CHANGES IN THE PROPERTIES OF RICE DURING STORAGE

- Quality change due to aging
- Rice aging: changes in physico-chemical and organoleptic characteristics
  - Ex: cooking, processing, nutritional qualities and commercial value
- Effectiveness is either deteriorative or desirable
- Desirable:
  - Fresh rice poor in quality
  - Less suitable for processing

- Rice aging time:
  - Min. 3 – 4 months of storage
  - Max. 6 -10 months of storage

Changes in Chemical Composition

- Chemical changes: bran or outer layer
- Outer most layer → 0.1 mm
  - High sugars, free AA, protein, FFA and enzyme
- Total N: not change - milled rice during common storage
- Total fat: constant during common storage @ different MC and temperature
- Oxidative rancidity high in milled rice
- Fatty acid index
  - Increase with temperature and MC

Nutritional compositions of four paddy varieties initially and after 9 months of storage in polybag and IRRI-bag

- Rice freshness:
  - High respiration enzyme activity indicate by Guaiacol + H₂O₂ treatment
    - Reddish-brown colour → fresh grain
    - No colour change → old rice
- Vitamin may losses during adverse storage
  - e.g: Thiamine, Riboflavin, Nicin = 3 -30% loss

Changes in physico-chemical properties

- Cooking Properties:
  - Storage → increased WAR
  - WAR during cooking @ storage temperature
- Older rice:
  - High WAR and less soluble solid storage @ ambient condition at 25 °C - 35 °C
- Gelatinisation characteristics:
  - Change during storage of milled rice
  - Older rice
    - Higher viscosity → high temp. Storage
    - Peak viscosity → Chang with high MC and long storage

Changes in Organoleptic Properties

- Colour and Odour
Colour rather stable during storage
Odour change rapidly during storage

- Cooking qualities
  - Fresh rice: poor in cooking qualities
  - Pasty mass
  - Swell less
  - Thick sticky gruel
  - Less expand
  - Grains burst lengthwise etc.

**FUNDAMENTALS OF PARBOILING**

> 70% of Sri Lankan consume as parboiled form

“Parboiling is partial boiling or cooking of rice within the husk and it is hydrothermal pre-treatment to the threshed paddy”

Steeping → Cooking/ Steaming → Drying (Hot/ ambient)

**CHARACTERISTICS OF PARBOILED RICE**

1. Removal of husk is easier
2. High % of head rice yield
3. Increases test wt and hardness
4. Translucent with glossy surface
5. Reduce the moisture absorption characteristics
6. Minimized cracking
7. Resistant to insect pests damage
8. Higher % of water-soluble vitamins
9. High retention of AAs after milling
10. Low nutrient loss during cooking
11. Better digestibility
12. Enzymes get completely inactivate
13. Problem: Smell, colour and MOs

**CHANGES DURING PARBOILING**

**Chemical changes**
Composition and properties changing during parboiling
- Soaking absorb water and SG swells
- SGs get gelatinized to certain extend

![Graph showing swelling ratio vs. soaking time at 50°C and 70°C](image-url)
Nutritional changes

- Increase dextrin content will increased
- Diffusion of water soluble vitamins
- Minerals diffusion from outer layers into the endosperm
- Diffusion of Vitamin B

Soaking of paddy:
- Diffusion of oil from grain/germ ➔ bran layer
- Parboiled bran contain more oil than raw rice

Physical Changes

1. Translucency and Hardness

- Kernel more translucent
  - Disrupt the protein bodies
  - Expand and fill the air space
- Disappearance of white belly
- Harder texture:
  - High adhesion/cohesion between SG-SG and SG-protein bodies
  - SG-SG adhesion ➔ low starch solubility @ cooking

2. Changes in Milling

- High head rice yield or low breakage
- Realignment and cementing of cracks and immature

Soaking time and Temperature

Optimal soaking Time depends on soaking Temperature ➔ Judged by white belly @ specific MC
Under/Over-soaking ➔ increase brakeage

Steaming on milling yield

Increases head rice yield
Better milling performance

Effect of bran removal

- Faster and better polishing
  - At 3% degree of polishing ➔ PR losses 80% surface bran colour
  - Raw R losses 70% surface bran colour

3. Grain Colour

- Disadvantage of PR: yellow colour kernels
- High steeping time and temp ➔ lower the whiteness
- Colour affected due to enzyme activity and pH of soaking H₂O
Causes colour change

- Diffusion of husk pigment into endosperm
- Structural alteration of SG → different light refraction
- Oxidation and polymerization of spread fats substances
- Maillards’ Browning

