STATISTICAL OPTIMIZATION OF PROCESS PARAMETERS FOR GELATINIZATION OF POTATO (CHANDRAMUKHI VARIETY)

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Abstract

Potato, a cost effective source of starch, a root vegetable is grown in more than 100 countries in the world. India holds 2nd position in potato production in the world and West Bengal 1st position in India. Potato is processed into a variety of products ranging from potato powder, potato starch, frozen potato flakes, baby food and alcohol, potato chips, French fries, potato flakes/powder etc.

In this study, the main objective was statistical optimization of the condition for potato gelatinization and effect of potassium metabisulphite (KMS) concentration on potato starch in gelatinization process. The range of the factors employed were gelatinization pressure, time and different concentration of KMS. The optimized gelatinization condition was 10psig for 15 minutes and 200ppm KMS. The percentage of gelatinized starch at optimized gelatinized condition was 35.67 (dry weight basis). Optimization of effective concentration of potassium metabisulphite (KMS) to retain the colour of potato was also studied and the optimized effective concentration of KMS to retain the colour was 200ppm. RSM modeling, simple regression was used as a tool to study different interactive and linear effect of different factors and significance of the factors.

Keywords: *potato starch, gelatinization, KMS concentration, colour retention, RSM modeling, regression equation.*

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1. INTRODUCTION

Potato in India is cultivated in approx 18-19 lakh hector which is around 21.9% of the total vegetable cultivated area. It contributed around 2.41% of GDP of agriculture in 2008 from 1.25% cultivated area. West Bengal contributed around 32% of the total production in India in 2010-2011(Source: Indian Agriculture Database, 2011).

Potato starch is unique in that it contains phosphate ester groups (0.2–0.4% of the glucose units) [1], covalently linked to AP mainly at the C-6 (61%) and C-3 (38%) positions with small levels on the C-2 position [2]. It consists of amylopectin [AP, a highly branched α-(1,4)-glucan with 5% α-(1,6)- bonds, MW= $1.7*10^8$ for wild type potato starch (wtps), $2.0*10^8$ for amylose free potato starch (amfps),] [3], amylose (AM, a nearly linear α-(1,4)-glucan, molecular weight (MW) = 1.03 $*10^6$ for wtps) [4].

Gelatinization is regarded as the hydration and irreversible swelling of the granule, the destruction of molecular order within the starch granule, and starch solubilization and can also be interpreted as the melting of starch crystals [5, 6]

Additionally the presence of alkali, salts, sugars, lipids, alcohol, organic acids and their salts have an impact on the gelatinization temperature and thus affect the extent of gelatinization [5]. In the presence of sodium chloride, the gelatinization enthalpy decreases with increasing salt concentration whereas the gelatinization temperature rises at NaCl concentrations up to 2M [7, 8].

Salts also have been shown to have a significant effect on the gelatinization and rheological properties of starches generally, and it has been found that they can cause an elevation or depression of the gelatinization temperature, Tp, as well as gelatinization enthalpy, ΔH [9, 10, 11, 12, 13], and similarly might increase or decrease the rate and degree of gelation [14] and retrogradation ([15, 16]

Peeled potatoes are cut in the form of slices, dices, and strips before blanching. After potatoes are cut in desirable form, they are blanched by heating, either in steam or hot water (93^0 to 100^0C). Blanching destroys or inactivates enzymes; otherwise, potatoes may darken during dehydration and develop off-flavors and off-odors during storage. Blanching also serves to reduce microbial contaminations and affects the way the dehydrated product reconstitutes. Degree of blanching has a very marked effect on the texture and appearance of finished product as well as on the way the potato tissue dehydrates and reconstitutes. The potatoes are sulfided immediately after blanching using sodium sulfite, sodium bisulfite, sodium metabisulfite, or combinations. Sulfite protects the product from non-enzymatic browning or scorching during dehydration and increases the storage life of the product under adverse temperature conditions [17].

In this study, gelatinization of potato is the function of pressure, time and concentration potassium meta-bisulphite (KMS). The parameters were optimized in this study. Another study of retention or change in colour of potato with different concentration of KMS was performed to determine the required effectiveness of KMS in blanching along with 2% sodium chloride (NaCl).

The easiest and most widely used approach to study linear and interaction of different factors have been response surface methodology (RSM). RSM is a collection of mathematical and, statistical technique useful for analyzing and optimizing the response of multivariate system. In RSM, generally attempts are made to identify the responses of system as a function of explanatory variables. In this study, different linear and interactive effect of different factors has been studied.

