UNIT 3 PARBOILING PRINCIPLES AND PRACTICES

Structure

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3.0 OBJECTIVES

After reading this unit, you should be able to explain:

- main unit operations in paddy parboiling process;
- effect of process variables on physico-chemical and nutritional changes in rice;
- various methods for making parboiled rice; and
- changes in nutrition of the product.

3.1 INTRODUCTION

Rice is one of the staple foods to the majority of Indian population. It is obtained from paddy by milling which removes the hull and bran. During milling, considerable amount

of breakage of kernel occurs. To withstand the pressure exerted during dehusking and whitening, the kernel may be hardened by a conditioning technique known as parboiling.

Parboiling of rice originated in ancient India and is still popular in the region. It is also being practiced in Bangladesh, Pakistan, Sri Lanka, Burma, Malaysia, Thailand, Italy, Spain, Uruguay, Brazil, France and United States. About 20% of the paddy produced worldwide and more than 50% of paddy produced in South Asia is parboiled. About 50% of the total rice production in India is parboiled, predominantly in Kerala, Tamilnadu, Orissa, Assam, Bihar, Andhra Pradesh and West Bengal states. Parboiled rice is also eaten in Punjab, UttarPradesh, MadhyaPradesh, Maharastra, Gujarat and Karnataka. Thus, Parboiling is one of the most widespread food industries in the world.

Parboiling is essentially cooking rice in paddy form. The process consists of giving a hydrothermal treatment to the threshed paddy followed by drying to bring the moisture content back to an optimum level for milling and storage.

The process therefore is divided into three separate operations:

1) soaking or steeping of paddy

2) heat treatment to raise the temperature of wet grains beyond the gelatinization temperature, and

3) drying of grains to 14% moisture content

The most suitable change brought by water and heat is gelatinization of starch and disintegration of protein bodies in the endosperm which expands to fill all the gaps and pressing the starch granules together thus sealing all cracks and abnormalities in the grain. Therefore parboiling is a potential method of preserving the lodged and water soaked paddy crop which would have broken and become powder completely if milled in raw state.

Check Your Progress 1

Note: a) Use space given below for your answers.
b) Check your answers with those given at the end of the unit.

1. Describe the paddy parboiling process?

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2. What are the main unit operations in paddy parboiling?

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3. What are the changes which occur during paddy parboiling process?

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3.2 HYDRATION CHARACTERISTICS

3.2.1 Soaking of Paddy

The process of water absorption is known as soaking, steeping or imbibation. It is a diffusion process. As a result of water absorption the paddy swells. The water moves inside the paddy as long as the water vapour pressure inside the grain is less than that of soak water and stops moving when equilibration is reached. Soaking is the result of molecular absorption, capillary absorption and hydration. The volume of paddy increases due to soaking. But the volume of soaked paddy is always less than the sum of the initial volume of paddy and the volume of water absorbed. The soaking process is always accompanied by release of heat. Soaking is done to provide the starch with a quantity of water sufficient for gelatinization. The rate of soaking is also dependent on temperature of soaking. The Figure 3.1 showing the effect of moisture absorption at different temperatures also known as soaking curves.