CHANGES IN ORGANOLEPTIC PROPERTIES
Flavour and Aroma

- PR has characteristic flavour and aroma
  1. Hydrolysis and decomposition of CHO, Protein
  2. S-AA → produce mercaptans

Cooking properties

1. Time to cook
2. Increase of volume
3. Consistency
4. Loss of SS

Heat alteration value

- Cohesive characteristics of rice when cooked
- Microscopic observation of SG @ 62 °C

Water uptake

- Hydration characteristics of rice
- Depends on gelatinization temperature, ε%
- Methods
  Cooking @ 60 °C for 2h – evaluation Raw R → PR
  Cooking @ 96 °C for 2h – evaluation of PRs

Sedimentation value

- Relation to water uptake
- Measure insoluble solid lost @ specific temp.
- Sedimentation value of PR = ¼ raw R

Iodine-blue value

- Correlation with total amylose and cooking behaviour
- Starch-I₂-blue soluble: estimate the degree of PR

Alkali spreading and cleaning

- Kernels immersed in dil. KOH (1.7%) at temperature -24 h
- Evaluate the spreading and transparency
- Rank them 1-7
- Extent of degradation α 1/ gelatinization temp.
  High GT → rank 2 = > 74 °C
  Intermediate GT → rank 3-5 = 70 – 74 °C
  Low GT → rank 6-7 = < 70 °C
**Gel Consistency**

Get an idea about total amylose content
Rice flour + bromothymol blue + 0.2 M KOH
Vortex ➔ heat in H₂O bath ➔ vortex ➔ cooled in ice
Measured the length of gel

<table>
<thead>
<tr>
<th>Consistency</th>
<th>Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft</td>
<td>61 - 100</td>
</tr>
<tr>
<td>Medium</td>
<td>41 – 60</td>
</tr>
<tr>
<td>Hard</td>
<td>26 – 40</td>
</tr>
</tbody>
</table>

Degree of milling has an effect

**SOAKING**

Moisture absorption = \( f \) (soaking time, soaking temp.)
Rate of MC absorption \( \propto \) soaking temp. (max. 80 °C)

- Soaking has 3 distinct patterns – depends on temp.
  1. Ambient – 60 °C ➔ rate of absorption is slow
  2. Temp. > 70 °C ➔ Moisture absorption high
  3. Transitional temp 65 – 70 °C

**Low Temperature Soaking:**
- Room temp. to 60 °C ➔ under parboil rice
- Soaking time 50–72 h ➔ low Gel ➔ high broken
- MC ➔ 30% ➔ unpleasant odour
- Soaking time ➔ high enz., activity, fermentation
- 40 °C not suitable ➔ high MO activity
- White belly

**Soaking at 60 – 70 °C**
Temp. @ the limit of Gelatinisation Temp.
  - Faster absorption of water
  - Soaking time is low

**Hot Soaking**
Soaking temp. > GT ➔ undesirable
Splitting of husk ➔ MC 55% (db) @ > 65 °C
Extensive swelling of kernels ➔ Bursting the grain
Leaching out of solids
Soaking temperature ≤ GT (GT of rice 60-70 °C)

Steam Treatment

- Well-soaked paddy = 40 - 45 % dry basis
- Paddy heated up to 100 - 105 °C → steam at ambient P or higher P
- Purpose: Gelatinization @ 5 – 10 min Quickly increase MC by 5 - 10%
  Reduce loss of soluble starch and Vit.
- Problem: localized over heating OR under heating
- Steaming: Open vessel ambient steaming; Higher pressure closed vessel

PARBOILING PROCESSES

(a) Traditional Parboiling
  1. Steeping (Soaking) paddy in water
  2. Cooking/ steaming of the steeped paddy
  3. Drying

(b) Home-scale Method
Steeping and cooking
  Use earthenware pots, Iron or brass vessel
  Cooking until the paddy- soft, swollen and split

(c) Large-scale Method

1. Single boiling Process

   Raw paddy soak at room temperate @ Cement tank
   Short grain – 24 h, Long grin - 48 h, Old -72 h
   In general soaking time: 2 – 3 days
   Wet paddy steamed @ 15-30 min.
   Short paddy: 15min  Long paddy: 20 – 30 min.
   Injection of steam in steel – from boiler
   Longer soaking caused fermentation → bad odour
   Solar drying

2. Double boiling Process
Soaking paddy in 50 °C H₂O: reduce soaking time
1. Soak in pre-heated (60 °C) water
2. Paddy is steam @ 95 °C and soak in room T H₂O
Soaked paddy is steamed
Sun drying

