

**UTILIZATION OF BY-PRODUCTS FROM FRUIT PROCESSING
INDUSTRIES FOR FUNCTIONAL FOOD PRODUCT DEVELOPMENT**

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**UTILIZATION OF BY-PRODUCTS FROM FRUIT PROCESSING INDUSTRIES FOR
FUNCTIONAL FOOD PRODUCT DEVELOPMENT**

By

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मेरी स्वर्गीय दादी को समर्पित



CERTIFICATE

This is to certify that the thesis entitled “**Utilization of By-Products from Fruit Processing Industries for Functional Food Product Development**” being submitted by Mr. Ajay Patel to the Centre for Rural Development and Technology for the award of “Doctor of Philosophy” is a record of bonafide research work carried out by him under our guidance and supervision in conformity with the rules and regulations of IIT, Delhi. The research report and rules presented in this thesis have not been submitted, in part or in full, to any other University or Institute for the award of any degree or diploma.

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Abstract

In the fast life of cities, people often prefer processed food as it saves time and reduces workload. So, it is necessary to provide healthy options of processed food to the people. Also, as the demand of processed food is increasing rapidly, the food processing industries would grow at faster rate. India produced 92.84 million metric tonnes of fruits and 175.00 million metric tonnes of vegetables according to National Horticulture Database published by National Horticulture Board (2018-19). India currently processes less than 10% of its agri output. Food Processing sector has been growing at an Average Annual Growth Rate (AAGR) of around 10.%. As the food-processing sector is growing faster, the waste generated will be huge from food industries. However, literature revealed that by-products generated from food processing industries contains phytochemicals and dietary fiber. Presently there is very less study has been done to use this by-product for production of value-added functional foods. This waste can be converted into wealth with cutting edge research and technology, at the same time the environmental problem will also be solved.

There are traditional Indian fruits which has historical importance for its nutritional and functional food value. Gular (*Ficus Racemosa*) is one such fruit which is mentioned in various Indian historical text possessing medicinal properties, *F. racemosa* is pharmacologically studied and reported for various activities including antidiabetic, antipyretic, anti-inflammatory, antitussive, hepatoprotective, and antimicrobial activities.

In the present study, apple and amla juice processing industries by-product called apple and amla pomace respectively were studied. The various physiochemical properties, functional properties and optimization of process parameters for phytochemical extraction of Apple and amla Pomace was studied. The dietary fiber obtained from apple and amla pomace was used to develop functional biscuits enriched with apple, amla and mix pomace. Also, underutilized

gular fruit at IIT Delhi campus was studied for different physiochemical characteristics of gular fruit, which may help in designing and developing of post-harvest processing equipment. The collected fruits were dried using three different techniques, further characterization of dried gular fruit powder has been done.

Apple pomace and amla pomace was dried using different drying methods i.e., sun drying (SD), oven drying (OD) and freeze drying (FD). Dried samples were characterized for properties i.e., proximate composition, dietary fiber content, elemental analysis by using ICP-MS, functional properties (WHC, OHC, SWC, BD, HD and HD), FTIR analysis and morphological properties. The effect of drying method on above properties were studied. It is observed that functional properties of freeze-dried sample were higher followed by oven drying and sun drying.

Optimization of process parameters i.e., A : temperature (°C), B: Time (min) and C: ethanol concentration (v/v) for extraction of polyphenol of both apple and amla pomace were done using response surface methodolog. Optimized process parameters along with their responses are A: (41.98 °C), B: (50.34 min), C: (80.30 v/v) while responses was DPPH (3.41 mg GAE/g) and TPC (3.12 mg GAE/g) for apple pomace extraction. Amla pomace extraction process parameters along with their responses are A: (49.57 °C), B: (37.97 min), C: (84.84 v/v) while responses was DPPH (30.60 mg GAE/g) and TPC (246.12 mg GAE/g).