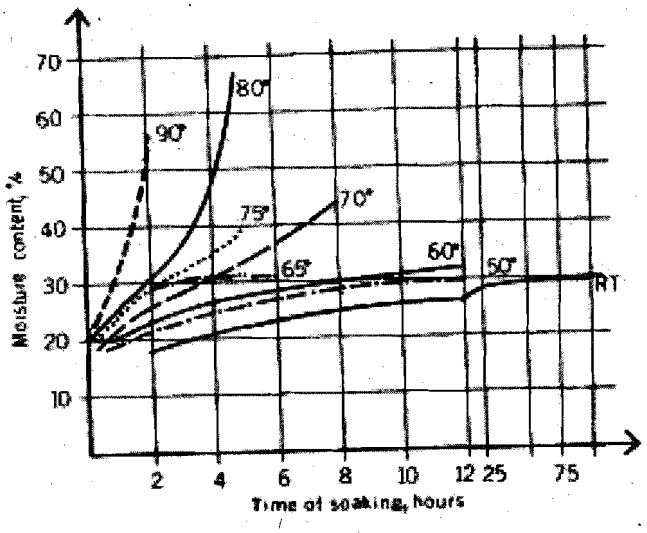

Fig. 3.1 Soaking curves for different temperatures

The rate of soaking is high initially but it decreases with time until bursting of the grain takes place when the soaking rate increases particularly at the gelatinization temperature and higher. Soaking time and temperature relationship for steeping of paddy is given in Table 3.1.

Table 3.1: Soaking time and temperature relationship of paddy

Temperature of paddy water mixture °C	Room temperature 20-30 °C	40 °C	50°C	60 °C	70 °C	72 °C
Optimum duration of soaking, hours	36-48	12	8	6	4	3.5
Average moisture content of soaked paddy	25%	27%	28%	30%	32%	35%

3.2.2 Soaking Methods

3.2.2.1 Soaking in Cold Water

Paddy soaking at low temperature (below 40 °C) requires longer soaking time which causes loss of vitamins, salts, and albumin from paddy into the water. These substances together with organic impurities form suspensions which decompose and cause putrid fermentation resulting in production of toxic substances and foul smell which are absorbed by rice kernel. Treated in this manner, the resultant rice can only be eaten by those

accustomed to its characteristics smell and taste. Longer soaking duration at low temperature is also responsible for loss of edible solid matter under the action of micro-organisms. The smell and losses can be controlled by either bubbling air through paddy water mixture during soaking or mixing small quantities of oxygen donating compounds (such as sodium chromate).

3.2.2.2 Soaking in Hot Water

Soaking paddy in hot water eliminates all the drawbacks of cold water soaking and reduces the time of soaking significantly (table 3.1). However, soaking at high temperatures induces the reaction of amino acids and sugars resulting in browning or yellowing rice grain (Maillard reaction) which is further increased during steaming of paddy. Therefore it has been seen that parboiled rice produced by hot soaking at elevated temperature has relatively darker colour than rice produced by cold soaking. Another major consideration while adopting hot soaking of paddy is use of steam or other fuels for maintaining the temperature of paddy water mixture at 70 °C for 3.5 to 4 hours about 200 kg of dry saturated steam at 4 atmospheric pressure is required, making the parboiling process as an energy-intensive process. Hot soaking is responsible for high energy consumption (200 kg of steam) than steaming itself which requires only 60 kg of steam per tonne of paddy for gelatinization.

Another important consideration in hot soaking process is the slower rate of cooking of resultant rice in comparison to the rice produced by cold soaking under optimum steaming conditions. In view of these facts soaking of paddy between 50-60 °C for 12 to 15 hours seems to be a better alternative. Alternatively for hot soaking, temperature of water is initially raised to 95-97 °C (near boiling) and cold paddy is dumped in it bringing mixture temperature to 70 °C. This mixture is soaked for 10-12 horus without any further heating of water or the paddy water mixture. Insulation of soaking tank may further decrease the heat loss and thereby the soaking time to about 8 hours.

3.2.2.3 Soaking Under High Pneumatic Pressure

Moisture content of paddy can be very rapidly increased by increasing the pressure in the soaking tank to 0.5 to 1.0 atmospheric pressure. Under these conditions soaking of paddy at 60-65 °C temperature can be completed in 30 minutes to 45 minutes.

3.2.3.4 Vapour Phase Soaking

Moisture content of paddy can also be increased very rapidly by treating paddy with steam under 0.3 to 0.5 atmosphere gauge pressure in a pressure vessel. Paddy can be soaked in 30 minutes to 45 minutes.

Check Your Progress 2

Note: a) Use space given below for your answers.
b) Check your answers with those given at the end of the unit.

1. Describe the soaking process?

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2. What are the methods of soaking?

