

# Contents

Abstract.....	i
Acknowledgement.....	iv
Acronym.....	vi
List of Figures.....	ix
List of Tables.....	xiii
List of Photographs.....	xv
Contents.....	xvi

## Chapter 1: Introduction

1.1 Tea .....	1
1.2 Overview of Assam Tea.....	1
1.3 Tea Processing Stages .....	5
1.3.1 Withering.....	7
1.3.2 Rolling & Cutting.....	9
1.3.3 Fermentation.....	10
1.3.4 Drying.....	10
1.3.5 Grading, Sorting and Packing.....	11
1.4 Effects on End Product.....	12
1.5 Basic Chemistry of Tea.....	16
1.6 Tea Quality Evaluation Technique.....	19
1.7 Analytical Methods of Quality Evaluation.....	20
1.7.1 Estimation of TF and TR (As Per ISO Specification).....	20
1.7.2 Detection and Analysis of TF and TR by Spectrophotometry...	20

1.7.3	Chromatographic Method for Determination of Chemical Composition of Tea.....	21
1.7.4	Colour Estimation.....	21
1.7.5	Determination of Caffeine Content by UV/Visible Spectrophotometer .....	22
1.7.6	Oxidation Test by Colorimetric Method.....	22
1.8	Conventional Method of Tea Tasting: Human Expert Judgment.....	22
1.9	Need of Smart Sensor in Tea Industries.....	24
1.10	Smart Sensors.....	25
1.11	Smart Sensor Network for Industrial Application.....	28
1.11.1	Highway Addressable Remote Transducer (HART).....	29
1.11.2	Interbus.....	29
1.11.3	Controller Area Network (CAN).....	30
1.11.4	Foundation Fieldbus.....	30
1.11.5	Profibus (Process Field Bus).....	30
1.12	Prospect of Soft Computing Application in Tea Industries.....	31
1.13	Review of Related Works.....	32
1.14	Research Objectives .....	34
1.15	Organization of the Thesis.....	35
	References.....	36

## **Chapter 2: Development of Instrumentation for Tea**

### **Process Parameters Monitoring**

2.1	Introduction.....	43
2.2	Overview of the System.....	44

2.3	Sensors.....	44
2.3.1	Sensing the Temperature.....	44
2.3.1.1	Thermocouple.....	44
2.3.1.2	LM35.....	47
2.3.2	Sensing the RH.....	47
2.4	Circuit Description.....	48
2.4.1	Microcontroller Based Measurement System.....	48
2.4.1.1	PIC18F452 Microcontroller.....	48
2.4.1.2	RS 485 Communication.....	50
2.4.2	Signal Conditioning Circuit.....	51
2.4.2.1	Thermocouple Signal Conditioning.....	51
2.5	Dryer Temperature Monitoring Sensor Node.....	52
2.5.1	Test of Signal Conditioning Circuit.....	53
2.6	Fermentation Room Monitoring Sensor Node.....	54
2.7	Firmware Development .....	55
2.8	Data Acquisition Software.....	56
2.9	Calibration and Analysis of the Sensor Nodes.....	57
2.9.1	Calibration of Fermentation Room Monitoring Sensor Node....	59
2.9.2	Calibration of Dryer Temperature Measurement Sensor Node...	62
2.10	Summary.....	65
	References.....	65

## **Chapter 3: Field Installation, Experience, Data Collection and Data Analysis**

3.1	Introduction.....	69
3.2	Overview of the Tea Factory Selected for Installation.....	70
3.3	Installation of the System in the Factory.....	71
3.4	Field Experience and Data Collection.....	73
	3.4.1 Pattern of Data for the Season 2013.....	73
	3.4.2 Pattern of Data for the Season 2014.....	76
	3.4.3 Pattern of Data for the Season 2015.....	78
3.5	Data Collection from Tea Taster.....	81
3.6	Summary.....	81

## **Chapter 4: Data Behaviour and Statistical Modeling Based on MLR**

4.1	Introduction.....	82
4.2	Data Behavior: PCA Technique.....	82
	4.2.1 Principal Component Analysis.....	83
	4.2.2 Data Visualisation .....	83
4.3	Statistical Approach for Predictive Model.....	85
	4.3.1 Multivariate Linear Regression Analysis .....	86
	4.3.2 Development of MLR Model.....	86
	4.3.3 Performance of MLR Model.....	87
4.4	Summary.....	88
	References.....	89

# **Chapter 5: Prediction of Tea Quality: A Soft Computing Approach**

5.1 Introduction .....	92
5.2 Artificial Neural Network.....	93
5.2.1 Background.....	93
5.2.2 Preliminaries.....	94
5.2.3 Multilayer Perceptron.....	96
1.3 Studies on Correlation between Process Parameters and OLR: A Basic Approach.....	97
5.3.1 Development and Training of ANN Model .....	97
5.3.2 Performance Study .....	102
5.3.3 Inference.....	103
5.4 Predictive Model Design: An Advanced Study.....	104
5.4.1 Development and Training Of NCV-ANN Model.....	104
5.4.2 Ten Fold Cross Validation (TFCV) Method.....	107
5.4.3 Performance of the TFCV-ANN Model .....	108
5.4.4 Inference.....	112
5.5 Summary .....	112
References.....	113

# **Chapter 6: Conclusion and Further Development**

6.1 Summary of the work.....	115
6.2 Conclusion.....	118
6.3 Future Work.....	119

List of Publications..... 120

Appendix A..... 123

Appendix B..... 125

Appendix C..... 127

Appendix D..... 130