2. MATERIAL & METHODS

2.1 Materials

Collection and Preparation of Raw Materials

Potatoes used in this study were of Chandramukhi variety collected from local market of South Kolkata. The potato samples were washed properly with running tap water and distilled water respectively to make it free from dirt and soil and followed by removal of excess surface water with a clean dry muslin cloth. The potatoes samples were then peeled and sliced into slices of equal thickness of 10±0.3 mm each and used for farther experiments.

The chemicals used in this study are of “MERCK”, α-amylase (activity- 10unit/mg) was collected form “SRL” and Amyloglucosidase aqueous solution (300unit/ml) was collected from “Sigma Aldrich co. (Novo Enzymes Corporation)”.

2.2 Methods

2.2.1 Proximate Analysis of Raw Potato

Moisture content, ash content, crude fiber content, starch content and sugar content of the raw potato was done according to A.O.A.C method.

2.2.2 Determination of Percentage of Gelatinized Starch in Blanched Potato Mash

The peeled potato samples were blanched in hot water (temperature- $90^0 \pm 2^0$ C) containing 2% of sodium chloride (NaCl) and varying concentrations of potassium metabisulphite (200ppm, 400ppm, 600ppm respectively) and without KMS for 10 minutes and followed by preparation of mash in a mixer grinder. After that 2 gm mashed sample was taken from each blanching case and gelatinized starch was determined according to the method Chiang and Johnson (1977) [18] followed by dextrose equivalent titration method for determination of gelatinized starch.

2.2.3 Optimization of Potassium Metabisulphite (KMS) Concentrations for Colour Retention

The peeled potato samples were blanched in hot water (temperature- $90^0 \pm 2^0$ C) containing 2% of sodium chloride (NaCl) and without KMS and with varying concentrations of potassium metabisulphite (200ppm, 400ppm, 600ppm respectively) for 10 minutes. After blanching potato samples were placed in air tight container and stored at 4^0C. The changes in colour were studied by Hunter Lab Colorimeter for 1 hour interval for first 6hrs and then at 24 and 26 hrs respectively.

Another study was carried out with optimized concentration of potassium metabisulphite (KMS) that was successfully retaining the colour at best. The optimized concentration was applied in blanching (for 10 minutes) of potato with 2% sodium chloride (NaCl) and then potato mash was prepared in a mixer grinder and gelatinized at optimized gelatinization condition (i.e. optimized time-temperature profile). The potato mash was stored in air tight container at 4^0C for 5 days. The changes in colour were studied by Hunter Lab Colorimeter for 5 days.

2.2.4 Optimization of Gelatinization Parameters

Production of gelatinized mass was done on the basis of variation of gelatinization pressure-time profile. The experiments were carried out on the basis of experimental design at 3^3 and 3^2 full factorial design. Functional effect of interacting factors (i.e. pressure, time, and KMS) was studied. KMS was used in this optimization to see whether it has any effect on gelatinization or not, without the retention of colour.

The blanched slices without KMS and with different concentration of KMS were mashed in a mixer grinder and mash was prepared. The potato mash was gelatinized in an autoclave at different time (10 minutes, 15 minutes, and 20 minutes) and pressure (5 psig, 10 psig, and 15 psig) and KMS (0ppm, 200ppm, 400ppm, and 600ppm) profile and gelatinized samples were withdrawn for measurement of gelatinized starch to optimize gelatinization parameters. Similar samples were taken for measurement of total starch.

2.2.4.1 Design of the Experiment

The factorial design with three levels of treatment temperature, time and concentration of KMS was assigned for 3^3 full factorial designs and three level of temperature, time, for 3^2 full factorial designs in case of blanching without KMS and the design leads to 27 sets and 9 sets of experiments respectively. The factorial design was applied to estimate the relationship between variables on gelatinization of potato starch. The three range level of factors are 5psig, 10psig, 15psig for pressure (-1, 0, +1 level respectively), 10minutes, 15minutes, 20minutes for time (-1, 0, +1 level respectively), 200ppm, 400ppm, 600ppm for concentration of KMS (-1, 0, +1 level respectively).

2.2.5 Hunter Lab Colorimeter study

The colour changes of the potato slices blanched with different concentration of KMS was studied using Hunter Lab Colorimeter (Color flex, 45/0 spec photometer). The color readings were expressed by CIE coordinates (L*a*b*) system. L*(varying from 0-black to 100-white), a*(varying from -60 to +60) and b*(varying from -60 to +60) indicates whiteness/darkness, redness/greenness, blueness/yellowness values, respectively.

