food Engineering, College of Technology, GBPUAT Pantnagar, Udham Singh Nagar, Uttarakhand, India

Enhancement on vacuum foam mat quality parameters of papaya powder by using chemical preservatives

Sachin Kumar, Anil Kumar, Dr. PK Omre, Khan Chan and Iftikhar Alam

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Abstract
Vacuum foam-mat drying is a technique that involves whipping a liquid concentration with an appropriate foaming agent into a stable foam that is then dehydrated into a thin mat of foam at a low temperature. The effect of variables on responses was determined using response surface methodology (RSM). The moisture content of raw papaya pulp was 856.023 % (db.). The total soluble solid (TSS) was tested by hand refractrometer i.e. 12.8 ⁰ Brix. Parameters such as whipping time (10 minute) , papaya pulp thickness (4 mm) and vacuum oven pressure (25 inch Hg), pH value 5.56 and TSS(10 ⁰ Brix) remain constant throughout the work. The drying time, drying rate and moisture ratio varies from 60 minutes to 840 minutes, 0.001-1.279 and 0.01-4.402 respectively. The drying duration, drying rate, and moisture ratio range from 60 to 840 minutes, respectively, 0.001-1.279 and 0.01-4.402. In experiment number 2, the ingredients, temperature (70 ^{o}C), maltodextrin 0.30 (w/w), glycerol monostearate 2.0 percent, and tricalcium phosphate 2.0 percent of dried papaya powder were combined to achieve a minimum drying time of 660 minutes. Experiments also revealed that increasing the amount of tricalcium phosphate (2%) and glycerol monostearate 2.0 percent in the materials reduced drying time, which helped to lower the moisture content of the papaya powder. As the drying time increases, the moisture ratio for all samples decreases in a nonlinear manner. The moisture ratio of each sample declined rapidly while the drying period was very short, but the rate of decrement of moisture ratio became quite slow as the drying time increased. The solubility of papaya powder is found to be as low as 69.08 percent in experiment number 24 and as high as 96.45 percent in experiment number 20. Ascorbic acid is found in the range of 88.43 to 115.75 (mg/100g) in experiment numbers 28 and 1, while beta carotene is found in the range of 10-51 (g/100g) experiment numbers 24 and 12. L* (Lightness) is varied from 53.1 to 82.79 experiment numbers 14 and 10, chromatic component a* (from green to red) is varied from 27.25 to 105.92 experiment numbers 3 and 17, and chromatic component b* (from blue to yellow) is varied from -15.92 experiment number 3 to 73.67 experiment number 10 during colour value estimation. It is reported that solubility increases with increase in maltodextrin at 5% level of significance**.** The interaction between maltodextrin and glycerol monostearate are significant at $P< 0.1$. Temperature had highest effect on solubility ($P< 0.01$).The effect of ascorbic acid at linear level is highly significant ($P< 0.01$).Temperature affected the ascorbic acid significantly at 1% level of significance, followed by maltodextrin, tricalcium phosphate and glycerol monostearate. The effect of beta carotene at linear level is highly significant ($P< 0.01$) the interactive and quadratic level are insignificant. Temperature affected the beta carotene significantly at 1% level of significance followed by maltodextrin, tricalcium phosphate and glycerol monostearate. It is observed that temperature, maltodextrin and glycerol monostearate affected the luminance index L* significantly at 1%,10% & 5% level of significance respectively, while tricalcium phosphate had no effect on luminance index L*. Only temperature had highest effect on luminance index L* because it has higher value of sum of square. Temperature and glycerol monostearate make impact on the chromatic component a* significantly at 1%, &10% level of significance on other hand maltodextrin and tricalcium phosphate had no effect on chromatic component a*.Temperature, maltodextrin, glycerol monostearate and tricalcium phosphate affected the chromatic component b* significantly at 5%, 5%, 1% & 5% level of significance respectively. Level of ingredients for optimum values of independent variables is calculated by using simultaneous optimization of solubility, ascorbic acid, beta carotene and colour values (L*,a*,b*) having value 59.05 °C temperature,0.55 gm per 100 gm of papaya solid, 1.78% glycerol monostearate and 2.5% tricalcium phosphate respectively. They can be used accordingly as given above to make a good quality papaya powder.

Keywords: Vacuum foam mat drying, papaya powder, color, ascorbic acid, quality parameters

1. Introduction
Papaya (*Carica papaya* L.) is one of the important fruits of tropical and subtropical regions grow well in the country upto 1000 meter above sea level. Papaya was originally derived from the southern part of Mexico; papaya is a perennial plant which is distributed over the whole tropical and subtropical area.

It is one of the most consumed fruits. The interior flesh of the fruit goes through color changes from green (immature) to yellow (ripe) and when it is to overripe ("McGrath and Karahadian", 1994) [62]. Total yearly world production is estimated at 11 million tonnes of fruits. India leads the world in papaya production with an annual output of about 4 million tonnes. Other leading producers are Brazil, Mexico, Nigeria, Indonesia, China, Peru, Thailand and Philippines (FAO STAT 2012a, 2012b) [30, 31]. Papaya (*Carica papaya*) is a plant that belongs to the family of Caricaceae. It is a herbaceous succulent plant with self-supporting stems ("Dick", 2003) [24]. The fruit is rich in β-carotene, vitamin-A and C, iron, calcium, protein, carbohydrates, phosphorous and good source of energy ("Gopalan *et al".*, 1972) [35]. Papaya can be made into jam, jelly, nectar, dried into slabs, canned in the form of slice and the fruit powder can be used for preparation of nectar, ice cream flavour, ready to eat fruited cereals. Most fruits including papaya have high moisture content and are highly perishable, cannot be preserved for longer period of time results massive losses. "Pantastico" (1979) [70] estimated for the Philippines that papaya postharvest loss ranged from 20 to 26%, with 8 – 12% of the loss being due to decay, 2 – 4% due to over ripening and 10% due to mechanical injury. A similar total loss figure of 23.7% was determined for Taiwan ("Liu and Ma", 1984) [59]. The total postharvest losses of papaya worked out to 25.49% (Gajanana *et al.,* 2010) [33]. Developed by Morgan *et al.* (1961) [64] foam-mat drying is a process by which a liquid concentrate along with a suitable foaming agent is used to whip to form stable foam and is subjected to dehydration in the form of a thin mat of foam at relatively low temperature. Drying occurs in multiple constant rate periods due to periodic bursting of successive layers of foam bubbles, thus exposing new surfaces for heat and mass transfer as the drying progresses ("Chandak and Chivate" 1972) [16]. This method is suitable for any heat sensitive, sticky and viscous materials which cannot be dried by spray drying ("Hart *et al.,* 1963 and Berry *et al.,* 1965) [36, 11]. Drying occurs in multiple constant rate periods due to periodic bursting of successive layers of foam bubbles, thus exposing new surfaces for heat and mass transfer as the drying progresses (Hart *et al.,* 1963 and Martin *et al.,* 1992) [36, 61]. This method is suitable for any heat sensitive, sticky and viscous materials which cannot be dried by spray drying. The foam-mat dried products have better reconstitution properties because of their honeycomb structure and are superior to drum and spray dried products (Chandak *et al.,* 1974) [17]. This method is suitable for any heat sensitive, sticky and viscous materials which cannot be dried by spray drying. The foam-mat dried products have better reconstitution properties because of their honeycomb structure and are superior to drum and spray dried products ("Chandak *et al".*, 1974) [17]. Renewed interest in foam-mat drying could be due to its simplicity, cost-effectiveness, rapid drying rate and enhanced product quality. Foaming of liquids and semi liquid materials has long been recognized as one of the methods to shorten drying time. Unlike other drying methods, foam-mat drying does not involve a large capital outlay. The product is also reduced to a light and porous form which, when packaged in polyethylene material, allows for good stability. Vacuum drying takes place in the absence of oxygen, the oxidative degradation e.g. Browning is low in the final product. The rate of drying is fast due to the creation of a frothy or puffed structure in the mango pulp, this expands structure creates the desired property of "instant" reconstitution and provides large surface area to volume ratio for good heat and mass transfer ("Jaya and Das", 2004) [42]. The temperature range used for vacuum drying is usually kept within 65-75 ^{o}C ("Anon", 1952; "Copley, Kaufman and Rasmussen", 1956). The drawback of this method is the throughput of the dryer as the moisture is removed from the thin layer of the foam hence the material spread per unit surface of drying area is very small ("Kudra *et al".*, 2006) [57]. Characterization of drying is of paramount importance as it determines drying time and control measures can be taken to obtain energy efficient process that produces quality product. Response surface methodology (RSM) has been used to develop products and find out the effect of variable on the responses ("Jaya and Das", 2004, "Hymvathi and Khader", 2004a) [42, 39]. It is used to get an optimum process conditions considering single response or multiple responses. It encompasses statistical and mathematical techniques. In view of the above, present study was undertaken with the following objectives:

To determine the dried papaya powder's quality parameters, such as solubility, ascorbic acid, beta carotene, and colour values.

2. Materials and Methods

The papaya fruits were purchased in Pantnagar local market. The fresh papaya pulp was hand peeled using a stainless steel knife, and the ripened pieces were pulped using a mixer grinder. In the Process and Food Engineering Laboratory of the Department of Post-Harvest Process and Food Engineering, College of Technology Pantnagar, preliminary work was done to set the parameters for the production of papaya powder with and without the addition of ingredients using the vacuum foam mat drying technique. To complete this work different type of experimental setups were required. The equipment's used for experiments were stain less steel knife, vacuum oven, centrifuge, vacuum pump, food processor, electronic balance, hot air oven, refrigerator etc. The list and specifications of these equipment's and the apparatus used are given in the Table 1.

2.1 Experimental Design

Temperature, maltodextrin, tricalcium phosphate, and glycerol monosterate were employed in the experimental design based on the review; the different variables used in this methodology were temperature, maltodextrin, tricalcium phosphate, and glycerol monosterate. The number of experiments at five levels was found by using a second order central composite rotatable design (CCRD). Experiments also were done at centre point. The design is rotatable which means that all the points in the design area are at equal distance from the central. The number of design points in (CCRD) is based upon a complete 2^k factorial design.

The total numbers of experiments are,

$$N= 2^k +2K+L \qquad 2.1$$

Where N= Total Number of experiments, K= Numbers of Factors and L= number of replicates of the central points

The details of the independent variable in the experimental plan and design of experiments are given in the Table 2. and Table 3 respectively. All the experiments were done using software tool named as Response Surface Methodology (RSM), was 30 in number.

To find out the effect of independent variables on the quality of powder a multiple linear regression analysis was used and

the data was fitted as a second order equation. The equation is given by,

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \beta_{ii} X_i^2 + \sum_{i=1}^{k-1} \sum_{j=i+1}^{k} \beta_{ij} X_i X_j \quad 2.2$$

Where,
β_0, β_i, β_{ii}, β_{ij} are regression coefficients, X_i and X_j are independent variables in coded form ,k is number of independent variables and Y is response.

