DECLARATION

I, hereby declare that this thesis entitled "**Accelerated ageing of cocoa mucilage wine through hydrodynamic cavitation**" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Place: Tavanur **HYDERALI SHIHABUDHEEN U H**

Date: **(2021-18-006)**

CERTIFICATE

Certified that this thesis entitled "**Accelerated ageing of cocoa mucilage wine through hydrodynamic cavitation**" is a bonafide record of research work done independently by **Er. Hyderali Shihabudheen U H (2021-18-006)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

Place: Tavanur
Date:

Dr. Prince M V
Professor & Head
Department of Processing and Food Engineering
KCAEFT Tavanur

CERTIFICATE

We, the undersigned members of the advisory committee of **Er. Hyderali Shihabudheen U. H. (2021-18-006)** a candidate for the degree of Master of Technology in Agricultural Engineering with major in Processing and Food Engineering, agree that the thesis entitled "**Accelerated ageing of cocoa mucilage wine through hydrodynamic cavitation**" may be submitted by **Er. Hyderali Shihabudheen U. H. (2021-18-006)** in partial fulfilment of the requirement for the degree.

Dr. Prince M V
(Chairman)
Professor & Head
Dept. of P&FE
KCAEFT Tavanur

Members

Dr. Rajesh G K
(Member)
Assistant Professor
Dept of P&FE
KCAEFT, Tavanur

Mrs. Sreeja R
(Member)
Assistant Professor
Dept of P&FE
KCAEFT, Tavanur

Dr. Lilia Baby
(Member)
Assistant Professor
Community Science
KVK, Malappuram

ACKNOWLEDGEMENT

Completion of this research work could not have been possible without the assistance and combined support of many. I take this opportunity to express my deep sense of gratitude by bowing my head in front of ***Almighty*** *for his blessings to accomplish my work and for all the things which I made today.*

I express my deep and sincere regards, profound sense of gratitude and indebtedness to my major advisor ***Dr. Prince M.V.****, Professor & Head, Department of Processing and Food Engineering, KCAEFT, Tavanur, for his proper guidance, benevolent criticisms and encouragement during the course of research work. I have real admiration and regards for his full-hearted support and untiring help.*

With extreme pleasure, I express my whole hearted gratitude to ***Dr. Jayan P.R.,*** *Dean i/c, Professor and Head of the Department of Farm Machinery and Power Engineering, for the infrastructure and facilities provided for my research study in his institution.*

I sincerely thank ***Dr. Rajesh G. K., Assistant*** *Professor and PI, ICAR- AICRP on PHET, Tavanur for his encouragement and support to complete the research work successfully.*

I avail this opportunity to express my appreciation and sincere thanks to my advisory committee members ***Dr. Rajesh G. K.,*** *Assistant Professor, ICAR-AICRP on PHET, Dept. of P&FE, KCAEFT, Tavanur,* ***Dr. Lilia Baby,*** *Assistant Professor, Community Science, KVK Malappuram,* ***Mrs. Sreeja R,*** *Assistant Professor, Dept. of P&FE, KCAEFT, for their intellectual comments and recommendations.*

My heartfelt thanks to ***Er. Sreelakshmi P, Er. Anjali M. G.****,* ***Er. Ann Annie Shaju*** *and* ***Er. Shamna N P*** *for their help, support and kind cooperation throughout the period of my investigation.*

I sincerely thank to ***Er. Gopika Gopi and Ms. Jumana Binth Ali*** *for their assistance during my research work.*

My abstruse regards go to ***Mrs. Pankajam, Mrs. Raseena, Mrs. Geetha, Mrs. Sandhya, Mr. Radhakrishnan, Mr. Lenin, Mr. Vipin and Mr. Surjith*** *to help in the laboratory work and for their encouragement during research work.*

I convey my earnest thanks to my beloved batch mates and all the seniors and juniors, who directly or indirectly helped me, successfully complete this project.

I wish to express my gratitude to all ***Teaching Assistants****, Department of Processing and Food Engineering****,*** *especially* ***Dr. Senthil Kumar, Dr. Pritty S Babu, Dr. Ashitha G N and Dr. Ajish K H*** *for their valuable suggestions.*

I express my heartfelt gratitude to the entire faculty at the Post- Harvest Technology Laboratory for their support and help during my lab work.