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3. What are the disadvantages of cold water soaking?

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4. What are the advantages of hot water soaking?

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5. What is the advantage of pneumatic pressure soaking?

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6. Describe vapour phase soaking?

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3.3 GELATINIZATION TEMPERATURE

Rice has one of the smallest starch granules of the cereal starches, varying ink size from 3 to 10 μm in the mature grain. Mean granule size varies from 4 to 6 μm. Starch granules of rice are compound, and they are polyhedral or pentagonal dodecahedron. As with other starches, waxy starch granules tend to have lower density than non-waxy granules. Commercial form of starch is composed of starch grains or granules with most of the moisture removed. It is insoluble in water. When put in cold water, the grains may absorb a small amount of the liquid. Up to 60 to 70 °C, the swelling is reversible, the degree of reversibility being dependent upon the particular starch. With higher temperatures in irreversible swelling called gelatinization begins.

Starch begins to gelatinize between 60 and 70 °C, the exact temperature dependent on the specific starch. For example, different starches exhibit different granular densities, which affect the ease with which these granules can absorb water. Since loss of birefringence occurs at the time of initial rapid gelatinization (swelling of the granule), loss of birefringence is a good indicator of the initial gelatinization temperature of a given starch. The largest granules, which are usually less compact, begin to swell first. Once optimum gelatinization of the grains has occurred, unnecessary agitation may fragment the swollen starch grains and cause thinning of the paste.

The gelatinization range refers to the temperature range over which all the granules are fully swollen irreversibly. This range is different for different starches. However, one can often observe this gelatinization because it is usually evidence by increased translucency and increased viscosity. This is due to water being absorbed away from the liquid phase into the starch granule. Time required for cooking is determined by the gelatinization temperature. Environmental conditions such as temperature during grain ripening influence gelatinization temperature. A high ambient temperature during grain development results in a starch with higher gelatinization temperature. The gelatinization temperature of rice varieties classified as low (55 to 69 °C), intermediate (70 to 74 °C), and (75 to 79 °C).

Gelatinization temperature is estimated by the extent of alkali spreading and clearing of milled rice soaked in 1.7% potassium hydroxide for 23 hours at room temperature. Rice with low gelatinization temperature disintegrate completely, whereas rice with intermediate gelatinization temperature show only partial disintegration. Rice with high gelatinization temperature remains largely unaffected in the alkali solution.

Check Your Progress 3

Note: a) Use space given below for your answers.
b) Check your answers with those given at the end of the unit.

1. Describe the rice starch granule?

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2. What is starch gelatinization temperature?

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3. List the classification of starch gelatinization temperature?

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4. Describe the procedure to determine degree of gelatinization?

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3.4 PHYSIOCHEMICAL AND NUTRITIONAL CHANGES DURING PARBOILING TREATMENT

The endosperm of the grain contains mainly polygonal starch granules. The voids or intergranular spaces are filled with air and moisture. That is why it looks opaque. Moreover, there are fissures and or cracks in the grain, developed during maturity, which can cause breakage of rice during milling. The most important change during parboiling is the gelatinisation of starch and disintegration of protein bodies in the endosperm. The starch and protein expand and fill the internal air spaces. The fissures and cracks in the endosperm are sealed making the grain translucent and hard as a result of which the breakage of grain during milling is minimized.

The colour of the rice changes into yellow or yellowish brown depending upon the paddy variety, soaking time and temperature, steaming time and temperature (pressure of steam), drying time and temperature and many other post harvest factors.

Parboiled rice takes a longer time to cook to the same degree of softness than raw rice of the same variety. The loss of protein and starch from parboiled rice in the cooling

water is low. Water-soluble B-vitamins and other water-soluble nutrients diffuse into the endosperm during parboiling and hence the loss of nutrients is less in parboiled rice even after polishing. The presence of vitamin E is particularly noted in parboiled rice. Slight dextrinisation and destruction of lipase occurs during parboiling. The heat treatment during parboiling causes destruction of some natural antioxidants and may result in increased rancidity of parboiled rice during storage.