The polar coordinate chroma or saturation (c*) is an indication of how vivid the product is (ranging from 0-60), which can be calculated from the L*a* and b* Cartesian co-ordinate by the expression

$$C^* = (a^{*2}+b^{*2})^{0.5} \qquad (1)$$

Total color difference (ΔE) was calculated from the following equation [19]

$$\Delta E = [(L^*-L_{standard})^2 + (a^*-a_{standard})^2 + (b^*-b_{standard})^2]^{0.5} \qquad (2)$$

The retention of colour of potato mash that was prepared from potato slices blanched for 10 minutes with 2% sodium chloride (NaCl) and with optimized concentration of KMS and stored at 4^0C also has been carried out using Hunter Lab Colorimeter (Color flex, 45/0 spec photometer). The total colour difference (ΔE) and polar coordinate chroma (C*) was calculated from the L*, a*, b* values respectively.

2.2.6 Assay method of Total Starch and Gelatinized Starch

Total starch was determined by modified Chiang and Johnson (1977) [18] method followed by Dextrose Equivalent titration method. Gelatinized starch content was determined by Dextrose Equivalent titration method.

Preparation of Enzymes

Preparation of phosphate buffer: 49.7ml 1molar K_2HPO_4 solution was mixed with 50.3ml of 1 molar KH_2PO_4 solution to prepare 100ml of buffer at pH 7.0

Preparation of α-amylase solution (4unit/ml): 4mg of α-amylase was weighed and mixed with 10ml of phosphate buffer and stored at 4^oC.

Preparation of Amyloglucosidase solution (4unit/ml): 2ml of amyloglucosidase was pipetted out and mixed with 150ml of phosphate buffer and stored at 4^0C.

2.2.6.1 Determination of Total Starch

2gm of gelatinized sample was measured accurately and transferred to a conical flask, 3ml distilled water and 1 ml of 1(N) NaOH was added to it. The conical flask was then incubated at 60^0C for 30 minutes with continuous shaking. Then neutralization was done by 1(N) HCl. Afterwards, 1ml of α-amylase solution (4unit/ml) and 8ml of glucoamylase solution (4unit/ml) was added to conical flask. After proper mixing of the contents, the conical flask was incubated in a hot water bath for 30 minutes at 40^0C with occasionally shaking. After that, the enzymes were inactivated by holding the conical flask in boiling water for about 1-2 minutes. The final volume is measured. The enzymes break the starch to reducing sugar which was then estimated by Lane- Eynon method i.e. by Dextrose Equivalent titration method. The steps described above were repeated for each gelatinized sample of different pressure-time profile. These derived data were subsequently used to evaluate the total starch content of potato.

2.2.6.2 Determination of Gelatinized Starch

2gm of gelatinized sample was measured accurately and transferred to a conical flask and 5ml distilled water was added to it. Then 1ml of α-amylase solution (4unit/ml) and 8ml of glucoamylase solution (4unit/ml) was added to the conical flask. After proper mixing of the contents, the test tube was incubated in a hot water bath for 30 minutes at 40^0C with occasionally shaking. After that, the enzymes were inactivated by holding the conical flask in boiling water for about 1-2 minutes. The final volume is measured. The enzymes break the starch to reducing sugar which was then estimated by Lane- Eynon method i.e. by Dextrose Equivalent titration method. The steps described above were repeated for each gelatinized sample of different pressure-time profile. These derived data were subsequently used to evaluate the optimization of gelatinization condition potato.

2.2.6.3 Dextrose Equivalent Titration Method

Materials:

- Standard dextrose solution: (2mg/ml)
- Fehling reagent: (Fehling A & Fehling B solution)
- Methylene blue

Method:

- 1ml of Fehling A and 1ml of Fehling B was pipetted out in a conical flask.
- The solution was heated to boil.

- The solution was titrated against standard dextrose solution until brick red colour developed using methylene blue as indicator and burette reading was recorded.

Again the first two steps were followed for different samples for determination of reducing sugar and titrated against different samples and burette reading was recorded.

Calculation:

% of total starch/gelatinized starch = [{(burette reading for standard titration*2)/burette reading for sample titration}*volume of content in conical flask*100*0.9]/weight of sample taken.

2.2.7 Localization of Optimum Condition for Gelatinized Starch Production

In localization study contour plots were obtained by using Statistica (version 7) (StatSoft, Inc.,USA). The Contour plot describing combined effect between pair of factors (i.e. pressure, time) on gelatinized potato starch was given in figure 2 by keeping other two variables constant at their middle level.

2.2.8 Determination of Regression Equation

2.2.8.1 RSM Modeling

The response surface methodology (RSM) was used as it helped to reduce the number of experiments without affecting the accuracy of results and to decide interaction effects of independent variables on the responses [20].