The dried apple and amla pomace was used to develop functional biscuits. The biscuits were prepared using different concentration of apple (A5%, A10%, A15%, A20%), amla (B5%, B10%, B15%, B20%) and Mix pomace apple-amlam (AB5%, AB10%, AB15%, AB20%). The rheological properties of formulated dough, sensory analysis along with various physico-chemical properties of functional biscuits were studied and found in required range.

Engineering properties of ripe and unripe gular fruits were found as follows: BD: ripe (473) > unripe (486); TD: ripe (824) > unripe (848). Also, coefficient of friction of gular fruit on

different surface was studied, for unripe fruit, the coefficient of friction was 0.48 on wooden, 0.44 on iron, 0.50 on aluminium and 0.49 on GI. While in case of ripened gular fruit, it was found to be 0.37 on wooden, 0.57 on iron, 0.47 on aluminium and 0.38 on GI.

Overall, present study concludes that pressurised liquid extraction technique (PLE) is efficient to extract phytochemicals from apple and amla pomace. The dietary fiber present in both pomace powder can be used as a wheat flour replacer (~15%) for functional biscuits preparation. Unutilized gular fruit powder can be used as a raw material (partial substitute) for functional food preparation.

सारांश

शहरों की भागदौड़ भरी जिंदगी में लोग अक्सर प्रोसेस्ड फूड पसंद करते हैं क्योंकि इससे समय की बचत होती है और काम का बोझ कम होता है। इसलिए, लोगों को प्रसंस्कृत भोजन के स्वस्थ विकल्प प्रदान करना आवश्यक है। साथ ही, जैसे-जैसे प्रसंस्कृत खाद्य की मांग तेजी से बढ़ रही है, खाद्य प्रसंस्करण उद्योग तेजी से बढ़ेंगे। राष्ट्रीय बागवानी बोर्ड (2018-19) द्वारा प्रकाशित राष्ट्रीय बागवानी डेटाबेस के अनुसार भारत ने 92.84 मिलियन मीट्रिक टन फल और 175.00 मिलियन मीट्रिक टन सब्जियों का उत्पादन किया। भारत वर्तमान में अपने कृषि उत्पादन का 10% से कम संसाधित करता है। खाद्य प्रसंस्करण क्षेत्र लगभग 10% की औसत वार्षिक वृद्धि दर (AAGR) से बढ़ रहा है। जैसे-जैसे खाद्य-प्रसंस्करण क्षेत्र तेजी से बढ़ रहा है, खाद्य उद्योगों से उत्पन्न होने वाला कचरा बहुत बड़ा होगा। हालांकि, साहित्य से पता चला है कि खाद्य प्रसंस्करण उद्योगों से उत्पन्न उप-उत्पादों में फाइटोकेमिकल्स और आहार फाइबर होते हैं। वर्तमान में मूल्य वर्धित कार्यात्मक खाद्य पदार्थों के उत्पादन के लिए इस उप-उत्पाद का उपयोग करने के लिए बहुत कम अध्ययन किया गया है। इस कचरे को अत्याधुनिक अनुसंधान और प्रौद्योगिकी से धन में बदला जा सकता है, साथ ही पर्यावरण की समस्या का भी समाधान किया जा सकेगा।

पारंपरिक भारतीय फल हैं जिनका पोषण और कार्यात्मक खाद्य मूल्य के लिए ऐतिहासिक महत्व है। गूलर (*Ficus Racemosa*) एक ऐसा फल है जिसका उल्लेख विभिन्न भारतीय ऐतिहासिक ग्रंथों में औषधीय गुण मिलता है। औषधीय रूप से अध्ययन करने पर विभिन्न प्रकार के गुण, जैसे एंटीडायबिटिक, एंटीपीयरेटिक, एंटी-इंफ्लेमेटरी, एंटीट्यूसिव, हेपेटोप्रोटेक्टिव और एंटीमाइक्रोबियल पाये गए हैं।

