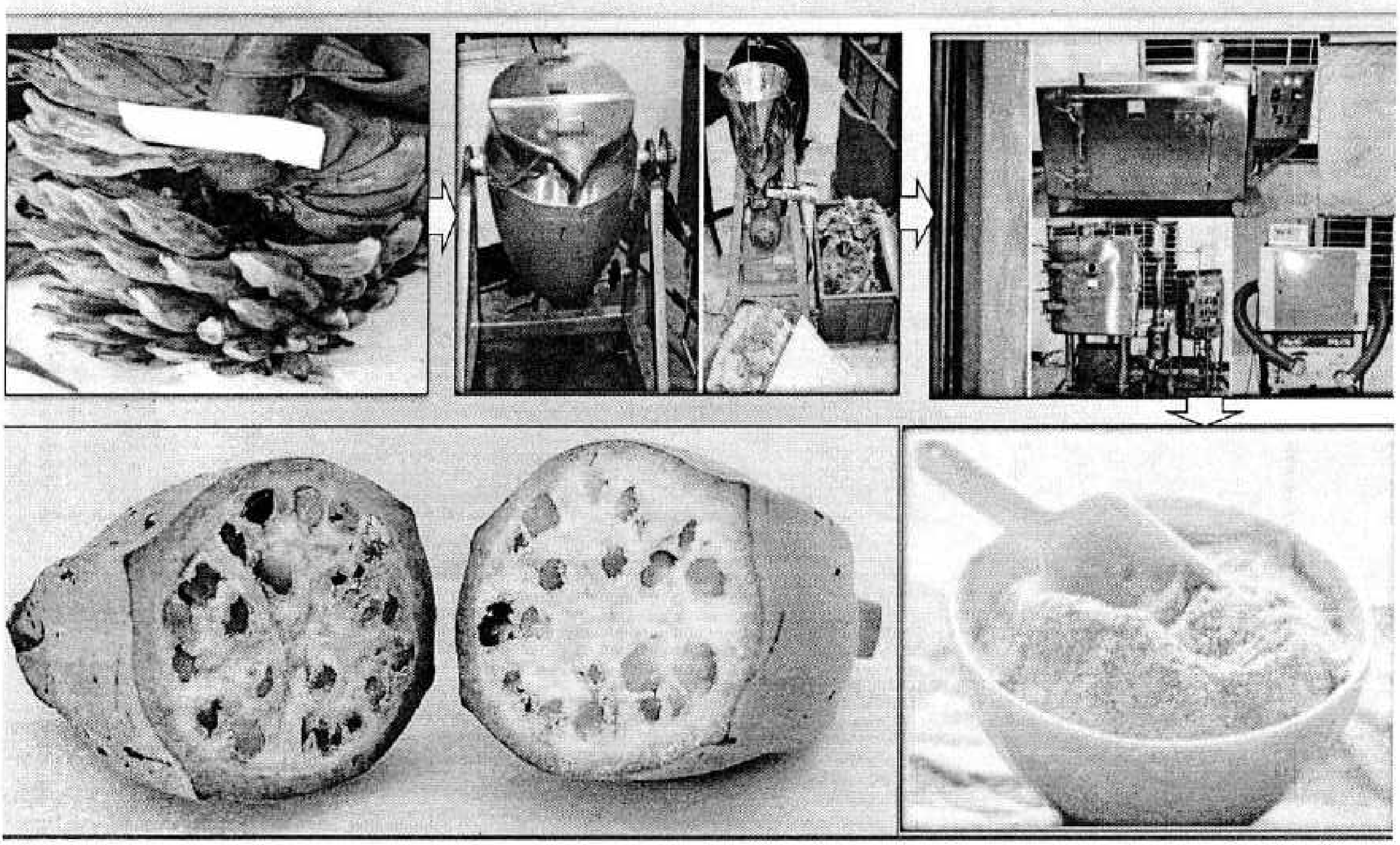
Project completion report entitled on

Pilot Scale Process Technology for 'Bhim Kol' (*Musa Balbisiana*) Slice, Grits and Powder Using Hybrid Drying Methods

(File No: SERB/MOFPI/0016/2013 dated 30.04.2013)



Supported by
Ministry of Food Processing and Industries
Government of India, New Delhi

by

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Duration : June 2013-December 2015

Final Project Completion Report

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December 2015

1.	Title of the project	:	**Pilot Scale Process Technology for 'BhimKol' (*Musa Balbisiana*) Slice, Grits and Powder Using Hybrid Drying Methods**
2.	Principal Investigator(s) and Co-Investigator(s):	:	(Dr. Brijesh Srivastava) (PI Name) Dr. M.K. Hazarika (Co. PI Name)
3.	Implementing Institution(s) and other collaborating Institution(s):	:	Department of Food Engineering & Technology, Tezpur University, Tezpur
4.	Date of commencement	:	12 June 2013
5.	Planned date of completion	:	12 June 2015
6.	Actual date of completion	:	12 Dec 2015
7.	Objectives as stated in the project proposal:	:	

- To develop a pulping/ deseeding operation with minimum enzymatic browning/ color change.
- To develop technologies for production of BhimKol slice, grits and powder on pilot plant scale.
- To study the storage stability of produced banana powder and grits.

8.	Deviation made from original objectives if any, while implementing the project and reasons thereof	:	No

9. Experimental work giving full details of experimental set up, methods adopted, data collected supported by necessary table, charts, diagrams & photographs:

Content

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To Whom It May Concern

This is to certify that the Project Work titled **"Pilot Scale Process Technology for 'BhimKol' (*Musa Balbisiana*) Slice, Grits and Powder Using Hybrid Drying Methods** (File No: SERB/MOFPI/0016/2013 dated 30.04.2013) successfully completed and report submitted to Science & Engineering Research Board, Department of science and technology, New Delhi. The project work has been carried out in Department of Food Engineering and Technology, Tezpur University. The tenure of work is three and half year.

Principal Investigator
(Dr. Brijesh Srivastava)

Co Principal Investigator
(Dr. Manoj Kumar Hazarika)

Experimental set up:

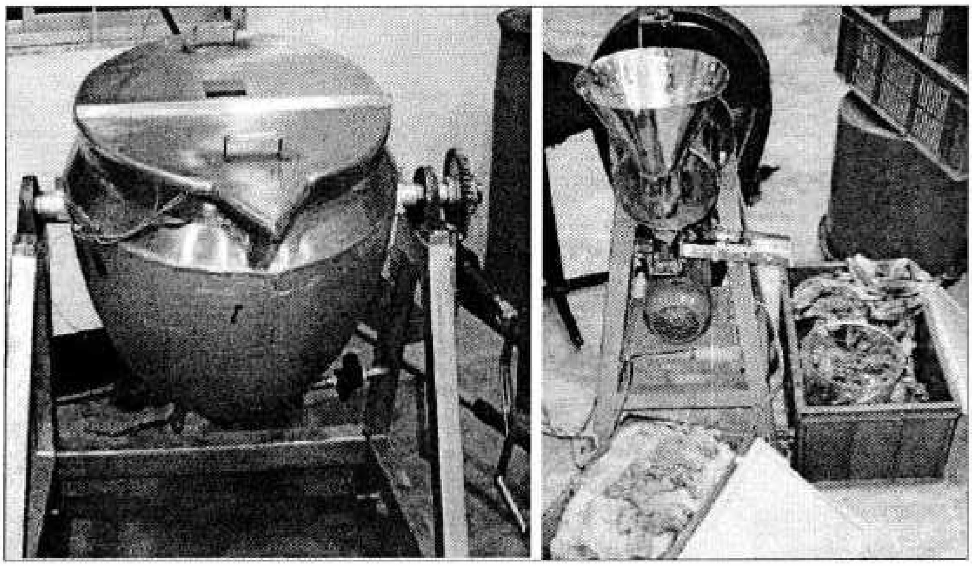


Fig: 1Blanching and pulping operation

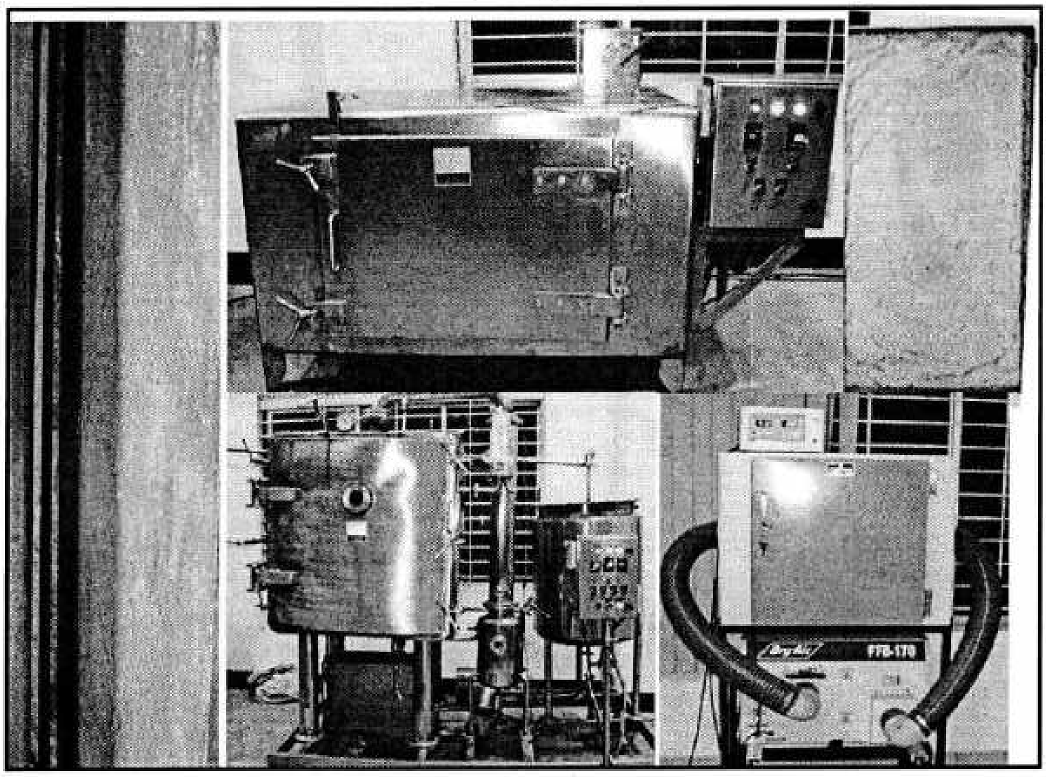


Fig: 2Drying set up and final product

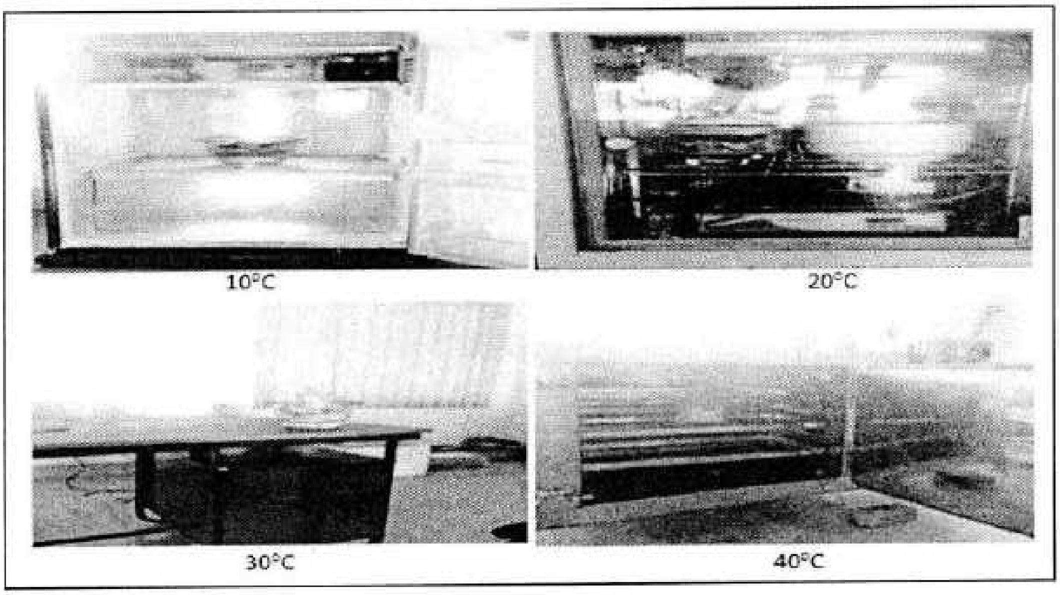


Fig: 3Storage study set up

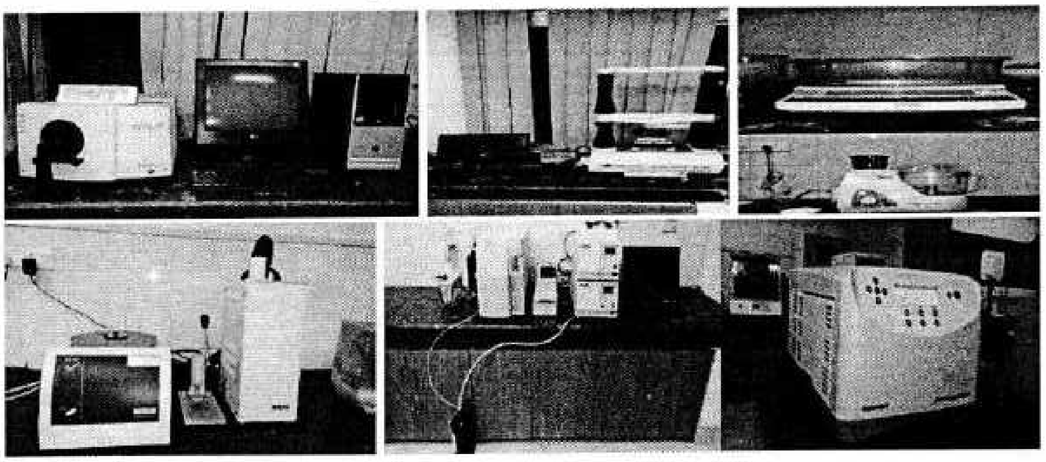


Fig: 4Analytical instruments and other appliance

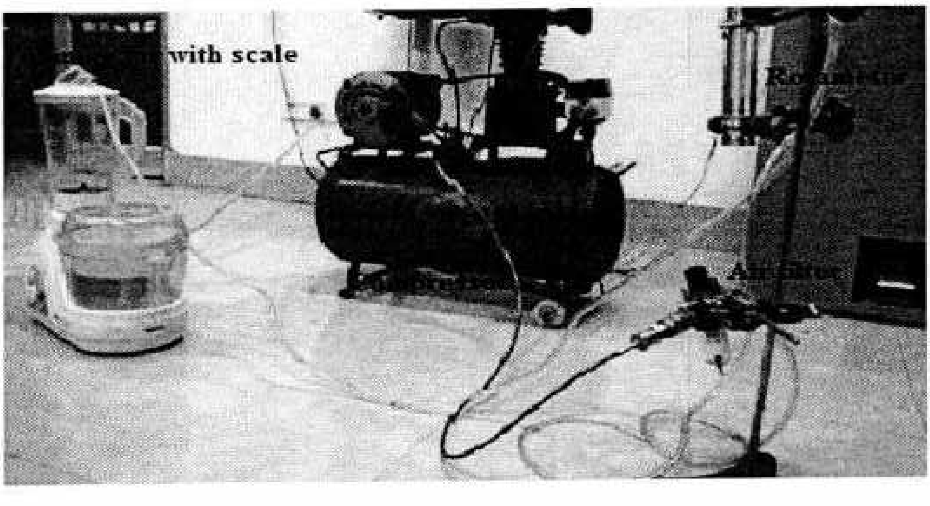


Fig: 5Foaming device

Material and methods:

Sample collection:

The Bhimkol were purchased from local market of Tezpur, Sonitpur, Assam. The thin layer of paddy straw was maintaining to reduce physical injuries of the fruit during transportation from field to laboratory.

Chemical properties:

Moisture (934.06), Fat (948.22), Ash (950.49), Protein (Micro-kjeldhal method) and Ascorbic acid were determined by standard method of AOAC, 1998. Non-reducing sugar was calculated by subtracting reducing sugar from total sugar (Khandker*et al.*2012). Pectin was determined as a calcium pectate with process described in Ranganna(2010).Total soluble solids content was determined by using hand refractometer (ATAGO, RX7000α, Japan) according to process mentioned by Muchui*et al.*(2010).Titrable acidity was determined by titration method (Pulp with 0.1N NaOH) described by Khandker*et al.*(2012). Starch and Total sugar by Anthrone method, reducing sugar by DNS method weredetermined as described inSadasivamandManickam,(1992).

Water activity (a_w):

The water activity of the powder was determined by using an electronic dew point water activity meter (Aqua lab Series 4TE, Decagon Devices, Inc., Pullman, Washington, USA). Duplicate samples were measured at 24.7 ± 1 °C.

Physical analysis:

Physical parameter such as volume, thickness, diameter of fruits (with peel) and fruit (without peel) was measured by process given by Abdullah *et al.* (1985).In this variety seed is distributed throughout the pulp. So manually deseeding was carried out after slicing. After that pulpto peel ratio was determined by dividing weight of flesh by weight of peel (Tapre and Jain, 2012).A sharp knife was used to remove peel from unripe banana.

Enzyme extraction:

Enzyme extraction was carried out with homogenization, centrifugation and filtration process. 1 gm of pulp was extracted and homogenized with 10 ml of 0.1 M phosphate buffer pH 7 containing 5 gm of polyvinylpyrrolidone. The homogenization process was carried out in mortal and pestle for 5min. Homogenized sample were centrifuged at 10,000 rpm for 10 min. All process was carried out in 4°C. The collected supernatant was used for determine enzyme assay of Polyphenol oxidase, Peroxidase and Catalase.

Polyphenol oxidase activity:

Polyphenol oxidase activity was determined according to process given by Arnnok*et al.*(2010). 1 ml 0.1 M catechol as a substrate, 1.95 ml 0.1 M phosphate buffer solution (Ph-7) and 50 µl Enzyme extract were added in to test tube for mixing vigorously. The mixture was transfer in cuvette andincreasing absorbance at 410 nm for 5 min was automatically recorded using a UV/visible spectrophotometer (CECIL, CE7400).

Peroxidase activity (POD):

Peroxidase (POD) activity was assayed by the procedure of Diaz*et al.* 2001.The reaction mixture contained 0.15 mL of 4% (v/v) guiacol, 0.15 mL of 1% (v/v) H_2O_2, and 2.66 mL of 0.1 M phosphate buffer pH 7 and 40 µL of the enzyme extract. This mixture was transferred in cuvette from test tube. Enzyme acted on H_2O_2 leading to colour change and increase in absorbance at 410 nm for 5 min which was automatically determined using a UV/visible spectrophotometer.

Catalase activity (CTA):

Catalase (CTA) was determined according process given by Singh 2000. The UV-Visible spectrophotometer recorded the absorbance according to decomposition of H_2O_2. The mixture contained 1 ml Phosphate buffer (50 mM at Ph-7) and 0.1 ml of 30 mM H_2O_2. The specific activity has been expressed with moles of H_2O_2 consumed/min/mg protein.

Sugar analysis (for profiling):

The determinations of sugars were performed by HPLC according to the method described by Rodriguez*et al.* 2010. About 1 g of the frozen homogenized Bhimkol pulp was weighed directly in polypropylene tubes and mixed with 2 mL of 4:1 ethanol: water. Thereafter, the tubes were put into an ultrasound bath for 5 min and centrifuged for 5 min at 1100 rpm. The supernatant was carefully recovered to prevent contamination. Then, another 2 mL of 4:1 ethanol: water was added to the pellet and placed in an ultrasound bath and centrifuged as above. The two supernatants were recovered in the same tube. This liquid phase was concentrated with a nitrogen stream until elimination of all the ethanol, and the residue was adjusted to 5 mL with ultra-pure water (Milli-Q water system) and stored at T = –80°C in the freezer. A milliliter of the dissolution was passed through a 0.45 µm filter GHP (Waters, Millford, MA, USA) prior to HPLC analysis.