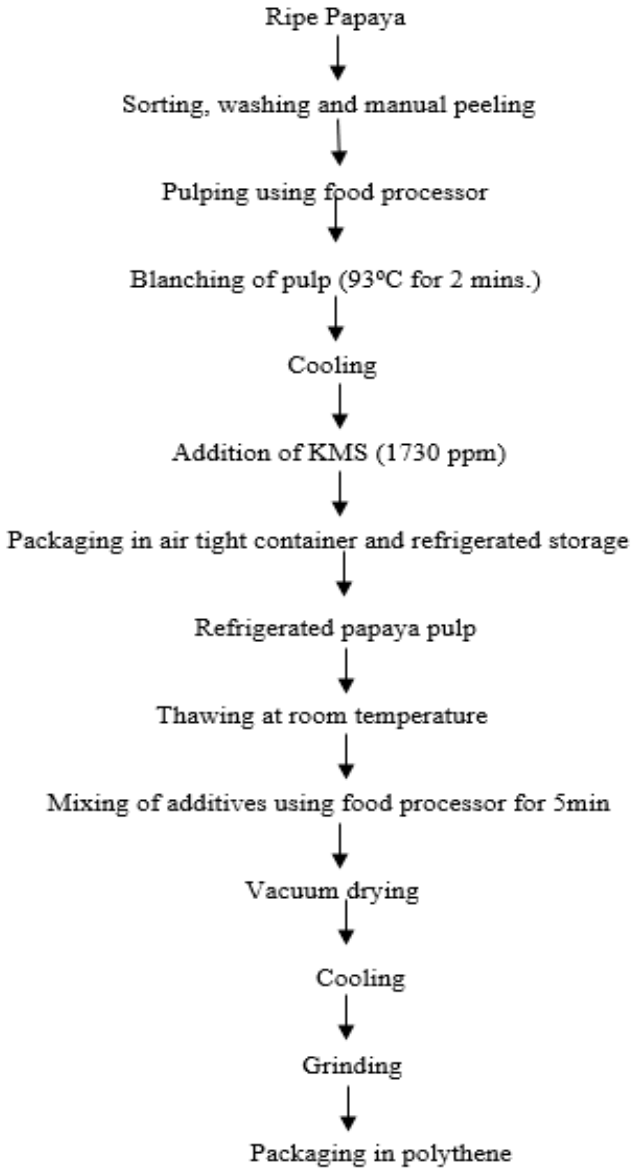

Fig 2.1: Process flow chart for preparation of papaya powder in vacuum dryer

2.2 Sample Preparation

The papaya was cleaned by fresh water and placed at room temperature until the desired peel colour is obtain. Fully ripened papaya was peeled manually using a stainless steel knife and the flesh portion was pulped by using a mixer grinder. The pulp was blanched at 93 ºC for 2 minute. 1730 ppm potassium metabisulphate was mixed into this. Now the pulp was stored in refrigerated condition inside a steel airtight container until its next use. The pulp was thawed at room temperature i.e. 27 º C before going through drying procedure. The distilled water mixed into papaya pulp to get appropriate pulp concentration (10º Brix). Different types of materials added as agents through different process. These materials are maltodextrin, glycerol monostearate and calcium phosphate. Maltodextrin used as drying agent, glycerol monostearate as foaming agent as well as stabilizer and tricalcium phosphate added as anti-caking agent. All materials used as limited in Prevention of food Adulteration Act (1955) of the government of India. Now the pilp was ready to characterize for chemical parameters such as moisture content, ascorbic acid (mg/100 gm) and beta-carotene (mg/100 gm).

2.2.1 Vacuum foam mat drying for the preparation of papaya powder

In laboratory model vacuum oven (MSW-218) the papaya pulp was dried. The mixture after suitable addition of drying aids was spread evenly on Petri dish and steel tray (coated with aluminium foil), having dimension of 10x15x1.5 cm. After this wards the tray was kept inside the vacuum oven dryer shelves and the pressure of vacuum inside the chamber was reduced until its reached to 25" Hg. Five different drying temperature viz 55, 60, 65, 70, 75ºC (Jadhav, 2008) [41] and drying time 1 hr, on each trial basis was selected to carry out vacuum drying. During vacuum foam mat drying process the initial quantity of the papaya pulp was kept constant. Five different drying temperatures viz. 55, 60, 65, 70, 75ºC and drying time viz. 0, 60, 120, 180, 240, 300, 360, 420, 480, 540, 600, 660, 720, 780 and 840 minutes were selected to conduct foam mat drying for each sample. The experimental setup of foam mat drying process is shown in Plate 2.1. The study of drying behavior was done in form of moisture content (%d.b) with respect to time and temperature. The dried papaya pulp was grinded into a fine particulate powder using a food processor at medium speed for 5min and packed in polythene. The prepared papaya powder from foam mat drying method was used for analysis of phsico-chemical characteristics viz. moisture content (%), flowability time (s), hygroscopicity (%), degree of caking, solubility (%) , ascorbic acid (mg/100g), β-carotene (mg/100g), and colour values L*, a* and b*.

2.3 Analysis Techniques

2.3.1 Solubility

For the determination of solubility of the papaya powder, 100 ml of distilled water was transferred into blender jar. The powder sample weighing 1g (db) was carefully added into the blender operating at high velocity for 5 min. The solution was placed in centrifuge tube and centrifuged at 3000 rpm for 5 min. An aliquot of 25 ml of the supernatant was transferred to preweighed petri dishes and immediately oven-dried at 105 ºC for 5 h. Then the solubility (%) was calculated by weight difference (Chauca *et al*., 2005) [18].

2.3.2 Ascorbic acid

For the determination of Ascorbic acid both before and after drying by 2, 6- dichlorophenol-indophenol visual titration method recommended by the Association of Vitamin Chemists ("Ranganna", 1986). The method is described below:

2.3.2.1 Principle
The dye which is blue in alkaline solution and red in acid solution is reduced by ascorbic acid to a colourless form. The reaction is quantitative and practically specific for ascorbic acid in solutions in the pH range 1-3.5.

2.3.2.2 Reagents
a. **3% Metaphosphoric Acid (HPO_3):** Prepare by dissolving the sticks or pellets of HPO_3 in glass distilled water.
b. **Ascorbic acid standard:** Weigh accurately 100 mg of L-ascorbic acid and make upto 100 ml with 3 % HPO_3 (1 ml = 0.1 mg of ascorbic acid).
c. **Dye solution:** Dissolve 50 mg of sodium salt of 2, 6-dichlorophenol-indophenol in approximately 150 ml of hot glass distilled water containing 42 mg of sodium bicarbonate. Cool and dilute with the glass distilled water to 200 ml. Store in the refrigerated condition and standardize it every day.

2.3.2.3 Procedure
a. **Standardization of Dye:** Take 5 ml of standard ascorbic acid solution and add 5 ml of HPO_3. Fill the microburette with dye. Titrate with the dye solution to a pink colour which persist for 15 sec. Determine the dye factor, i.e. mg of ascorbic acid required to reduce 1 ml of the dye, using the formula

Dye factor = 0.5/titre … (2.1)

b. **Preparation of the sample**: Take 10 g of sample, blend with 3 % HPO_3 and make upto 100 ml with HPO_3. Filter or centrifuge.

c. **Assay of Extract:** Take an aliquot (2-10 ml) of the HPO_3 extract of the sample and titrate with the standard dye to a pink end point which should persist for at least 15 s. Titrate rapidly and make preliminary determination of the titre. In the next determination, add most of the dye required and titrate accurately. The aliquot of the sample should be such that the titre should not exceed 3 to 5 ml.

2.3.2.4 Calculation
The ascorbic acid content of the sample was calculated by following formula:

$$\text{Ascorbic acid } (\frac{\text{mg}}{100}\text{g}) = \frac{\text{Titre x Volume made up x drying factor x 100}}{\text{Aliquot of extract taken for estimation x Volume of sample taken for estimation}} \quad \ldots(2.2)$$

2.3.3 β-carotene
2.3.3.1 Principle
Beta carotene present in the sample is extracted by butanol and intensity of pigment is measured by recording absorbance using the UV spectrophotometer (Nagi *et al.*, 2007).

2.3.3.2 Material required
The various materials were required to carry out the experiments such as Analytical balance, Whatman No. 1 Filter paper, Volumetric flask, 50 ml and UV spectrophotometer. The reagents used for analysis as water saturated n- butanol, CH_3 $(CH_2)_3OH$, prepare a solution of n-butanol and water in a proportion of 6:2 (v/v) and shake vigorously. Use the clear upper layer after separation of the phases. Diethyl ether,$C_4H_{10}O$ (Sisco Research Lab) and Synthetic beta-carotene, $C_{40}H_{56}$ (Himedia).
Weigh 10 g of powder and disperse it in 50 ml of water saturated n-butanol to give a homogeneous suspension. Shake gently and allow it to stand overnight (16 hours) at room temperature under dark conditions. Shake and filter through whatman No. 1 filter paper into a 100 ml volumetric flask, and make up the volume with water saturated n-butanol. Measure the optical density of clear filtrate at 440 nm as absorbance, on spectrophotometer. Use water saturated n-butanol as a blank. Solution required for preparation of standard beta-carotene. Weigh 0.25 g of beta-carotene in 1000 ml volumetric flask. Make a volume with diethyl ether, 20 ml of this solution (equivalent to 5 mg of beta-carotene) is pipette into a 250 ml volumetric flask. Make volume up to the mark with water saturated n-butanol. Further take 25 ml of this solution and dilute with n-butanol to 100 ml. This standard solution has the following concentration:

ml = 0.005 mg or 5µg of beta-carotene.

Prepare suitable dilutions of the standard solution with water saturated n-butanol in calibrated 10 ml volumetric flask (e.g. from 0.5-3 ml of standard solution in 10 ml). Measure the absorbance, A, of each dilution and establish calibration curve (beta-carotene in 10 ml of solution as a function of absorbance).

2.4 Colour
For the measurement of colour of powder, a combination of digital camera, computer and Adobe Photoshop 7.0 software provides a less expensive and more versatile way to determine colour parameters of food products than traditional colour measuring equipments and good colour of sample depends upon the intensity of light and distance between sample and camera. This colour measurement technique involves setting up a lighting system, high resolution digital camera to capture images of food samples (Spyridon *et al.*, 2000) [88].

2.4.1 Method
The powder sample was placed under the source of light at minimum distance and the intensity of light over the food sample should be uniform for good quality colour. Digital camera (Sony-2 mega pixels) was used to capture the image of sample. The L^*, a^*, b^* values of powder were measured by using Adobe Photoshop 7.0 software. Similar method used by (Smita, 2008). To convert lightness, a and b values obtained from the Histogram window to L^*, a^*, b^*, following formulas were used,

$$L^* = (\frac{\text{Lightness}}{250}) \times 100 \quad (2.3)$$

$$a^* = (\frac{240 \times a}{255}) - 120 \quad (2.4)$$

$$b^* = (\frac{240 \times b}{255}) - 120 \quad (2.5)$$

2.4.2 Measurement of moisture content
The initial and final moisture content after vacuum drying was determined by hot air oven drying method as described

by Ranganna (1977) for fruits and vegetables. After complete drying when weight of the samples shown constant values. The moisture content (%) on dry basis and drying rate were determined as described by Chakravarty (1997) [14].

$$\text{Moisture Content (\% d.b)} = \frac{W1-W2}{Wd} \times 100 \quad (2.6)$$

W1= weight of sample before drying in gram
W2 = weight of sample after drying in gram
W_{d} = weight of solid

2.3.3 Equilibrium moisture content

Hygroscopicity is a fundamental characteristic of biological materials. When such material exposed to a given atmosphere, they have a tendency to lose or gain moisture depending on temperature and relative humidity of surrounding atmosphere and their own moisture content. Equilibrium Moisture Content was required for calculations of moisture ratio (MR). It was determined using a method developed by Henderson and Perry (1976), in which last three moisture content readings of drying experiment were taken. Equation was used to determine the equilibrium moisture content.

$$Me = \frac{M_1 \, x \, M_3-(M_2)^2}{M_1+M_3-2M_2} \quad (2.7)$$

Where
M_1–Moisture content (% db) at time t_1
M_2-Moisture content (% db) at time t_2
M_3–Moisture content (% db) at time t_3
Moisture content should be taken with the following condition $(t_3 – t_2) = (t_2 – t_1)$.

2.3.4 Moisture ratio and drying rate

Moisture Ratio (MR) is defined by using following relation,

$$MR = \frac{M-M_e}{M_0-M_e} \quad (2.8)$$

Where
M–Average moisture content (% db) at time t (min) during drying M_0–Moisture content (% db) at the initiation of drying i.e. at 0 time Me–Equilibrium moisture content (% db)

Drying Rate is defined by using following relation as,

$$\frac{dm}{dt} = \frac{M_2-M_1}{\Delta t} \quad (2.9)$$

Where
Δt – difference in time.
To study the drying characteristics of papaya pulp, moisture ratio and drying rate at different time intervals were calculated as by using Equation 2.7 and 2.9.

3. Results and Discussions

3.1 Drying Behavior

The value of moisture content is obtained from 242.99 to 515.59% (db.), these values based on the amount of added ingredients before drying, while it has in the range of 2.03 to 4.71 % (db.) after drying in vacuum oven. The result of work in the vacuum foam mat drying of papaya pulp as a function of weight of testing materials and time. The drying time, drying rate and moisture ratio varies from 60 minutes to 840 minutes, 0.001-1.279 and 0.01-4.402 respectively. The drying duration, drying rate, and moisture ratio range from 60 to 840 minutes, respectively, 0.001-1.279 and 0.01-4.402. In experiment number 2, the ingredients, temperature (70°C), maltodextrin 0.30 (w/w), glycerol monostearate 2.0 percent, and tricalcium phosphate 2.0 percent of dried papaya powder were combined to achieve a minimum drying time of 660 minutes. Experiments also revealed that increasing the amount of tricalcium phosphate (2%) and glycerol monostearate 2.0 percent in the materials reduced drying time, which helped to lower the moisture content of the papaya powder. As the drying time increases, the moisture ratio for all samples decreases in a nonlinear manner. The moisture ratio of each sample declined rapidly while the drying period was very short, but the rate of decrement of moisture ratio became quite slow as the drying time increased.
The relationship between drying rate and moisture content is shown in Figures 3.1 (a), (b), (c), (d), (e), (f). From all experiments it is clear that drying rate decreased with decrease in moisture content for all samples.