वर्तमान अध्ययन में सेब और आंवला रस प्रसंस्करण उद्योगों के उप-उत्पाद जिन्हें क्रमशः सेब और आंवला पोमेस कहा जाता है, का अध्ययन किया गया। सेब और आंवला पोमेस के फाइटोकेमिकल निष्कर्षण के लिए विभिन्न भौतिक रासायनिक गुणों, कार्यात्मक गुणों और प्रक्रिया मापदंडों के अनुकूलन

का अध्ययन किया गया था। सेब और आंवला पोमेस से प्राप्त आहार फाइबर का उपयोग सेब, आंवला और मिक्स पोमेस से समृद्ध कार्यात्मक बिस्कुट विकसित करने के लिए किया गया था। इसके अलावा, आईआईटी दिल्ली परिसर में कम उपयोग किए गए गूलर फल का अध्ययन गूलर फल की विभिन्न भौतिक रासायनिक विशेषताओं के लिए किया गया था, जो कटाई के बाद के प्रसंस्करण उपकरणों के डिजाइन और विकास में मदद कर सकता है। एकत्रित फलों को तीन अलग-अलग तकनीकों का उपयोग करके सुखाया गया, सूखे गूलर के फलों के पाउडर का और अधिक लक्षण वर्णन किया गया है। सेब पोमेस और आंवला पोमेस को अलग-अलग सुखाने के तरीकों यानी धूप में सुखाना (SD), ओवन सुखाने (OD) और लियोफिलिज़ेशन (FD) का उपयोग करके सुखाया गया था। सूखे नमूनों को गुणों के लिए चित्रित किया गया था, अर्थात्, समीपस्थ संरचना, आहार फाइबर सामग्री, ICP-MS का उपयोग करके मौलिक विश्लेषण, कार्यात्मक गुण (WHC, OHC, SWC, BD, HD और HD), FTIR विश्लेषण और रूपात्मक गुण। उपरोक्त गुणों पर सुखाने की विधि के प्रभाव का अध्ययन किया गया। यह देखा गया है कि फ्रीज-सूखे नमूने के कार्यात्मक गुण अधिक थे, इसके बाद ओवन में सुखाना और धूप में सुखाना था।

प्रतिक्रिया सतह पद्धति का उपयोग करके सेब और आंवला पोमेस दोनों के पॉलीफेनोल के निष्कर्षण के लिए प्रक्रिया मापदंडों यानी ए: तापमान ($^{\circ}\text{C}$), बी: समय (minute) और सी: इथेनॉल एकाग्रता (v/v) का अनुकूलन किया गया था। उनकी प्रतिक्रियाओं के साथ अनुकूलित प्रक्रिया पैरामीटर ए: (41.98 $^{\circ}\text{C}$), बी: (50.34 मिनट), सी: (80.30 वी/वी) हैं जबकि प्रतिक्रियाएं डीपीपीएच (3.41 mg GAE/g) और टीपीसी (3.12 mg GAE/g) थीं।) सेब खली निकासी के लिए। आंवला पोमेस निष्कर्षण प्रक्रिया पैरामीटर उनकी प्रतिक्रियाओं के साथ ए: (49.57 $^{\circ}\text{C}$), बी: (37.97 minute), सी: (84.84 v/v) हैं, जबकि प्रतिक्रियाएं डीपीपीएच (30.60 mg GAE/g) और टीपीसी (246.12 mg GAE/g) थीं।

सूखे सेब और आंवला पोमेस का उपयोग कार्यात्मक बिस्कुट विकसित करने के लिए किया गया था।

सेब (A5%, A10%, A15%, A20%), आंवला (B5%, B10%, B15%, B20%) और मिक्स पोमेस सेब-

आंवला (AB5%, AB10%) की विभिन्न सांद्रता का उपयोग करके बिस्कुट तैयार किए गए थे। AB15%, AB20%)। तैयार किए गए आटे के रियोलॉजिकल गुण, संवेदी विश्लेषण के साथ-साथ कार्यात्मक बिस्कुट के विभिन्न भौतिक-रासायनिक गुणों का अध्ययन किया गया और आवश्यक सीमा में पाया गया।