Check Your Progress 4

Note: a) Use space given below for your answers.
b) Check your answers with those given at the end of the unit.

1. What are changes occur during paddy parboiling process?

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3.5 WATER AND ENERGY REQUIREMENT FOR PARBOILING

3.5.1 Water Requirement for Parboiling

During parboiling process, paddy is soaked in cold or hot water to raise its moisture content uniformly through out the kernel for gelatinization of starch granules. Partial soaking results white belly or opaque white core in the resultant parboiled rice and finally low head rice recovery. Therefore it is necessary that paddy should be soaked in water for optimum duration for uniform distribution of moisture throughout the kernel.

The total quantity of water absorbed during the soaking operation is calculated as:

$$W = W_d \left(M_f - M_i\right) + W_p \qquad (1)$$

Where, W = quantity of water (kg) required for soaking (excluding evaporation loss),

W_d = weight of paddy at initial moisture content (kg),

M_i = initial moisture content of paddy (%),

M_f = final moisture content of soaked paddy (%),

W_p = weight of water required to fill the intergranular spaces (kg) and is expressed as:

$$W_p = \left(W_d \times \varepsilon / \rho_b\right) \times \rho_w$$

Where $\tilde{n}_w$ = unit weight of water (1000 kg m^{-3})

$\tilde{n}_b$ = bulk density of paddy (kg m^{-3})

å = porosity (%)

Soaking of paddy is important during parboiling and its duration decides the total period of the process. Duration of soaking mainly depends upon the soaking characteristics and the variety of paddy.

3.5.2 Energy Requirement in Parboiling

Rice processing includes parboiling and subsequent drying of paddy followed by milling. Rice milling involves the removal of the outer layer (husk) and the underlying bran layers

from the paddy, raw and parboiled. Parboiling and drying operations need thermal energy, while milling needs mechanical energy. The thermal energy requirement for soaking and steaming i.e. for parboiling one kg of paddy, is given below

$$E = \left[\left(\frac{mc_f - mc_i}{1+mc_i}\right)+\left(\frac{p\times d_w}{b}\right)\right]C_w(T_w - T_d)+\left(\frac{T_{sp}-T_p}{1+mc_i}\right)\left[C_p+(mc_f\times C_w)\right] \quad (2)$$

Where

E = thermal energy requirement (kJ/kg)

mc_i = initial moisture content of paddy before soaking (%db)

mc_f = final moisture content of paddy after soaking (%db)

p = porosity

b = bulk density (kg/m^3)

d_w = density of water (kg/m^3)

C_w = Specific heat of water (kJ/kgK)

C_p = Specific heat of paddy (kJ/kgK)

T_a = absolute ambient temperature (K)

T_w = absolute temperature of soaking water (K)

T_{sp} = absolute temperature of steamed paddy (K)

The above equation can be suitably modified for single steam method and double steam method, and also for the cases where soaking is not being done in hot water. Thermal energy intensity values using the above expression for different parboiling methods is presented in the table 3.2 given below

Table 3.2: Thermal energy requirement of various parboiling methods

Sl. No	Parboiling method	Thermal energy requirement (kJ/kg)
1	Single steam boiling method	241
2	Double steam boiling method	391
3	Open drum	391
4	Hot soaking and steaming	425
5	Pressure parboiling	270

In general it is difficult to compare the energy intensity values reported by different authors. This is because of the variations in the processing methods followed and the efficiencies of conversion / utilization devices.

Check Your Progress 5

Note: a) Use space given below for your answers.

b) Check your answers with those given at the end of the unit.

1. What is the disadvantage of partial soaking?

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2. How do you calculate the amount of water absorbed by paddy during soaking process?

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3. List out the parameter, which decide the total period of paddy parboiling process ?

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4. What are the parameters which decide the duration of soaking?

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5. Which operations are included in thermal energy calculations?