Drawbacks of Traditional method

Off-flavour development – starch fermentation during long soaking (after 18 h)
Brown colour due to fungus and impurities
High breakage

Modern Process
1. Cleaning and grading
2. Parboiling
3. Drying
4. Tempering
5. Milling
6. Packaging
7. Storage

Soaking @ 60 - 75 °C by hot water or steam passes through the soaking tanks
Soaking time 3 - 4 h
Parboiled in the same tank @ 1-2 atm steam
Mechanical drying

Modern Parboiling Systems and Plants

1. Avorio process – Italian
   Fully mechanized system
   Mechanically submerge in hot water for soaking
   Autoclaves in a rotating perforated cylinders
   Cooking time 15 - 20 min.
   Mechanical column drying: 45 – 50 °C
   Amber colour products

2. Crystallo process - Italian
   Paddy cleaned with cold water
   Vacuum soaked and then hydrostatic P @ contr. T
   Autoclave @ GT
   Drying under vacuum

3. Rice conversion process – UK
   Cleaned and wet the paddy
   Autoclaved 10 min for deaeration
   Soaked @ 75 – 85 °C under 5 - 7 kg/cm² pressure ➔ soaking time < 3 h
   Water remove under partial vacuum and heat
   Steaming: rotary autoclave
   Yellow colour rice

4. Rice growers Asso. California process – USA
   ➔ Soaking @ 40 °C for 10 h
   ➔ Steaming time 3 min. @ 5 kg/cm²

5. Malck process – USA

6. Fernandes process - USA
7. **CFTRI process – India**
   - Semi-automated system
   - Soaking: hot water @ 70 °C for 5 h
   - Steaming in steam tank: 5 - 10 min

8. **Jadavpur University process – India**
   - Similar to CFTRI but mechanized

### DRYING

#### I. INTRODUCTION

- Paddy is harvested @ 20% MC > safe storage levels
- Usual drying process:
  - Outer layers dry faster than the inside ➔ developed internal stresses
  - If moisture is removed quickly ➔ cracks
- Optimum harvest time
  - Highest head yields: harvested 20% MC
- Effect of time of harvesting on grain MC and yield

**Preharvest Chemical Drying**
- Preharvest chemical desiccants ➔ speedup drying in the field
- Sodium chlorate + Magnesium chlorate ➔ applied as sprays @ 20-27% MC
- Reducing the MC ≈ 1% day⁻¹ depends on RH
- But reduce the milling yield
- Germination was unaffected

**Sun Drying**
- Threshed grains are dried on drying yard: 2-3 cm thick layer
- Grains are continuously mix by manually

**Disadvantage of Sun Drying**
- Sun-drying is uncontrolled process
  - Non-uniform drying ➔ Cracks ➔ Low head rice yield
- Depend on whether condition
- Take long time to achieve complete drying

**Advantage of Mechanical Drying**
- No influence by weather
- High rice recovery: even after early harvest
- Temperature can be controlled
- No-off-flavour and off-colour development

#### Drying-Rate Computation

- Drying rate:
  - Air T and RH%
  - Airflow rate
  - Rice MC and temperature
  - Moisture distribution within rice kernel

- Rice grain type and variety
- Drying depth
- Resident time of rice in drier

#### Drying Methods

- Natural convection and forced convection airflow system
- Forced-air driers may use either unheated (natural) air or heated air
- Energy: Hot air, IR, Dielectric heating etc.
Drying of Parboiled Paddy

- MC of parboiled rice > 55 °C
- Textural change due to gelatinisation
- Drying of parboiled rice starts during steaming
- Husk of parboiled rice split to some extent
- Developed MC gradient → surface and the centre
- Produce stress → on cooling → irreversible crack
- Controls moisture gradient → control cracks

1. **Tempering**
   - Two passes drying
   - Damage starts about MC 16%
   - When MC of paddy ≈ MC 17% stop drying
   - Tempering - moisture distributes evenly
   - Dry again

2. **Conditioning**
   - Keep paddy hot after drying
   - Hot storage intervals
   - Condition time about ≈ 2 h

Method of drying
1. High or medium temperature air
2. Cooling before drying
   - Parboiled rice cool before drying < 60 °C
   - Stop gelatinisation
   - Use high or medium temp. air drying
3. Vacuum drying – remove off-flavour
4. Tempering during drying / Conditioning after drying

Drying temperature should enhance the gelatinization of rice

**Types of dyers**

1. Bin Dryer
2. Vertical Column dryer
3. Rotary Dryer