पके और कच्चे गूलर फलों के इंजीनियरिंग गुण इस प्रकार पाए गए: BD: ripe (473) > unripe (486); TD: ripe (824) > unripe (848)। इसके अलावा, विभिन्न सतह पर गूलर फल के घर्षण के गुणांक का अध्ययन किया गया था, कच्चे फलों के लिए, घर्षण का गुणांक लकड़ी पर 0.48, लोहे पर 0.44, एल्यूमीनियम पर 0.50 और जीआई पर 0.49 था। जबकि पके हुए गूलर फल के मामले में लकड़ी पर 0.37, लोहे पर 0.57, एल्यूमीनियम पर 0.47 और जीआई पर 0.38 पाया गया।

कुल मिलाकर, वर्तमान अध्ययन का निष्कर्ष है कि प्रेशराइज्ड लिक्विड एक्सट्रैक्शन तकनीक (PLE) सेब और आंवला पोमेस से फाइटोकेमिकल्स निकालने में सक्षम है। दोनों पोमेस पाउडर में मौजूद आहार फाइबर को कार्यात्मक बिस्कुट तैयार करने के लिए गेहूं के आटे की प्रतिकृति (~ 15%) के रूप में इस्तेमाल किया जा सकता है। अप्रयुक्त गूलर फल पाउडर को कार्यात्मक भोजन तैयार करने के लिए कच्चे माल (partial substitute) के रूप में इस्तेमाल किया जा सकता है।

CONTENT

	Page No.
Certificate	i
Acknowledgement	ii
Abstract	iv
Contents	x
List of Figures	xvii
List of Tables	xxiii
List of Abbreviations	xxv
Chapter-1 Introduction	1-12
1.1 Background	1
1.2 Current Scenario	2
1.3 Extraction of functional ingredients from waste products of food industries	4
1.4 Apple processing industrial wastes	6
1.5 Amla processing waste	7
1.6 Gular Fruit (<i>Ficus racemosa</i>) as potential source of functional food ingredients	8
1.7 Dietary fiber from fruit processing waste	8
1.8 Extraction of polyphenols from fruit processing wastes	9
1.9 Functional Food	10
1.10 Research gaps and main aim of the study	10
1.11 Objectives of the study	11
1.12 Organization of the thesis	11

Chapter-2 Review of Literature	13-29
2.1 Fruit industry by-products and its utilization	13
2.2 Apple pomace and its health promoting characteristics	17
2.2.1 Composition of apple pomace	17
2.2.2 Antiproliferative property of apple	19
2.2.3 Anti-cancerous property	19
2.2.4 Anti-inflammatory	19
2.2.5 Anti-diabetic properties	19
2.2.6 Cardio protective effect	20
2.3 Amla	20
2.4 Gular fruits functional/nutraceutical properties	20
2.5 Dietary fiber	23
2.6 Polyphenols and its functional/nutraceutical properties	25
2.7 Pressurized liquid extraction technique for extraction of Bio-active compounds	27
Chapter-3 Industrial Visit and Survey of Gular Tree in IIT Delhi Campus	30-38
3.1 Visit to Ms. HPMC, Parwanoo (HP) apple juice processing plant to understand process flow and to collect sample	30
3.1.1 Observation during HPMC Visit	32
3.2 Visit to Patanjali Food and Herbal Park, Padartha, Haridwar (UK)	33
3.2.1 Observation of Visit to Patanjali Herbal and Food Park	35
3.3 Survey of Gular (<i>Ficus Racemosa</i>) trees in IIT Delhi campus	36
3.3.1 Observations	37
Chapter-4 Material and Methods	39-52