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3.6 STEAMING AND OTHER HEAT TREATMENT TECHNIQUES FOR GELATINIZATION OF HIGH MOISTURE PADDY

The purpose of steaming the soaked paddy is to gelatinize the starch. If the grain has been hydrated adequately and evenly, steaming for just 2 min at atmospheric pressure is enough to gelatinize it. However, the heat input has an effect on the milling quality. The ability of the parboiled grain to withstand adverse conditions of drying without giving rise to cracks increases with increasing severity of heat treatment. The husk splits during steaming, probably as a result of the swelling caused by absorption of the adhering water or the condensate. No splitting of husk occurs in processes where the grain moisture remains low.

Steaming, although used almost exclusively in practice, is by no means essential for parboiling. Other systems of heating, such as mild heating at 80 ^{0}C in a closed box immersed in a bath (or) heating in a closed rotating drum by flue gases in the jacket by thermic fluid (or) by electrical resistance (or) by ohmic heating (or) by microwave and even by hot sand or air, can be used.

3.6.1 Methods of Steaming

3.6.1.1 Heat Treatment

For gelatinization the paddy grain must be uniformly heated to temperatures higher than the gelatinization temperature (GT) of paddy. The gelatinization temperature of most paddy varieties ranges from 65 to 75 °C. Therefore for obtaining good quality parboiled rice, soaked grain must be heated in the manner that even the central core of each grains

attains temperature beyond GT. The following method of heat treatment of soaked grains are commonly used for producing parboiled rice at domestic and/or commercial levels.

3.6.1.2 Soaking in Hot Water at 90 °C

Soaked paddy is dumped into boiling water and temperature of mixture is regulated at 90 °C for 15-30 minutes. After hot water treatment water is drained to obtain parboiled rice. This method is used widely in producing parboiled paddy at domestic levels in India. After soaking mixture of paddy and water is heated and brought to boiling temperature in 30 minutes duration and then water is immediately drained off. Splitting and cooking of grains can be avoided by controlling the rate of heating.

3.6.1.3 Soaking paddy in hot Water (90 °C) under Pneumatic Pressure

Soaked paddy can be parboiled by raising the temperature of mixture to 90 °C and raising the pressure in the soaking tank to 2 atmospheres for a short period of 5 minutes.

3.6.1.4 Open Steaming

This is most common method of quickly raising the grain temperature to 90 °C by passing saturated steam at 1-4 atmospheric pressure for 30 to 50 minutes depending upon the size of the steaming tank.

3.6.1.5 Steaming Under Pressure (Auto-claving)

Soaked paddy is treated with high pressure steam at 1 to 2 atmospheric pressure in a pressure vessel which is sometimes resolved for uniformity of treatment and condensate constantly removed to a steam trap.

3.6.1.6 Conduction Heating Over Hot Flat Plate

Soaked paddy is heated on flat hot iron pan (big size) while constantly stirring the grains, it is practiced in Pakistan. The temperature of paddy is allowed to rise very close to 90-95 °C during roasting. Hot grains are unloaded and cooled by blowing atmospheric air which dries the grain to 15-16 per cent moisture content and requires drying for a short period in sun before milling. This process produces light coloured soft cooking rice.

3.6.1.7 Roasting in Hot Sand (Dry-Heat Parboiling)

Soaking paddy is roasted in hot sand at 150-200 °C temperature for a very short duration (3 to 5 minutes). For this treatment soaked paddy is mixed with hot sand in the ratio of 1:4 of paddy to sand. Good contact between sand and paddy causes efficient and quick heat transfer and raises the temperature of the grain. During roasting it is ensured that grains do not get parched or their husk burnt. After roasting mixture of sand and rice is unloaded into hand sieve and paddy is sieved out and hot sand again re-circulated to the paddy husk stove for reheating to appropriate temperature. This process is traditionally practiced in India and Pakistan specially for parboiling super-fine paddy varieties. Based on the results of traditional process an automatic sand roaster similar to concrete mixture has been designed in which the sand is heated to a controlled temperature by oil burner. Roasted paddy is cooled for short duration by blowing atmospheric air over paddy which dries the paddy to 13 to 14% and needs to further drying.