Functional relationships between the independent variables (temperature, pressure) and dependent variables (% gelatinized starch), in case of gelatinization, and independent variable (time) and dependent variable (total colour difference (ΔE), Polar Co-ordinate Chroma respectively) for potato slices blanched with NaCl (2%) and optimized KMS concentration were determined using multiple regression technique by fitting second order regression equation [21] of the following type

$$Y=\beta_o + \sum_{i=1}^{n} \beta_i X_i + \sum_{i=1}^{n} \beta_{ii} X_i^2 + \sum_{i=1}^{n} \sum_{j=i+1}^{n-1} \beta_{ij} X_i X_j + e \quad \ldots\ldots (3)$$

where β_0, β_i, β_{ii}, β_{ij} are regression coefficients of variables for intercept, linear, quadratic and interaction terms, respectively, X_i, X_j are the independent variables, Y is the dependent variables n is number of independent variables.

The relationships between the responses were judged by correlation coefficients of determination (R^2). The significance or P-value was decided at a probability level of 0.05.

2.2.8.2 Simple Regression

A simple regression in between dependent variable (total colour difference (ΔE)) and independent variable (time) has been determined for potato mash prepared from potato slices blanched with 2% NaCl and optimized concentration of KMS, using the first order regression equation of following type

$$Y= a + bX \quad \ldots\ldots (4)$$

Where, a, and b is the intercept and slope respectively, and Y is dependent variables and X is independent variables. The relationships between the responses were judged by correlation coefficients of determination (R^2). The significance or P-value was decided at a probability level of 0.05.

3. RESULTS & DISCUSSIONS

3.1 Proximate Composition of Raw Potato

All the parameters of proximate analysis were done in triplicate times.

Table 1: Proximate Composition of Potato

Parameters	Raw Potato (%)	
	Wet basis	Dry basis
Moisture	82.34 ± 0.27	-
Ash	1.1377 ± 0.14	6.4421± 0.79
Crude Fiber	3.0844 ± 0.08	17.4654 ± 0.45
Starch	12.3547 ± 0.44	69.9586 ± 2.49

Starch percentage was calculated from standard maltose curve (Fig: 1) given below

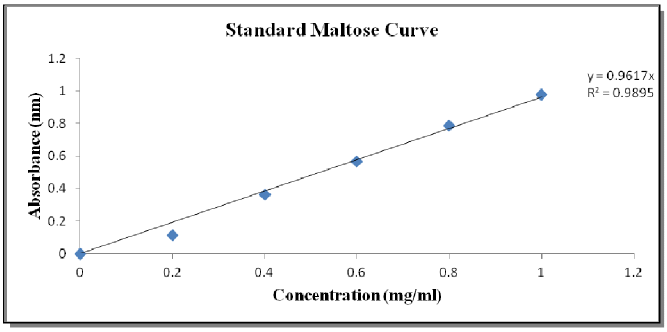

Fig 1: Standard Maltose Curve

3.2 Determination of Percentage of Gelatinized Starch in Blanched Potato Mash

From the data of table 2 it was very clear that gelatinized starch is very low in potato after blanching and there are very close differences in percentage of gelatinized starch.

Table 2: Percentage of gelatinized starch in blanched potato mash

Concentration of KMS (ppm)	Time (minutes)	Pressure (psig)	% of Gelatinized Starch*
0	0	0	8.10
200	0	0	9.9
400	0	0	8.49
600	0	0	9.38

* Dry weight basis

3.3 Optimization of Potassium Metabisulphite (KMS) Concentrations for Colour Retention

The blanching was carried out without KMS and with three different concentrations of KMS (200, 400, and 600 respectively), and it was found that 200ppm was the optimized condition (Table: 5) for retention of colour in blanched potato sample.

The optimized concentration of KMS i.e. 200ppm was successfully retaining the colour the potato mash and very little changes in colour was obtained (Table: 6).

3.4 Optimization of Gelatinization Parameters

Gelatinization experiments were carried out on the basis of experimental design at 3^3 and 3^2 full factorial design. The factors were concentration of KMS, pressure, gelatinization time. The results (Table: 3 and Table: 4) shows that % gelatinized starch is obtained best at 10 psig for 15 minutes. The results also show that at higher temperature and pressure and gelatinized starch percentage reduced means the change in pressure of autoclaving is observed to have an effect on yield percentage of gelatinized starch.

