# DRYING OF AROMATIC RICE IN FLUIDIZED BED DRYER FOLLOWED BY FIXED BED DRYER AND SUN DRYING METHOD

**A THESIS**

**BY**


## GOUTAM CHANDRA ROY

STUDENT ID: 1405196

SEMESTER: JULY – DECEMBER, 2015


**MASTER OF SCIENCE (MS)**
**IN**
**FOOD ENGINEERING AND TECHNOLOGY**



**DEPARTMENT OF FOOD ENGINEERING AND TECHNOLOGY**

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY

DINAJPUR-5200



JULY-DECEMBER, 2016

# DRYING OF AROMATIC RICE IN FLUIDIZED BED DRYER FOLLOWED BY FIXED BED DRYER AND SUN DRYING METHOD

**A THESIS**

**BY**


## GOUTAM CHANDRA ROY

STUDENT ID: 1405196

SEMESTER: JULY – DECEMBER, 2015


Submitted to the

Department of Food Engineering and Technology,

Hajee Mohammad Danesh Science and TechnologyUniversity, Dinajpur-5200

***In partial fulfillment of the requirements for the degree of***

**MASTER OF SCIENCE (MS)**
**IN**
**FOOD ENGINEERING AND TECHNOLOGY**


**DEPARTMENT OF FOOD ENGINEERING AND TECHNOLOGY**

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY

DINAJPUR-5200


JULY-DECEMBER, 2016

# DRYING OF AROMATIC RICE IN FLUIDIZED BED DRYER FOLLOWED BY FIXED BED DRYER AND SUN DRYING METHOD

**A THESIS**

**BY**


## GOUTAM CHANDRA ROY

STUDENT ID: 1405196

SEMESTER: JULY – DECEMBER, 2015


***Approved as to the style and contents by***

…….

**Dr. Md. Sazzat Hossain Sarker**
**Associate Professor**
**Supervisor**

…….

**Dr. Md. Ayub Hossain**
**Principal Scientific Officer**
Farm Machinery and Postharvest Process Engineering Division,
Bangladesh Agricultural Research Institute
**Co-supervisor**

…….

**Chairman of the Examination Committee**
**And**
**Chairman**


**DEPARTMENT OF FOOD ENGINEERING AND TECHNOLOGY**

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY

DINAJPUR-5200



JULY-DECEMBER, 2016


DEDICATED
TO MY
BELOVED PARENTS
AND
WELL WISHERS

## *ACKNOWLEDGEMENT*

*I express the deepest sense of gratefulness to the **"Almighty God" Who** has enabled me to complete the thesis work. I take this opportunity with pride and enormous gratification to express the feelings of thanks and gratefulness from the bottom of my heart to all the persons who backed me directly or indirectly throughout the materialization of this research work at this magnitude.*

*First and foremost, I deem it a rare opportunity to pronounce my deep sense of gratitude to the tutelary **Dr. Md. Sazzat Hossain Sarker, Associate Professor and Chairman**, Department of Food Engineering and Technology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, for his exemplary guidance, which enabled my research efforts to come in shape with meaningful conclusions. His concern and endearing demeanor always encouraged me enthusiasm in research, which otherwise bound to be lackadaisical. His keen interest in my research progress would have been unrequited if I had not heed his remarks of excellence.*

*With great pleasure I thank Co-supervisor, **Dr. Md. Ayub Hossain, Principal Scientific Officer,** Farm Machinery and Postharvest Process Engineering Division, Bangladesh Agricultural Research Institute, Gazipur-1701, for his valuable advice, exclusive suggestions and provisions of facilities and supports needed to complete this research work.*

*The author expresses especially grateful to **Dr. Md. Abdur Rahman, Dr. A K M Saiful Islam** and **Dr. Golam Kibria**, Farm Machinery amd Post Harvest Technology Division and to the staff of Bangladesh Rice Research Institute, Gazipur, for their limitless help in milling the dried samples in their laboratory. The author also thanks to the staff of the Department of Food Engineering and Technology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur for coordination and helping to my research work.*

*It is an incontrovertible fact that the help I received from and I owe my special thanks to Md. Abdus Samad, Principal, Uttaran Polytechnique Institute, Kalitola, Dinajpur and Technicians, Uttaran Engineering Workshop, Dinajpur for their excellent service during research period.*

*Above all I would like to acknowledge my Beloved Parents, brother, sister, for vital and moral support without which this effort of mine would have not paid off.*

