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AICRP ON POST HARVEST ENGINEERING AND TECHNOLOGY JUNAGADH CENTRE

ANNUAL REPORT

(2020-2021)

AICRP ON POST HARVEST ENGINEERING AND TECHNOLOGY
COLLEGE OF AGRICULTURAL ENGINEERING & TECHNOLOGY
JUNAGADH AGRICULTURAL UNIVERSITY
JUNAGADH – 362 001 (GUJARAT)

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ANNUAL REPORT
2020- 2021

ALL INDIA COORDINATED RESEARCH PROJECT (ICAR)

ON

POST HARVEST ENGINEERING AND TECHNOLOGY

JUNAGADH CENTRE

Presented online at

Junagadh, during 27 -29, 2022

AICRP on Post Harvest Engineering and Technology
Department of Processing and Food Engineering
College of Agricultural Engineering & Technology
Junagadh Agricultural University
JUNAGADH – 362001

FOREWORD

Value addition of agricultural products through processing is the need to increase the farmers' welfare. Post-harvest engineering and technology is the one of the instrument for value addition. This conceptions are for agricultural products after harvesting, such as storage and processing of grains, fruits, vegetables, animal products, milk and other foods. This results for prevention of post-harvest losses, improvement in nutrition and add value to the products. Generation of employment in rural area through storage and processing of agricultural products at rural level, diminish poverty and motivate development of other related financial segments.

The Junagadh centre added productively by establishing agro processing centres, storage of groundnut pods and kernels, reducing time of curing of onion to facilitate the land for new crops, onion storage, development of machines for fruits cleaning and grading, spice processing, value addition to groundnut etc. In view of the shortage of capital, an arrangement of custom hiring service facility was provided to the farmers in meeting the requirements for onion storage. These findings of research work became useful to farmers, industries and entrepreneurs.

As per the requirement of this region, the Junagadh centre has functioned constantly and advanced technologies related to feed block making machine, solar dryer cum green house, peanut butter, coriander dhal milling process, vacuum packaging of mangoes, storage technique for coriander and wheat (seed), onion storage structures, sapota cleaner, pectin extraction, enzyme extraction, spice processing etc. for the benefit of farmers and processing industries. The centre has also installed onion dehydration unit. However, in view of the recent trends, still much remains to be done for value addition to groundnut, spices and onion. This centre has space for laboratory work, office room, analytical facilities, etc., but due do continuous expansion and with a view to impart training and accommodate precious and sensitive instruments / equipments purchased so far, this centre need a separate building / space for better sitting and laboratory arrangements, for which necessary efforts are being made to fulfill the same at university level.

The financial assistance delivered by the ICAR under the AICRP on Post Harvest Engineering and Technology is gratefully admitted. I am sure the Junagadh centre will serve the need of the agro industries and the life flourishing of the farmers of the region.

13 January, 2022
Junagadh

(N. K. Gontia)
Principal & Dean
College of Agril.Engg.& Technology
JAU, Junagadh

ACKNOWLEDGEMENT

All India ICAR Co-ordinated Research Project on Post-harvest Engineering and Technology is operative at Junagadh Agricultural University, Junagadh since 1980. This report is the consequence of honest efforts and tough effort of concerned research scientists. Value addition and post-harvest technology are recognized as sun rising segment accountable for welfare of the farmers.

The All India Coordinated Research Project on Post-Harvest Engineering and Technology staff wish to converse their solemn acknowledgements to Dr. V. P. Chovatiya, I/c Vice Chancellor and Director of Research, Junagadh Agricultural University, Junagadh; for their highly support in the activities of the scheme. We hereby affirmative our honest thanks to and Dr. N. K. Gontia, Principal & Dean, College of Agricultural Engineering & Technology, Junagadh for able nurturing of the scheme work.

The staff members of the scheme pleasingly discriminate the financial assistance received by ICAR to run the scheme absolutely. The constructive approach and esteemed remark of Dr. K. Alagusundaram, Deputy Director General (Engineering) and Dr. S. N. Jha, Assistant Director General (PE) ICAR, New Delhi are gratefully recognized. We express our most earnest thanks to Dr. S. K. Tyagi, Project Coordinator, AICRP on Post-Harvest Engineering and Technology, Central Institute of Post-Harvest Engineering & Technology, Ludhiana for their inspiring direction, harmonization as well as their keen attentiveness in the activities of the scheme.

We are also thankful to all the staff members of the Department of Processing and Food Engineering for their support and taking due interest in the activities of the scheme work.

January 13, 2022
Junagadh

(M. N. Dabhi)
Research Engineer
for Scheme Staff

C O N T E N T S

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ALL INDIA CO-ORDINATED RESEARCH PROJECT (ICAR)

ON

POST HARVEST ENGINEERING AND TECHNOLOGY SCHEME

JUNAGADH AGRICULTURAL UNIVERSITY

JUNAGADH CENTRE

GENERAL INFORMATION

1.	**Title of the scheme**	:	All India Co-ordinated Research Project (ICAR) on Post Harvest Engineering and Technology
2.	**ICAR sanction No. & Date**	**:**	1(41)/PHT/2006/XI Plan/1010998, dtd. 21.3.2009 (PC letter No.)
3.	**Date of commencement**	**:**	April, 1980
4.	**Date of completion**	:	The scheme is sanctioned for the 12th Five Year Plan
5.	**Sanctioned grant for the Year 2020-2021 for which this report is presented**	:	Rs**. 95,33,333**/- (ICAR+State)

6. Staff position in the scheme

Sr. No.	Designation	No. of posts			Name of the incumbent	Present Scale of pay	Date of joining / vacant
		S	F	V			
1.	Research Engineer	1	1	-	Dr. M. N. Dabhi	131400-217100	01.09.2016
2.	Asstt. Bio-Chemist	1	1	-	Dr. P. J. Rathod	57700-182400	01.12.2018
3.	Asstt. Entomologist	1	1	-	Prof. R. D. Dhudashia	131400-217100	01.06.1997
4.	Asstt. Food Microbiologist	1	1	-	Prof. A.M. Joshi	68900-205500	18.02.2009
5.	Asstt. Res. Engineer (ASPE)	1	1	-	Prof. P. R. Davara	68900-205500	01.01.2011
6.	Asstt. Process Engr. (Testing & Eva.)	1	-	1	Vacant	57700-182400	23.07.2020
7.	Senior Tech. Asstt.	1	1	-	Er. H. R. Sojaliya	39900-126600	14.02.2012
8.	Investigator	1	1	-	Shri P. R. Mathukiya	38090 (fixed)	01.11.2019
9.	Draftman (Mech.)	1	1	-	Shri R. V. Bokhiriya	31340 (fixed)	01.01.2021
10.	Craftman-I (Welder)	1	1	-	Shri V. S. Kava	25500-81100	01.11.2014
11.	Craftman-II (Fitter)	1	1	-	Shri N. V. Vora	19900-63200	28.12.2008
12.	Craftman-III (Tinsmith)	1	-	1	Vacant	19900-63200	1.07.2016
13.	Senior Mechanic	1	1	-	Shri A. P. Zezariya	29200-92300	26.07.2018

7. Expenditure Statement for the year 2020-2021 (Upto March, 2021)

Head-wise breakup of Receipts, Expenditure and Closing Balances for the financial year 2020-21 (ICAR share)
Period : 01-04-2020 to 31-03-2021

Sr. No.	Budget Head	Opening balance as on 01-04-2020 Rs.	Receipts during the previous years Rs.	Total opening balance as on 01-04-2020 Rs. (3+4)	Grant received during the year 2020-21 Rs.	Revalidated amount of Unspent Balances of 2019-20, Rs.	Total grant Rs. (6+7)	Expenditure incurred for the councils share during the year 2020-21 Rs.	Closing balance at the end of the year 2020-21 as on 31-03-2021 Rs. (6-7)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	Pay and Allowances	42,41,615.56	68,464.00	43,10,079.56	60,00,000.00	43,10,079.56	1,03,10,079.56	86,35,614.00	**16,74,465.56**
2	Travelling Allowance	2,91,578.00	-	2,91,578.00	30,000.00	2,91,578.00	3,21,578.00	2,368.50	**3,19,209.50**
3	Recurring Contingencies (Including HRD)	13,041.00	-	13,041.00	9,20,000.00	13,041.00	9,33,041.00	7,41,794.25	**1,91,246.75**
4	Non recurring contingencies	49,781.00	-	49,781.00	2,00,000.00	49,781.00	2,49,781.00	1,07,643.00	**1,42,138.00**
	Total, Rs.	**45,96,015.56**	**68,464.00**	**46,64,479.56**	**71,50,000.00**	**46,64,479.56**	**1,18,14,479.56**	**94,87,419.75**	**23,27,059.81**

8. Technical Programme

Sr.No.	Code No.	Title
1	PH/JU/85/1	Establishment of Agro Processing Centre training and demonstration of technologies (Operational research project on Agro Processing Centres)
2	PH/JU/2018/02	Design and development of grain treater for enzymatic pre-treatment to pigeon pea grains
3	PH/JU/2019/01	Low temperature grinding of spices.
4	PH/JU/2020/01	Standardization of process technology for preparation of peanut sauce and peanut wadi (Chunks).
5	PH/JU/2020/02	Application of microwave technology for disinfestations of groundnut kernels.
6	New Experiment-I	Development of peanut tempeh through fermentation process.
7	New Experiment-II	Refrigerated grinding of spices.
8	New Experiment-III	Processing of green tender sorghum.

Investigation No. : 1

1.1 Scheme code No. : **PH/JU/85/1**

1.2 Title of Investigation: Establishment of Agro Processing Centre training and demonstration of technologies (Operational research project on Agro Processing Centres)

1.3 Name of Investigators: 1. Dr. M. N. Dabhi
2. Prof. P. R. Davara

1.4 Objectives

1. Survey of selected villages to identify the available agro-processing equipment.
2. To transfer the developed and improved agro-processing equipment to the selected village to give value added product.
3. To evaluate the techno-economic feasibility of the agro-processing centre.

1.5 Justification

Migration from the village to the cities not only disturbs the rural based economy but also causes a saturated and explosive urban population growth. The dire need of the hour is to prevent this migratory trend from villages to cities, so as to increase the activities concerned with farming thereby increase food production. This could be prevented by stabilizing industries in the proximity of the source of raw materials or near the vicinity of consumption catchment's area to avoid higher transportation cost. This will help the village to become self-sufficient in production, processing and consumption of raw materials produce by them. More job opportunities would also be created, resulting in more income generation.

1.6 Date of start: April - 2012

1.7 Date of completion: Continue

1.8 Past Work done

Major equipment installed at agro processing centres were used for their operational work. In this period, oil milling, spice milling, groundnut decorticating, groundnut threshing, cleaning and grading of wheat were taken up. The detailed operational performance data and expenditure incurred, income obtained along with profit / loss were determined.

1.9 Progress of work

Agro processing centers were visited for monitoring the progress made by the centers. Loej, Virol, and Tadka pipaliya centre has also deposited installment for the year 2020-21. The detailed operational performance data and expenditure incurred, income obtained along with profit / loss were determined and presented in Table: 1.1.

Table 1.1 : Operational performance and income from the processed products

S. N.	Activities	Raw material processed (kg)	Finished material produced (kg)	Expenditure incurred (Rs.)	Income (Rs.)	Net income (Rs.)
	Tadaka Pipaliya Agro Processing Centre					
1	Oil milling (groundnut)	48000 kg	-	120000 (@ 2.5 Rs./kg.)	240000 (@ 5Rs./kg.)	120000
2	Cleaning and grading of wheat,	5100 kg	-	-	5100 (@ 1 Rs/kg.)	5100
3	Groundnut decortication (manually)	-	_	_	280 (@ 20Rs/day x 2 nos.)	280
4	Sesame processing	280 kg	-	8400	16800	8400
5	Groundnut threshing	-	-	-	27000 (@600Rs./hr; Total 45 hrs.)	27000
6	Pulse mill	560 kg	-	1120	5600	4480
7	Spice milling	430 kg	-	860	4300	3440
	Loej Agro Processing Centre					
1	Oil milling (groundnut)	102000 kg	-	255000 (@ 2.5 Rs./kg.)	510000 (@ 5Rs./kg.)	255000
2	Cleaning and grading of wheat,	5400 kg	-	-	5400 (@ 1Rs./kg.)	5400
	Virol Agro Processing Centre					
1	Oil milling (groundnut)	114000 kg	-	285000 (@ 2.5 Rs./kg.)	570000 (@5 Rs./kg.)	285000
2	Cleaning and grading of wheat,	5700kg	-	-	5700 (@ 1 Rs./kg.)	5700

3	Spice milling	1000 kg Chilly 207 kg turmeric 131 kg cumin Total 1338	-	4014	13380	9366
	Panchal Vikas Mandal, Chotila					
1.	Oil milling (groundnut)	8100 kg	-	20250 (@ 2.5 Rs./kg.)	40500 (@ 5Rs./kg.)	20250

1.10 Conclusion:

Agro Processing Centres are running very well for utilization of processing machinery and processing of farmers produce at village level.

1.11 Future plan of work

The experiment will be continued.

PROJECT – 1

Title : Value Chain on groundnut

INVESTIGATION – 1

ANNEXURE - V

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

RESEARCH PROJECT PROFORMA FOR MONITORING ANNUAL PROGRESS (RPP- II)

(Refer for Guidelines ANNEXURE-XI (E))

1. Institute Project Code : PH/JU/2020/01
2. Project Title : Standardization of process technology for preparation of peanut sauce and peanut wadi (Chunks).
3. Reporting Period : 01-02-2020 to 31-12-2021
4. Project Duration: Date of Start – 01-02-2020
   LikelyDate of Completion– 30-06-2022
5. Project Team (Name(s) and designation of PI, CC-PI and all project Co-PIs, (with time spent for the project) if any additions/deletions

S. No.	Name, designation and institute	Status in the project (PI/CC-PI/ Co-PI)	Time to be spent (%)	Work components to be assigned to individual scientist
1.	Dr. P. R. Davara, Assistant Research Engineer, AICRP on PHET, Dept. of Processing and Food Engg., College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh	PI	60%	1. Review collection/literature survey 2. Designing of the experiment 3. Procurement of raw materials 4. Procurement of microbial cultures and chemicals required to conduct the research trials 5. Quality analysis of the raw materials 6. Preliminary trials for production of peanut sauce and peanut wadi 7. Final trials for development of peanut sauce and peanut wadi using defatted peanut flour/kernels as per the different treatments 8. Physico-chemical and sensory analysis of the products

				9. Data collection and its analysis 10. Optimization of process parameters based on the experimental data 11. Report writing
2.	Prof. A. M. Joshi Assistant Microbiologist, AICRP on PHET, Dept. of Processing and Food Engg., College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh	Co-PI-I	15%	1. To assist the PI during fermentation process for peanut sauce 2. To assist the PI to carry out the microbiological analysis of the peanut sauce
3.	Dr. P. J. Rathod Assistant Biochemist, AICRP on PHET, Dept. of Bio-Technology, JAU, Junagadh	Co-PI-II	15%	1. To assist the PI to carry out biochemical analysis of the product
4.	Dr. M. N. Dabhi, Research Engineer, AICRP on PHET, Dept. of Processing and Food Engg., College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh	Co-PI-III	10%	To assist the PI in taking administrative approvals as and when needed to carry out the different project related activities

6. (a) Activities and outputs earmarked for the year (as per activities schedule given in RPP-I)

Objective wise	Activity	Scientist responsible	% of activity envisaged to be completed as per RPP-I	% achieved as targeted
1. To develop a process technology for preparation of peanut sauce and peanut wadi.	1. Review collection/literature survey	Dr. P. R. Davara	100%	100%
	2. Designing of the experiment	Dr. P. R. Davara	100%	100%
	3. Procurement of raw materials	Dr. P. R. Davara Dr. M. N. Dabhi	100%	10%
	4. Procurement of microbial cultures	Dr.P. R. Davara Prof.A.M. Joshi	100%	10%

	and chemicals required to conduct the research trials	Dr. M.N. Dabhi		
	5. Quality analysis of the raw materials	Dr. P. R. Davara	100%	50%
	6. Preliminary trials for production of peanut sauce and peanut wadi	Dr. P. R. Davara Prof. A. M. Joshi	100%	40%
	7. Final trials for development of peanut sauce and peanut wadi using defatted peanut flour/kernels as per the different treatments	Dr. P. R. Davara Prof. A. M. Joshi	50%	0%
2. To study the effect of process parameters on different quality and sensory parameters of peanut sauce and peanut wadi	1. Physico-chemical and sensory analysis of the developed products 2. Microbiological analysis of the peanut sauce	Dr. P. R. Davara Dr. P. J. Rathod Prof. A. M. Joshi	50%	0%
3. To standardize the process parameters for preparation of peanut sauce and peanut wadi	1. Data collection and its analysis 2. Optimization of process parameters based on the experimental data	Dr. P. R. Davara Dr. M. N. Dabhi	50%	0%

(b) If shortfall/addition, reasons for the same and how to catch up with the intended activities

7. Annual Progress Report (research results and achievements in bullets)

- Defatted peanut flour is purchased from the Nutrinity Foundation, Junagadh to test its feasibility for the preparation of peanut wadi.
- Quality analysis of defatted peanut flour was done. Values of different biochemical characteristics of defatted peanut flour are presented as under.

Sr. No.	Characteristic	Average values	SD
1.	Moisture content % (w.b.)	5.64	0.09
2.	Carbohydrate (%)	23.59	0.57
3.	Protein (%)	61.98	0.77
4.	Fat (%)	3.96	0.19
5.	Ash (%)	4.76	0.17

- Preliminary trials were conducted for preparation of peanut wadi using the Twin Screw Extruder. There was an issue with the feeding of peanut dough in the twin screw extruder and therefore the results obtained are not up to expectation. Further, trials are to be conducted as soon as the issue is solved. Hence, the trials will be repeated in the coming time.

- *Aspergillus oryzae (Koji mold)* and *Saccharomyces rouxii* have already been purchased from the ATCC, Chandigarh. *Pediococcus halophilus* is to be purchased from the USA. Purchase order for the purchase of *Pediococcus halophilus* has already been issued to the supplier and culture is awaited.

▪ **Work to be done**

1. Procurement of defatted peanut kernels is still awaited from the supplier
2. Quality analysis of raw material for peanut sauce preparation
3. Procurement of *Pediococcus halophilus*
4. Preliminary trials for production of peanut sauce will be carried out as soon the raw materials and microbial cultures are obtained
5. Final trials for development of peanut sauce and peanut wadi using defatted peanut flour/kernels as per the different treatments
6. Physico-chemical and sensory analysis of the products
7. Data collection and its analysis
8. Optimization of process parameters based on the experimental data
9. Report writing

8. Output During Period Under Report

a. Special attainments/innovations
b. List of Publications (one copy each to be submitted with RPP-II)
   i. Research papers - Nil
   ii. Reports/Manuals - Nil
   iii. Working and Concept Papers - Nil
   iv. Popular articles - Nil
   v. Books/Book Chapters - Nil
   vi. Extension Bulletins - Nil
c. Intellectual Property Generation
   (Patents - filed/obtained; Copyrights- filed/obtained; Designs- filed/obtained; Registration details of variety/germplasm/accession if any)
d. Presentation in Workshop/Seminars/Symposia/Conferences
   (relevant to the project in which scientists have participated)

e. Details of technology developed
(Crop-based; Animal-based, including vaccines; Biological – biofertilizer, biopesticide, etc; IT based – database, software; Any other – please specify)
f. Trainings/demonstrations organized - Nil
g. Training received - Nil
h. Any other relevant information – Project is under progress

9. Constraints experienced, if any
- No any supplier is there in India who can provide the *Pediococcus halophilus* bacteria required for the fermentation process in the preparation of peanut sauce. It is expected to be purchased from the ATCC, USA.

10. Lessons Learnt : - Nil-

11. Evaluation

Self evaluation of the project for the period under report by the PI with rating in the scale of 1 to 10 8

(a) Evaluation by PI on the contribution of the team in the project including self

S. No.	Name	Status in the project (PI/CC-PI/Co-PI)	Rating in the scale of 1 to 10
1	Dr. P. R. Davara	PI	8
2	Prof. A. M. Joshi	Co-PI	8
3	Dr. P. J. Rathod	Co-PI	8
4	Dr. M. N. Dabhi	Co-PI	8

12. Signature of PI, CC-PI(s), all Co-PIs

13. Signature (with specific comments on progress/achievements, shortfall and constraints along with rating of the project in the scale of 1 to 10) of Head of Division/Regional Center / Section ☐

14. Comments of IRC

15. Signature (with specific comments on progress/achievements, shortfall and constraints along with rating of the project in the scale of 1 to 10) of JD (R)/ Director ☐

Title : Value Chain on groundnut

INVESTIGATION – 2

ANNEXURE - V

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
RESEARCH PROJECT PROFORMA FOR MONITORING ANNUAL PROGRESS (RPP- II)

(Refer for Guidelines ANNEXURE-XI (E))

1. Institute Project Code : PH/JU/2020/02
2. Project Title: Application of microwave technology for disinfestations of groundnut kernels.
3. Reporting Period: January 2021 to December 2021
4. Project Duration: Date of Start –May 2020

   Likely Date of Completion –December 2021
5. Project Team (Name(s) and designation of PI, CC-PI and all project Co-PIs, (with time spent for the project) if any additions/deletions

Sr. No	Name, designation and institute	Status in the project (PI/CC-PI/ Co-PI)	Time spent (%)	Work components assigned to individual scientist
1.	R.D.Dhudashia Assistant Entomologist, AICRP on PHET, Dept. of Processing and Food Engg., College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh	PI	60%	Planning, data collection, statistical analysis and final report Writing
2.	A.M.Joshi, Assistant Moicrobiologist, AICRP on PHET, Dept. of Processing and Food Engg., College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh	Co-PI	20%	Helping in analysis and data collection

3.	Dr. M. N. Dabhi, Research Engineer, AICRP on PHET, Dept. of Processing and Food Engg., College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh	Co-PI	20%	Supervision and Co-ordination

6. (a) Activities and outputs earmarked for the year (as per activities schedule given in RPP-I)

Objective wise	Activity	Scientist responsible	% of activity envisaged to be completed as per RPP-I	% achieved as targeted
1.	Planning the experiment	R.D.Dhudashia M.N.Dabhi	Planning the experiment	100%
2.	Data collection	R.D.Dhudashia A.M.joshi	Data collection was achieved 60%	60%
3	Statistical analysis and Report writing	R.D.Dhudashia M.N.Dabhi	Statistical analysis and Report writing is completed	100%

(b) If shortfall/addition, reasons for the same and how to catch up with the intended Activities.

7. **Annual Progress Report** (research results and achievements in bullets)

(Experiment was completed for second year and presented in 37th workshop.)

Back ground information:

Groundnut is an important oilseed crop in India. In India, groundnut occupies 4.77million hectares area with total production of 4.75 million tonnes in year 2012-13.(anonymous 2015). Groundnut when stored is often attacked by number of pests, viz. groundnut bruchid, rust red flour beetle, rice moth etc. Among this, groundnut bruchid (*Caryedon serratus* Olivier.) is one of the major and important storage insect species, causing more damage to groundnut (Dick,K.M. 1987a). 20% dry weight loss of kernals due to bruchid infestation in warehouse in Andra Pradesh was reported by Dick K.M.(1987b). Pest infestation reduces the market value and germination of seeds. High Moisture content is also increase the risk of mould growth which indirectly spoils the quality of groundnut. Hence farmers and exporter have a problem for storing of groundnut. Various scientists were tested different methods for minimizing storage losses of groundnut. Among these,Fumigation is the best technique to completely remove the pests from the grains. Many fumigants have been found effective against storage pests, but are hazardous, due to their residual effect in the grains. This adverse effect of chemical fumigants need diversified efforts for evolving more convenient, safer and alternative methods to minimize the losses on groundnut. The use of microwave technology is safe to environment and effective against storage pest. Various scientists were tested microwave technology for disinfestations. However, Very little information is available effect of microwave energy on pest incidence in during storage of groundnut. Thus it is necessary to find out the effective microwave treatment for safe storage of groundnut.

Objectives:

1. To evaluate the effect of microwave treatment against storage insect pest of groundnut kernels.
2. To study on moisture content and aflatoxin level of groundnut kernels in different microwave treatments.
3. To evaluate the effect of microwave treatment on germination of groundnut kernels.

Technical programme:

(a) Design: CRD

(b) Replication: 3

(c) Treatments: 10

1. Microwave treatment @power level 360 W for 30 second expose time
2. Microwave treatment @power level 360 W for 60 second expose time
3. Microwave treatment @power level 360 W for 90 second expose time
4. Microwave treatment @power level 480 W for 30 second expose time
5. Microwave treatment @power level 480 W for 60 second expose time
6. Microwave treatment @power level 480 W for 90 second expose time
7. Microwave treatment @power level 600 W for 30 second expose time
8. Microwave treatment @power level 600 W for 60 second expose time
9. Microwave treatment @power level 600 W for 90 second expose time
10. Control (Untreated)

Observation recorded:

(A) Entomological Parameters:

i. Pest population

ii. Percent kernels damage

(B) Physical parameters

i. Germination percentage

ii. Moisture content percentage

(C) Microbial parameters

(i) Aflatoxin level

Methodology:

A good quality groundnut kernels were procured from seed processers. Initial Observation viz, moisture content,germination percent and insect infestation, damage etc. were recorded at time of storage.10 kg grains was stored in different bags after treatment of microwave and kept at room temperature in laboratory. Monthly observations were recorded on entomological and physical parameters during storage. The observations were recorded from groundnut samples of 250 g.

Initial observation:

Germination %	:	92.00
Moisture %	:	6.78
Insect damage and live insect	:	Nil
Aflatoxin	:	Nil

Results of project:

(i)Pest population:

(a) Pest population builds up of groundnut bruchid: Nil

The infestation of bruchid was not found in all the treatments during the storage time.

(b)Pest populations build up of Red rust flour beetle:Nil

The infestation ofRed rust flour beetle was not found in all the treatments during the storage time.

(ii) Percent grain damage: Nil

(iii) Percent Germination:

Table - 3.1 : Percent Germination of groundnut kernels during storage

Treatment Details		Germination % of groundnut Kernel		
		after microwave treatment	**after 4th months**	**after 8th months**
1.	Microwave treatment @power level 360 W for 30 second expose time	71.95*(90.40)**	67.40(85.24)	66.26(83.79)
2.	Microwave treatment @power level 360 W for 60 second expose time	70.69(89.07)	66.26(83.79)	62.29(78.38)
3.	Microwave treatment @power level 360 W for 90 second expose time	68.66(86.76)	64.81(81.88)	61.44(76.71)
4.	Microwave treatment @power level 480 W for 30 second expose time	71.95(90.40)	70.50(88.86)	64.69(81.73)
5.	Microwave treatment @power level 480 W for 60 second expose time	67.21(85.00)	64.69(81.73)	61.22(76.82)

6.	Microwave treatment @power level 480 W for 90 second expose time	70.11(88.43)	64.81(81.88)	60.07(75.11)
7.	Microwave treatment @power level 600 W for 30 second expose time	70.11(88.43)	63.55(80.16)	62.48(78.65)
8.	Microwave treatment @power level 600 W for 60 second expose time	68.86(86.99)	62.48(78.65)	60.07(75.11)
9.	Microwave treatment @power level 600 W for 90 second expose time	67.21(85.00)	64.81(81.88)	61.14(76.71)
10.	Control (Untreated)	73.79(92.21)	71.95(90.40)	67.40(85.24)
	S. Em ±	2.38	2.62	2.10
	CD at 5%	NS	NS	NS
	CV%	5.88	6.85	5.79

*arcsin √percentage transformation value**figure in parenthesis are retransformed value

The results showed in Table - 3.1 indicated that the effect of microwave treatment on germination was found non-significant after given microwave treatment at storage time and four and eight month of storage of groundnut kernels. Germination percent was found non- significant it means no adverse effect of microwave treatment on germination. The germination was decreased after eight month of storage, which may be due to storage period.

The results showed in Table – 3.2 indicated that the effect of microwave treatment on moisture content was found significant after given microwave treatment at storage time and after one and two month of storage of groundnut kernels. Moisture content was found non-significant after three month of storage to eight month of storage of groundnut kernels. Moisture content increased in monsoon season.

Conclusion: The pest population and kernels damage was not found in all the treatments (including control) it may be due to PICS bag storage. Germination percent was found non-significant it means no adverse effect of microwave treatment on germination. The germination was decreased after eight month of storage, which may be due to storage period. The effect of microwave treatment on moisture content was found significant after given microwave treatment at storage time and after one and two month of storage of groundnut kernels. Moisture content was found non-significant after three month of storage to eight month of storage of groundnut kernels. Moisture content increased in monsoon season.

(iv) Percent moisture content:

Table - 3.2 : Percent moisture content of groundnut kernels during storage

Treatments		%Moisture content of kernels								
		After microwave treatment	After 1 month	After 2 months	After 3 months	After 4 months	After 5 months	After 6 months	After 7 months	After 8 months
1.	Microwave treatment @ power level 360 W for 30 second expose time	6.68	6.58	6.55	6.60	6.62	6.93	7.33	7.49	7.39
2.	Microwave treatment @power level 360 W for 60 second expose time	6.63	6.60	6.59	6.59	6.61	6.91	7.33	7.47	7.38
3.	Microwave treatment @power level 360 W for 90 second expose time	6.57	6.56	6.56	6.57	6.59	6.85	7.32	7.44	7.35
4.	Microwave treatment @power level 480 W for 30 second expose time	6.53	6.52	6.53	6.52	6.53	6.81	7.33	7.42	7.39
5.	Microwave treatment @power level 480 W for 60 second expose time	6.47	6.45	6.43	6.46	6.50	6.84	7.35	7.39	7.38
6.	Microwave treatment @power level 480 W for 90 second expose time	6.43	6.4	6.38	6.45	6.51	6.83	7.32	7.43	7.37
7.	Microwave treatment @power level 600 W for 30 second expose time	6.48	6.43	6.41	6.47	6.53	6.82	7.29	7.39	7.35
8.	Microwave treatment @power level 600 W for 60 second expose time	6.43	6.4	6.37	6.46	6.54	6.84	7.30	7.49	7.34
9.	Microwave treatment @power level 600 W for 90 second expose time	6.37	6.35	6.35	6.48	6.53	6.85	7.28	7.36	7.35
10.	Control (Untreated)	6.78	6.61	6.56	6.62	6.67	6.92	7.37	7.53	7.41
S. Em ±		0.03	0.03	0.03	0.05	0.06	0.05	0.04	0.06	0.05
CD at 5%		0.10	0.09	0.08	NS	NS	NS	NS	NS	NS
CV%		0.88	0.80	0.72	1.39	1.57	1.18	0.91	1.28	1.24

8. Output during Period under Report

a. Special attainments/innovations
b. List of Publications (one copy each to be submitted with RPP-II)
   i. Research papers
   ii. Reports/Manuals
   iii. Working and Concept Papers
   iv. Popular articles
   v. Books/Book Chapters
   vi. Extension Bulletins
c. Intellectual Property Generation
   (Patents - filed/obtained; Copyrights- filed/obtained; Designs- filed/obtained; Registration details of variety/germplasm/accession if any)
d. Presentation in Workshop/Seminars/Symposia/Conferences
   (relevant to the project in which scientists have participated)
e. Details of technology developed
   (Crop-based; Animal-based, including vaccines; Biological – biofertilizer, biopesticide, etc; IT based – database, software; Any other – please specify)
f. Trainings/demonstrations organized
g. Training received
h. Any other relevant information

9. Constraints experienced, if any: Conducting the experiment was late due to lock down, hence results not obtained satisfactory. Experiment will be carried out next year.

10. Lessons Learnt

11. Evaluation

(a) Self evaluation of the project for the period under report by the PI with rating in the scale of 1 to 10 — 9

(b) Evaluation by PI on the contribution of the team in the project including self

Sr. No.	Name	Status in the project (PI/CC-PI/Co-PI)	Rating in the scale of 1 to 10
1	Prof. R.D. Dhudashia	PI	9
2	Prof. A.M. Joshi	Co PI	8
3	Dr. M. N. Dabhi	Co PI	9

12. Signature of PI, CC-PI(s), all Co-PIs

13. Signature (with specific comments on progress/achievements, shortfall and constraints along with rating of the project in the scale of 1 to 10) of Head of Division/Regional Center / Section

14. Comments of IRC

15. Signature (with specific comments on progress/achievements, shortfall and constraints along with rating of the project in the scale of 1 to 10) of JD (R)/ Director

INVESTIGATION NO. 1

ANNEXURE -VI

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

CHECKLIST FOR SUBMISSION OF FINAL RESEARCH PROJECT REPORT (RPP-III)

(For Guidelines Refer ANNEXURE – XI (F))

1. Institute Project Code : PH/JU/2018/02
2. Investigators as approved in RPP-I, If any change attach IRC proceedings:

Principal Investigator	Co-PI
Dr. P. R. Davara	Dr. M. N. Dabhi

3. Any change in objectives and activities No
   (If yes, attach IRC proceedings)

4.	Date of Start & Date of Completion (Actual). If any extension granted enclose IRC proceedings		01-03-2018	30-06-2021
5.	Whether all objectives met		Yes	Yes
6.	All activities completed		Yes	Yes
7.	Salient achievements/major recommendations included		Yes	Yes
8.	Annual Progress Reports (RPP-II) submitted	1st Year	Yes	Yes
		2nd Year	Yes	Yes
9.	Reprint of each of publication attached		Yes	Yes
10	Action for further pursuit of obtained results indicated		Yes	Yes
11	Report presented in Divisional seminar (enclose proceedings & action taken report)		Yes	Yes
12	Report presented in Institute seminar (enclose proceedings & action taken report)		Yes	Yes
13	IRC number in which the project was adopted		IRC No:	
14	Any other Information			

15. Signature:

P. R. Davara Principal Investigator	**M. N. Dabhi** Co-PI

HOD/PD/I/c.

ANNEXURE - VII

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

FINAL RESEARCH PROJECT REPORT (RPP- III)

(For Guidelines Refer ANNEXURE – XI(G))

PROJECT REPORT (RPP- III)

1. Institute Project Code : PH/JU/2018/02

2. Project Title : Design and development of grain treater for enzymatic pre-treatment to pigeon pea grains

3. Key Words : Grain treater, enzymatic pre-treatment, pigeon pea, hulling efficiency

4. (a) Name of the Lead Institute : College of Agril. Engg. & Technology
(b) Name of Division/ Regional Center/ Section : AICRP on PHT, Junagadh

5. (a) Name of the Collaborating Institute(s) : --
(b) Name of Division/ Regional Center/ Section of Collaborating Institute(s) : --

6. Project Team(Name(s) and designation of PI, CC-PI and all project Co-PIs, with time spent)

S. No.	Name, designation and institute	Status in the project (PI/CC-PI/ Co-PI)	Time spent (%)	Work components assigned to individual scientist
1	Prof. P. R. Davara, Asstt. Research Engineer, AICRP on PHT, Dept. of Processing & Food Engineering, College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh	PI	75%	1. Designing of grain treater 2. Development and fabrication of grain treater 3. Laboratory experiments 4. Modifications in the grain treater 5. Data collection and its analysis 6. Report writing
2.	Dr. M. N. Dabhi, Research Engineer, AICRP on PHT, Dept. of Processing & Food Engineering, College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh	Co-PI	25%	To assist the PI in all above aspects

7. Priority Area : Post Harvest Technology
8. Project Duration: Three years

Date of Start : 01-03-2018 Date of Completion : 30-06-2021

9. a. Objectives :
   1. To design and develop the grain treater for enzymatic pre-treatment to pigeon pea grains.
   2. To optimize the machine parameters of grain treater for maximizing hulling efficiency of pigeon pea grains.
   3. To estimate the cost of developed machine and to evaluate the cost economics for enzymatic pre-treatment to pigeon pea grains using developed grain treater.

b. Practical utility :
   1. The machine for giving the enzymatic pre-treatment to pigeon pea grain will be made available.
   2. The dehulling efficiency of the pigeon pea will be improved.
   3. The developed machine will be useful for variety of the pulse grain for giving enzymatic pre-treatment.
   4. The process parameters for giving enzymatic pre-treatment to pigeon pea grain will be optimized.

10. Final Report on the Project (materials and methods used, results and discussion, objective wise achievements and conclusions)

10.1 Material and methods

❖ **Design of grain treater**

- **Specification of grain treater**

  Drum length : 125 cm

  Diameter : 65 cm

  Material : Stainless steel (SS 304)

  Capacity : 100 kg per batch

- **Machine parts :**

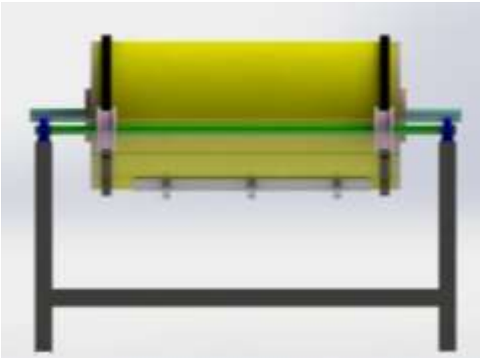
1. Rotating drum with internal flights
2. Atomizers for water spray
3. Heating accessories (heating elements and thermocouple)
4. Airtight discharge gate
5. Drum speed regulator

- **Machine features :**

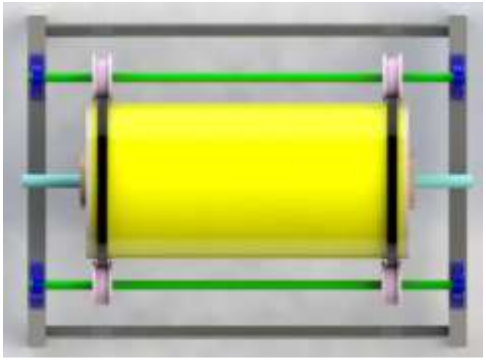
1. Internal mixing flights create a gentle, four-way mixing action that tumbles, folds and turns the material.
2. Openable air tight gate fitted at the surface of drum makes easy discharge of grains after treatment.
3. Hollow pipe act as a shaft as well as facilitate the fitting of atomizers and heating accessories to create and maintain the internal condition for enzyme incubation.