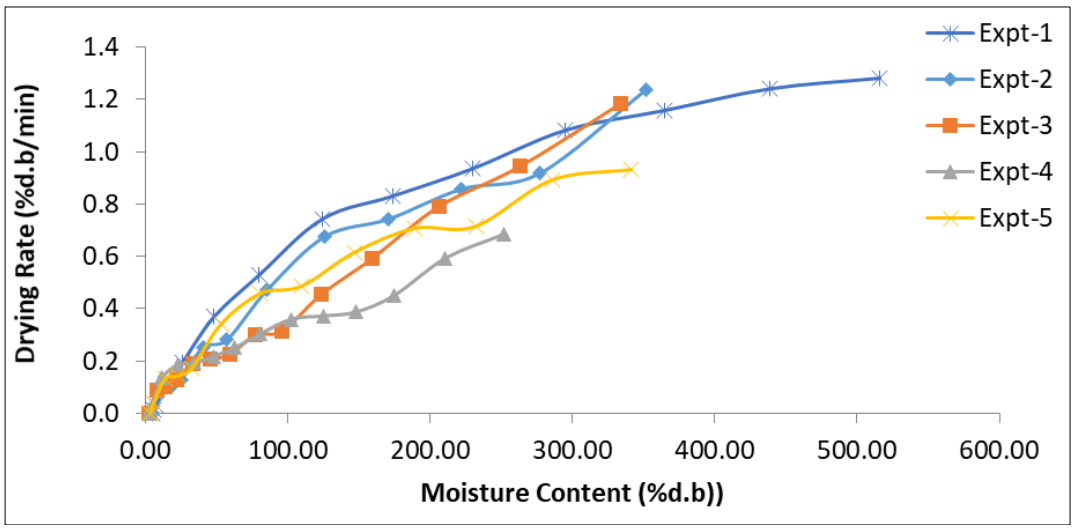

Fig 3.1 (a): Variation of drying rate with moisture content

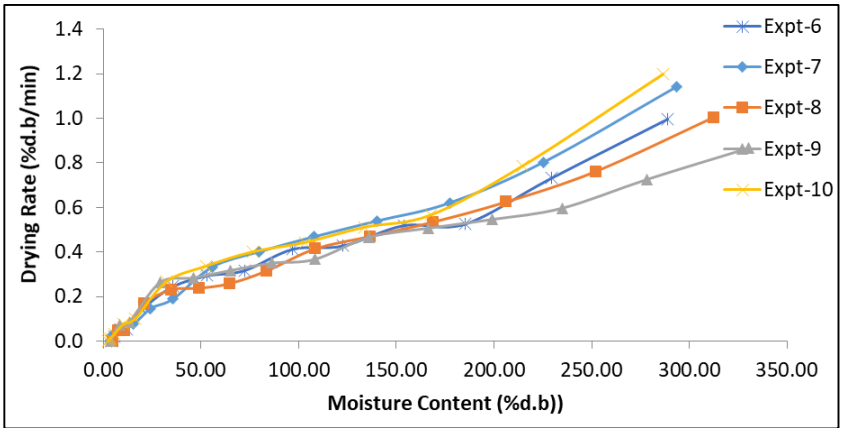

Fig. 3.1(b): Variation of drying rate with moisture content

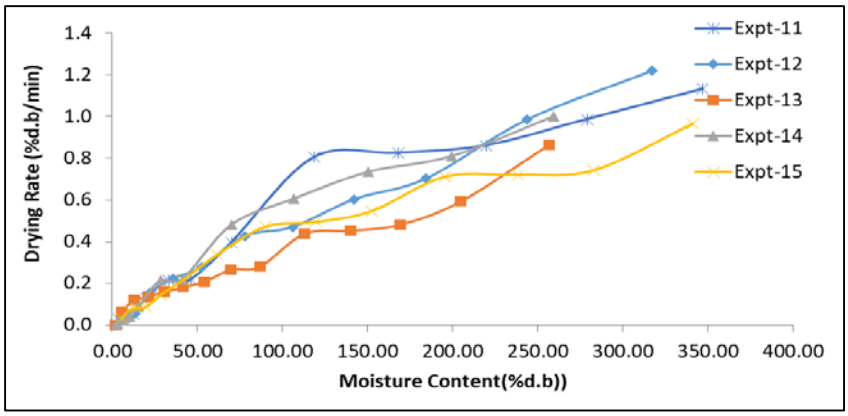

Fig. 3.1(c): Variation of drying rate with moisture content

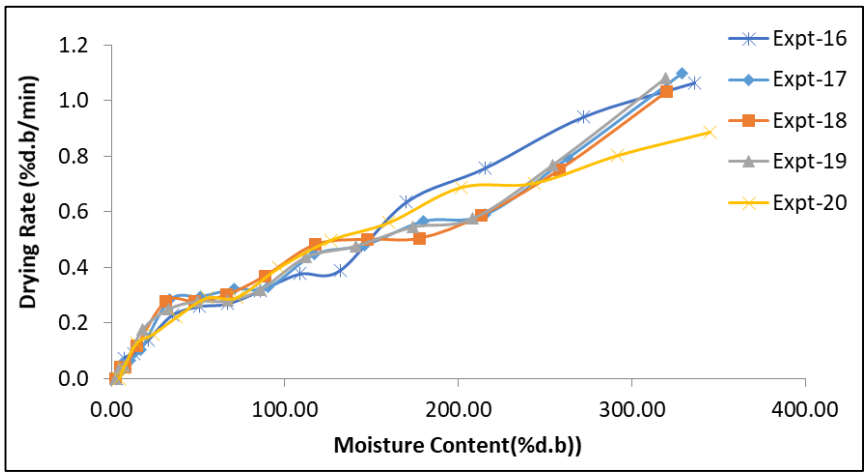

Fig 3.1(d): Variation of drying rate with moisture content

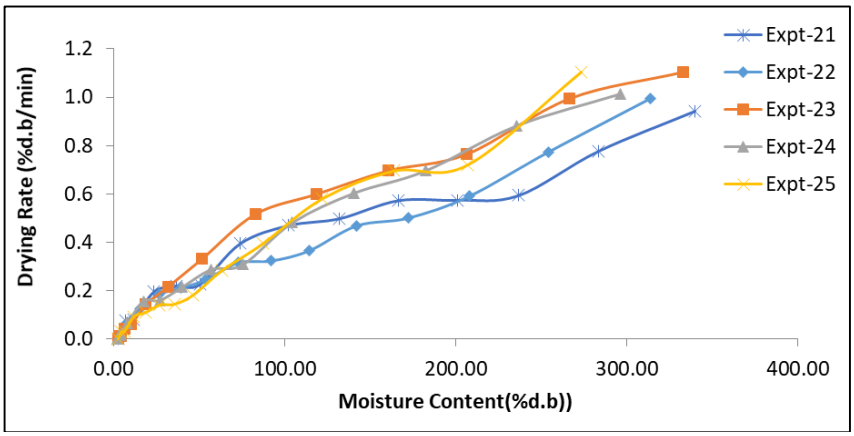

Fig 3.1(e): Variation of drying rate with moisture content

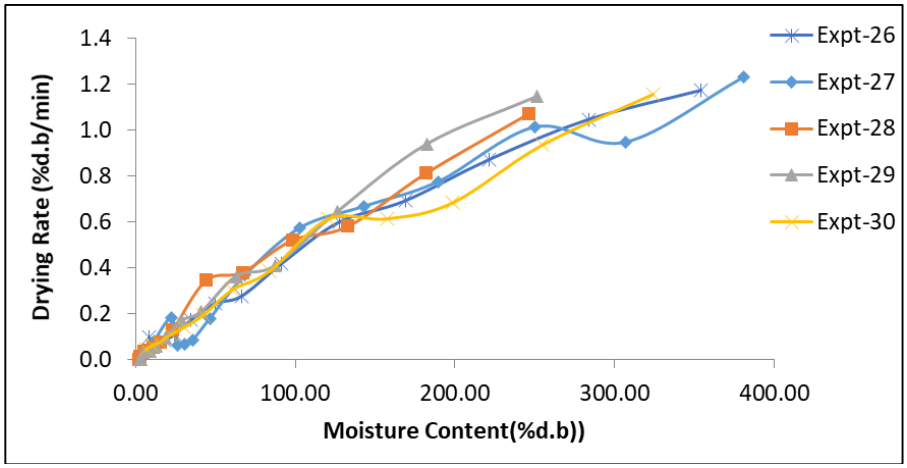

Fig 3.1(f): Variation of drying rate with moisture content.

3.2 Variables Influence on Solubility

As indicated in Table 1, the solubility of papaya powder ranges from 69.08 percent in experiment number 24 to 96.45 percent in experiment number 20. The coefficient of determination (R^2) for the regression model for solubility was 76.06 percent, suggesting that the model accounted for 76.06 percent of the variability in the data. Due to its low R^2 and F values, the model was deemed insufficient. The influence of temperature was significant ($P< 0.01$) at the linear level, as shown in Table 1. At a 5% level of significance, solubility increases with an increase in maltodextrin ("Chauca *et al.*, 2005 and Smita", 2008) [18]. Effect of ingredients at linear, quadratic and interactive levels is reported in Table 1. It shows that the effect at linear level was significant at 10% level of significance and effect at quadratic and interactive level was insignificant.

Table 2 shows the total effect of each parameter on solubility. Temperature and maltodextrin were found to have a substantial effect on solubility at the 1% and 5% levels of significance, respectively. Solubility was most affected by temperature ($P< 0.01$).

Table 1: ANOVA for solubility

SOURCE	DF	SS	MS	F_{-Cal}	F_{-Tab}
Model	14	906.01	64.72	3.4**	2.42
Linear	4	663.37	165.84	8.719*	4.893
Interactive	6	152.22	25.37	1.334	1.99
Quadratic	4	87.19	21.997	1.146	1.99
Residual error	15	285.23	19.02		
Total	29	1191.24			

*, **, *** Significant at 1, 5 & 10% level of significance respectively,
(Model- $F_{(14, 15, 0.01)} = 3.56$, $F_{(14, 15, 0.05)} = 2.42$ & $F_{(14, 15, 0.1)} = 1.99$), (Linear & Quadratic level- $F_{(4, 15, 0.01)} = 4.893$, $F_{(4, 15, 0.05)} = 3.056$ & $F_{(4, 15, 0.1)} = 2.36$) and (Interactive level-$F_{(6, 15, 0.01)} = 4.318$, $F_{(6, 15, 0.05)} = 2.79$ & $F_{(6, 15, 0.05)} = 2.208$)

Table 2: Total effect of individual parameters on solubility

Source	DF	SS	MS	F_{-Cal}	F_{-Tab}
Model	14	906.01	64.72	3.4**	2.42
Temperature (X_1)	5	559.68	111.94	5.885*	4.556
Maltodextrin(X_2)	5	269.03	53.806	2.828***	2.273
Glycerol Monostearate (X_3)	5	129.16	25.832	1.358	2.273
Tricalcium Phosphate (X_4)	5	97.03	19.406	1.02	2.273
Residual error	15	285.23	19.02		
Total	29	1191.24			

*, **, *** significant at 1, 5 & 10% level of significance respectively
(Model- $F_{(14, 15, 0.01)} = 3.56$, $F_{(14, 15, 0.05)} = 2.42$ & $F_{(14, 15, 0.1)} = 1.99$) and (Independent variables-F $F_{(5, 15, 0.01)} = 4.556$, $F_{(5, 15, 0.05)} = 2.901$ & $F_{(5, 15, 0.1)} = 2.273$).
Second order predictive quadratic equation for solubility (%) is given below

$$Y=83.84-4.68X_1-2.19X_2-0.28X_3-0.93X_4+1.29X_1X_2+0.12X_1X_3-0.64X_1X_4-1.95X_2X_3+1.18X_2X_4+1.51X_3X_4-0.22X_1^2-1.27X_2^2-1.05X_3^2+0.65X_4^2 \ldots (3.1)$$

Significant predictive equation for solubility (%) is given below

$$Y=83.84-4.68X_1-2.19X_2-1.95X_2X_3 \quad \ldots (3.2)$$

Where, Y is solubility (%), X_1, X_2, X_3 and X_4 are coded variables for temperature, maltodextrin, glycerol monostearate and tricalcium phosphate.

3.2.1 Visual representation of solubility

Figure 3.2 (a) shows the variation of solubility with temperature of maltodextrin (0.55 percent), glycerol

monostearate (1.78 percent), and tricalcium phosphate (2.5 percent) of papaya powder at the quadratic level. The solubility decreases as the temperature rises, as shown in the graph. At a temperature of 55 0 C, the maximum solubility was achieved.