Initially when the pressure increases from 5psig to 10psig there is an increase in yield but with further increase in pressure to 15psig there is a decrease in yield. In this context it is to be noted that with increase in pressure is accompanied by an increase in temperature which is a key player in gelatinization which is previously described by Hoseney, 1986 [22] according to Hoseney, 1986 [22] in order to enhance the solubility of starches, the temperature must be raised. Temperature also plays a vital role in retrogradation of starch.
With increase in temperature and pressure more and more starch micelles initially burst to take part in gelatinization of starch but with continued increase in temperature/pressure water continues to evaporate from the matrix leading to a change in enthalpy of the product and effecting the water holding capacity of the gel which disintegrates resulting in retrogradation of starch and in turn decrease in gelatinized starch percentage.

Another probable cause maybe excess bisulphate of KMS (i.e. in case of 400ppm, 600ppm) may react with water or water vapour at higher pressure and temperature and produce sulphuric acid and the sulphuric acid reacts with the carbohydrate and produces furfural group.

Table 3: Percentage of gelatinized starch of 3^3 full factorial design experiments

3**(3-0) full factorial design, 1 block , 27 runs				
Standard run	Kms (ppm)	Pressure (Psig)	Time (Minutes)	% gelatinized starch (dry wt. basis)
1	200.0000	5.00000	10.00000	11.89
2	200.0000	5.00000	15.00000	13.72
3	200.0000	5.00000	20.00000	11.89
4	200.0000	10.00000	10.00000	22.29
5	200.0000	10.00000	15.00000	35.67
6	200.0000	10.00000	20.00000	25.48
7	200.0000	15.00000	10.00000	19.81
8	200.0000	15.00000	15.00000	19.81
9	200.0000	15.00000	20.00000	17.83
10	400.0000	5.00000	10.00000	12.74
11	400.0000	5.00000	15.00000	8.9
12	400.0000	5.00000	20.00000	8.9
13	400.0000	10.00000	10.00000	22.29
14	400.0000	10.00000	15.00000	27.44
15	400.0000	10.00000	20.00000	29.72
16	400.0000	15.00000	10.00000	17.83
17	400.0000	15.00000	15.00000	17.83
18	400.0000	15.00000	20.00000	17.83
19	600.0000	5.00000	10.00000	14.86
20	600.0000	5.00000	15.00000	11.15
21	600.0000	5.00000	20.00000	12.74
22	600.0000	10.00000	10.00000	25.48
23	600.0000	10.00000	15.00000	25.48
24	600.0000	10.00000	20.00000	25.48
25	600.0000	15.00000	10.00000	17.83
26	600.0000	15.00000	15.00000	19.81
27	600.0000	15.00000	20.00000	17.83

Table 4: Percentage of gelatinized starch of 3^2 full factorial design experiments

3**(2-0) full factorial design, 1 block , 9 runs			
Standard Run	Pressure (Psig)	Time (Minutes)	% gelatinized Starch (dry wt. basis)
1	5.00000	10.00000	11.15
2	5.00000	15.00000	8.9
3	5.00000	20.00000	7.1
4	10.00000	10.00000	29.72
5	10.00000	15.00000	27.44
6	10.00000	20.00000	25.48
7	15.00000	10.00000	14.86
8	15.00000	15.00000	17.83
9	15.00000	20.00000	16.22

The total starch was simultaneously studied in each case of time-temperature-KMS concentration profile. The total starch was found 73%±3% (dry wt. basis).

3.5 Localization of Optimum Condition for Gelatinized Starch Production

Fig- 2 indicates that percentage of gelatinized starch yield (dry wt. basis) as a function of pressure and time. It indicates that the percentage of gelatinized starch yield (dry wt. basis) concentration maximum at middle level of pressure and Temperature.

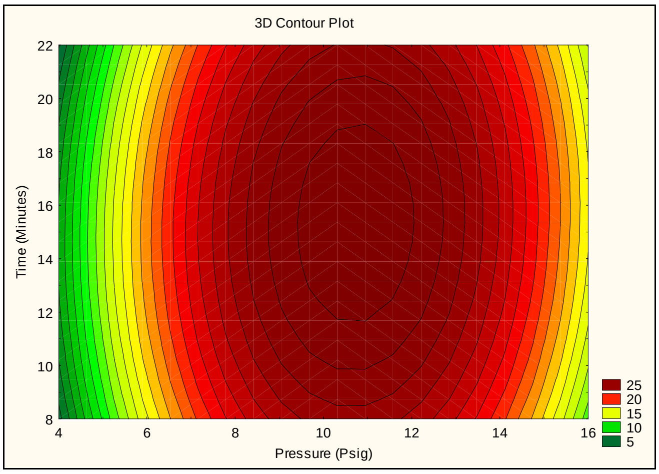

Fig 2: Contour plot of the combined effect of pressure and time on % gelatinized starch (dry wt. basis) concentration

3.6 Hunter Lab Colorimeter Study

Determination of colour retention or changes can be an index for determination the effectiveness of blanching (with KMS) in prevention of browning and scorching during storage at 4^0C.