4.1 Materials	39
4.1.1 Collection of raw material	40
4.1.2 Drying of apple pomace, amla pomace and gular fruits	40
4.2 Chemical and reagents	40
4.3 Characterization of dried amla pomace, apple pomace and gular fruit powder	41
4.3.1 Proximate analysis	41
4.3.2 Dietary fiber content analysis	41
4.3.3 Elemental analysis	41
4.3.4 Measurement of functional properties	42
4.3.4.1 Different Densities of Apple and Amla Pomace	42
4.3.4.2 Water holding capacity (WHC) of Apple and Amla Pomace	42
4.3.4.3 Oil holding capacity (OHC) of Apple and Amla Pomace	42
4.3.4.4 Swelling capacity (SWC) of Apple and Amla Pomace	43
4.3.5 Morphological characterization of pomace	43
4.3.6 FTIR analysis	43
4.4 Extraction of polyphenols and optimization of process parameters	43
4.4.1 Experimental Design by using: Central Composite Rotatable Design (CCRD) with the help of Design expert 7.0 Software	43
4.4.1.1 Independent Process Variables	44
4.4.1.2 Dependent Process Variables	44
4.4.1.3 Extraction of polyphenols by using Pressurized liquid extraction method	44
4.5 Analysis of Extracts	47
4.5.1 Total phenol content (TPC)	47

4.5.2 Diphenyl-1-picrylhydrazyl (DPPH) method	48
4.6 Dietary fiber enriched functional product development	48
4.6.1 Preparation of biscuits	48
4.6.2 Rheological properties	49
4.6.3 Physical analysis of biscuit characteristics	49
4.6.4 Color	50
4.6.5 Textural analysis	50
4.6.6 Sensory analysis	51
4.6.7 X-ray μ CT scanning and image analysis	51
4.7 Evaluation of physical properties of Gular fruits	52
4.8 Statistical analysis	52
Chapter-5 Characterization and Optimization of Extraction Process	53-78
Parameters of Apple Pomace	
5.1 Apple pomace and its functional properties	54
5.2 Proximate analysis of apple pomace	54
5.3 Dietary fiber content estimation of Apple Pomace	55
5.4 Mineral content	56
5.5 Functional properties analysis of Apple Pomace	57
5.6 Microstructure analysis	60
5.7 FTIR spectra of apple pomace	61
5.8 Pressurized liquid extraction and optimization of process parameters using response surface methodology	62
5.8.1 Experimental design using CCRD	62
5.8.2 Diagnostic Checking of the Fitted Model	64
5.8.3 Effect of Time, temperature, and ethanol concentration on DPPH	65

value of apple pomace extract	
5.8.4 Effect of Time, temperature, and ethanol concentration on DPPH	71
value of apple pomace extract	
5.8.5 Optimization and validation of Independent Variables for	76
extraction of polyphenols from Apple Pomace	
5.8.6 Comparison between predicted and experimental value of	77
responses	
5.8.7 Comparison of PLE with conventional shaking bath extraction	78
technique	
Chapter-6 Characterization and Optimization of Extraction Process	79-103
Parameters of Amla Pomace	
6.1 Analysis of physiochemical properties, functional properties of Amla	79
Pomace	
6.1.1 Proximate composition of amla pomace	80
6.1.2 Dietary fiber content estimation of Amla Pomace	80
6.1.3 Mineral content analysis of Amla Pomace	81
6.1.4 Functional Properties of Amla Pomace	82
6.1.5 Micro-Structure analysis of Amla Pomace	84
6.1.6 FTIR spectra of apple pomace	86
6.2 Pressurized liquid extraction and optimization of process parameters using	86
response surface methodology	
6.2.1 Experimental design using CCRD	87
6.2.2 Diagnostic Checking of the Fitted Model	88
6.2.3 Effect of Time, temperature, and ethanol concentration on DPPH	89
value of amla pomace extract	