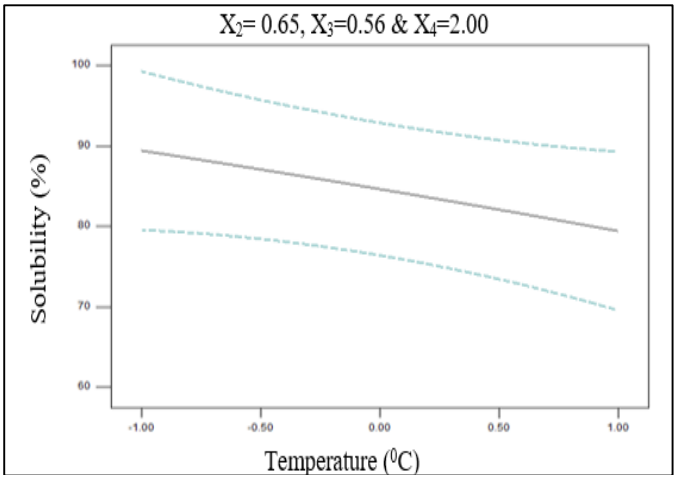

Fig 3.2(a): Variation of solubility (%) with temperature (^{0}C) at quadratic optimum points (0.65, 0.56 & 2.00)

3.2.2 Visual representation of solubility

The variation of solubility with maltodextrin at optimum points of temperature (59.050C), glycerol monostearate (0.56 percent), and tricalcium phosphate (2.5 percent) at linear level is shown in Fig. 3.2 (b). It was concluded that maltodextrin had little effect on the solubility of papaya powder.

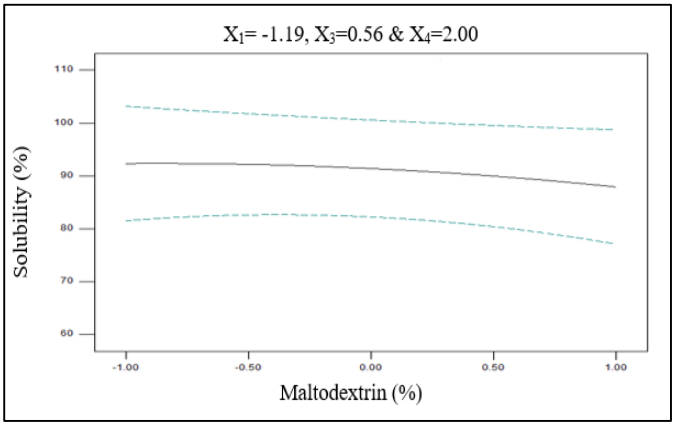

Fig 3.2(b): Variation of solubility (%) with maltodextrin (%) at optimum points (-1.19, 0.56 & 2.00)

3.2.3 Visual representation on solubility

The contour plot of glycerol monostearate and maltodextrin on solubility at optimum temperature (59.05 ^{0}C) and tricalcium phosphate (2.5 percent) at interactive level is shown in Fig. 3.2 (c). It was concluded that increasing the level of maltodextrin in the papaya powder gradually decreased its solubility, whereas increasing the level of glycerol monostearate in the papaya powder increased its solubility. The highest solubility (92%) was obtained with glycerol monostearate (2.00%) and maltodextrin (0.3705 w/w).

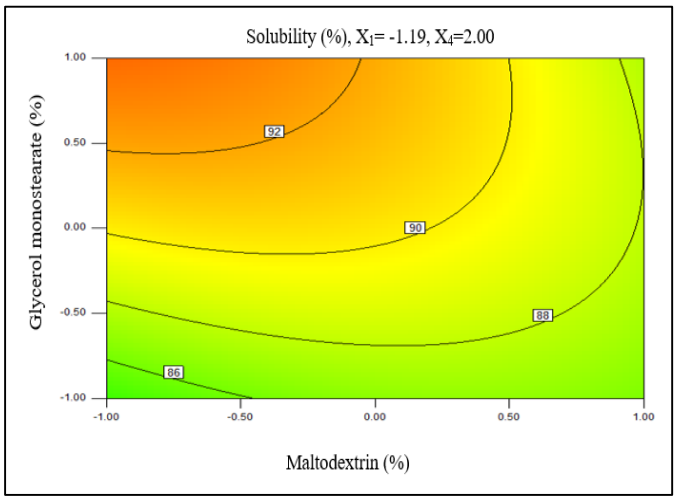

Fig 3.2(c): Variation of solubility (%) with maltodextrin (%) at interaction optimum points (-1.19, 2.00)

3.3 Variables Influence on Ascorbic Acid

Table 3.2 shows that ascorbic acid levels in experiment numbers 28 and 1 range from 88.43 to 115.75 (mg/100g). The coefficient of determination (R2) of the regression model for ascorbic acid is 82.50 percent, implying that this model guarantees 82.50 percent variability in data. The lack of fit is insignificant. Because the experimental F-value (5.051) is greater than the reference F-value, the model was significant at the 1% level of significance (3.56 at 1 percent). The linear temperature term is significant (P<0.01). The coefficient of temperature, maltodextrin and glycerol monostearate was negative which indicate that the increment in the level of these variables is due to decrement in quantity of ascorbic acid.

Effect of ingredients at linear, quadratic and interactive levels are reported in Table 3.2.3 which shows that the effect of ascorbic acid at linear level was highly significant (P<0.01).

Table 3.2.4 shows the total effect of individual parameters on ascorbic acid calculated using the sequential sum of squares method. Temperature was found to have a significant effect on ascorbic acid at the 1% level of significance because it had a higher sum of square, highly affected ascorbic acid in comparison to other variables.

Table 3.2.3: ANOVA for ascorbic acid

Source	DF	SS	MS	F-$_{Cal}$	F-$_{Tab}$
Model	14	1380.332	98.595	5.05*	3.56
Linear	4	1314.63	328.656	16.837*	4.893
Interactive	6	51.390	8.565	0.439	1.99
Quadratic	4	17.490	4.373	0.224	1.99
Residual error	15	292.79	19.52		
Total	29	1673.122			

*, **, *** Significant at 1, 5 & 10% level of significance respectively,,

(Model- $F_{(14, 15, 0.01)} = 3.56$, $F_{(14, 15, 0.05)} = 2.42$ & $F_{(14, 15, 0.1)} = 1.99$), (Linear & Quadratic level- $F_{(4, 15, 0.01)} = 4.893$, $F_{(4, 15, 0.05)} = 3.056$ & $F_{(4, 15, 0.1)} = 2.36$) and (Interactive level-$F_{(6, 15, 0.01)} = 4.318$, $F_{(6, 15, 0.05)} = 2.79$ & $F_{(6, 15, 0.05)} = 2.208$)

Table 3.2.4: Total effect of individual parameters on ascorbic acid

Source	DF	SS	MS	F_{-Cal}	F_{-Tab}
Model	14	1380.332	98.595	5.05*	3.56
Temperature (X_1)	5	1287.43	257.486	13.19*	4.556
Maltodextrin(X_2)	5	47.05	9.41	0.482	4.556
Glycerol Monostearate (X_3)	5	28.15	5.63	0.288	2.273
Tricalcium Phosphate (X_4)	5	33.36	6.672	0.342	2.273
Residual error	15	292.79	19.52		
Total	**29**	**1673.122**			

*, **, *** significant at 1, 5 & 10% level of significance respectively.

(Model- $F_{(14, 15, 0.01)} = 3.56$, $F_{(14, 15, 0.05)} = 2.42$ & $F_{(14, 15, 0.1)} = 1.99$) and (Independent variables-F $F_{(5, 15, 0.01)} = 4.556$, $F_{(5, 15, 0.05)} = 2.901$ & $F_{(5, 15, 0.1)} = 2.276$).

Second order predictive quadratic equation for ascorbic acid (mg/100g) is given below

$$Y=103.59-7.231X_1-0.90X_2-1.28X_3-0.16X_4+0.42X_1X_2-1.22X_1X_3+0.11X1X4-0.40X_2X_3+1.17X_2X_4-0.11X_3X_4-0.45X_1^2-0.13X_2^2-0.19\ X_3^2-0.62X_4^2 \quad (3.3)$$

Significant predictive equation for ascorbic acid (mg/100g) is given below

$$Y=103.59-7.231X_1 \quad (3.4)$$

Where,

Y is ascorbic acid (mg/100g)

X_1, X_2, X_3 and X_4 are coded variables for temperature, maltodextrin, glycerol monostearate and tricalcium phosphate.

3.3.1 Visual representation on ascorbic acid

Figure 3.3 (a) depicts the variation of ascorbic acid with temperature at the optimum point of maltodextrin (0.55 percent), glycerol monostearate (1.78 percent), and tricalcium phosphate (2.5 percent). It means that as the temperature rose, the amount of ascorbic acid decreased. The maximum ascorbic acid concentration was obtained at 55 ^{0}C and the lowest concentration was obtained at 75 ^{0}C.

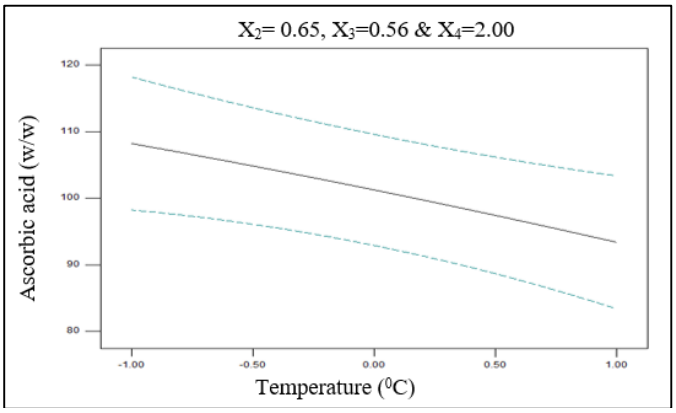

Fig 4.8(a): Variation of ascorbic acid (w/w) with temperature (^{0}C) at optimum points (0.65, 0.56 & 2.00)

3.4 Variables Influence on Beta-Carotene

Table 3.2 shows that beta carotene is found in the 10-51 (g/100g) range in experiments 24 and 12. The coefficient of determination (R2) of the beta carotene regression model is 86.04 percent, indicating that the model can account for 86.04 percent of the variability in data, as shown in **Table 3.1**. Because the calculated F-value (6.61) is higher at the 1% level of significance, the model is considered adequate in describing the effect of ingredients on beta carotene. The temperature coefficients of maltodextrin and tricalcium phosphate are negative, indicating that as the levels of these variables rise, so does the level of beta carotene. These findings are similar to those of Jaya *et al* (2006). Negative coefficients in quadratic terms indicate that the maximum of beta carotene is at the centre point, whereas positive coefficients in quadratic terms indicate the minimum response. Coefficients that are negative the term "interactive" denotes that the level of one variable of the interaction can be increased while the level of the other is decreased at the same time.

Table 3.2.5 shows the effect of ingredients at linear, quadratic, and interactive levels. It demonstrates that the effect at the linear level was highly significant (P0.01), as it had a higher calculated F-value than the other levels. Because of the low calculated F-value, the interactive and quadratic levels have no effect on beta carotene. Total effect of individual parameter on beta carotene was calculated by using the sequential sum of squares method, and it is given in the Table 3.2.6. It has been observed that temperature affected the beta carotene significantly at 1% level of significance while maltodextrin, tricalcium phosphate and glycerol monostearate had no effect on beta carotene. Temperature had highest effect on beta carotene because it had higher value of sum of square. Similar results were calculated by "Jaya and Das" (2000) [22] and Smita (2008).