***The Author***

# ABSTRACT

Drying and management of aromatic rice (*Oryza sativa L.*) are important issues because of its increased demand in Bangladesh. Feasibility of two-stage drying of aromatic rice (locally known as *Chinigura*) and the effects of the drying technique on milling quality were investigated. The milling quality of dried aromatic rice was compared with existing industrial milling results where Louisiana State University (LSU) dryer was used. A laboratory fluidized bed dryer was used for the first stage drying to reduce the initial high moisture content of 22-24% (wb) to 18-19% (wb). A fixed bed dryer and sun drying method were used for the second stage drying for further drying of paddy up to the milling level of 14% (wb) or less. The thicknesses in fluidized bed drying were 8 cm, 10 cm and 12 cm. Three drying air temperatures of 65°C, 85°C and 100°C were applied for each bed thickness. The fixed bed dryer was operated at the temperature of $40^0$C and fixed bed thickness of 30 cm. The tempering of paddy was done at product's temperature in a closed container for 30 minutes of each dried samples after first stage drying in the fluidized bed dryer. Shorter drying time (4.33 to 4.67 hr) required in application of the two stage drying technique contrast to drying time needed by industrial method (10-12 hours).

Two stage drying employing fluidized bed drying and sun drying yielded to 0.6% to 17.35% higher head rice yield than existing industrial drying method. On the other hand, two stage drying with fluidized bed dryer followed by fixed bed dryer gave 4.45% to 14.2% higher head rice yield than industrial drying method. The bed thickness and drying temperature had significant effect on the quality of aromatic rice. On the other hand, milling recovery, whiteness in terms of lightness (L*) and aroma of dried aromatic rice samples were insignificantly varried for all tested samples. Therefore, two-stage drying technique equipped with fluidized bed dryer may be recommended for drying of aromatic rice to save drying time as well as energy.

# CONTENTS


| | | PAGE |
|---|---|---|
| **ACKNOWLEDGEMENT** | | I |
| **ABSTRACT** | | II |
| **CONTENTS** | | III |
| **LIST OF TABLES** | | VI |
| **LIST OF FIGURES** | | VII |
| **LIST OF APPENDICES** | | IX |
| **LIST OF ABBREVIATIONS** | | X |
| **CHAPTER** | | |
| **I** | **INTRODUCTION** | **1-4** |
| | 1.1 Background of aromatic rice drying | 1 |
| | 1.2 Two–stage drying of aromatic rice | 2 |
| | 1.3 Problems statement | 3 |
| | 1.4 General objectives | 4 |
| | 1.5 Specific objectives | 4 |
| | 1.6 Organization of the thesis | 4 |
| **II** | **REVIEW OF LITERATURE** | **5-22** |
| | 2.1 Introduction | 5 |
| | 2.2 Overview of aromatic rice | 5 |
| | 2.2.1 Origin of aromatic rice | 5 |
| | 2.2.2 Importance of aromatic rice | 5 |
| | 2.3 Principles of grain drying | 6 |
| | 2.4 Rice drying methods and dryer types | 7 |
| | 2.4.1 Overview of drying methods | 7 |
| | 2.4.2 Overview of different types of grain dryer | 8 |
| | 2.4.2.1 Batch dryers | 8 |
| | 2.4.2.2 Continuous- flow dryers | 8 |
| | 2.4.2.3 LSU dryer | 9 |
| | 2.4.2.4 Fluidized bed dryer or flash dryer | 10 |
| | 2.5 Options for heated air drying of rice | 11 |
| | 2.5.1 Two stage drying of rice | 11 |
| | 2.5.2 High temperature drying of rice | 14 |

2.6 Drying of aromatic rice 16
2.7 Drying methods and quality aspects of aromatic rice 18
2.7.1 Milling and head-rice recovery 19
2.7.1.1 Milling recovery 20
2.7.1.2 Head rice recovery 20
2.8 Sensory characteristics of aromatic rice 20
2.8.1 Aroma 20
2.9 Evaluation of drying method 21
**III MATERIALS AND METHODS 23-37**
3.1 Baseline survey and data collection 23
3.2 Determination of the bulk density of aromatic rice 23
3.3 Design considerations for fabrication of a laboratory scale fluidized bed dryer 23
3.4 Design calculation for fabrication of the dryer 24
3.4.1 Design calculation for fluidized bed dryer 24
3.4.1.1 Drying chamber 24
3.4.1.2 Hold-up mass calculation 25
3.4.1.3 Calculation of open area of air distributor 25
3.4.1.4 Air flow rate 27
3.4.1.5 Pressure drop in fluidization 27
3.4.1.6 Calculation of blower power 28
3.4.1.7 Calculation of heater power 28
3.4.1.8 Final assembly of the fluidized bed dryer 28
3.4.2 Fabrication of a fixed bed dryer 30
3.5 Collection of samples 31
3.5.1 Cleaning of samples 31
3.5.2 Moisture content determination 31
3.6 Control sample drying 32
3.7 Drying experiment 32
3.7.1 First stage drying 32
3.7.1.1 Experimental design for fluidized bed drying 33
3.7.2 Second stage drying 33
3.7.2.1 Experimental condition for fixed bed drying 33
3.7.2.2 Experimental condition for sun drying 33
3.8 Milling of dried sample 33