4. The consistent and efficient flow pattern of grains assists in creation of ideal conditions for uniform application of water and exposure to heat for achieving homogeneous treatment.
5. Speed regulator assists to adjust the speed of drum.

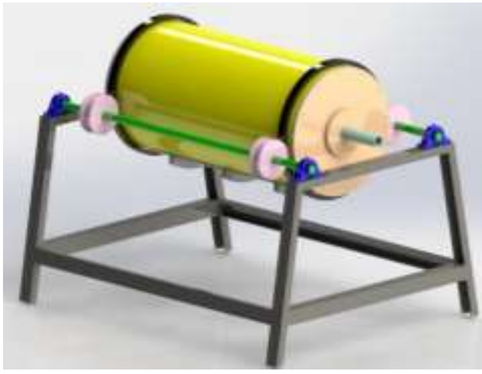
- **Conceptual design/drawings of the proposed grain treater**



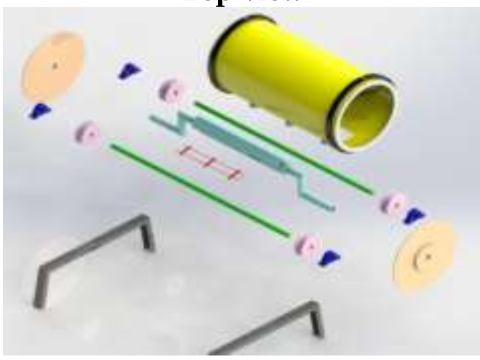
Side view



Top view



Inclined view



Functional parts

Fig. 4.1 Computerized layout of the grain treater.

❖ **Selection of variety and procurement**

Amongst different varieties of pigeon pea cultivated in Gujarat, the BDN-2 variety is most commonly grown by the farmers throughout the state. Moreover, BDN-2 variety is milled in the pulse mills of Gujarat on large scale for obtaining pigeon pea dhal. In view of this, BDN-2 variety of pigeon pea was selected for the present investigation. The pigeon pea grain, used for the study was procured from farmers field at Vill. Boriya, Tal. Jamkandorna, Dist. Rajkot during the year 2020-21.

Plate 4.1 Pigeon pea grains (Variety : BDN-2).

- **Cleaning of pigeon pea grains**

The pigeon pea grains were cleaned mechanically at Pulse Processing Plant, Dept. of Processing and Food Engineering, College of Agril. Engg. and Technology, JAU, Junagadh to remove all foreign matters such as dust, dirt, stones, chaff, immature grains, insect eaten and broken grains. The cleaned grains were then graded to obtain uniform sized grains. The cleaned and graded pigeon pea grains were finally stored in the polypropylene woven bags for future utilization.

Plate 4.2 Pulse processing plant available at Dept. of Processing and Food Engineering.

❖ **Determination of moisture content of pigeon pea grains**

Moisture content of sample was determined based on drop in weight from initial weight of sample by using formula given in Eq. 10.1.

$$\text{Moisture content (\%w.b.)} = \frac{\text{Initial wt. of sample-Oven dried wt. of sample}}{\text{Initial wt. of sample}} \times 100 \quad \ldots(10.1)$$

Plate 4.3 Moisture content determination of pigeon pea grains using hot air oven.

❖ **Physical properties of pigeon pea grains**

- **Size and sphericity**

The physical dimensions of the grains were measured at two different moisture contents, i.e. at initial moisture content of 10.62%(w.b.) and at 26%(w.b.). The size and sphericity were then calculated using the formulae given in Eq. 10.2 and 10.3 respectively. (Mohsenin, 1986).

$$\text{Size} = (a \times b \times c)^{1/3} \quad \ldots..(10.2)$$

$$\text{Sphericity} = \frac{(a \times b \times c)^{1/3}}{a} \quad \ldots..(10.3)$$

Where,

a = length of grain, mm

b = width of grain, mm and

c = thickness of grain, mm

Plate 4.4 Measurement of physical dimensions of pigeon pea grains using vernier caliper.

- **Thousand grain mass**

Thousand grain mass was determined by counting 1000 grains and weighing them through a digital electronic balance having an accuracy of ± 0.001 g. The thousand grain mass was determined at two different moisture contents, i.e. at initial moisture content of 10.62%(w.b.) and at 26%(w.b.).

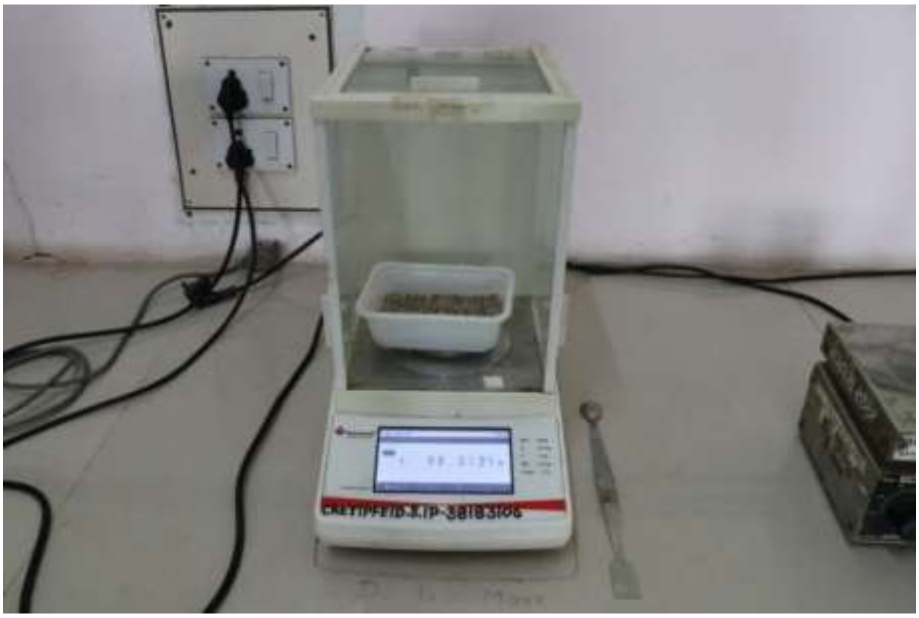


Plate 4.5 Measurement of thousand grain mass of pigeon pea grains

- **Bulk density**

The bulk density of the grains was measured at two different moisture contents, i.e. at initial moisture content of 10.62%(w.b.) and at 26%(w.b.). Bulk density of pigeon pea grains were then calculated using the formula given in Eq. 10.4

$$\text{Bulk density, } \rho_b = \frac{W}{V} \qquad \text{.....(10.4)}$$

Where,

W = Mass of grains, g

V = Volume occupied by grains, cc

Plate 4.6 Measurement of bulk density of pigeon pea grains.

- **True density**

True density was then calculated using the formula given in Eq. 10.5. The true density of the grains was measured at two different moisture contents, i.e. at initial moisture content of 10.62%(w.b.) and at 26%(w.b.).

$$\text{True density, } \rho_t = \frac{W_t}{V_t} \quad \text{.....(10.5)}$$

Where,

W_t = Mass of grains, g

V_t = True volume occupied by the same grains, cc

Plate 4.7 Measurement of true volume of pigeon pea grains.

- **Porosity**

The porosity of pigeon pea grains at selected levels of moisture content was calculated from the values of bulk and true densities using the equation given in 10.6 as described by Mohsenin (1986).

$$\text{Porosity}, \rho_t = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100 \qquad \text{.....(10.6)}$$

Where,

ρ_b = Bulk density

ρ_t= True density

- **Angle of Repose**

The angle of repose of pigeon pea grains was determined by standard circular platform method as given by Mohsenin (1986). The angle of repose of the grains was measured at two different moisture contents, i.e. at initial moisture content of 10.62%(w.b.) and at 26%(w.b.). The angle of repose was calculated by the Eq. 10.7

$$\theta = \tan^{-1}\left(\frac{2h}{d}\right) \qquad \text{.... (10.7)}$$

Where,

θ = Angle of repose,

h = Height of cone, cm

d = Diameter of cone, cm

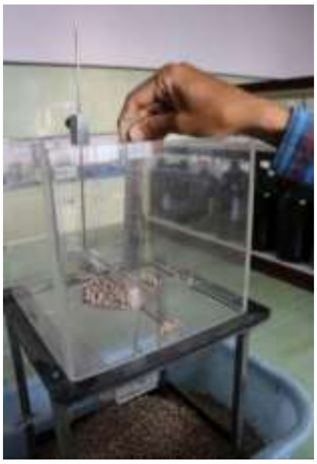


Plate 4.8 Measurement of angle of repose of pigeon pea grains.

- **Static coefficient of friction**

The static coefficient of friction of pigeon pea grains was determined considering three different surfaces, namely glass, galvanized sheet and plywood surface. The coefficient of friction was determined by the inclined plane method as described by Mohsenin (1986). This coefficient was measured at two different moisture contents, i.e. at initial moisture content of 10.62%(w.b.) and at 26%(w.b.). The values of Y and X were used to calculate the coefficient of friction using the formula given in Eq. 10.8

$$\text{Coefficient of friction, } \tan \phi = \frac{Y}{X} \quad \text{` } \qquad \ldots. (10.8)$$

Where,

Y = Vertical distance, cm

X = Horizontal distance, cm

Plate 4.9 Measurement of coefficient of friction of pigeon pea grains

❖ **Enzyme solution**

- **Determination of desired quantity of water**

The sample of desired moisture levels were prepared by adding the required amount of distilled water as calculated by the formula given in equation 10.9 (Coskun *et. al*., 2005).

$$Q = \frac{W_i(M_f - M_i)}{(100 - M_f)} \quad \text{…. (10.9)}$$

Where,

Q = Mass of water to be added (g),

W_i = Initial mass of sample (g),

M_i = Initial moisture content of sample (% w.b.) and

M_f= Final moisture content of sample (% w.b.)

- **Determination of desired quantity of enzyme**

The procedure for calculation of weight of three different enzymes required preparation of different enzyme concentrations is given as under.

- **Calculation of weight of enzyme required for preparation of different enzyme concentrations**

Enzyme concentration (For 1 Kg sample)

Sample size = 1 kg

Initial moisture content = 10.62 %(w.b.)

$$Amount\ of\ water\ in\ 1\ kg\ sample = \frac{Moisture\ content\ \%(w.b.)\ x\ Weight\ of\ sample\ (g)}{100}$$

$$= \frac{10.62\ \%\ (w.b.)\ x\ 1000\ (g)}{100}$$

= 106.2 g

Dry weight of sample = 1000 – 106.2

= 893.8 g dry weigh of sample

Recommended enzyme concentration = 37.8 mg/ 100 g dry sample

Weight of enzyme required for 893.8 g dry sample

$$= \frac{37.8\ x\ 893.8}{100}$$

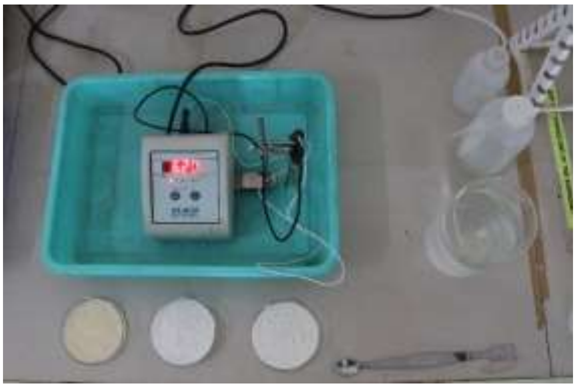
= 337.86 mg = 338 mg

Accordingly, the quantity of different enzymes required for 1 kg of pigeon pea grain sample was determined.

Plate 4.10 Xylanase, Pectinase and Cellulase used for giving enzymatic pre-treatment to pigeon pea grains.

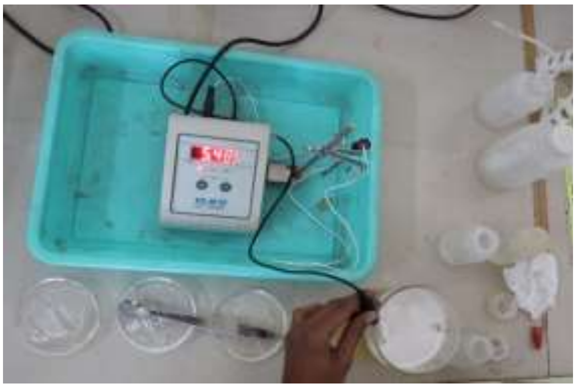
- **Preparation of enzyme solution**

The required quantity of water to elevate the moisture content of grain from initial moisture content to 26% (w.b.) moisture content was calculated using the Eq. 9.9. The desired quantity of pre-mixed enzyme powder at a recommended proportion of all three enzymes (Xylanase :Cellulase : Pectinase – 2:1:1) was then added in the water and mixing was carried out until the enzyme powder was completely dissolved in the water. Simultaneously, pH of the enzyme solution was adjusted to 5.49 during the mixing process by adding the 37% hydrochloric acid. Digital pH meter was used to check the pH of the solution during pH adjustment. Hence, the final enzyme solution contained 2 parts of Xylanase, 1 part of Cellulase and 1 part of pectinase with a pH of 5.49. The prepared enzyme solution was stoked in the water tank for the utilization during enzymatic pre-treatment to pigeon pea grains.



Set up for pH adjustment

Addition of enzymes into water



Adjustment of pH of enzyme solution **Final enzyme solution**

Plate 4.11 Preparation of enzyme solution

- **Enzymatic pre-treatment using developed grain treater and milling of pigeon pea grains**

The grain treater for giving the enzymatic pre-treatment to the pigeon pea grains is shown in the Plate 4.12.

The process flowchart for giving the enzymatic pre-treatment to pigeon pea grains using developed grain treater as well as milling of grains is given in Fig. 4.2 The processing conditions as optimized and recommended by Sangani *et al.* (2014) was applied for giving the enzymatic pre-treatment to pigeon pea grains. The process photographs for giving enzymatic pre-treatment to pigeon pea grains are presented in the Plate 4.13.

Plate 4.12 Grain treater used for giving enzymatic pre-treatment to pigeon pea grains.

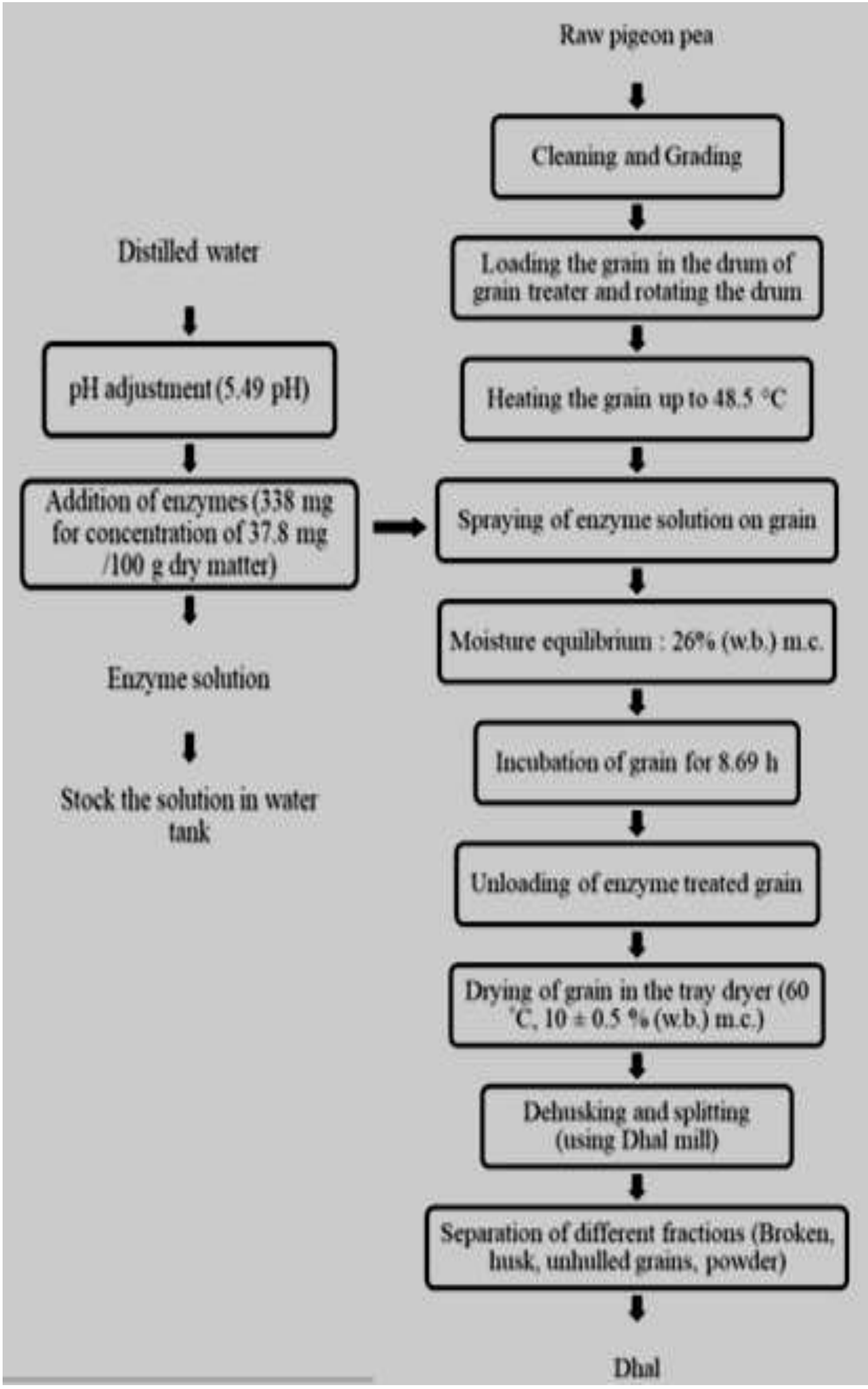


Fig. 4.2 Flow chart for giving enzymatic pre-treatment using developed grain treater and milling of pigeon pea

Cleaned pigeon pea grains

Loading of pigeon pea grain in the drum

Unloading of pigeon pea grains

Enzyme treated pigeon pea grains

Drying of enzyme treated pigeon pea grains in the tray dryer

Plate 4.13 Enzymatic pre-treatment to pigeon pea grains using developed grain treater.

❖ **Milling of sample**

Enzymatically pre-treated pigeon pea grains having about 10±0.5 % (w.b.) were milled using small scale dehusking machine/dhal mill (Plate. 4.14). Grains were milled at the standard settings of the machine, i.e., 1420 rpm operating speed and 64 kg/h feed rate (Plate 4.15). After milling, all the milled fractions were collected in polypropylene bag.

Plate 4.14 Dehusking machine used for milling of pigeon pea grains

Dehulling of treated pigeon pea grains **Dhal separation from milled grain**

Plate 4.15 Milling of enzyme treated pigeon pea grains.

- **Dehulled sample separation**

From the total milled grain, 1 kg of sample was randomly collected to find the proportion of different fractions in the milled sample. The different fractions of the milled grain from the collected sample were separated by suitable sieves and hand picking such as whole dehulled grains, split dehulled grains, partly dehulled and unhulled grains, broken, husk and powder. A grain was considered completely dehulled when there was no husk adhering to it.

- **Husk content**

The husk (seed coat) content in whole grain was determined by soaking approximately 10 g of pigeon pea grain in distilled water (2 h at 50 °C). The seed coats were then separated manually from the cotyledons, dried in a hot air oven at 100 ± 5 °C up to initial moisture content of 10.62 % (w.b.) (Bharodia, 2004).The data regarding husk content are given in Appendix F. The husk content in % was calculated using the Eq. 10.10.

$$\text{Husk content, \%} = \frac{\text{Weight of husk}}{\text{Weight of pigeon pea grain}} \text{ x } 100 \qquad \text{....(10.10)}$$

- **Dehulled fractions**

All the fractions were weighed accurately using digital weighing balance with an accuracy of ± 0.01g. (Mettler, model PE 3600). Following equations were used to calculate dehulled fractions obtained by dehulling treatments (Singh *et al.*, 2004).

$$\text{Husk removed (HR), \%} = \frac{HR_d}{H_t} \text{ x } 100 \qquad \text{..... (10.11)}$$

$$\text{Coefficient of hulling (Ch)} = 1 - \frac{W_{uh}}{W_{th}} \qquad \text{..... (10.12)}$$

$$\text{Coefficient of wholenes of kernel (Cwk)} = \frac{W_{fp}}{W_{fp}+W_{br}+W_{po}} \text{..... (10.13)}$$

Where,

HR_d = Husk removed during dehusking,(g)

H_t = Total husk content (g)

= husk content in fraction X weight of grain used for milling (g)

W_{uh} = Weight of unhulled grain after milling (g)

W_{th} = Weight of grain used for milling (g)

W_{fp} = Weight of finished product (g) (Splits and whole dehulled grain)

W_{br} = Weight of brokens (g)

W_{po} = Weight of powder (g)

The hulling efficiency was determined using Eq. 10.14

$$\text{Hulling efficiency (HE)}, \% = \text{Ch x Cwk x 100} \quad \text{…. (10.14)}$$

Plate 4.16 Different fractions after milling of pigeon pea grains.

- **Experimental design**

To evaluate the performance of the grain treater and to optimize the machine parameters, the effects of two independent variables *viz.*, drum speed (X_1)and drum occupied volume (X_2) on hulling efficiency were studied. Response Surface Methodology (RSM) was used for designing the experiments. A Central Composite Rotatable Design (CCRD) of 2 variables at 5 levels each with 5 centre point combinations were used (Khuri and Cornell, 1987). Altogether, 13 combinations (including 5 replications at the centre point and single observation at other points) were obtained using Design Expert Software (Version 10). The coded and uncoded variable values of the design are presented in Table 4.1 whereas the treatment details is presented in the Table 4.2.

Table 4.1 Coded and uncoded value of different variables.

Sr. No.	Parameters	Code	Coded levels				
			-2	-1	0	+1	+2
1	Drum speed (rpm)	X_1	5	7.5	10	12.5	15

2	Drum occupied volume (%)	X_2	25	28.75	32.5	36.25	40

Table 4.2 Treatment details giving enzymatic pre-treatment to pigeon pea grains using developed grain treater.

Treatment No.	Coded variables		Uncoded variables	
	X_1	X_2	Drum speed (rpm)	Drum occupied volume (%)
1	-1	-1	7.5	28.75
2	1	-1	12.5	28.75
3	-1	1	7.5	36.25
4	1	1	12.5	36.25
5	-2	0	5	32.5
6	2	0	15	32.5
7	0	-2	10	25
8	0	2	10	40
9	0	0	10	32.5
10	0	0	10	32.5
11	0	0	10	32.5
12	0	0	10	32.5
13	0	0	10	32.5

- **Data analysis and optimization**

The CCRD design was used to conduct experiments and the Response Surface Methodology (RSM) was applied to the experimental data using a commercial statistical package, Design Expert (Version 10.0) (Stat-ease, 2009). Analysis of variance (ANOVA) was conducted for fitting the model represented by Eq. 10.15 to examine the statistical significance of the model terms. Model analysis with respect to lack-of fit test and R^2 (co-efficient of determination) was done for determining adequacy of model. The co-efficient of variation (CV) was calculated to find the relative dispersion of the experimental points from the prediction of the model. Response surfaces were generated and by using the same software, numerical optimization was done. The most commonlyused model for optimization using response surface methodologyis a second order polynomial equation (Bas and Boyaci, 2007). The model is of the form:

$$Y_k = b_{k0} + \sum_{i=1}^{3} b_{ki} X_i + \sum_{i=1}^{3} b_{kii} X_i^2 + \sum_{i \neq j=1}^{3} b_{kij} X_i X_j \quad \ldots (10.15)$$

(k=0, 1, 2, 3….)

Where, Y_k is the response, b_{k0}, b_{ki}, b_{kii}, and b_{kij} are the constant, linear, quadratic and cross-product regression coefficients, respectively and X_i's are the coded independent variables.

- **Validity test**

The optimum conditions obtained after data analysis using Design Expert Software was verified by conducting the experiment in triplicates at the optimized condition. The average value of dehulling efficiency as obtained after validation experiment were compared with the optimized value to check the validity of the optimized process parameters.

❖ **Results and discussion**

➢ **Moisture content of pigeon pea grain**

The moisture content of pigeon pea grain was varied from 10.37 % (w.b.) to 10.83 % (w.b.) and the average moisture content of the grain was obtained as 10.62 % (w.b.).

- **Effect of moisture content on physical properties of pigeon pea grain**

The physical properties of pigeon pea grains was determined at the initial moisture content of 10.62% (w.b.) and after attaining the moisture content of 26% (w.b.). The average physical dimensions of grain at these two different moisture contents is presented in the Table 4.3. It can be seen from the table that the average length, width and thickness of grains was 6.12 mm, 5.51 mm and 4.58 mm, respectively at moisture content of 10.62% (w.b.) while the average length, width and thickness of grains was found to be increased up to 6.34 mm, 5.67 mm and 4.74 mm, respectively at moisture content of 26% (w.b.). Accordingly, the equivalent diameter and sphericity was obtained as 5.36 mm and 0.877, respectively at moisture content of 10.62% (w.b.). The equivalent diameter was observed to be increased up to 5.54 mm upon attainment of grain moisture content at 26% (w.b.). The sphericity of grains was little decreased from 0.877 to 0.875 when the grain moisture content was increased from 10.62% (w.b.) to 26% (w.b.).

Table 4.3 Physical dimensions of pigeon pea grains (n=15).

M.C. %(w.b)	Value	Length (mm)	Width (mm)	Thickness (mm)	Size, Equivalent diameter (mm)	Sphericity
10.62%	Minimum	6.28	5.78	4.92	5.55	0.923

(initial)	Maximum	6.01	5.28	4.32	5.23	0.843
	Average	**6.12**	**5.51**	**4.58**	**5.36**	**0.877**
26%	Minimum	6.48	5.84	4.86	5.60	0.891
	Maximum	6.22	5.45	4.61	5.49	0.856
	Average	**6.34**	**5.67**	**4.74**	**5.54**	**0.875**

- **Effect of moisture content on grain mass and densities of pigeon pea grain**

The thousand grain mass, bulk density, true density and porosity of pigeon pea grains was determined at the initial moisture content of 10.62% (w.b.) and after attaining the moisture content of 26% (w.b.). The average thousand grain mass, bulk density, true density and porosity of pigeon pea grains at 10.62% (w.b.) and 26% (w.b.) moisture contents is presented in the Table 4.4. Table revealed that at the initial moisture content of 10.62% (w.b.) the thousand grain mass was varied from 97.76 g to 98.56 g while at the moisture content of 26% (w.b.) it was varied from 118.78 g to 119.07 g. It can also be observed from the table that the average thousand grain mass of the grain was increased from 98.22 g to 118.95 g when the moisture content was increased from 10.62% (w.b.) to 26% (w.b.). The minimum bulk density, true density and porosity were observed as 864 kg/m^3, 1349 kg/m^3 and 35.36%, respectively and maximum bulk density, true density and porosity were observed as 874 kg/m^3, 1356 kg/m^3 and 36.00%, respectively at moisture content of 10.62% (w.b.). Similarly, the minimum bulk density, true density and porosity were observed as 802 kg/m^3, 1292 kg/m^3 and 37.55%, respectively and maximum bulk density, true density and porosity were observed as 815 kg/m^3, 1307 kg/m^3 and 38.50%, respectively at moisture content of 26% (w.b.). The average value of bulk density, true density and porosity were observed as 870 kg/m^3, 1352 kg/m^3 and 35.6 %, respectively at moisture content of 10.62% (w.b.) similarly the average value of bulk density, true density and porosity were observed as 808 kg/m^3, 1300 kg/m^3 and 37.85%, respectively at moisture content of 26% (w.b.).

Table 4.4 Grain mass and densities of pigeon pea grains (n=5).

M.C. %(w.b)	**Value**	**Thousand grain mass (g)**	**Bulk density (kg/m^3)**	**True density (kg/m^3)**	**Porosity (%)**
10.62% (initial)	Minimum	97.76	864	1349	35.36
	Maximum	98.56	874	1356	36.00
	Average	**98.22**	**870**	**1352**	**35.65**
26%	Minimum	118.78	802	1292	37.55
	Maximum	119.07	815	1307	38.50
	Average	**118.95**	**808**	**1300**	**37.85**

- **Effect of moisture content on frictional properties of pigeon pea grain**

The important frictional properties like angle of repose and coefficient of friction for the different surfaces for the pigeon pea grains was determined at the initial moisture content of 10.62% (w.b) and after attaining the moisture content of 26% (w.b). The average value of angle of repose and static coefficient of friction with respect to different surfaces are presented in the Table 4.5. Value of all the frictional properties was increased upon increase in the moisture content from 10.62% (w.b.) to 26% (w.b.). The minimum, maximum and average value of angle of repose at the initial moisture content of 10.62% (w.b.) was observed as 27.89°, 29.11° and 28.37°, respectively while the minimum, maximum and average value of angle of repose at moisture content of 26% (w.b.) was observed as 35.62°, 35.85° and 35.76°, respectively. The minimum, maximum and average value of static coefficient of friction with respect to galvanized surface at the initial moisture content of 10.62% (w.b.) was observed as 0.335, 0.356 and 0.348, respectively while the minimum, maximum and average value of coefficient of friction at moisture content of 26% (w.b.) was observed as 0.545, 0.561 and 0.552, respectively. The minimum, maximum and average value of static coefficient of friction with respect to plywood surface at the initial moisture content of 10.62% (w.b.) was observed as 0.391, 0.452 and 0.419, respectively while the minimum, maximum and average value of static coefficient of friction with respect to plywood surface at the moisture content of 26% (w.b.) was observed as 0.632, 0.665 and 0.651, respectively. Similarly, the minimum, maximum and average value of static coefficient of friction with respect to glass surface at the initial moisture content of 10.62% (w.b.) was observed as 0.329, 0.348 and 0.340, respectively and the minimum, maximum and average value of static coefficient of friction with respect to glass surface at moisture content of 26% (w.b.) was observed as 0.487, 0.498 and 0.493, respectively.

Table 4.5 Frictional properties of pigeon pea grains (n=5).

M.C.%(w.b)	Value	Angle of repose (degree)	Static coefficient of friction		
			Galvanized	Plywood	Glass
10.62% (initial)	Minimum	27.89	0.335	0.391	0.329
	Maximum	29.11	0.356	0.452	0.348
	Average	**28.37**	**0.348**	**0.419**	**0.340**
26%	Minimum	35.62	0.545	0.632	0.487
	Maximum	35.85	0.561	0.665	0.498
	Average	**35.76**	**0.552**	**0.651**	**0.493**

➢ **Husk content of pigeon pea grain**

The minimum, maximum and average value of weight of different grain components and accordingly the husk content are presented in the Table 4.6. The minimum, maximum and average husk content in the pigeon pea grain was determined as 13.14%, 13.98% and 13.45%, respectively.

Table 4.6 Husk content of pigeon pea grains (n=5).

Value	Weight of cotyledon (g)	Weight of husk (g)	Total weight (g)	Husk content (%)
Minimum	8.414	1.312	9.727	13.14
Maximum	8.918	1.389	10.267	13.98
Average	**8.647**	**1.344**	**9.991**	**13.45**

➢ **Requirement of quantity of different enzymes**

The processing conditions as optimized and recommended by Sangani *et al.* (2014) for giving enzymatic pre-treatment to pigeon pea grains is presented here under in the Table 4.7.

Table 4.7 Recommended processing condition for giving enzymatic pre-treatment to pigeon pea grains (Sangani *et al.*, 2014).

Variety	Moisture content of grain (%w.b.)	Enzyme concentration (mg / 100 g dry matter)	Incubation time (h)	Incubation temperature (°C)	pH
BDN2	26	37.8	8.69	48.5	5.49

Accordingly, the quantity of different enzymes required for 1 kg of pigeon pea grain sample having an initial moisture content of 10.62% (w.b.) was determined as per the procedure explained in the previous section and presented in the Table 4.8. On the basis of that, the total quantity of selected enzymes required for the different treatments was determined and presented in the Table 4.9.

Table 4.8 Quantity of different enzymes required for 1 kg sample (M.C.=10.62%(w.b.).

Qty. of grain sample (g)	Total qty. of enzyme required for 1 kg of sample (mg)	Enzyme Proportion (2 : 1 : 1)		
		Xylanase (mg)	Pectinase (mg)	Cellulase (mg)
1000	338	169.0	84.5	84.5

Table 4.9 Quantity of selected enzymes required for different treatments (M.C.=10.62%(w.b.).

Treatment No.	Total qty. of grain sample (kg)	Total weight of enzymes (mg)	Enzyme Proportion (2 : 1 : 1)		
			Xylanase (mg)	Pectinase (mg)	Cellulase (mg)
1	104.1	35170	17585.00	8792.50	8792.50
2	104.1	35170	17585.00	8792.50	8792.50
3	131.2	44344	22172.00	11086.00	11086.00
4	131.2	44344	22172.00	11086.00	11086.00
5	117.6	39757	19878.50	9939.25	9939.25
6	117.6	39757	19878.50	9939.25	9939.25
7	90.5	30582	15291.00	7645.50	7645.50
8	144.8	48932	24466.00	12233.00	12233.00
9	117.6	39757	19878.50	9939.25	9939.25
10	117.6	39757	19878.50	9939.25	9939.25
11	117.6	39757	19878.50	9939.25	9939.25
12	117.6	39757	19878.50	9939.25	9939.25
13	117.6	39757	19878.50	9939.25	9939.25

- **Effect of enzymatic pre-treatment given through grain treater on hulling efficiency of pigeon pea grains**

The efficacy of enzymatic pre-treatment given to pigeon pea grains using grain treater was evaluated in terms of hulling efficiency for the different combinations of drum speed and drum occupied volume. These two machine parameters were optimized to maximize the hulling efficiency of pigeon pea grains. The detailed discussion regarding the effect of these machine parameters on hulling efficiency is narrated as under.

- **Effect of drum speed and drum occupied volume on hulling efficiency of pigeon pea grains**

The effect of drum speed and drum occupied volume on hulling efficiency of enzyme treated pigeon pea grains is presented in Table 4.10. It could be observed from the table that the hulling efficiency of pigeon pea grains after enzymatic pre-treatments given by developed grain treater was varied from 86.14% to 89.64%. The highest hulling efficiency (89.64%) was obtained for the treatment no. 11 having a drum speed of 10 and drum occupied volume of 32.5% while the lowest hulling efficiency (86.15%) was obtained for the treatment no. 8 having a drum speed of 10 and maximum drum occupied volume of 40%.

Table 4.10 Hulling efficiency obtained at different combination of process variables.

Tr. No.	Drum speed (rpm)	Drum occupied volume (%)	Coefficient of hulling (Ch)	Coefficient of wholeness of kernel (Cwk)	Hulling efficiency (%)
1	7.5	28.75	0.94	0.95	89.33
2	12.5	28.75	0.94	0.94	88.28
3	7.5	36.25	0.94	0.94	88.72
4	12.5	36.25	0.94	0.93	88.01
5	5	32.5	0.94	0.94	88.23
6	15	32.5	0.94	0.94	87.94
7	10	25	0.94	0.93	88.06
8	10	40	0.93	0.92	86.15
9	10	32.5	0.94	0.94	89.09
10	10	32.5	0.95	0.95	89.45
11	10	32.5	0.95	0.95	89.64
12	10	32.5	0.94	0.95	88.99
13	10	32.5	0.95	0.95	89.37

The response surface curves and contour plots for hulling efficiency of pigeon pea grains after enzymatic pre-treatments given by developed grain treater are shown in the Fig. 4.3. It was observed from the contour map, that the hulling efficiency was increased with an increase in drum speed up to 9 rpm and drum occupied volume up to 31%. With this combination of drum speed and drum occupied volume, the hulling efficiency was expected to be increased up to 89.46%. With further increase in drum speed above 9 rpm, the hulling efficiency was observed to be decreased. Similarly, it was found to be decreased with an increase in drum occupied volume beyond 31%. However, the rate of variation in the hulling efficiency with respect to change in the drum speed and drum occupied volume was nominal.

The decrease in hulling efficiency beyond drum speed of 9 rpm and drum occupied volume of 31% might be due to non-uniform treatment received by individual grains during the drum rotation. It can be assumed that at higher drum speed the mixing efficiency of the grains might have affected negatively and at higher percentage of drum occupied volume the temperature gradient within the grain bed might have increased resulted in the poor efficiency of enzyme treatment which ultimately affected the hulling efficiency negatively.

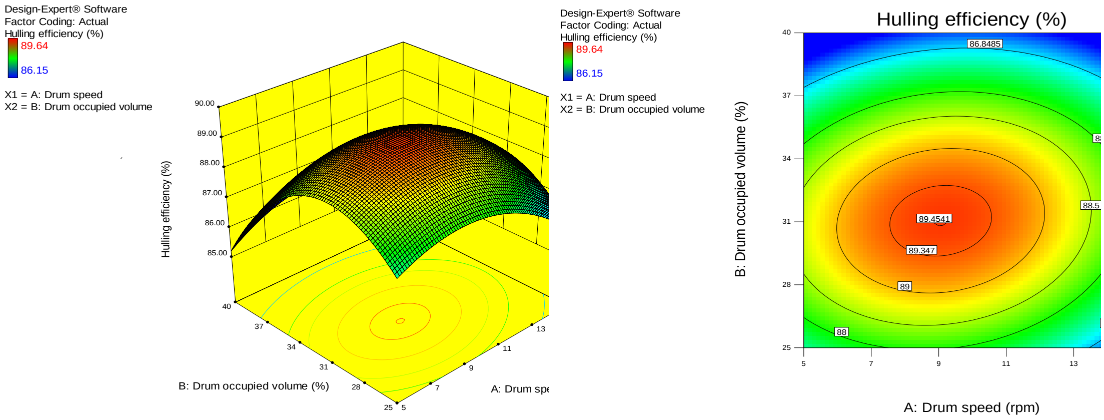


Fig. 4.3 Response surface and contour plot for hulling efficiency of pigeon pea grains as a function of drum speed and drum occupied volume.