3.6.1 Study of Change in Colour of Potato Slices with Change in Concentration of Potassium metabisulphite (KMS)

The data Table: 5 shows the value of L*, a*, b* of potato slices blanched with 2% NaCl and 200ppm, 400ppm, and 600ppm concentration of KMS respectively. The total colour difference (ΔE) of potato is found minimum in case of blanching with 200ppm concentration of potassium meta-bisulphite (KMS), hence, the concentration found most effective in preservation of colour. Higher concentrations show darkening of colour after sometime, one potential reason could be binding of metal present in potato with residual sulphite forms black sulphite precipitate.

Table 5: L*, a*, b* value for potato slices blanched with 2% NaCl and different concentration of KMS

Time (Hrs.)	Concentration of KMS (ppm)	L*	a*	b*	ΔE	C*
Raw Potato Slices (Standard)		69.39	-1.40	15.92	-	±15.98
0	0	63.72	-1.32	14.91	±5.76	±14.96
	200	61.90	-1.31	14.83	±7.57	±14.89
	400	69.43	-0.88	17.04	±1.23	±17.06
	600	60.17	-1.42	14.58	±9.32	±14.65
1	0	63.09	-1.31	14.61	±6.43	±14.67
	200	61.86	-1.31	14.71	±7.63	±14.76
	400	64.00	-0.89	16.92	±5.50	±16.94
	600	58.57	-1.45	14.40	±10.92	±14.47
2	0	62.98	-1.32	14.21	±6.63	±14.27
	200	61.81	-1.29	14.57	±7.7	±14.63
	400	62.62	-0.94	16.74	±6.83	±16.76
	600	57.50	-1.42	14.15	±12.02	±14.22
3	0	62.07	-1.29	14.06	±7.5	±14.12
	200	61.72	-1.26	14.41	±7.82	±14.47
	400	61.82	-0.97	16.55	±7.61	±16.58
	600	57.00	-1.47	13.83	±12.56	±13.91
4	0	60.06	-1.30	13.35	±9.68	±13.41
	200	61.68	-1.25	14.29	±7.88	±14.34
	400	61.39	-0.92	16.31	±8.02	±16.33

Time (Hrs.)	Concentration of KMS (ppm)	L*	a*	b*	ΔE	C*
	600	53.17	-1.52	13.53	±16.39	±13.61
5	0	59.57	-1.26	12.77	±10.31	±12.83
	200	61.63	-1.27	14.11	±7.96	±14.16
	400	61	-0.94	15.16	±8.43	±15.19
	600	51	-1.49	13.36	±18.57	±13.44
6	0	57.81	-1.21	12.00	±12.23	±12.06
	200	61.61	-1.31	13.98	±8.01	±14.04
	400	60.77	-0.97	15.03	±8.67	±15.06
	600	48.35	-1.53	13.11	±21.22	±13.2
24	0	42.33	-0.94	10.97	±27.51	±11.01
	200	60.98	-1.30	13.88	±8.65	±13.94
	400	57.33	-1.21	14.34	±12.16	±14.39
	600	42.76	-1.63	12.53	±26.84	±12.63
26	0	39.01	-0.88	10.08	±30.94	±10.12
	200	60.95	-1.31	13.81	±8.7	±13.87
	400	57.01	-1.28	14.07	±12.51	±14.13
	600	42.31	-1.57	12.10	±27.35	±12.20

3.6.2 Study of Colour Change of Gelatinized Potato Mash

Another 5-day study was undertaken to determine the effectiveness of 200ppm of potassium metabisulphite (KMS) on gelatinized potato mash prepared under optimized gelatinization condition (i.e. 10psig for 15minutes). The result (Table: 6) was found satisfactory as the optimized concentration of potassium metabisulphite (KMS) was found to be equally effective in preserving the colour of mashed potato stored at 4^0C for 5 days. The standard in this case was potato blanched with 2% NaCl and 200ppm KMS and then mashed in a mixer grinder.