3.9 Quality determination of dried sample 34
3.9.1 Milling recovery 35
3.9.2 Head rice yield 35
3.9.3 Broken rice percentage 35
3.9.4 Color measurement 35
3.10 Sensory evaluation for aroma 36
3.11 Statistical analysis 37
**IV RESULTS AND DISCUSSION 38-54**
4.1 Status of existing drying in Bangladesh 38
4.2 Drying characteristics during drying of control sample 39
4.3 Two stage drying by fluidized bed drying and sun drying 39
4.3.1 First stage drying by fluidized bed dryer 39
4.3.2 Second stage drying of paddy by sun drying 40
4.3.3 Second stage drying of paddy by fixed bed drying 42
4.4 Quality of dried sample 47
4.4.1 Effect of bed thickness and drying temperature of fluidized bed dryer on quality parameters of dried sample 47
4.4.2 Effect of drying methods on quality characteristics of dried sample 50
4.4.3 Comparison of head rice yield of aromatic rice obtained from industrial, control sample drying and two options of two stage drying 52
4.4.4 Color assessment 54
4.5 Sensory evaluation of aroma 55
**V CONCLUSIONS 56**
**REFERENCES 57-62**
**LIST OF APPENDICES 63-69**

# LIST OF TABLES


| TABLE | TITLE | PAGE |
|---|---|---|
| 2.1 | Different types of drying methods with their advantages and disadvantages | 7 |
| 4.1 | Status of rice (*Chinigura* rice, un-parboiled) drying and milling of rice mills in Dinajpur district | 38 |
| 4.2 | Effect of bed thickness and drying temperature on drying time during the first stage drying of aromatic rice by fluidized bed dryer | 40 |
| 4.3 | The experimental condition in the second stage drying by sun drying | 41 |
| 4.4 | Analysis of variance (ANOVA) indicating the effect of temperature and bed thickness on differnt quality of dried rice | 48 |
| 4.5 | Effect of bed thickness and drying temperature of fluidized bed dryer on various quality attributes | 49 |
| 4.6 | Comparison of quality parameters of aromatic rice obtained from industrial, control sample drying and different two stage drying by FBD and sun drying method | 50 |
| 4.7 | Comparison of quality parameters of aromatic rice obtained from industrial, control sample drying and different two stage drying by FBD and fixed bed drying method | 51 |
| 4.8 | Color assessment of polished aromatic rice samples from paddy dried by industrial, control and two stage drying by fluidized bed dryer (FBD) and sun drying | 54 |
| 4.9 | Color assessment of polished aromatic rice samples from paddy dried by industrial, control and two stage drying by FBD and fixed bed drying | 54 |
| 4.10 | Effect of drying method on aroma of cooked aromatic rice sample | 55 |

# LIST OF FIGURES


| FIGURE | TITLE | PAGE |
|---|---|---|
| 2.1 | A batch type (Flat bed) grain dryer | 8 |
| 2.2 | (A) Non-mixing and (B) mixing type columnar dryer | 9 |
| 2.3 | Pattern of air and rice flow in a LSU dryer | 10 |
| 2.4 | Schematic diagram of a fluidized bed dryer | 11 |
| 2.5 | Schematics of fixed bed and fluidized bed grain dryers | 14 |
| 3.1 | Schematic view of air distributor | 26 |
| 3.2 | Digital anemometer (Model: TA430, UK) | 27 |
| 3.3 | Schematic diagram of experimental fluidized bed dryer | 29 |
| 3.4 | Photographic view of the fluidized bed dryer | 30 |
| 3.5 | Photographic view of an experimental fixed bed dryer | 31 |
| 3.6 | A digital grain moisture meter (GMK 303 RS) | 32 |
| 3.7 | A laboratory scale paddy de-husker | 34 |
| 3.8 | A laboratory scale polisher | 34 |
| 3.9 | Photographic view of a mono Chroma meter (CR 400, Japan) for color measurement | 36 |
| 3.10 | CIE (Lab) chromaticity | 36 |
| 4.1 | Drying curve during drying of rice in open sun drying | 39 |
| 4.2 | Drying curve of aromatic rice in the second stage drying (sun drying) | 41 |
| 4.3 (a) | Drying curve during fixed bed drying at 30 cm bed thickness, drying temperature $40\pm3^0$C and air velocity 0.59 $ms^{-1}$ after drying in fluidized bed dryer at 8 cm bed thickness and drying temperature $100^0$C | 42 |
| 4.3 (b) | Drying curve during fixed bed drying at 30 cm bed thickness, drying temperature $40\pm3^0$C and air velocity 0.59 $ms^{-1}$ after drying in fluidized bed dryer at 10 cm bed thickness and drying temperature $100^0$C | 42 |
| 4.3 (c) | Drying curve during fixed bed drying at 30 cm bed thickness, drying temperature $40\pm3^0$C and air velocity 0.59 $ms^{-1}$ after drying in fluidized bed dryer at 12 cm bed thickness and drying temperature $100^0$C | 43 |
| 4.3 (d) | Drying curve during fixed bed drying at 30 cm bed thickness, drying temperature $40\pm3^0$C and air velocity 0.59 $ms^{-1}$ after drying in fluidized bed dryer at 8 cm bed thickness and drying temperature $85^0$C | 43 |
| 4.3 (e) | Drying curve during fixed bed drying at 30 cm bed thickness, drying temperature $40\pm3^0$C and air velocity 0.59 $ms^{-1}$ after drying in fluidized bed dryer at 10 cm bed thickness and drying temperature $85^0$C | 44 |