This process may have considerable potential for parboiling paddy in India, because both heat treatment and drying are done in one step. Sun drying of parboiled paddy during rainy season (May to October) is difficult and time consuming due to overeast sky and frequent heavy rains. Therefore roasting of soaked paddy in hot sand may provide better method of parboiling and drying of grains under these conditions.

3.6.1.8 Infrared or MicrowaveHeating

Soaked paddy is heated to 90 to 95 °C by infrared or microwave to yield uniformly parboiled paddy in very short duration (20-30 seconds). However these methods are

very expensive with high initial investment and high electrical energy requirement and therefore have not become popular in industry.

Check Your Progress 6

Note: a) Use space given below for your answers.
b) Check your answers with those given at the end of the unit.

1. What is the main purpose of steaming?

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2. What are the other methods of heating soaked paddy for gelatinization, other than steaming?

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3. What are the advantages of dry heat parboiling?

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4. What is the advantage of microwave heating in parboiling?

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3.7 COLD AND HOT WATER PARBOILING

3.7.1 Cold Water Parboiling

Raw paddy either received direct from the field or from storage is dumped in the ground-level soaking tanks containing water. About 15 to 30 cm of water is maintained above the paddy and it is soaked at room temperature. In places where the consumers prefer rice with 'white belly', soaking is restricted for a few hours, and in other cases paddy is soaked for 2-3 days. Such a prolonged soaking emits off-odour and the colour is imparted to the resultant milled rice also. At the end of the desired soaking period, the water is drained, soaked paddy transferred to steaming kettles (or tanks) for steaming and sun dried in the yard before milling. The steaming tanks are made of copper, cast iron, mild steel, concrete or masonry. Considering its cheapness, this method is still adopted in certain areas.

3.7.2 Hot Water Parboiling

The method was developed at the Rice Process Engineering Centre, Kharagpur. Soaking paddy at 70-75 ^{0}C for a sufficiently long time was enough to parboil the rice. The process consists of soaking the paddy in water at or a little above the gelatinization temperature of the starch, for a suitable period, which depends upon the paddy variety. During soaking, the paddy absorbs moisture and heat, and the parboiling process is

complete. The milling quality of the paddy produced by the RPEC method is similar to that of paddy parboiled by conventional methods, and after milling both rice look alike. The degree of gelatinization of starch in hot-soaked parboiled rice was lightly less than in the rice produced by conventional methods: however this process reduces the cooking time. The main advantage of this method is the elimination of boiler, which is one of the most costly items in a parboiling plant. The water for soaking the paddy can be directly heated by a suitable husk furnace

Check Your Progress 7

Note: a) Use space given below for your answers.
b) Check your answers with those given at the end of the unit.

1. Describe cold water parboiling?

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2. Describe hot water parboiling?

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3. What are the advantages of hot water parboiling?

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3.8 CFTRI METHOD

CFTRI (Hot-Soaking) Process

The prolonged soaking in cold or warm water generally causes a lot of microbial fermentation, especially if the tanks are not regularly cleaned and if unfavorable weather causes a delay in drying, resulting in a characteristic offensive odour that remains in the product. The CFTRI (Central Food Technological Research Institute), Mysore method consists of upright, conical-bottom, and above ground, mild-steel tanks, each holding 4 tonnes of paddy and fitted with steaming manifolds. Water first is taken into the tank and heated by injecting steam to ~90 ^{0}C, or hot water form a separate storage tank is pumped into the soaking tanks. Paddy previously cleaned and lifted to an overhead bin then is dropped into the water; the floating chaff is removed, and the rice is allowed to soak for 3-4 hrs at ~70 ^{0}C, with occasional recirculation of water within the tank to equalize the temperature between the top and the bottom. After soaking, the water is drained out and steam is passed through the steaming manifold, with the drain cock kept open to drain the condensate. Steaming is stopped after excess steam comes out from the bottom and the top. If the rice is dried mechanically, it is discharged onto a belt or screw conveyor and fed to the dryer through an elevator.