6.2.4 Effect of Time, temperature, and ethanol concentration on TPC value of amla pomace extract	96
6.2.5 Optimization and validation of Independent Variables for higher extraction of TPC from Amla Pomace	101
6.2.6 Comparison between predicted and experimental value of responses	102
6.2.7 Comparison of PLE with conventional shaking bath extraction technique	103
Chapter-7 Study on Engineering Properties of Gular Fruit and Characterization of Gular Fruit Powder	104-118
7.1 Collection and Drying of Gular Fruits	104
7.2 Physiochemical characteristics of ripen and unripe gular fruit	105
7.2.1 Physical properties of gular fruit	106
7.2.2 Coefficient of friction of gular fruit	107
7.2.3 Textural and frictional properties of Unripe and Ripe Gular Fruit	108
7.3 Characterization of gular fruit powder	110
7.3.1 Proximate analysis of apple pomace	110
7.3.2 Mineral content of Gular fruit Powder	111
7.3.3 Functional properties analysis of gular fruit	111
7.3.4 SEM analysis of gular fruit powder	113
7.3.5 FTIR spectra of gular fruit powder	115
7.3.6 Particle Size distribution of Gular Fruit Powder	115
Chapter-8 Dietary Fiber Enriched Functional Product Development Based on Apple and Amla Pomace Powder	119-144
8.1 Rheological properties of formulated dough	120

8.2 Physical attributes of Dietary fiber enriched biscuits	123
8.3 Color analysis of developed functional biscuits	126
8.3.1 Functional biscuits fortified with apple pomace	127
8.3.2 Functional biscuits fortified with amla pomace	128
8.3.3 Functional biscuits fortified with mix apple and amla pomace	130
8.4 Micro-structural Analysis	134
8.5 Sensory evaluation	143
Chapter-9 Conclusions and Future Scope	145-152
References	153-181
Biodata	182-184

LIST OF FIGURES

Figure no.	Title	Page no.
1.1	Production of fruits, vegetables and total horticultural crops over the year	3
1.2	Last five-year data of production of apple and amla fruit	4
3.1	Process flow diagram of apple juice processing plant	31
3.2	Apple pomace from plant after separation of juice	32
3.3	Process flow diagram of amla juice processing plant	34
3.4	Amla pomace after juice separation	34
3.5	Drying of amla pomace in vacuum oven drier	36
3.6	IIT Delhi campus map	37
3.7	Survey of gular plant in IIT campus	37
4.1	Brief flow chart of overall thesis	39
4.2	Experimental set up of PLE process	46
4.3	Schematic diagram of Pressurized liquid extraction unit	47
5.1	Flow chart for waste management system in apple juice industry	54
5.2	Effect of drying techniques on dietary fiber content of apple pomace	56
5.3	Effect of drying techniques on mineral content of apple pomace	57
5.4	Effect of drying techniques on functional properties of apple pomace	60
5.5	SEM images of apple pomace powder	61
5.6	Effect of drying technique on chemical composition of apple pomace using FTIR	62
5.7	3D plots showing the interaction effect between time and temperature process variables, among temperature, time and ethanol concentration	69

	on DPPH value	
5.8	3D plots showing the interaction effect between ethanol conc. and temperature process variables, among temperature, time and ethanol concentration on DPPH value	70
5.9	3D plots showing the interaction effect between ethanol concentration and time variables among, temperature, time and ethanol concentration on DPPH value	70
5.10	3D plots showing the interaction effect between time and temperature process variables among temperature, time and ethanol concentration on TPC value	74
5.11	3D plots showing the interaction effect between ethanol conc. and temperature process variables among temperature, time and ethanol concentration on TPC value	75
5.12	3D plots showing the interaction effect between ethanol concentration and time process variables among temperature, time and ethanol concentration on TPC value	75
6.1	Effect of drying techniques on dietary fiber content of amla pomace	81
6.2	Effect of drying techniques on mineral content of apple pomace	82
6.3	Effect of drying techniques on functional properties of amla pomace	84
6.4	SEM images of amla pomace powder dried with sun, oven and freeze drying	85
6.5	Effect of drying technique on chemical composition of amla pomace using FTIR	86
6.6	Plot between actual and predicted value of DPPH (EC ₅₀)	90
6.7	3D plots showing the interaction effect between time and temperature	94

