

Declaration

The candidate certificate that the thesis entitled “**Instant controlled pressure drop assisted production of curcumin rich turmeric powder for its use in infusion drink**” is being submitted to School of Engineering Tezpur University in part fulfilment for the award of the degree of Dictor of Philosophy in the Department of Food Engineering and Technology is a record of research work accomplished by me under the supervision of Dr. Manuj Kumar Hazarika. Professor, Department of Food Engineering and Technology.

All assistance received from various sources have been appropriately acknowledged

No part of the thesis has been submitted elsewhere for the award of any other degree

Date: 24-12-2024

Place: Tezpur



(Swapnil Prashant Gautam)

Reg No. TZ189880



तेजपुर विश्वविद्यालय/ **TEZPUR UNIVERSITY**
(संसद के अधिनियम द्वारा स्थापित केंद्रीय विश्वविद्यालय)
(A Central University established by an Act of Parliament)
तेजपुर-784028 :: असम/ **TEZPUR-784028 :: ASSAM**

(सर्वोत्तम विश्वविद्यालय के लिए कुलाध्यक्ष पुरस्कार, 2016 और भारत के 100 श्रेष्ठ उच्च शिक्षण संस्थानों में पंचम स्थान प्राप्त विश्वविद्यालय)
(Awardee of Visitor's Best University Award, 2016 and 5th among India's Top 100 Universities, MHRD-NIRF Ranking, 2016)

Dr. Manuj Kumar Hazarika
Professor
Department of Food Engineering and Technology

Mobile: +91-9435700993
Phone: 03712-275706
Email: mkhazarika@tezu.ernet.in

CERTIFICATE

This is to certify that the thesis entitled “Instant Controlled Pressure Drop Assisted Production of Curcumin rich Turmeric Powder for its use in Infusion Drink” submitted to the School of Engineering, Tezpur University in partial fulfilment for the award of the degree of Doctor of Philosophy in Food Engineering and Technology, is a record of research work carried out by Swapnil Prashant Gautam under my supervision and guidance.

All assistance received by him from various sources have been duly acknowledged.
No part of this thesis has been submitted elsewhere for award of any other degree.

Manuj Kumar Hazarika
Supervisor

Date: 24-12-2024

(Dr. Manuj Kumar Hazarika)

Place: Tezpur

Acknowledgements

I express my deepest appreciation to all individuals who have supported and contributed to my journey throughout my Ph.D. program.

Firstly, my sincere gratitude is extended to my Ph.D. advisor, Professor M.K. Hazarika, whose guidance, and encouragement have been invaluable. I am grateful for his insightful ideas and unwavering support.

I extend my sincere gratitude to the esteemed faculty members, my DRC committee, and the dedicated technical and office staff of the Department of Food Engineering and Technology, TU. Your unwavering support, guidance, and assistance have been instrumental in my academic journey. Your expertise, encouragement, and willingness to share knowledge have enriched my learning experience and helped me navigate through the complexities of my Ph.D. program.

Special thanks to my DC members, Prof. Santnu Sharma and Prof. Brijesh Srivastava, for their valuable suggestions.

I am grateful for the support received from the energy department for providing technical appliances, which have been essential in facilitating my research endeavours.

I extend my heartfelt thanks to my friends, batchmates, and lab-mates for fostering a supportive and conducive work environment. Throughout my journey, their encouragement and friendship have been vital.

My deepest gratitude goes to my parents, wife, brother, and sister for their unwavering love, encouragement, and support. Their constant belief in me has been a source of strength and motivation.

Finally, I sincerely thank God for giving me the fortitude, well-being, and perseverance I needed to finish my research.

Thank you all for your invaluable contributions and support.

Swapnil Prashant Gautam

List of Table

Table. No	Name of list	Page no
Table-1.1	Chemical composition of turmeric rhizome	1
Table-2.1	Applications of experimental conditions of DIC technology of different foods	12
Table-3.1	Design experiment table of different variable	29
Table-3.2	Model fitting parameter of drying kinetic of turmeric slices	30
Table-4.1	Dimensions of turmeric rhizome fresh cured and dried	47
Table-4.2	Showing the performance of drying model	53
Table-4.3	Represents significant effect for the predictive models of DT, CC and YV.	55
Table-4.4	ANOVA results of the fitted models for the response variables	56
Table-4.5	Drying kinetics of turmeric slices	69
Table-4.6	Moisture Diffusivity of turmeric slices of different technologies	69
Table-4.7	Analysis of Variance's matrices of response 1 DPPH	81
Table-4.8	Response 2 TPC ANOVA	82
Table-4.9	Antioxidant Activity of TPC properties and analyses by Design experiment	83
Table-4.1	Response 3 TFC ANOVA	86
Table-4.11	Antioxidant Activity of TFC properties and analyses by Design experiment.	95
Table-4.12	Optimization solution of phytochemicals	99
Table-4.13	Showing the colour value of turmeric drink	104
Table-4.14	Color properties of turmeric drink	104
Table-4.15	Antioxidant activity of turmeric drink	107