➢ **Statistical analysis**

- **Hulling efficiency**

The regression analysis and ANOVA results for the hulling efficiency of pigeon pea grain after enzymatic pre-treatments given by developed grain treater are shown in the Table 4.11.

Table 4.11 Analysis of variance table and regression coefficients for response surface quadratic model of hulling efficiency of pigeon pea grains.

Source	Hulling efficiency (%)
b_0 (Intercept)	89.34^{**}
Linear terms	
b_1 (X_1)	-0.20
b_2 (X_2)	-0.39^{**}
Interaction terms	
b_{12} (X_1X_2)	0.086
Quadratic terms	
b_{11} (X_1^2)	-0.30^{**}
b_{22} (X_2^2)	-0.55^{***}
Indicators for model fitting	
R^2	0.9180
Adj-R^2	0.8594
Pred- R^2	0.4168
Adeq. Precision	12.407
F-value	15.67
Lack of Fit	NS
C.V.,%	0.40

X_1 = Drum speed, X_2 = Drum occupied volume

***Significant at p<0.001, **Significant at p<0.01, *Significant at p<0.05

It can be seen from the table, that drum speed and drum occupied volume showed a negative linear effect on hulling efficiency, among which the drum occupied volume was significant at p<0.01. Similarly, the quadratic effect of both, drum speed and drum occupied volume was significantly negative at $p<0.01$ and at $p<0.001$, respectively. However, the interaction between the selected variables showed no significant effect on hulling efficiency ($p>0.05$) and this effect was positive.

The derived model, giving the empirical relation between the hulling efficiency and the test variables in coded units, was obtained as under :

$$\text{Hulling efficiency (\%)} = 89.34 - 0.20X_1 - 0.39X_2 - 0.30X_1^2 - 0.55X_2^2 + 0.086X_1X_2 \quad \ldots\ldots(10.1)$$

Where, X_1 and X_2 are the coded factors of drum speed and drum occupied volume, respectively.

The calculated F-value for hulling efficiency (15.67) was significant at $p<0.01$. At the same time, it possessed non-significant lack of fit ($p>0.05$). These values indicated that the model for hulling efficiency was fitted and reliable. The R^2 value and Adj-R^2 value for the juice yield were 0.9180 and 0.8594, respectively, which were higher than the 0.8, indicating the adequacy, good fit and high significance of the model. The high Adeq Precision value (>4) again supported the significance of the model for hulling efficiency. The small value of coefficient of variation (0.40%) for hulling efficiency explained that the experimental results were precise and reliable (Table 4.11).

- **Optimization and validation of process variables**

The optimum grain treater parameters for improving the efficacy of enzymatic pre-treatment and for maximizing the hulling efficiency of pigeon pea grains was determined by the numerical optimization technique, using Design Expert software : version 10 (State-Ease Inc., Minneapolis, MN, USA). The main criteria applied for constraints optimization in the study were: (a) drum speed: in the range, (b) drum occupied volume: in the range, and (c) hulling efficiency : maximum. Accordingly, the goals that were set for variables and responses to obtain the best combination are illustrated in the Table 4.12. All the independent variables and responses were given an equal importance, i.e. three, during optimization process. Under these constraints, the optimum treatment conditions were found to be, 9 rpm drum speed and 31% drum occupied volume. The analysis showed that at this combination of drum speed and drum occupied volume, it would be possible achieve the hulling efficiency of 89.46%.

Using these optimized conditions the experiments were again conducted to find the variation in the selected response variable. The results revealed that the experimental values of conducted experiments were very close to the predicted values (Table 4.13).

The closeness of the observed and predicted responses indicated the validity of developed model.

Table 4.12 Constraints, criteria and output for numerical optimization of grain treater parameters for giving enzymatic pre-treatment to pigeon pea grains.

Variables					
Constraint	**Goal**	**Importance**	**Optimum value**		
Drum speed (rpm)	In the range	3	9.06 = 9		
Drum occupied volume (%)	In the range	3	31.05 = 31		
Responses					
Constraint	**Goal**	**Importance**	**Predicted value**	**Experimental value**	**Deviation (%)**
Hulling efficiency (%)	Maximize	3	89.46	88.73	0.82

- **Improved method recommended for giving enzymatic pre-treatment to pigeon pea grains using developed grain treater**

As a result of studies conducted on various aspects of giving enzymatic pre-treatment to pigeon pea grain using developed grain treater an improved method is suggested through a flow diagram given in Fig. 4.4.

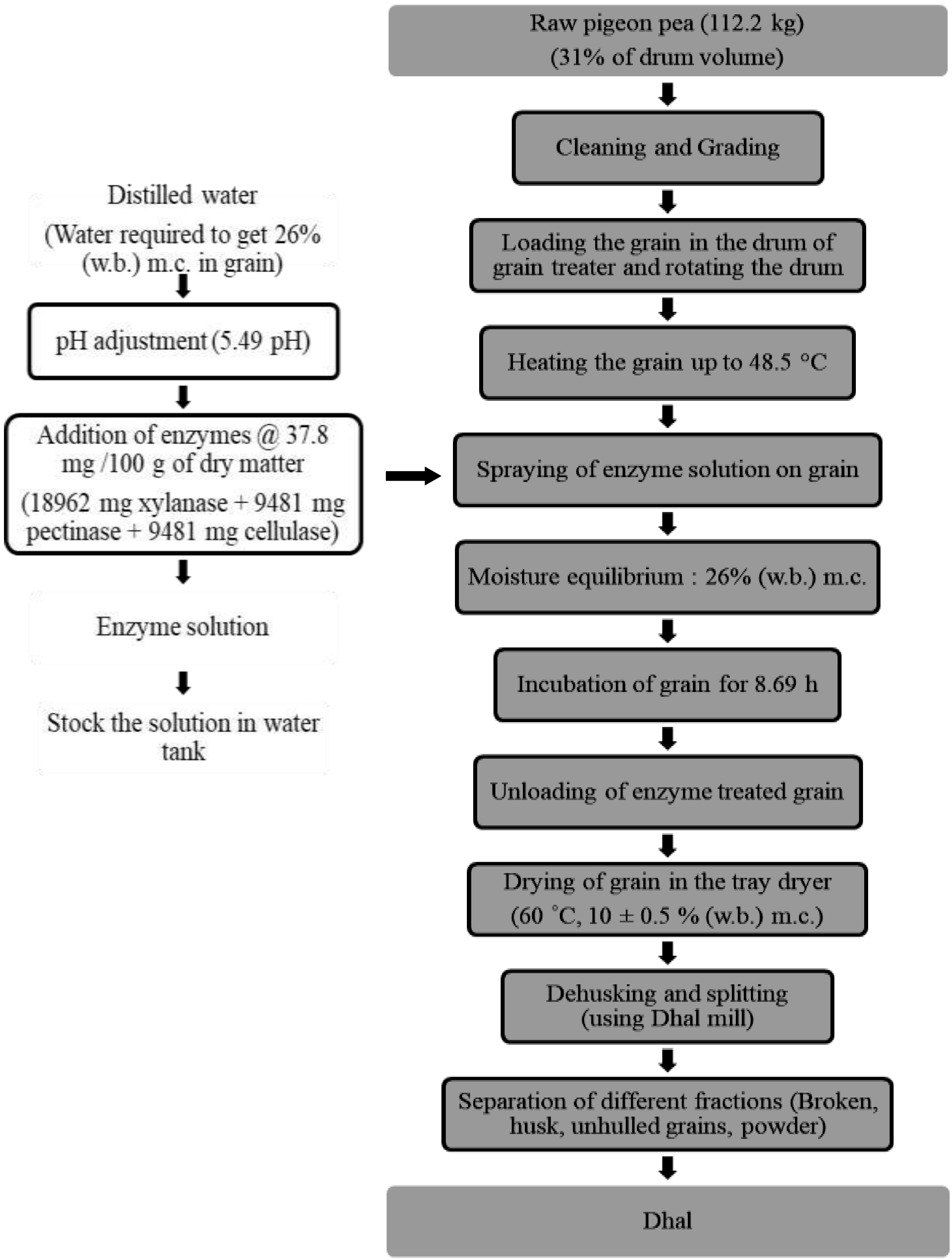


Fig. 4.4 Recommended flow chart for giving enzymatic pre-treatment to pigeon pea grain using grain treater.

- **Cost of the machine and cost economics of the process**

Cost of the developed grain treater was determined by considering the actual cost of the different material and parts used in the fabrication. The total cost incurred in the fabrication of the machine was derives as Rs. 1,56,867.00. The cost economics for the production of pigeon pea dhal using traditional method (dry milling method) and developed method (after enzymatic pre-treatment using developed grain treater) is given in the Table 4.13. The processing time requirement per batch of 100 kg raw material was taken into consideration in the calculation of the cost economics and accordingly the total quantity of the pigeon pea processed per month was derived. From the table it can be seen that the Benefit Cost Ratio (BCR) for the dhal prepared after giving enzymatic treatment using grain treater (1.19) was higher than that of the dhal prepared using dry milling method (1.12). Break even point obtained better for the dhal prepared after giving enzymatic treatment using grain treater (1.82).

Table 4.13 Cost economics for the production of pigeon pea dhal using dry milling method.

Sr. No.	Particular	Unit	Value (Dry milling method)	Value (Enzyme treatment using grain treater)
1	Total quantity of pigeon pea processed per month	kg	2000	2805
2	Total quantity of pigeon pea dhal (dhal+gota) prepared per month	kg	1544.8	2166.58
3	Total income per month	Rs.	1,74,277.60	2,44,424.33
4	Total expenditure per month	Rs.	1,56,071.18	2,04,546.04
5	Processing cost per kg of raw material (including cost of raw material)	Rs.	78.04	72.92
6	Production cost per kg of dhal (including cost of raw material)	Rs.	97.20	90.58
7	Production cost per kg of dhal (excluding cost of raw material)	Rs.	39.20	32.58
8	Monthly profit (Total income - Total expenditure)	Rs.	18,206.43	39,878.29
9	Annual profit (12 x Monthly profit)	Rs.	2,18,477.10	4,78,539.53
10	% profit on scale (Profit / monthly sales income)	%	10.45	16.32
11	% profit on capital investment /Rate of return on investment (Annual profit / total capital investment)	%	29.58	50.49
12	Benefit Cost Ratio (BCR) (Monthly benefit / Monthly cost)	--	1.12	1.19
13	Annual Fixed Cost			
	a. All depreciations	Rs.	2,500.00	3,098.33
	b. Interest	Rs.	1,250.00	1,549.17
	c. 40% of salary, wages, utility, contingency	Rs.	2,796.80	4,234.94
	Total annual fixed cost	Rs.	6,546.80	8,882.44

Note : Cost of the raw material, chemicals, enzymes, instruments, machines, labours, etc. was considered at the rate prevailing in the market at the time of experiment.

11. Financial Implications (` in Lakhs)

11.1 Expenditure on

(a) Manpower : ` 32.00

(b) Research/Recurring Contingencies : ` 0.32

(c) Non-Recurring Cost (Including cost of equipment) : ` 0.00

(d) Any Other Expenditure Incurred

11.2 Total Expenditure : ` 32.32

12. Cumulative Output

a. Special attainments/innovations -

b. List of Publications (one copy each to be submitted if not already submitted)

i. Research papers : Preparation is under progress
ii. Reports/Manuals : Prepared
iii. Working and Concept Papers : Nil
iv. Popular articles : Nil
v. Books/Book Chapters : Nil
vi. Extension Bulletins : Preparation is under progress

c. Intellectual Property Generation
(Patents - filed/obtained; Copyrights- filed/obtained; Designs- filed/obtained; Registration details of variety/germplasm/accession if any) : Nil

d. Presentation in Workshop/Seminars/Symposia/Conferences : Nil
(relevant to the project in which scientists have participated)

e. Details of technology developed : (Crop-based; Animal-based, including vaccines; Biological – biofertilizer, biopesticide, etc; IT based – database, software; Any other – please specify)
- Crop based technology

f. Trainings/demonstrations organized : Yes

g. Training received : Nil

i. Any other relevant information : The developed machine will be useful to the pulse processing industries for giving the enzymatic pre-treatment to pigeon pea grains. The developed machine can give enzymatic pre-treatment to pigeon pea grains very efficiently which increases the hulling efficiency and thereby reduces the processing cost and improves the benefit cost ratio as compared to traditional dhal processing method.

13. (a) Extent of achievement of objectives and outputs earmarked as per RPP-I

Objective wise	Activity	Envisaged output of monitorable target(s)	Output achieved	Extent of Achievement (%)
1. To design and develop the grain treater for enzymatic pre-treatment to pigeon pea grains.	1. Preparation of conceptual design of grain treater 2. Procurement of raw materials for the fabrication of grain treater. 3. Fabrication of the different functional part of the grain treater 4. Complete setup of the grain treater	1. The design was conceptualized by keeping in mind the different engineering properties of pigeon pea grains and requirement of process of enzymatic pre-treatment. 2. Quantity of fabrication materials was derived and purchased from the local supplier. 3. Fabrication of the different functional parts of the grain treater was carried out. 4. All the fabricated parts were assembled and complete setup of the grain treater was erected.	All the activities were completed and envisaged output was achieved	100%
2. To optimize the machine parameters of grain treater for maximizing hulling efficiency of pigeon pea grains.	1. Procurement of the required quantity of pigeon pea grain and enzymes 2. Laboratory experiments as per the treatments 3. Evaluation of different dependent parameters to check the effect of	1. Pigeon pea grains (Var. BDN-2) were procured from the farmer's field and enzymes were purchased from the Advanced Enzymes. Thane. 2. Grains were analysed for its engineering properties. 3. Laboratory trials were carried out as per the treatments	All the activities were completed and envisaged output was achieved	100%

	process parameters 5. Analysis of data 6. Optimization of machine parameters	using developed grain treater 4. Dehulling of enzyme treated grains were carried using dehusker. 5. Hulling efficiency for the different samples were determined as per the standard method and data were analysed to study the effect of machine parameters on dependent parameter. 6. Machine parameters were optimized through Design Expert software to maximize the hulling efficiency.		
3. To estimate the cost of developed machine and to evaluate the cost economics for enzymatic pre-treatment to pigeon pea grains using developed grain treater.	1. To estimate the cost of manufacturing the developed grain treater. 2. To evaluate the cost economics of the developed process using developed grain treater. 3. To compare the cost for preparing the dhal using grain treater and traditional method. 4. Preparation of research report	1. Cost of different functional parts were determined on actual basis and added altogether to get the total cost of the grain treater. 2. The cost economics of the dhal production process using grain treater were evaluated by taking into consideration the fixed costs and variable costs. 3. The cost of dhal production using grain treater was compared with the cost of the dhal production using traditional method.	All the activities were completed and envisaged output was achieved	100%

		4. Research report was prepared and submitted to PC, AICRP on PHET		

(b) Reasons of shortfall, if any : -Nil-

14. Efforts made for commercialization/technology transfer : The working of the machine and the procedure for operating the machine for giving enzymatic pre-treatment to pigeon pea grain was demonstrated to the visiting entrepreneurs as well as students of the college. Further, the effort will be carried for approaching the other pulse processors and farmers for transfer of the developed technology.

15. (a) How the output is proposed to be utilized?

The output of the project/developed machine are to be utilized by the pulse processing industries prior to milling of the pulses to improved the milling efficiency and reducing the cost of dhal production.

(b) How it will help in knowledge creation?

The laboratory process for giving the enzymatic treatment to pigeon pea grain was already developed. The developed grain treater will increase the rate of adoption of this technology due to mechanization.

16. Expected benefits and economic impact(if any)

1. The machine for giving the enzymatic pre-treatment to pigeon pea grain will be made available.
2. The dehulling efficiency of the pigeon pea will be improved.
3. The developed machine will be useful for variety of the pulse grain for giving enzymatic pre-treatment.
4. The process parameters for giving enzymatic pre-treatment to pigeon pea grain will be optimized.
5. The cost of production of dhal will be reduced as compared to traditional method.
6. Time saving process

17. Specify whether the project requires submission of RPP-IV for up scaling of research output. - No

18. Future line of research work/other identifiable problems

1. Training programmes will be arranged for the students and entrepreneurs.
2. The demonstration will be provided to all pulse processors to aware them about the developed machine and to provide hands on training.

19. Details on the research data (registers and records) generated out of the project deposited with the institute for future use

20. Signature of PI, CC-PI(s), all Co-PIs

P. R. Davara Principal Investigator	**M. N. Dabhi** Co-PI

21. Signature of Head of Division

22. Observations of PME Cell based on Evaluation of Research Project after Completion

23. Signature (with comments if any along with rating of the project in the scale of 1 to 10 on the overall quality of the work) of JD (R)/ Director

INVESTIGATION NO. 2

Title : Low temperature grinding of spices.

ANNEXURE -VI
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
CHECKLIST FOR SUBMISSION OF FINAL RESEARCH PROJECT REPORT (RPP-III)
(For Guidelines Refer ANNEXURE – XI (F))

1. Institute Project Code: PH/JU/2019/01
2. Investigators as approved in RPP-I, If any change attach IRC proceedings: Yes

Principal Investigator	CC-PI	Co-PI
Dr. M.N Dabhi	Dr. P. R. Davara	Dr. H. P. Gajera

3. Any change in objectives and activities ~~Yes~~/No
   (If yes, attach IRC proceedings)

i.	Date of Start & Date of Completion (Actual). If any extension granted enclose IRC proceedings		Yes	~~No~~
ii.	Whether all objectives met		Yes	~~No~~
iii.	All activities completed		Yes	~~No~~
iv.	Salient achievements/major recommendations included		Yes	~~No~~
v.	Annual Progress Reports (RPP-II) submitted	1st Year	Yes	~~No~~
vi.	Reprint of each of publication attached		Yes	~~No~~
vii.	Action for further pursuit of obtained results indicated		Yes	~~No~~
viii	Report presented in Divisional seminar (enclose proceedings & action taken report) (AGRESCO meeting)		Yes	~~No~~
ix.	Report presented in Institute seminar (enclose proceedings & action taken report) (Annual Workshop)		Yes	~~No~~
x.	IRC number in which the project was adopted		IRC No:	
xi.	Any other Information		N.A	

4. Signature:

(M. N. Dabhi) (P. R. Davara) (H. P. Gajera)
Project Leader Co-PI Co-PI HOD

ANNEXURE - VII

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

FINAL RESEARCH PROJECT REPORT (RPP- III)

(For Guidelines Refer ANNEXURE – XI(G))

PROJECT REPORT (RPP- III)

1. Institute Project Code : PH/JU/2019/01
2. Project Title: Low temperature grinding of spices.
3. Key Words: Grinding, spices, low temperature
4. (a) Name of the Lead Institute : AICRP on PHET, Junagadh
(b) Name of Division/ Regional Center/ Section: -
5. (a) Name of the Collaborating Institute(s): -
(b) Name of Division/ Regional Center/ Section of Collaborating Institute(s): -
6. Project Team(Name(s) and designation of PI, CC-PI and all project Co-PIs, with time spent)

S. No.	Name, designation and institute	Status in the project (PI/CC-PI/ Co-PI)	Time spent (%)	Work components assigned to individual scientist
1	Dr. M. N. Dabhi Research Engineer, AICRP on PHET, Dept. of Processing and Food Engg., College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh	PI	60%	Planning, data collection, statistical analysis and final report Writing
2	Dr. P. R. Davara, Assistant Research Engineeri, AICRP on PHET, Dept. of Processing and Food Engg., College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh	Co-PI	20%	Helping in analysis and data collection
3	Dr. H. P. Gajera Associate Research Scientist Department of Biotechnology College of Agriculture, Junagadh Agril. University, Junagadh	Co-PI	20%	1. Assessment of biochemical and volatile compound in spiced powder. 2. Data collection and report writing of biochemical and volatile compound available in spice powder through laboratory analysis.

7. Priority Area : Post Harvest Technology
8. Project Duration: Date of Start : 01-03-2019 Date of Completion : 31-03-2021

9. a. Objectives

1. Development of low temperature grinding machine
2. Grinding of spices (Fenugreek seed, Turmeric) at low temperature
3. Assessment of biochemical and volatile compound of spice powder.

c. Practical utility

10. Final Report on the Project (materials and methods used, results and discussion, objective wise achievements and conclusions)

10.1 Experimental details

Experimental design : FCRD

Independent parameters

First Factor **Different Grinding Methods**

A_1 - Ambient grinding
A_2 - By circulating ambient temperature water
A_3 - By circulating chilled water
A_4 - By circulating coolant

Second Factor **Different Feed Temperatures**

B_1 - Ambient temperature feed
B_2 - Low temperature feed (-10 ± 2˚C)

Dependent parameters

Physical Parameters : Size, Sphericity, Bulk density, True density, Porosity, Angle of repose, Coefficient of friction

Mechanical Parameters : Hardness

Biochemical Parameters : Proximate composition (Moisture, Total carbohydrate, Total protein, Crude fat, Total ash) and Other biochemical constituents (Total oil content, Oleoresin, Total phenol concentration, Total flavonoid concentration, Antioxidant activity, Volatile oil, Volatile oil compounds)

10.2Results and Discussions :

Results for Turmeric are presented for recommendation.

10.2.1 Moisture content of turmeric rhizomes

The values of moisture content of rhizomes, estimated with the help of Dean and Stark apparatus are shown in the following table (Table 5.1).

Table 5.1 Moisture content of cleaned turmeric rhizomes

Moisture content % (w.b.)					Mean % (w.b.)	S. D. % (w.b.)
R-1	R-2	R-3	R-4	R-5		
8.22	8.69	8.83	8.54	8.65	8.59	0.205

The mean moisture content of seeds was found to be 8.000 ± 0.176% (w.b.).

10.2.2 Physical properties of turmeric

The mean values obtained for various physical properties of raw turmeric at moisture content of 8.59 % (w.b.) are given in following table (Table 5.2) and are discussed separately below.

Table 5.2 Physical properties of turmeric

Sr. No.	Physical property	Mean ± S. D.
1	Size (Geometric mean diameter) (mm)	20.099 ± 0.169
2	Sphericity	0.365 ± 0.079
3	Bulk density (g/cm^3)	0.558 ± 0.820
4	True density (g/cm^3)	1.345 ± 1.820
5	Porosity (%)	58.51
6	Static angle of repose (°)	36.55 ± 0.13
7	Coefficient of external friction (static) Metal (Galvanized iron) surface	0.252 ± 0.001

Size (Geometric mean diameter)

The mean value for size of turmeric was determined based on values of length, breadth and thickness of 50 randomly selected seeds. The mean value of size in terms of geometric mean diameter was found to be 20.099 ± 0.169 mm.

Sphericity

The mean value of sphericity of 50 randomly selected seeds was found to be 0.365 ± 0.079.

Bulk density

The mean value of four replication of bulk density of selected turmeric rhizomes was found to be 0.558 ± 0.820 g/cm^3.

True density

The mean value of four replication of true density of randomly selected turmeric rhizomes was found to be 1.345 ± 1.820 g/cm^3.

Porosity

The mean value of four replications of porosity for turmeric was calculated based on mean values of bulk and true density. It was found to be 58.51.

Static angle of repose

The mean value of four replications of angle of repose was found to be 36.55 ± 0.13°.

Coefficient of external friction (static)

The mean values four replications was found to be 0.252 ± 0.001for metal (galvanized iron) surface.

Rupture force of turmeric rhizomes

Compressive force or rupture force of turmeric rhizomes was observed 116.68±8.58 kg.

10.2.3 Performance evaluation of low temperature grinding mill

Performance evaluation of low temperature grinding mill was carried out by observing time to grind the material, temperature profile of liquid entering and leaving the grinding chamber along with temperature profile inside the grinding chamber, temperature inside the grinding chamber at the end of grinding operation, temperature of ground product, sieve clogging, milling and machine loss for each treatment combination. In addition to that, temperature of surrounding was noted every time before starting off grinding operation. The mean values of each parameter for all the treatments and the effect of two factors, *viz*. grinding method and feed temperature on all the dependent parameters are shown in following tables (Table 5.3 and 5.4 respectively). Results of this section are discussed separately for each parameter in detail below.

Table 5.3 Mean values of parameters evaluating performance of low temperature grinding mill

Treatment	Ambient temperature (℃)	Temp. inside grinding chamber at end (℃)	Time to grind the material (min)	Temp. of ground product (℃)	Milling loss (%)	Machine loss (%)
L_0T_0	32.00	43.00	6.36	42.00	11.53	7.47
L_0T_1	31.33	39.33	7.46	39.33	14	8.32
L_1T_0	32.33	36.67	7.50	40.00	10.56	7.82
L_1T_1	32.33	33.67	8.20	38.33	10.99	8.35
L_2T_0	32.33	23.33	9.49	37.00	10.35	7.81
L_2T_1	32.00	21.67	10.43	36.33	10.37	8.45
L_3T_0	32.00	20.00	11.06	33.67	10.20	8.82
L_3T_1	32.00	18.33	11.88	33.33	10.14	9.15

Ambient temperature before grinding

Ambient temperature is an important independent parameter which can affect the conditions and results of grinding operation. Ambient temperature, observed with the help of a glass thermometer before each treatment including three. Results showed that the mean value among all the treatments varied from minimum of 31.33℃ to maximum of 32.33 ℃. For all the treatments which include ambient temperature as feed temperature, the values of feed temperature can be found from these ambient temperature itself for the respective treatments.

Table 5.4 Effect of grinding method and feed temperature on parameters evaluating performance of low temperature grinding mill

Effect	Temperature inside grinding chamber at the end (°C)	Time to grind the material (min)	Temperature of ground product (°C)	Milling loss (%)	Machine loss (%)
Grinding method (L)					
Ambient temperature grinding(L_0)	41.17	6.91	40.67	11.83	7.89
Ambient temperature water circulation (L_1)	35.17	7.85	39.17	10.78	8.09
Chilled water circulation (L_2)	22.50	9.96	36.67	10.36	8.13
Coolant circulation (L_3)	19.17	11.47	33.50	10.17	8.98
S. Em±	0.4787	0.1327	0.3997	0.1965	0.1884
C. D. at 5%	1.4352	0.3979	1.1982	0.5893	0.5694
Feed temperature (T)					
Ambient temperature feed (T_0)	35.75	8.60	38.17	10.66	7.98
Low temp. feed (T_1)	34.08	9.49	36.83	10.91	8.57
S. Em±	0.3333	0.0938	0.2826	0.1390	0.1332
C. D. at 5%	0.9994	0.2814	0.8417	NS	0.3995
Interaction (L*T)					
S. Em±	0.6667	0.1877	0.5652	0.278	0.2665
C. D. at 5%	NS	NS	NS	NS	NS
C. V%	**3.307**	**3.5926**	**2.6105**	**4.4644**	**5.5788**

Temperature profile inside the grinding chamber

The values of temperature of liquid entering and leaving the grinding chamber, temperature of liquid inside the refrigeration tank and temperature inside the grinding chamber at every minute during the whole grinding operation for all the treatments are recorded. The values were observed once the temperature of grinding chamber lowered as possible as and became constant for nearly 15 minutes by circulation of liquid without load (without feed) condition.

Temperature profile inside the grinding chamber for all the treatments are shown graphically below (Fig. 5.1). Fig. 5.1(a) shows the trend of change in temperature for the treatments involving ambient temperature feed while fig 5.1(b) shows trend for treatments involving low temperature feed.

From fig. 5.1(a), it can be said that the value of temperature inside the grinding chamber stayed high for ambient grinding treatment whereas all-time low for coolant circulation treatment compared to all other treatments. In case of rise in temperature, treatment involving ambient water circulation grinding treatment has lesser rise of temperature (16.0 ^{o}C) as there is already initial temperature is high. Even it was reported that continuous circulation of ambient water increases the temperature inside the grinding chamber and there was less rise of temperature (16.00 ^{o}C) compared to ambient grinding treatment (18.0 ^{o}C). While treatment involving chilled water circulation, have less rise of temperature (28.0 ^{o}C) compared to coolant circulation treatment (31.7 ^{o}C). There was considerable gap in the graph between the treatments for which refrigerator remained OFF (ambient grinding and ambient temperature water circulation) and refrigerator remained ON (chilled water and coolant circulation) during the whole grinding operation. For all the treatments, temperature inside the grinding chamber increased rapidly at initiation of grinding, increased moderately in middle and rose even swiftly at the end. Fig. 1(b) shows the same trend for treatment involving low temperature feed. The only difference of changing the feed temperature was slight decrease in temperature inside the grinding chamber on the very next minute of feeding in case of low temperature feed. Overall, the initial and final value of temperature inside the grinding chamber for all the treatments are given in following table (Table 5.5).

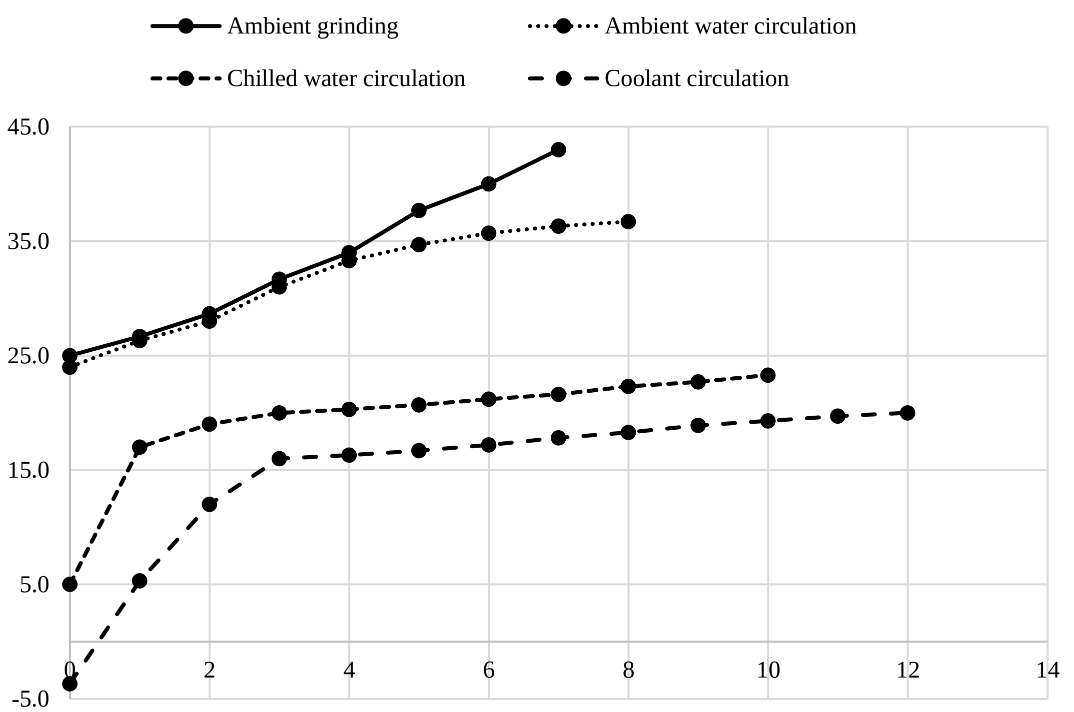


Fig. 5.1(a) Temperature profile of grinding chamber for ambient temperature feed

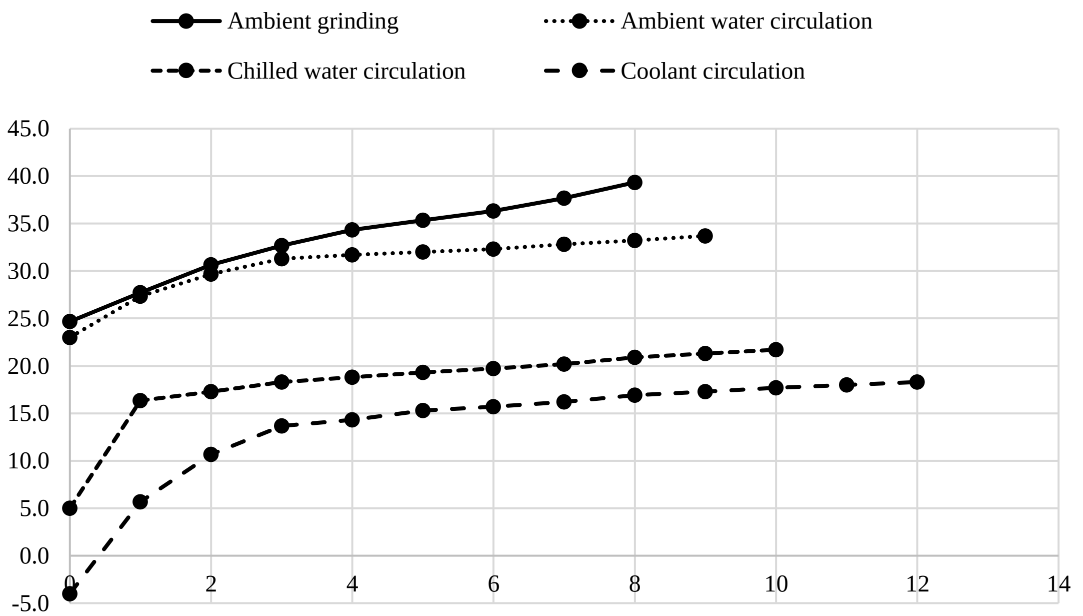


Fig. 5.1(b) Temperature profile of grinding chamber for low temperature feed

Fig. 5.1 Temperature profile of grinding chamber for all the treatments

Table 5.5 Initial and final value of temperature inside the grinding chamber for all the treatments

Treatment	Temperature inside grinding chamber (°C)	
	At beginning of grinding	At the end of grinding
L_0T_0	25.00	43.00
L_0T_1	24.67	39.33
L_1T_0	24.00	36.67
L_1T_1	23.00	33.67
L_2T_0	5.00	23.33
L_2T_1	5.00	21.67
L_3T_0	-3.67	20.00
L_3T_1	-4.00	18.33

Temperature inside the grinding chamber at the end of grinding

From table 5.4, it is clear that grinding method affects significantly on the value of temperature inside the grinding chamber at the end of grinding. The highest temperature (41.17 °C) was found for the grinding method ambient grinding (L_0). The significantly lowest temperature (19.17 °C) was found for the method having coolant circulation around the grinding chamber (L_3). The effect of feed temperature (at 5% level) on the same parameter was also found significant (Table 5.4). The significant highest value found was 35.75 °C for ambient temperature feed (T_0). The value in case of low temperature feed (T_1) was significantly lowest i.e. 34.08 °C. In addition to that, the interaction effect of grinding method and feed temperature (L*T) on the value of temperature inside the grinding chamber at the end of grinding was found non-significant.

The mean values for this parameter for all the treatments are graphically presented in the following figure (Fig. 5.2). It varied from 43.00 °C for ambient water circulation grinding with ambient temperature feed (L_0T_0) to 18.33 °C in coolant circulation with ambient temperature feed (L_3T_1). But fall in temperature becomes substantial with the change in grinding method compared to the change in feed temperature keeping the grinding method same, especially when jumping to chilled water and coolant circulation methods from ambient temperature water circulation. Possibly, resting of considerable amount of time in feed hopper increased the temperature of low temperature feed which in turn diminished its effect to some extent.

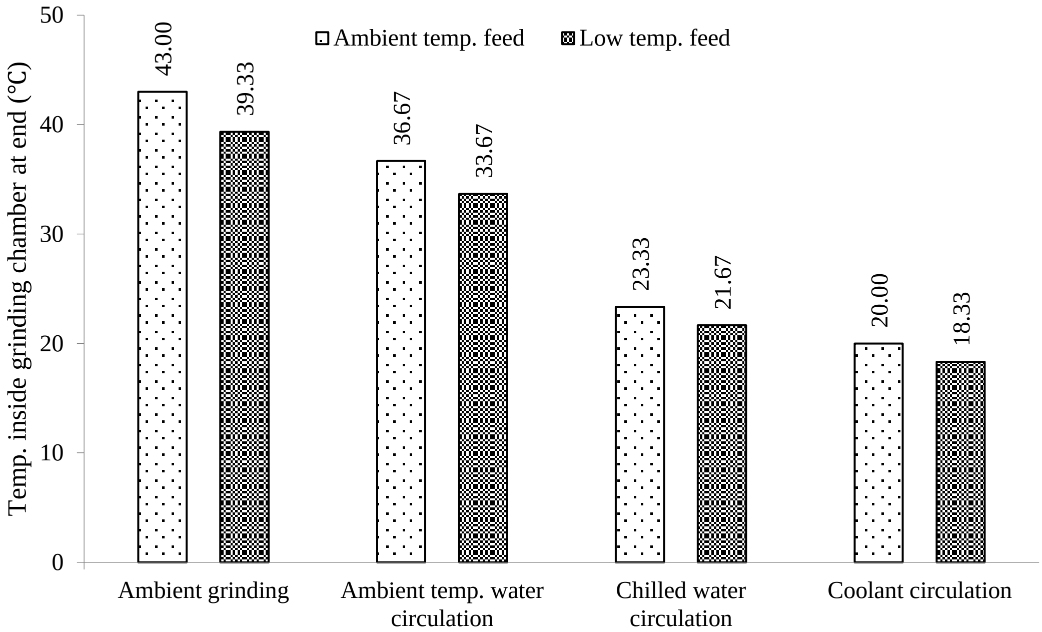


Fig. 5.2 Effect of various treatments on temperature inside the grinding chamber at the end of grinding

From fig. 5.2, it can be concluded that lowering feed temperature as well as circulation of coolant around the grinding chamber positively decreases the final value of temperature inside the grinding chamber. That was caused by continuous absorption of heat generated during grinding operation. Additionally, lowering the temperature of liquid, circulating around the grinding chamber results in appreciable falling of final temperature inside the grinding chamber. That was caused by absorption of more amount of heat generated during grinding operation due to increase in the value of difference in temperature between grinding chamber and circulating liquid around.