The sugars were determined using an HPLC method with differential refractive index (DRI) detector. The Waters (Milford, MA, USA) apparatus comprised of a pump (600 E multisolvent Delivery System), an auto sampler (700 Wisp Model) and a DRI detector (Waters model 2414). The separation was performed by using a water carbohydrate analysis column (3.9 × 300 mm) with a particle size diameter of 10 µm, equipped with a waters carbohydrate CarboTM 4 µm guard column. The column was kept at 25°C throughout the experiments. The HPLC pumps, auto sampler, column oven and DRI detector were monitored and controlled using the millennium32 system. The mobile phase was composed of 4:1 acetonitrile: water. The injection volumes of the samples were 25 µL for both standards and sample extracts, with a flow rate of 2 mL·min−1. The HPLC sample peaks were identified by comparing the retention times obtained from standards. The Bhimkol pulp was also spiked with standards in order to verify the identity of the chromatographic peaks. After that peak areas were used for the quantification.

Mechanical Properties

Fruit (pulp) texture profiling:

The mechanical properties of flesh such as firmness, springiness, cohesiveness, chewiness and adhesiveness were measured by using TPA test by Texture analyzer (TA-HD plus TPA). The 12.5 mm probe and heavy duty platform (HDP/90) was used for texture determination. At the time of texture profiling, readings were taken at apical, middle and basal part of fruit. Texture analyzer was linked to a software program (Texture Expert, Version 1.22, Stable Micro Systems, and UK) of computer. The test speed of the cylindrical probe was kept 2 mm/s. Pre test and post test speed were 2mm/s and 5mm/s. respectively. Sample has been kept at the center of heavy duty platform and probe penetrated up to 4 mm distance in above mentioned places of the fruit. Thetriplicatereadings of texture profiling parameter of fruit have been calculated.

Peel texture profiling:

The peel was more resistance due to the fibrous nature. The 12.5 mm probe was not responding during TPA test, hence 2 mm probe was used for measure the firmness in terms of amount of force required for penetration of 4 mm distance. The operating parameter for penetration in TPA test selected were : pretest speed 1.0 mm/s, Test speed 2.0 mm/s , Post test speed 3.0 mm/s and distance 4mm. The study was conducted using texture analyzer (TA-Hdi, Stable Micro systems, UK) equipped with 5 kg load cell. The mean value has been calculated of from triplicate readings of texture profiling parameter of peel.

Foaming properties

Drying of banana takes longer time due to the dense structure leading to high energy consumption and poor dried product. Dense structure is also responsible for inhibiting the crisp banana-based snacks (Thuwapanichayanan*et al.* 2012). The foam structure, its expansion, and stability play major role in moisture movement during drying and subsequently the product quality. Foams that do not collapse for at least 1 h are considered mechanically or thermally stable for the entire drying process (Bag *et al.* 2011).

Foam density (FD):

The Bhimkol foam was transferred in to a 100 ml measuring cylinder and care was taken such that foam structure does not collapse and trapping the air voids. After that weight and volume of foam were noted and foam density calculates by following formula given by Karim and Wai,(1999).

$$Density = \frac{Weigh\ of\ foam\ (g)}{Volume\ of\ foam\ (Cm^3)}$$

Drainage volume (DV):

This method was slightly modified by Bag*et al.* 2011 with reference of method described by Raju and Pal, (2009). In the modified method Buchner filter (80mm) was used for drainage of liquid in 100 ml measuring cylinder. Buchner filter was placed on measuring cylinder and foam was poured slowly in Buchner filter. Then volume of separated liquid (ml) from foaming measuring cylinder was measuredafter hour at room temperature (25-30°C.)

Foam expansion (FE):

The indication of amount of air incorporated in juice during whipping was measured by foam expansion. Foam expansion was calculated using following formula (Balasubramanianand Paridhi, 2012).

$$FE\ (\%) \frac{V1 - V0}{V0}$$

Where, V_O=Initial volume (cc) and V1 is the final volume (cc)

Physical properties of Bhimkol flour

Flour is normally used for the preparation of various foods such as bakery products and weaning food industries. Information of physical parameter is necessary for preparation of food products. Therefore following parameters will be analyzed for the knowledge of physical behavior.

Bulk density and tapped density:

The 20 gm sample Bhimkol powder was measured in 100 ml graduated cylinder and the volume occupied by powder was noted. The bulk density was calculated by dividing the mass of Bhimkol powder by volume occupied in measuring cylinder. During measurement of tapped density, graduated cylinder was taken and sample repeatedly tapped from same distance up to no further change in volume (Koc*et al.* 2014).

Water holding capacity (WHC):

Twenty-five milliliters of distilled water was added to 1 g of dry sample, stirred and incubated at 40, 60 or 80°C for 1 h. Tubes were centrifuged at 3000*g* for 20 min, the supernatant was decanted, and the tubes were allowed to drain for 10 min at a 45° angle. The residue was weighed and the WHC was calculated as g water per g dry sample (Abbas *et al.* 2009).

Oil holding capacity (OHC):

The above procedure of water holding capacity (WHC) was followed for analysis of oil holding capacity (OHC).

Solubility:

Solubility was determined by method described by Caparino*et a*l. 2012. 100 ml of distilled H_2O was transferred into blender jar. The powder sample (1g dry basis) was carefully added into the blender operating at high velocity for 5 min. The solution was placed in tube and centrifuged at 3000×g during 5 min. An aliquot of 25 ml of the supernatant was transferred to reweighed Petri dishes and will be oven-dried at 105 °C for 5 h. Then the solubility (%) was calculated by weight difference.

Hygroscopicity (HG):

Ten grams dried Bhimkol powder solids was placed in an open glass container at 75.5% humidityusing a saturated solution of NaCland was stored at 25°C till the samples attains equilibrium condition. A sample was prepared at 20 °C. Hygroscopicity (%) or 1 g of adsorbed moisture per 100 g dry solids (g/100 g) was calculated using the following equation:

$$HG = \frac{\Delta m/\,(M + mi)}{1 + \Delta m/M}$$

WhereΔm is the increase in weight of powder after equilibrium, M is the initial mass of powder and Mi (% wb) is the free water contents of the powder before exposing to the humid air environment (Sablani*et al.* 2008).

Flowability:

Flow ability was determined according to Carrindex (CI) and Harsher ratio (HR). The Carr index and Haushner ratio were evaluated by following formula.

$$CI = 100X\frac{\rho T - \rho B}{\rho T} 1)$$

$$HR = \frac{\rho T}{\rho B} 2)$$

Where, ρβ and ρT *denotes* bulk density and tap density, respectively. Flowability was described Bulk Density and tapped density was calculated by method described by (Koc*et al.* 2014). The classification described in table: 1 indicates the flowability of powder. The powders with CI and HR values that range from excellent to passable are acceptable and the remaining refers to a lower quality powder (Asokapandian*et al.* 2015).

Table: 1 Indication of the flowability of powder

Flow ability	Carr Index (CI in %)	Hausner ratio (HR)
Excellent	0-10	1.00-1.11
Good	11-15	1.12-1.18
Fair	16-20	1.19-1.25
Passable	21-25	1.26-1.34
Poor	26-31	1.35-1.45
Very poor	32-37	1.46-1.59
Poor, Very poor	>38	>1.60

Color determination Pulp and peel:

I) Color of peel observed by two methods:

a) Photographic method

b) Hunter colorimeter

II) Color of pulp observed by one method:

Hunter colorimeter

a) Photographic method:

The photography of Bhimkolbunch (with peel) was done by using 21.1 Megapixel cameras (Canon PC 1474, Made in Malaysia). Bhimkol bunch photo was captured on the dorsal side. The changing of peel appearance with respect to color was observed visually.

b) Hunter colorimeter:

The peel and fleshcolorwere measured using Hunter colorimeter (Model: 45°/0°, M/s Hunter Lab, Reston, Virginia, USA) after two days interval.According to (Shahir and Visvanathan, 2014)Hunter colorimeter works on the principle of collecting the light and measures energy from the sample reflected across the entire visible spectrum. The mathematical models on "standard observer curves" that define the amount of red, green, blue. Primary lights are required to match a series of colors across the visible spectrum. The colour was calibrated by using Black and White trap respectively. The separated peel and pulpwas placed on color flex meter. It provides reading in terms of L (Black = 0, White = 100), a (-a*=greenness and + a*= redness) and b (-b* =blueness and + b*= yellowness). The colour was determined as per the above mentioned features of 'L', 'a' and 'b' values. All experiment was carried out in triplicate form.

Thermal effect:

Glass transition temperature:

The calorimeter was calibrated for heat flow and temperature using standard indium and sapphire. Twelve to sixteen milligrams of each Bhimkol powder sample was sealed in an aluminum pan. The samples at -90°C was scanned to 90 °C then cooled down to 25 °C. Scanning of all samples was carried out using the same heating and cooling rate of 5 °C /min. To avoid condensation on the surface of the powder particles, a nitrogen carrier gas was purged at a flow rate of 50 ml/min (Syamaladevi*et al*. 2009).

Microstructure analyses:

A small quantity of Bhimkol powders from different drying systems were mounted on aluminum stubs and coated with a fine layer of gold (15 nm) using a sputter gold coater. Two samples of powder were examined by Scanning Electron Microscopy using SEM Hitachi S- 570 camera (Hitachi Ltd., Tokyo, Japan) operated at an accelerating voltage of 20 kV. Micrographs were photographed at a magnification of 100×, 300× and 1000× at scale bar of 0.30 mm, 100 μm and 30 μm (Caparino*etal*. 2012).

Structural analysis:

X ray diffraction: X-ray diffraction (XRD) characteristics of Bhimkol powders obtained from different drying processes were investigated using a Siemens D-500 diffractometer (Bruker, Karlsruhe, Germany). The powder samples (180–250 μm) were placed and slightly pressed in an aluminum holder using a glass slide. The diffractometer was operated at a wavelength of 0.15 nm and the input energy was set at 30 mA and 35 kV. Diffractograms were taken between 5° and 50° (2θ) with a step angle of 0.02° and scan rate of 1 s per step. The XRD patterns of all the samples were plotted for comparison (Caparino*et al*. 2012).

Statistical analysis:

Statistical analyses of chemical compounds were performed with SPSS statistical software (PASW statistics version 20.0, SPSS Inc., Chicago, USA). In the postharvest phase, means of the sensor-data were compared by analysis of variance (one-way ANOVA), and significant differences among the treatment groups were determined according to Duncan's multiple range test ($p \leq 0.05$).

Experimental design and statistical analysis:

Response surface methodology (RSM) was applied to the experimental data using commercial statistical package (Design Expert version 8.0.7.1, StateaseInc, Minneapolis, MN) for the generation of response surface plots and optimization of process variables (Bag *et al.*2011). Central composite randomized design (CCRD) was used for designing the experiments on foaming using three factors with three levels. A total of 20 runs of different combinations were conducted in this study. The statistical significance of the terms in the regression equation was examined by analysis of variance (ANOVA). The optimization of the responses was also found by Derringer's desired function methodology using Design Expert 8.0.7.1 software.

Terminologies:

Pulp recovery:

The recovery of pulp was calculated on the basis of fruit. Pre weighed slice of fruit were taken for pulping. The separating pulp was weight in preweighed utensil.

$$\frac{A-B}{C} * 100$$

A= weight of utensils + Pulp

B= weight of utensils

C= weight of fruit

Waste:

The wastage was calculated on the basis of fruit. Pre weighed slice of fruit were taken for pulping. The separating waste was weight in pre weighed utensil.

$$\frac{Waste}{Weight\ ofFruit} * 100$$

A= weight of utensils + waste

B= weight of utensils

C= weight of fruit

Seed crushing:

The crushing of seed was calculated on the basis of total seed. The separated waste was washed in water and floated seeds taken for measured weight.

$$\frac{Crushedseed}{Totalseed} * 100$$

Process:

1) The bunch of "Bhimkol (*Musa balbisiana)* " fruit was harvested after 150 days of flowering. The harvested bunch was arranged in plastic carets and transported immediately from field to laboratory and kept for ripening at temperature 22°C ±2% and 90% ±2% humidity. Samplings of fruit was carried out in 2 day's interval for analyze the chemical, physical and mechanical properties.

Table: 2 Chemical, physical and mechanical properties.

Sampling Time	Dependent variable	
	a) Physico-mechanical parameter	b) Chemical analysis
2 days interval	Pulp color, Peel colour, Pulp/ peel ratio, Cutting force, TPA (Firmness, Rupture force) of peel and fruit.	Moisture content, Total sugar, Starch, Total soluble solid, %Titrable acidity, Vitamin-C., Pectin, Reducingsugar, Ash, Protein, Acid/Brix ratio.

2) Then the 10 kg fruit was selected at the optimum maturity i.e., fully ripe for carried out the pulping or further processing.

3) During processing peeling was carried out manually i.e., by hand. Before peeling fruits are washed under tap water for removing foreign materials.

4) Then peeled banana; 6–9 bananas can be accommodated at a time in feeder in order to get machine capacity in the range of 50kg/h. The slices length was kept 2-3 cm approximately.

5) Blanching was carried out in steam jacketed kettle (SJC). SJK was mounted on stainless steel stand with tilting arrangement of gear. Steam was circulatedtroughjacket. Then water was added in SJK on the basis of slice weight i.e., 0.645kg/ kg slice. Then blanching treatment was optimized by using full factorial design made in Design expert software version 7.1. The selected parameters were time (0-5 min), temperature (40-90) and enzyme inhibition are intendment and dependent variable respectively. Even .some random experiments also carried out at 10 ° C for 1,2,3,4 and 5 min respectively.

Table: 3 Selected parameters for enzyme inhibition

Independent variable		Dependent variable
Temperature (°C)	40-90	Polyphenol oxidase , Catalase and Peroxidase activity
Time (min)	1-5	

6) After the blanching treatment, fruits and water were taken for pulping. The pulping was carried out by using slices and treated water. There was 3 types of pulping methods used are described as follows:-

a) Bamboo sieve (Traditional method):

The selected fruits were sliced uniformly. The sliced fruit were crushed on bamboo sieve which was round shaped and perforated (2-4 mm dia.). The pulp was collected in a steel vessel.

b) Hand pulper (HP):

The sliced fruit was crushed to separate hard seeds and pulp of the fruit using hand operated screw type fruit juice extractor. The pulp of fruit was collected in steel vessel. The all contacting parts of machine made of by aluminum.

c)Modified drum type pulper (MDTP):

The sliced fruit were transfer in to Hopper (vertical narrow). The modified drum type pulper unit consists of two brushes which give combined beating and brushing action. Due to the adjusted gap between round sieve (0.5-1μ) and nylon brush (beater), smooth pulp was separated. The narrow hopper was used to resist fruit from moving away due to the back force of beater. The all contacting parts of machine were made of stainless steel.

Then best pulping operation were selected on the basis of highest pulp recovery (%), lowest waste (%) and seed (%).

Foaming device:

After the pulping, for the foaming laboratory sale device was developed. The laboratory scale foaming device containing mixer jar, kitchen mixer, rotameter and compressor. Mixer jar (153mm diameter and 280mm height) with graduated scale and connected brass nozzle at bottom side was placed on kitchen mixer (Company: Usha, Model: 2663 and made in India). One end of rubber pipe was connected to nozzle and other end with rotometer. Then same connection of pipe was arranged in between rotometer and compressor. The whipping blade with 1.6mm thick and three cutting ages placed in jar. Rotometer and stroboscope (1531AB, GR Co., USA) were used for measure air flow and speed of blade respectively.

Foaming trials:

The central composite design was used for determine effect on foaming characteristics. According to design (CCRD) particular concentration of Bhimkol pulp (500ml) and required quantity of SMP was added in mixer jar. The desired concentration of pulp adjusted from higher to lower or vice versa with addition of water or pulp respectively was calculated by Pearson square method (Kandasamy*et al.* 2014). The operating time of foaming devices with 5000 rpm at room temperature (25-30°C) was kept in between 10-180sec.. The air flow rate was maintained 10L/min which is incorporated bottom side of jar. The foamed pulp samples were slowly removed from foaming device and used for measure FD, DV and FE.

Table: 4 Selected parameters for foaming behaviour

Independent variables			Dependent variable
Parameter	Level		
Whipping time(sec)	10	180	Foam density, Foam expansion, Foam stability.
SMP (%)	1	10	
Pulp concentration (^{O}Brix)	8	16	

Drying procedure

The raw banana pulp or foamed pulp were dried in tray drier (Newtech Instruments Ind. (P) Ltd, Made in India, accuracy ±5°c). After the dryer reach at set temperature, raw or foamed pulp samples were uniformly spread (1 cm ±0.5mm layer) in round stainless still trays (size: 900mm by 600mm) and kept for drying. When initial moisture reduced up to 50% sample then tray shifted to vacuum dryer. The moisture loss was recorded by digital balance of 0.010g accuracy (Shimadzu UW1020H, Made in Japan). Then finely trays transferred in dehumidify drying for finishing. Then the drying behavior was analyzed.

Then scraped flakes were milled by lab mill with 10% RH at room temperature. The powder (150-200 μ) was packed in polypropylene zip bag and aluminum coated sealing bag. Then storage study was carried out at temperature range 10, 20, 30 and 40°C with 50-60% relative humidity. Then following physical and functional characteristics was analyzed.

Table: 5 Physical, structural and functional characteristics

Dependent variable/ parameter
Moisture content, Water activity, Water holding capacity; Solubility; Colour;Hygroscopisity; Bulk density; Oil holding capacity, X-Ray diffraction, Morphological analysis (SEM), Colour and Recovery of powder.

Result and discussion:

Objective1: To develop a pulping/ deseeding operation with minimum enzymatic browning/ color change.

This above objective comprises 3 sub objectives which explained are as follows:-

1.1 To characterize the raw material (Bhimkol) pertaining to powder making process.

Bhimkol *(Musa balbisiana)* is a very fast growing species attains height up to 15-20 feet. The brown seed (2-3 mm Dia.) are distributed trough out the flesh of fruit. The peel thicknesses are more than the other species of banana. It is a delicious fruit which comprises high nutritional and medicinal properties (Barthakur*et al.*1990, Mudoia*et al* 2011).

There is lack of information about maturity indices of Bhimkol are influence on food processors, consumers. The indices study is the only way to decide trade regulation, marketing strategy and utilization purpose of Bhimkol fruit. Apart from that changes during different ripening stages of banana are the most important for processing attributes such as sorting, peeling, crushing and packaging etc. Therefore, aim of this study is to determine the physical, mechanical and chemical changes of Bhimkol *(Musa balbisiana)* at advanced stage of maturity during ripening.

Physical properties:

Pulp/Peel ratio:

Pulp to peel ratio can be considered as the coefficient of ripeness in fruits. A significant increase in pulp (with seed) to peel ratio (0.845-2.146) was observed in BhimKol. Abdullah *et al* 1986 reported similar finding that increase pulp to peel ratio in ripening of banana. The reason for measuring pulp (with seed) to peel ratio instead of flesh to peel was that seed is distributed through the pulp that make trouble for pulping. The initial ratio of flesh to peel of Bhimkol was found to be 0.903 which increased up to 2.012. This increase can be attributed to increase sugar content of pulp which eventually resulting in osmotic transfer of moisture from peel to pulp (Thomas *et al.*2007).Due to the same reason density of flesh (with seed) and flesh (without seed) increases with increase in days of ripening. The colourof Bhimkol fruit (with peel) was found different compared to ordinary banana.After harvesting, up to the 7^{th}day it was found that loss of greenness and increase the yellowness. This same result was found in ordinary banana according to **SH Pratt & Co (Bananas) Ltd. (Luton).** However, in case of Bhimkol, loss of yellowness and increase in redness was found after 7^{th} day to 13^{th} days. There are two variation in color of Bhimkol was observed during ripening like greenness to yellow and yellowness to red. The changes from greenness to yellow weredue to the loss of chlorophyll and increased carotenoid i.e., xanthophylls and carotene (Seymour *et al.*1987,Venkata*et al.* 2013). After 7th days Bhimkol start to get red color, that change it may be due to the increase the carotene and decrease the xanthophylls.