Table 3.2.5: ANOVA for β-carotene

Source	DF	SS	MS	F_{-Cal}	F_{-Tab}
Model	14	2.55	0.18	6.61*	3.56
Linear	4	2.283	0.5708	20.388*	4.893
Interactive	6	0.0596	0.0099	0.355	1.99
Quadratic	4	0.190	0.0475	1.698	1.99
Residual error	15	0.41	0.028		
Total	29	2.96			

*, **, *** Significant at 1, 5 & 10% level of significance respectively,

(Model- $F_{(14, 15, 0.01)} = 3.56$, $F_{(14, 15, 0.05)} = 2.42$ & $F_{(14, 15, 0.1)} = 1.99$), (Linear & Quadratic level- $F_{(4, 15, 0.01)} = 4.893$, $F_{(4, 15, 0.05)} = 3.056$ & $F_{(4, 15, 0.1)} = 2.36$) and (Interactive level-$F_{(6, 15, 0.01)} = 4.318$, $F_{(6, 15, 0.05)} = 2.79$ & $F_{(6, 15, 0.05)} = 2.208$)

Table 3.2.6: Total effect of individual parameters on β-carotene

Source	DF	SS	MS	F_{-Cal}	F_{-Tab}
Model	14	2.55	0.18	6.61*	3.56
Temperature (X_1)	5	2.2613	0.4522	16.152*	4.556
Maltodextrin(X_2)	5	0.1254	0.025	0.896	2.273
Glycerol Monostearate (X_3)	5	0.0295	0.0059	0.211	2.273
Tricalcium Phosphate (X_4)	5	0.1027	0.0205	0.733	2.273
Residual error	15	0.41	0.028		
Total	29	2.96			

*, **, *** significant at 1, 5 & 10% level of significance respectively

(Model- $F_{(14, 15, 0.01)} = 3.56$, $F_{(14, 15, 0.05)} = 2.42$ & $F_{(14, 15, 0.1)} = 1.99$) and (Independent variables-F $F_{(5, 15, 0.01)} = 4.556$, $F_{(5, 15, 0.05)} = 2.901$ & $F_{(5, 15, 0.1)} = 2.273$).

Second order predictive quadratic equation for β- carotene (µg/100g**)** is given below

$$Y=3.66-0.24X_1-0.078X_2-0.009583X_3-0.024X_4+0.024X_1X_2-0.003125X_1X_3-0.013X_1X_4+0.021X_2X_3+0.018X_2X_4-0.012X_3X_4+0.009271X_1^2+0.005521X_2^2+0.023X_3^2+0.064X_4^2 \quad \ldots (3.5)$$

Significant predictive equation for β- carotene (µg/100g**)** is given below

$$Y=3.66-0.24X_1-0.078X_2 \quad \ldots (3.6)$$

Where,

Y is β-carotene (mg/100g)

X_1, X_2, X_3 and X_4 are coded variables for temperature, maltodextrin, glycerol monostearate and tricalcium phosphate.

3.4.1 Visual representation on beta-carotene

At linear level **Fig. 3.4 (a)** depicts that the variation of beta carotene with temperature at optimum point of maltodextrin (0.55%), glycerol monostearate (1.78%) and tricalcium phosphate (2.5%). It is decreasing with increasing the level of temperature. The maximum and minimum beta carotene was obtained at temperature 55^{0}C and 75^{0}C respectively.

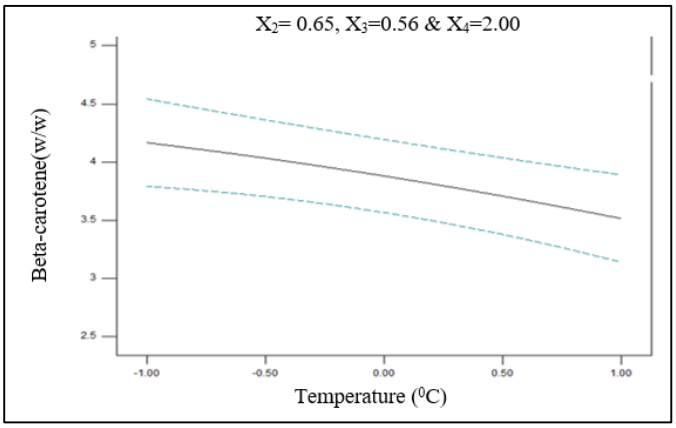

Fig 3.4 (a): Variation of beta-carotene (w/w) with temperature (^{0}C) at optimum points (0.65, 0.56 & 2.00)

3.4.2 Visual representation on on beta-carotene

Fig. 3.4 (b) shows that a relationship between beta carotene and maltodextrin at optimum point of temperature (59.05^{o}C), glycerol monostearate (1.78%) and tricalcium phosphate (2.5%) at linear level. Slightly decreased beta carotene with increased the level of maltodextrin.

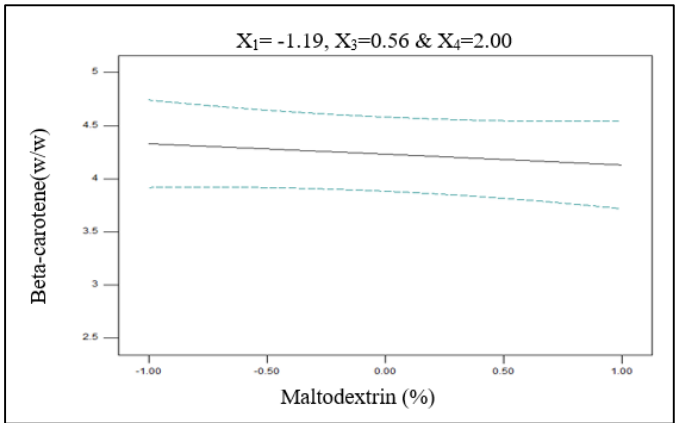

Fig 4.9(b): Variation of beta-carotene (w/w) with maltodextrin (%) at optimum points (-1.19, 0.56 & 2.00)

3.5 Variables Influence on Colour Value of Luminance Index (L*)

The regression analysis is shown in Table 3.1, which includes the regression coefficients in the model as well as the significance of each term. To investigate the effect of variables, a second order mathematical model (Eqn 3.2) was applied to the luminance index L* data. The regression model's coefficient of determination (R2) for the luminance index L* is 87.03 percent, implying that the model can account for 87.03 percent of data variability. Because the calculated F (7.19) is higher at the 1% level of significance, the model is considered tolerable in describing the effect of ingredients on the luminance index L*. The effect of ingredients at linear, quadratic, and interactive levels is represented in Table 3.5.1. It was discovered that the effect at the linear and quadratic levels was significant at 1% and 5%, respectively, due to a higher calculated F-value than at the other levels. Because of the low calculated F-value, the interactive level has little effect on the luminance index L*. Table 3.5.2 depicts the sequential sum of squares method used to calculate the total effect of individual parameters on the luminance index L*. Temperature, maltodextrin, and glycerol monostearate all had a significant effect on the luminance index L* at the 1%, 10%, and 5% levels of significance, respectively, whereas tricalcium phosphate had no effect on the luminance index L*. Only temperature had the greatest effect on the luminance index L* because it has a higher sum of squares value. **Jaya and Das** presented comparable results (2000) [22].

Table 3.2.7: ANOVA for luminance index L*

Source	DF	SS	MS	F_{-Cal}	F_{-Tab}
Model	14	565.2	40.37	7.19*	3.56
Linear	4	453.4	113.35	20.21*	4.893
Interactive	6	7.53	1.25	0.244	2.208
Quadratic	4	92.92	23.23	4.141**	3.056
Residual error	15	84.19	5.61		
Total	29	649.39			

*, **, *** Significant at 1, 5 & 10% level of significance respectively,
(Model- $F_{(14, 15, 0.01)} = 3.56$, $F_{(14, 15, 0.05)} = 2.42$ & $F_{(14, 15, 0.1)} = 1.99$), (Linear & Quadratic level- $F_{(4, 15, 0.01)} = 4.893$, $F_{(4, 15, 0.05)} = 3.056$ & $F_{(4, 15, 0.1)} = 2.36$) and (Interactive level-$F_{(6, 15, 0.01)} = 4.318$, $F_{(6, 15, 0.05)} = 2.79$ & $F_{(6, 15, 0.05)} = 2.208$)

Table 3.2.8: Total effect of individual parameters on luminance index L*

Source	DF	SS	MS	F_{-Cal}	F_{-Tab}
Model	14	565.2	40.37	7.19*	3.56
Temperature (X_1)	5	409.57	81.92	14.60*	4.556
Maltodextrin(X_2)	5	24.68	4.94	0.8798	2.273
Glycerol Monostearate (X_3)	5	109.91	21.98	3.918**	2.901
Tricalcium Phosphate (X_4)	5	17.206	3.44	0.6134	2.273
Residual error	15	84.19	5.61		
Total	**29**	**2.96**			

*, **, *** significant at 1, 5 & 10% level of significance respectively,
(Model- $F_{(14, 15, 0.01)} = 3.56$, $F_{(14, 15, 0.05)} = 2.42$ & $F_{(14, 15, 0.1)} = 1.99$) and (Independent variables-F $F_{(5, 15, 0.01)} = 4.556$, $F_{(5, 15, 0.05)} = 2.901$ & $F_{(5, 15, 0.1)} = 2.273$).
Second order predictive quadratic equation for luminance Index (L*) is given below

$$Y=61.76-4.1X_1+0.88X_2-1.14X_3+0.19X_4-0.52X_1X_2+0.39X_1X_3-0.041X_1X_4-0.071 \quad X_2X_3+0.20X_2X_4-0.001875X_3X_4-0.046X_1^2-0.18X_2^2 \quad -1.67X_3^2 +0.76X_4^2 \qquad (3.7)$$

Significant predictive equation for L* is given below

$$Y=61.76-4.1X_1+0.88X_2-1.14X_3-1.67X_3^2 \qquad \ldots (3.8)$$

Where,
Y is luminance index L*, X_1, X_2, X_3 and X_4 are coded variables for temperature, maltodextrin, glycerol monostearate and tricalcium phosphate.

3.5.1 Visual representation on luminance index L*

Fig. 3.5 (a) depicts a linear relationship between the luminance index L* and temperature at the optimum point of maltodextrin (0.55 percent), glycerol monostearate (1.78 percent), and tricalcium phosphate (2.5 percent). Temperature had a significant impact on the luminance index L* of papaya powder. With increasing temperature, the luminance index L* changes rapidly.

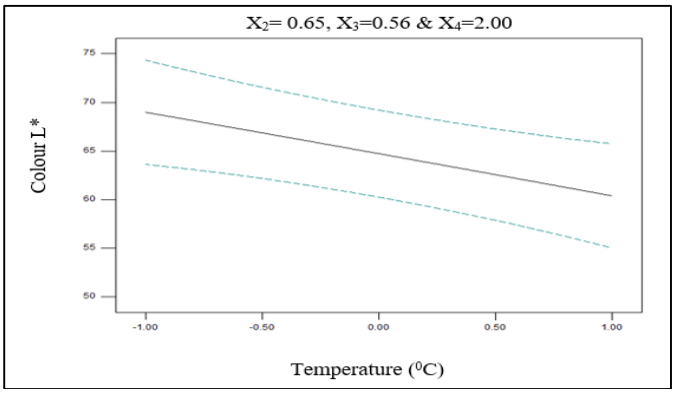

Fig 3.5(a): Variation of colour L* with temperature (^{0}C) at optimum points (0.65, 0.56 & 2.00)

3.5.2 Visual representation on luminance index L*

Figure 3.5 (b) depicts the effect of maltodextrin on the luminance index L* at the optimum temperature (59.05oC), glycerol monostearate (1.78 percent), and tricalcium phosphate on the luminance index L* at the linear level (2.5 percent). Maltodextrin has a significant impact on the luminance index L*. The luminance index L* decreased as the amount of maltodextrin increased.L*.

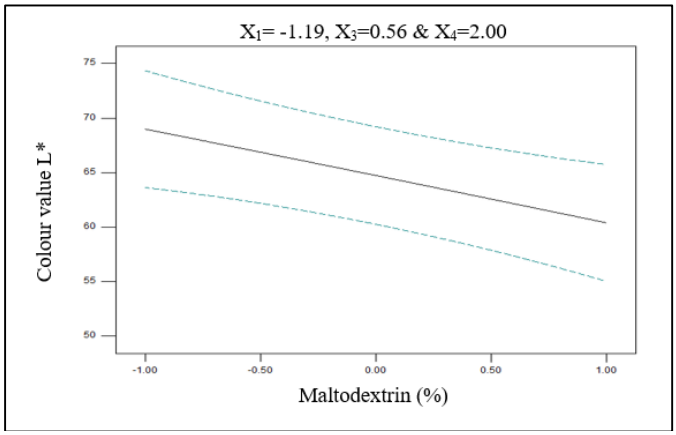

Fig 4.10(b): Variation of colour value L* with maltodextrin (%) at optimum points (-1.19, 0.56 & 2.00)

3.5.3 Visual representation on luminance index L*

At the linear level, Fig. 3.5 (c) shows the effect of glycerol monostearate on the luminance index L* at the optimum temperature (59.05oC), maoltodextrin (0.55 percent) and tricalcium phosphate (2.5 percent) of the papaya powder luminance index L* increased up to (0.50 percent), then decreased as the glycerol monostearate was increased.