	process variables, among temperature, time and ethanol concentration on DPPH value	
6.8	3D plots showing the interaction effect between ethanol conc. and temperature process variables, among temperature, time and ethanol concentration on DPPH value	95
6.9	3D plots showing the interaction effect between ethanol conc. and time process variables, among temperature, time and ethanol concentration on DPPH value	95
6.10	Plot between actual and predicted value of TPC of amla pomace extract	96
6.11	3D plots showing the interaction effect between time and temperature process variables, among temperature, time and ethanol concentration on TPC	100
6.12	3D plots showing the interaction effect between ethanol conc. and temperature process variables, among temperature, time and ethanol concentration on TPC	100
6.13	3D plots showing the interaction effect between ethanol conc. and temperature process variables, among temperature, time and ethanol concentration on TPC	101
7.1	Flow chart of gular fruit collection, drying and fruit powder	105
7.2	Various physical properties of ripen and unripen gular fruit	107
7.3	Coefficient of friction of ripen and unripe gular fruit	108
7.4	Picture showing measurement of textural properties using texture analyser and experiment setup to measure coefficient of friction	109
7.5	Bioyield point and fruit firmness of ripe and unripe gular fruit	109

7.6	Effect of drying method on C, H, N and ass content of gular fruit powder	110
7.7	Comparison of elemental analysis of gular fruit powder dried with different drying methods	111
7.8	Comparison of functional properties of gular fruit powder dried with different drying methods	112
7.9	Sem image of gular fruit powder	114
7.10	Effect of drying technique on chemical composition of gular fruit powder using FTIR	115
7.11	Graphs showing particle size distribution in freeze dried gular fruit powder	117
7.12	Graphs showing particle size distribution of oven dried gular fruit powder	117
7.13	Graphs showing particle size distribution of sun-dried gular fruit powder	118
8.1	Functional biscuit formulated by using different concentration of apple, amla and mix pomace	120
8.2	Effect of addition of amla pomace on storage and loss moduli of dough Frequency sweep test was conducted at the strain of 0.1%.	121
8.3	Effect of addition of apple pomace on storage and loss moduli of dough. Frequency sweep test was conducted at the strain of 0.1%.	122
8.4	Effect of different concentration of apple pomace on biscuit physical properties	124
8.5	Effect of different concentration of amla pomace on biscuit physical	125

	properties	
8.6	Effect of different concentration of mixed (50%apple and 50% amla) pomace on biscuit physical properties	126
8.7	Effect of different concentration of apple pomace on biscuit (Top surface) color	127
8.8	Effect of different concentration of apple pomace on bottom surface of biscuit color	128
8.9	Effect of different concentration of amla pomace on biscuit (Top surface) color	129
8.10	Effect of different concentration of amla pomace on bottom surface of biscuit color	130
8.11	Effect of different concentration of mixed (50%amla and 50% apple) pomace on top surface of biscuit (top surface) color	131
8.12	Effect of different concentration of mixed (50%amla and 50% apple) pomace on bottom surface of biscuit color	131
8.13	Comparison of 2D (XY-top view, YZ-side view, and XZ-front view) and 3D images representing volumetric size distribution of pores in control biscuit sample	137
8.14	Comparison of 2D (XY-top view, YZ-side view, and XZ-front view) and 3D images representing volumetric size distribution of pores in apple pomace biscuit samples	138
8.15	Comparison of 2D (XY-top view, YZ-side view, and XZ-front view) and 3D images representing volumetric size distribution of pores in amla pomace biscuit samples	139
8.16	Comparison of 2D (XY-top view, YZ-side view, and XZ-front view)	140

and 3D images representing volumetric size distribution of pores in mixed amla and apple pomace biscuit samples

8.17	Histogram of volumetric size distribution of pores in biscuit samples: (1) A10 and A20 are apple pomace biscuit; (2) B10 and B20 are amla pomace biscuit; (3) AB10 and AB20 mixed pomace biscuit	142
8.18	Sensory attributes of apple pomace biscuits	143
8.19	Sensory attributes of amla pomace biscuits	144
8.20	Sensory attributes of mixed (50% apple and 50% amla) pomace biscuits	144