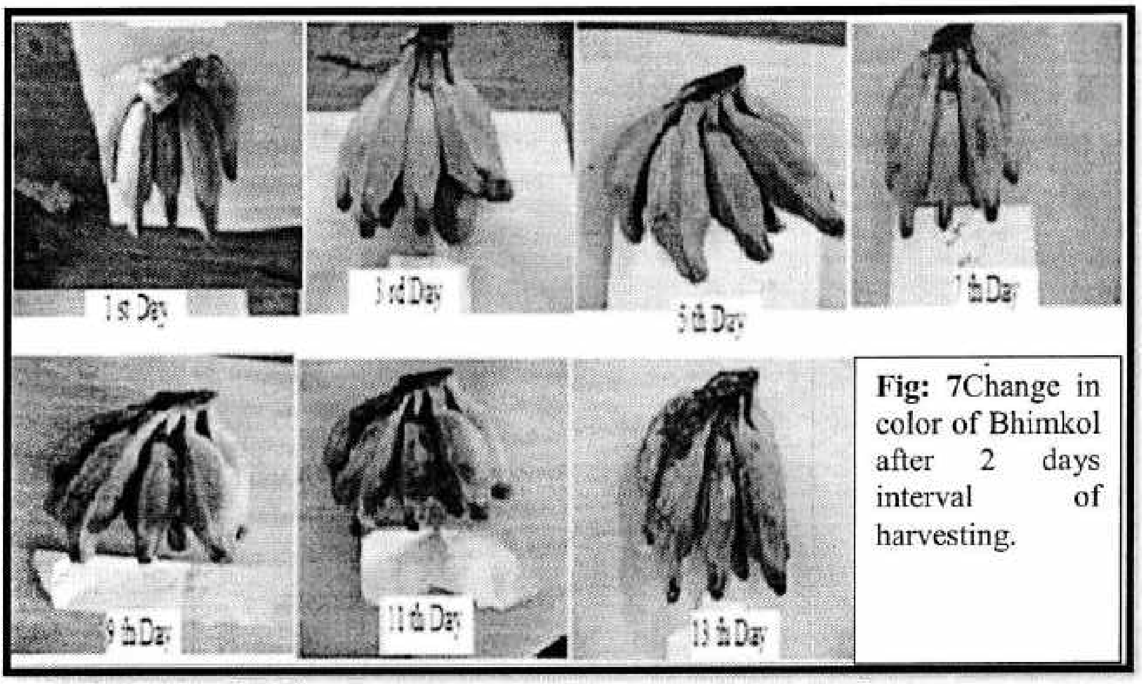


Fig: 7 Change in color of Bhimkol after 2 days interval of harvesting.

Table 6: Chemical properties of Bhimkol pulp

	Storage days						
Parameters	1	3	5	7	9	11	13
**Moisture (%)	65.242^{a}	65.189^{a}	71.304^{b}	73.036^{bc}	73.437^{bc}	75.442^{cd}	77.356^{d}
*Ash (%)	2.131^{ab}	1.356^{a}	2.234^{ab}	2.307^{ab}	1.890^{ab}	1.857^{b}	1.770^{a}
Fat (%)	0.284^{a}	0.339^{b}	0.392^{c}	0.434^{d}	0.562^{f}	0.483^{e}	0.476^{e}
*Protein (%)	0.876^{d}	0.821^{c}	0.759^{b}	0.684^{a}	0.539^{a}	0.525^{a}	0.510^{a}
*Pectin (%)	0.670^{a}	0.563^{a}	0.678^{a}	0.781^{a}	0.893^{b}	1.050^{bc}	1.070^{c}
*Ascorbic acid (mg/kg)	139.284^{c}	87.054^{b}	65.997^{a}	41.008^{a}	36.284^{a}	31.250^{a}	31.121^{a}
*pH	4.75	4.90	4.98	5.74	5.63	5.59	5.52
*%Titrable Acidity (in terms of mallic acid)	0.223^{a}	0.163^{a}	0.223^{a}	0.232^{a}	0.323^{a}	0.370^{a}	0.393^{a}
*Total soluble solid (°Brix)	4	7	13	18	22	24	26
**Starch (%)	20.736^{e}	15.229^{d}	11.444^{c}	7.659^{b}	5.280^{ab}	4.130^{a}	3.914^{a}
**Total sugar (%)	3.927^{a}	5.127^{ab}	7.287^{b}	11.508^{c}	14.748^{d}	17.477^{e}	19.845^{f}
**Reducing sugar (%)	1.110^{a}	1.170^{a}	4.236^{b}	7.040^{c}	9.103^{d}	10.918^{e}	11.993^{e}
* Pulp to peel ratio	0.903^{a}	1.294^{b}	1.302^{b}	1.563^{c}	1.780^{d}	1.936^{de}	2.012^{e}
*Fruit(with seed) to Peel ratio (w/w)	0.845	0.945	1.005	1.228	1.684	2.083	2.146
**Density of pulp (kg/m^{3})	1974	1812	1775.6	1170	1181.46	1194	1221.67
Storage period differ: *significantly ($p \leq 0.05$), (n=3) and ** non-significantly ($p \leq 0.05$), (n=3). The values mentioned in rows, having the same letter(s) do not differ significantly as per DMRT at 0.05 levels.							

The total sugar increased from 3.92 to 19.84 % in 1 to 13th days respectively. According to earlier study in banana, total sugar increased from less than 2% to 20% in ripening stages (Poland *et al.* 1938, Mohapatra*et al.* 2010). In this study, starch content of Bhimkol pulp decreased significantly (20.73 to 3.91).Okita*et al.* 2013 also observed starch decreased from

21% to 19% at room temperature. This can be attributed to the fact that starch is degraded and accumulation of sugar occurs during ripening (Dawson*et al* 2008). Various enzymes such as amylase, glycosidase, phosphorylase, sucrosesynthase and invertase acts on starch for its rapid degradation to soluble sugars which are responsible for the sweetness of the fruit (Dawson*et al.* 2008). The trend like increasing of sugar and decreasing of starch found by many researchers (Okita*et al.* 2013, Shyamrao*et al.* 2011, Christophe*et al.* 2013). The reducing sugar content increasing in Bhimkol from 1.110 to 11.999% during storage from 4th day to 13th day respectively. This changes take place because of starch are degraded by amylase and maltase enzymes and converted in to glucose and fructose (Hakim 2012). Chacon *et al.* (1987) mentioned the total reducing sugar in green and ripe bananas were 0.52% and 10.3%, respectively. Stratton and Loesecke (1930) reported that reducing sugar content increased progressively from 0.24% to 15.3%.

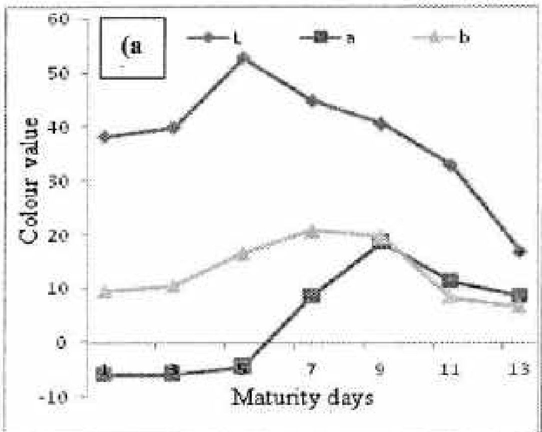
The total soluble solid (TSS) of Bhimkol gradually increased with respect to ripening. The TSS of Bhimkol increased from 4°Brix (1st day) to 26 °Brix (13th day) during 13 days of ripening. Similar trend was observed at the stage of 2nd and 5th in Cavendishvarietyof banana (Mahmoud *et al.* 2010).The increase in TSS is due to the hydrolysis of starch into soluble sugars such as glucose, sucrose and fructose (Tapre and Jain, 2012). Significantly increasing moisture content from 65.24 to 77.35% was observed in of Bhimkol from 1st day to 13thday respectively. The results are almost similar to the moisture content of ripe Palayankodan (*AAB*) variety of banana i, e. 77.316 % (Sreedevi and Divakar, 2015). The increasing trend of moisture content in banana pulp is due to the breakdown of starch by enzymes and osmotic transfer take place from the peel to pulp (Mohapatra*et al.* 2010, Tapre and Jain, 2012). The protein content decreased during the process of ripening whereas fat content increased. The increasing fat of content Bhimkol may be due to small amount of sucrose transport in phloem from photosynthetic tissues. The glycerol and acetyl CoA helps to synthesize lipid and they are formed by sucrose via glycolytic pathway (Chesworth*et al.* 2012). , reported that protein content of Bhimkol varied from 1.16-1.04. Moreover, the fat content of Bhimkol was found higher than reported for *Musa Robusta* and *Sapientum*(Tapre and Jain, 2012, Zaman *et al.*2007).This change occurred due to the different genome, variety, climate and altitude (Mohapatra*et al.* 2010). Ash content of Bhimkol varied between 2.131-1.770. Balthakur (1990) observed 1% ash content in Bhimkol pulp which is lower than present result.

The pectin content of Bhimkol observed in the range of 0.670-1.070 and it was high as compare to reported value by Tapre and Jain, 2012. Conrad (1930) reported that during ripening of fruits pectin increases at the expense of protopectin. The inter conversion of pectic substance is presumed to be involved in the characteristic softening which occurs during fruit ripening. Also it may be no correlation between other components present in tissue with pectin resulting more extraction of pectin.

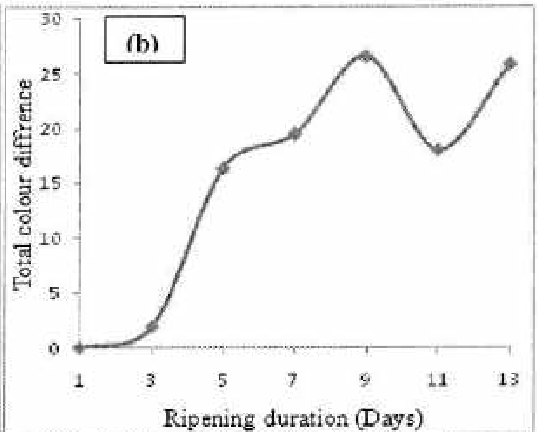
Titrable acidity of Bhimkol was increases gradually from 1[st]day (0.223) to 13[th]days (0.393). According to Lustre, (1976) titrable acidity increases with increase ripening of banana. The pH range of Bhimkol was found from 4.75 to 5.52. However pH decreasedwith fruit ripening at 9 [th] days. The suddenly decrease in pH may be responsible for increasing acidity of Bhimkol pulp. The ascorbic acid of Bhimkol was found in the range of 139.284-31.121 mg/kg. Balthakur (1990) observed close value i.e., 26 mg/kg in same variety of banana.

Physical analysis:

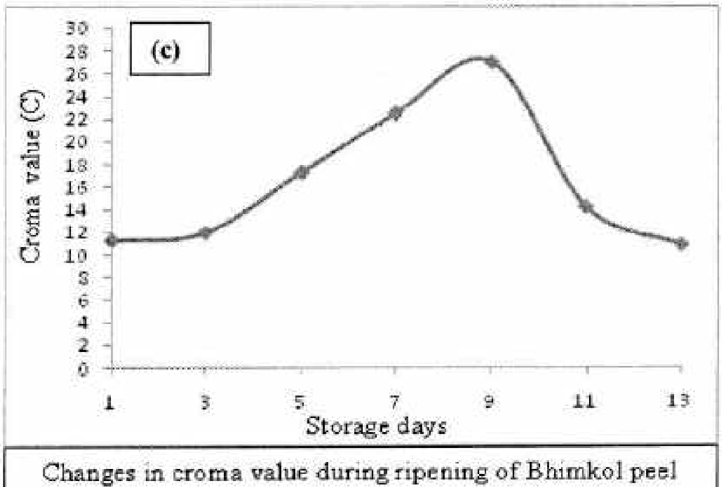
Peel color: Changes in color values ('L', 'a', 'b') during ripening for the period of thirteen days and after two days interval were presented



Changes in lightness ('L'), greenness ('a') and yellowness ('b') value during ripening of Bhimkol Peel



Changes in total color difference value during ripening of Bhimkol Peel



Changes in croma value during ripening of Bhimkol peel

Fig: 8 Represent the colour changes, colour difference and croma value.

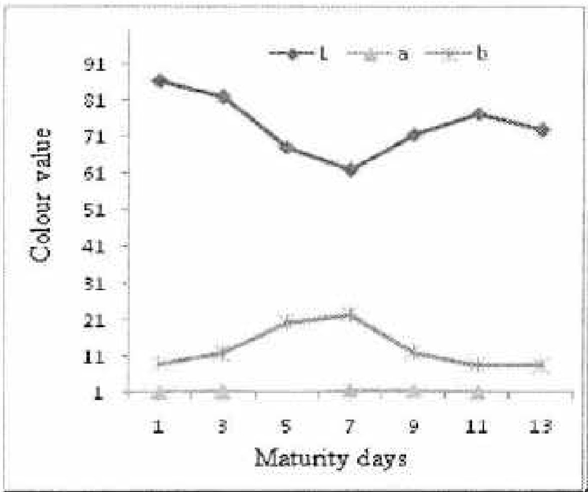
The observation is that lightness of peel increased up to the 7th days of ripening and darkness was seen increased letter on. The yellowness value found increased from 1st day to 9 thday. At same time redness (+ve 'a') increased simultaneously and greenness (- ve 'a') was decreased. After the 9th days the yellowness (b value) became decreased and at the last stage brown color was observed. Similar results of yellow color development on 4th day and later brown spots were observed by Salvador*et al.*2007 during ripening of banana fruits. The reason may be for increasing lightness and yellowness value due to degradation of chlorophyll and increase incarotenoid pigment (Shahir and Risvanathan,2014).In case of Bhimkol (*Musa balbisiana*) redness ('a' value) increased continuously upto 11 days. After that increase in darkness (Brown)and decrease inblueness was observed. Hence at this stage banana appeared dark red. According to Mahmoud *et al.(*2010) increased redness in banana during ripening is due to the chlorophyll degradation in peel tissue.

Color difference in peel:

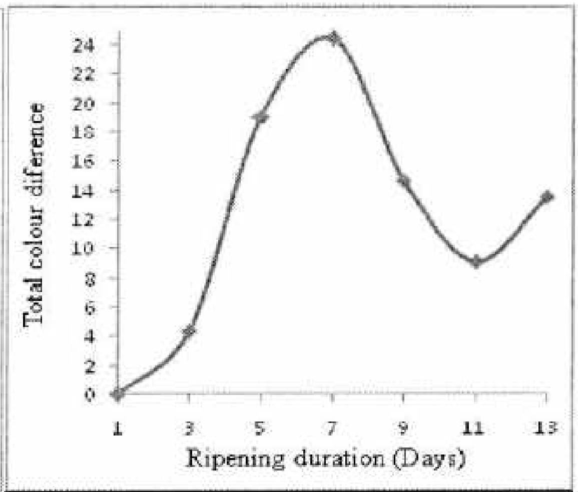
Total color difference was measured with deviation between ('L', 'a', 'b') values of individual fruit. Figure **8** shows that during storage, color difference increased up to 9th day found but decreased thereafter. The same trend was reported by Shahir and Visvanathan,(2014). They found that peak value of colour difference is 18.92 in Banana *var. Grand Naine.*The Bhimkol indicates less deviation in color value at11th and 13 thday of ripening. This might be due to the decreasing 'a' (redness) and 'b'value while storage period from 11 thdays to 13thdays. After 11daysyellowness value decreased. These changes during ripening are due to the decrease in chlorophyll and might be increase in carotenoidpigment in the peel. The reason of chlorophyll degradation in banana peels is due to reduction of Mg-dechelatase activity (Xiao-tang *et al.* 2009).

Pulpcolor:

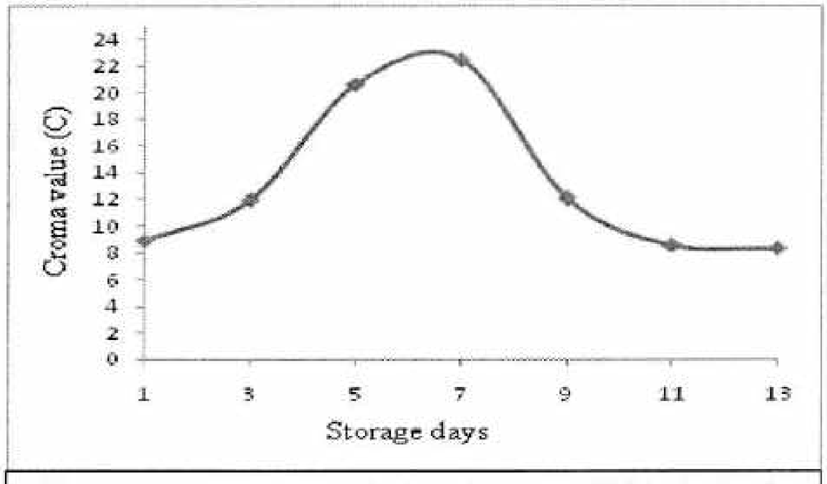
Changes in color values ('L', 'a', 'b') during ripening for the period of seven days were presented in Figure **9.**



Changes in lightness ('L'), greenness ('a') and yellowness ('b') value during ripening of Bhimkol pulp



Changes in total colour difference value during ripening of Bhimkol pulp



Changes in croma value during ripening of Bhimkol pulp

Fig: 9Represent the colour changes, colour difference and croma value.

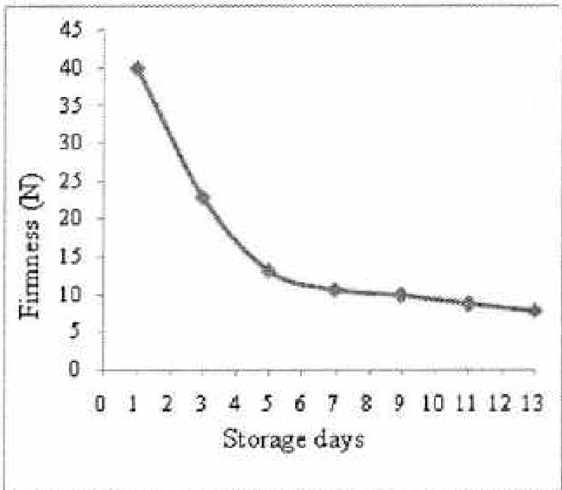
The result shows that at the initial days of storage (1st to 3th) lightness of pericarp (pulp) was almost similar but later stage (5thto13thdays) it was found decreased. The b value of pulp increased up to 7th day and in further days decreased. The 'a' value increased with increase in days of storage but last few days it decreased. Heliofabia*et al.* (2015) reported that trans-carotenoid has increased with respect to ripening in pulp. The increasing yellowness and redness effect in Bhimkol pulp may be due to the increasing trans-carotenoid. .The visual observation can't judge accurately that changes occurred in pulp but hunter color value shows that changes occurred during different stage of ripening.