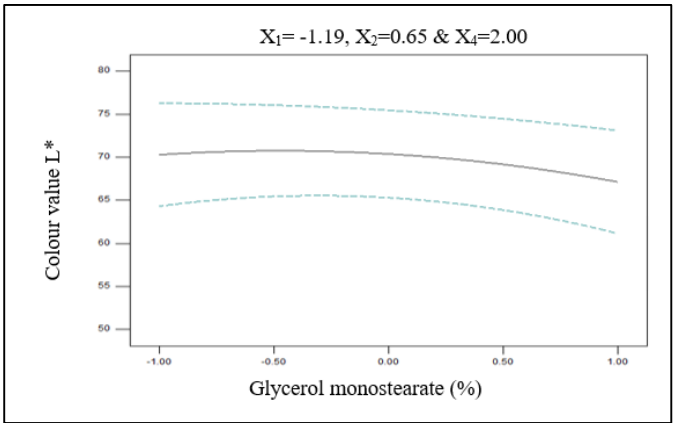

Fig 4.10(c): Variation of colour value L* with glycerol monostearate (%) at optimum points (-1.19, 0.65 & 2.00)

3.6 Variables Influence on chromatic component a*

The temperature and glycerol monostearate coefficients are both negative, indicating that as the levels of these variables rise, the chromatic component a* (green to red) decreases. These findings are similar to those of Jaya *et al* (2006) [44]. The maximum of the chromatic component a* is at the centre point, while the minimum response is given by the positive quadratic term, as indicated by the negative coefficients of the quadratic terms. Positive coefficients interactive term means that the level of one variable of the interaction can be increased while the level of the other variable is also increased. The regression analysis results are tabulated in Table 3, and a second order mathematical model (Eqn. 3.9) has been fitted to the colour data. The coefficient of determination (R^2) for the regression model for colour is 82.64 percent, indicating that the model can account for 82.64 percent of data variations. The model is deemed adequate, indicating that the effect of ingredients on chromatic component a* is significant due to a higher calculated F-value (5.10) at the 1% level of significance, and the lack of fit is significant. The effect of ingredients on linear, quadratic, and interactive levels is shown in Table 4. It depicts the effect on the linear and quadratic levels, which were significant at 1% and 5%, respectively, due to a higher calculated F-value than the other levels. Because of the low calculated F-value, the interactive level had little effect on the chromatic component a*. It was calculated that temperature and glycerol monostearate make impact on the chromatic component a* significantly at 1% & 10% level of significance on other hand maltodextrin and tricalcium phosphate had no effect on chromatic component a*. These result can be verified by result was given by "Jaya and Das" (2000) [22].

Table 3: ANOVA for a*

Source	DF	SS	MS	F_{-Cal}	F_{-Tab}
Model	14	1916.38	136.88	5.10*	3.56
Linear	4	1540.9	385.225	14.352*	4.893
Interactive	6	50.42	8.403	0.3131	2.208
Quadratic	4	403.24	100.81	3.756**	3.056
Residual error	15	402.57	26.84		
Total	29	2318.95			

*, **, *** Significant at 1, 5 & 10% level of significance respectively,,
(Model- $F_{(14, 15, 0.01)} = 3.56$, $F_{(14, 15, 0.05)} = 2.42$ & $F_{(14, 15, 0.1)} = 1.99$), (Linear & Quadratic level- $F_{(4, 15, 0.01)} = 4.893$, $F_{(4, 15, 0.05)} = 3.056$ & $F_{(4, 15, 0.1)} = 2.36$) and (Interactive level-$F_{(6, 15, 0.01)} = 4.318$, $F_{(6, 15, 0.05)} = 2.79$ & $F_{(6, 15, 0.05)} = 2.208$)

Table 4: Total effect of individual parameters on a*

Source	DF	SS	MS	F_{-Cal}	F_{-Tab}
Model	14	1916.38	136.88	5.10*	3.56
Temperature (X_1)	5	1456.36	291.272	10.852*	4.556
Maltodextrin(X_2)	5	53.58	10.716	0.399	2.273
Glycerol Monostearate (X_3)	5	356.44	71.288	2.65***	2.273
Tricalcium Phosphate (X_4)	5	178.6	35.72	1.331	2.273
Residual error	15	402.57	26.84	402.57	
Total	**29**	**2318.95**			

*, **, *** significant at 1, 5 & 10% level of significance respectively.
(Model- $F_{(14, 15, 0.01)} = 3.56$, $F_{(14, 15, 0.05)} = 2.42$ & $F_{(14, 15, 0.1)} = 1.99$) and (Independent variables-F $F_{(5, 15, 0.01)} = 4.556$, $F_{(5, 15, 0.05)} = 2.901$ & $F_{(5, 15, 0.1)} = 2.273$)
Second order predictive quadratic equation for a*is given below

$$Y=51.54-7.74X_1+0.32X_2-2.19X_3+1.87X_4+0.42X_1X_2+0.16X_1X_3+0.55X_1X_4-0.24\ X_2X_3+1.16X_2X_4-0.005X_3X_4-1.99X_1^2-0.46X_2^2-2.96X_3^2-1.33X_4^2 \quad \ldots (3.9)$$

Significant predictive equation for β- carotene (µg/100g**)** is given below

$$Y=51.54-7.74X_1-2.19X_3+1.87X_4-1.99X_1^2-2.96X_3^2 \quad \ldots (3.10)$$

Where,
Y is chromatic component a*
X_1, X_2, X_3 and X_4 are coded variables for temperature, maltodextrin, glycerol monostearate and tricalcium phosphate.

3.6.1 Visual representation of chromatic component a*

Fig. 3.6 (a) depicts the variation of colour value a* with temperature at the optimum point of maltodextrin (0.55 percent), glycerol monostearate (1.78 percent), and tricalcium phosphate (2.5 percent) in papaya powder. The temperature has had a significant impact on the powder's colour value a*. Reduced the colour value a* while increasing the temperature level.

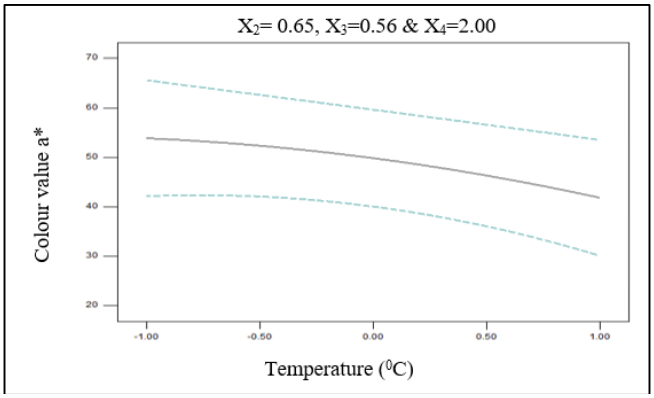

Fig 4.6(a): Variation of colour value a* with Temperature (^{0}C) at optimum points (0.65, 0.56 & 2.00)

3.6.2 Visual representation of chromatic component a*

At the linear level, Fig. 3.6 (b) depicts the effect of glycerol monostearate on the colour value a* at the optimum temperature (59.05oC) and maltodextrin (0.55 percent) up to (0.50 percent), after which the value decreases as the amount of glycerol monostearate increases.

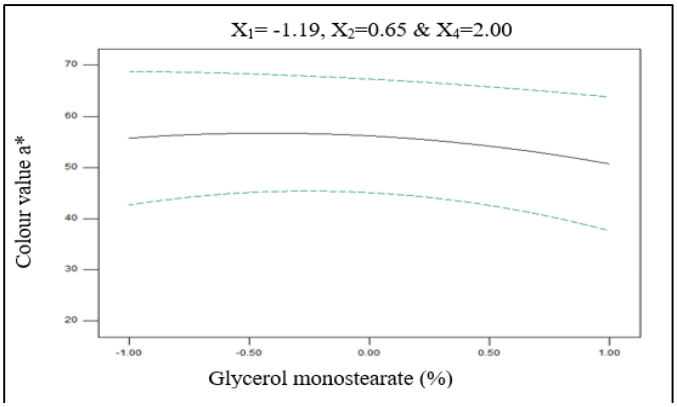

Fig 4.11(b): Variation of colour value a* with glycerol monostearate (%) at optimum points (-1.19, 0.65 & 2.00)

3.6.3 Visual representation of chromatic component a*

At the linear level, Fig. 3.6 (c) depicts the variation of colour value a* with tricalcium phosphate at the optimum temperature (59.05oC), maltodextrin (0.55 percent), and glycerol monostearate (1.78 percent). It was discovered that increasing the level of tricalcium phosphate slightly increased the colour value a*.

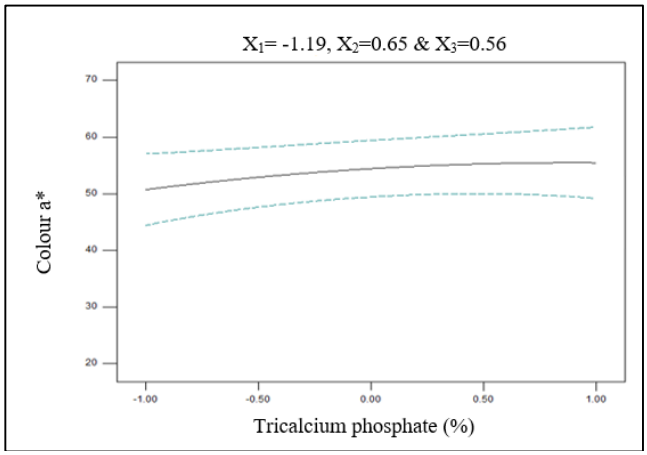

Fig 4.11(c): Variation of colour a* (%) with tricalcium phosphate (%) at optimum points (-1.19, 0.65 & 0.56)

3.6.4 Visual representation of chromatic component a*

Fig. 3.6 (d) shows the variation in colour value a* with temperature at the optimum point of maltodextrin (0.55 percent), glycerol monostearate (1.78 percent), and tricalcium phosphate at the quadratic level (2.5 percent). It was first increased up to 0.54 percent, then decreased as the temperature increased.

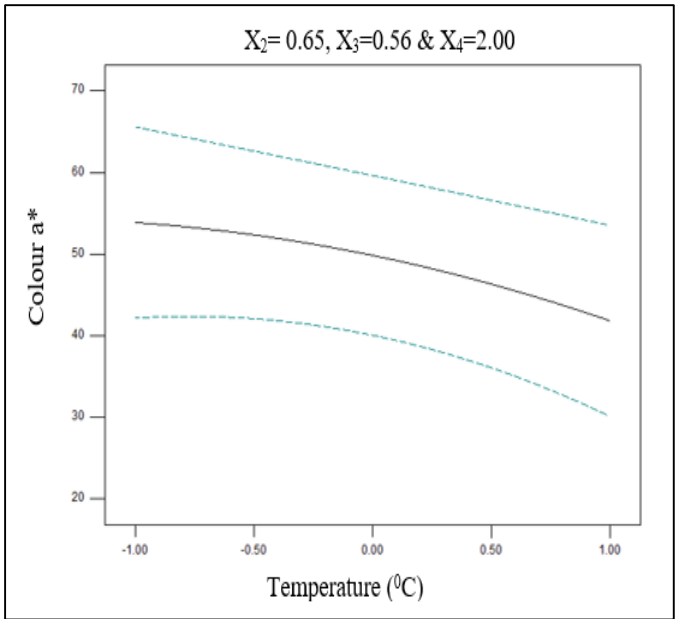

Fig 4.11(d): Variation of colour a* with Temperature (^{0}C) at quadratic optimum points (0.65, 0.56 & 2.00)

3.7 Variables Influence on chromatic component b*

The chromatic component b* data is subjected to a second order mathematical model (Eqn. 3.2), and the regression analysis results are tabulated in Table 4.2. The regression model's coefficient of determination (R2) for colour value b* is 81.81 percent, indicating that the model can account for 81.81 percent of the variability in data. The lack of fit is insignificant, and the model is deemed adequate in describing the effect of ingredients on chromatic component b* due to a higher calculated F- value (4.82) at the 1% level of significance. Table 3.2.11 shows the effect of ingredients at linear, quadratic, and interactive levels. It demonstrates that the effect at the interaction and quadratic levels was significant at the 1% level of significance due to a higher calculated F-value. Because of the low calculated F-value, the linear level has little effect on the chromatic component b*.

The total effect of each parameter on the chromatic component b* was calculated using the sequential sum of squares method and is shown in Table 3.2.12. Temperature, maltodextrin, glycerol monostearate, and tricalcium phosphate all had a significant effect on the chromatic component b* at the 5%, 5%, 1%, and 5% levels of significance, respectively. Jaya and Das reported similar findings (2000) [22].