List of Figures

Figure No	Name of figure	Page
Figure -3.1	Overall flowchart of all objective	24
Figure -3.2	Instant controlled pressure drop technology machine for food processing unit	25
Figure -3.3 (a)	Turmeric rhizome	25
Figure -3.3 (b)	Turmeric slices for treatment in ICPD	25
Figure -3.4	Refractance window drying unit	36
Figure -3.5	Turmeric drying in refractance window	37
Figure -3.6	Sensory Panel for scoring grade ion	42
Figure -3.7	Turmeric drink for sensory evaluation	43
Figure -3.8	Membership function turmeric drink for sensory evaluation	42
Figure -4.1	Turmeric slice	47
Figure -4.2	Turmeric slice for treatment	47
Figure -4.3	Moisture content of turmeric slices using instant controlled pressure drop technology	48
Figure -4.4	Moisture ratio of turmeric slices using instant controlled pressure drop technology assisted with hot air drying	51
Figure -4.5	Moisture ratio of hot air drying	54
Figure -4.6	Effect of IDASC-HAD treatment conditions on hot air drying time (DT) of slices and curcumin content (CC) and yellowness value (YV) of powder.	59
Figure -4.7	Comparison of properties of turmeric powders produced by IDASC-HAD and CBWC-HAD methods	61
Figure -4.8	Micro-structures of i) turmeric powder, produced by (a) CBWC-HAD and (b) IDASC-HAD methods	63
Figure -4.9	Curcumin content with respect to time	64
Figure -4.10	Curcumin content with respect to pressure	64
Figure -4.11	Moisture ratio of turmeric slices using instant controlled pressure drop technology assisted with Reactance window drying	67
Figure -4.12	Moisture diffusivity of turmeric slices by using advance drying methods	70
Figure -4.13	Rehydration ratio of turmeric slices by using different methods	70
Figure -4.14	shrinkage ratio of ginger slices for different drying methods,	72
Figure -4.15	Hardness of turmeric slices for different drying methods	74
Figure -4.16	Tannin content in turmeric powder prepared by different methods	76

Figure -4.17	The XRD pattern of turmeric IDASC-RWD Powder for different drying methods	77
Figure -4.18	The XRD pattern of turmeric IDASC-HAD Powder for different drying methods	78
Figure -4.19	The X-ray diffraction pattern of turmeric powder convention for different drying methods.	79
Figure -4.20	Response surface for the effect of DPPH activity and pressure on the time of treatment.	84
Figure -4.21	Response surface for the effect of Time and total phenolic content	88
Figure -4.22	Response surface for the effect of pressure and time on total flavonoid content of IDASC treated powder.	89
Figure -4.24	IDASC-RWD turmeric powder	90
Figure -4.25	IDASC-HAD turmeric powder	90
Figure -4.26	Chromatograms of curcumin standard ($20 \mu\text{g mL}^{-1}$)	92
Figure -4.27	Chromatograms of Turmeric extract of IDASC-RWD ($20 \mu\text{g mL}^{-1}$)	92
Figure -4.27	IDASC-RW dried microstructure of turmeric	92
Figure -4.28	HA dried microstructure of turmeric	93
Figure -4.30	Turmeric beverage prepared by mixing of ICPD-HAD (S1), ICPD-RWD (S2), HAD (S3), Marketed (S4) samples added odd flavor masking as lemon, honey, vanilla and palm candy	94
Figure -4.31	Ferric reducing antioxidant power assay of turmeric beverages	97
Figure -4.32	ABTS and reducing power activity of turmeric	97
Figure -4.33	DPPH activity of turmeric beverage at different methods	99
Figure -4.34	Radar chart for the sensory scores of the quality attributes of turmeric drink	100
Figure -4.35	Effect of storage at different temperature on loss of TPC activity and loss of Curcumin in percentage	106
Figure -4.36	Effect of storage at different temperature on DPPH activity and Curcumin loss in percentage	108
Figure -4.37	Storage study of turmeric drink and pH change in under $\pm 4^\circ\text{C}$	110

List of abbreviation

ICPD=Instant controlled pressure drop technology
IDASC= Instant decompression assisted steam curing
DIC= Instant controlled pressure drop
CC= Curcumin content
DT= Temperature of drying
TT= Treatment time
IDASC-HAD=Instant decompression assisted steam cuing assisted hot air drying
IDASC-RWD=Instant decompression assisted steam curing assisted refractance of window drying
ICPD-HAD= Instant controlled pressure drop assisted hot air drying
ICPD-RWD= Instant controlled pressure drop assisted refractance of window drying
TPC= Total phenolic content
TFC= Total flavonoid content
YV = Yellowness value
DPPH= 2,2 Diphenyl 1 pycryldrazyl
FRAP= Ferric reducing antioxidant potential
HTST= High treatment short time
MPa = Mega pascal
BDNF = Brain-derived neurotrophic factor
IMC = Initial moisture content
POP = polyphenol oxidase
HPLC =High performance liquid chromatography
HPTLC = High performance thin layer chromatography
SEM = Scanning electron microscopy
RSM = Response surface methodology
BBD = Box-Behnken
CCD = Central composite design
CCCD = central composite circumscribed design
LDL = Low density lipoprotein
ASTA = American Spice Trade Association
SRVTA = Steam releasing valve towards atmosphere
PDR = Pressure decompression rate
MMD = Mass mean diameter
AMD = Average mean diameter
APS = Average particle size
PSO = Particle swarm analysis
CBWC = Conventional boiling water curing
TTC = Total tannin content
XRD = X-ray diffraction