Color difference in pulp:

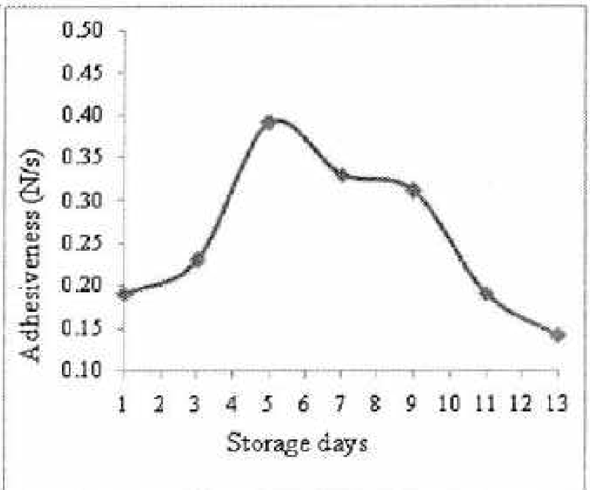
Total color difference was measured with deviation between ('L', 'a', 'b') values of individual fruit. Figure **9** **(b)**shows that color difference of fruit up to 7th days found increased (4.396- 24.421) but after that decreasing trend was seen up to 11day. The decreasing trend of color value indicates increase in lightness of fruit and formation of redness with yellowness increased. This effect is a total opposite of the peel. The reason fluctuation in color difference in fruit still not found. It might be due to the carotenoid pigment variation in fruit during ripening.

Mechanical properties

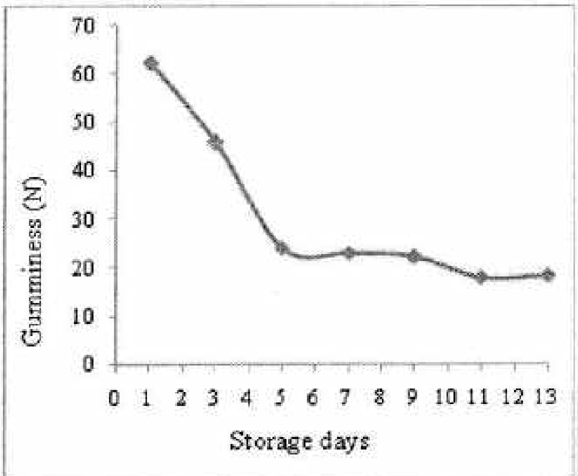
Effect of ripening period on textural properties of Bhimkol pulp:



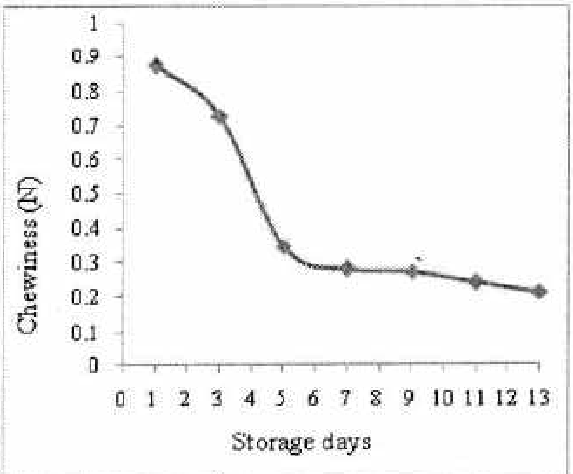
(a) Changes in firmness during ripening of Bhimkol pulp



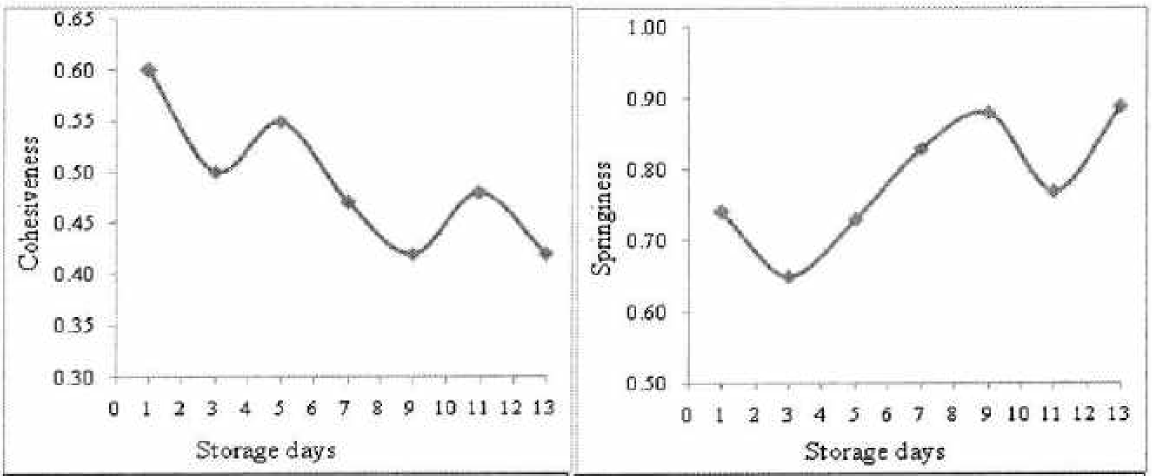
(b) Changes in adhesiveness during ripening of Bhimkol pulp



(c) Changes in gumminess during ripening of Bhimkol pulp



(d) Changes in chewinessduring ripening of Bhimkol pulp

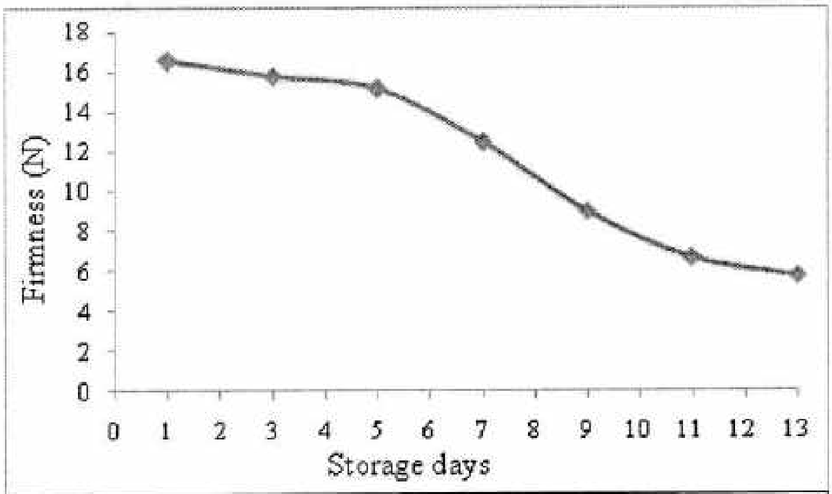


(e) Changes in cohesiveness during ripening of Bhimkol pulp

(f) Changes in springiness during ripening of Bhimkol pulp

Fig: 11Graphycal reprentation of changes in textural properties of pulp.

Decrease in texture of treated fruits during ripening could be due to breakdown of insoluble protopectin into soluble pectin or by cellular disintegration leading to membrane permeability (Kulkarni*et al.* 2011).Firmness was defined as the maximum force required for break the tissues of banana pulp (Liewand Lau,2012). The change in firmness during ripening due to the hydrolysis of starch in to sugar (Hailu*et al.* 2013) and insoluble protopectine get converted in to soluble pectin. According to Szczesniak, (2002) hardness/ firmness /softness are measure the resistance force for compression. In case of Bhimkol decreasing trend of firmness (39.98-7.78 N) was found during ripening stage at 1st day to 13th day. Thefirmness value during 3rd day of storage of Bhimkol found almost similar with raw *Musa*, AAA group variety (23 N) reported by Baoxiu*et al.*2000. Springiness measure the energy that required for sample gets back in original shape after deformation (Baoxiu*et al.* 2000, Ng*et al.* 2014).The springiness of Bhimkol was seen alternatively increase and decreased from 1st to 13 th days. The value was found varied in between 0.74-0.89. The trend of springiness of banana pulp from 0.358 to 0.410 earlier determined (Silas *et al.*1997). Adhesiveness represents the negative force area or amount of force required to adhere material remove from the mouth (Bugaud*et al.* 2013). The figure **11**(b) shows that the value of adhesiveness varied between 0.19 to 0.14 N/Sec.Here adhesiveness was calculated in terms of time. Adhesiveness of Bhimkol pulp found increased to the 5 thdays and after that it was decreased. Bugaud*et al.*(2013) reported the value of adhesiveness of banana during eating stage at 4.9 N/cm. Chewiness is the ratio ofgumminess and springiness. The chewiness of Bhimkol was found in the decreasing way (0.873-2.115N) while ripening increase. The similar trend was shown by Tapre and Jain,(2012). They reported that chewiness of banana varied (4.80-2.68 kgf) from ripening stage of 5th to 7th. The cohesiveness of Bhimkol was found higher than Musa spvar '*Robusta*. In case of Bhimkol value of cohesiveness varied from 0.60 -0.42. The trend of cohesiveness was found at randomly.



(e) Changes in firmness during ripening of Bhimkol peel

Fig.12 Changes in firmness during ripening of Bhimkol peel

The firmness of peel is one of the important parameter for quality of fruit. The figure **12** (e) shows that penetration force decreased with increased storage days of ripening. The firmness value on 1st day of peel was noted 16.563N and it goes decrease up to 5.770N on 13 th days of ripening.According to Jaiswal *et al.* 2012, 16 % firmness was decreased in banana (*Musa sapientum*).In case of Bhimkol, 65.87 % firmness declined from 1st to 13 th days of storage. The firmness of Bhimkol peel decreased slowly in between 3rd and 5 th days (15.832-15.157) but after that it goes gradually from 12.452 (7 th day) to 5.770 (13 th day).The loss of firmness takes place due to the structural changes in solubilised pectin, hemicellulose and cellulose (Jaiswal *et al.*2012). The high declined trend in firmness of Bhimkol peel maybe due to structural change in the high pectin and high cellulose during ripening leads to peel became a soft.

Sugar profiling:

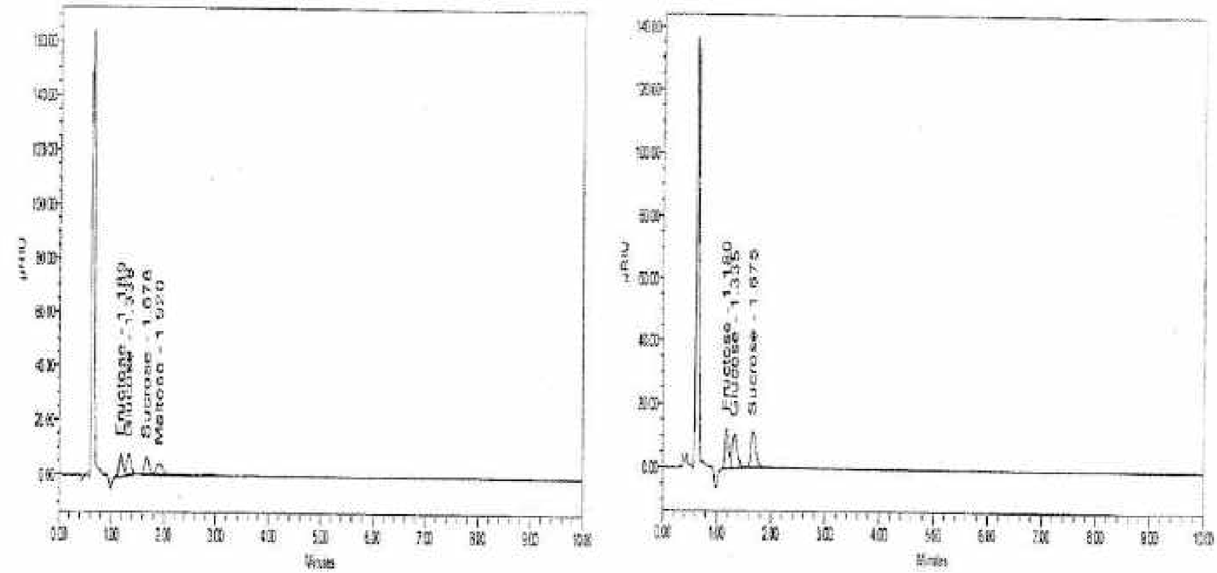


Fig:13 a) Chromatogram of sugar profiling b) Chromatogram of standard

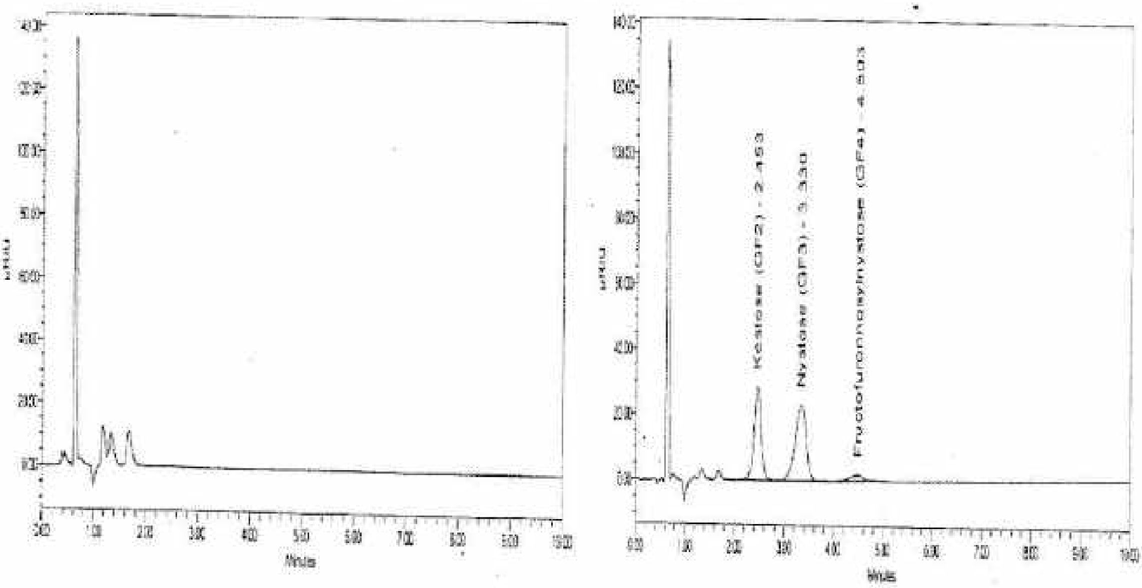


Fig: 14C) Standard of fructooligosaccharide d) Chromatogram of fructooligosaccharide

Table :7Quantification of sugar and fructooligosaccharide on the basis of Chromatogram			
Sr. No	Sugar profiling	Unit of measurement	Result
1	Sucrose (dry basis)	%	14.22
2	Glucose (dry basis)	%	12.46
3	Fructose (dry basis)	%	12.14
4	Fructooligosaccharides (FOS)	%	Not detected

Objective 1.2: Effect of thermal treatment and holding time on polyphenoloxidase, and catalase activity in Bhimkol (*Musa balbisiana).*

Blanching is a thermal treatment applied to inactivate enzymes that catalyzereactions which degrade fruit and vegetable products during storage. This thermal treatment stabilizes food because of its capacity to destroy microorganisms and to inactivate enzymes (Cruz*et al.* 2006). Additionally, it improves the color of products, prevents discoloration making the product more attractive for its consumption

Optimum temperature of polyphenol oxidase (PPO) and catalase (CAT) activity:

The polyphenol activity has been determined with respect to time (1-5 min.) temperature (50-90°C) combination.

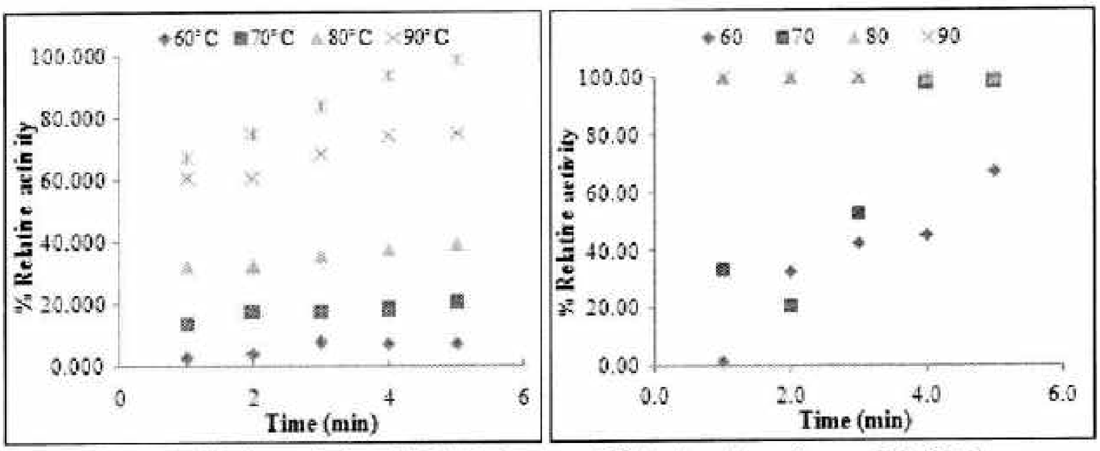


Fig.15 Relative activity of Bhimkol pulp : a) Polyphenol oxydase and b) Catalase

In case of PPO, enzyme activity of Bhimkol pulp decreased with increasing temperature and time. Here no drastic change has shown when slice heated at 60 and 70 for 1-5 min. respectively. Only 10 and 20 % activity decreased but when heat on 80°C the activity of enzyme start to reduce fastely. The activity of PPO enzyme reduced up to 75% at 90°C for 5 min. 99% of PPO activity lost after banana slice heated at 95°C for 5 min. The same result obtained by Almeida and Nogueira,(1995) in banana fruit. Mahendran and Prasannath(2010) reported that in case of banana blanching no loss of nutrient after processing. Srivastavaand Dwivedi(2000)Studied that the activity of catalase increased with ripening. In the case of catalase activity it increased at 70°C up to 2. The 100 % catalase activity suppressed when slice heated at 70 C for 4 min. Hua-Wei *etal.* 2010 reported similar fact that 100% catalase activity reduced after heated at 70 C.

Peroxidase activity (PO):

Peroxidase is a one of the iron containing enzyme situated in cell wall which is responsible for oxidation of phenolic compound. The activity of peroxides in Bhimkol was found negligible i.e. no colour change during qualitative test. During qualitative test of Bhimkol activity was found 0.0291 (AU/min/ mg of protein). Even though qualitative analysis also showed the negative test i, e. no color change up to 5 min. The apple pulp also tested for the confirmation of the test. In case of apple, positive test was take place i.e., brown color was seen within the 30 min. Arora*et al.* (2008) observed activity of peroxidase shown in banana peel. However, negligible activity found in nine different varieties of banana pulp. They also reported with increase the ripening of banana decrease the peroxides enzyme activity.

Objective 1.3: To develop a pulping/ deseeding operation with minimum browning/ color change.

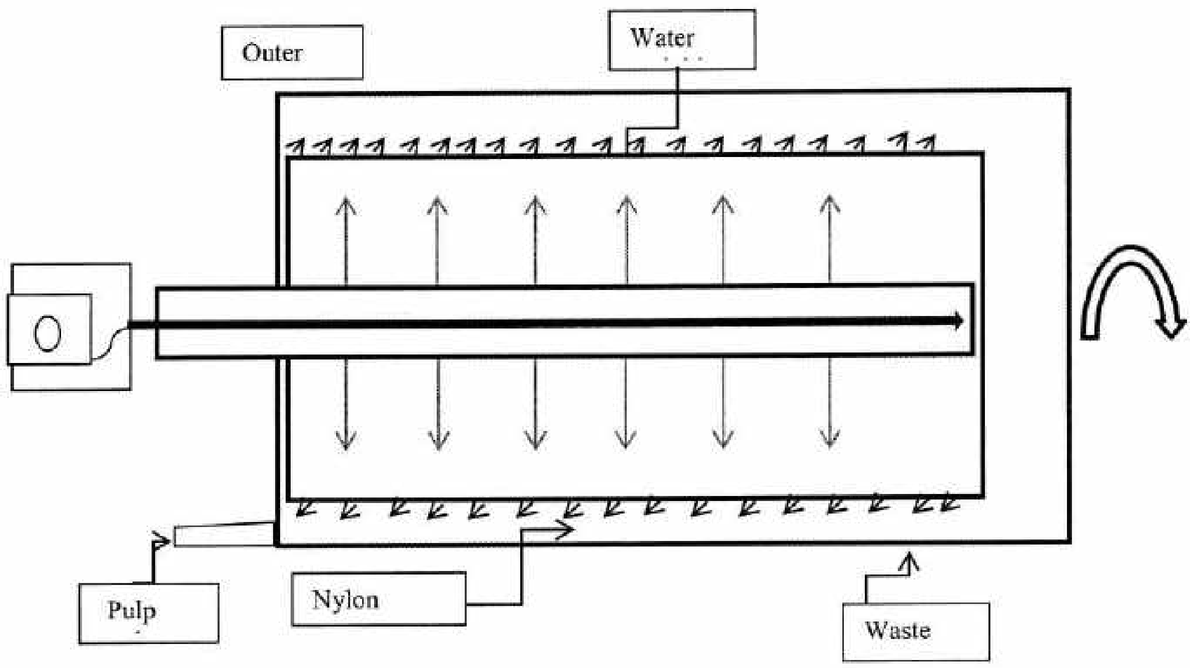


Fig: 16 Schematic diagramme of pulping machine.