Time to grind the material (Grinding time)

From table 5.4, it is clear that effect of grinding method on the value of grinding time was non-significant. The highest time (11.47 min) was found for the grinding method having coolant circulation around the grinding chamber (L_3). The lowest time (6.91 min) was found for the method without liquid circulation (L_0). The effect of feed temperature on the same parameter was also found significant (Table 4). The significantly lowest value was found 8.60 min for ambient temperature feed (T_0). While value in case of low temperature feed (T_1) was significantly highest i.e. 9.49 min. Additionally, the interaction effect of grinding method and feed temperature (L*T) on the value of time to grind the material was found non-significant.

The mean values for this parameter for all the treatments are graphically displayed in the following figure (Fig. 5.3).The values varied from 11.88 min for coolant circulation with low temperature feed (L_3T_1) to 6.36 min for ambient grinding with ambient temperature feed (L_0T_0). From the figure, lowering the feed temperature conclusively lowers the time required for grinding the material except for ambient grinding case. That was possibly due to the fact that lowering feed temperature made turmeric rhizome much brittle which in turn made them easy to be ground.

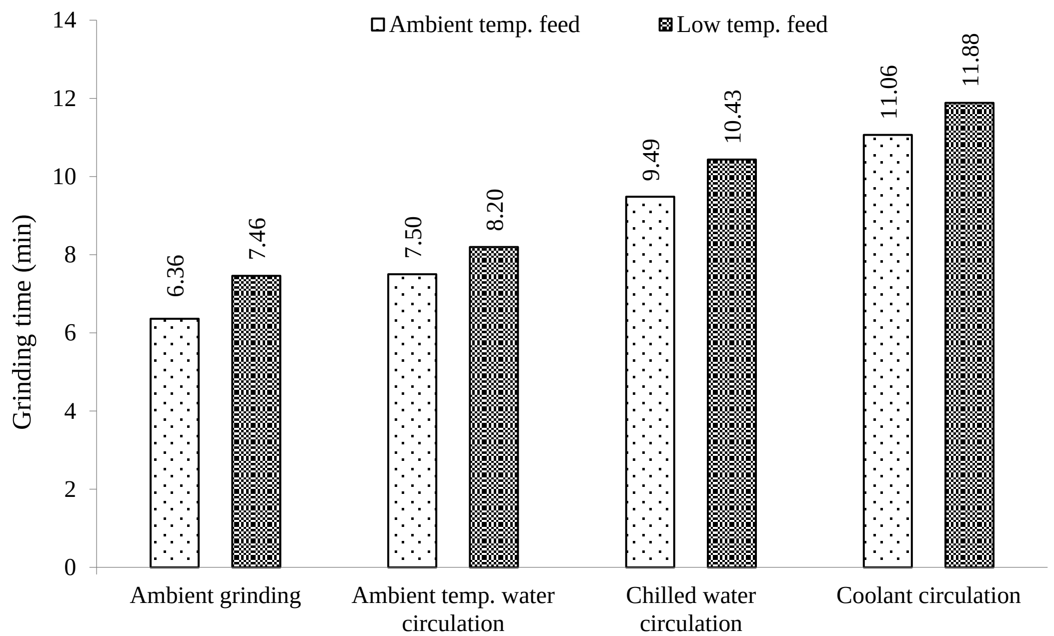


Fig. 5.3 Effect of various treatments on time to grind the material

Temperature of ground product

From table 5.4, it is clear that grinding method affects significantly on the value of temperature of ground powder at the end of grinding. The significantly highest temperature (40.67 °C) was found for the ambient grinding method (L_0). The significantly lowest temperature (33.50 °C) was found for the method involving coolant circulation around the grinding chamber (L_3). The effect of feed temperature (at 5% level) on the same parameter was also found significant (Table 4). The significantly highest value 38.17 °C was found for ambient temperature feed (T_0). Besides that, the interaction effect of grinding method and feed temperature (L*T) on the value of temperature of ground product was also found non-significant.

The mean values for the same parameter for all the treatments are graphically presented in the following figure (Fig. 5.4). Figure shows that temperature of ground product decreases when moving from left to right *i.e.* treatments involving ambient grinding to ambient water, chilled water and coolant circulation treatments. The value varied from 42.00 °C for ambient grinding treatment (L_0T_0) to 33.33 °C in coolant circulation with low temperature feed (L_3T_1). But fall in temperature becomes pronounced with the change in grinding method compared to the change in feed temperature keeping the grinding method same.

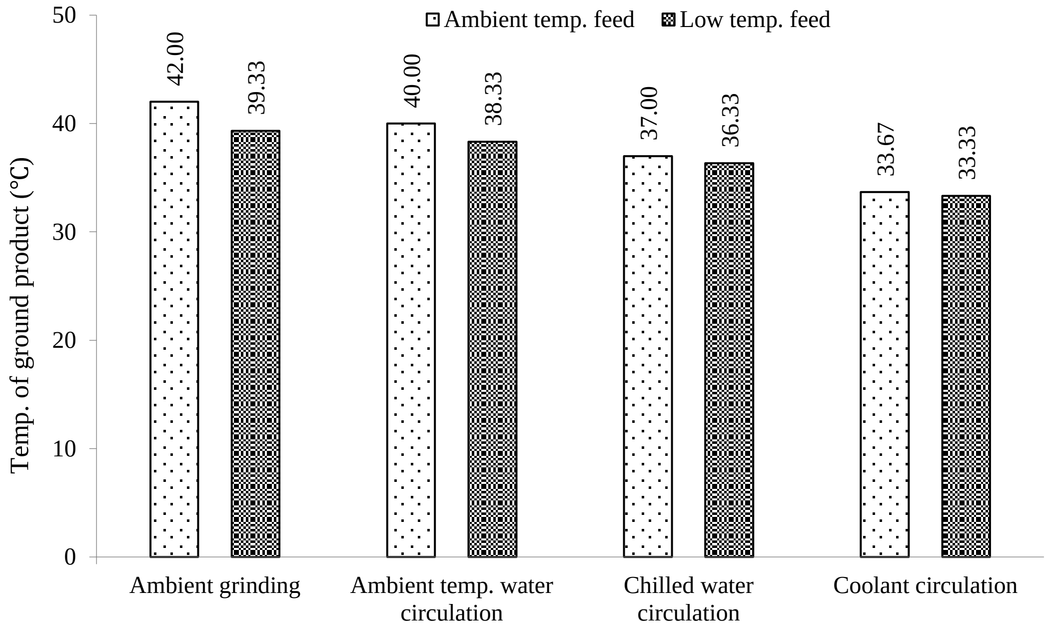


Fig. 5.4 Effect of various treatments on temperature of turmeric powder

From fig. 5.4, it can be concluded that lowering feed temperature as well as circulating liquid (and lowering the temperature of circulating liquid) around the grinding chamber positively decreases the value of temperature of ground product. That was caused by reduction in the value of temperature inside the grinding chamber at the end of grinding due to the continuous absorption of heat generated during grinding operation.

Milling loss

From table 5.4, it is clear that effect of grinding method on the value of milling loss at 5% level is non-significant. . The significantly highest grinding time (11.83 min) was found for the ambient grinding method (L_0). The significantly lowest grinding time (10.17 min) was found for the method involving coolant circulation around the grinding chamber (L_3). While the effect of feed temperature on the same parameter was found non-significant. The high value (10.91%) was found for low temperature feed (T_1). While lowest value in case of ambient temperature feed (T_0) was 10.66%. Additionally, the interaction effect of grinding method and feed temperature (L*T) on the value of per cent milling loss was found non-significant.

The mean values for this parameter for all the treatments are graphically shown in the following figure (Fig. 5.5). The values did not vary to a considerable extent while changing grinding method, keeping feed temperature same. It varied from 10.20% to 11.53% for ambient temperature feed and 10.14 to 14% for low temperature feed among all grinding methods. While from the figure, lowering the feed temperature conclusively increases the value of per cent milling loss. That was attributed to the fact that lowering feed temperature made turmeric rhizomes more brittle which in turn made them ground to finer particles comparatively. The formation of finer particles could easily be lost in the form of dust particles. That ultimately increased the value of per cent milling loss in case of low temperature feed.

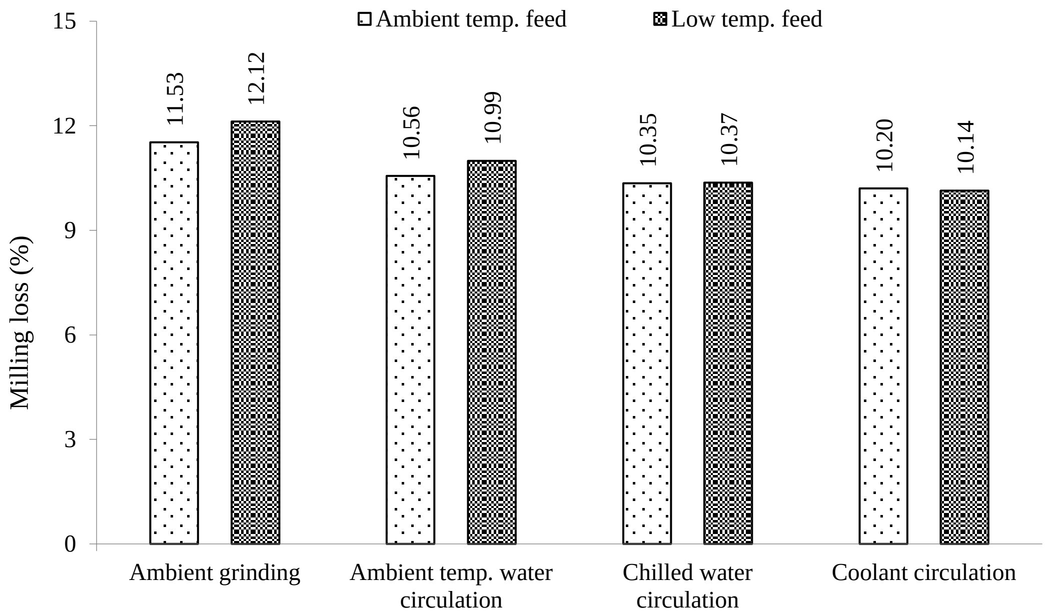


Fig. 5.5 Effect of various treatments on milling loss of turmeric powder

Machine loss

Table 5.4 shows that effect of grinding method as well as effect of feed temperature on the value of machine loss at 5% level is significant. . The significantly highest machine loss (8.98%) was found for the coolant circulation method (L_3).The significantly lowest machine loss (7.89%) was found for the method ambient grinding (L_0). The value found was highest i.e. 8.57% for low temperature feed (T_1). While value in case of ambient temperature feed (T_0) was 7.98%. Additionally, the interaction effect of grinding method and feed temperature (L*T) on the value of per cent machine loss was found non-significant.

The mean values for this parameter for all the treatments are graphically shown in the following figure (Fig. 5.6). The values did not vary to a considerable extent while changing grinding method, keeping feed temperature same. It varied from 7.47 to 8.82% for ambient temperature feed and 8.32 to 9.15% for low temperature feed among all grinding methods. While from the figure, lowering the feed temperature conclusively increases the value of per cent machine loss. This is due to the increase in milling loss in the form of dust in case of low temperature feed. Particles lost in the form of dust stuck to the internal surfaces of product outlet area which in turn increased the value of per cent machine loss.

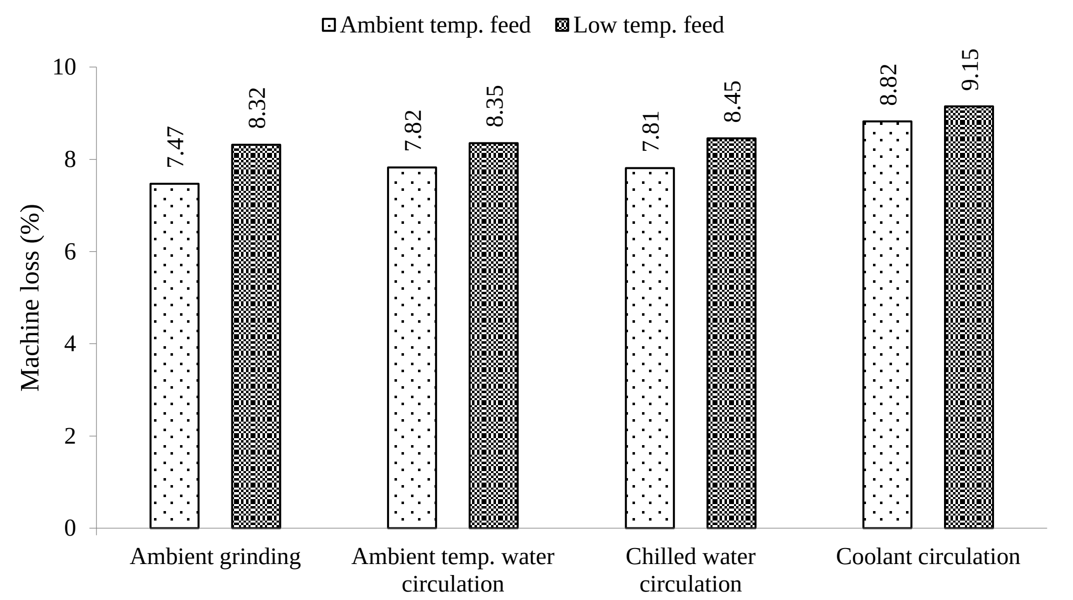


Fig. 5.6 Effect of various treatments on machine loss of turmeric powder

10.2.4 Biochemical parameters of turmeric powder

The values obtained for various biochemical parameters of ground turmeric powder obtained through different treatments are given in table 10.6 and are discussed separately below.

Table 5.6 Mean value of biochemical parameters of turmeric powder obtained through various treatments.

Treatment	Biochemical parameters										
	Moisture content (%w.b.)	**Total carbo-hydrate (%)**	**Crude fibre (%)**	**True protein (%)**	**Total oil (%)**	**Total ash (%)**	**Volatile oil yield (%)**	**Total Phenol**	**Flavonoids cotnetn**	**Antioxidant Activity**	**Curcumin content**
L_0T_0	7.00	52.66	5.21	8.33	5.26	6.22	2.917	1.83	1.09	47.14	2.23
L_0T_1	7.66	54.47	5.90	8.44	5.67	6.30	3.047	2.00	1.15	49.16	2.37
L_1T_0	7.46	54.74	6.00	9.29	6.03	6.05	3.193	2.32	1.24	51.91	2
L_1T_1	8.06	55.09	6.04	9.53	6.22	6.11	3.440	2.49	1.25	53.47	2.33
L_2T_0	8.14	56.74	6.28	10.09	6.42	5.71	3.483	2.66	1.33	54.89	2.41
L_2T_1	8.38	57.26	6.37	10.71	6.59	5.98	3.567	3.01	1.39	55.11	2.48
L_3T_0	8.22	58.29	6.60	10.89	6.68	5.34	3.660	3.03	1.42	56.54	2.35
L_3T_1	8.40	59.47	6.65	11.64	6.87	5.58	3.820	3.13	1.43	59.31	2.44

Table 5.7 Effect of grinding method and feed temperature on biochemical parameters of turmeric powder

Effect	M. C. (%w.b.)	Total carbo-hydrate (%)	Crude fibre (%)	True protein (%)	Total oil (%)	Total ash (%)	Volatile oil yield (%)	Phenol content (mg/g)	Flavonoids content (mgQE/g)	Anti-Oxidant Activity (%)	Curcumin content (%)
Grinding method (L)											
Without liquid circulation (L_0)	7.33	53.56	5.56	8.38	5.47	6.26	2.98	1.91	1.12	48.15	2.30
Ambient temperature water circulation (L_1)	7.76	54.91	6.02	9.41	6.13	6.08	3.32	2.41	1.24	52.69	2.27
Chilled water circulation (L_2)	8.26	57.00	6.33	10.40	6.51	5.84	3.53	2.84	1.36	55.00	2.44
Coolant circulation (L_3)	8.31	58.88	6.63	11.27	6.78	5.46	3.74	3.08	1.42	57.92	2.39
S. Em±	0.0766	0.3278	0.0827	0.1001	0.0501	0.0545	0.0595	0.0685	0.0167	0.7269	0.0435
C. D. at 5%	0.2296	0.9829	0.248	0.3002	0.1501	0.1635	0.1784	0.2053	0.05	2.1792	0.1304
Feed temperature (T)											
Ambient temperature feed (T_0)	7.70	55.61	6.03	9.65	6.10	5.83	3.31	2.46	1.27	52.62	2.30
Low temp. feed (T_1)	8.13	56.57	6.24	10.08	6.34	5.99	3.47	2.66	1.31	54.62	2.40
S. Em±	0.0541	0.2318	0.585	0.0708	0.354	0.0386	0.0421	0.0484	0.0118	0.5140	0.0307
C. D. at 5%	0.1623	0.695	0.1754	0.2123	0.1062	0.1156	0.1262	0.1452	0.0354	1.5409	0.0922
Interaction (L*T)											
S. Em±	0.1083	0.4636	0.117	0.1416	0.0708	0.0771	0.0842	0.0969	0.0236	1.0279	0.0615
C. D. at 5%	NS	NS	0.3507	NS	NS	NS	NS	NS	NS	NS	NS
C. V%	**2.3694**	**1.4317**	**3.3037**	**2.4864**	**1.9727**	**2.2609**	**4.2966**	**6.5555**	**3.1779**	**3.3317**	**4.5302**

Moisture content

From the table 5.7, it can be observed that grinding method affects significantly ($p<0.05$) on the value of moisture content of ground product. The lowest value (7.33%) was found for the grinding method ambient grinding (L_0) while method involving coolant circulation around the grinding chamber (L_3) exhibited to higher percentages of moisture (8.31%). The effect of feed temperature on the value of moisture content was also found significant ($p<0.05$). The values found were 7.70% and 8.13% for ambient temperature and low temperature feed, respectively. In addition to individual effects, the interaction effect of grinding method and feed temperature (L*T) on the same parameter was found non-significant.

The mean values of moisture content of ground powder for all the treatments are graphically presented in the following figure (Fig. 5.7). Figure reveals that the value of moisture content of ground powder increases when moving from left to right *i.e.* treatments involving ambient grinding to ambient water, chilled water and coolant circulation treatments. Values varied from minimum of 7.00% for ambient grinding with ambient feed (L_0T_0) to maximum of 8.40% in coolant circulation with low temperature feed (L_3T_1). Increase in moisture content of ground powder might be attributed to the condensation of moisture. Further, lower temperature of ground powder might decrease the loss of moisture in surrounding by evaporation. However, decrease in the value of moisture content in ground powder compared to moisture of turmeric rhizome (8.59%) for all the treatments was observed. That might be due to the loss of moisture at higher temperature generated during grinding operation.

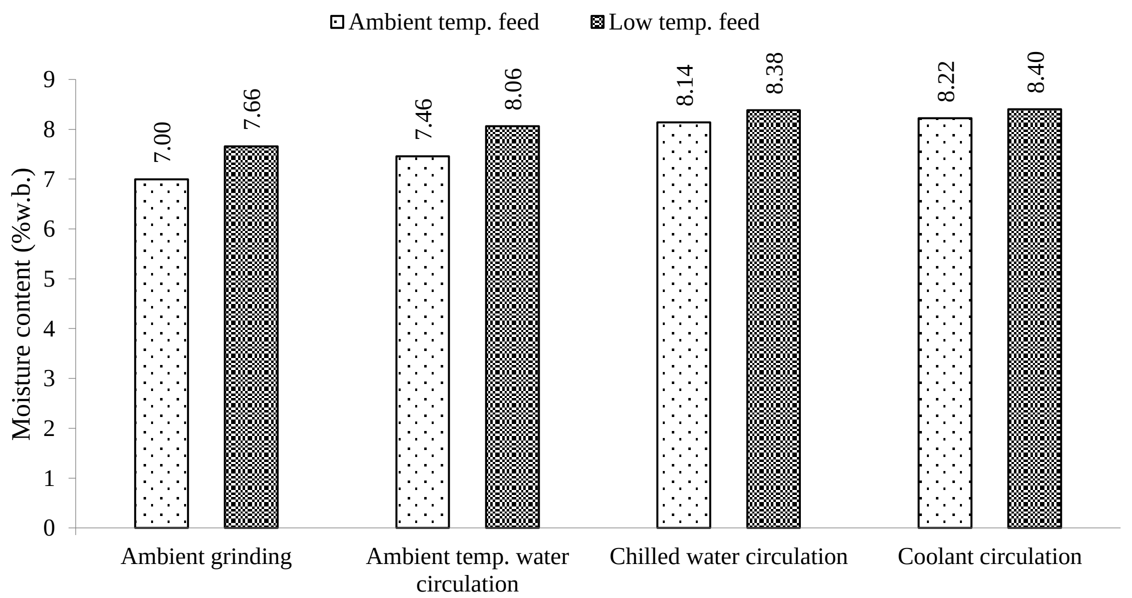


Fig. 5.7 Effect of various treatments on moisture content of turmeric powder

Total carbohydrate content

The table 5.7 clears that grinding method affects significantly ($p<0.05$) on the value of total carbohydrate of ground product. The lowest value (53.56%) was found for the grinding method with ambient grinding (L_0) while method involving coolant circulation around the grinding chamber (L_3) found to retain higher percentages of carbohydrate (58.88%). The effect of feed temperature on the value of total carbohydrate content was also found statistically significant at the same level of significance (Table 5.7). The values found were 55.61 and 56.57% for ambient temperature feed and low temperature feed, respectively. Further, the interaction effect of grinding method and feed temperature (L*T) on the value of total carbohydrate was found non-significant.

The mean values of total carbohydrate content of ground powder for all the treatments are graphically displayed in the following figure (Fig. 5.8). Figure reveals that the value of total carbohydrate in ground powder increases from ambient grinding with ambient feed to coolant circulation with low temperature feed treatments. Values varied from minimum of 52.66% for ambient grinding with ambient temperature feed (L_0T_0) to maximum of 59.47% in coolant circulation with low temperature feed (L_3T_1).

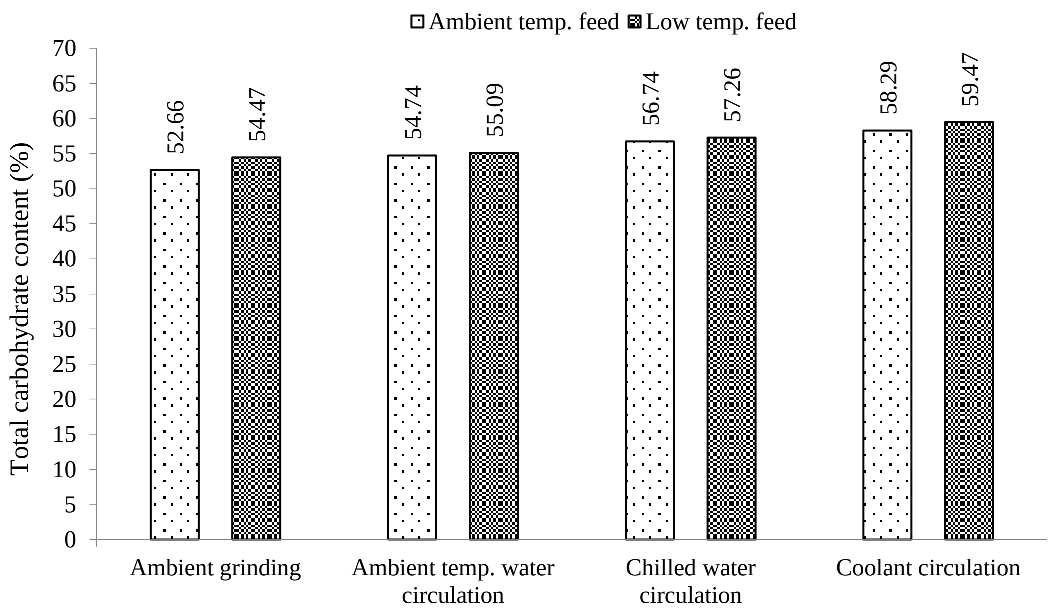


Fig. 5.8 Effect of various treatments on total carbohydrate content of turmeric powder

Crude fibre content

The table 5.7 clears that grinding method affects significantly ($p<0.05$) on the value of crude fibre in ground product. The lowest value (5.56%) was found for the grinding method ambient grinding (L_0). On the other hand, method involving coolant circulation around the grinding chamber (L_2) found to have higher percentages of crude fibre (6.63%). Besides grinding method, the effect of feed temperature on the same parameter was also found statistically significant at the same level of significance. The values found were 6.03 and 6.24% for ambient temperature feed and low temperature feed, respectively. Further, the interaction effect of grinding method and feed temperature (L*T) on the value of crude fibre content was also found significant.

The mean values of crude fibre of ground powder for all the treatments are graphically demonstrated in the following figure (Fig. 5.9). Figure indicates that the value of crude fibre in ground powder increases when moving from treatments involving ambient grinding to coolant circulation treatments in the both the case i.e. ambient temperature feed and low temperature feed. The mean values varied from minimum of 5.21% for ambient grinding with ambient temperature feed treatment (L_0T_0) to maximum of 6.65% in coolant circulation with low temperature feed (L_3T_1). Increase in crude fibre content in ground powder with moving from left to right in the graph might be attributed to decrease in elevation of temperature during grinding operation. Higher temperature developed during grinding operation might cause the conversion of insoluble dietary fibre to soluble dietary fibre which in turn perhaps decreased the percentages of crude fibre in ground powder, as crude fibre is composed of insoluble cellulose and lignin. Rise in temperature breaks the weak bonds between polysaccharide chains and split glycosidic linkages in the dietary fibre polysaccharides. So, the architecture of the fibre matrix may be modified and insoluble fibre changes to soluble dietary fibre. This may be the case for more lowering temperature.

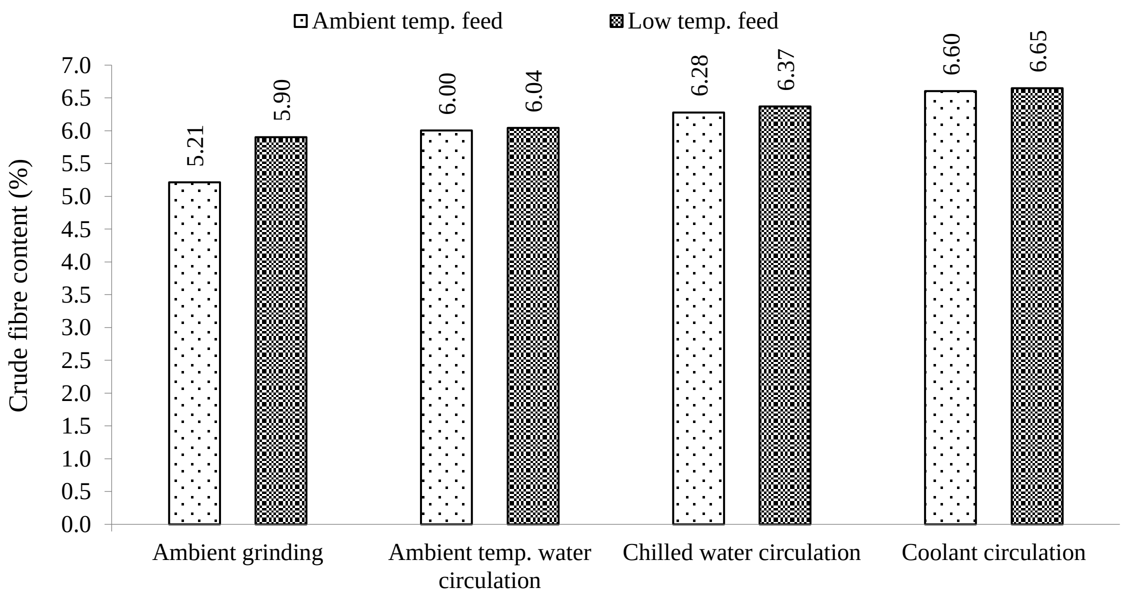


Fig. 5.9 Effect of various treatments on crude fibre content of turmeric powder

True protein content

Effect of grinding method on the value of true protein content of ground powder was found significant ($p<0.05$) (Table 5.7). The lowest value (8.38%) was found for the grinding treatment ambient grinding (L_0) while method involving coolant circulation around the grinding chamber (L_3) found to produce powder having higher percentages of true protein (11.27%). The effect of feed temperature on the value of true protein was also found statistically significant ($p<0.05$). The value found for low temperature feed (9.65%) and that of ambient temperature feed (10.08%). Additionally, the interaction effect of grinding method and feed temperature (L*T) on the value of true protein content was found non-significant at the same level of significance.

The mean values of true protein of ground powder for all the treatments are graphically displayed in the following figure (Fig. 5.10). Figure indicates that the value of true protein of ground powder increases when moving from treatments involving ambient grinding to ambient, chilled water and coolant circulation treatments. Values ranged from minimum of 8.33% for ambient grinding treatment (L_0T_0) to maximum of 11.64% in coolant circulation with low temperature feed (L_3T_1). Increase in true protein content of ground powder with moving from left to right in the graph might be attributed to the decrease in elevation of temperature during grinding operation. As higher temperature causes protein denaturation, it decreases the percentages of true protein.

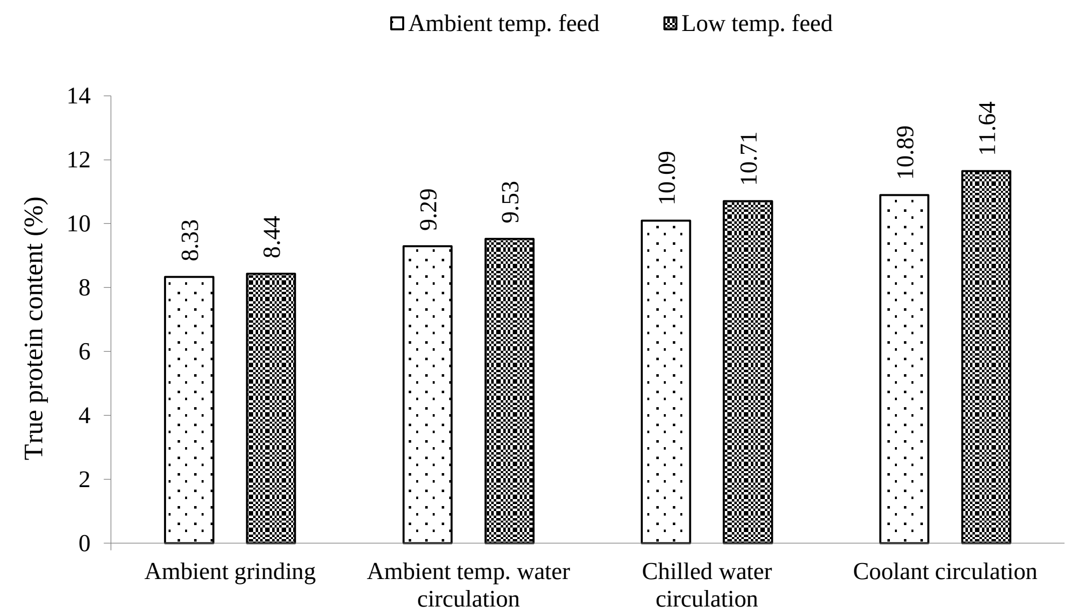


Fig. 5.10 Effect of various treatments on true protein content of turmeric powder

Total oil content

From the table 5.7, it can be seen that grinding method affects significantly on the value of total oil content of ground product ($p<0.05$). The lowest value (5.47%) was found for the grinding method without liquid circulation (L_0). While the method incorporating coolant circulation (L_3) exhibited to produce powder containing comparatively higher percentages of fixed oil (6.78%). The effect of feed temperature on the same parameter was also found significant ($p<0.05$). The values found were 6.10% and 6.34% for ambient temperature and low temperature feed, respectively. In addition to individual effects, the interaction effect of grinding method and feed temperature (L*T) on the value of total oil content in ground powder was found non-significant at the same level of significance.

The mean values of total oil of ground powder for all the treatments are graphically presented in the following figure (Fig. 5.11). Figure shows that the value of total oil in ground powder increases when moving from left to right *i.e.* treatments involving ambient grinding to ambient, chilled water and coolant circulation treatments. Values varied from minimum of 5.26% for ambient grinding with ambient temperature feed treatment (L_0T_0) to maximum of 6.87% in coolant circulation with low temperature feed (L_3T_1). Increase in oil percentages in ground powder with moving from ambient grinding to coolant circulation might be attributed to the reduction in the degree of melting of fat present in the rhizomes. Moving from left to right in the graph decreased the value of temperature inside the chamber at the end of grinding operation which in turn decreased the extent of melting and sticking of fat on grinding surfaces and sieve. That caused increase in the oil percentages in ground powder. While higher temperature developed during grinding operation caused reduction in the value of total oil in ambient grinding treatment.

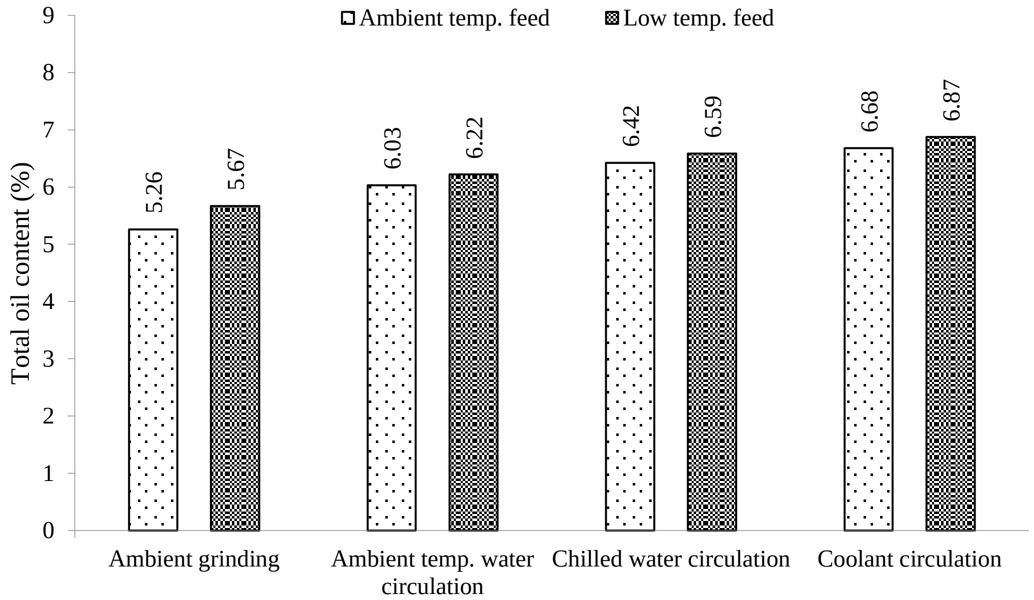


Fig. 5.11 Effect of various treatments on total oil content of turmeric powder

Total ash content

From the table 5.7, it can be concluded that grinding method and feed temperature individually affected significantly ($p<0.05$) on the value of total ash content of ground product. For the grinding method, the lowest value (5.46%) was found for the method involving coolant circulation around the grinding chamber (L_3) and highest in case of ambient grinding (6.26%). Effect of feed temperature was also found significant with higher value for low temperature feed (5.99%) and lower value for ambient temperature feed (5.83%). Besides that, the interaction effect of grinding method and feed temperature (L*T) on the same parameter was also found non-significant at the same level of significance.

The mean values of total ash of ground powder for all the treatments are graphically shown in the following figure (Fig. 5.12). Figure indicates that the value of total ash in ground powder decreases when moving from treatments involving ambient grinding to coolant circulation treatment. Values ranged from minimum of 5.58% for coolant circulation with low temperature feed (L_3T_1) to maximum of 6.22% in ambient grinding with ambient temperature feed (L_0T_0). Increase in total ash content of ground powder was found for low temperature feed as compared ambient temperature feed for all grinding treatment. Increased moisture of low temperature feed caused decrease in the solid percentages of ground powder which in turn caused reduction in the value of ash content. So, variation of moisture content pattern was also found for the variation of ash content.

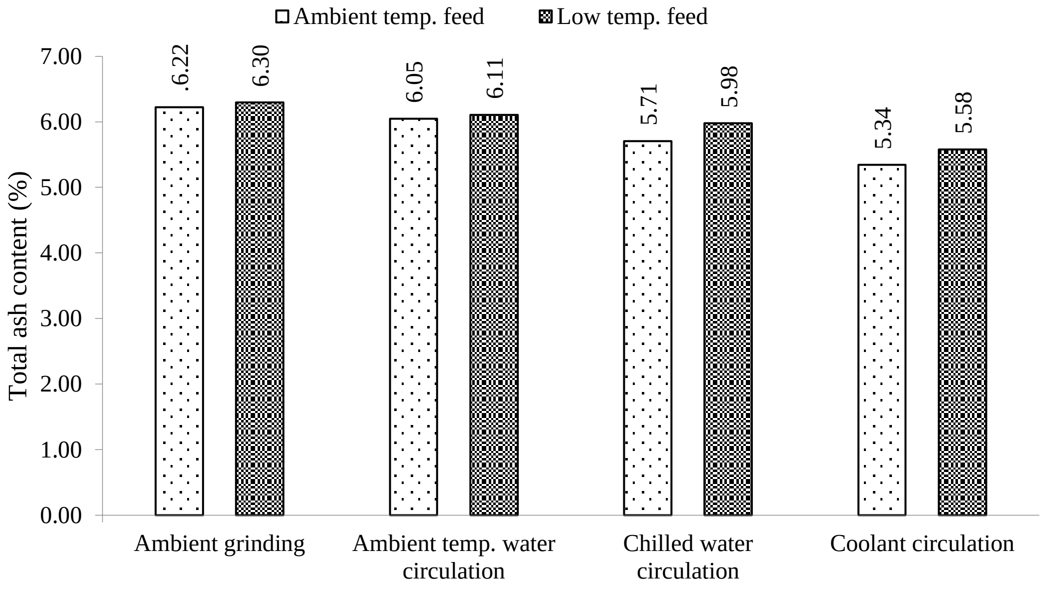


Fig. 5.12 Effect of various treatments on total ash content of turmeric powder

Volatile oil content

From the table 5.7, it can be concluded that grinding method affects significantly ($p<0.05$) on the value of volatile oil content of ground product. The lowest value (2.98%) was found for the grinding method without liquid circulation (L_0) while the highest (3.74%) for the method involving coolant circulation around the grinding chamber (L_3). The effect of feed temperature on the value of volatile oil per cent was also found statistically significant ($p<0.05$). The value found was 3.31% and 3.47% for both, ambient and low temperature feed respectively. Besides that, the interaction effect of grinding method and feed temperature (L*T) on the same parameter was found non-significant at the same level of significance.