I express my thanks to all the faculty members of KCAEFT and members of Library KCAEFT Tavanur, for their ever-willing help and co-operation.

My heartfelt thanks to ***Kerala Agricultural University*** *in providing the favorable circumstances for the study.*

I feel inadequacy of diction to express my sense of gratitude and affection to my father ***Mr. Hussain U.,*** *mother* ***Mrs. Febeena K B and Mrs. Amina Shahanas U H*** *and all my relatives and friends for their keen interest as well as constant and ambitious encouragement in my career, which spurred me towards higher course.*

One last word; since it is practically impossible to list all the names who have contributed to my work, it seems proper to issue a blanket of thanks for those who helped me directly or indirectly during the course of study.

..... any omission in this small manuscript does not mean lack of gratitude.

Hyderali Shihabudheen U H

Dedicated

to

My Beloved Family, Teachers and Friends

TABLE OF CONTENTS

Chapter No.	Title	Page No.
	LIST OF TABLES	
	LIST OF FIGURES	
	LIST OF PLATES	
	SYMBOLS AND ABBREVATIONS	
I	INTRODUCTION	1
II	REVIEW OF LITERATURE	5
III	MATERIALS AND METHODS	31
IV	RESULTS AND DISCUSSIONS	47
V	SUMMARY AND CONCLUSION	83
VI	REFERENCES	85
	APPENDICES	
	ABSTRACT	

LIST OF TABLES

Table No.	Title	Page No.
3.1	Independent parameters selected for HC treatment	41
3.2	Experimental design with the actual values of process variables for the accelerated aging of cocoa mucilage wine through hydrodynamic cavitation	41
3.3	Sample name and labelling selected for sensory analysis	45
3.4	Nine Point Hedonic Scale	45
4.1	Physico-chemical characteristics of cocoa mucilage	47
4.2	Physico-chemical characteristics of freshly prepared cocoa mucilage wine	50
4.3	Effect of process parameters on the performance of HC reactor system for the accelerated ageing of cocoa mucilage wine	52
4.4	Analysis of variance (ANOVA) for TPC of cocoa mucilage wine	56
4.5	Analysis of variance (ANOVA) for cavitation number	59
4.6	Analysis of variance (ANOVA) for volume flow rate	62
4.7	Analysis of variance (ANOVA) for energy released during HC treatment	66
4.8	Optimum criteria of response variables obtained from desirability analysis	67
4.9	Sensory scores of different cocoa mucilage wines	80

LIST OF FIGURES

Figure No.	Title	Page No.
2.1	Graphical illustration of hydrodynamic cavitation	11
2.2	Principle of hydrodynamic cavitation	12
2.3	Mechanism of hydrodynamic cavitation	13
2.4	Liquid whistle reactor	16
2.5	High pressure homogenization	17
2.6	Schematic of section of hydrodynamic cavitation and schematic for movement of liquid flow in indentations	17
2.7	Microfluidizer	18
2.8	Illustration of an orifice plate with a pressure profile	18
2.9	Illustration of a different orifice design	19
2.10	Illustration of the geometric design of different venturis	20
3.1	Schematic diagram of slit venturi	37
3.2	Schematic diagram of elliptical venturi	38
3.3	Schematic diagram of orifice plate	38
3.4	Schematic diagram of hydrodynamic cavitation reactor system	39
4.1	Surface response on total phenolic content on various cavitation elements (a) Orifice (b) Slit venturi (c) elliptical venturi	55
4.2	Surface response on cavitation number on various cavitation elements (a) Orifice (b) Slit venturi (c) elliptical venturi	58
4.3	Surface response on volume flow rate on various cavitation elements (a) Orifice (b) Slit venturi (c) elliptical venturi	61
4.4	Surface response on energy released on various cavitation elements (a) Orifice (b) Slit venturi (c) elliptical venturi	64
4.5	Desirability ramps for numerical optimisation of cavitation number, volume flow rate, total phenolic content and energy released	67