Table: 8 Specification of designed or fabricated pulper

Material	Size (ID)	Size (O.D)	Length	Height	Purpose
Sieve(1-2 mm hole)	145 mm	155mm	200 cm	------	Separate the seed and smooth pulp
Drum	90mm	165mm	250 mm	------	Occupied sieve and shaft.
Teflon shaft With micro holes.	20mm	22mm	4 inch	-------	For sprinkling hot water
Motor (1 HP)	-------	------	------	-------	Rotate the shaft
Nylon brush	-------	------	-------	--------	For crushing fruit.
Hopper	Upper-200mm Center-150mm Base-50mm	201mm	-------	6 inch	Used for feeding fruit.
Modification					
Hopper connector (U shaped)	50 mm	52mm	5 cm	2.5 inch	Used for resist fruit to come out.
Water inlet	9mm	10mm	50mm	------	For feeding hot water
Stainless steel nipple With micro holes.	20mm	22mm	4 inch	-------	For sprinkling water
Peristaltic pump	Flow rate: Min. 0.08ml to Max.450 ml per min. with On/Off control, Digital LCD display, Variable speed.				
Speed controller	400 ml per min water was inserted trough stainless steel nozzle for sprinkling.				For controlling speed.

The modified drum type pulper is designed on the basis of above criteria. The stainless steel drum having 165 mm (ID), 90mm (OD) and 250mm (length). Inside the drum perforated sieve has been placed which having size 145 mm (ID), 155mm (OD) and 200cm (length). The two nylon brush was placed inside the sieve which is attached to paddles. In between the paddle one cavity formed for placing the stainless steel shaft for sprinkle the water. The outlets of shaft are sealed for creating pressure for sprinkling. The 1 Hp motor used for the rotating shaft. The round cone shaped hopper consisting ID size 200 mm, 150 mm and 50mm in upper, center and base respectively. The length of hopper is 6 inch. The U shaped connector placed in between drum and hopper which was helped us for resist fruit to come out from drum. The size of connector is 50mm (ID), 52 mm (OD) and 2.5 inch length. Hot water inlet was connected to outer center of the drum.The inlet of flexible pipe connected to peristaltic pump and outlet to water inlet of pulper. The flow of water maintained by peristaltic pump.

Comparison of different type pulping operation:

The hand operated screw juice, Bamboo Sieve (Traditional method), Drum type pulperwas used to compare with modified deseeding operation of Bhimkol fruit. To achieve the objective the experiments were conducted under two conditions. Peeled banana of different sizes were fed to the machine and operated for different time. The performance of the machine was measured by estimating the pulp recovery, seed removed.

The experiment was carried out on the basis of following criteria:

(i) Peeled and sliced banana followed by multi pass crushing

(ii) Peeled and sliced banana blanching followed by multi passes crushing.

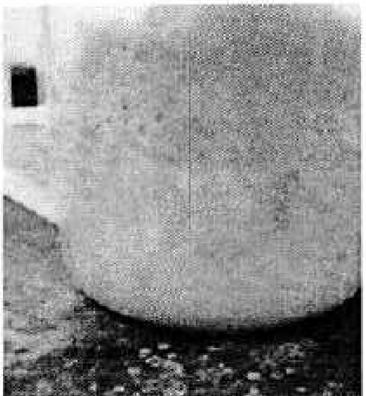
Table: 9 Effect of pulping operations

Sample type	Type of pulping operation	Pulp recovery (%)	By product (%)	Seed crushing (%)
Control	Bamboo sieve (BS)	35	65	5
Control	Drum type pulper (DTP)	20	80	0
Control	Hand operated screw type pulper (HOP)	48.93	49.61	40.34
Control	Modified drum type pulper (MDTP)	78	22	0
Blanched fruit (BS)	Bamboo sieve (BS)	38	67	7
Blanched fruit (DTP)	Drum type pulper (DTP)	22	78	0
Blanched fruit (HOP)	Hand operated screw type pulper (HOP)	51	49	45
Blanched fruit (MDTP)	Modified drum type pulper (MDTP)	80	20	0
Blanched fruit+ water (BS)	Bamboo sieve (BS)	---------	-------	---------
Blanched fruit+ water (BS)	Drum type pulper (DTP)	65	35	0
Blanched fruit+ water (BS)	Hand operated screw type pulper (HOP)	115	35	8
Blanched fruit+ water (BS)	Modified drum type pulper (MDTP)	140	23	0

In this study, four different types of pulping methods were employed - Bamboo sieve, Hand operated screw type juice extractor, Drum type pulperand modifies drum type pulper. The recovery of fruit by modified drum type pulper is found to be higher i.e. 78.02 % as compared to Bamboo sieve (35 %) and Hand operated screw type juice extractor (60.78%). This has been found primarily because of the increasing effectiveness of nylon brush in washing of the pulp. Nylon brush creates the force for pass the pulp through sieve. Hand operated screw juice extractor is best for households but the quality of pulp lost is more due to the crushing of seed (40.34%) during pulping.

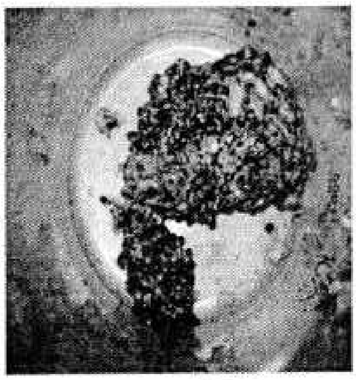
Here, the lack of sufficient space between outlet and narrow screw create a high pressure which again might be responsible for crushing of seed. The wastage of pulp was found as 65%, 39.22%, 80% and 23.53% in BS, HSJE, DTP and MDTP respectively. The pulp extracted from bamboo sieve was more brownish than that of the Hand operated screw juice extractor and Drum type pulper. This pulp obtained by drum type pulping has got greater smoothness and whitish as compared to the other two methods. The smoothness of pulp found due to the proper washing and beating by nylon brush and perforated (0.5-1 mm diameter) sieve. The perforated stainless steel nipple placed between the two paddles which help to sprinkle water. The water used during blanching further used for sprinkle trough perforated tap inside the drum. The sprinkle of water helps us to wash pulp properly and improve the pulp recovery. After the sprinkling of water shiny seeds only come out through the pulper as wastage. Even reduce the consistency of pulp due to sprinkling water helps to pulp come out smoothly through the pulper. Reduce consistency of pulp further helps in processing i.e., foaming operation.

However, among above studied pulping methods, modified drum type pulper was found to be the best method for pulping of Bhimkol fruit with a high recovery and best physical attributes.



Pulp extracted by MDTP from untreated Bhimko

Pulp extracted by MDTP from treated Bhimk



Waste obtained by MDTP during pul of untreated Bhimkol fruit

Fig: 17 Treated and untreated pulp

Objective 2: Optimization of process parameters for foaming of Bhimkol (*Musa balbisiana*) fruit pulp.

The foaming characteristics such as density, drainage volume and foam expansion plays the major role in quality and drying characteristics of final product. Foam stability and expansion depend upon the nature foaming agent. More stable and high expansion shows the strength of the foaming agent for respective food material. Whipping time, concentration of pulp and foaming agent also affecting on the foaming properties during processing (Karim and Wai, 1999; Thuwapanichayanan*et al.* 2008). Therefore, in the present study following sub- objectives were formulated.

Objective 2.1: Selection of dryer for the preparation of Bhimkol powder.

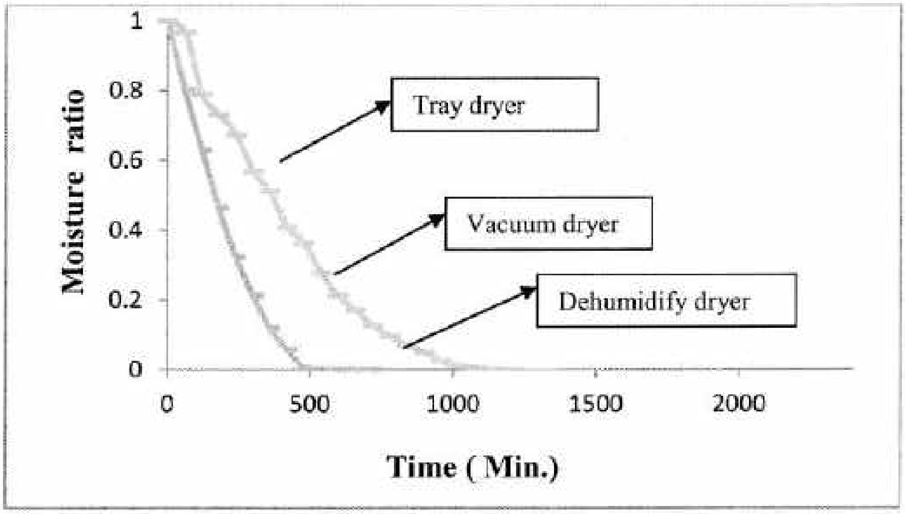


Fig: 18 Curve of MR vs DT during hybrid drying of Bhimkol powder

Objective 2.2: Optimize the effect of whipping time, pulp concentration, and skim milk powder on foaming properties of Bhimkol fruit pulp by using response surface methodology.

The value of all the responses (FD, DV and FE) on the basis of different experimental combinations was observed. The significance of model developed for all the responses is shown in table 11. From the table, it can be observed that models developed for FD, DV and FE were significant, whereas lack of fit was insignificant showing accuracy of the developed models. For all the responses, coefficient of determination (R^2) was 0.829, 0.768 and 0.756 respectively which shows accurate fitting of the developed model.

Table 10: Foaming properties (FD, DV and FE) of Bhimkol for different combinations of experimental conditions

	Independent variable			Experimental response variable		
Experiment No	Pulp TSS (x_1)	Skim milk powder (x_2)	Whipping Time (x_3)	FD (gm/cm3)	DV (ml)	FE (%)
1	9.62	2.82	44.46	0.8	27.27	15
2	14.38	2.82	44.46	0.919	9.09	2
3	9.62	8.18	44.46	0.76	48.14	11
4	14.38	8.18	44.46	0.795	32.23	5
5	9.62	2.82	145.54	0.801	25.45	8
6	14.38	2.82	145.54	0.933	12.72	0
7	9.62	8.18	145.54	0.674	51.78	13
8	14.38	8.18	145.54	0.818	26.66	4
9	8.00	5.50	95.00	0.757	25.86	6
10	16.00	5.50	95.00	0.948	11.3	0
11	12.00	0.99	95.00	0.93	8.63	0
12	12.00	10.01	95.00	0.69	63.63	17
13	12.00	5.50	10.00	0.82	21.42	19
14	12.00	5.50	180.00	0.685	39.45	17
15	12.00	5.50	95.00	0.7	28.05	15
16	12.00	5.50	95.00	0.7	28.07	19
17	12.00	5.50	95.00	0.71	33	18
18	12.00	5.50	95.00	0.691	25.13	18
19	12.00	5.50	95.00	0.798	26.65	15
20	12.00	5.50	95.00	0.7	34	21

FD foam density, **DV** drainage volume, **FE** foam expansion.

Table 11: ANOVA (Analysis of variance) result of the fitted model for the response variables

Variables	df	Estimated variables			F value		
		FD	DV	FE	FD	DV	FE
Model	9	0.72	29.12	17.73	10.99***	10.07***	7.61**
x_1-Pulp TSS	1	0.0550	-7.06	-3.37	28.27***	18.30**	12.06**
x_2-SMP	1	-0.0590	12.94	2.68	32.84***	61.49***	7.60*
x_3-Time	1	-0.0200	2.21	-0.83	3.79	1.79	0.73
x_1^2	1	0.0490	-3.56	-5.63	23.22	4.91	35.42***
x_2^2	1	0.0340	2.64	-3.69	11.07	2.71	15.18**
x_3^2	1	0.0130	0.63	-0.33	1.71	0.15	0.12
x_1x_2	1	-0.0090	-1.26	0.75	0.44***	0.34	0.35
x_1x_3	1	0.0150	-0.47	0.25	1.27**	0.047	0.039
x_2x_3	1	-0.0098	-0.47	1.25	0.52	0.047	0.97
R^2		0.9082	0.9006	0.8726			
Adjusted R^2		0.8255	0.8112	0.7580			
Lack of Fit				4.89	0.79	3.72	

***$p<0.001$; **$p<0.01$;* $p<0.05$

FD foam density, DV drainage volume, FE foam expansion

Effect of Foaming Process Variables:

Foam density (FD):

For evaluating whipping properties, FD is an important factor. Whip ability of the foam increases due to incorporation of more air which results in low density of foam (Bag *et al.*2011). Density of the foam was found in the range of 0.685-0.948gm/cm^3. For the ANOVA result (table 11), it can be observed that linear terms of pulp TSS and SMP has significant effect (1% level) on the foam density (FD). The quadratic terms had no effect on FD, whereas interaction terms x_1x_2 (Pulp TSS and SMP) and x_1x_3 (Pulp TSS and Whipping time) were significant at 0.01% and 1% significant level.

The final equation for showing the effect of different independent variables on the density of produced (FD) can be given as:

$$FD=+0.72+0.055 * x_1-0.059* x_2-0.020* x_3 + 0.049* x_1^2+0.034* x_2^2+0.013* x_3^2-0.0090* x_1* x_2 +0.015* x_1 * x_3-0.0098* x_2 * x_3$$

Where, x_1 is pulp-TSS (^{0}Brix); x_2 is SMP (%); x_3 is time (sec);FD is foam density (gm/cm^3)

The effects of different independent variables (pulp-TSS, SMP and time) on the density of produced foam (FD) have been presented by 3D plots. From figure **19**a effect of time and pulp TSS on FD can be observed. Pulp TSS has an increasing effect on the density of foam produced (FD). From equation 1, increasing effect of pulp TSS on FD can be observed. This is due to the reason that higher pulp TSS does not allow more air to entrap in the foam which results in higher density of foam produced, whereas lower pulp TSS allows more air to entrap in the system and hence density of foam produced also decreases. Similar finding was observed by Bag *et al.* (2011).

Figure **19**b represents the effect of SMP and pulp TSS on FD. From the figure**19**(c) it can be observed that SMP has a decreasing effect on FD whereas pulp TSS has a increasing effect on FD. Figure**19** c also represents the decreasing effect of SMP on FD, whereas time did not show any significant effect. Similar behavior can be obtained from equation 1.The decrease in density of foam produced with SMP may be due to the reason that higher concentration of SMP increases air bubble stability because of the difficulty of critical thickness formation of the interfacial film, whereas lower concentration of SMP supports the air bubble stability that results in increase in density of foam produced (FD). Similar findings were represented by Karim and Wai (1999b).

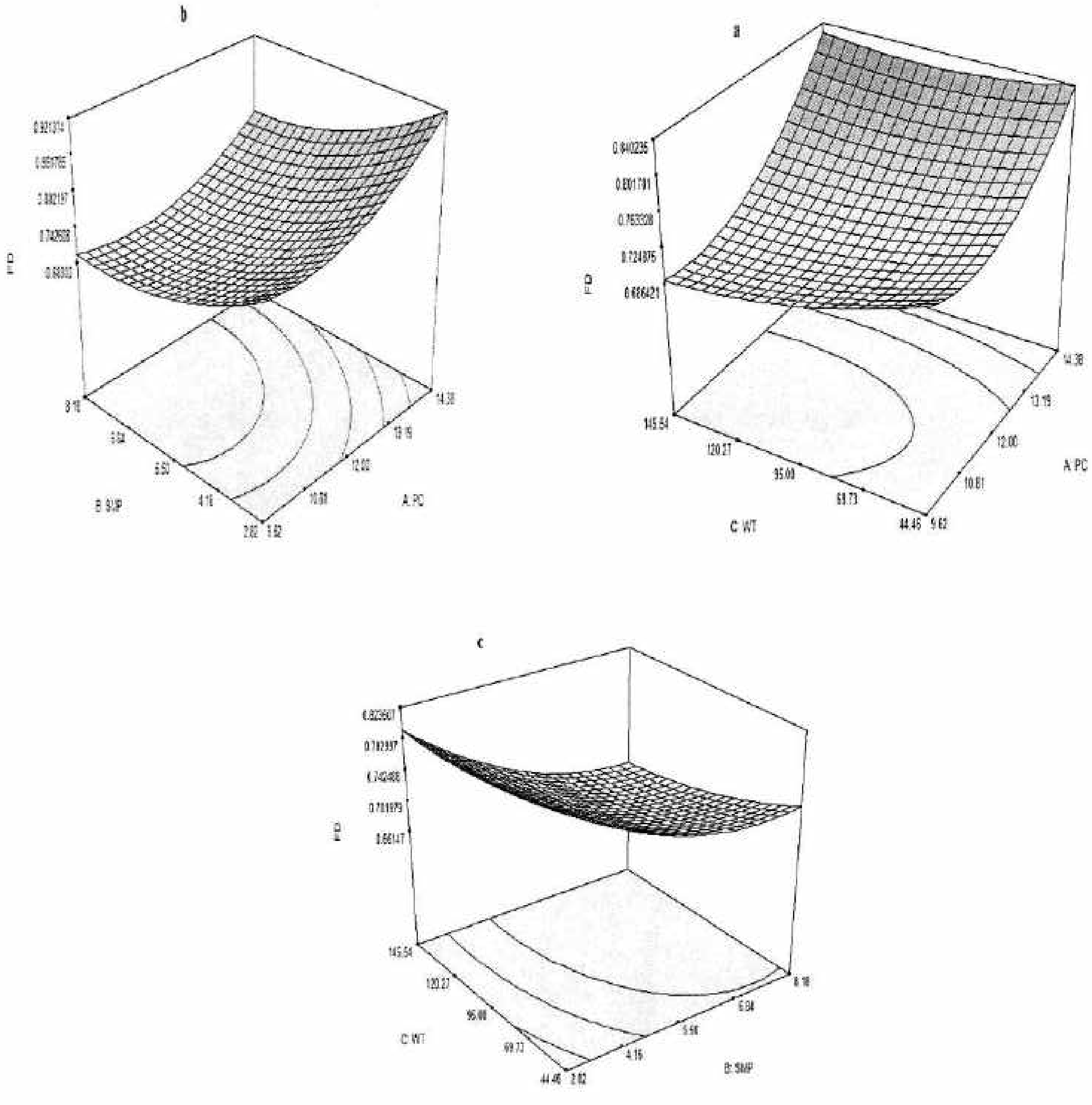


Fig 19: 3D plots showing a) effect of time and pulp TSS on FD b) effect of SMP and pulp TSS on FD c) effect of time and SMP on FD.

Drainage volume (DV):

Water holding capacity of foam can be represented by drainage volume(DV). Measuring the rate of liquid draining out of the foam is one method to determine the stability of foam (Kampf*et al.* 2003). The liquid is entrapped between the thin films and plateau borders. Plateau border suction that is difference between the pressure of thin film and plateau border, is responsible for the drainage of liquid from thin film to plateau border. Finally, all the liquids between the bubbles are drained off due to action of gravity (Narsimhan 1991).