Table 3.2.11: ANOVA for chromatic component b*

Source	DF	SS	MS	F_{-Cal}	F_{-Tab}
Model	14	11136.24	795.45	4.82*	3.56
Linear	4	1161.76	290.44	1.759	1.99
Interactive	6	5740.78	956.796	5.796*	4.318
Quadratic	4	3854.63	963.658	5.838*	4.893
Residual error	15	2476.14	165.08		
Total	29	13612.38			

*, **, *** Significant at 1, 5 & 10% level of significance respectively,
(Model- $F_{(14, 15, 0.01)} = 3.56$, $F_{(14, 15, 0.05)} = 2.42$ & $F_{(14, 15, 0.1)} = 1.99$), (Linear & Quadratic level- $F_{(4, 15, 0.01)} = 4.893$, $F_{(4, 15, 0.05)} = 3.056$ & $F_{(4, 15, 0.1)} = 2.36$) and (Interactive level-$F_{(6, 15, 0.01)} = 4.318$, $F_{(6, 15, 0.05)} = 2.79$ & $F_{(6, 15, 0.05)} = 2.208$)

Table 3.2.12: Total effect of individual parameters on b*

Source	DF	SS	MS	F_{-Cal}	F_{-Tab}
Model	14	11136.24	795.45	4.82*	3.56
Temperature (X_1)	5	2421.56	484.312	2.934**	2.901
Maltodextrin(X_2)	5	3471.5	694.3	4.206**	2.901
Glycerol Monostearate (X_3)	5	6899.12	1379.824	8.359*	4.556
Tricalcium Phosphate (X_4)	5	3705.77	741.154	4.489**	2.901
Residual error	15	2476.14	165.08		
Total	29	13612.38			

*, **, *** significant at 1, 5 & 10% level of significance respectively,
(Model- $F_{(14, 15, 0.01)} = 3.56$, $F_{(14, 15, 0.05)} = 2.42$ & $F_{(14, 15, 0.1)} = 1.99$) and (Independent variables-F $F_{(5, 15, 0.01)} = 4.556$, $F_{(5, 15, 0.05)} = 2.901$ & $F_{(5, 15, 0.1)} = 2.273$).
Second order predictive quadratic equation for b* is given below

$$Y=40.38-0.37X_1+4.34X_2-5.16X_3-1.68X_4+3.92X_1X_2-3.35X_1X_3+8.66X_1X_4-10.28X_2X_3-3.19X_2X_4-11.90X_3X_4-5.38X_1^2+5.8X_2^2-8.80X_3^2-0.68X_4^2 \quad \ldots (3.11)$$

Significant predictive equation for b* is given below

$$Y=40.38-5.16X_3+8.66X_1X_4-10.28X_2X_3-11.90X_3X_4-5.38X_1^2+5.8X_2^2-8.80X_3^2 \ldots (3.12)$$

Where,
Y is b* chromatic component b*
X_1, X_2, X_3 and X_4 are coded variables for temperature, maltodextrin, glycerol monostearate and tricalcium phosphate.

3.7.1 Visual representation of chromatic component b*

At the linear level, Fig. 3.7 (a) depicts the effect of glycerol monostearate at the optimum temperature (59.05oC), maltodextrin (0.65%), and tricalcium phosphate (2.5 percent). The colour value b* decreases gradually as the amount of glycerol monostearate in the papaya powder increases.

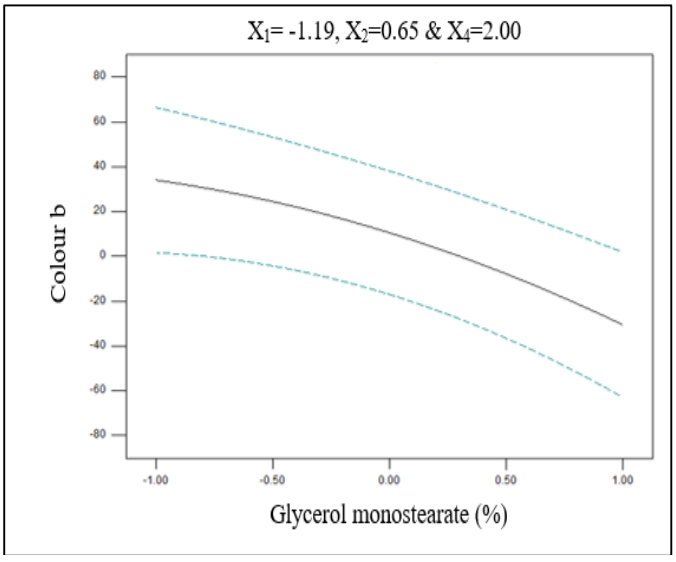

Fig 4.12(a): Variation of colour b* with glycerol monostearate (%) at optimum points (-1.19, 0.65 & 2.00)

3.7.2 Visual representation on chromatic component b*

The interactive effect of temperature and tricalcium phosphate on the colour value b* of papaya powder is depicted in Fig. 3.7 (b). The colour value b* decreases with increasing temperature but increases with decreasing tricalcium phosphate level.

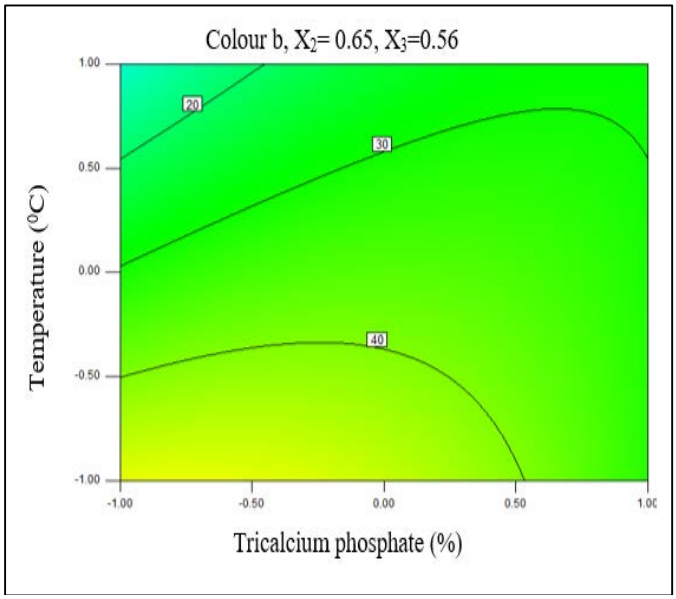

Fig 3.7(b): Variation of colour b* (%) with tricalcium phosphate (%) and temperature (^{0}C) at interaction optimum points (0.65 & 0.56)

3.7.3 Graphical representation on chromatic component b*

Figure 4.12 (c) shows the effect of temperature at the optimum point of glycerol monostearate (1.78 percent), maltodextrin (0.55 percent), and tricalcium phosphate at the linear level (2.5 percent). It is observed that as the temperature rises, the colour value b* rises as well.

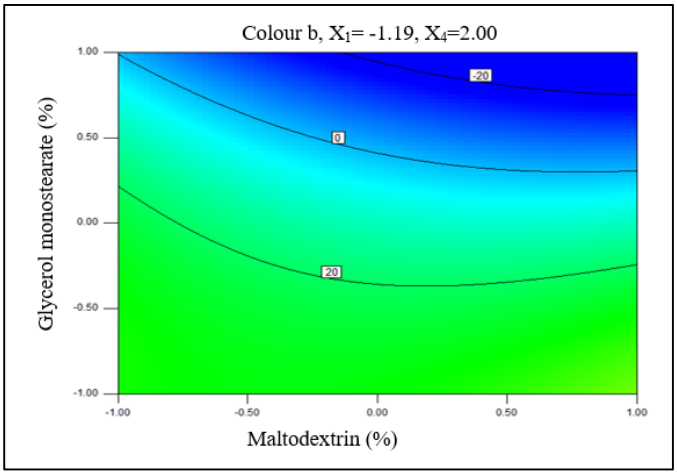

Fig 3.7(c): Variation of colour b* (%) with glycerol monostearate (%) and maltodextrin (%) at interaction optimum points (-1.19 & 2.00)

3.7.4 Graphical representation on chromatic component b*

Figure 3.7 (d) shows the effect of glycerol monostearate at the optimum temperature (59.05oC), maltodextrin (0.55 percent), and tricalcium phosphate at the linear level (2.5 percent). The colour value b* gradually decreases as the amount of glycerol monostearate in the papaya powder is increased.

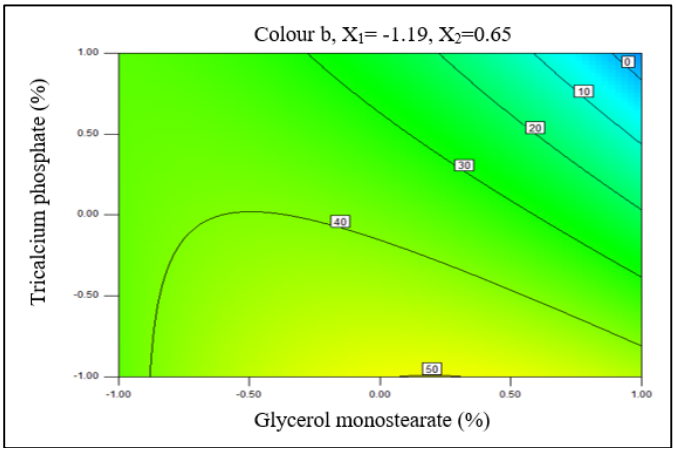

Fig 3.7(d): Variation of colour b* (%) with tricalcium phosphate (%) and glycerol monostearate (%) at optimum points (-1.19&0.65)

3.8 Optimization of Ingredient Variables for Production of Papaya powder

The numerical optimization of independent variables was carried out in this study utilising the statistical programme Design–Expert 8.0.6. The main goal was to keep within the solubility, ascorbic acid, beta carotene, and colour ranges provided in tables 3.3. To achieve the goal, the work began at a random beginning point and proceeded up and down the steepest slope on the response surface in search of the response's greatest and minimum values, respectively. Level of ingredients for optimum values of independent variables is calculated by using simultaneous optimization of solubility, ascorbic acid, beta carotene and colour values (L*,a*,b*) having value 59.05°C temperature,0.55 gm per 100 gm of papaya solid, 1.78% glycerol monostearate and 2.5% tricalcium phosphate respectively as shown in **table 3.4**.

4. Summary and Conclusions

The moisture content of raw papaya pulp was 856.023 % (db.). The total soluble solid (TSS) was tested by hand refractrometer i.e. 12.8 ⁰ Brix. Parameters such as whipping time (10 minute) , papaya pulp thickness (4 mm) and vacuum oven pressure (25 inch Hg), pH value 5.56 and TSS(10 ⁰ Brix) remain constant throughout the work. The drying time, drying rate and moisture ratio varies from 60 minutes to 840 minutes, 0.001-1.279 and 0.01-4.402 respectively. The drying duration, drying rate, and moisture ratio range from 60 to 840 minutes, respectively, 0.001-1.279 and 0.01-4.402. In experiment number 2, the ingredients, temperature (70^{o}C), maltodextrin 0.30 (w/w), glycerol monostearate 2.0 percent, and tricalcium phosphate 2.0 percent of dried papaya powder were combined to achieve a minimum drying time of 660 minutes. Experiments also revealed that increasing the amount of tricalcium phosphate (2%) and glycerol monostearate 2.0 percent in the materials reduced drying time, which helped to lower the moisture content of the papaya powder. As the drying time increases, the moisture ratio for all samples decreases in a nonlinear manner. The moisture ratio of each sample declined rapidly while the drying period was very short, but the rate of decrement of moisture ratio became quite slow as the drying time increased. The solubility of papaya powder is found to be as low as 69.08 percent in experiment number 24 and as high as 96.45 percent in experiment number 20. Ascorbic acid is found in the range of 88.43 experiment number to 115.75 (mg/100g) experiment number 1, while beta carotene is found in the range of 10-51 (g/100g) experiment numbers 24 and 12. L* (Lightness) is varied from 53.1 to 82.79 experiment numbers 14 and 10, chromatic component a* (from green to red) is varied from 27.25 to 105.92 experiment numbers 3 and 17, and chromatic component b* (from blue to yellow) is varied from -15.92 experiment number 3 to 73.67 experiment number 10 during colour value estimation. Level of ingredients for optimum values of independent variables is calculated by using simultaneous optimization of solubility, ascorbic acid, beta carotene and colour values (L*,a*,b*) having value 59.05°C temperature,0.55 gm per 100 gm of papaya solid, 1.78% glycerol monostearate and 2.5% tricalcium phosphate respectively. They can be used accordingly as given above to make a good quality papaya powder under vacuum foam mat drying.

5. Acknowledgement.

I am grateful to the department of PHPFE, College of Technol ogy, GBPUAT Pantnagar, Udham Singh Nagar, Uttarakhand f or allowing me to conduct this research.