The mean values of volatile oil content of ground powder for all the treatments are graphically displayed in the following figure (Fig. 5.13). Figure shows that the value of volatile oil in ground powder increases when moving from treatments involving ambient grinding to ambient, chilled water and coolant circulation treatments. Values ranged from minimum of 2.917 % for ambient grinding with ambient temperature feed (L_0T_0) to maximum of 3.820 % in coolant circulation with low temperature feed (L_3T_1). Increase in volatile oil yield of ground powder with moving from left to right in the graph may be credited to the fall of temperature inside the grinding chamber. As higher temperature developed during ambient grinding process causes loss of volatile oil. Powder obtained through ambient grinding treatment showed the lowest percentages of volatile oil.

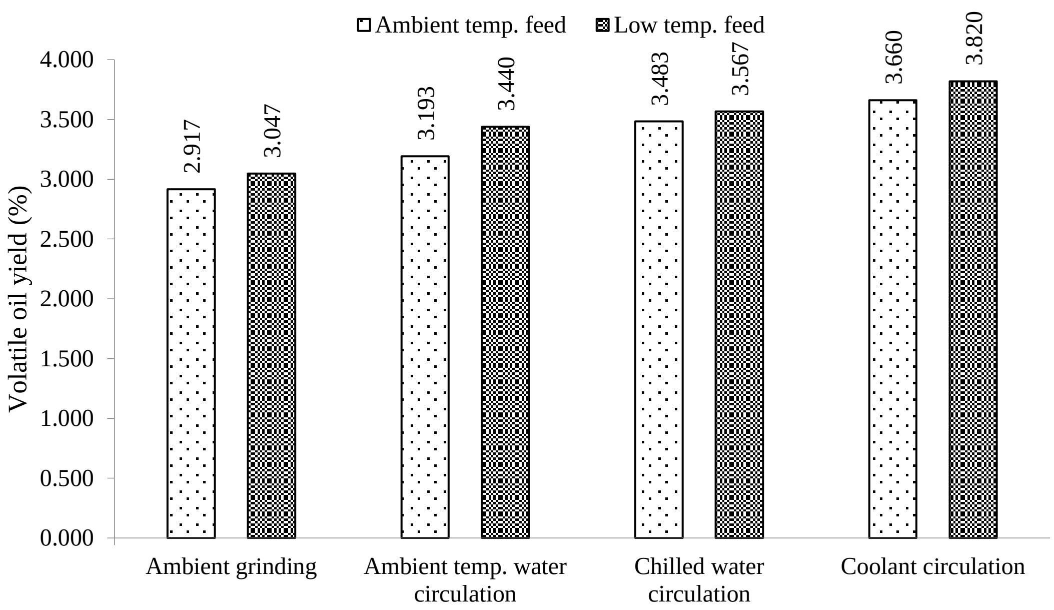


Fig. 5.13 Effect of various treatments on volatile oil content of turmeric powder

Total phenol content

From the Table 5.7, it can be observed that grinding method affects significantly ($p<0.05$) on the value of total phenol content of ground product. The lowest value (1.91 mg/g) was found for the grinding method without liquid circulation (L_0) while method having coolant circulation around the grinding chamber (L_3) found to have highest value of total phenol (3.08%) in ground powder. Additionally, the effect of feed temperature on the value of total phenol was also found significant statistically at 5% level of significance. The value found in case of low temperature feed (2.66 mg/g) was higher than that of ambient temperature feed (2.46 mg/g). Besides that, the interaction effect of grinding method and feed temperature (L*T) on the value of total phenol content of ground powder was found non-significant at the same level of significance.

The mean values of total phenol of ground powder for all the treatments are graphically displayed in the following figure (Fig. 5.14). Figure shows that the value of total phenol of ground powder increases when moving from treatments involving no circulation to coolant circulation treatments. Values ranged from minimum of 1.83% for ambient grinding with ambient temperature feed treatment (L_0T_0) to maximum of 3.13% in coolant circulation with low temperature feed (L_3T_1). Increase in total phenol of ground powder with moving from left to right in the graph might be due to the fall in the value of temperature inside the grinding chamber at the end of grinding operation. As higher temperature causes degradation of phenolic compounds, it decreases total phenol content in ground powder.

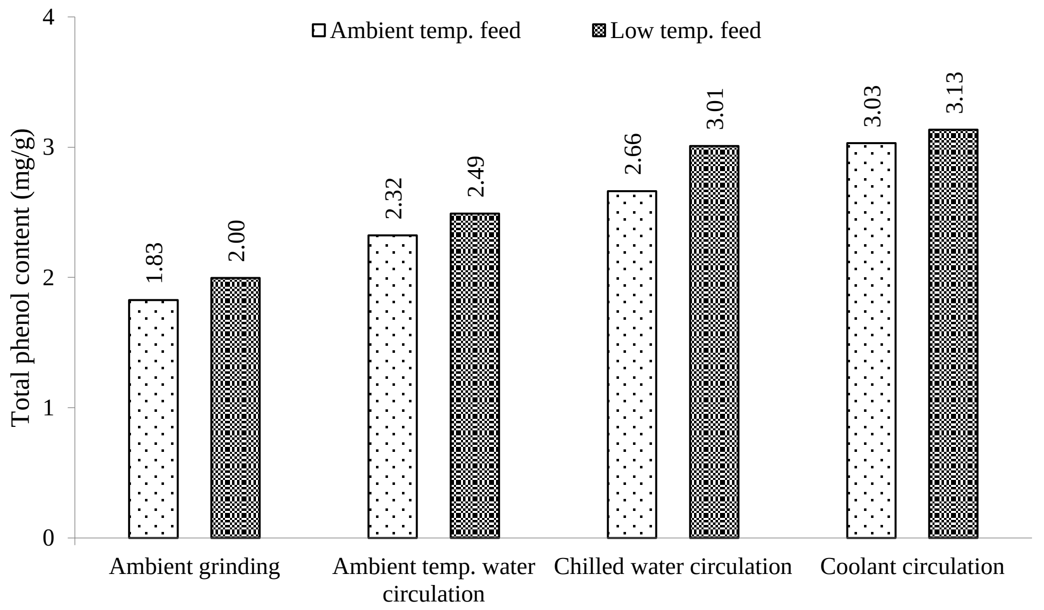


Fig. 5.14 Effect of various treatments on total phenol content of turmeric powder

Total flavonoid content

Table 5.7 shows that grinding method affects significantly ($p<0.05$) on the value of total flavonoid content of ground product. The lowest value (1.12 mg QE/g extract) was found for the grinding method without liquid circulation (L_0) while the highest (1.42 mg QE/g extract) for the method involving coolant circulation around the grinding chamber (L_3). The effect of feed temperature on the value of total flavonoid was also found statistically significant ($p<0.05$). The values found in case of ambient feed and low temperature feed were 1.27 and 1.31 mg QE/g extract, respectively. Besides that, the interaction effect of grinding method and feed temperature (L*T) on total flavonoid content of ground powder was found non-significant at the same level of significance.

The mean values of total flavonoid of ground powder for all the treatments are graphically shown in the following figure (Fig. 5.15). Figure indicates that the value of total flavonoid of ground powder increases when moving from treatments involving no circulation to ambient, chilled water and coolant circulation treatments. Values ranged from minimum of 1.09 mg QE/g extract for ambient grinding with ambient temperature feed treatment (L_0T_0) to maximum of 1.43 mg QE/g extract in coolant circulation with low temperature feed (L_3T_1). Increase in total flavonoid of ground powder with moving from left to right in the graph might be due to the decrease in the elevation of temperature inside the grinding chamber at the end of grinding operation. As flavonoids are the largest group of phenolic compounds (naturally occurring) (Sulaiman and Balachandran, 2012), higher temperature engenders degradation of flavonoids and it decreases total flavonoid content in ground powder.

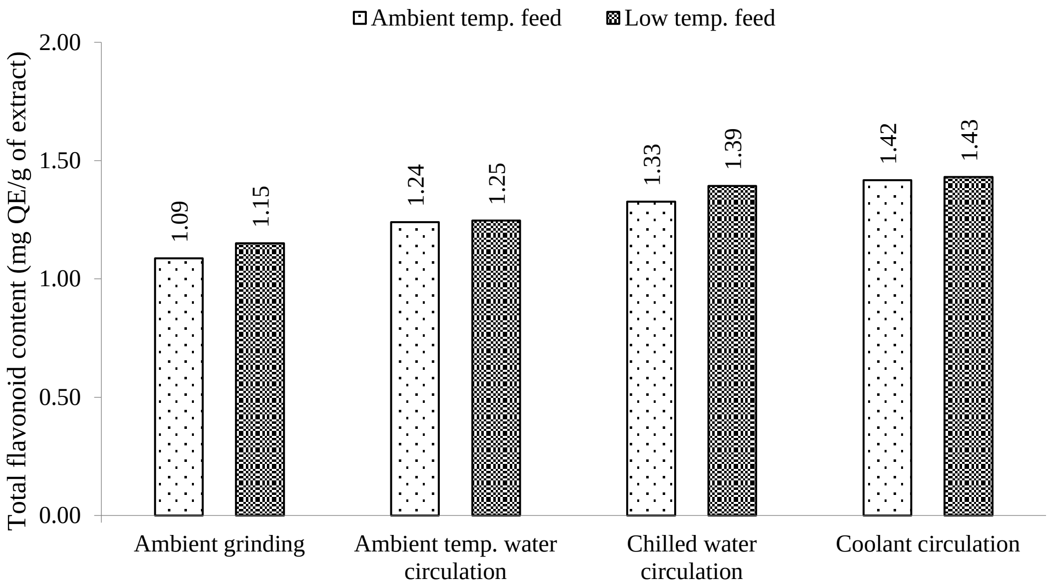


Fig. 5.15 Effect of various treatments on total flavonoid content of turmeric powder

Antioxidant activity

From the Table 5.7, it is clear that grinding method affects significantly ($p<0.05$) on the value of antioxidant activity of ground product. The lowest value (48.15 %) was found for the grinding method without liquid circulation (L_0) while the highest (57.92 %) for the method involving coolant circulation around the grinding chamber (L_3). The effect of feed temperature on the value of same parameter was also found statistically significant ($p<0.05$). The value found in case of low temperature feed (54.26%) was significantly higher with that of ambient temperature feed (52.62%). Besides that, the interaction effect of grinding method and feed temperature (L*T) on the value of antioxidant activity was found non-significant at the same level of significance.

The mean values of antioxidant activity of ground powder for all the treatments are graphically demonstrated in the following figure (Fig. 5.16). Figure shows that the value of antioxidant activity of ground powder increases when moving from treatments involving no circulation to ambient, chilled water and coolant circulation treatments. Values ranged from minimum of 47.14 % DPPH scavenging for ambient grinding with ambient temperature feed treatment (L_0T_0) to maximum of 59.31 % DPPH scavenging in coolant circulation with low temperature feed (L_3T_1). The same reason of increase in grinding chamber temperature can be concluded for decrease in DPPH scavenging per cent when moving from right to left in the graph. As phenolics are the largest group of phytochemicals which account for most of the antioxidant activity in plants (Sulaiman and Balachandran, 2012), degradation of phenolic compounds at higher temperature also caused decrease in antioxidant activity percentages in ground turmeric powder. The pattern for increase in antioxidant of ground powder is same as total flavonoid content of ground powder. Tanvir et al., (2017) reported that flavonoids are the antioxidants that can prevent or delay the oxidation of substrates even when it is present in low concentrations, so as to prevent oxidation by the prooxidants (ROS and RNS).

These nonenzymatic antioxidants (phenolics and flavonoids) react with the prooxidants leading to inactivation.

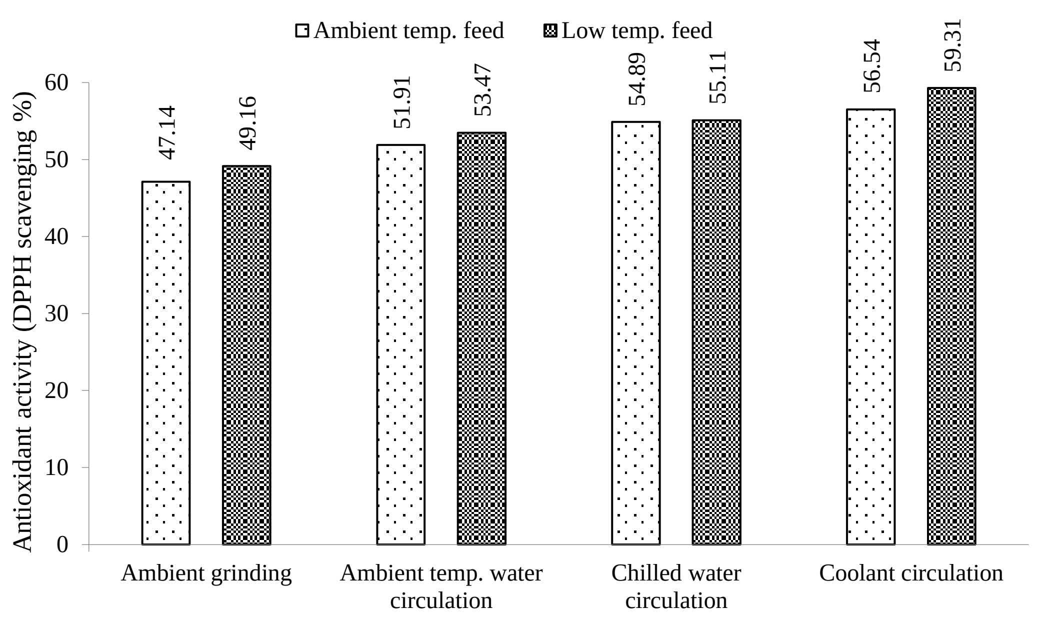


Fig. 5.16 Effect of various treatments on antioxidant activity of turmeric powder

Curcumin content

From the Table 5.7, it is clear that grinding method affects significantly ($p<0.05$) on the value of curcumin content of ground product. The lowest value (2.30 %) was found for the grinding method without liquid circulation (L_0) which was at par with grinding method with ambient water circulation (L_1); while the highest (2.44 %) for the method involving chilled water circulation around the grinding chamber (L_2) which was at par with the grinding method with coolant circulation (L_3). The effect of feed temperature on the value of same parameter was also found statistically significant ($p<0.05$). The value found in case of low temperature feed (2.40%) was significantly higher with that of ambient temperature feed (2.30%). Besides that, the interaction effect of grinding method and feed temperature (L*T) on the value of antioxidant activity was found non-significant at the same level of significance.

The mean values of curcumin content of ground powder for all the treatments are graphically demonstrated in the following figure (Fig. 5.17). Figure shows that the value of curcumin content of ground powder was higher for low temperature feed as compared to ambient temperature feed for all grinding methods. Values ranged from minimum of 2.23% for ambient water circulation treatment with ambient temperature feed (L_1T_0) to maximum of 2.48 % in chilled water circulation with low temperature feed (L_2T_1).

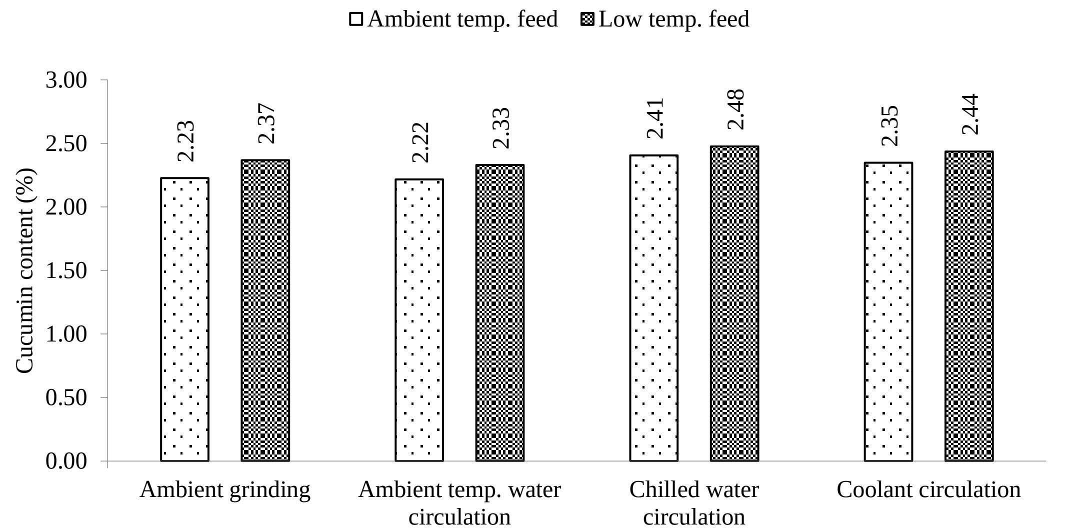


Fig. 5.17 Effect of various treatments on curcumin content in turmeric powder

10.2.5 Particle size analysis

Table 5.8 Effect of grinding method and feed temperature on particle size of turmeric powder

Effect	Temperature inside grinding chamber at the end (℃)
Grinding method (L)	
Ambient temperature grinding(L_0)	315.95[a]
Ambient temperature water circulation (L_1)	309.41[a]
Chilled water circulation (L_2)	267.74
Coolant circulation (L_3)	252.85
S. Em±	2.4795
C. D. at 5%	7.4339
Feed temperature (T)	
Ambient temperature feed (T_0)	292.73
Low temp. feed (T_1)	280.25
S. Em±	1.7533
C. D. at 5%	5.2566
Interaction (L*T)	
S. Em±	3.5066
C. D. at 5%	10.5132
C. V%	4

The values obtained for the effect of two factors, *viz*. grinding method and feed temperature on average particle size of ground powder of each treatment the same parameter is shown in the Table 5.8.

From the Table 5.8, it can be observed that grinding method affects significantly ($p<0.05$) on the value of average particle size of ground product. The finest value (252.85 µ) was found for the grinding method involving coolant circulation around the grinding chamber (L_3) while the coarsest value (485.25 µ) for the method without liquid circulation (L_0) which was at par with the grinding method involving ambient water circulation (L_1). Further, the effect of feed temperature on the value of average particle size was also found statistically significant (at 5% level). The highest value found was 292.73 µ for ambient temperature feed. Comparing with that, the value (280.25 µ) found in case of low temperature feed was significantly less. Besides that, the interaction effect of grinding method and feed temperature (L*T) on the same parameter was found non-significant at the same level of significance.

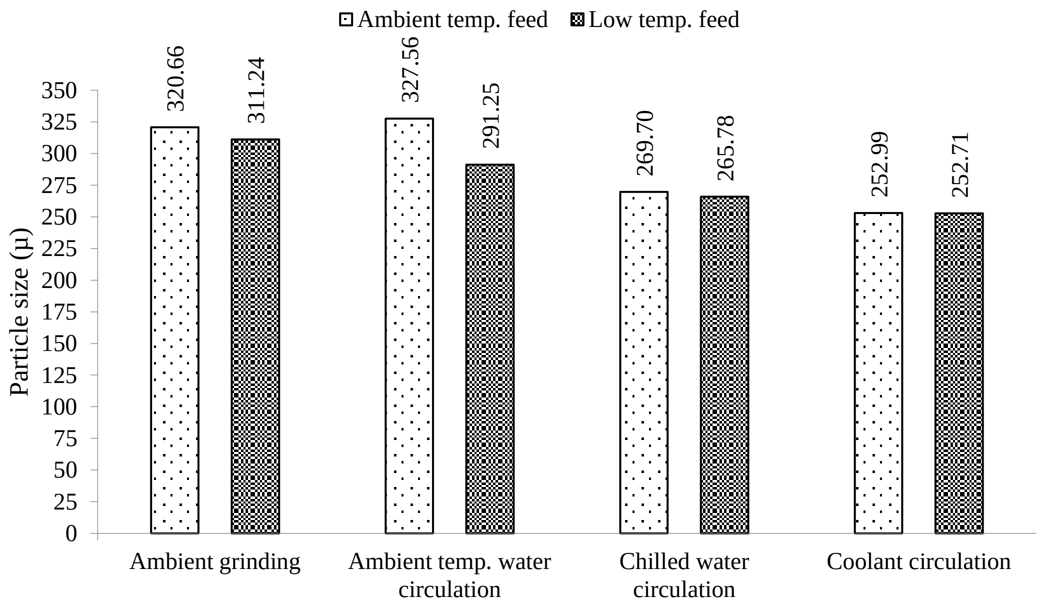


Fig. 5.18 Effect of various treatments on particle size of turmeric powder

Mathematical modelling of particle size distribution of turmeric powder

The model parameters of RRB and GS model are tabulated in the Table 5.9. In RRB model, the size parameter (X_R) varied as the treatment differed. The size parameter of different treatments was found to be varied from 407.263 to 637.673 (Table 5.9). A higher number of distribution parameter (n_R) indicates the better uniformity of particle size distribution. The size parameters of ambient grinding treatments were found the more than the size parameter of low temperature ground powders. The distribution parameter of various treatments was found varying from 1.649 to 3.773. Manohar and Sridhar (2001) carried out the mathematical modelling of the cryogenic and conventional ground turmeric powder. They found that the distribution parameter or uniformity index was 2.60 for conventional ground turmeric powder and 3.01 for cryogenic ground powder. Shashidhar *et al*., (2013) in their study of mathematical modelling of coriander seeds found that the distribution parameter was varied from 1.85 to 2.33 as the screen size of hammer mill was increased from 0.5 to 3.0 mm. Lower number of distribution parameter in the L_2T_0 treatment (1.649) shows the retention of the higher percentage of particles on a finer size as it has the lowest size parameter (407.263).

Table 5.9 Model parameters of different mathematical models for PSD of turmeric powder

	Rosin Rammler Bennet		Gaudin Schumann	
	Size parameter, X_R	**Distribution parameter, n_R**	**Size parameter, X_G**	**Distribution parameter, n_G**
$L_0\ T_0$	541.460	3.710	161.243	3.058
$L_0\ T_1$	511.253	3.721	150.391	2.946
$L_1\ T_0$	637.673	3.079	142.710	2.373
$L_1\ T_1$	621.408	3.177	149.664	2.442
$L_2\ T_0$	407.263	1.649	109.039	2.498
$L_2\ T_1$	600.604	3.110	135.758	2.379
$L_3\ T_0$	459.066	3.773	137.922	2.940
$L_3\ T_1$	447.123	3.316	110.756	2.682

Similarly for the GS model, the size parameter (X_G) of different treatments as found to be varied from the 109.039 to 161.243 (Table 5.9). It as evident that the size parameter of ambient ground powder was found more than the size parameter of low temperature ground powder, which indicates the positive effect of low temperature grinding on the finer particle size of the turmeric powder. The distribution parameter (n_G) was varied from the 2.373 to 3.058 among different treatments. However, there was no any clear trend between the distribution parameter and the different treatments.

Table 5.10 Model parameters of Log normal distribution for PSD of turmeric powder

	$L_0\ T_0$	$L_0\ T_1$	$L_1\ T_0$	$L_1\ T_1$	$L_2\ T_0$	$L_2\ T_1$	$L_3\ T_0$	$L_3\ T_1$
Mean	320.655	311.238	327.560	291.251	269.696	265.777	252.990	252.714
Std. Dev.	0.918	0.918	1.089	1.089	0.918	1.089	0.918	0.918
X_{50} (µm)	363.371	360.471	370.376	333.875	282.920	275.947	273.807	265.054
X_{84} (µm)	426.792	424.245	508.441	408.728	405.627	416.411	404.571	391.019
σ_g	1.175	1.177	1.373	1.224	1.434	1.509	1.478	1.475
b	19.320	18.842	4.981	12.219	3.852	2.953	3.281	3.307
c	0.974	0.974	0.904	0.960	0.878	0.844	0.859	0.860
X_m (Mode)	354.087	351.031	335.001	320.489	248.481	232.970	235.100	227.864

ξ	0.0069	0.0069	0.0036	0.0060	0.0042	0.0038	0.0040	0.0042

The model parameters of log normal distribution are tabulated in the Table 5.10. The mean diameter of different samples varied from the 327.56 to 252.714. The steepness constant (b) of different treatments was to be varying between 2.953 to 19.320. The steepness constant (b) in the ambient ground powder was found to be more than the low temperature ground powder. The distribution function (σ_g) was found to be in the range of 1.175 to 1.509 among different treatments. The higher number of distribution function among the low temperature ground powder indicates the distribution of finer particles than the ones found in the ambient ground powder. The mode of the size distribution tends to decreased as the temperature of grinding was lowered. The mode of the size distribution was varied from 227.864 to 354.087. The model parameter (ξ) was to found to be in the range of 0.0036 to 0.0069. Similar positive trend of low temperature grinding as discussed earlier was followed in the model parameter of different treatments.

Table 5.11 Statistical parameters of different mathematical models for PSD of turmeric powder

	Rosin Rammler Bennet			**Gaudin Schumann**			**Log Normal**		
	RSS	**RMSE**	**R^2**	**RSS**	**RMSE**	**R^2**	**RSS**	**RMSE**	**R^2**
L_0T_0	2939.223	20.491	0.927	171640.868	156.589	0.880	4065.641	24.100	0.949
L_0T_1	2215.018	17.789	0.929	134254.777	138.489	0.854	13783.335	44.374	0.975
L_1T_0	3976.180	22.294	0.895	225472.317	167.881	0.790	2788.514	18.670	0.973
L_1T_1	6148.141	27.722	0.845	267300.687	182.791	0.745	3191.773	19.974	0.967
L_2T_0	1545.696	14.860	0.949	97966.200	118.301	0.802	2033.084	17.042	0.971
L_2T_1	6849.193	29.260	0.800	312841.619	197.750	0.678	1440.341	13.418	0.985
L_3T_0	3735.170	23.100	0.879	241350.431	185.684	0.788	4164.048	24.390	0.966
L_3T_1	3398.171	22.033	0.850	258955.056	192.337	0.760	2238.145	17.881	0.917

The statistical parameters viz., coefficient of regression (R^2), rooted sum of square (RSS) and root mean square error (RMSE) all three models were calculated and mentioned in the Table 5.11. The higher coefficient of regression and lower value of rooted sum of square and root mean square error is desirable to fit the suitable mathematical model. Based on the different plots of cumulative percentage of mass retained or passed to the particle size, the regression equations of all three models have been derived (Table 5,12) which indicates the fitting of different models in respective treatments. The log normal distribution had the highest coefficient of regression among different treatments which was varied from 0.917 to 0.985, followed by the coefficient of regression in the RRB model (0.800 to 0.949). For the GS model, the coefficient of regression was found to be lowest among all three models (0.678 to 0.880). Similarly, the RSS and RMSE values of log normal distribution as found to be lowest among all three models. The RSS and RMSE values of RRB model was found to be slightly higher than the log normal distribution model which shows good fitting of RRB model. However, the RSS and RMSE values of GS model was found to varied significantly higher than the RRB and log normal distribution, which may have happened due to the application of the GS models in the limitations of the sieve size (0 to 600 μm) and higher percentage of error found in the sieve size greater than 600 μm.

Table 5.12 Regression equation of the different models of PSD of ground turmeric powder

	Rosin Rammler Bennet	Gaudin Schumann	Log Normal Distribution
$\mathbf{L_0\ T_0}$	ln ln(1/(1-F(x))) = 3.7102 ln (x) - 23.353	ln (F(x)) = 3.0575 ln (x) - 15.541	ln (R(x)) = -0.005 x + 5.2871
$\mathbf{L_0\ T_1}$	ln ln(1/(1-F(x))) = 3.7211 ln (x) - 23.208	ln (F(x)) =2.9464 ln (x) - 14.771	ln (R(x)) = -0.0074 x + 5.8777
$\mathbf{L_1\ T_0}$	ln ln(1/(1-F(x))) = 3.0789 ln (x) - 19.883	ln (F(x)) = 2.3734 ln (x) - 11.774	ln (R(x)) = -0.0042 x + 5.0844
$\mathbf{L_1\ T_1}$	ln ln(1/(1-F(x))) = 3.1774 ln (x) - 20.437	ln (F(x)) = 2.4423 ln (x) - 12.232	ln (R(x)) = -0.0046 x + 5.0075
$\mathbf{L_2\ T_0}$	ln ln(1/(1-F(x))) = 1.6491 ln (x) - 9.9102	ln (F(x)) = 2.4976 ln (x) - 11.718	ln (R(x)) = -0.0053 x - 5.186
$\mathbf{L_2\ T_1}$	ln ln(1/(1-F(x))) = 3.1101 ln (x) - 19.84	ln (F(x)) = 2.3786 ln (x) - 11.681	ln (R(x)) = -0.0046 x + 4.9616
$\mathbf{L_3\ T_0}$	ln ln(1/(1-F(x))) = 3.7726 ln (x) - 23.123	ln (F(x)) = 2.9395 ln (x) - 14.482	ln (R(x)) = -0.0076 x + 5.5584
$\mathbf{L_3\ T_1}$	ln ln(1/(1-F(x))) = 3.3160 ln (x) - 20.237	ln (F(x)) = 2.6822 ln (x) - 12.626	ln (R(x)) = -0.0043 x + 4.8307

x = particle size (μm), F(x) = cumulative % mass passed, R(x) = cumulative % mass retained

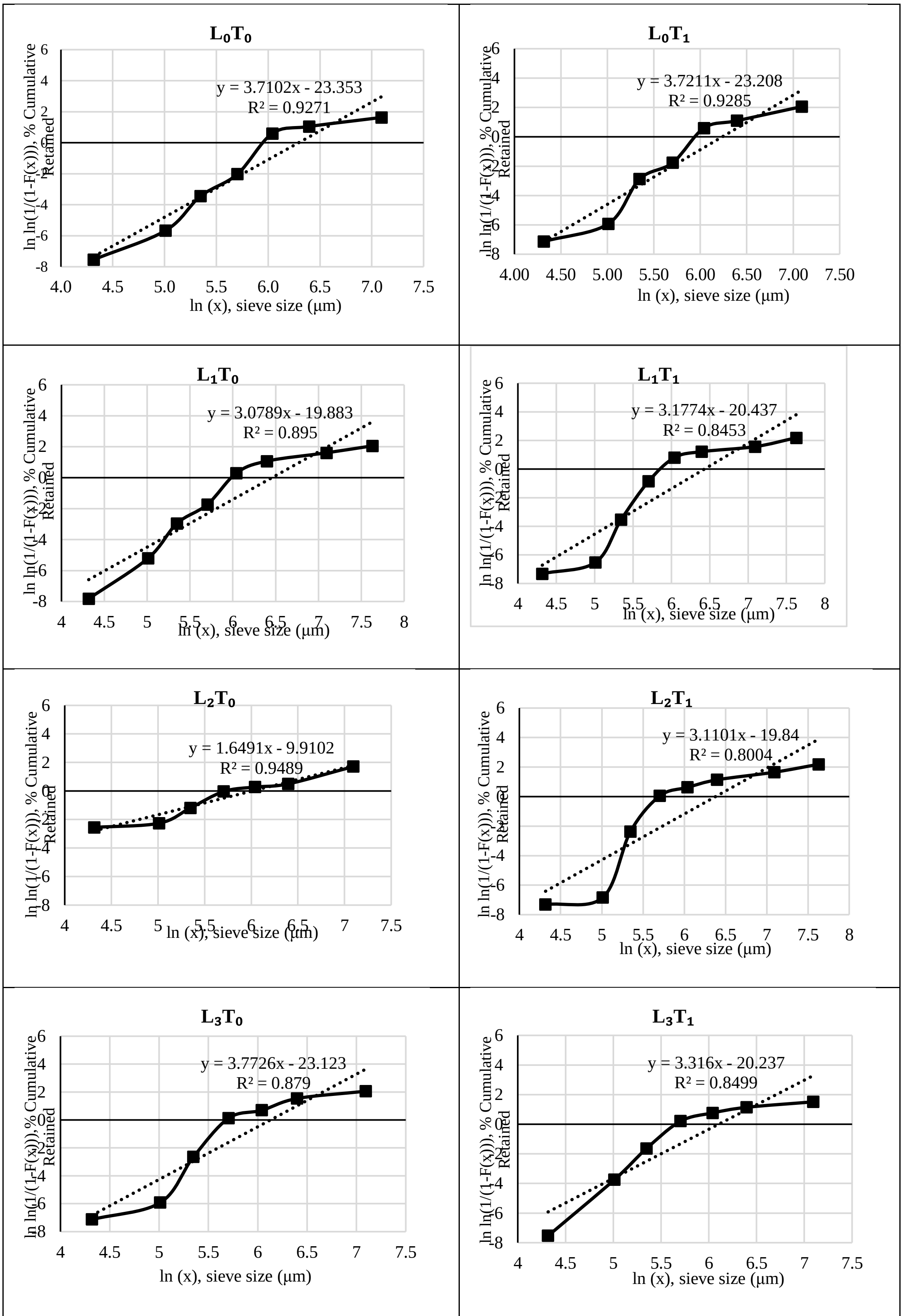


Fig. 5.19 Rosin Rammler Bennett plots for different grinding treatments of turmeric

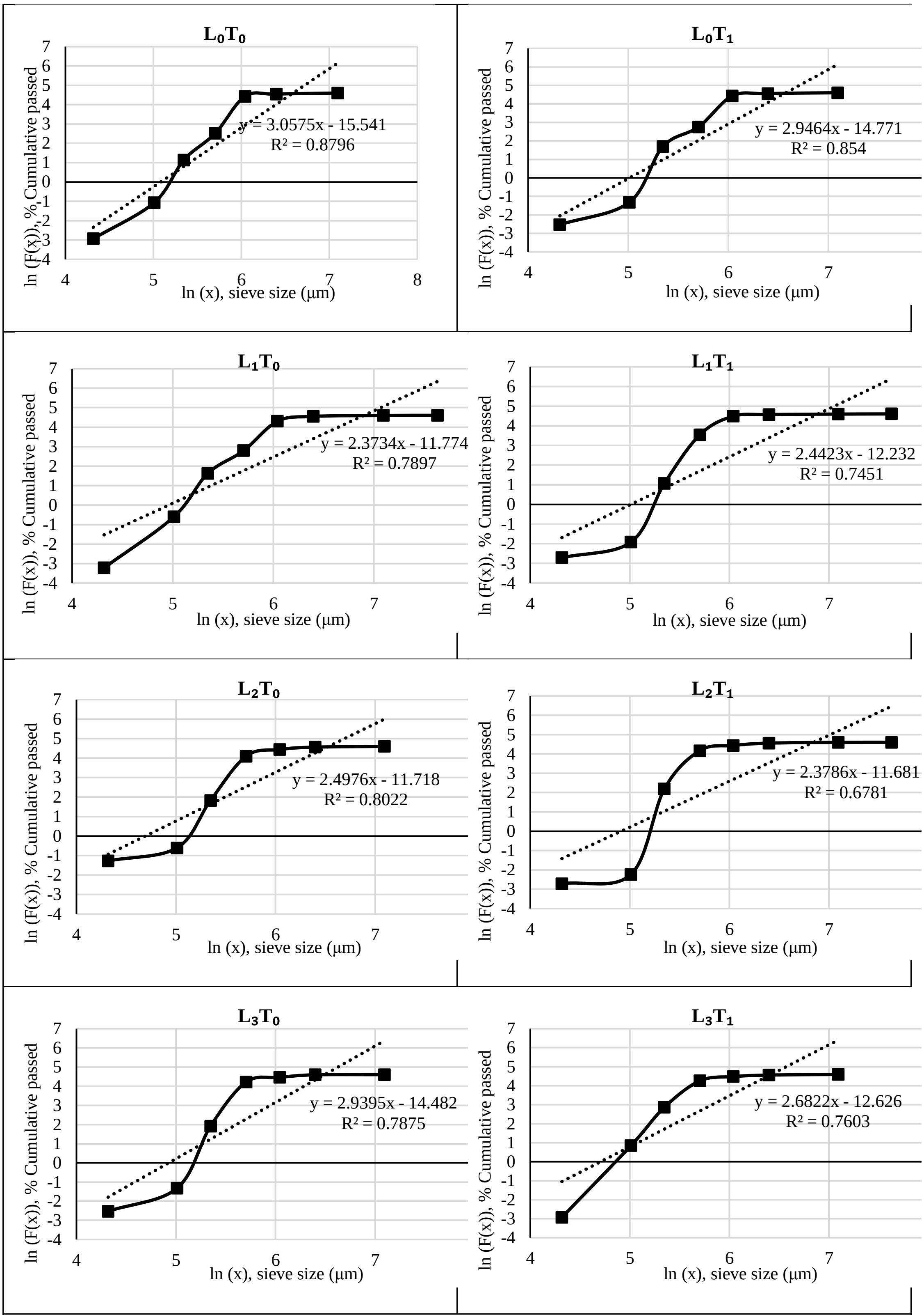


Fig. 5.20 Gaudin Schumann plots for different grinding treatments of turmeric

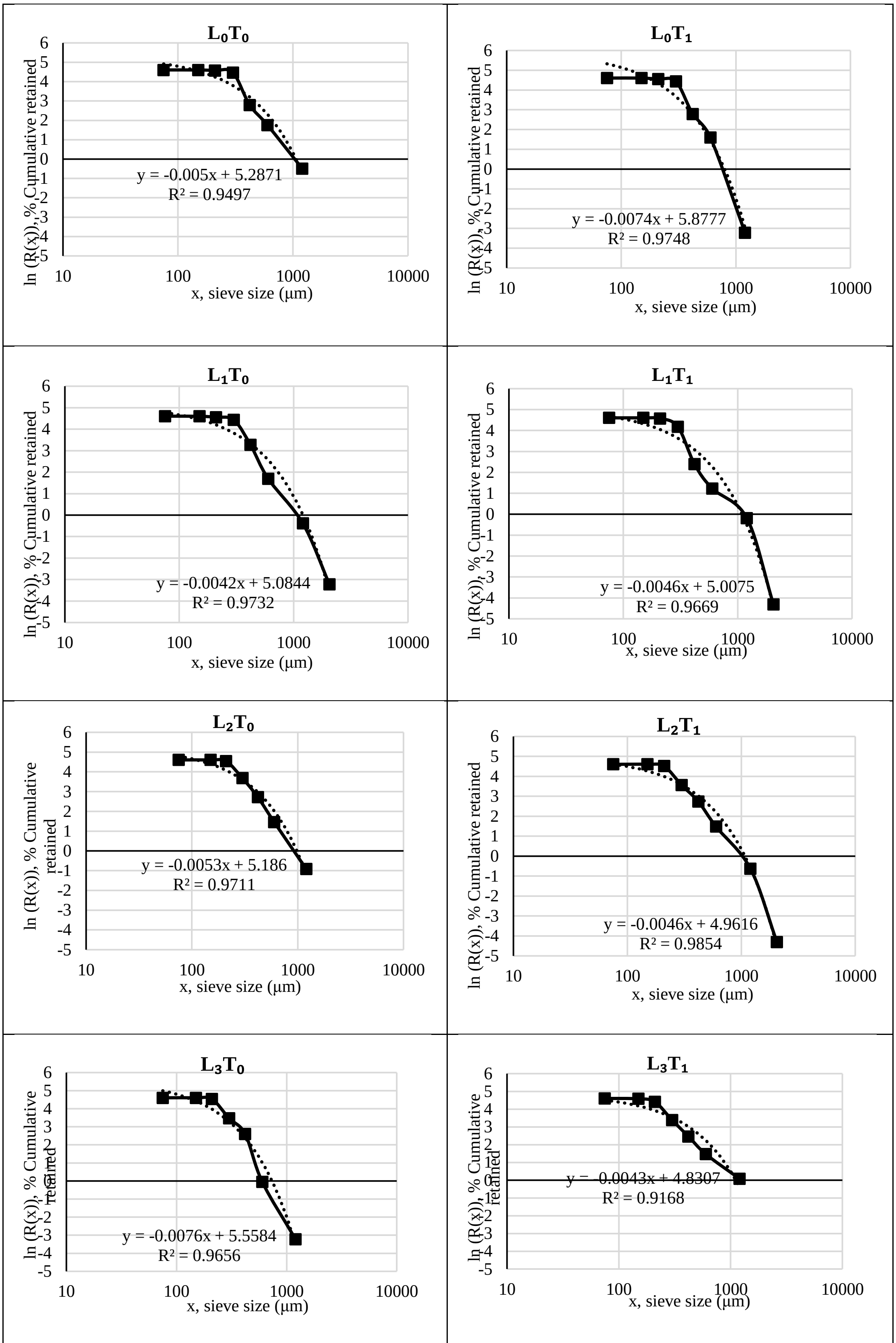


Fig. 5.21 Log Normal distribution plots for different grinding treatments of turmeric