During the drainage, probability of film collapse increases due to progressive thinning of lamellae (Durian and Weitz, 1994). Increase in drying time and reduction in product quality may occur due to excessive drainage or breakage of foam. For the present study, drainage volume varies from 9.09 to 63.63 ml. From the ANOVA result (table 11), it can be observed that linear terms pulp TSS (x_1) and SMP (x_2) has significant effect on DV at 1% and 0.1 % level respectively. Lack of fit is not significant of the developed model, whereas coefficient of determination (R^2) value is 0.9006. It shows the accuracy of the developed drainage volume (DV) model.

The final equation for showing the effect of different independent variables on the drainage volume (DV) can be given as:

$$\mathbf{DV=+29.12-7.06* x_1+12.94* x_2+2.21* x_3-3.56* x_1^2+2.64* x_2^2+0.63* x_3^2-1.26* x_1 * x_2-0.47* x_1 * x_3- 0.47* x_2 * x_3}$$

Where, x_1 is pulp-TSS (^{0}Brix); x_2 is SMP (%); x_3 is time (sec); FD is foam density (gm/cm^3)

From the equation it can be observed that pulp-TSS (x_1) has negative effect on DV, whereas SMP (x_2) has positive effect on DV. It indicates that drainage volume decreases with the increase of pulp TSS but increases with the increase of SMP. Whipping time (x_3) does not have any significant effect on DV. The variation of DV with respect to different independent variables can also be explained with the help of 3D plots.

Figure 20 (a)represents the effect of pulp TSS and SMP on drainage volume. It is observed that pulp TSS has a decreasing effect on DV, whereas SMP has an increasing effect on DV.Figure 20 (b) shows the effect of pulp TSS and whipping time on DV. In this figure, same decreasing effect of pulp TSS on FD can be observed. From figure 20 (c), once again increasing effect of SMP on DV can be observed. In both the figures, whipping time (WT) does not show any significant effect. The decreasing effect of pulp TSS may be due to the reason that higher concentration of pulp TSS increases the foam stability, which results in higher foam density. As a result of which DV volume gradually decreases with the increase of pulp TSS. Bag*et al.* (2011) showed similar decreasing effect of pulp concentration on the drainage volume (DV).Besides that, Falade*et al.* (2003) also reported that increasing effect of total solid content of the food material on the foam stability enhancement.

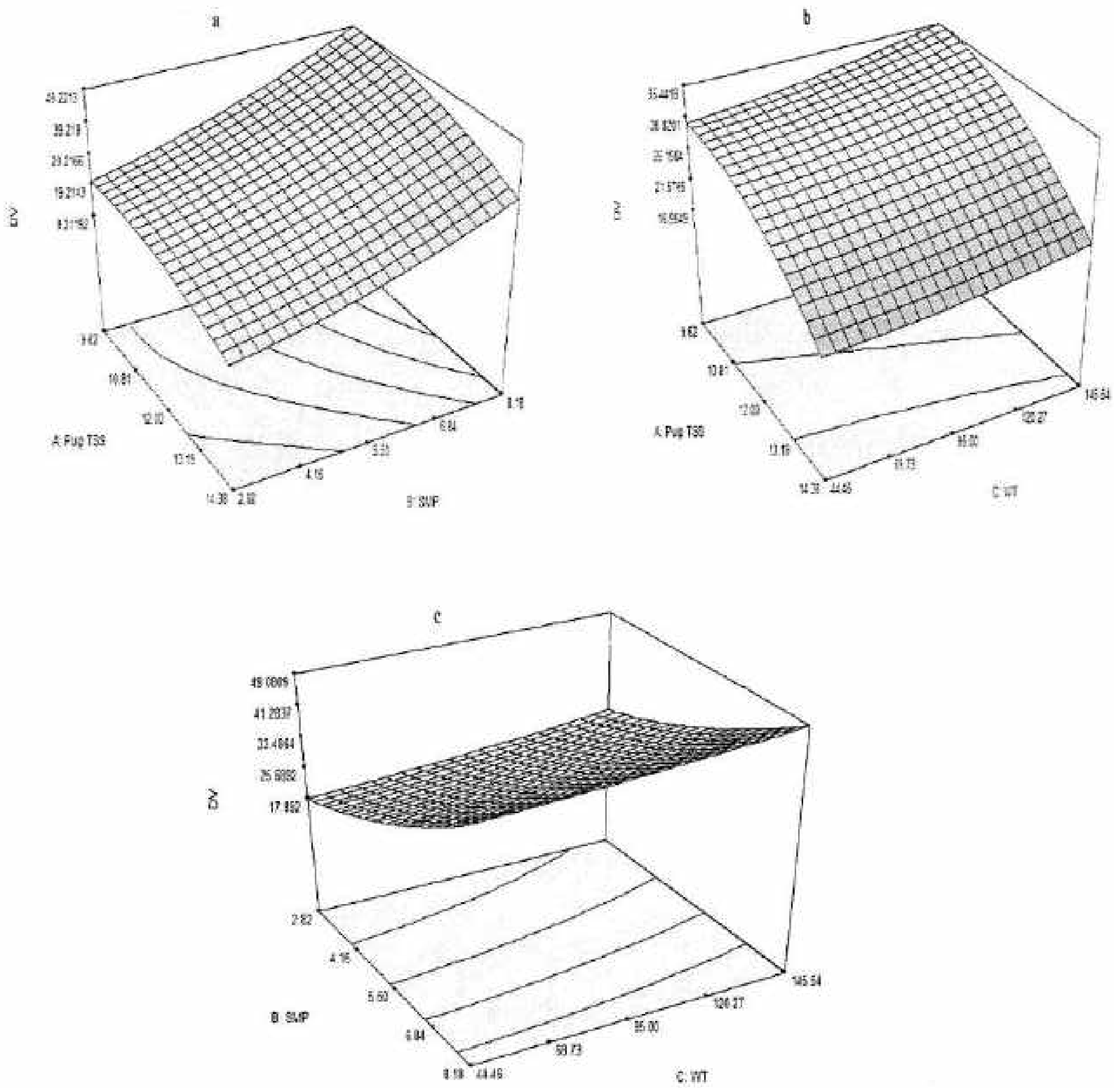


Fig 20: 3D plots showing a) effect pulp TSS and SMP on DV b) effect of pulp TSS and whipping time (WT) on DV c) effect of whipping time (WT) and SMP on DV.

Foam expansion (FE):

Foam expansion is an important parameter for describing the foaming property. In the foam expansion, entrapment of air in the foam is a substantial consideration. It is closely related to the foam density. If the foam density is high, less air will be trapped in the foam, whereas low density of foam allows more air to entrap in the foam. So, less density is preferable for the higher foam expansion rate. In the present study, foam expansion varies from 0 to 21%. From the ANOVA result (table 11), it can be obtained that linear term of pulp TSS and SMP has a significant effect on foam expansion (FE) at 1% and 5% level respectively. The quadratic terms of pulp TSS and SMP are significant at 0.1% and 1% level respectively. Excluding these, rests of the terms are not significant. The value of coefficient of determination (R2) is 0.8726, whereas lack of fit of the model is not significant. These results show the accuracy of the developed model.

The final equation for showing the effect of different independent variables on the foam expansion (FE) can be given as:

$$FE = +17.73 - 3.37 * x_1 + 2.68 * x_2 - 0.83 * x_3 - 5.63 * x_1^2 - 3.69 * x_2^2 - 0.33 * x_3^2 + 0.75 * x_1 * x_2 + 0.25 * x_1 * x_3 + 1.25 * x_2 * x_3$$

From the equation, it can be observed that pulp TSS has negative effect on FE, wheereas SMP has positive effect on FE. It means foam expansion (FE) decreases with the increase of pulp TSS but incraeses with the increase of SMP. Whipping time (WT) does not have any significant effect on FE.

The interaction effect of three independent variables is represents by Fig 21 (a) shows the effect of pulp TSS and SMP on the foam expansion (FE).From the figure, it can be observed that pulp TSS has decreasing effect on FE, whereas SMP has increasing effect on FE. The decrease in foam expansion(FE) with the increase of pulp may be due to the reason that higher concentration of pulp increase foam density which leads to incorporation of less air in the foam resulting in less foam expansion. On the onther end, increase in SMP, creates low density of foam resulting in entrapement of more air in the foam. As a result of which, higher value of SMP leads to greater foam expansion (FE). Same results has been shown by Bag*et. al*.(2011) in terms foam density (FD).Figure 21 (b) represents the effect of pulp TSS and whipping time on FE. In this figure, same decreasing effect of pulp TSS on FE can be observed. From figure 21 (c), once again increasing effect of SMP on FE can be observed.

Optimization and validation of foaming properties:

Optimization of foaming properties of Bhimkol on the basis of different independent variables (pulp TSS, Skim milk powder and whipping time) was done in order to obtain minimum foam density and drainage volume and maximum foam expansion. Optimization can be done by adopting several methods. One method is overlapping çounter plots, whereas finding optimized condition on the basis of desirability function is another important method (Park and Cheung,1997). In the present study, optimization was done on the basis of desirability function. The optimized conditions for the Bhimkol foaming are shown in table 4. For the validation, an experiment of Bhimkol foaming was again carried out at the optimized conditions obtained from RSM (response surface methodology) shown in Table: 12.

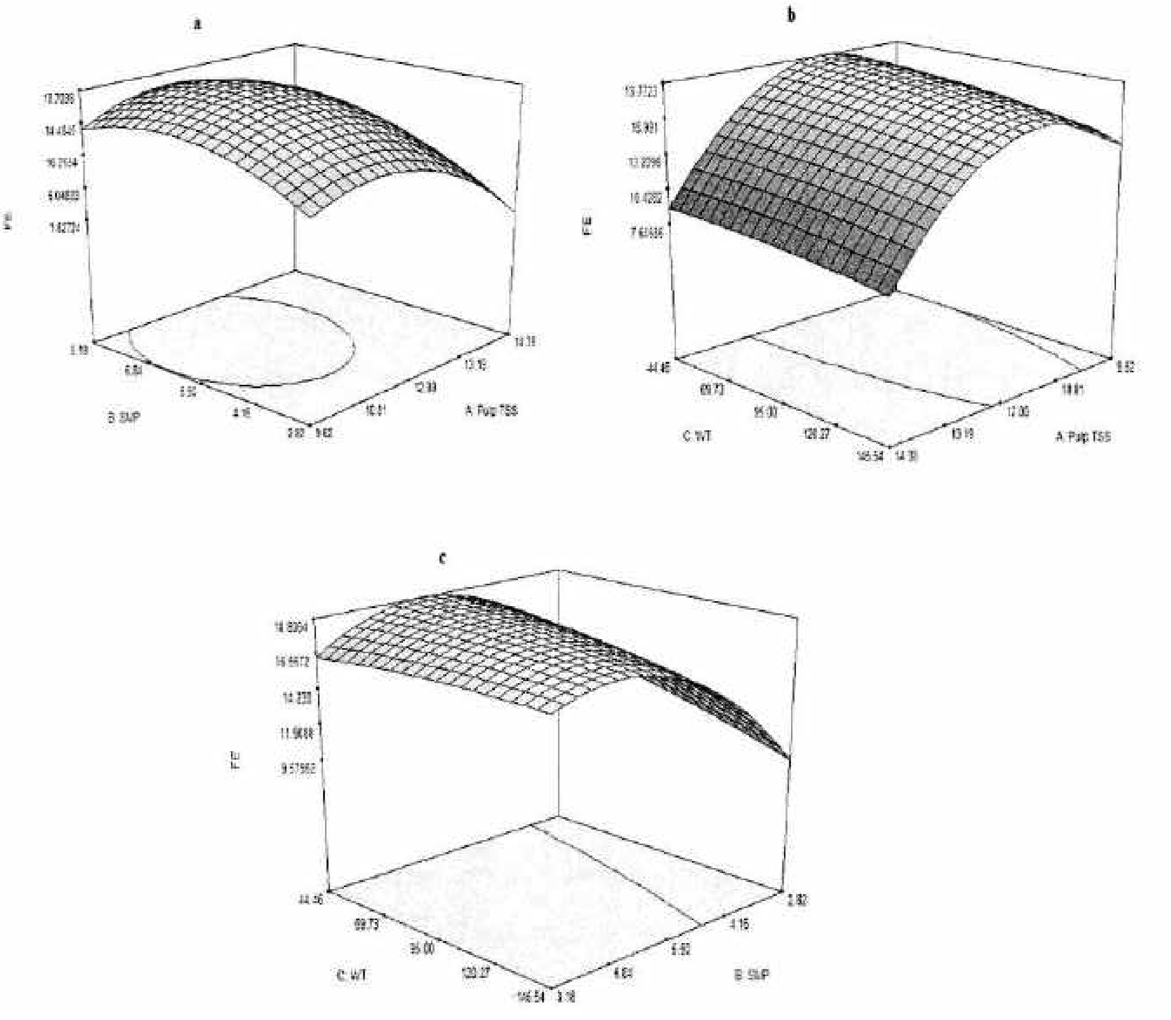


Fig 21: 3D plots showing a) effect pulp TSS and SMP on FE b) effect of pulp TSS and whipping time (WT) on FE c) effect of whipping time (WT) and SMP on FE.

Table 12: Optimized condition of Bhimkol foaming

Pulp TSS(^{0}Brix)	**SMP (%)**	**WT (Sec)**	**FD(gm /cm3)**	**DV (ml)**	**FE (%)**	**Desirability**
9.62	8.18	130.00	0.668	51.342	13.669	0.62

Objective 2.2: Material Balance for powder making process

Ripe Bhimkol fruit
(100 fruits/ wt-15 kg) (MC-74-76%)

↓ → Peeling (2.5 kg)

Peeled fruit (12.50 Kg) (TSS: 18-24°B)

↓

Slicing (10 mm)

↓

Thermal treatment with hot water
(Water ((@64-70g/100g) Added water: 8.5 kg

↓

Pulping or deseeding with hot water

↓ → Seed and other wastage (20%) (2.5 – 2.75 kg)

Pulp (14-16°B) (18.5 kg)

↓

Standardization of pulp (TSS: 9.6°B) ← Water (25g/kg pulp) (4.6 kg)

↓

Addition of SMP followed by mixing & foaming
(SMP: 81-83 g/kg of standard pulp) (Mixing & Foaming: 2-2.5 min)
Total pulp wt: 25kg with TSS: 12-13%

↓

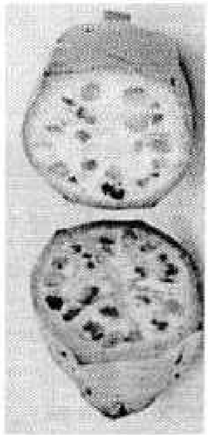
Hybrid/ Combination drying (Hot air—Vacuum – dehumidified air)
Temp: 50°C - 50°C – 40°C; Time: [5h+3h+2h=10h]

↓

Grits / Powder (MC: 7-8%) (wt: 3.50 kg)
Quality: Free flowing; Low density; White color & Solubility etc.

↓

Packaging & Storage



Objective 2.3 To produce Bhimkol powder by using tray: foam mat drying and measure the physical properties and drying rate at 50^0C.

Optimization of quality characteristics of Bhimkolpowder:

Table: 13 Experimental design and analysis

Experiment No	A:pulp TSS	B:SMP	C:WT	HY	SI	BD	WI	FMC at 10 h
1	%	%	Sec	%	%	g/cc	%	%
2	9.62	2.82	145.54	26.17	20.54	0.46	17.92	0.03
3	16.00	5.50	95.00	21.24	21.23	0.52	20.48	0.26
4	12.00	5.50	95.00	24.02	23.63	0.50	22.23	0.05
5	14.38	2.82	44.46	22.38	23.27	0.60	25.39	0.25
6	12.00	5.50	95.00	22.82	22.53	0.47	23.33	0.12
7	9.62	8.18	145.54	20.21	23.78	0.45	18.57	0.00
8	12.00	5.50	95.00	22.62	23.73	0.45	23.13	0.07
9	12.00	5.50	95.00	22.62	23.73	0.43	21.84	0.03
10	12.00	5.50	180.00	25.28	22.81	0.48	17.91	0.08
11	12.00	5.50	10.00	26.15	23.72	0.39	24.89	0.13
12	12.00	1.00	95.00	25.96	25.21	0.75	29.70	0.21
13	9.62	2.82	44.46	23.94	20.60	0.50	23.27	0.08
14	9.62	8.18	44.46	18.65	22.00	0.52	19.01	0.02
15	14.38	8.18	44.46	24.09	21.73	0.45	22.81	0.29
16	8.00	5.50	95.00	20.86	19.77	0.52	15.65	0.04
17	14.38	8.18	145.54	22.21	22.85	0.48	22.20	0.20
18	12.00	5.50	95.00	23.97	22.93	0.51	21.83	0.09
19	14.38	2.82	145.54	21.18	22.54	0.55	19.87	0.09
20	12.00	10.00	95.00	21.20	25.55	0.44	25.08	0.01

The graphical representation of physical and functional properties:

1) Hygroscopicity (HG):

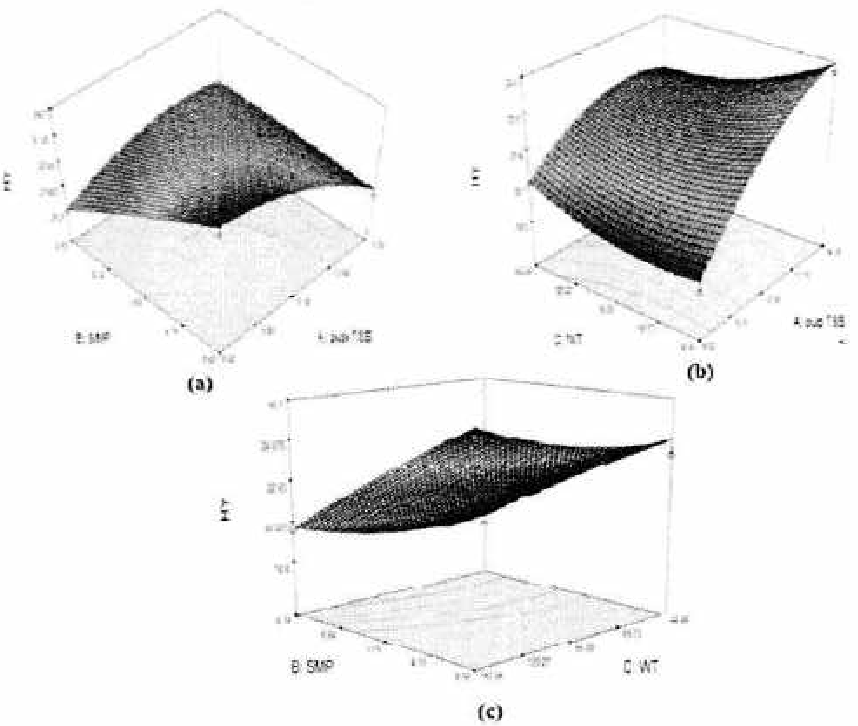


Fig: 22 Graphical representation of hygroscopicity

The influence of pulp TSS on hygroscopicity was significant. As the plot shows, increase the pulp TSS with increase the hygroscpicity. This effect may be due to increasing the low molecular sugar which is already available in pulp. During increasing the total soluble solids of Bhimkolpulp, increasing naturally available low molecular weight sugar such as glucose, fructose and sucrose.Jaya*et al.* 2006 also reported glucose, fructose and sucrose is very hygroscopic in amorphous state. The influence of whipping time on hygroscopicity was insignificant. According to plot the increasing the whipping time responsible for decreasing the hygroscopicity.The influence of SMP concentration on hygroscopicity was insignificant. The increasing the concentration of SMP with decreasing the trend of hygroscopicity was found. This effect may be due to denaturation of protein increasing with increasing mechanical action during increasing whipping time. The researcher reported that during denaturation of protein, breakage of hydrogen bonds or cross linking of the protein are take place leads to hydrophobic nature of surface increased. The breakage of hydrogen bonds or cross linking of protein decreasing there interaction of water.