Table 6: L*, a*, b* value for Blanched potato mash

Time (days)	L*	a*	b*	ΔE	C*
Potato Mash (Standard)	75.35	-1.27	13.79	-	±15.98
1	75.33	-1.24	13.76	±0.0469	±13.81
2	75.31	-1.21	13.74	±0.0877	±13.79
3	75.30	-1.23	13.72	±0.0948	±13.77
4	75.29	-1.25	13.69	±0.1183	±13.75
5	75.27	-1.22	13.65	±0.1688	±13.70

3.7 RSM Modeling

3.7.1 % Gelatinized Starch (%GS)

Initially second order model was fitted to response data of % gelatinized starch data from standard order run 1-9 (Table: 3), because the optimized gelatinization condition was found in this factorial design zone. It was found that pressure and square term of pressure was significant at p= 0.05 for % gelatinized starch, increase of pressure means also increase in temperature. So, the significance of pressure also supported by the theory described earlier Hosney, 1986 [22].
Therefore, model with linear and interactive terms was fitted to experimental data because of high value of coefficient of determination (R^2=0.88). Therefore, model with linear and interactive terms was best fitted to experimental data.

$$\% \ GS = -70.9344 + 10.5527*P - 0.4735*P^2 + 6.0803T - 0.1947*T^2 - 0.0198*P*T \qquad (5)$$

Where GS is gelatinized starch, P is Pressure (psig), and T is Time (minutes)

Table 7: Observations of equation (5)

Multiple R	Multiple R^2	Adjusted R^2	Value of p for pressure	Value of p for square term of pressure
0.939	0.8817	0.68005	0.03797	0.028012

From the equation (5) the values of % GS can be predicted and correlation of experimental and predicted data (Fig: 3) provided an observation that a good relationship exit between experimental and calculated data means coefficient of determination value is high (R^2= 0.88).

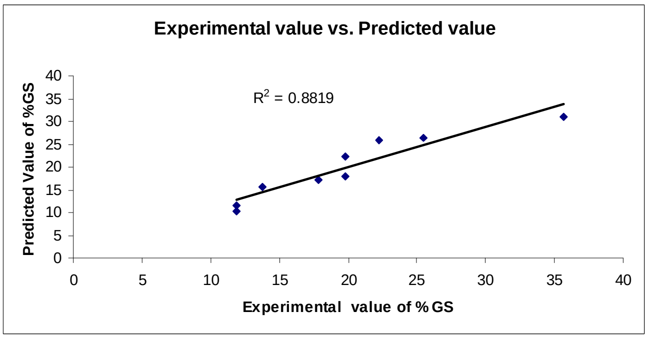

Fig 3: Correlation between experimental and predicted values of % GS

3.7.2 Total Colour Difference (ΔE) and Polar Coordinate Chroma (C*) of Blanched Potato Slices

The RSM modeling was also fitted to response data of total colour difference (ΔE) and polar coordinate chroma (C*) of blanched potato slices (table: 5). It was found that time and square term of time both were significant at p= 0.05 in both of the modeling. The multiple and adjusted value of coefficient of determination (R^2) was found to be very good which indicates that the model with linear and interactive terms was fitted to experimental data because of high value of coefficient of determination (R^2).

T.C.D (ΔE) = 7.560223 + 0.085354*t - 0.001625*t^2…….. (6)

C* = 14.90249-0.16457*t + 0.00496*t^2………………….. (7)

Where in equation (6) and (7), t is Time (hour(s))

Table 8: Observations of equation (6)

Multiple R	Multiple R^2	Adjusted R^2	Value of p for time	Value of p for square term of time
0.99953	0.998307	0.997743	0.000002	0.000066

Table 9: Observations of equation (7)

Multiple R	Multiple R^2	Adjusted R^2	Value of p for time	Value of p for square term of time
0.98349	0.967259	0.956346	0.000091	0.000261

From the equation (6) the values of total colour difference (ΔE) can be predicted and correlation of experimental and predicted data (Fig: 4) provided an observation that a strong relationship exit between experimental and calculated data means coefficient of determination value is high (R^2= 0.99).

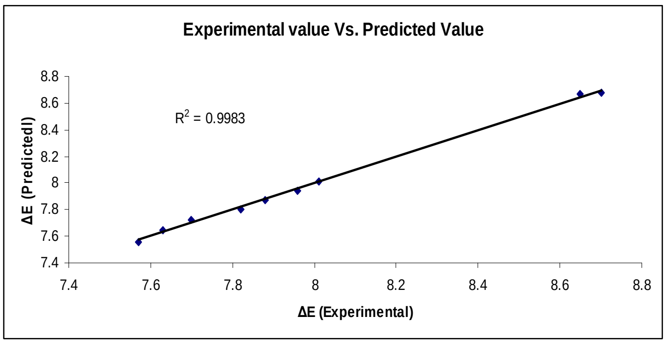

Fig 4: Correlation between experimental and predicted values of T.C.D (ΔE)

From the equation (7) the values of polar coordinate chroma (C*) can be predicted and plotting of experimental and predicted data (Fig: 5) provided an observation that a strong relationship exit between experimental and calculated data means coefficient of determination value is high (R^2= 0.96).