4.6	Desirability interaction graphs for numerical optimisation of cavitation number, volume flow rate, total phenolic content and energy released	68
4.7	Total phenolic content of 3 wine samples	69
4.8	Antioxidant (DPPH) scavenging activity of 3 wine samples	70
4.9	Vitamin C content of 3 wine samples	72
4.10	Reducing sugar content of 3 wine samples	73
4.11	pH values of 3 wine samples	74
4.12	Titrable acidity content of 3 wine samples	75
4.13	TSS content of 3 wine samples	76
4.14	Colour values (L*, a* and b*) of 3 wine samples	77
4.15	Alcohol content of 3 wine samples	78
4.16	Mineral content of 3 wine samples	79
4.17	Bar chart with grouping based on LSD test	81
4.18	Sensory analysis of different cocoa mucilage wine	82

LIST OF PLATES

Plate No.	Title	Page No.
3.1	Fresh cocoa pods	31
3.2	Digital pH meter	34
3.3	Refractometer	34
3.4	Lovibond tintometer	35
3.5	Samples for sensory evaluation	45
4.1	Cocoa mucilage wine	48
4.2	Hydrodynamic cavitation reactor system	51

SYMBOLS AND ABBREVIATIONS

%	: Per cent
&	: And
@	: At the rate
/	: Per
+	: Plus
<	: Less than
=	: Equal to
>	: Greater than
±	: Plus or minus
°C	: Degree Celsius
μ	: Viscosity
μl	: Micro litre
a*	: Greenness or redness
°N	: Degree north
°S	: Degree south
pH	: Potential of Hydrogen
Kg	: Kilogram
cm	: Centimeter
CPH	: Cocoa Pod Husks
K	: Kelvin
GPa	: Giga Pascal
ρ	: fluid density
P	: Pressure
V	: Fluid velocity
OH	: Hydroxyl
H	: Hydrogen
p1	: Upstream pressure

p2	: Downstream pressure
mm	: millimeter
kHz	: Kilo Hertz
W	: Watts
L	: Liter
CFU/J	: Colony Forming Unit per Joule
HPC	: High Pressure Cavitation
MPa	: Mega Pascal
HIU	: High Intensity Ultrasound
HPP	: High Pressure Processing
HPH	: High Pressure Homogenization
LPI	: Lentil Protein Isolate
SPI	: Soybean Protein Isolate
WSMP-P	: Water Soluble Myofibrillar Protein Powder
Psi	: Pounds square inch
MPs	: Myofibrillar Proteins
α-LA	: α-lactalbumin
SH	: Sulfhydryl
MMP	: Muscle Myofibrillar Protein
mg	: milligram
mV	: milli Volt
µm	: micro meter
nm	: nano meter
ICAR	: Indian Council of Agricultural Research
AICRP	: All India Coordinated Research Project
PHET	: Post Harvest Engineering & Technology
VFD	: Variable Frequency Drive
rpm	: rotations per minute
m/v	: mass per volume

µg	: microgram
DNSA	: 3,5-dinitrosalicylic acid
CPVC	: Chlorinated Poly Vinyl Chloride
Kg/cm2	: Kilogram per centimeter square
MMT	: Million Metric Ton
EU	: European Union
CCD	: Central Composite Design
Cυ	: Cavitation number
Pd	: Downstream pressure
kPa	: kilo Pascal
Pv	: Vapor pressure of the fluid
υ	: Velocity at the orifice (m/s).
L/h	: Liter per hour
V	: Total volume
E	: Energy
t	: time
hp	: horse power
ANOVA	: Analysis of Variance
US	: Ultrasound
SSF	: Simultaneous Saccharification and Fermentation
et al.	: And others
L*	: Lightness or darkness
a*	: Greenness or redness
b*	: Blueness or yellowness
AOAC	: Association of official analytical chemists
b*	: Blueness or yellowness
CBS	: Cocoa Bean Shell
et al.	: And others
FAO	: Food and Agricultural Organization

Fig	: Figure
g	: gram
g/cm3	: gram per centimeter cube
g/l	: gram per liter
HC	: Hydrodynamic Cavitation
m/s	: meter per second
MC	: Moisture Content
meq O_2/kg	: milli equivalent oxygen per kilogram
mg/l	: milligram per litre
Min	: Minute
ml	: milli litre
ml/min	: milli litre per minute
MS	: Mild Steel
Na_2S_2O	: Sodium thiosulphate
NaOH	: Sodium hydroxide
RSM	: Response Surface Methodology
SS	: Stainless Steel
TPC	: Total phenolic content
TSS	: Total soluble solids
VFR	: Volume Flow Rate