2) Solubility (SOL):

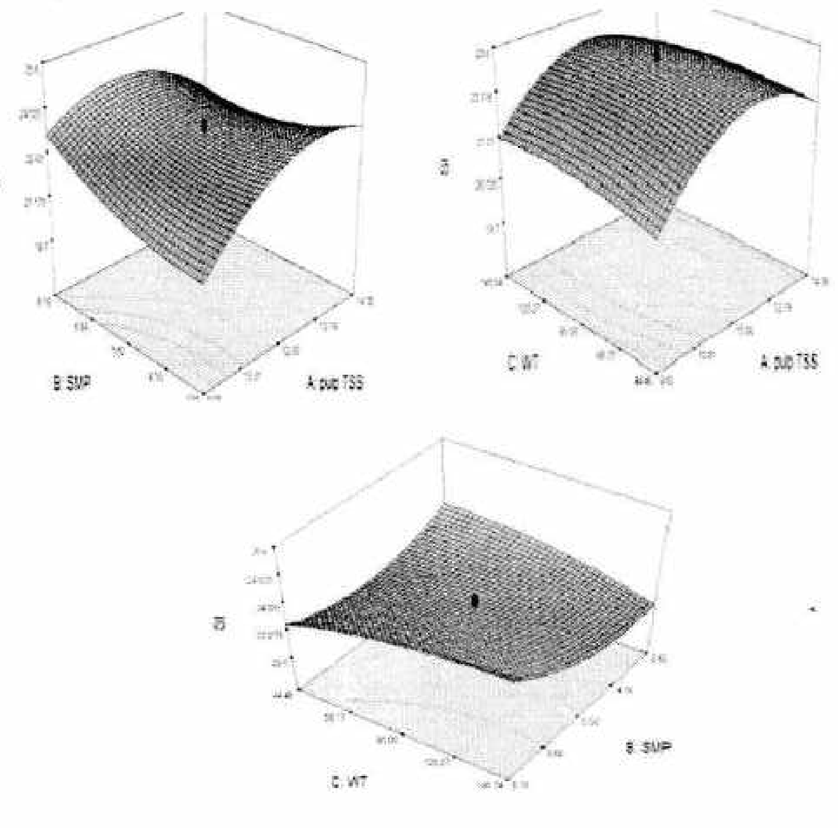


Fig:23Graphical representation of Solubility

3) Bulk density (BD):

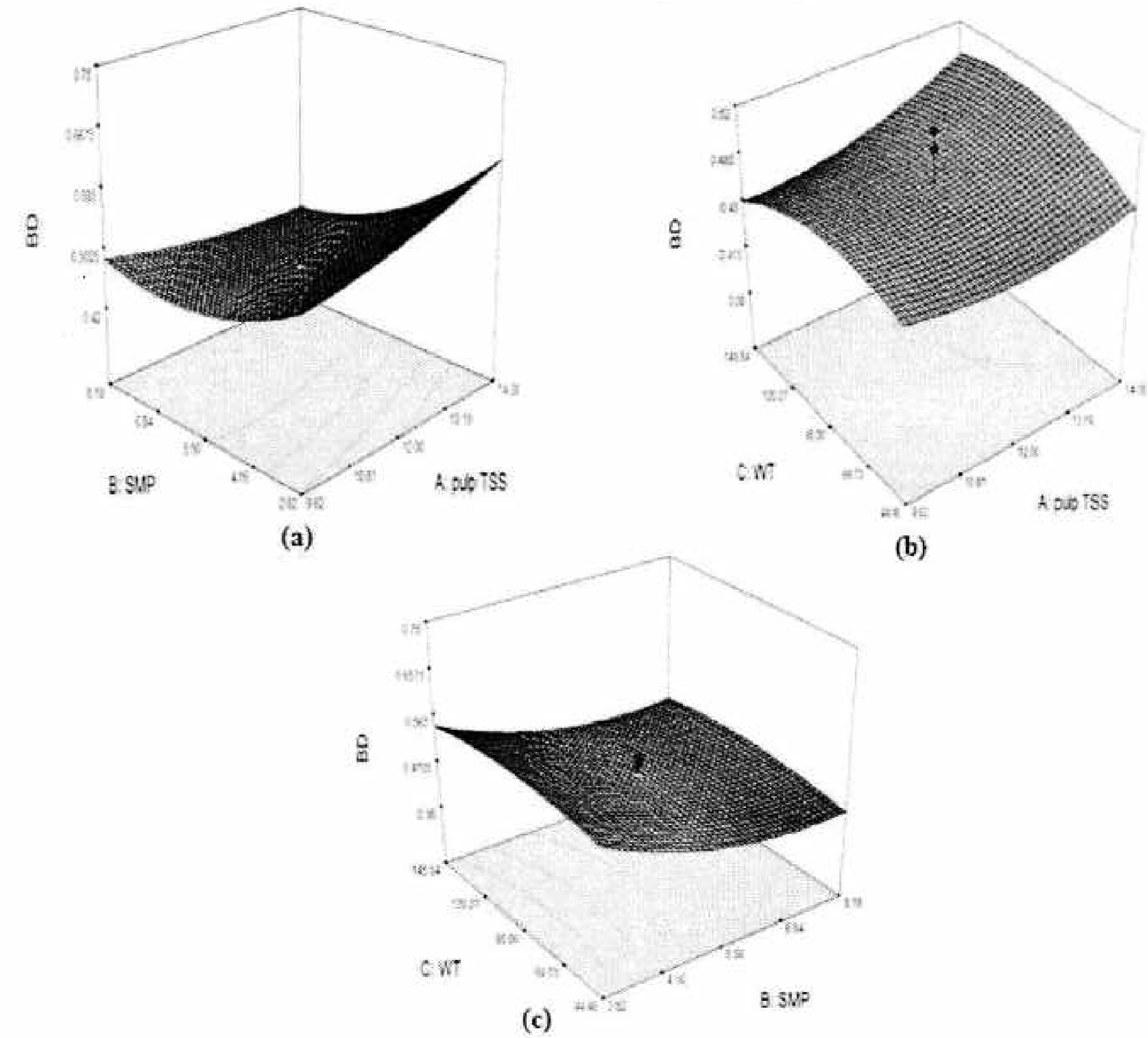


Fig: 24Graphical representation of Bulk density

The influence of PC, SMP and WT was found insignificant on bulk density. The graph shows that increasing the pulp TSS with increasing bulk density. This may be due to increasing solid content of powder. then graph shows the increasing whiping time with increasing bulk density of powder. this result may be due to the collase of foam during denatration. The graph shows the increasing the concentration of SMP leads to decreasing the density of powder. decreasing tend was found due the foaming protien occupied the air and helps to rduce density of powder.

The influence of Pulp TSS on whitening index was found insignificant. The graph represents the increase the whitening index with respect to increasing the pulp TSS. The influence of SMP on WI was observed significant. The increasing with increase the whitening index was observed. The same effect was observed by whipping time.

The increasing the SMP and WT, decrease the whitning index. White-yellowish colour of milk and increasing glass transition temperature of sample responsible for decreasing trend of whitning index. Here, minimal whitnng index is better becouse it was considered by comparing colour of unfoamed sample.

4) Whitness index (WI):

Whitning index determine the acceptability of product by consumer. The low whitning index as compare to control shows the maximum acceptability. There was increasing SMP and decreasing TSS affect on possitive effect on whitning index. TSS and Time also shows the effect on whitning index of final product. The increasing Time and decreasing TSS also shows the good effect on whitning index.

5) Moisture content (MC):

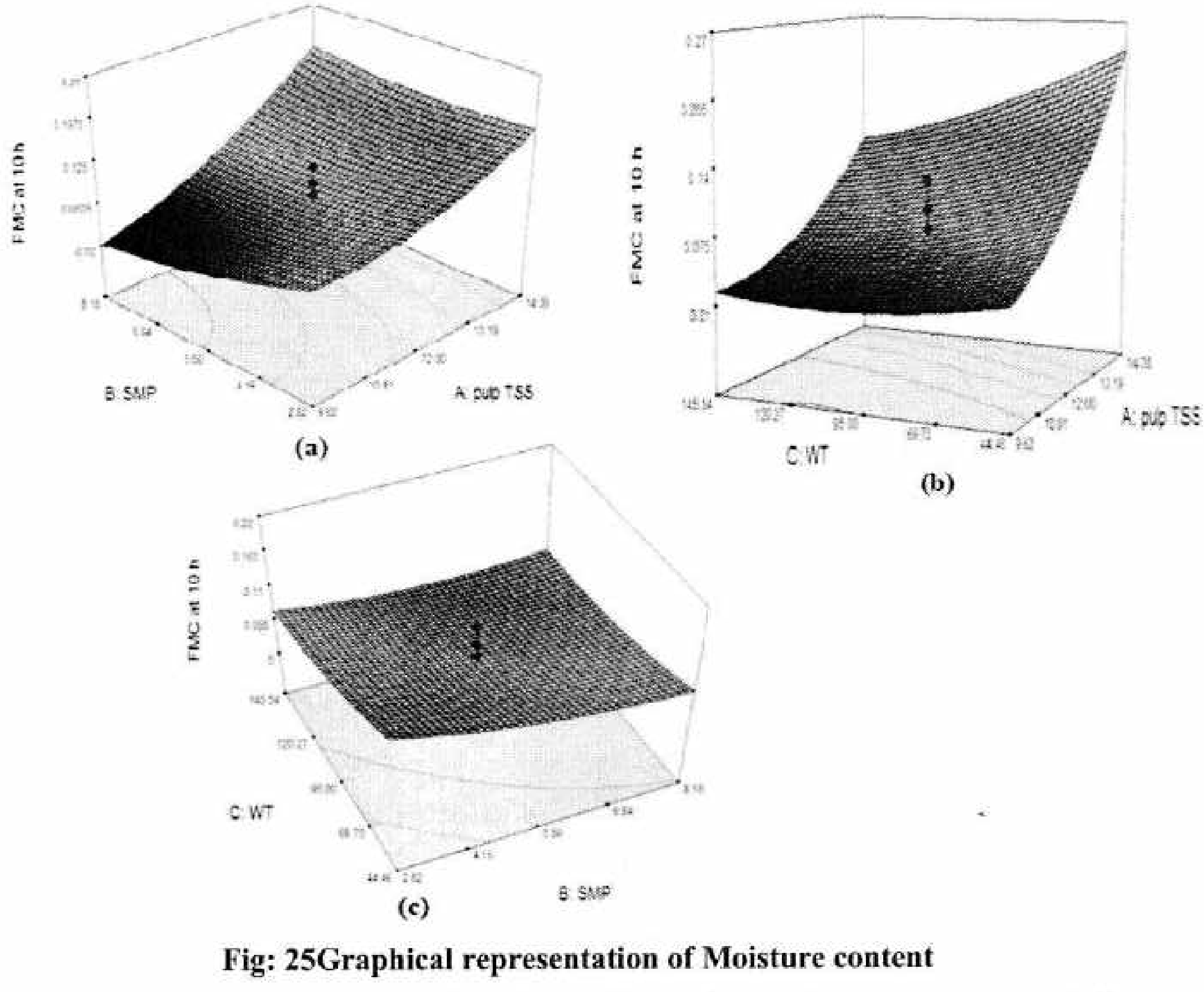


Fig: 25Graphical representation of Moisture content

The influce of pulp TSS on FMC shows insignificant, the graphical representation indicate the increase the pulp TSS with increase the FMC. The effect of SMP and WT also found insignificant. The influence of whiping time and SMP concentration was seen insignificant. The decreasing FMC content trend was observed with increasing SMP concentration. The whiping time also shows the insignificant effect on FMC. The increasing WT responsible for the decreasing FMC was seen in graphical representation. This effect due to increasing protien content generate when increasing the SMP. Then increasing whiping time responsible for increase air incorporation leads to increase surface area. Increasing surface area of foam resulting higher moisture loss.

Objective 2.4: To see effect on structural and morphological behavior by using powder XRD and SEM respectively.

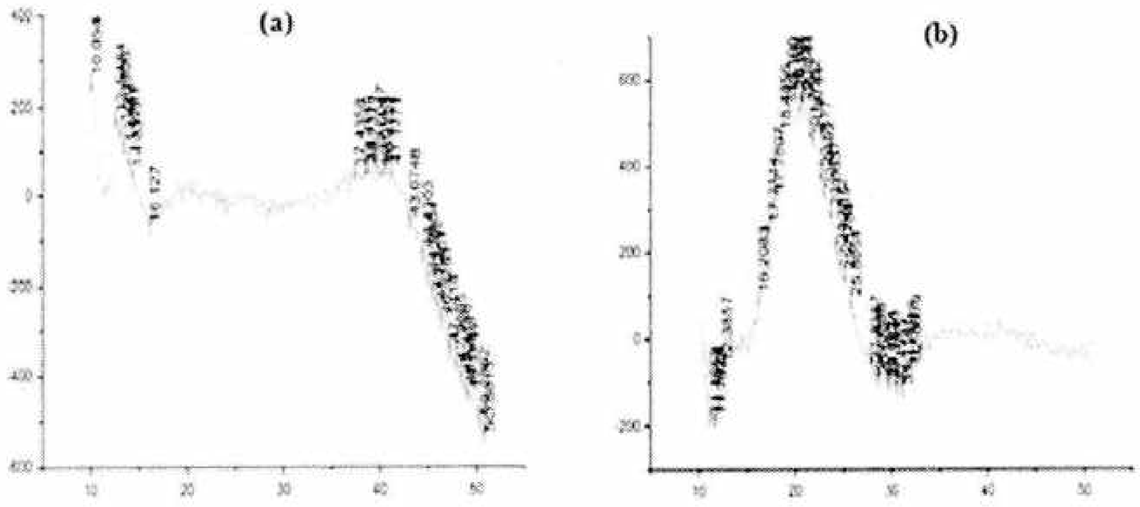
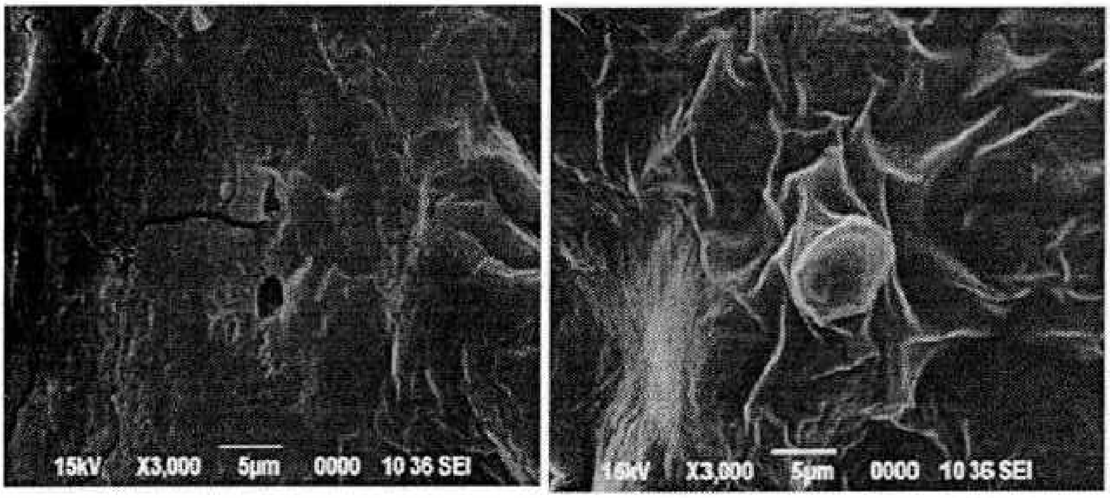


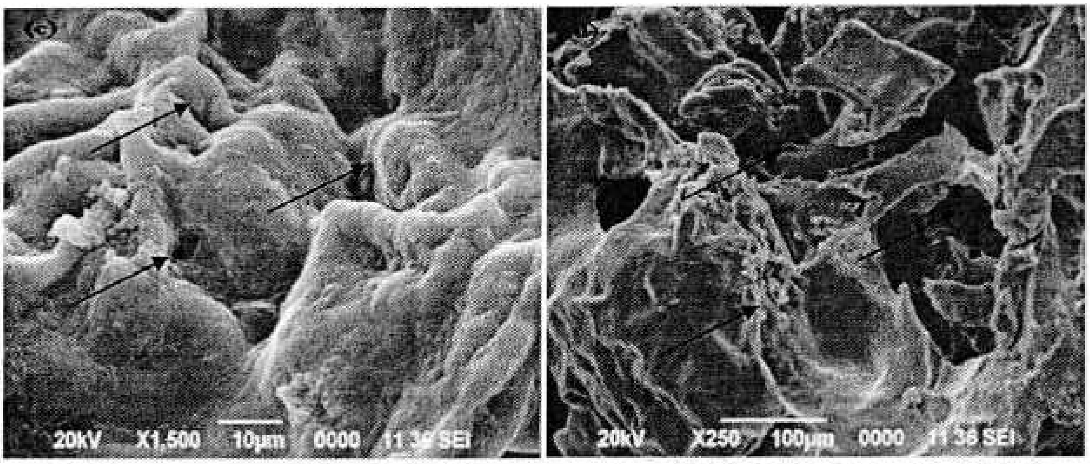
Fig:26 XRD of Bhimkol powder: (a) Control (b) Optimized foam dried sample

The X-ray diffraction is a common technique used to confirm the crystalline–amorphous state of dried products in a powder form. The analysis by X-ray diffraction showed the presence of diffused and large peaks containing amorphous material due to the fact that in the amorphous state the molecules were disorderly displayed, producing disperse bands whereas crystalline materials yielded sharp and defined peaks, since they were presented in a highly ordered state (Cano-Chauca*et al.* 2005). The X-ray diffraction spectrum showed the presence of many rustling and peaks without definition or uniform behavior, which was not characteristic of crystalline samples. The presence of amorphous material could be due to the fact that during the drying process, the material did not crystallize because the lactose had high molecular weight and high viscosity that increased the glass transition temperature, turning the surface amorphous.Gurak*et al.* 2013 also observed same trend when maltodextrine added dried grape juice powder. Cano-Chauca*et al.* 2005 reported that crystalline nature take place in such type of powder when temperature above glass transition. There is minimal time of drying resulting insufficient time to convert amorphous to crystalline nature of presented low molecular weight sugar in Bhimkol pulp. The diffractogram of freeze-dried mango powder obtained in this study was similar to the one reported by Harnkarnsujarit and Charoenrein (2011).

Scanning electron microscope of Bhimkol powder:



SEM image of dried Bhimkol pulp: a) Dried in P_2O_5 and b) dried in tray dryer at 50°C at 3000 magnification.



SEM image of tray dried optimized foamed sample at 50°C. (c) 1500X and (d) 250 X magnifications.

Fig: 27 Microstructure of the Bhimkol powder.

The effect of foaming and tray drying was observed on the microstructure of the Bhimkol powder. Tray dried foamed Bhimkol pulp shows puffy porous structure figure27 (c) at 1500x magnification. The appearances of powder are irregular fluffy shapes and porous holes indicate the high porosity. The figure27 (d) shows the skeletal-like structure with high porosity and stretched pore shape. Incorporation of air may be responsible for fluffiness and porous structure in figure c and d. The similar results are observed in foam freeze dried apple powder by Jakubczyka*et al*. 2011.The bulk density of powder reduced which may be due to the air trapped during homogenization of pulp. The void space of air may be responsible for thin dried flakes. Balaswamy*et al.* 2016 suggested similar reason in case of foamed muskmelon tray dried powder. The figure 27 (a) and (b) shows less porous structure as compare to figure27 (c) and (d). The compact and high shrinkage nature shows more in tray dried sample than the sample dried in P_2O_5. This may be due to the application of heat during drying. Jakubczyka*et al.*(2011) also obtained similar result in non foamed apple powder.