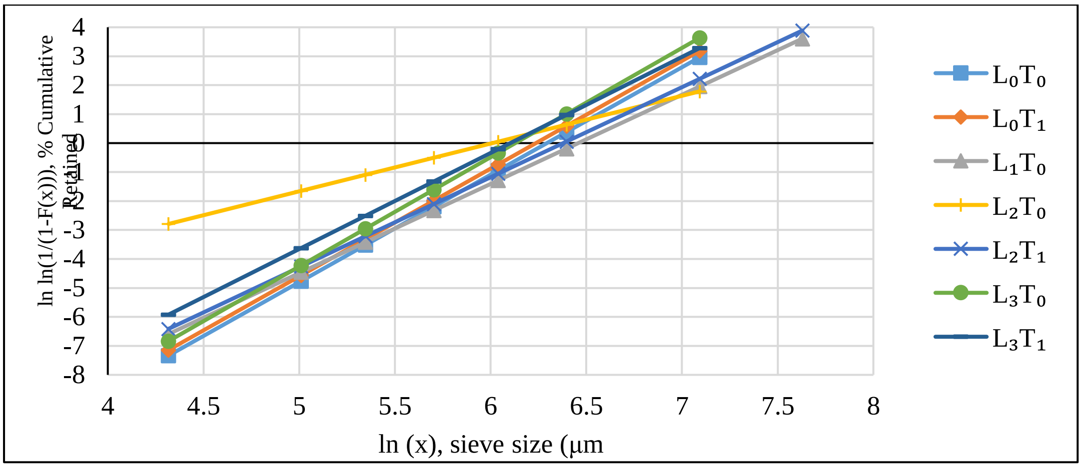


Fig. 5.22 Particle size distribution as regressed by the Rosin Rammler Bennet model

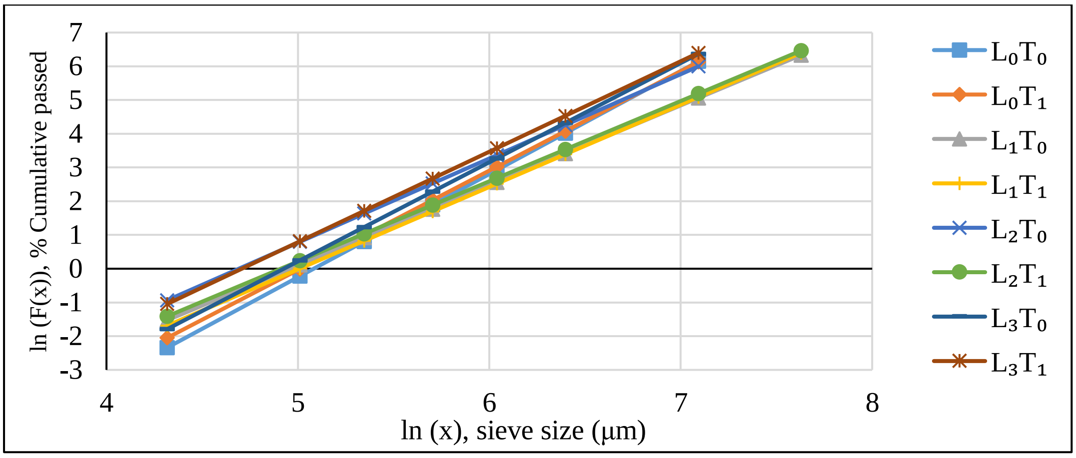


Fig. 5.23 Particle size distribution as regressed by the Gaudin Schumann model

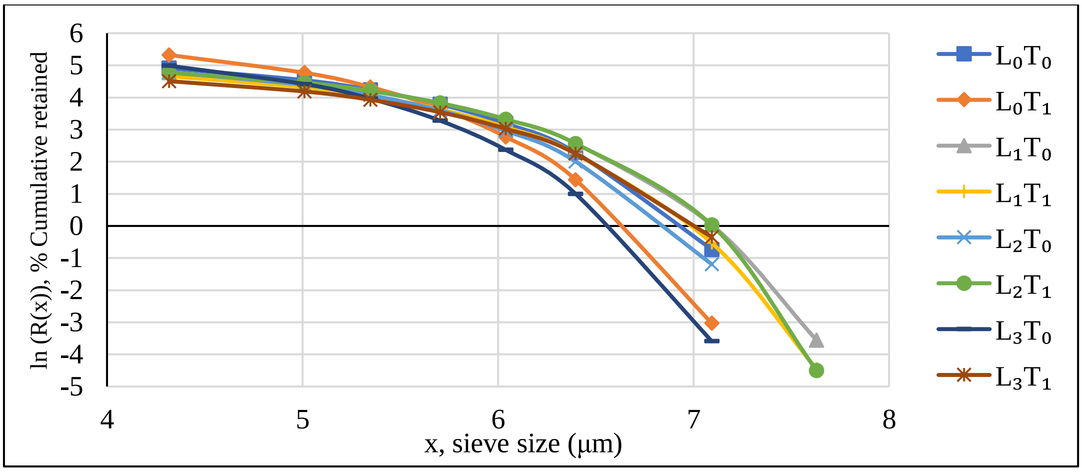


Fig. 5.24 Particle size distribution as regressed by the Log Normal distribution model

The linear relationship between the log of the cumulative percentage retained and the log of sieve size is illustrated by the RRB model of particle size distribution for the individual treatments (Fig. 5.19). The Gaudin Schumann particle size distribution graphs of different treatments indicates the linear relationship between the log of cumulative percentage passed to the log of sieve size (Fig. 5.20). Similarly, the log normal distribution graphs of different treatments are illustrated in the Fig. 5.21 which shows skewed relationship between the log of cumulative percentage retained and the sieve size. The fitted particle size distribution graphs of RRB, GS and Log Normal models based on the fitted regression equation from Table 7 are subsequently presented in the Fig. 5.22, 5.23 and 5.24, respectively.

Comparison between cryogenic, low temperature and traditional grinding

Sr. No.	Cryogenic grinding	Low temperature grinding	Traditional grinding
1.	Cryogenic grinding process produces much more finely ground particles than conventional milling methods.	This type of grinding is intermediate between cryogenic and traditional grinding system.	The traditional grinding often uses a conventional high powered mill set and fed material is ground into a small particle.
2.	Cryogenic grinding mills are able to grind many materials to 10µm average particle size or smaller.	This grinding mills are able to grind turmeric to 200 µm average particle size or smaller.	It is common to produce 600 to 2000 µm material using this relatively inexpensive method to produce relatively large crumb.
3.	A typical process generates 1800 to 2700 kg per hour.	Time requires to grind the material is more as compared to traditional grinding method.	Several cracker mills are often used in series. Typical yields are 900-1000 kg per hour for 10-20 mesh and 500 kg per hour for 30-40 mesh.
4.	Cost of cryogenic grinding is high	Cost for low temperature grinding is more than traditional grinding and less than cryogenic grinding.	Cost of grinding is less
5.	Initial investment is high	Initial investment is low hence, entrepreneurs can easily use this grinding mill.	Initial investment is low
6	There is need of liquid nitrogen.	There is need of chilling plant.	There is no need of liquid nitrogen or chilling plant.
7	The application of cryogen in moist atmosphere may cause formation of ice around the delivery nozzle and the piping system carrying the cryogen. This may cause a possible blockage in the delivery system of liquid nitrogen.	The application of low temperature in moist atmosphere may cause formation of water droplets around the grinding chamber and the piping system propylene glycol.	There is no such possibilities.
8	This is often a paddle type mill	This is a modification and attachment to hammer mill	This is a hammer mill
9	The loss of volatile oil is less	The loss of volatile oil is less than traditional grinding	The loss of volatile oil is more

10.2.6 Conclusions:

1. Grinding method effects significantly for all performance parameters i.e. temperature inside the grinding chamber at the end, grinding time, temperature of powder, milling loss and machine loss.
2. Feed temperature effects significantly for all performance parameters except milling loss.
3. Interaction effect between grinding method and feed temperature is non-significant for all performance parameters.
4. The temperature inside grinding chamber at the end, temperature of ground product and milling loss were minimum in the treatment coolant circulation with low temperature feed.
5. The grinding time and machine loss were maximum in the treatment coolant circulation with low temperature feed.
6. Grinding method as well as feed temperature effect significantly for all biochemical parameters i.e. moisture content, total carbohydrate, crude fiber, protein, fat, ash, volatile oil, phenol, falavonoids, antioxidant activity and curcumin.
7. Interaction effect between grinding method and feed temperature is non-significant for all biochemical parameters except crude fibre.
8. Statically all biochemical parameters value except ash content and curcumin content are maximum for coolant circulation grinding method.
9. Statically all biochemical parameters value are maximum for low temperature method.
10. Curcumin content value is maximum for chilled water circulation grinding method which was at par with coolant circulation.
11. Ash content value is maximum for ambient grinding method.
12. It is recommended to grind the turmeric rhizome with coolant circulation and low temperature feed for better retaining of biochemical content in the powder.
13. The different mathematical models RRB, GS and Log-Normal distribution were applied to the data of sieve analysis of different treatments. The different models indicated the positive effect of low temperature grinding techniques to yield the finer particles and wider distribution of particle size. For the fitting, statistical parameters showed that the Log Normal distribution was found to be the most suitable with the highest coefficient of regression and lower values of rooted sum of square and root mean square error, followed by the RRB and GS model.

11. Financial Implications (Rs. in Lakhs)

11.1 Expenditure on

(a) Manpower : Rs. 25.50 lakh
(b) Research/Recurring Contingencies: Rs. 1.50 lakh
(c) Non-Recurring Cost (Including cost of equipment) : Rs 35000/-

(d) Any Other Expenditure Incurred : -Nil-

11.2 Total Expenditure : 27.35 lakh

Cumulative Output

a. Special attainments/innovations : Reduction of post harvest losses
b. List of Publications (one copy each to be submitted if not already submitted)
    i. Research papers: Shelake P. S., M. N. Dabhi. 2019. Development of cooling system assisted grinding mechanism for spices. Journal of Food Process Engineering. 42(8):DOI:101111/jfpe.13288.Reports/Manuals: -Nil-
    ii. Working and Concept Papers: -Nil-
    iii. Popular articles: -Nil-
    iv. Books/Book Chapters: -Nil-
    v. Extension Bulletins: -Nil-

c. Intellectual Property Generation
(Patents - filed/obtained; Copyrights- filed/obtained; Designs- filed/obtained; Registration details of variety/germplasm/accession if any): -Nil-
d. Presentation in Workshop/Seminars/Symposia/Conferences
(relevant to the project in which scientists have participated):
e. Details of technology developed : **Crop-based**
Low temperature grinding machine was developed for 20-25 kg per hour capacity of spices.

(Crop-based; Animal-based, including vaccines; Biological – biofertilizer, biopesticide, etc; IT based – database, software; Any other – please specify)
f. Trainings/demonstrations organized **:** -Nil-
g. Training received: -Nil-
h. Any other relevant information: -Nil-

(a) Extent of achievement of objectives and outputs earmarked as per RPP-I

Objective wise	Activity	Envisaged output of monitorable target(s)	Output achieved	Extent of Achievement (%)
1. Development of low temperature grinding machine	1. March - Dec 2019-Development of low temperature grinding machine	Achieved	Fully matched	100%
2. Grinding of spices (Fenugreek seed, Turmeric) at low temperature	2. Jan – Mar 2020 Grinding of spices. 3. Jan-April 2021 (Repetition for turmeric)	Grinding of fenugreek is completed by Sept. 2020 and for turmeric it is	Achieved	100%

		completed by Nov. 2020. Repeption completed by May 2021.		
3. Assessment of biochemical and volatile compound of spice powder.	4. April-Dec 2021: Biochemical analysis of ground powder.	Achieved	Fully matched	100%

(b) Reasons of shortfall, if any: Due to pandemic covid 19 the grinding operation was late and in odd season.

Efforts made for commercialization/technology transfer:-

(a) How the output is proposed to be utilized?

The outcome of this project helps to retain biochemical metabolites in ground powder.

(b) How it will help in knowledge creation?

Low temperature grinding retain the important volatile compounds as compared to ambient temperature grinding.

Expected benefits and economic impact (if any)

The ground powder of Fenugreek seed and turmeric will contain important volatile compounds

Specify whether the project requires submission of RPP-IV for up scaling of research output. -Nil-

Future line of research work/other identifiable problems

1. The varietal research on curing system is needed.

Details on the research data (registers and records) generated out of the project deposited with the institute for future use

As in point 10.

Signature of PI, CC-PI(s), all Co-PIs

(M. N. Dabhi)	(P. R. Davara)	(H. R. Sojaliya)
Principal Investigator	Co-PI	Co-PI

Signature of Head of Division

Observations of PME Cell based on Evaluation of Research Project after Completion

Signature (with comments if any along with rating of the project in the scale of 1 to 10 on the overall quality of the work) of JD (R)/ Director

ANNEXURE - VIII

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

(For Guidelines Refer ANNEXURE – XI(H))

PROFORMA FOR RESEARCH PERFORMANCE EVALUATION OF INDIVIDUAL SCIENTIST

1. Institute Project Code : PH/JU/2019/01

2. Evaluation by PI on the contribution of the team in the project including self

Sr. No.	Name	Status in the project	Rating in the scale of 1 to 10
1	Dr. M. N. Dabhi	PI	9

3. Signature of PI :

M. N. Dabhi

Principal Investigator

ANNEXURE - VIII

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

(For Guidelines Refer ANNEXURE – XI(H))

PROFORMA FOR RESEARCH PERFORMANCE EVALUATION OF INDIVIDUAL SCIENTIST

1. Institute Project Code: PH/JU/2019/01

2. Evaluation by PI on the contribution of the team in the project including self

Sr. No.	Name	Status in the project	Rating in the scale of 1 to 10
1	Dr. P. R. Davara	Co-PI	8

3. Signature of PI :

M. N. Dabhi
Principal Investigator

ANNEXURE - VIII

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

(For Guidelines Refer ANNEXURE – XI(H))

PROFORMA FOR RESEARCH PERFORMANCE EVALUATION OF INDIVIDUAL SCIENTIST

1. Institute Project Code: PH/JU/2019/01

2. Evaluation by PI on the contribution of the team in the project including self

Sr. No.	Name	Status in the project	Rating in the scale of 1 to 10
1	Dr. H. P. Gajera	Co-PI	8

3. Signature of PI :

M. N. Dabhi
Principal Investigator

NEW INVESTIGATION – I

ANNEXURE - I

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

PROFORMA FOR PREPARATION OF STATUS REPORT FOR PROPOSAL OF A NEW RESEARCH PROJECT (RPP-I)
(Refer for Guidelines ANNEXURE-XI(A))

1. Institute Name : College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh
2. Title of the project : Development of peanut tempeh through fermentation process.
3. Type of research project: Basic/~~Applied/Extension/Farmer Participatory/Other~~ (specify)
4. Genesis and rationale of the project :

   Nowadays, the world's population increases rapidly every day. Also, food demand is increasing as every time. Protein is an important type in a balanced diet. Fermented foods and beverages contribute significantly to the diets of many people throughout the world. The food industry has targeted healthy and diversified food for the development of new products in the market all over the world. The fermented food is a good example of recent products demanded by a considerable population group whose interest in variability and new foods with functional, nutritional, and tasty attributes.

   Fermented items of soybean are the best example to reach its popularity and Tempeh is one of the fermented items of soybean in which the protein content is increased after the fermentation process. Table 6.1 reveals the nutritional content of soybean and soy tempeh. (Vaidehi et al, 1985).

   Fungi *Rhizopus oligosporus*&*Rhizopusoryzae* played a great role in such a product development. Many fungal strains in genera such as *Aspergillus, Fusarium, Monascus, Neurospora*, and *Rhizopus* are categorized as GRAS (Generally Recognised as Safe) by the United States Food and Drug Administration (USFDA), their application as animal feed and even human food is allowed. (Ferreira et al., 2013).

Table 6.1 : Proximate Nutrient Composition of Soybean &Soy tempeh. (per 100 g)

Nutritional component	Soybean	Soy tempeh
Moisture	6.60 %	8.00 %
Protein	36.49 %	48.60 %
Fats	19.94 %	21.60 %
Fibre	9.3 %	4.8 %
Carbohydrate	30.16 %	18.00 %

Niacin (B3)	1.62 mg	4.63 mg
Vitamin B12	0.0 mg	1.0 μg
Vitamin A	2.0 μg	69 μg
Vitamin C (ascorbic acid)	6. 0 mg	0.0 mg
Zinc	4.9 mg	1.81 mg
Copper (Cu)	1.7 mg	0.67 mg
Calories (Kcal per 100 g)	446	461.00

It was observed that sporulation, and aflatoxin production from *Aspergillus flavus* and *A. parasiticus* are considerably suppressed by *R. oligosporus*. (Djion et al., 1979, "Use of Microbial Cultivar; Legume and Cereal Products," Economic Microbiol., 4: 115). Similarly, it was also noted that there is an active principle against Gram-positive bacteria, including *Clostridium botulinum*, *Bacillus subtilis*, and *Staphylococcus aureus* by *R. oligosporus*. (Wang et al., 1981, "Use of Microbial Cultures: Legume and Cereal Products," Food Technol., 35 (1): 79 & "Antibacterial Compound from a Soybean Product Fermented by *R. oligosporus*," Soc. Exp. Biol. Med., 131: 57911969).

5. Knowledge/Technology gaps and justification for taking up the present project including the questions to be answered :

Peanut is the oilseed which is high in fat content, good in protein content, high in energy content, average in carbohydrate content and good in fiber content. It also contains many other functional compounds like fibers, polyphenols, antioxidants, vitamins and minerals. (Kathleen, 2015). Peanuts contain all the 20 amino acids in variable proportions and is the biggest source of the protein called "arginine" (USDA, 2014). After the peanut oil is extracted, the protein content in the cake can reach 50% (Zhao et al., 2011). Commercially it is used mainly for oil production. Apart from oil, peanuts are widely used for production of peanut butter, confections, roasted peanuts, snack products, extenders in meat product formulation, peanut sauce, peanut flour, peanut milk, peanut beverage, peanut snacks (salted and sweet bars) and peanut cheese analogs (Arya et al., 2016).

Many peanut based commercial products like peanut butter, confections, roasted peanuts and snack products, extenders in meat product formulation, peanut flour, peanut milk, peanut beverage, peanut snacks (salted and sweet bars) and peanut cheese analogs are available in the market. The method for production of soy based tempeh is already been well known. But, very negligible information is available for utilization peanut for tempeh manufacturing.

Hence, the experiment on defatted peanut kernels is adopted in this study to develop the process technology for the production of peanut tempeh and to generate the information about the interaction between process parameters to optimize their levels for production of good quality peanut tempeh.

Table 6.2 : Proximate Nutrient Composition of Raw & Defatted peanut kernels. (per 100 g)

Nutritional component	Raw Peanut Kernels	Defatted Peanut Kernels
Moisture	6.98 %	3.8 %
Protein	23.40 %	36.22 %
Fat	46.88 %	7.5 %
Carbohydrate	18.54 %	23.89 %
Ash	2.3 %	3.8 %
Fibre	4.8 %	4.76 %

6. Critical review of present status of the technology at national and international levels along with complete references :

- Nout M.J.R. (2005) studied the small scale and medium industrial scale, commercial production of soy tempeh. It was also studied that microbiological composition in soybean make changes in nutritional characteristics especially in enzymes and other bioactive compounds as well as it was also studied that tempeh in food consumption has evolved from the stages of basic nutrition to the development of derived products such as burgers and salads which possesses important health benefits for human consumption.
- Syamsuri R. (2020) developed the soy tempeh sausage and determined the quality of tempeh sausages, especially chemical and sensory content produced from various soybean varieties and variation of cooking methods. The research had a Complete Random Design of the factorial pattern with 3 repeats. The first factor is tempeh from various of soybean varieties (Import, Anjasmoro, Argomulyo, Burangrang, and Grobogan), the second factor is the cooking method (steamed, boiled and oven). The observation parameters include: moisture content, ash content, fat level, protein level, and sensory/organoleptic test. The result was showed that varieties of treatment and cooking methods gave a real interaction effect on ash content, fat content and protein of tempeh sausage. Tempeh sausage was produced from imported soybean, has the lowest water content for the oven cooking method and sausage tempeh of soybean Anjasmoro with steamed method has the lowest ash content. Tempeh sausage produced from soybean Argomulyo has the highest fat content for steamed cooking methods and the highest protein for the oven cooking method. Based on sensory analysis, it is known that having the highest level of preference is tempeh sausage from Grobogan and steamed treatment with a moisture content of 56.25%, ash content is 0.97%, fat 17.38%, and protein 12.91%.
- Vital R.J. (2018) carried out an experiment with white bean as raw material for making tempeh burger, also determined and compared its nutritional, microbiological and sensory properties with conventional soybean-based tempeh burger. In this experiment it was observed that white bean tempeh burgers showed similar appearance and crispy consistency, but received lower scores for flavor, compared to the soybean burgers,

probably due to their residual beany flavor. The beany flavor could be minimized by increasing the cooking time of the beans. White bean tempeh can be a good alternative for healthy eating, and its manufacture could promote the production of new products made from beans.

- W. Srapinkornburee (2009) discussed in the research that red kidney bean acted as a good material for tempeh production. Red kidney bean tempeh looks like the original tempeh but it was found that it was darker in colour. Fried red kidney bean tempeh in three different types of packaging which were stored at room temperature with sufficient oxygen head space in the packaging. In an experiment, it was concluded that nylon B container was more suitable material for packaging fried red kidney bean tempeh.

References :

- Arya S.S., Akshata R. Salve & S. Chauhan. Peanuts as functional food: a review. J Food Sci Technol. 2016. 53(1):31–41.
- Gianluca Rizzo and Luciana Baroni. Soy, Soy Foods and Their Role in Vegetarian Diets. Nutrients. 2018. 10, 43.
- Nout M.J.R. & Kiers J.L.. Tempe fermentation, innovation and functionality: update into the third millennium. Journal of Applied Microbiology. 2005. 98, 789–805.
- Syamsuri R., Dewayani W., Septianti E. &Maintang. Chemical characteristic and sensory of tempeh sausage on different soybean varieties and cooking methods variation. IOP Conf. Series: Earth and Environmental Science. 2020.575.
- US Department of Agriculture (USDA). Food Composition Databases Show Foods List. Available online: https://ndb.nal.usda.gov/ndb/search/list.
- Vaidehi M.P., Annapurna M.L., & Vishwanath N.R. Nutritional and sensory evaluation of tempeh products made with soybean. Food and Nutrition Bulletin, vol. 7, no. 1. 1985.
- Vital R.J., Bassinello P.Z., Cruz Q.A., Carvalho R.N., Júlia C.M. de Paiva& Colombo A.O.. Production, Quality, and Acceptance of Tempeh and White Bean Tempeh Burgers. www.mdpi.com/journal/foods. 2018, 7, 136.
- W. Srapinkornburee, U. Tassanaudom and S. Nipornram. Commercial development of red kidney bean tempeh. 2009. 2(03), 362-372.

7. Expertise available with the investigating group/Institute

The PI & Co-PI of project is having enough experience of working in the field of Processing and Food Engineering. Both are the experts in the field of Processing and Food Engineering. The PI is quite capable and qualified to handle this microbiological project. The facility and man power is available in the institute to conduct the process activities in the laboratory.

8. Brief note on Proprietary/Patent Perspective (for projects related to technology development)/Ethics/Animal Welfare/Bio Safety Issues

- No issues are there on these aspects.

9. (a) Expected output

- The process technology for the production of peanut tempeh will be standardized.
- The new fermented product based on peanut will be developed.
- The process technology for production of nutrient rich peanut tempeh can be made available to the commercial players and food processors.
- The process parameters for the preparation of peanut tempeh will be optimized.

(b) Clientele/Stake holders (including economic and socio aspects)

i. Peanut growers
ii. Peanut processors
iii. Consumers

10. Signatures

[Project Leader] [Co-PIs] ……

11. Comments and signature

[Head of Division]

ANNEXURE- II

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

RESEARCH PROJECT PROFORMA FOR INITIATION OF A RESEARCH PROJECT (RPP - I)

(Refer for Guidelines ANNEXURE-XI (B))

1. Institute Project Code (to be provided by PME Cell)
2. Project Title :Development of peanut tempeh through fermentation process.
3. Key Words :Defatted peanut kernels, fermentation, peanut tempeh
4. (a) Name of the Lead Institute : College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh

   (b) Name of Division/ Regional Center/ Section : AICRP on PHET, Junagadh centre
5. (a) Name of the Collaborating Institute(s) : --

   (b) Name of Division/ Regional Center/ Section of Collaborating Institute(s) : --
6. Project Team(Name(s) and designation of PI, CC-PI and all project Co-PIs, with time proposed to be spent)

Sr. No.	Name, designation and institute	Status in the project (PI/CC-PI/ Co-PI)	Time to be spent (%)	Work components to be assigned to individual scientist
1.	Prof. A. M. Joshi Assistant Microbiologist, AICRP on PHET, Dept. of Processing and Food Engg., College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh	PI	60%	1. Review collection/literature survey. 2. Preliminary trial for production of peanut tempeh. 3. Development of peanut tempeh using defatted peanut kernels. 4. Laboratory trials as per the different process parameters. 5. Physico-chemical and sensory analysis of the products. 6. Data collection and its analysis. 7. Report writing

2.	Dr. P. R. Davara, Assistant Research Engineer, AICRP on PHET, Dept. of Processing and Food Engg., College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh	Co-PI-I	15%	1. To assist the PI during product formation process. 2. Work on RSM Design. 3. To assist the PI to carry out the engineering parameters of the product.
3.	Dr. P. J. Rathod Assistant Biochemist, AICRP on PHET, Dept. of Bio-Technology, JAU, Junagadh	Co-PI-II	15%	To assist the PI to carry out biochemical analysis of the product
4.	Dr. M. N. Dabhi, Research Engineer, AICRP on PHET, Dept. of Processing and Food Engg., College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh.	Co-PI-III	10%	Overall guidance, supervision and assist the PI in taking administrative approvals as and when needed to carry out the different project related activities.

8. Priority Area to which the project belongs : Post Harvest Technology
(If not already in the priority area, give justification)

9. Project Duration : Date of Start: 01-03-2022
Likely Date of Completion **:**31-01-2024

10. (a) Objectives :

- To study the feasibility of defatted peanut kernels in the preparation of peanut tempeh.
- To study the effect of process parameters and sensory parameters on quality of peanut tempeh.
- To optimize the process parameters for preparation of peanut tempeh.

(b) Practical utility :

1. The process technology for the production of peanut tempeh will be standardized.
2. The new fermented product based on peanut will be developed using defatted peanut.
3. The process technology for production of nutrient rich peanut tempeh can be made available to the commercial players and food processors.
4. The proposed process technology will suggest the proper byproduct utilization of peanut for the preparation of value added product.
5. The process parameters for the preparation of peanut tempeh will be optimized.

11. Activities and outputs details :.

Objective wise	Activity	Month & Year of		% to be carried out	Scientist(s) responsible

				Output monitorable target(s)	in different years		
		Start	Comple-tion		1	2	
1.	Review collection	March-22	May-22	1. To collect the data on tempeh manufacturing process and defatted peanut kernelsutilization. 2. To study the work done in the past.	100 %	--	Prof. A. M. Joshi
2.	Procurement and Quality analysis of proposed product raw material	June-22	Aug-22	Quality of defatted peanut kernels will be analysed.	100 %	--	Prof. A. M. Joshi
3.	Preliminary laboratory trials	Sept-22	Jan-23	Preliminary trial run for preparation of peanut tempeh will be carried out	100 %	--	Prof. A. M. Joshi, Dr. P. R. Davara
4.	Preparation of peanut tempeh as per the final treatments	Feb-23	May-23	Final treatment trials will be carried out	--	100 %	Prof. A. M. Joshi, Dr. P. R. Davara
5.	Quality analysis of peanut tempeh prepared by different treatments	June-23	Sept-23	Developed peanut product will be analysed for its physico-chemical and sensory quality as well as different microbiological aspects will be studied	--	100 %	Dr. P. R. Davara, Prof. A. M. Joshi, Dr. P. J. Rathod
6.	Data analysis and	Oct-23	Jan-24	Compilation of collected data and	--	100 %	Prof. A. M. Joshi,

	report writing			preparation of report			Dr. M. N. Dabhi

	2022									2023												2024
Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Review collection																						
			Procurement and Quality analysis of proposed product raw material																			
						Preliminary laboratory trials																
											Preparation of peanut tempeh as per the final treatments											
															Quality analysis of peanut tempeh prepared by different treatments							
																			Data analysis and report writing			

12. Technical Programme (brief)

Justification :

Nowadays, the world's population increases rapidly every day. Also, food demand is increasing as every time. Protein is an important type in a balanced diet. Fermented foods and beverages contribute significantly to the diets of many people throughout the world. The food industry has targeted healthy and diversified food for the development of new products in the market all over the world. The fermented food is a good example of recent products demanded by a considerable population group whose interest in variability and new foods with functional, nutritional, and tasty attributes.

Fermented items of soybean are the best example to reach its popularity. And Tempeh is one of the fermented items of soybean in which the protein content is increased after the fermentation process. Table 6.1 reveals the nutritional content of soybean and soy tempeh. (Vaidehi et al, 1985).

Fungi *Rhizopus oligosporus*&*Rhizopusoryzae* played a great role in such a product development. Many fungal strains in genera such as *Aspergillus, Fusarium, Monascus, Neurospora*, and *Rhizopus* are categorized as GRAS (Generally Recognised as Safe) by the United States Food and Drug Administration (USFDA), their application as animal feed and even human food is allowed. (Ferreira et al., 2013)

Peanut is the oilseed which is high in fat content, good in protein content, high in energy content, average in carbohydrate content and good in fiber content. It also contains many other functional compounds like fibers, polyphenols, antioxidants, vitamins and minerals. (Kathleen, 2015). Peanuts contain all the 20 amino acids in variable proportions and is the biggest source of the protein called “arginine” (USDA, 2014). After the peanut oil is extracted, the protein content in the cake can reach 50% (Zhao et al., 2011). Commercially it is used mainly for oil production. Apart from oil, peanuts are widely used for production of peanut butter, confections, roasted peanuts, snack products, extenders in meat product formulation, peanut sauce, peanut flour, peanut milk, peanut beverage, peanut snacks (salted and sweet bars) and peanut cheese analogs (Arya et al., 2016).

Many peanut based commercial products like peanut butter, confections, roasted peanuts and snack products, extenders in meat product formulation, peanut flour, peanut milk, peanut beverage, peanut snacks (salted and sweet bars) and peanut cheese analogs are available in the market. The method for production of soy based tempeh is already been well known. But, very negligible information is available for utilization peanut for tempeh manufacturing. Hence, the experiment is adopted in this study to develop the process technology for the production of peanut tempeh and to generate the information about the interaction between process parameters to optimize their levels for production of good quality peanut tempeh.

Status (review) :

- Nout M.J.R. (2005) studied the small scale and medium industrial scale, commercial production of soy tempeh. It was also studied that microbiological composition in soybean make changes in nutritional characteristics especially in enzymes and other bioactive compounds as well as it was also studied that tempeh in food consumption has evolved from the stages of basic nutrition to the development of derived products such as burgers and salads which possesses important health benefits for human consumption.
- Syamsuri R. (2020) developed the soy tempeh sausage and determined the quality of tempeh sausages, especially chemical and sensory content produced from various soybean varieties and variation of cooking methods. The research had a Complete Random Design of the factorial pattern with 3 repeats. The first factor is tempeh from various of soybean varieties (Import, Anjasmoro, Argomulyo, Burangrang, and Grobogan), the second factor is the cooking method (steamed, boiled and oven). The observation parameters include: moisture content, ash content, fat level, protein level, and sensory/organoleptic test. The result was showed that varieties of treatment and cooking methods gave a real interaction effect on ash content, fat content and protein of tempeh sausage. Tempeh sausage was produced from imported soybean, has the lowest water content for the oven cooking method and sausage tempeh of soybean Anjasmoro with steamed method has the lowest ash content. Tempeh sausage produced from soybean Argomulyo has the highest fat content for steamed cooking methods and the highest protein for the oven cooking method. Based on sensory analysis, it is known that

having the highest level of preference is tempeh sausage from Grobogan and steamed treatment with a moisture content of 56.25%, ash content is 0.97%, fat 17.38%, and protein 12.91%.

- Vital R.J. (2018) carried out an experiment with white bean as raw material for making tempeh burger, also determined and compared its nutritional, microbiological and sensory properties with conventional soybean-based tempeh burger. In this experiment it was observed that white bean tempeh burgers showed similar appearance and crispy consistency, but received lower scores for flavor, compared to the soybean burgers, probably due to their residual beany flavor. The beany flavor could be minimized by increasing the cooking time of the beans. White bean tempeh can be a good alternative for healthy eating, and its manufacture could promote the production of new products made from beans.
- W. Srapinkornburee (2009) discussed in the research that red kidney bean acted as a good material for tempeh production. Red kidney bean tempeh looks like the original tempeh but it was found that it was darker in colour. Fried red kidney bean tempeh in three different types of packaging which were stored at room temperature with sufficient oxygen head space in the packaging. In an experiment, it was concluded that nylon B container was more suitable material for packaging fried red kidney bean tempeh.

Objectives :

1. To study the feasibility of defatted peanut kernels in the preparation of peanut tempeh.
2. To study the effect of process parameters and sensory parameters on quality of peanut tempeh.
3. To optimize the process parameters for preparation of peanut tempeh.

Technical programme

Defatted peanut kernels

↓

Adding Vinegar for acidic environment

↓

Mixing

↓

Autoclaving (121°C for 15 mins.)

↓

Cooling of sample

↓

Inoculate the fungal culture

↓

Mixing of samples

↓

Prepare packages or beds with marginal exposure to open air

↓

Incubation

↓

Harvest fresh tempeh

↓

Deep-frying in oil

↓

Crispy snacks

Fig. 6.1. Process flow chart for preparation of peanut tempeh.

- **Experimental Detail :**
  - Raw material : Defatted Peanut kernels (*Arachishypogaea L.*)
  - Fungi : *Rhizopusoligosporus&Rhizopusoryzae*
  - Experimental Design : Response Surface Methodology : CCRD (2 factors)
  - Inoculum : 10^4 CFU g^{-1}
- **Treatments Detail :**
  - **Independent parameters (for both *Rhizopus oligosporus* &*Rhizopus oryzae)***

Sr. No.	Parameters	Code	Coded levels				
			-1.41	**-1**	**0**	**+1**	**+1.41**
1	Fermentation temp. (°C)	(X_1)	24	31	48	65	72
2	Fermentation time (hr)	(X_2)	25	27.2	32.5	37.8	40

  - **Treatment combinations :**

Treatment Run	Coded variables		Uncoded variables	
	X_1	X_2	Fermentation temp. (°C)	Fermentation time (hr)
1	-1	1	31.0	37.8
2	-1.41	0	24.0	32.5
3	1	-1	65.0	27.2
4	-1	-1	31.0	27.2
5	0	0	48.0	32.5
6	0	0	48.0	32.5
7	0	1.41	48.0	40.0
8	0	-1.41	48.0	25.0
9	0	0	48.0	32.5
10	0	0	48.0	32.5
11	0	0	48.0	32.5
12	1.41	0	72.0	32.5
13	1	1	65.0	37.8

  - **Dependent Parameters :**
    - Biochemical Parameters :
      - Moisture content
      - Protein
      - Fibre
      - Fat
      - Carbohydrate
    - Sensory Parameters :
      - Colour
      - Flavour
      - Taste
      - Crispness
      - Overall acceptability
    - Microbiological Parameters :
      - Coliforms count
      - Salmonella count

Possible outputs :

- The process technology for the production of peanut tempeh will be standardized.
- The new fermented product based on peanut will be developed using defatted peanut.
- The process technology for production of nutrient rich peanut product can be made available to the commercial players and food processors.
- The proposed process technology will suggest the proper byproduct utilization of peanut for the preparation of value added product.
- The process parameters for the preparation of peanut tempeh will be optimized.