Table 2.1: Specification of experimental equipments / apparatus

Equipments/ apparatus	Specification	Make
Balance electronic	Capacity - 300g Least count:0.01g	Winsor
Vacuum Oven	Temperature:40 - 130°C Vacuum:0-760mm Hg Voltage:220-230V	Macro Scientific Works
Vacuum pump	Capacity: 150 lit/min	Macro Scientific Works

	Oil required:0.5lit Motor-H.P.:0.33 Volt:220AC Phase 1 RPM:1420	
UV Spectrophotometer	200-1000nm Accuracy:3nm	Beckman
Centrifuge	R8C,11-32,3000-6000rpm	Remi equipments
Water bath	No:1188, 220 volt, 50Hz	JSGW
Beaker	Capacity: 100,250,500, 1000ml	Borosil
Conical flack	Capacity: 25, 50, 100, 250ml	Borosil
Measuring cylinder	50 mm diameter	Borosil
Funnel	Capacity: 100, 250, 500ml	Borosil
Volumetric flask	Glass,	Borosil
Sieve	Dia:500 micron	Associate Instrument Ltd
Pipette	Capacity: 1, 5, 10ml	Borosil
Test tube	25,50ml	Borosil
Refrigerator	310 liter	Kelvinator
Filter Paper	Whatman No.1,dia-125mm	AXIVA, Sichem Biotech
Food Processor	No of speed-3, $D_1/Q_0/M/2632$,810w	Sujata ltd
Digital Camera	2.0 mega pixels	Sony
Stop watch	Range 15min, Least count 0.01sec	Timax
Thermometer	Range:0-110°C 300 mm	Sonar Laboratory
Desiccator	Diameter: 150 and 300 mm	Borosil
Petri dish	Disposable	Borosil

Table 2.2: Values of independent variables in coded and actual form

Independent variables	**Coded levels**					
Name	**Code**	**-α**	**-1**	**0**	**+1**	**+α**
	Actual Levels (%)					
Temperature (°C)	X_1	55	60	65	70	75
Maltodextrin (kg/kg papay pulp solid)	X_2	0.15	0.3	0.45	0.6	0.75
Glycerol monostearate (%)	X_3	0.50	1.0	1.50	2.0	2.5
Tricalcium phosphate (%)	X_4	0.50	1.0	1.50	2.0	2.5

Table 2.3: List of additives and their functions

Additives	**Function**
Maltodextrin (MD) $(C_6H_{10}O_5)_n$ (LOBA chemie Pvt Ltd.)	▪ Used as a drying aids. ▪ MD treatment increases degree of solubility, upto 90% ▪ Reduces the stickiness of fruit powders ▪ Produces non sticky, free flowing powder ▪ Reduces the hygroscopicity of the powder
Tricalcium Phosphate (TCP) $(Ca_3\ O_8\ P_2)$ (LOBA chemie Pvt Ltd.)	▪ Used as an anticaking agent ▪ Reduces the hygroscopicity of powder ▪ Improve the flowability and inhibit the tendency to cake
Glycerol monosterate (GMS) ($C_{17}H_{35}COOCH_2CHOHCH_2OH$) (LOBA chemie Pvt Ltd.)	▪ Act as a foam stablizer ▪ For retention of puffed structure created in the initial stage of vacuum drying.

Table 2.4: Total numbers of experiments (designed by design expert trial version 8.0.6)

Expt No.	**Coded values**				**Actual values of independent variables**			
	X_1	**X_2**	**X_3**	**X_4**	**Temp. °C**	**MD %**	**GMS %**	**TCP %**
1	-2	0	0	0	55	0.45	1.5	1.5
2	1	-1	1	1	70	0.3	2	2
3	0	0	2	0	65	0.45	2.5	1.5
4	-1	1	-1	1	60	0.6	1	2
5	-1	1	1	1	60	0.6	2	2
6	0	0	0	-2	65	0.45	1.5	0.5
7	1	1	1	-1	70	0.6	2	1
8	0	0	0	0	65	0.45	1.5	1.5
9	-1	1	-1	-1	60	0.6	1	1
10	1	1	-1	1	70	0.6	1	2
11	0	0	0	0	65	0.45	1.5	1.5
12	1	1	-1	-1	70	0.6	1	1
13	-1	1	1	-1	60	0.6	2	1
14	1	-1	-1	-1	70	0.3	1	1
15	-1	-1	-1	1	60	0.3	1	2

16	0	-2	0	0	65	0.15	1.5	1.5
17	0	0	0	0	65	0.45	1.5	1.5
18	0	0	0	0	65	0.45	1.5	1.5
19	0	0	0	0	65	0.45	1.5	1.5
20	-1	-1	-1	-1	60	0.3	1	1
21	-1	-1	1	-1	60	0.3	2	1
22	-1	-1	1	1	60	0.3	2	2
23	0	0	-2	0	65	0.45	0.5	1.5
24	0	2	0	0	65	0.75	1.5	1.5
25	1	-1	-1	1	70	0.3	1	2
26	0	0	0	0	65	0.45	1.5	1.5
27	1	-1	1	-1	70	0.3	2	1
28	2	0	0	0	75	0.45	1.5	1.5
29	1	1	1	1	70	0.6	2	2
30	0	0	0	2	65	0.45	1.5	2.5

X_1= Temperature °C, X_2= Maltodestrin (w/w), X_3= Glycerol monosterate (%) and X_4= Tricalcium Phosphate (%)

Table 3.1: Results of regression analysis of papaya powder properties

	Solubility (%)	
	Coeff.	**P (%)**
Cons	83.838	1.23**
X_1	-4.679	0.01*
X_2	-2.192	2.64**
X_3	-0.283	75.50
X_4	-0.929	31.29
X_1X_2	1.292	25.44
X_1X_3	0.123	91.16
X_1X_4	-0.614	58.14
X_2X_3	-1.948	9.42***
X_2X_4	1.179	29.64
X_3X_4	1.506	18.75
X_1X_1	-0.219	79.55
X_2X_2	-1.268	14.85
X_3X_3	-1.046	22.83
X_4X_4	0.654	44.44
R^2 (%)	**76.06**	
F	**3.4**	
LOF	**NS**	

*, **, *** Significant at 1, 5 and 10 % level of significance respectively,Cons= Constant and Coeff. = Coefficient

	Ascorbic Acid		**Beta-Carotene**		**Colour**					
					L*		**a***		**b***	
	Coeff.	**P (%)**	**Coeff.**	**P (%)**	**Coeff.**	**P (%)**	**Coeff.**	**P (%)**	**Coeff.**	**P (%)**
Cons	103.6	0.18*	3.675	0.04*	61.756	0.02*	51.54	0.17*	40.37	0.23*
X_1	-7.231	0.01*	-0.301	0 .01*	-4.096	0.01*	-7.470	0.01*	-0.372	88.91
X_2	-90.04	33.39	-6.458	7.61***	88.458	8.73***	0.32	76.6	4.338	11.89
X_3	-1.284	17.51	0.625	85.62	-1.137	3.28**	-2.188	5.63***	-5.159	6.79**
X_4	0.164	85.83	-0.010	76.3	0.193	69.6	1.872	9.71***	-1.682	53.10
X_1X_2	0.417	71.1	0.035	42.0	-0.519	39.4	0.419	75.1	3.916	24.17
X_1X_3	-1.221	28.7	-0.032	45.5	0.393	51.7	0.16	90.3	-3.347	31.39
X_1X_4	0.114	91.9	-0.014	73.4	-0.041	94.6	0.545	67.9	8.656	1.66**
X_2X_3	-0.399	72.2	0.023	58.6	-0.071	90.7	-0.239	85.6	-10.28	0.60*
X_2X_4	1.168	30.7	-0.007	87.0	0.198	74.2	1.611	23.3	-3.186	33.70
X_3X_4	-0.107	92.4	0.027	52.7	-0.002	99.7	-0.005	99.7	-11.89	0.21*
X_1X_1	-0.453	59.9	-0.039	22.9	-0.046	92.0	-1.992	6.2***	-5.384	4.44**
X_2X_2	-0.125	88.4	-0.002	94.6	-0.178	69.9	-0.462	64.7	5.795	3.21**
X_3X_3	-0.185	82.9	0.048	15.2	-1.668	0.22*	-2.959	0.91*	-8.804	0.27*
X_4X_4	-0.619	47.5	0.055	10.2	0.756	11.6	-1.326	20.0	-0.679	78.55
R^2 (%)	82.50		86.04		87.04		82.64		81.81	
F	5.051*		6.61*		7.19*		5.10*		4.82*	
LOF	NS		NS		S		S		NS	

*, **, *** Significant at 1, 5 and 10 % level of significance respectively.
Cons= Constant and Coeff. = Coefficient

Table 3.2: Quality parameters for papaya powder

Expt No.	Coded levels				SL,%	AC,mg/100gm	BC,mg/100gm	Colour values		
	X_1	X_2	X_3	X_4				L*	a*	b*
1	-2	0	0	0	91.56	115.75*	4.15*	69.74*	59.92*	21.9
2	1	-1	1	1	82.42	96.68	3.63	57.64	29.73	29.63
3	0	0	2	0	80.75	99.34	3.97	48.04**	28.2	-15.92**
4	-1	1	-1	1	88.94	112.03	4.02	68.45	54.2	51.6
5	-1	1	1	1	84.98	110.45	4.01	67.34	53.13	-6.34
6	0	0	0	-2	85.36	106.09	3.98	66.01	40.57	51.99
7	1	1	1	-1	79.46	89.45	3.54	58.12	31.65	27.08
8	0	0	0	0	83.14	102.5	3.73	61.58	48.86	39.39
9	-1	1	-1	-1	85.77	102	3.82	66	53.01	39.94
10	1	1	-1	1	81.24	97.54	3.48	57.89	38.56	73.67*
11	0	0	0	0	84.67	98.45	3.51	62.12	52.24	46.47
12	1	1	-1	-1	82.11	94.65	3.46	56	36.87	43.17
13	-1	1	1	-1	78.98	104.32	4	64.3	46.75	47.76
14	1	-1	-1	-1	82.1	95.73	3.69	55.4	32.28	0.81
15	-1	-1	-1	1	82.54	109.27	4.09	63.33	49.65	29.99
16	0	-2	0	0	85.34	101.34	3.93	60.18	49.07	53.83
17	0	0	0	0	86.28	102.42	3.52	61.98	51.99	58.85
18	0	0	0	0	79.61	108.5	3.76	62.32	52.65	18.305
19	0	0	0	0	83.56	110.38	3.7	60.78	52.87	48.97
20	-1	-1	-1	-1	96.45*	113.63	4.12	63.14	52.87	7.28
21	-1	-1	1	-1	90.32	112.79	4.1	62.9	51.68	59.79
22	-1	-1	1	1	89.74	111.37	4.07	63	53.87	26.69
23	0	0	-2	0	75.45	106.98	3.77	61.45	51.43	18.31
24	0	2	0	0	69.08**	105.46	3.41	61.23	50.54	65.35
25	1	-1	-1	1	71.43	99.32	3.32	56.34	43.56	47.52
26	0	0	0	0	85.77	99.28	3.83	61.76	50.65	30.27
27	1	-1	1	-1	76.93	92.54	3.11	55	41.97	24.05
28	2	0	0	0	71.25	88.43**	2.89**	52.73	27.45**	7.85
29	1	1	1	1	70.36	91.04	3.29	57.78	46.18	29.95
30	0	0	0	2	84.44	96.76	3.82	62.87	52.13	15.39

*- for maximum, **- for minimum

SL-solubility, AC-ascorbic acid, BC-beta-carotene, L*-luminance index, a*& b*-chromatic components

Table 3.3: Value of dependent variables for optimization

Name	Goal	Lower Limit	Upper Limit
Temperature (X_1)	is in range	-2	2
Maltodextrin(X_2)	is in range	-2	2
Glycerol Monostearate (X_3)	is in range	-2	2
Tricalcium Phosphate (X_4)	is in range	-2	2
Flowability Time	minimize	15.65	23.62
Hygroscopicity	minimize	2.24	6.84
Degree of Caking	minimize	1.83	5.45
Solubility	maximize	69.08	96.45
Ascorbic acid(mg/100gm)	maximize	88.43	115.75
β-carotene(mg/100gm)	maximize	10.0	51.0
L*	is in range	48.04	69.74
a*	is in range	27.45	59.92
b*	is in range	-15.92	73.67

Table 3.4: Value of ingredients for optimization

Independent variables	Coded levels	Actual levels
Temperature (X_1)	-1.19	59.05 (°C)
Maltodextrin(X_2)	0.65	0.55 (%)
Glycerol Monostearate (X_3)	0.56	1.78 (%)
Tricalcium Phosphate (X_4)	2.0	2.5 (%)

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