Objective 3: To study the storage stability of produced banana powder and grits.

The storage study of Bhimkol powder was carried out on different temperatures and packaging materials. The phycochemical changes were observed up to 20 days.

Table: 14 Storage study of Bhimkol powder by using Polypropylene zip bag.

Storage study of Bhimkol powder							
Storage week		0	4	8	12	16	20
Parameter/ Packaging material/Temperature (°C)		PP	PP	PP	PP	PP	PP
MC (%)	10	7.954	10.985	11.959	11.601	11.959	12.126
MC (%)	20	7.954	10.202	12.705	11.958	12.392	12.623
MC (%)	30	7.954	10.039	9.105	10.083	10.794	11.341
MC (%)	40	7.954	11.240	12.252	14.243	16.264	16.382
WA	10	0.320	0.409	0.4141	0.420	0.444	0.446
WA	20	0.320	0.384	0.407	0.413	0.437	0.453
WA	30	0.320	0.375	0.392	0.403	0.434	0.437
WA	40	0.320	0.399	0.470	0.572	0.611	0.661
SI (%)	10	20.316	19.389	22.133	26.766	24.639	21.56
SI (%)	20	20.316	14.25	20.932	26.933	21.898	19.23
SI (%)	30	20.316	13.937	29.557	22.977	22.035	24.52
SI (%)	40	20.316	18.987	22.844	24.622	25.890	25.243
WHC (%)	10	42.56	46.599	55.373	67.771	107.81	111.32
WHC (%)	20	42.56	58.794	47.777	68.75	71.567	89.23
WHC (%)	30	42.56	83.262	69.357	81.80	80.281	92.31
WHC (%)	40	42.56	64.226	35.780	116.92	127.63	112.36
BD (gm/cc)	10	0.429	0.456	0.537	0.546	0.566	0.583
BD (gm/cc)	20	0.429	0.462	0.473	0.548	0.562	0.584
BD (gm/cc)	30	0.429	0.498	0.532	0.582	0.596	0.594
BD (gm/cc)	40	0.429	0.475	0.477	0.585	0.646	0.668
FWT (HR)	10	1.161	1.167	1.182	1.185	1.182	1.187
FWT (HR)	20	1.161	1.173	1.173	1.188	1.190	1.195
FWT (HR)	30	1.161	1.187	1.212	1.204	1.232	1.236
FWT (HR)	40	1.161	1.195	1.227	1.236	1.243	1.263
MC= Moisture content; **BD**= Bulk density; **FWT** (HR) = Flowability (Harsher ratio); **SI**=Solubility Index; **WA**=Water activity; **WHC**=Water holding capacity.							

The Table 14 and 15 represent the physico chemical changes in Bhimkol powder packed in PP and ASP respectively. The moisture content of powder stored at 10°C and 20°C did not show drastic increase in PP and ASP. A low bulk density and high flowability was observed at 10°C in both packaging material. There was slight changes in bulk density and flowability in PP at 20°C. However, higher bulk density and low flowability was observed at 30 and 40°C due to increase in moisture in both packaging material. The water activity was minimal at 10 and 20°C minimal whereas it increased at 30 and 40°C. Solubility of stored sample in PP was found minimal up to 4 days. The solubility of stored sample in ASP was observed similar during the storage period when compared to PP. This is may be due to the lower permeability of ASP. The WHC of stored sample was found maximum at 30and 10°C in PP and ASP respectively. Colour change has been observed during the storage and browning was observed at 30 and 40°C which may be attributed to the maillard reaction at high temperature.

Table: 15 Storage study of Bhimkol powder by using aluminum sealing pouch

Storage study of Bhimkol powder							
Storage study		0	4	8	12	16	20
Parameter/ Packaging material/Temperature		ASP	ASP	ASP	ASP	ASP	ASP
MC (%)	10	7.954	7.954	8.950	9.450	9.895	9.563
MC (%)	20	7.954	7.442	9.286	9.371	9.863	9.871
MC (%)	30	7.954	9.3609	9.740	9.812	9.912	10.416
MC (%)	40	7.954	8.500	9.832	12.59	13.40	13.506
WA	10	0.320	0.315	0.377	0.392	0.412	0.413
WA	20	0.320	0.327	0.333	0.387	0.391	0.424
WA	30	0.320	0.338	0.382	0.384	0.390	0.521
WA	40	0.320	0.335	0.416	0.501	0.596	0.598
SI (%)	10	20.316	25.908	26.279	26.112	23.046	24.678
SI (%)	20	20.316	23.447	22.979	24.304	22.035	23.589
SI (%)	30	20.316	21.846	26.817	24.773	19.441	19.643
SI (%)	40	20.316	26.860	18.358	21.837	18.385	22.364
WHC (%)	10	42.56	56.321	66.315	92.190	125.19	139.23
WHC (%)	20	42.56	80.779	78.683	50.380	91.397	99.34
WHC (%)	30	42.56	65.146	62.921	68.313	66.325	86.21
WHC (%)	40	42.56	72.923	81.838	83.779	89.009	94.56
BD (gm/cc)	10	0.429	0.444	0.459	0.518	0.541	0.546
BD (gm/cc)	20	0.429	0.478	0.463	0.529	0.545	0.547
BD (gm/cc)	30	0.429	0.480	0.468	0.534	0.552	0.551
BD (gm/cc)	40	0.429	0.529	0.569	0.602	0.626	0.631
FWT (HR)	10	1.161	1.155	1.168	1.166	1.179	1.170
FWT (HR)	20	1.161	1.163	1.179	1.180	1.189	1.190
FWT (HR)	30	1.161	1.179	1.188	1.191	1.194	1.194
FWT (HR)	40	1.161	1.198	1.201	1.217	1.232	1.248
MC= Moisture content; **BD**= Bulk density; **FWT** (HR) = Flowability (Harsher ratio); **SI**=Solubility Index; **WA**=Water activity; **WHC**=Water holding capacity.							

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10. Detailed analysis of results indicating contributions made towards increasing the state of knowledge in the subject:

The present study on Bhimkol revealed some unknown facts about the physico chemical properties of the fruit. The weight of individual fruit varies from 140-150g. The whole comprises of approximately 20% peel, 20-25% seed and central core rest share to the pulp. The initial moisture content of pulp ranges between 70-78% depending upon their maturity. The fruit is rich in simple sugars such as glucose, sucrose, fructose and minerals.

The powder making process depends on the appropriate maturity of the fruit. In the present study, the optimum level of maturity was determined pertaining to powder making process. Enzymatic browning is one of the major causes of quality deterioration in fruits and vegetables. Thermal treatment were designed and tested to inactivate the enzymes present in the fruit for better quality during storage of powder.

The seed spread over the whole fruit is one of the limitations in pulping operation of the fruit. Simultaneously the moisture content of the fruit was not found suitable for pulping operation. Therefore, the existing fruit pulper was modified to spray the hot water during the pulping operation. This modification resulted in higher pulp recovery and low wastage during pulping operation.

Banana being a high sugar fruit could not be dried normally with hot air. It is well known that moisture removal become tough as drying proceeds. To maintain a desired drying rate, a combination/hybrid drying was proposed in present study. Initial phase of drying needs less energy due to availability of abundant free water. Hot air drying was employed to remove this free water. As drying proceeds moisture available in bound form needs more driving force. Thus the second phase of drying was shifted to vacuum drying to maintain the desired drying rate. Final/finishing stage of drying is more dependent on a slow rate process i.e. diffusion. Thus final/finishing stage was performed in dehumidifier chamber to bring down the moisture of fruit pulp as low as 7%.

Foam mat drying was applied to dry the banana pulp. Foaming conditions were optimized based on the foam characteristics. Skim milk powder was added as a foaming agent and also to increase glass transition temperature to felicitate drying at elevated temperature. This banana foam was dried as per the procedure developed for hybrid drying. A good quality banana powder was produced in terms of colour and flowability.

The storage study of this powder under different temperature conditions was found stable for 3 months.

The main achievement of this project was development of pilot scale processing technology for Bhimkol powder using hybrid drying methods.

11. Conclusions summarizing the achievements and indication of scope for future work:

- ✓ Optimum ripening stage of the fruit was identified for powder making.
- ✓ Process technology at pilot scale (deseeding, pulping, enzyme inactivation, foaming and drying) for production of banana powder was developed.
- ✓ Approximate 3.5 kg powder with 7% (MC) was produced from 15 kg (100 Nos) fruit.
- ✓ The powder was free flowing, lighter and acceptable color with good sensory results.
- ✓ The powder stored in aluminum foil packets retains better quality when stored at room temperature (25°C)
- ✓ In future aspect, this technology can be applied for preparation of powder from mango, banana, tomato etc.

12. S&T benefits accrued:

i. List of Research publications

Sr No	Authors	Title of paper	Journal Name	Volume	Pages	Year
	Papers in conference proceeding					
	Presented a paper in National conference at North Eastern Regional Institute of Science and Technology, Nirjuli on titled thin layer drying study and moisture diffusivity of Bhimkol pulp in hot air drying dated on 8th 9th November,2015					
	Presented a paper in National conference at Tezpur Central University, Tezpur, Assam titled on comparative study of different pulping operation for Bhimkol fruit dated on 27th-28th March 2015.					
	Presented Poster National conference at OUAT, Bhuvneshwar, Odisha, titled on Effect of thermal treatment and holding time on polyphenoloxidase, and catalase activity in Bhimkol (*Musa balbisiana*) dated on 21-24 January 2016.					
1	RiteshWatharkar and Brijesh Srivastava*	Studies on physico-chemical and mechanical changes during advanced maturity stages of Bhimkol*(Musa balbisiana vs.* BB*)*	Engineering in Agriculture, Environment and Food	communicated	------	------
2	RiteshWatharkar, SourabhChakrborthy and Brijesh Srivastava*	Optimization of process parameters for foaming of Bhimkol (*Musa balbisiana*) Fruit pulp.	Journal of Food Process Engineering	communicated	-------	------
3	Ritesh B. Watharkar , Brijesh Srivastava*, Sourav Chakrabortry, Prasanna Kumar G.V.	Application of a general code developed in MATLAB and master curve technique for the thin layer drying kinetic analysis of wild Banana *(Musa balbasiana)* Pulp	Journal of Food Process Engineering	To be communicated		

ii. Manpower trained on the project

a) Research Scientists or Research Associates: Nil
b) No. of Ph.D. produced: **One (Continuing)**
c) Other Technical Personnel trained: Nil
d) Patents taken, if any: N/A

13. Financial Position:

No	Financial Position/ Budget Head	Funds Sanctioned (Lac.)	Expenditure (Lac.)	% of Total cost
I	Salaries/ Manpower costs	4.714	4.714	100
II	Equipment	29.00	28.999	99.99
III	Supplies & Materials (Consumables)	2.00	1.97	98.50
V	Travel	0.60	0.60	100
VI	Overhead Expenses	0.0	0.0	0.0
	Total	36.31	36.28	99.62

14. Procurement/ Usage of Equipment: a)

Sr. No	Name of Equipment	Make/Model	Cost (FE/ Rs)	Utilization Rate (%)	Remarks regarding maintenance/ breakdown
1	Vacuum Tray dryer with Accessories viz. Vacuum pump; HW generator; condenser; Receiver; Steam C V etc.	Newtech Equipment, Mumbai/ VTD-12	1109400.00	100	Nil
2	Tray dryer	-Do-	266000.00	-Do-	Nil
3	Pulper	-Do-	61250.00	-Do-	Nil
4	Steam jacketed kettle	-Do-	62250.00	-Do-	Nil
5	Dehumidifier with Accessories viz drying chamber	Bry-air, FFB-170	285079.00	-Do-	Nil
6	Baby boiler (IE-40)	Industrial services, Kolkata	363344.00	-Do-	Nil
7	Deseeder	R.S Enterprises, Howrah	25016.00	-Do-	Nil
8	Water Activity meter	Aqua lab-4TE	575000.00	-Do-	Nil
9	Digital Balance	Shimadzu - UW1020 H	71663.00	-Do-	Nil
10	Utensils (SS)	Local Make	30350.00	-Do-	Nil
11	Peristaltic pump	Entertech, Mumbai	50510.00	-Do-	Nil
		Total=	2899862.00		

b) Plans for utilizing the equipment facilities in future

1. Laboratory Class
2. Student Project work
3. Other sponsored research project

Name and Signature with Date

a. ____________________
(Principal Investigator)

b. ____________________
(Co-Investigator)

Principal Investigator
Dr. Brijesh Srivastava,
Associate Professor,
Research Area: Process & Food Engineering, Fruits & Vegetable Processing and Machineries, Drying & Dehydration, Food Engineering Unit Operation.

Co-Principal Investigator
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Project Reference No.: SERB/MOFPI/0016/2013

Project Title: Pilot scale process technology for Bhimkol *(Musa balbisiana)* slice, grits and powder using hybrid drying methods

Principle Investigator: Dr. Brijesh Srivastava

Name of Manpower: Mr. Ritesh Balaso Watharkar

Designation: SRF

Date of Joining: 22nd July 2013 Date of Resignation: 21st July 2015

S.No	Month & Year	Salary Paid (A)	Salary Due (B)	Remark
1.	22nd July 2013	5161.00	----------	
2.	August 2013	16000.00	----------	
3.	September 2013	16000.00	----------	
4.	October 2013	16000.00	----------	
5.	November 2013	16000.00	----------	
6.	December 2013	16000.00	----------	
7.	January 2014	16000.00	----------	
8.	February 2014	16000.00	----------	
9.	March 2014	16000.00	----------	
10.	April 2014	16000.00	----------	
11.	May 2014	16000.00	----------	
12.	June 2014	16000.00	----------	
13.	July 2014	16000.00	----------	
14.	August 2014	16000.00	----------	
15.	September 2014	16000.00	----------	
16.	October 2014	16000.00	9000.00	Revised @ ₹ 25000 PM
17.	November 2014	16000.00	9000.00	
18.	December 2014	16000.00	9000.00	
19.	January 2015	16000.00	9000.00	
20.	February 2015	16000.00	9000.00	
21.	March 2015	0	25000.00	
22.	April 2015	0	25000.00	
23.	May 2015	0	25000.00	
24.	June 2015	10133.00	9166.00	
25.	22nd July 2015	11354.00	00.00	
		330648.00	**129166.00**	
	Total (A+B)	**459814.00**		

This is to certify that Mr. Ritesh B. Watharkar is a registered and continuing as a Ph. D. student in the department. The funds released as salary arrears will be reimbursed to him after disbursing from your end.

Signature of Principal Investigator

Signature of Competent Authority

कुलसचिव
तेजपुर विश्वविद्यालय
Registrar
Tezpur University

Annexure-II

REQUEST FOR ANNUAL INSTALMENT WITH UP-TO-DATE STATEMENT OF EXPENDITURE

1.	Sanction Order No and date	:	**SERB/MOFPI/0016/2013 dated 30.04.2013**
2.	Total Project Cost	:	**₹ 3532400.00**
3.	Revised Project Cost (if applicable)	:	**₹ 3582400.00 (₹3631096.00 after manpower salary revision)**
4.	Date of Commencement	:	**12 June 2013**
5.	Statement of Expenditure	:	
	(month wise expenditure incurred during current financial year)		

Month & year	***Expenditure incurred/ committed***	***Total for FY***
April-2014	379344.00	
May-2014	72070.00	
June-2014	16000.00	
July-2014	16000.00	
Augut-2014	92014.00	
Sep-Dec 2014	0	
Jan-2015	48000.00	
Feb-2015	20169.00	
March-2015	44440.00	688037.00
April-May2015	0	
June-2015	50510.00	
July-2015	14025.00	
Nov-2015	32000.00	
Mar-2016	150653.00 (salary)	
Mar-2016	92911.00 (TA + Consumables)	340099.00

8.	Grant received in each year		
	a. 1st Year		₹ 3191200.00
	b. 2nd Year		NIL
	c. 3rd Year		₹150000.00
	d. 4th Year		₹100000.00
	Interest (if any)		NIL
	Total		₹ 3441200.00

Finance Officer
Tezpur University

Statement of Expenditure

Period: 12.06.2013 to 31st March 2014 ;01-04-2014 till 31.03.2015, 01.04.2015 to 31.03.2016, and 01.04.2016 -11.12.2016

Sr No	Sanctioned Heads	Funds Allocated (indicate sanctioned or revised)		Expenditure Incurred			Total (IV+V+VI)	Balance, if any	Remarks
(I)	(II)	(III)		(DOS to 31st March 2014)	(1st April 2014 to 31st March 2015)	(1st April 2015 to 11th Dec 2015)			(included committed expenditure as on 11 Dec 2015)
		Funds Allocated (indicate sanctioned or revised)	Total Released amount	(IV)	(V)	(VI)			
1.	Manpower costs	422400.00	309161.00	117161.00	160000.00	182653.00	459814.00	-150653.00	150653.00
2.	Consumables	200000.00	172039.00	23276.00	89158.00	84516.00	196950.00	-24911.00	24911.00
3.	Travel	60000.00	60000.00	17411.00	20169.00	22420.00	60000.00	0.00	0
4.	Contingencies	0	0	0	0	0	0	0	0
5.	Others, if any	0	0	0	0	0	0	0	0
6.	Equipment	2900000.00	2900000.00	2430642.00	418710.00	50510	2899862.00	138.00	0
7.	Overhead expenses	0	0	0	0	0	0	0	0
8.	Total	3582400.00	3441200.00	2588490.00	688037.00	340099.00	3616626.00	-175426.00	175564.00

Name and Signature of Principal Investigator:
Date: 23/5/17

Signature of Competent financial/ audit authority: ________
(with seal) Date: 24/5/17

Finance Officer
Tezpur University

* DOS: Date of Start of Project 12 June 2013

Annexure-III

UTILISATION CERTIFICATE (2 COPIES)
FOR THE FINANCIAL YEAR - (1st April 2015 to 11th Dec 2015)

1.	Title of the Project/ Scheme	**Pilot scale process technology for Bhimkol(*Musa balbisiana*) slice, grits and powder using hybrid drying methods**
2.	Name of the Institution	Tezpur University, Napaam,Asaam,784028
3.	Principal Investigator	Dr. Brijesh Srivastava, Associate professor
4.	Department of Science & Technology sanction order No & date sanctioning the project	SERB/MOFPI/0016/2013 DATED 30.04.2013
5.	Head of account as given in the original sanction order	'GRANT-IN-AID' (MoFPI)
6.	Amount brought forward from the previous Financial year quoting DST letter no and date in which the authority to carry forward the said amount was given	(i) Amount: ₹64673.00 (ii) Letter: SERB/MOFPI/0016/2013 (iii) Date: 14.11.2014
7.	Amount received during the financial year (Please give DST letter/order no and date)	(i) Amount: 100000.00 (ii) Letter: SERB/MOFPI/0016/2013 (iii) Date: 18th Sep 2015
8.	Total amount that was available for expenditure (excluding commitments) during the financial year (Sr. No. 6+7)	₹164673.00
9.	Actual Expenditure (excluding commitments) Incurred during the financial year	**₹340099.00.00**
10	Balance amount available at the end of the financial year	**₹ - 175426.00**
11	Unspent balance refunded, if any (please give details of cheque no etc.)	NIL
12	Amount to be carried forward to the next financial year (if applicable)	NIL

UTILISATION CERTIFICATE

Certified that out of 100000.00of grants-in-aid sanctioned during the year 2015-2016 in favour of The Registrar, Tezpur University under this Ministry/ Department letter/ order No **SERB/MOFPI/0016/2013 dt 18th Sep 2015** and ₹64673.00on account of unspent balance of the previous year, a sum of **₹340099.00** has been utilized for the purpose of implementation of research project for which it was sanctioned. The excess expenditure incurred of ₹ **175426.00.00** may kindly be released.

Signature of PI
Date 23/5/17

Signature of Registrar
Date
Registrar
Tezpur University

Accounts Officer of the Institute
Date 24.5.17
Finance Officer
Tezpur University