References :

- Arya S.S., Akshata R. Salve & S. Chauhan. Peanuts as functional food: a review. J Food Sci Technol. 2016. 53(1):31–41.
- Gianluca Rizzo and Luciana Baroni. Soy, Soy Foods and Their Role in Vegetarian Diets. Nutrients. 2018. 10, 43.
- Nout M.J.R. & Kiers J.L.. Tempe fermentation, innovation and functionality: update into the third millennium. Journal of Applied Microbiology. 2005. 98, 789–805.
- Syamsuri R., Dewayani W., Septianti E. &Maintang. Chemical characteristic and sensory of tempeh sausage on different soybean varieties and cooking methods variation. IOP Conf. Series: Earth and Environmental Science. 2020.575.
- US Department of Agriculture (USDA). Food Composition Databases Show Foods List. Available online: https://ndb.nal.usda.gov/ndb/search/list.
- Vaidehi M.P., Annapurna M.L., & Vishwanath N.R. Nutritional and sensory evaluation of tempeh products made with soybean. Food and Nutrition Bulletin, vol. 7, no. 1. 1985.
- Vital R.J., Bassinello P.Z., Cruz Q.A., Carvalho R.N., Júlia C.M. de Paiva& Colombo A.O.. Production, Quality, and Acceptance of Tempeh and White Bean Tempeh Burgers. www.mdpi.com/journal/foods. 2018, 7, 136.
- W. Srapinkornburee, U. Tassanaudom and S. Nipornram. Commercial development of red kidney bean tempeh. 2009. 2(03), 362-372.

13. Financial Implications (in Lakhs) : Rs. 39.32 lakhs

(A) Financed by the institute

12.1 Manpower (Salaries / Wages)

Sr. No.	Staff Category	Man months	Cost
1.	Scientific	23	35,00,000
2.	Technical	5	4,00,000
3.	Supporting	--	--
4.	SRFs/RAs	--	--
5.	Contractual	--	--
	Total	28	39,00,000

12.2 Research/Recurring Contingency

S. No.	Item	Year(1)	Year (2)	Year (3)…	Total
1.	Consumables	10000	10000	--	20000
2.	Travel	5000	--	--	5000
3.	Field Preparation/ Planting/ Harvesting (Man-days/costs)	--	--	--	--
4.	Inter-cultivation & Dressing (Man-days/costs)	--	--	--	--
5.	Animal/Green house/Computer Systems/Machinery Maintenance	2000	--	--	2000
6.	Miscellaneous(Other costs)	5000	--	--	5000
	Total(Recurring)	22000	10000	--	32000

Justification : --

12.3 Non-recurring (Equipment)

S. No.	Item	Year (1)	Year (2)	Year (3)…	Total
1.	--	--	--	--	--
2.	--	--	--	--	--
	Total (Non-recurring)	--	--	--	--

Justification : --

12.4 Any Other Special Facility required (including cost)

12.5 Grand Total (12.1 to 12.4)

Item	Year (1)	Year (2)	Year (3)	Total
Grand Total	20,00,000	19,32,000	--	39,32,000

(B) Financed by an organization other than the Institute (if applicable) : No

(i) Name of Financing Organization : NA

(ii) Total Budget of the Project :

(iii) Budget details

S. No.	Item	Year(1)	Year(2)	Year (3)…	Total
1	Recurring Contingency				

	Travelling Allowance	--	--	--	--
	Workshops	--	--	--	--
	Contractual Services/ Salaries	--	--	--	--
	Operational Cost	--	--	--	--
	Consumables	--	--	--	--
2	Non - Recurring Contingency				
	Equipment	--	--	--	--
	Furniture	--	--	--	--
	Vehicle	--	--	--	--
	Others (Miscellaneous)	--	--	--	--
3	HRD Component				
	Training	--	--	--	--
	Consultancy	--	--	--	--
4	Works (i) New (ii) Renovation	--	--	--	--
5	Institutional Charges				

ANNEXURE - III
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
CHECKLIST FOR SUBMISSION OF RPP-I
(Refer for Guidelines ANNEXURE-XI(C)

1. Project Title : Development of peanut tempeh through fermentation process.

2. Date of Start & Duration : March – 2022 to January - 2024

3. Institute Project [/] or Externally Funded [ ]

4. Estimated Cost of the Project : 39,32,000/- INR

5. Project Presented in the Divisional/Institutional Seminar? Yes / ~~No~~ [/]

6. Have suggested modifications incorporated? ~~Yes~~ / No [ ]

7. Status Report enclosed ~~Yes~~ / No

8. Details of work load of investigators in approved ongoing projects:

Project Leader				Co-PI – I				Co-PI – II…			
Proj. Code.	% Time spent	Date of start	Date of completion	Proj. Code.	% Time spent	Date of start	Date of completion	Proj. Code.	% Time spent	Date of start	Date of completion
PH/JU/2020/1	15	1/2/2020	30/06/2022	PH/JU/2020/1	60	1/2/2020	30/06/2022	PH/JU/2020/1	10	1/2/2020	30/06/2022
PH/JU/2020/2	20	1/5/2020	1/12/2022								

9. Work Plan/Activity Chart enclosed Yes / ~~No~~ [√]

10. Included in Institute Plan Activity Yes / ~~No~~ [√]

11. Any previous Institute/Adhoc/Foreign aided projects on similar lines? ~~Yes~~ / No [√]

12. New equipment required for the project ~~Yes~~ / No [√]

13. Funds available for new equipment ~~Yes~~ / No [√]

14. Signatures

Project Leader Co-PI-I Co-PI-II Co-PI–III

HOD/PD/I/c

ANNEXURE - IV
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
APPRAISAL BY THE PMECELL OF RPP-I
(Refer for Guidelines ANNEXURE-XI (D)

1. Institute Name : AICRP on PHET, JAU, Junagadh
2. Project Title : Development of peanut tempeh through fermentation process.
3. On scale 1-10 give score to (a) to (j)

(a)	Relevance of research questions	☐
(b)	Addressing priority of the institute and/or National priority	☐
(c)	New innovativeness expected in the study	☐
(d)	Appropriateness of design/techniques for the questions to be answered	☐
(e)	Elements of bias addressed in the study	☐
(f)	Adequacy of scientist(s) time allocation	☐
(g)	Extent of system review and meta analysis	☐
(h)	Effective control to experiments	☐
(i)	Economic evaluation and cost efficiency analysis	☐
(j)	How appropriately the expected output answers the questions being addressed in the specific subject matter/area (Basic/Applied/Translational/Others)?	☐
	***Total Score out of 100**	

* The score obtained is suggestive of the overall quality ranking of the project

4. Was there any other project carried in the past in the same area/topic?

Yes ☐ No ☐

If yes, list the project numbers.

5. Signature of PME Cell Incharge

NEW INVESTIGATION – II

ANNEXURE - I

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

PROFORMA FOR PREPARATION OF STATUS REPORT
FOR PROPOSAL OF A NEW RESEARCH PROJECT
(Refer for Guidelines ANNEXURE-XI(A))

1. **Institute Name**: College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh
2. **Title of the project**: Refrigerated grinding of spices.
3. **Type of research project**: ~~Basic/~~Applied~~/Extension/Farmer Participatory/Other~~ (specify)
4. **Genesis and rationale of the project** :

Out of many agricultural commodities spices are important because of their great prices. The country is considered as 'The Land of Spices'.These commodities are useful for for flavouring, seasoning and imparting aroma in foods. The spices are used in the whole form or in the ground form. It is hence important to give weightage to this product for its quality and grinding. (Purthi, 1998).

The size reduction process for spices in the form of powder is considered as the term 'grinding' (Perry, 1950). It is a very important step in the post-harvest processing of spices considering retaining of the aroma and flavour compounds present in spices (Gopalkrishnan *et al*., 1991). They are ground at one stage or the other before consumption though whole spices are also used in culinary practices to a certain extent. They are ground either for direct use or making value-added products, such as, ground spices, mixes, oleoresins and spice oil extract which have vast industrial applications (Anon., 2001).

5. **Knowledge/Technology gaps and justification for taking up the present project including the questions to be answered**

The chief purpose of spice grinding is to obtain its powder form with retaining of good product quality in terms flavour and colour (Singh and Goswami, 1999).

In traditional grinding of spices, frictional heat is generated in the grinder due to high oil content. Due to temperature rise during grinding spices loose a significant fraction of its volatile oil. Rise of temperature during grinding ranges from 42-95ºC depending on the spice product (Pruthi and Mishra, 1963).Temperature inside the mill at the end of grinding of turmeric at ambient grinding (control treatment) was 62ºC (Shelake, 2017). The data of temperature inside the grinding chamber at the end of grinding varied from maximum of 91.33 °C for ambient grinding of fenugreek seeds (Sirwani, 2021).

The losses of volatile oil for different spices have been reported to be in the range of 37 per cent for nutmeg, 14 per cent for mace, 17 per cent for cinnamon and 17 per cent for oregano (Andres, 1976). The loss of volatile oil during grinding of caraway seed has been reported to be 32% less at the temperature of 45ºC than that of -17 (Wolf and Pahl, 1990). Shelake (2017) reported loss of 23% volatile oil at ambient grinding as compared to grinding at 0ºC for turmeric. Sirwani (2021) reported the loss of 37% volatile oil at ambient grinding as compared to grinding with circulation of coolant around the grinding chamber.

The loss of volatile oil can be significantly reduced by cryogenic grinding technique, refrigerated grinding, grinding with water jacket and circulation of coolant around the grinding chamber (Pruthi, 1987, Shelake 2017, Sirwani 2021.). Liquid nitrogen at -195.6ºC provides the refrigeration needed to pre-cool the spices and maintain the desired low temperature by absorbing the heat generated during the grinding operation. In addition to maintaining the low temperature, vapourization of the liquid nitrogen to a gaseous state, creates an inert and dry atmosphere for additional protection of spice quality. Circulation of coolant around the grinding chamber absorbs the heat generated during the grinding and releases it during its cooling. Continuous low temperature maintained within the mill reduces the loss of volatile oils and moisture thereby retaining most of the flavour strength per unit mass of spice**.**

Extremely low temperature in the grinder, solidifies oils so that the spices become embrittled; so that they crumble and easily permitting finer grinding and more consistent particle size. With cryogenic grinding, the temperature of the products can be as low as -195.6ºC. But such a low temperature is not required for all the spices. In practice, it is regulated anywhere from -195.6ºC to a few degrees below ambient temperatures (Russo, 1976).

6. **Critical review of present status of the technology at national and international levels along with complete references** :

Pruthi and Mishra (1963) reported that during grinding, the temperature of a product rises to a level in the range of 42-95ºC which varies with the oil and moisture content of the spices. The spices lose a significant fraction of their volatile oil or flavouring components due to temperature rise.

Singh and Goswami (1997) reported that the temperature raises to the range of 42-93ºC in spice grinding causes a loss of volatile oil and flavouring constituents for materials with high oil content, oil comes out during grinding, which makes the ground product gummy, sticky and results in chocking of sieves through which the product passes.

Malkin and Guo (2007) suggested that a better product could be obtained by reducing the temperature of the two rubbing surfaces. The temperature rise of the product can be minimized to some extent by circulating cold air or water around the grinder. But this technique is not sufficient enough to significantly reduce the temperature rise of the product. The extremely low temperature in the grinder solidifies the oil, therefore that the spices become brittle; they crumble easily permitting grinding to a finer and more consistent size.

Shelake (2017) worked on refrigerated household flour mill using copper plate and copper pipes around the grinding chamber. Refrigerant passing through pipes and hence cooling of copper Procereduces the temperature of the grinding chamber.

Sirwani (2021) worked on arranging jacket over the grinding chamber and circulating coolant through this jacket to reduce the temperature of the grinding chamber.

References :
1. Andres C. 1976. Grinding spices at cryogenic temperatures retains volatiles and oils, *Food Proc*., 37(9):52-53.
2. B. Manohar and B.S. Sridhar. 2001. Size and shape characterization of conventionally and cryogenically ground turmeric (*Curcuma domestica*) particles, *Pow.Tech.*, 120:292–297.
3. P. Barnwal1, A. Mohite, K.K. Singh, P. Kumar, T.J. Zachariahand and S.N. Saxena. 2014. Effect of cryogenic and ambient grinding on grinding characteristics of cinnamon and turmeric, *Int. J. Seed Spi.*, 4(2):26-31.
4. Shelake P. 2017. Low-temperature grinding of spices (turmeric). An unpublished M. Tech. Thesis. Junagadh Agricultural University, Junagadh.
5. Singh, K.K., and Goswami, T.K. 2000. Thermal properties of cumin seed. J. Food Engg. 45:181–187.
6. Singh, K.K., and Goswami, T.K.1999. Design of a Cryogenic Grinding System for Spices. Journal of Food Engineering. 39(10): 359-368.
7. Sirwani, P. 2021. Low-temperature grinding of fenugreek (*Trigonella foenum-graecum* L.) seeds. An unpublished M. Tech. Thesis. Junagadh Agricultural University, Junagadh.
8. Take Ajaykumar M., JadhavSandeep L. and Bhotmange Madhukar G. 2012. Effect of Pretreatments on Quality Attributes of Dried Green Chilli Powder, ISCA J. of Eng. Sci., 1(1):71-74.
9. Wolf T. and Pahl M.H. 1990. Cold grinding of caraway seeds in impact mill, Int. J. of Tech. and Food Pro. Eng., 41(10):596-604.

7. Expertise available with the investigating group/Institute

The low temperature grinding of fenugreek and turmeric is already carried out by this centre. This is advance stage of this project. As the indirect cooling was carried out in that project. Direct cooling will be carried out in this project for better result and economy. The PI & Co-PI of project is having enough experience of working in the field of Processing and Food Engineering. Both are the experts in the field of Processing and Food Engineering. The PI is quite capable and qualified to handle this project. The facility and man power is available in the institute for fabrication of the machine and to conduct the operations in the laboratory. Co-PIs from Biochemistry Department of Junagadh Agricultural University are handling laboratory for GC-MS, HPLC, TLC etc. hence, biochemical and volatile compound analysis will become possible.

8. Brief note on Proprietary/Patent Perspective (for projects related to technology development)/Ethics/Animal Welfare/Bio Safety Issues

- No issues are there on these aspects.

9. (a) **Expected output**

i. The existing spice grinding process will be modified in low temperature grinding. It will be more efficient in comparison to conventional process.
ii. The proposed technology will be economical and can be affordable by the small processors also.
iii. There will be reduction in the processing cost.

a. Clientele/Stake holders (including economic and socio aspects)

i. Food scientists
ii. Spice grinders
iii. Grinder manufacturers.
iv. Consumers

10. **Signatures**

[Project Leader] [Co-PIs] ……

11. **Comments and signature**

[Head of Division]

ANNEXURE- II

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

RESEARCH PROJECT PROFORMA FOR INITIATION OF A RESEARCH PROJECT (RPP - I)

(Refer for Guidelines ANNEXURE-XI (B))

1. Institute Project Code (to be provided by PME Cell)
2. Project Title: Refrigerated grinding of spices.
3. Key Words: Grinding, spices, refrigerated.
4. (a) Name of the Lead Institute: College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh
5. (b) Name of Division/ Regional Center/ Section: AICRP on PHET, Junagadh centre
6. (a) Name of the Collaborating Institute(s) : --
7. (b) Name of Division/ Regional Center/ Section of Collaborating Institute(s) : Department of Biochemistry, JAU, Junagadh.
8. Project Team(Name(s) and designation of PI, CC-PI and all project Co-PIs, with time proposed to be spent)

S. No.	Name, designation and institute	Status in the project (PI/CC-PI/ Co-PI)	Time to be spent (%)	Work components to be assigned to individual scientist
1.	Dr. M. N. Dabhi, Research Engineer, AICRP on PHET, Dept. of Processing and Food Engg., College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh	PI	60%	1. Development of low temperature grinder 2. Grinding of spices 3. Modifications in the low temperature grinder 4. Data collection and its analysis 5. Report writing
2.	Dr. P. R. Davara, Assistant Research Engineer, AICRP on PHET, Dept. of Processing and Food Engg., College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh	Co-PI	10%	To assist the PI in all above aspects

3	Dr. P. J. Rathod Assistant Professor Department of Biochemistry College of Agriculture, Junagadh Agril. University, Junagadh	Co-PI	20%	1. Assessment of biochemical and volatile compound in spiced powder. 2. Data collection and report writing of biochemical and volatile compound available in spice powder through laboratory analysis.

9. Priority Area to which the project belongs : Post Harvest Technology
(If not already in the priority area, give justification)

10. Project Duration: Date of Start: 01-04-2022
Likely Date of Completion: 31-03-2024

11. (a) Objectives

1. Development of refrigerated grinding system using hammer mill
2. Grinding of turmeric and cumin in developed refrigerated grinding system
3. Analysis of biochemical and volatile compound of turmeric and cumin powder.

(b) Practical utility

i. Cryogenic grinding is present technology to preserve biochemical and volatile compound in spice powder which is costly for general purpose. This technology will be cost economic for grinding of spice powder with preserving biochemical and volatile compound.

ii. The refrigerated grinding of household grinding mill is useful but it has low capacity. The jacketed grinding mill is also capable to reduce the grinding temperature but it has limitation for reduction of temperature.

iii. The proposed technology will be economical and can be affordable by the small processors also.

12. Activities and outputs details

Objective wise	Activity	Month & Year of		Output monitorable target(s)	% to be carried out in different years			Scientist(s) responsible
		Start	Completion		1	2	..	
1.	1.Develop-ment of refrigerated grinding system	April-22	Dec-22	To develop refrigerated grinding system over the grinding mill	100%	--	--	Dr. M. N. Dabhi
	2. Testing of refrigerated grinding system	Dec-22	Mar-23	Testing of developed refrigerated grinding system and	100%	--	--	Dr. M. N. Dabhi,

				making changes if necessary				
2.	Grinding of spices	Mar-23	June-23	Grinding of turmeric and cumin will be carried out and temperature profile will be prepared	50%	50 %	- -	Dr. M. N. Dabhi Dr. P. R. Davara,
3.	Analysis of biochemical and volatile compound	July-23	Dec-23	Biochemical analysis will be carried out using appropriate technology of chromatography	50%	50 %	- -	Dr. P. J. Rathod
4.	Report writing	Jan-24	Marh-24	Compilation of collected data and preparation of report	--	100%	- -	Dr. M. N. Dabhi

Work Plan/Activity Chart

2022									2023												2024		
Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Development of refrigerated grinding system																							
								Testing of refrigerated grinding system															
											Grinding of spices												
															Analysis of biochemical and volatile compound								
																					Report writing		

13. Technical Programme (brief)

<u>Justification</u> :

Spice is used as powder after the grinding which leads to increase the temperature as high as 43-95°C under ambient or normal conditions which leads to losses of essential oils and quality deterioration of the obtained powder (Singh and Goswami, 1999, 2000). During grinding process lot of heat generated in the grinding chamber shoots 45 °C up to 90 °C due to friction (Manohar, 2001; Barnwal, 2012). However, etheric oil, volatile components and heat-sensitive constituents of spices boils off at temperature about 50 – 60 °C, results in reducing of inferior qualities aroma and taste of the ground product (Wolf and Pahl, 1990; Singh and Goswami, 1999). For better quality retention of chilly is obtained by grinding process at lower operating temperatures. Cryogenic grinding is a unique and advanced technique of grinding process which supports in retaining virtuous flavour, colour, aroma and volatile oil of the ground product (Andres, 1976). In cryogenic grinding technique liquid nitrogen is used to control grinding chamber temperature ranging from 0 to -21 °C. Important volatile compound of spices are not available after grinding because of higher temperature during grinding. This may cause of no use of ground spices for special purpose. Cryogenic grinding is costly and requires to lower the temperature upto -190 °C. If grinding temperature can be reduced to the vapourising temperature of volatile compound of spices than it could be restored in ground powder of spices. The refrigerated grinding for household flour mill enhance the retaining of volatile oil and curcumin for turmeric. Similarly, jacketed grinding mill with coolant circulation also retaining of volatile oil for fenugreek seeds powder.

Objectives

1. Development of refrigerated grinding system using hammer mill
2. Grinding of turmeric and cumin in developed refrigerated grinding system
3. Analysis of biochemical and volatile compound of turmeric and cumin powder.

Technical programme

1. Development of refrigeration system for lowering the temperature surrounding the grinding case.
2. Grinding of spices (Turmeric, cumin) starting from 0 and 10 degree temperature.
3. Assessment of biochemical compound and volatile compound of spice powder through GC-MS.

Methodology:

Whenever the grinding of spices is carried out its grinder inner temperature will be increasing. Generally liquid nitrogen or water are passed over the casing of grinding mill which helps in decreasing the grinder inside temperature. If refrigeration coils are overlapped over the casing, this will help to decrease the inside temperature of casing. Thus low temperature inside the casing can be created, which will help to preserve the volatile oil, aroma etc.

i. Development of refrigerated system over grinding mill

The design of low temperature grinding mill is shown in Fig. 7.1 with its different functional components. The design criterion for the functional components of the grinding mill was as follows:

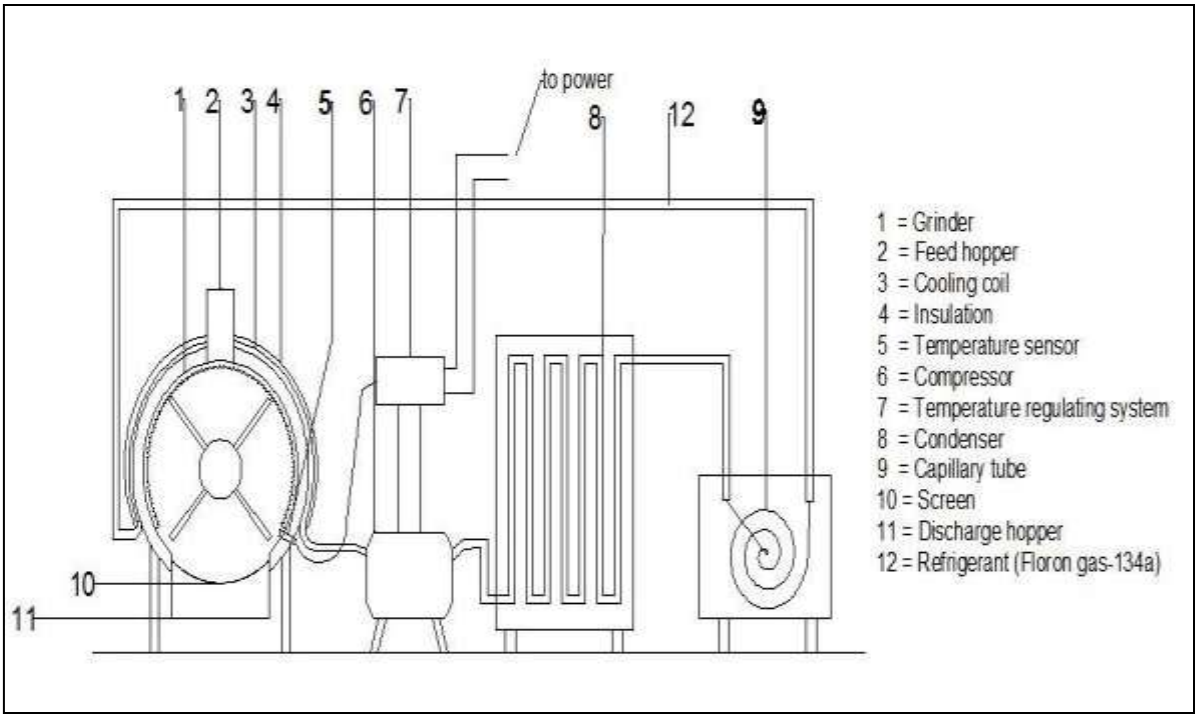


Fig 7.1: Design of low temperature grinding mill

ii. Grinding mill

The grinding mill will be fabricated as per our design. Capacity of grinding mill will be 25 kg/hr. Casing of grinding chamber will be made of cast iron and grinding plates made of anti-rust stainless steel.

Specification of grinding mill

Grinding capacity	25 kg/hr
Electric motor	5 H.P. (2800 rpm.)
Hopper capacity	5 kg (Approx.)

Possible outputs :

- The process technology for preserving biochemical compound of spice in the powder will be available at economical cost.

References :

1. Andres C. 1976. Grinding spices at cryogenic temperatures retains volatiles and oils, *Food Proc.*, 37(9):52-53.
2. B. Manohar and B.S. Sridhar. 2001. Size and shape characterization of conventionally and cryogenically ground turmeric (*Curcuma domestica*) particles, *Pow.Tech.*, 120:292–297.

3. P. Barnwal1, A. Mohite, K.K. Singh, P. Kumar, T.J. Zachariahand and S.N. Saxena. 2014. Effect of cryogenic and ambient grinding on grinding characteristics of cinnamon and turmeric, *Int. J. Seed Spi.*, 4(2):26-31.
4. Shelake P. 2017. Low-temperature grinding of spices (turmeric). An unpublished M. Tech. Thesis. Junagadh Agricultural University, Junagadh.
5. Singh, K.K., and Goswami, T.K. 2000. Thermal properties of cumin seed. J. Food Engg. 45:181–187.
6. Singh, K.K., and Goswami, T.K.1999. Design of a Cryogenic Grinding System for Spices. Journal of Food Engineering. 39(10): 359-368.
7. Sirwani, P. 2021. Low-temperature grinding of fenugreek (*Trigonella foenum-graecum* L.) seeds. An unpublished M. Tech. Thesis. Junagadh Agricultural University, Junagadh.
8. Take Ajaykumar M., JadhavSandeep L. and Bhotmange Madhukar G. 2012. Effect of Pretreatments on Quality Attributes of Dried Green Chilli Powder, ISCA J. of Eng. Sci., 1(1):71-74.
9. Wolf T. and Pahl M.H. 1990. Cold grinding of caraway seeds in impact mill, Int. J. of Tech. and Food Pro. Eng., 41(10):596-604.

14. Financial Implications (` in Lakhs) : Rs. 32.92 lakhs

(A) Financed by the institute

14.1 **Manpower (Salaries / Wages)**

S. No.	Staff Category	Man months	Cost
1.	Scientific	18	30,00,000
2.	Technical	5	2,00,000
3.	Supporting	--	--
4.	SRFs/RAs	--	--
5.	Contractual	--	--
	Total	23	32,00,000

14.2 **Research/Recurring Contingency**

S. No.	Item	Year(1)	Year (2)	Year (3)	Total
1.	Consumables	25000	10000	--	35000
2.	Travel	5000	--	--	5000
3.	Field Preparation/ Planting/ Harvesting (Man-days/costs)	--	--	--	--
4.	Inter-cultivation & Dressing (Man-days/costs)	--	--	--	--
5.	Animal/Green house/Computer Systems/Machinery Maintenance	5000	--	--	5000
6.	Miscellaneous(Other costs)	5000	--	--	5000
	Total(Recurring)	40000	10000	--	50000

Justification : --

14.3 **Non-recurring (Equipment)**

S. No.	Item	Year (1)	Year (2)	Year (3)…	Total
1.	Spice grinder	100000	-	--	100000
	Total (Non-recurring)	100000	--	--	100000

Justification : --

14.4 **Any Other Special Facility required (including cost)**

14.5 **Grand Total (12.1 to 12.4)**

Item	Year (1)	Year (2)	Year (3)	Total
Grand Total	17,40,000	16,10,000	--	33,50,000

(B) **Financed by an organization other than the Institute (if applicable)** : No

(i) Name of Financing Organization : NA

(ii) Total Budget of the Project : --

(iii) Budget details

S. No.	Item	Year(1)	Year(2)	Year (3)	Total
1	Recurring Contingency				
	Travelling Allowance	--	--	--	--
	Workshops	--	--	--	--
	Contractual Services/ Salaries	--	--	--	--
	Operational Cost	--	--	--	--
	Consumables	--	--	--	--

2	Non - Recurring Contingency				
	Equipment	--	--	--	--
	Furniture	--	--	--	--
	Vehicle	--	--	--	--
	Others (Miscellaneous)	--	--	--	--
3	HRD Component				
	Training	--	--	--	--
	Consultancy	--	--	--	--
4	Works (i) New (ii) Renovation	--	--	--	--
5	Institutional Charges				

15. Expected Output : New technology for refrigerated grinding will be available.

16. Expected Benefits and Economic Impact

- High cost technology of cryogenic grinding can be replaced by low temperature grinding.
- Cost economic of spice grinding could be available.
- Preservation of biochemical and volatile compound could be possible without cryogenic grinding.

17. Risk Analysis

18. Signature

Project Leader   Co-PI-I   Co-PI-II

19. Signature of HoD

20. Signature of JD (R)/ Director

ANNEXURE - III

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

CHECKLIST FOR SUBMISSION OF RPP-I

(Refer for Guidelines ANNEXURE-XI(C))

1. **Project Title** : Low temperature grinding of spices.
2. **Date of Start & Duration** : Date of Start: 01-04-2022

   Likely Date of Completion : 31-03-2024
3. **Institute Project** [√] or Externally Funded [ ]
4. **Estimated Cost of the Project** : 33.50 lakh
5. **Project Presented in the Divisional/Institutional Seminar?** ~~Yes~~ / No
6. **Have suggested modifications incorporated?** ~~Yes~~ / No
7. **Status Report enclosed** Yes / ~~No~~
8. **Details of work load of investigators in approved ongoing projects**:

Project Leader				Co-PI – I				Co-PI – II…
Proj. Code.	% Time spent	Date of start	Date of compl-etion	Proj. Code.	% Time spent	Date of start	Date of completion	………
-	-	-	-	PH/JU/2020/01	60	1-2-2020	30-6-2022	

9. **Work Plan/Activity Chart enclosed** Yes / ~~No~~
10. **Included in Institute Plan Activity** Yes / ~~No~~
11. **Any previous Institute/Adhoc/Foreign aided projects on similar lines?** ~~Yes~~ / No
12. **New equipment required for the project** Yes / ~~No~~
13. **Funds available for new equipment** ~~Yes~~ / No
14. **Signatures**

Project Leader Co-PI-I Co-PI-II Co-PI–n

HOD/PD/I/c

ANNEXURE - IV

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

APPRAISAL BY THE PMECELL OF RPP-I

(Refer for Guidelines ANNEXURE-XI (D))

1. **Institute Name**
2. **Project Title**
3. **On scale 1-10 give score to (a) to (j)**

(a)	Relevance of research questions	☐
(b)	Addressing priority of the institute and/or National priority	☐
(c)	New innovativeness expected in the study	☐
(d)	Appropriateness of design/techniques for the questions to be answered	☐
(e)	Elements of bias addressed in the study	☐
(f)	Adequacy of scientist(s) time allocation	☐
(g)	Extent of system review and meta-analysis	☐
(h)	Effective control to experiments	☐
(i)	Economic evaluation and cost efficiency analysis	☐
(j)	How appropriately the expected output answers the questions being addressed in the specific subject matter/area (Basic/Applied/Translational/Others)?	☐
	***Total Score out of 100**	

* The score obtained is suggestive of the overall quality ranking of the project

4. **Was there any other project carried in the past in the same area/topic?**

Yes ☐ No ☐

If yes, list the project numbers.

5. **Signature of PME Cell Incharge**

NEW PROJECT – III

ANNEXURE - I

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

PROFORMA FOR PREPARATION OF STATUS REPORT FOR PROPOSAL OF A NEW RESEARCH PROJECT (Refer for Guidelines ANNEXURE-XI(A))

1. **Institute Name**: College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh
2. **Title of the project**: Processing of green tender sorghum.
3. **Type of research project**: ~~Basic/~~Applied~~/Extension/Farmer Participatory/Other~~ (specify)
4. **Genesis and rationale of the project** :

   The sorghum is perhaps the world's most versatile crop because of its used for culinary purpose like; boiled like rice, cracked like oats (porridge), malted like barely (beer), baked like wheat (flat bread), popped like corn (pop-sorghum), sweetener like sugarcane (jaggary, syrup), etc. use for industrial e.g. industrial alcohol, vegetable oil, adhesives, waxes, dyes, sizing for paper & cloth, starches for lubricating oil-well drills, etc. use for agricultural e.g. forage, hay, silage, shelter, windbreaker, fencing, crop cover, staking for climbers, etc., as well as used for feeding of cattle, poultry, swine, etc. as value added products.

   The grains of sorghum at soft dough stage i.e. before physical maturity are known as *Pauk* or *Hurda*. These varieties are also known as *Pauk* or *Hurda* variety mainly cultivated during *kharif*. Patil, et al., (2013) reported '*Hurda (*Pauk' purpose sorghum varieties like; *Wani-105 (PDKV Kartiki), Phule Madhur, PKV Ashwini,* SGS8-4, *Rao saheb, Seetani Jola* and *Sakkari Murkkari Jola* under AICSIP. The roasted and cleaned tender green sweet sorghum seed are used to consume in various way in Gujarat, Rajasthan and Maharashtra as reported by Patil, et al., (2010) and Chavan, et al., (2013). Roasted green tender sweet grain of sorghum is known as *pauk* in Gujarat.

5. **Knowledge/Technology gaps and justification for taking up the present project including the questions to be answered**

   In certain countries, sorghum is eaten like sweet corn. The whole seed head (panicle) is harvested even while the (soft dough) development stage – 7 of grain. It is roasted over open coals, and the soft, sweet seeds make a very pleasant food. These strains are found notably in Maharashtra and Gujarat, India. Like sweet cor n, they have sugary endosperms containing 30 percent glycogen as well as grains that shrivel when dry. They are a treat for anyone. This unique method turns sorghum into a vegetable crop – more like broccoli than like barley. It has so far received little or no serious study from scientists, but it could be a powerful way to capitalize on the plant's ability to produce food in sites where most crops fail. The types that perform this way should be collected, compared, and cultivated in trials. The traditional processes by which they are used should be analyzed, as should the nutritional value. Seed heads in the dough stage may have a better-than- expected food value.

Presently in south Gujarat, the process of pauk preparation involves heating of harvested sorghum head in wood or coal fire pit or on stove fire for little time, which may have temperature above 250 °C. The fire pit or stove is not properly designed, so the dissipation of heat increases the surrounding temperature and does not allow the worker to stand there for few minutes. The floating of ash dust in air is an additional health hazard to worker. A gang of workers is engaged in beating the heated sorghum head by covering it under the cloth. This separates the tender sweet and green sorghum seed from head, which are further cleaned and kept for sell. The continuous beating resulted in shoulder and hand pain, joint dislocation and fatigue to worker. The unhygienic environment and lack of awareness about good hygienic and manufacturing practices increase the risk of microbial contamination and thus reduced the shelf life of the pauk. These products of sorghum have potential to tape the national and export market if the processing may do under controlled conditions. The mechanization is the best way to control the process parameters and generate hygienic environmental condition. The mechanization for roasting and threshing not only improves the production efficiency but also reduce the overall processing cost.

6. **Critical review of present status of the technology at national and international levels along with complete references** :

Sharanagat, et al. (2019) investigated the effects of microwave roasting on physical, thermal, functional, pasting and antioxidant properties of sorghum. The results demonstrate a significant ($p < 0 .05$) reduction in sorghum bulk density upon roasting (778–546 kgm-3). Roasting increased the total colour change and browning but decreased the lightness Onset temperature, peak temperature, and end temperature for the amylose - lipid complex decreased by 21 .00 %, 19 .01 %, and 17. 03 %, respectively. Similarly during roasting; peak viscosity, pasting viscosity, breakdown viscosity and setback from the trough decreased from 2295 , 26. 15, 984.8 and 2013 to 35 .42 , 16 .67, 8. 38 and 17. 97 , respectively. Non- significant variations in starch gelatinization and functional properties were observed. However, roasting had significant effects on total phenolic content, total flavonoid content and antioxidant properties of sorghum flour changing.

Dharmaputra, et al. (2012) experimented to investigate the effect of postharvest handling (threshing and storing) methods on the quality of sorghum (Sorghum bicolor (L) Moench) grains variety Numbu, in terms of the percentages of damaged grains and seed germination, population growth of Sitophilus zeamais, Fusarium proliferatum and F. verticillioides, fumonisin B and carbohydrate contents, and the percentage of weight loss during storage. The change of moisture contents of sorghum grains was also recorded. Threshing was conducted using wooden stick and a paddy thresher. At the beginning of storage, the percentage of damaged grains caused by threshing using wooden stick was higher than that of using a paddy thresher. The percentage of seed germination of sorghum threshed using wooden stick was lower than that of threshed using a paddy thresher. Fumonisin B1 content of sorghum threshed using wooden stick was higher than that of using a paddy 1 thresher during one, two and three months of storage. Fumonisin B1 contents were considered low. Threshing of sorghum using a paddy thresher was better in comparison to threshing using wooden stick.

Pandit and Varshney (2019) surveyed fifty Pauk processing centers within Bharuch, Surat, Navsari, Valsad and Tapi Districts of Gujarat using predefined terms and questionnaires. The roasting, threshing (beating) and cleaning were found three main steps for processing of pauk. The average processing capacity of pauk center was varied about 1.5 kgh-1 to 5. 0 kgh-1. The hygiene condition of pauk center surrounding was not suitable for food processing. There is a tremendous scope for improvement and mechanization of pauk processing operations by developing tools and machineries for improving the capacity of sweet and green tender sorghum seed processing operations.