| FIGURE | TITLE | PAGE |
|---|---|---|
| 4.3 (f) | Drying curve during fixed bed drying at 30 cm bed thickness, drying temperature 40±3$^0$C and air velocity 0.59 ms$^{-1}$ after drying in fluidized bed dryer at 12 cm bed thickness and drying temperature 85$^0$C | 44 |
| 4.3 (g) | Drying curve during fixed bed drying at 30 cm bed thickness, drying temperature 40±3$^0$C and air velocity 0.59 ms$^{-1}$ after drying in fluidized bed dryer at 8 cm bed thickness and drying temperature 65$^0$C | 45 |
| 4.3 (h) | Drying curve during fixed bed drying at 30 cm bed thickness, drying temperature 40±3$^0$C and air velocity 0.59 ms$^{-1}$ after drying in fluidized bed dryer at 10 cm bed thickness and drying temperature 65$^0$C | 45 |
| 4.3 (i) | Drying curve during fixed bed drying at 30 cm bed thickness, drying temperature 40±3$^0$C and air velocity 0.59 ms$^{-1}$ after drying in fluidized bed dryer at 12 cm bed thickness and drying temperature 65$^0$C | 46 |
| 4.4 | Comparison of head rice yield of aromatic rice obtained from industrial, control sample drying and different two stage drying by FBD and sun drying method | 52 |
| 4.5 | Comparison of head rice yield of aromatic rice obtained from industrial, control sample drying and different two stage drying by FBD and fixed bed drying method | 53 |

# LIST OF APPENDICES


| APPENDIX | TITLE | PAGE |
|---|---|---|
| 1.1 | Physico-chemical properties of some fine and aromatic rice of Bangladesh | 63 |
| 1.2 | Questionnaire for field data collection for the evaluation of the existing aromatic rice drying systems in Bangladesh | 64 |
| 1.3 | Single factor Analysis of variance (ANOVA) | 65 |
| 1.4 | Two factor Analysis of variance (ANOVA) | 66 |
| 1.5 | Rating score for aroma of cooked aromatic rice | 68 |
| 1.6 | Single factor analysis of variance (ANOVA) for aroma | 69 |

## LIST OF ABBREVIATIONS

| | |
|---|---|
| AOAC | Association of Official Agricultural Chemists |
| ASAE | American Society of Association Executives |
| BRRI | Bangladesh Rice Research Institute |
| BARI | Bangladesh Agricultural Research Institute |
| BRF | Bangladesh Rice Foundation |
| db | Dry Basis |
| EMC | Equilibrium Moisture Content |
| FPMU | Food Planning and Monitoring Unit |
| FMC | Final Moisture Content |
| FBD | Fluidized Bed Dryer |
| FD | Fixed Bed Dryer |
| HSTU | Hajee Mohammad Danesh Science and Technology University |
| HRY | Head Rice Yield |
| IRRI | International Rice Research Institute |
| IMC | Initial Moisture Content |
| LSU | Louisiana State University |
| MC | Moisture Content |
| MT | Metric Ton |
| min | Minute |
| RH | Relative Humidity |
| SPEC | Specific Energy Consumption |
| wb | Wet Basis |
| *et al.* | and others |
| $^0$C | Degree centigrade |
| % | Percentage |
| g | Gravitational acceleration |
| kWh | Kilowatt-hour |
| cm | Centimeter |
| m | Meter |