LIST OF TABLES

Table no.	Title	Page no.
1.1	Industrial by-products/wastes: source of natural antioxidants	5
2.1	Polyphenolic compounds identified in apples	18
4.1	Details of the preparation of functional biscuits with different concentration of pomace	48
5.1	Proximate analysis of Apple pomace dried with different drying techniques	54
5.2	Combined Time, temperature, and ethanol concentration conditions according to rotatable central composite design (CCRD) and corresponding responses for the apple pomace.	63
5.3	The coded regression models for process variables and corresponding ANOVA data	65
5.4	Analysis of variance (ANOVA) data for quadratic model fitted to response surface for DPPH	66
5.5	Analysis of variance (ANOVA) data for quadratic model fitted to response surface for TPC	71
5.6	The set of constraints for different parameters targeting higher polyphenols concentration in extract obtained through combined Time, temperature and ethanol concentration	76
5.7	Comparison between predicted and experimental value of responses	77
5.8	Comparison of PLE extract with conventional extraction methods	78
6.1	Effect of drying technique on proximate analysis of amla pomace	80

6.2	Combined Time, temperature, and ethanol concentration conditions according to rotatable central composite design (CCRD) and corresponding responses for the amla pomace	87
6.3	The coded regression models for process variables and corresponding ANOVA data	89
6.4	Analysis of variance (ANOVA) data for quadratic model fitted to response surface for DPPH value of amla pomace extract	91
6.5	Analysis of variance (ANOVA) data for quadratic model fitted to response surface for TPC	97
6.6	The set of constraints for different parameters targeting higher polyphenols concentration in extract obtained through combined Time, temperature and ethanol concentration	102
6.7	Comparison between predicted and experimental value of responses	103
6.8	Comparison of PLE extract with conventional extraction methods	103
7.1	Size distribution indicators of gular fruit powder dried with different drying method	116
8.1	Micro-structural characteristics of biscuits formulated with different concentration of apple and amla pomace along with hardness	132

LIST OF ABBREVIATIONS

Abbreviations	Full Form
000, MT	Million metric tonne
HPLC	High performance liquid chromatography
BHA	Butylated hydroxyanisole
BHT	Butylated hydroxytoluene
DPPH	2,2-diphenyl-1-picryl-hydrazyl-hydrate
TDF	Total dietary fiber
IDF	Insoluble dietary fiber
SDF	Soluble dietary fiber
TD	True density
BD	Bulk density
HD	Hydrated density
SWC	Swelling capacity
OHC	Oil holding capacity
WHC	Water holding capacity
FTIR	Fourier transform infrared spectroscopy
RCCD	rotatable central composite design
TPC	Total phenolic content
ANOVA	Analysis of variance
HPMC	Horticulture produce marketing and processing corporation ltd.
AOAC	Association of official analytical collaboration

SD	Sun drying/dried
OD	Oven drying/dried
FD	Freeze drying/dried
ICP-MS	Inductively coupled plasma mass spectrometry
DFC	Dried fiber concentrate
SEM	Scanning electron microscopy
NS	Not significant
PPO	Polyphenoloxidase
PLE	Pressurised liquid extraction
RSM	Response surface methodology
FRAP	Ferric reducing ability of plasma
GI	Galvanized iron
FDG	Freeze drying/dried gular fruit powder
SDG	Sun drying/dried gular fruit powder
ODG	Oven drying/dried gular fruit powder
DLS	Dynamic light scattering
WL	Weight loss
UK	Uttarakhand
HP	Himachal Pradesh
i.e.,	That is
e.g.,	For example
rpm	Revolutions per minute
df	Degree of freedom
μCT	Micro computed tomography
Wt.	Weight

GAE

Gallic acid equivalents

EC50

Half maximal effective concentration

φ

Sphericity