Dale and Lebanon (1987) patented a grain roasting machine in USA, included an elongated hollow roasting drum mounted for rotation about its fore-and aft longitudinally- extending central axis and a burner for producing a roasting flame within the drum in a direction extending generally longitudinally of the drum from one end toward the other end of the drum.

References :

1. Chavan, U. D., Dalvi, U. S., Pawar, G. H. and Shinde, M. S, (2013). Selection of genotype and development of technology for sorghum hurda production. International Food Research Journal , Vol.-20(3): 1379 -1382.
2. Dale, L. S. and Lebanon, P. A. (1987). Grain Roasting Machine and Method. United States Patent – Patent Number: 4,639, 216 ; Date of Patent: Jan. 27, 1987.
3. Dharmaputra, O. S., Ambarwati, S. and Retnowati, I. (2012). Postharvest Quality Improvement of sorghum (Sorghum Bicolor (L.) Moench) Grains. BIOTROPIA, Vol. - 19(2): 115 – 129p.
4. Pandit, P. S. and Varshney, A. K. (2019). Sweet and Tender Green Sorghum Seed Processing in South Gujarat. Multilogic in Science, Vol.- VIII , Special Issue(B), NAHEP ICAR Sponsored, International Conference on EARES -2019, AT Dr. PDKV AKOLA;pp:58 -59.
5. Patil, J. V., Chapke, R. R., Mishra, J. S., Umakanth, A. V. and Hariprasanna, K. (2013). Sorghum cultivation - A compendium of improved technologies, Vol - I. Directorate of Sorghum Research, Hyderabad. ISBN: 89335 - 41-3:115p. Publication No: DSR Pub. No. 03/2012 -13/Compendium of Improved Technologies (Volume- I).
6. Patil, P. B., Sajjanar, G. M., Biradar, B. D., Patil, H. B., and Devarnavadagi, S. B. (2010). Technology of Hurda Production by Microwave Oven.Journal of Dairying, Foods and Home Sciences , Vol.-29 (3and4); pp: 232-236.
7. Sharanagat, V. S., Suhag, R., Anand, P., Deswal, G., Kumar, R., Chaudhary, A., Singh, L., Kushwah, O. S., Mani, S., Kumar, Y., Nema, P. K. (2019). Physico-functional, thermo-pasting and antioxidant properties of microwave roasted sorghum [Sorghum bicolor (L.) Moench].Journalof Cereal Science, Vol.- 85: 111 - 119p. https://doi.org/10.1016/j.jcs.2018. 11. 013.

7. Expertise available with the investigating group/Institute

The PI & Co-PI of project is having enough experience of working in the field of Processing and Food Engineering. Both are the experts in the field of Processing and Food Engineering. The PI is quite capable and qualified to handle this project. The facility and man power is available in the institute for fabrication of the machine and to conduct the operations in the laboratory. The co-PI has already carried out this work during his higher studies. Full-fledged work will be carried out during this project work by this centre. Co-PIs from Biochemistry Department of Junagadh Agricultural University are handling laboratory for GC-MS, HPLC, TLC etc. hence, biochemical and volatile compound analysis will become possible.

8. Brief note on Proprietary/Patent Perspective (for projects related to technology development)/Ethics/Animal Welfare/Bio Safety Issues

- No issues are there on these aspects.

9. (a) **Expected output**

iv. The existing traditional process will be mechanized.

v. The proposed technology will be economical and can be affordable by the small processors also.

vi. There will be reduction in the processing cost and time as well as drudgery of the workers.

a. Clientele/Stake holders (including economic and socio aspects)

v. Processors

vi. Consumers

10. **Signatures**

[Project Leader] [Co-PIs] ……

11. **Comments and signature**

[Head of Division]

ANNEXURE- II

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

RESEARCH PROJECT PROFORMA FOR INITIATION OF A RESEARCH PROJECT (RPP - I)

(Refer for Guidelines ANNEXURE-XI (B))

1. Institute Project Code (to be provided by PME Cell)
2. Project Title: **Processing of green tender sorghum.**
3. **Key Words**: green sorghum, pauk.
4. **(a) Name of the Lead Institute**: College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh
   (b) Name of Division/ Regional Center/ Section: AICRP on PHET, Junagadh centre
5. **(a) Name of the Collaborating Institute(s)** : --
   (b) Name of Division/ Regional Center/ Section of Collaborating Institute(s) : Department of Biochemistry, JAU, Junagadh.
6. **Project Team(Name(s) and designation of PI, CC-PI and all project Co-PIs, with time proposed to be spent)**

S. No.	Name, designation and institute	Status in the project (PI/CC-PI/ Co-PI)	Time to be spent (%)	Work components to be assigned to individual scientist
1.	Dr. M. N. Dabhi, Research Engineer, AICRP on PHET, Dept. of Processing and Food Engg., College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh	PI	60%	12. Development of roaster, thresher and cleaner 13. Roasting of green sorghum 14. Threshing of roasted green sorghum 15. Cleaning of threshed roasted green sorghum 16. Data collection and its analysis 17. Report writing
2.	Dr. P. R. Davara, Assistant Research Engineer, AICRP on PHET, Dept. of Processing and Food Engg., College of Agril. Engg. & Tech., Junagadh Agril. University, Junagadh	Co-PI	10%	To assist the PI in all above aspects

3	Dr. P. S. Pandit Assistant Professor, Centre of PHT, Navsari Agricutltural University, Navsari.	Co-PI	20%	To assist in the development of roaster, thresher and cleaner
4	Dr. P. J. Rathod Assistant Professor Department of Biochemistry College of Agriculture, Junagadh Agril. University, Junagadh	Co-PI	10%	1. Assessment of biochemical content of pauk 2. Data collection and report writing of biochemical pauk through laboratory analysis.

7. **Priority Area to which the project belongs** : Post Harvest Technology
   (If not already in the priority area, give justification)

8. Project Duration: Date of Start: 01-04-2022
   Likely Date of Completion: 31-03-2025

9. **(a) Objectives**
   1. Development of roaster, thresher and cleaner for green tender sorghum
   2. Standardization of machine parameters for roasting, threshing and cleaning of green tender sorghum (pauk).
   3. Physicochemical and sensory analysis of roasted green tender sorghum grains (pauk).

   (b) Practical utility

   i. Present traditional process for *pauk* making from green tender sorghum is unhygienic and drudgery some.
   ii. The developed machinery will reduce the drudgery and hence also time.
   iii. The proposed technology will be economical and can be affordable by the small processors also.

10. **Activities and outputs details**

Objective wise	Activity	Month & Year of		Output monitorable target(s)	% to be carried out in different years			Scientist (s) responsible
		Start	Completion		1	2	..	
1.	1. Development of roaster, thresher and cleaner.	April-22	Oct-23	To develop roaster, thresher and cleaner	50 %	50 %	--	Dr. M. N. Dabhi and Dr. P. S. Pandit

	2. Testing of roaster, thresher and cleaner	Oct-23	Mar-24	Testing of developed roaster, thresher and cleaner and making changes if necessary	--	75 %	25 %	Dr. M. N. Dabhi,and Dr. P. R. Davara
2.	Making of *pauk*	Mar-24	June-24	Grinding of turmeric and cumin will be carried out and temperature profile will be prepared	--	--	100 %	Dr. M. N. Dabhi Dr. P. R. Davara,
3.	Analysis of biochemical compound	July-24	Dec-24	Biochemical analysis will be carried out using appropriate technology of chromatography	--	--	100 %	Dr. P. J. Rathod
4.	Report writing	Jan-25	March-25	Compilation of collected data and preparation of report	--	--	100 %	Dr. M. N. Dabhi

Work Plan/Activity Chart

2022									2023													2024												2025		
A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Development of roaster, thresher and cleaner.																																			
																		Testing of roaster, thresher and cleaner																	
																							Making of pauk												
																											Analysis of biochemical compound								
																																	Report writing		

11. **Technical Programme (brief)**

Justification :

In certain countries, sorghum is eaten like sweet corn. The whole seed head (panicle) is harvested even while the (soft dough) development stage – 7 of grain. It is roasted over open coals, and the soft, sweet seeds make a very pleasant food. These strains are found notably in Maharashtra and Gujarat, India. Like sweet cor n, they have sugary endosperms containing 30 percent glycogen as well as grains that shrivel when dry. They are a treat for anyone. This unique method turns sorghum into a vegetable crop – more like broccoli than like barley. It has so far received little or no serious study from scientists, but it could be a powerful way to capitalize on the plant's ability to produce food in sites where most crops fail. The types that perform this way should be collected, compared, and cultivated in trials. The traditional processes by which they are used should be analyzed, as should the nutritional value. Seed heads in the dough stage may have a better-than-expected food value.

Presently in south Gujarat, the process of pauk preparation involves heating of harvested sorghum head in wood or coal fire pit or on stove fire for little time, which may have temperature above 250 °C. The fire pit or stove is not properly designed, so the dissipation of heat increases the surrounding temperature and does not allow the worker to stand there for few minutes. The floating of ash dust in air is an additional health hazard to worker. A gang of workers is engaged in beating the heated sorghum head by covering it under the cloth. This separates the tender sweet and green sorghum seed from head, which are further cleaned and kept for sell. The continuous beating resulted in shoulder and hand pain, joint dislocation and fatigue to worker. The unhygienic environment and lack of awareness about good hygienic and manufacturing practices increase the risk of microbial contamination and thus reduced the shelf life of the pauk. These products of sorghum have potential to tape the national and export market if the processing may do under controlled conditions. The mechanization is the best way to control the process parameters and generate hygienic environmental condition. The mechanization for roasting and threshing not only improves the production efficiency but also reduce the overall processing cost.

Objectives

1. Development of roaster, thresher and cleaner for green tender sorghum
2. Standardization of machine parameters for roasting, threshing and cleaning of green tender sorghum (*pauk*).
3. Physicochemical and sensory analysis of roasted green tender sorghum grains (*pauk*).

Technical programme

1. Development of roaster for green tender sorghum.
2. Development of thresher for roasted green tender sorghum.
3. Development of threshed roasted green tender sorghum to separate the *pauk.*
4. Assessment of biochemical compound of *pauk*.
5. Sensory assessment of *pauk.*

Methodology:

Many roaster are developed for different crops. Mostly sand roasting methods are used for roasting purpose. Continuous sand roaster available in the market will used and necessary modification will be made for roasting of green tender sorghum. According to physical properties of roasted green tender sorghum thresher available in the market will be modified. Screen separator to separate out the *pauk* will be developed.

Possible outputs :

- The process technology for processing of green tender sorghum will be available at economical cost.

References :

i. Chavan, U. D., Dalvi, U. S., Pawar, G. H. and Shinde, M. S, (2013). Selection of genotype and development of technology for sorghum hurda production. International Food Research Journal, Vol.-20(3): 1379 -1382.

ii. Dale, L. S. and Lebanon, P. A. (1987). Grain Roasting Machine and Method. United States Patent – Patent Number: 4,639, 216; Date of Patent: Jan. 27, 1987.

iii. Dharmaputra, O. S., Ambarwati, S. and Retnowati, I. (2012). Postharvest Quality Improvement of sorghum (Sorghum Bicolor (L.) Moench) Grains. BIOTROPIA, Vol. - 19(2): 115 – 129p.

iv. Pandit, P. S. and Varshney, A. K. (2019). Sweet and Tender Green Sorghum Seed Processing in South Gujarat. Multilogic in Science, Vol.- VIII , Special Issue(B), NAHEP ICAR Sponsored, International Conference on EARES -2019, AT Dr. PDKV AKOLA;pp:58 -59.

v. Patil, J. V., Chapke, R. R., Mishra, J. S., Umakanth, A. V. and Hariprasanna, K. (2013). Sorghum cultivation - A compendium of improved technologies, Vol - I. Directorate of Sorghum Research, Hyderabad. ISBN: 89335 - 41-3:115p. Publication No: DSR Pub. No. 03/2012 -13/Compendium of Improved Technologies (Volume- I).

vi. Patil, P. B., Sajjanar, G. M., Biradar, B. D., Patil, H. B., and Devarnavadagi, S. B. (2010). Technology of Hurda Production by Microwave Oven.Journal of Dairying, Foods and Home Sciences, Vol.-29 (3and4); pp: 232-236.

vii. Sharanagat, V. S., Suhag, R., Anand, P., Deswal, G., Kumar, R., Chaudhary, A., Singh, L., Kushwah, O. S., Mani, S., Kumar, Y., Nema, P. K. (2019). Physico-functional, thermo-pasting and antioxidant properties of microwave roasted sorghum [Sorghum bicolor (L.) Moench]. Journal of Cereal Science, Vol.- 85: 111 - 119p. https://doi.org/10.1016/j.jcs.2018. 11. 013.

12. Financial Implications (` in Lakhs) : Rs. 55.30 lakhs

(A) Financed by the institute

12.1 **Manpower (Salaries / Wages)**

S. No.	**Staff Category**	**Man months**	**Cost**
1.	Scientific	24	50,00,000
2.	Technical	5	2,00,000

3.	Supporting	--	--
4.	SRFs/RAs	--	--
5.	Contractual	--	--
	Total	29	52,00,000

12.2 **Research/Recurring Contingency**

S. No.	**Item**	**Year(1)**	**Year (2)**	**Year (3)**	**Total**
1.	Consumables	100000	10000	5000	115000
2.	Travel	5000	--	--	5000
3.	Field Preparation/ Planting/ Harvesting (Man-days/costs)	--	--	--	--
4.	Inter-cultivation & Dressing (Man-days/costs)	--	--	--	--
5.	Animal/Green house/Computer Systems/Machinery Maintenance	5000	--	--	5000
6.	Miscellaneous(Other costs)	5000	--	--	5000
	Total(Recurring)	115000	10000	5000	130000

Justification : ---

12.3 **Non-recurring (Equipment)**

S. No.	Item	Year (1)	Year (2)	Year (3)…	Total
1.	Roaster, Thersher, Cleanser	100000	100000	--	200000
	Total (Non-recurring)	100000	100000	--	200000

Justification : ---

12.4 **Any Other Special Facility required (including cost)**

12.5 **Grand Total (12.1 to 12.4)**

Item	Year (1)	Year (2)	Year (3)	Total
Grand Total	28,15,000	22,10,000	505000	55,30,000

(B) **Financed by an organization other than the Institute (if applicable)** : No

(i) Name of Financing Organization : NA

(ii) Total Budget of the Project : --

(iii) Budget details

S. No.	Item	Year(1)	Year(2)	Year (3)	Total
1	Recurring Contingency				
	Travelling Allowance	--	--	--	--
	Workshops	--	--	--	--
	Contractual Services/ Salaries	--	--	--	--
	Operational Cost	--	--	--	--
	Consumables	--	--	--	--
2	Non - Recurring Contingency				
	Equipment	--	--	--	--
	Furniture	--	--	--	--
	Vehicle	--	--	--	--
	Others (Miscellaneous)	--	--	--	--
3	HRD Component				
	Training	--	--	--	--
	Consultancy	--	--	--	--
4	Works (i) New (ii) Renovation	--	--	--	--
5	Institutional Charges				

13. Expected Output : Mechanization of processing of green tender sorughum will be available.

14. Expected Benefits and Economic Impact

- Mechanization of processing of green tender sorghum will be available.
- Cost economic of processing of green tender sorghum could be available.
- Reduction of drudgery.

15. **Risk Analysis**

16. **Signature**

Project Leader Co-PI-I Co-PI-II

17. **Signature of HoD**

18. **Signature of JD (R)/ Director**

ANNEXURE - III

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

CHECKLIST FOR SUBMISSION OF RPP-I

(Refer for Guidelines ANNEXURE-XI(C))

1. **Project Title** : Processing of green tender sorghum.
2. **Date of Start & Duration** : Date of Start: 01-04-2022

   Likely Date of Completion : 31-03-2025
3. **Institute Project** [√] or Externally Funded [ ]
4. **Estimated Cost of the Project** : 55.30 lakh
5. **Project Presented in the Divisional/Institutional Seminar?** ~~Yes~~ / No
6. **Have suggested modifications incorporated?** ~~Yes~~ / No
7. **Status Report enclosed** Yes / ~~No~~
8. **Details of work load of investigators in approved ongoing projects**:

Project Leader				Co-PI – I				Co-PI – II…
Proj. Code.	% Time spent	Date of start	Date of compl-etion	Proj. Code.	% Time spent	Date of start	Date of completion	………
-	-	-	-	PH/JU/2020/01	60	1-2-2020	30-6-2022	

9. **Work Plan/Activity Chart enclosed** Yes / ~~No~~
10. **Included in Institute Plan Activity** Yes / ~~No~~
11. **Any previous Institute/Adhoc/Foreign aided projects on similar lines?** ~~Yes~~ / No
12. **New equipment required for the project** Yes / ~~No~~
13. **Funds available for new equipment** ~~Yes~~ / No
14. **Signatures**

Project Leader Co-PI-I Co-PI-II Co-PI–n

HOD/PD/I/c

ANNEXURE - IV

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

APPRAISAL BY THE PME CELL OF RPP-I

(Refer for Guidelines ANNEXURE-XI (D))

1. **Institute Name**
2. **Project Title**
3. **On scale 1-10 give score to (a) to (j)**

(a)	Relevance of research questions	☐
(b)	Addressing priority of the institute and/or National priority	☐
(c)	New innovativeness expected in the study	☐
(d)	Appropriateness of design/techniques for the questions to be answered	☐
(e)	Elements of bias addressed in the study	☐
(f)	Adequacy of scientist(s) time allocation	☐
(g)	Extent of system review and meta analysis	☐
(h)	Effective control to experiments	☐
(i)	Economic evaluation and cost efficiency analysis	☐
(j)	How appropriately the expected output answers the questions being addressed in the specific subject matter/area (Basic/Applied/Translational/Others)?	☐
	***Total Score out of 100**	

* The score obtained is suggestive of the overall quality ranking of the project

4. **Was there any other project carried in the past in the same area/topic?**

Yes ☐ No ☐

If yes, list the project numbers.

5. **Signature of PME Cell Incharge**

SUMMARY OF PROGRESS REPORT

1. PH/JU/85/1 : Operational research project on Agro- processing center.

At Tadka Pipliya agro processing center, oil milling, wheat cleaning, groundnut decortication, sesame processing, groundnut threshing, pulse milling and spice milling operations were carried out. They have earned about Rs. 169000/-.

At Agro Processing Centre, Virol, oil milling, spice milling and wheat cleaning were carried.

At Agro Processing Centre, Loej, oil milling and wheat cleaning were carried out. They have earned Rs. 260000/-.

At Agro Processing Centre, Chotila, oil milling was carried out. They have earned about Rs. 20000/-.

2. PH/JU/2019/01 : Low temperature grinding of spices.

The turmeric grinding was carried out at ambient temperature, ambient water circulation, chilled water circulation and coolant circulation in the jacket over the grinding chamber. The turmeric was fed at ambient temperature as well as at 10 ^{o}C. Grinding method effects significantly for all performance parameters i.e. temperature inside the grinding chamber at the end, grinding time, temperature of powder, milling loss and machine loss. Feed temperature effects significantly for all performance parameters except milling loss. Interaction effect between grinding method and feed temperature is non-significant for all performance parameters. The temperature inside grinding chamber at the end, temperature of ground product and milling loss were minimum in the treatment coolant circulation with low temperature feed. The grinding time and machine loss were maximum in the treatment coolant circulation with low temperature feed. Grinding method as well as feed temperature effect significantly for all biochemical parameters i.e. moisture content, total carbohydrate, crude fiber, protein, fat, ash, volatile oil, phenol, falavonoids, antioxidant activity and curcumin. Interaction effect between grinding method and feed temperature is non-significant for all biochemical parameters except crude fibre. Statically all biochemical parameters value except ash content and curcumin content are maximum for coolant circulation grinding method. Statically all biochemical parameters value are maximum for low temperature method. Curcumin content value is maximum for chilled water circulation grinding method which was at par with coolant circulation. Ash content value is maximum for ambient grinding method. It is recommended to grind the turmeric rhizome with coolant circulation and low temperature feed for better retaining of biochemical content in the powder.

3. PH/JU/2018/02 : Design and development of grain treater for enzymatic pre-treatment to pigeon pea grains.

The grain treater is designed and developed for pigeon pea (Variety BDN2). The optimum grain treater parameters for enzymatic pretreatment and for maximizing the hulling efficiency of pigeon pea grains was determined by the numerical optimization technique, using Design Expert software : version 10 (State-Ease Inc., Minneapolis, MN, USA). The optimum treatment conditions were found to be, 9 rpm drum speed and 31% drum occupied volume. The analysis showed that at this combination of drum speed and drum occupied volume, it would be possible achieve the hulling efficiency of 89.46%. Cost of the developed grain treater was determined by considering the actual cost of the different material and parts used in the fabrication. The total cost incurred in the fabrication of the machine was derives as Rs. 156867.00.

4. PH/JU/2020/01 : Application of microwave technology for disinfestations of groundnut kernels.

Storage experiment was conducted for storage of groundnut kernels. Microwave treatment were carried out with different power and time. Entomological, physical and microbiological parameters were observed during the storage period. The pest population and kernels damage was not found in all the treatments (including control) it may be due to PICS bag storage. Germination percent was found non-significant it means no adverse effect of microwave treatment on germination. The germination was decreased after eight month of storage, which may be due to storage period. The effect of microwave treatment on moisture content was found significant after given microwave treatment at storage time and after one and two month of storage of groundnut kernels. Moisture content was found non-significant after three month of storage to eight month of storage of groundnut kernels. Moisture content increased in monsoon season.

5. PH/JU/2020/02: Standardization of process technology for preparation of peanut sauce and peanut wadi (Chunks).

Defatted peanut flour is purchased from the Nutrinity Foundation, Junagadh to test its feasibility for the preparation of peanut wadi. Preliminary trials were conducted for preparation of peanut wadi using the Twin Screw Extruder. There was an issue with the feeding of peanut dough in the twin screw extruder and therefore the results obtained are not up to expectation. Further, trials are to be conducted as soon as the issue is solved. Hence, the trials will be repeated in the coming time. *Aspergillus oryzae (Koji mold)* and *Saccharomyces rouxii* have already been purchased from the ATCC, Chandigarh. *Pediococcus halophilus* is to be purchased from the USA. Purchase order for the purchase of *Pediococcus halophilus* has already been issued to the supplier and culture is awaited.

Tentative Technical Programme for the year 2022-2023

Sr. No.	Code No.	Title
1.	PH/JU/85/1	Operational research project on Agro-processing center.
2.	PH/JU/2020/1	Application of microwave technology fordisinfestation of groundnut kernels.
3.	PH/JU/2020/2	Standardization of process technology for preparation of peanut sauce and peanut wadi (Chunks).
4.	New Project-I	Development of peanut tempeh through fermentation process.
5.	New Project-II	Refrigerated grinding of spices.

Action taken of proceeding of 36th Annual Workshop:

Sr. No.	Project	Comment	Action taken
1	Design and development of grain treater for enzymatic pretreatment to pigeon pea grains.	Progress Noted ▪ **Treated as RPPIII,** complete your remaining work and Submit final report of RPP-III in June, 2021.	Submitted RPP III in the annual report.
2	Low temperature grinding of spices.	Approved ▪ Incorporate a comparative table between cryogenic, low temperature and traditional grinding in RPP III • Incorporate mathematical modelling	▪ Incorporated a comparative table between cryogenic, low temperature and traditional grinding in RPP III ▪ Incorporated mathematical modelling ▪ Submitted RPP III in the annual report

PUBLICATION, TRAINING AND DEMONSTRATION

Publications:

Books/Book chapter/Bulletin:

1. Joshi A. M., Khanpara Brijesh, Vagh Dhara. 2021. Effect of ozone and plastic material against the microbes of tomatoes.LAP Lambert Academic Publishing.
2. Gojiya D.K., Dobariya U.M., Joshi A. M. 2021. Studies on physical properties of peanuts popular in saurashtra region.LAP Lambert Academic Publishing.
3. Davara, P. R., Gadhiya, P. P., Sudhir and Mitesh Kumar. 2021. Protein Enriched Ready To Eat Product.Scholar's Press, International Book Market Service Ltd., member of OmniScriptum Publishing Group, Mauritius.
4. Sangani, V. P., Chotaliya, V. C. and Davara, P. R. 2021. Pigeon Pea Milling.Scholar's Press, International Book Market Service Ltd., member of OmniScriptum Publishing Group, Mauritius.
5. Sojitra, J. B., Vyas, D. M., Davara, P. R. 2021. Papain Production Technology.
6. Davara, P. R., Thumar, N. C., Agravat, H. V. and Limbasiya, J. J. 2021. Wheat Grinding Under Evaporative Water Cooled Condition.Scholar's Press, International Book Market Service Ltd., member of OmniScriptum Publishing Group, Mauritius.

Research Articles

1. Gojiya D. K., Cholera S.P., Joshi A. M. (2020). Influence of Gamma Irradiation on Microbial Load of Peanut (Arachis hypogaea L) Kernels. Int.J.Curr.Microbiol.App.Sci. 9(8):589-602.
2. Chougale B. D., Sangani V. P., Davara P. R.and Rathod P. J. (2020). Optimization of foaming and stabilizing process parameters for foam mat drying of prickly pear (*Opuntia elatior* Mill.) pulp. International Journal of Chemical Studies. 8(5):2458-2462
3. Davara P. R., Sangani V. P., Vora P. P., Thumar N. C., Agravat H. V. and Limbasiya J. J. (2020). Effect of Evaporative Water Cooled Grinding on Milling Quality of Wheat.International Journal of Current Microbiology and Applied Sciences. 9(6):1183-1190.
4. Parmar, A. R., Davara, P. R., Joshi, N. U., Rahod, P. J. and Antala, D. K. (2020). Optimization of process parameters for foam mat dried papaya powder.International Journal of Current Microbiology and Applied Sciences. 9(11):669-681.
5. Neha J. Hirpara and M. N. Dabhi. 2021. A Review on Effect of Amylose/Amylopectin, Lipid and Relative Humidity on Starch Based Biodegradable Films. International Journal of Current Microbiology and Applied Sciences. 10(4):500-531. https://doi.org/10.20546/ijcmas.2021.1004.05.1.
6. Neha J. Hirpara, M. N. Dabhi and P. J. Rathod. 2021. Development of Potato Starch Based Biodegradable Packaging Film. Biological Forum-An International Journal. 13(1):529-541. 2021.

Abstract Published

-Nil-

Extension Activities

1. Dr. M. N. Dabhi has delivered the lecture on "Challenges posed by COVID-19 pandemic on post-harvest food handling systems and the way forward during and post-COVID-19

periods" on 11.06.2020 organized by PC office, AICRP on PHET, ICAR-CIPHET, Ludhiana.

2. Dr. P. R. Davara has delivered the lecture on "Seed spice crops export procedure for national and international system"during farmers training organised by Vegetable Research Station, Junagadh Agricultural university, Junagadh on 28-01-2021.
3. Dr. P. R. Davara has delivered the radio talk on Junagadh Janvani 91.2 FM
   - i. Processing and Value Addition of Groundnut on 19/06/2020
   - ii. Shelf life increase of fruits and vegetables through ozone technology on 22/07/2020
   - iii. Post-harvest value addition and management of agrictultural crops on 10/09/2020.

<u>Demonstration conducted :</u>

1. Demonstration of developed processing machineries are arranged at Technology and Machinery Demonstration Mela-2020 on 19 February, 2020.
2. Demonstration of developed processing machineries are arranged at Food & Agri Tech, Surat during 06-08 March, 2020.
3. Demonstration of model of cumin cleaner cum grader and sapota graded was arranged at KVK, Kodinar on 09 March, 2021

- **HUMAN RESOURCE DEVELOPMENT**
  - Dr. M. N. Dabhi attended e-training on "Smart Handling and Processing Systems of Horticultural Produce"
  - Organized by CAAST-CSAWM, MPKV, Rahuri during 09-14.05.2020.
  - Dr. M. N. Dabhi, Prof. A. M. Joshi, Dr. P. R. Davara attended National Webinar on Post COVID-19 Agribusiness: Challenges and Opportunities Organized by JAU, Junagadh during 13-14.06.2020.
  - Dr. M. N. Dabhi attended International e-Conference on "Novel Nutrition Approach and Emerging Opprotunities to Sustain in Pandemic Scenario" Organized by Department of Nutrition and Dietetics, Mount Carmel College, Autonomous, Bengaluru during 15-18.06.2020.
  - Dr. M. N. Dabhi attended Webinar on "Role of Higher Educational Institutions to promote deep tech startups" Organized by i-Hub, SSIP, Govt of Gujarat, Gandhinagar during 24.06.2020.
  - Dr. P. R. Davara attended Webinar on "Food Waste Management & Importance of Medicinal Plants in the Food Industry" Organized by UU, Dehradoon during 24.06.2020.
  - Dr. P. R. Davara attended webinar on "The Ten Power Performance Principles" Organized by i-Hub, Gujarat during 25.06.2020.
  - Dr. M. N. Dabhi, Dr. P. R. Davara attended Webinar on "Food Processing: Prospects and Opportunities" Organized by MPUAET, Udaipur during 26.06.2020.
  - Dr. P. R. Davara attended webinar on "Crafting a Golden Pitch : From Investor's Lense" Organized by i-Hub, Gujarat during 26.06.2020.
  - Dr. P. R. Davara attended webinar on "India's transition from Jugaad to Systematic Innovation: Role of Start-ups" Organized by i-Hub, Gujarat during 27.06.2020.

- Dr. P. R. Davara attended Online International Students and faculty Development Programme on “Innovative Food Processing Technologies: Value Addition, Food Safety and Security” Organized by RVSKVV, Gwalior during 29.06.20- 01.07.20.
- Dr. M. N. Dabhi attended International Webinar on “Young Minds Matter: Towards the Mental Health & Well-being of Youth” Organized by Women’s Polytechnic College, Puducherry during 29-30.06.2020.
- Dr. P. R. Davara attended webinar on “Startup India Incentives for Start-ups” Organized by i-Hub, Gujarat during 30.06.2020.
- Dr. P. R. Davara attended webinar on “Agricultural market reforms and market intelligence” Organized by AAU, Anand during 07-08.07.2020.
- Dr. P. R. Davara attended webinar on “Education & Innovation in the Post Covid Times” Organized by i-Hub, Gujarat during 10.07.2020.
- Dr. M. N. Dabhi attended Webinar on “Covid-19 Precautionary Measures for FBO & Food Safety” Organized by Lets Earn | Learn Digitally, Mulgao, Goa 403503 during 12.07.2020.
- Dr. P. R. Davara attended webinar on “Addressing COVID-19 impact on food security, nutrition and future livelihood: A special focus to Gujarat” Organized by College of Agriculture, NAU, Bharuch during 15-16.07.2020.
- Dr. P. R. Davara attended International webinar on “Advances in Food Processing for the development of functional foods” Organized by Dept. of Food Engg. & Tech., Sant Longowal Inst. Of Engg. & Tech., Longowal (Punjab) during 27.07.2020.
- Dr. M. N. Dabhi attended Webinar on “Advanced Agricultural Engineering Technologies for Sustainable Agriculture” Organized by College of Agricultural Engineering, UAS, Raichur during 04-05.08.2020.
- Dr. M. N. Dabhi attended e-Training on “IIndian Agricultural Education System and Entrepreneurship Scope in 21st Century Organized by NAHEP, Faculty of Agricultural Engineering, PDKV, Akola during 05-14.08.2020.
- Dr. P. R. Davara attended webinar on “Recent development in Food Processing” Organized by Dept. of Food Engineering and Technology, Longowal (Punjab) during 05.08.2020.
- Prof. A. M. Joshi attended National webinar on “Opportunities and challenges in food processing and technology during this area”. Organized by Atal Bihari Vajpayee University, Bilaspur (C.G.) during 08.08.2020.
- Prof. A. M. Joshi attended Webinar on “Newer sensory methods for consumer insights”. Organized by Dept. of food science & Technology, NIFTEM, Kundli, Sonepat (Haryana) during 12.08.2020.
- Prof. A. M. Joshi attended International webinar on “Sustainability in Food Industry-Is it now the time!” Organized by Dept. of Food Engg. & Technology, Sant Longowal institute of Engg. & Technology,Longowal (Punjab) during 12.08.2020.
- Prof. A. M. Joshi attended Webinar on “Entrepreneurial Opportunities in Food Processing sector” Organized by School of Agril. Sciences & Technology, NMIMS deemed university during 13.08.2020.
- Prof. A. M. Joshi attended Webinar on “Developing entrepreneurial skills among agri-graduates”. Organized by NMIMS, Mumbai during 21.08.2020.
- Prof. A. M. Joshi attended Webinar on “Entrepreneurs in food processing: a value chain perspective”. Organized by NIFTEM, Kundli during 22.08.2020.

- Prof. A. M. Joshi attended International webinar on “Epidemiology, detection, treatment, transmission and comparative genomics of SARS-CoV-2 and managing personal and professional life during COVID-19 pandemic and lockdown”. Organized by Association of Microbiologists of India, Rohtak during 23.08.2020.
- Prof. A. M. Joshi attended National webinar on “Recent advances in soil microbiological research with a special thrust to biofertilizer technology”. Organized by BAU, Bhagalpur (Bihar) during 25.08.2020.
- Dr. P. R. Davara attended International webinar on “Geospatial Technologies for Managing Agriculture: Applications from USA, Europe and Asia” Organized by Centre for Geospatial Technologies, Vaugh Inst. of Agril. Engg. & Tech., SHUATS during 27-28.08.2020.
- Dr. P. R. Davara attended webinar on “Importance of Rheology in the Development of Nanopackaging Materials” Organized by NIFTEM, Kundli during 28.08.2020.
- Dr. M. N. Dabhi, Dr. P. R. Davara attended webinar on “Entrepreneurship opportunities in processing of fruit and vegetable of the arid region” Organized by College of Horticulture, SDAU, Jagudan, during 02.09.2020.
- Dr. P. R. Davara attended webinar on “Farm-fresh produce processing: Challenges and intervention” Organized by CIAE, Regional Center, Coimbatore during 04.09.2020.
- Prof. A. M. Joshi attended Webinar on “Dietary management of coeliac disease”. Organized by Bhaskaracharya college of applied sciences, University of Delhi during 05.09.2020.
- Dr. M. N. Dabhi, Dr. P. R. Davara attended webinar on “Scope of food technology in light of Covid-19” Organized by NIT, Rourkela during 06.09.2020.
- Prof. A. M. Joshi attended International webinar on “Process-driven organic contaminants in food and mitigation strategies”. Organized by NIFTEM, Kundli during 10.09.2020.
- Dr. M. N. Dabhi attended e-National Level Workshop on “Recent Advances in Dairy & Food Engineering” Organized by Department of Dairy Technology, Faculty of Agriculture, Parul Institute of Technology, Parul University, Vadodara during 15.09.2020.
- Dr. P. R. Davara attended webinar on “Trade in F&V products and dairy commodities” Organized by AAU, Anand during 15.09.2020.
- Dr. P. R. Davara attended webinar on “Recent Trends in Food Processing and Preservation” Organized by NIT, Rourkela during 26-27.09.2020.
- Dr. P. R. Davara attended webinar on “Value Addition of Underutilized Food Crops” Organized by CTAE, MPUAT, Udaipur during 08.10.2020.
- Dr. P. R. Davara attended webinar on “Turmeric processing: A spice to boost immunity” Organized by CIAE, Regional Center, Coimbatore during 16.10.2020.
- Dr. P. R. Davara attended webinar on “Technical Writing” Organized by AAU, Anand during 17.10.2020.
- Dr. M. N. Dabhi attended Online Training for Master Trainers on Fruits and Vegetable Processing Organized by IIFPT, Thanjavur during 17-21.11.2020.
- Dr. P. R. Davara attended webinar on “Entrepreneurship through Value Addition of Banana and its By-Products” Organized by OUA&T Bhubaneswar during 19.12.2020.
- Dr. M. N. Dabhi, Dr. P. R. Davara attended webinar on “Status and strategies for Farm Mechanization in India” Organized by JAU, Junagadh during 24.12.2020.

- Dr. M. N. Dabhi, Dr. P. R. Davara, Prof. R. D. Dhudasia, Prof. A. M. Joshi attended 36th Annual workshop of AICRP on Post-Harvest Engg. and Technology, Organized by PC office, AICRP on PHET, Ludhiana during 03-05.02.2021.
- Dr. P. R. Davara attended webinar on “Food Safety Management: Contemporary Scenario and Issues” Organized by NAU, Navsari during 27.02.2021.
- Dr. P. R. Davara attended Attended webinar on “Super-heated steam drying: Role in Food Preservation and Food Security” Organized by NIFTEM, Kundli during 13.03.2021.
- Dr. M. N. Dabhi attended Webinar on “Agriculture Residue and Waste Utilization for Energy Generation” Organized by JAU, Junagadh during 16-17.03.21.
- Dr. P. R. Davara attended webinar on “Food Quality and Safety: Indian Perspective” Organized by NAU, Navasari during 27.03.2021.
- Dr. M. N. Dabhi has participated in the virtual Bueno Fest Trio 2021 organized by IIPM, Bengaluru on 8 May, 2021.
- Dr. M. N. Dabhi has participated in the National Webinar on “Agriculture Residue and Waste Utilization for Energy Generation” organized by JAU, Junagadh during 16-17 March, 2021.
- Dr. M. N. Dabhi has participated in National Level Virtual Seminar on “Health of Mother Earth-Conservation of Ecosystem and Biodiversity for Sustainable Development” organized by JAU, Junagadh on 4 June, 2021.
- Dr. M. N. Dabhi has participated in the National Webinar on “Ecology Restoration” organized by NIFTE, on 5 June, 2021.
- Dr. M. N. Dabhi has participated in one day event conducted on the occasion of World Food Safety Day-2021 organized by the Department of Food Technology and Department of Dairy Technology, Parul University, on 07 June, 2021.
- Dr. M. N. Dabhi and Dr. P. R. Davara has attended online training workshop on “Response Surface Methodology” organized by ICAR-NAARM, Hyderabad during 24-26 August, 2021.
- Dr. M. N. Dabhi has participated in Expert Lecture on the topic “Opportunities and Challenges in Food Industries” organized by the AKS University, Satna, MP, on 17 September, 2021.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