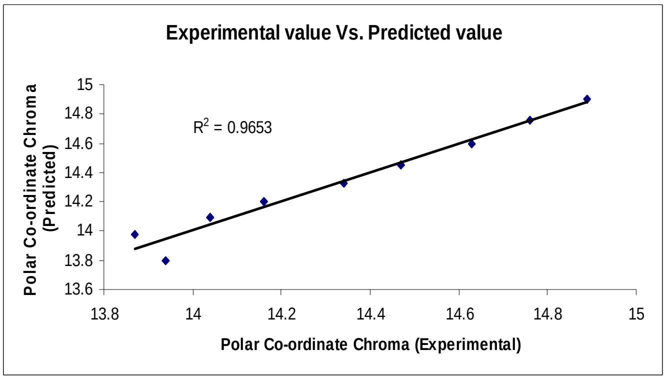

Fig 5: Correlation between experimental and predicted values of polar coordinate chroma (C*)

3.8 Regression of Colour Changes of Gelatinized Potato Mash

A simple regression has been done to obtain the model equation for dependent variable (total colour difference (ΔE)) and independent variable (time) for gelatinized potato mash (table: 6). It was found that a good relationship between the dependent and independent variable exist as the coefficient of determination value is high (R^2= 0.93). The model equation is

ΔE= 0.02098+ 0.02744*D………………..………………. (8)

Where, D is number of day(s)

Table 10: observation of equation (8)

Multiple R	Multiple R^2	Adjusted R^2	Value of p for day(s)
0.969435	0.939803	0.919738	0.006385

From the equation (8) the values of total colour difference (ΔE) can be predicted and correlation of experimental and predicted data (Fig: 6) provided an observation that a good relationship exit between experimental and calculated data as the coefficient of determination value is high (R^2= 0.93).

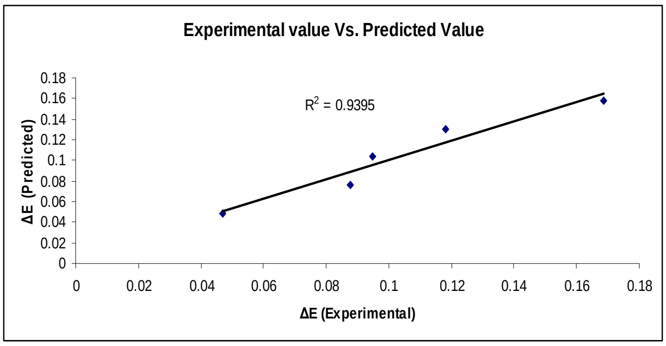

Fig 6: Correlation between experimental and predicted values of T.C.D (ΔE)

CONCLUSION

A study to optimize the best condition of gelatinization was performed and also the effect of KMS in gelatinization was studied. The optimized condition was 10 psig for 15 minutes. During higher temperature and pressure the percentage of gelatinized starch reduced, one probable reason is at higher pressure and temperature starch retrogradation may take place. Another possible reason is excess sulphite from KMS salt produces sulphur dioxide which under pressure may produce sulphurus and sulphuric acid and the acids react with the carbohydrate to produce furfural group which decreases the final carbohydrate content.

The experimental study with different concentration of KMS to retain the colour of potato slices was performed and the results show that 200 ppm was the optimized concentration. Without KMS and also with higher concentration of KMS the colour of blanched potato slices hugely. One potential reason could be binding of iron present in potato with residual sulphite form black iron sulphite precipitate. The optimized concentration of KMS i.e. 200ppm also effective to retain the colour of gelatinized potato mash if the mash stored at 4^0C.

Joglekar and May (1987), [23] have suggested for good fit of a model, regression coefficient (R^2) should be at least 80%, all the R^2 value of different modelling equation in this study are more 80% (i.e. $R^2 > 0.80$) and also a high similarity was observed between the predicted and experimental results of different cases, which reflected the accuracy and applicability of regression equations or regression model equation of the study.

ACKNOWLEDGEMENTS

Authors gratefully acknowledge TIFAC-CORE for financial supports & Techno India for infrastructural facilities.

ABBREVIATIONS

^{0}C - Degree centigrade
% - Percentage
N – Normality
Psig- Pounds per square inch gage
ΔE – Total colour difference
C* - Polar coordinate chroma
ppm - Parts per million
KMS -Potassium metabisulphite
NaCl – Sodium Chloride
p - Significance level
R^2 – Coefficient of determination

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