This is an extremely simple and effective process, although it is entirely manually controlled. It is a batch process but can be made semi-continuous by using a number of tanks and staggering their operation. The process has been adopted fairly widely in India, although the older processes and sun drying have by no means disappeared. Its simplicity, inexpensiveness, flexibility, and absence of any patent protection have helped

its fairly wide adoption even outside India, including South America, Bangladesh, Sri Lanka, Nepal, Nigeria, and Vietnam.

Check Your Progress 8

Note: a) Use space given below for your answers.

b) Check your answers with those given at the end of the unit.

1. What are the advantages and disadvantages of CFTRI method of parboiling?

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2. Describe the process of CFTRI method of parboiling?

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3. What are the main features of CFTRI method of parboiling?

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3.9 PNEUMATIC PARBOILING

The current practice of paddy parboiling using steam in rice processing units involves long processing time of 6 hours. This results in large amount of steam consumption per tonne of paddy and therefore energy. Moreover the resultant rice produced in the process has dark colour due to long exposure to steam. Thus, in view of the disadvantages of the parboiling methods in use, and the growing importance of parboiled rice in India and elsewhere in the world, demanding hygienic quality, "pneumatic paddy parboiling method" was developed. In this process, the paddy is soaked in hot water at an intermediate temperature of water under pneumatic pressure and steam treatment to soaked paddy at gelatinization temperature. Pneumatic Pressure Paddy Parboiling method reduces the parboiling time from 6 hrs to 2.5 hrs, improves the milling quality (5-6%) and produces white coloured, and soft textured parboiled rice.

The process involves filling the dry paddy in the pressure parboiler, after pre-cleaning and applying the steam for 2-3 minutes to preheat the paddy. After preheating, hot water was poured into the pressure parboiler. After attaining desired soaking temperature, the pneumatic pressure inside the pressure parboiler is raised to required pressure, was kept for 2 hrs. When soaking was completed, the pneumatic pressure was released and soak water is drained out from pressure parboiler. After draining out soak water, the soaked paddy was heated to above gelatinization temperature by applying steam. The hot paddy is taken out from the pressure parboiler, dried and milled.

Check Your Progress 9

Note: a) Use space given below for your answers.
b) Check your answers with those given at the end of the unit.

1. What are disadvantages of current practice of parboiling method?

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2. What are the advantages of pneumatic pressure paddy parboiling?

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3. Describe the pneumatic pressure paddy parboiling?

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3.10 TESTS FOR PARBOILED RICE

Different tests for parboiled rice are tabulated below (Table3.3)

Table 3.3: Different tests for parboiled paddy

Property	Principle of Test
Water-uptake ratio	Rice is cooked in water at a) 50-60 °C, and b) boiling temperature for a definite time. The ratio of the two water-uptake values, expressed as a percent, goes up from about 5% for raw rice to 50% or more for severely parboiled rice.
Equilibrium moisture content attained by rice when soaked in ambient water (EMCS).	Rice is soaked in ambient water overnight. The equilibrium moisture content attained goes up from about 28% (wb) for raw rice to 50% or more for severely parboiled rice.
Soluble-amylose ratio	Rice flour is extracted with water at a) 40-50 °C and b) boiling temperature. The ratio of the dissolved amylose, expressed as a percent, goes up from about 2% for raw to about 15% or more for severely parboiled rice.
Alkali degradation	Rice kernels are put in 0.5-1.0% KOH. Extent of kernel degradation increases with increasing degree of parboiling.
Slurry viscosity	Rice flour is made into a slurry with water (20%,db). Viscosity increases with increasing degree of parboiling.

Sediment volume	A 2% slurry of rice flour in 0.05N HCL is allowed to stand in a measuring cylinder. Sediment volume increases with parboiling
Alkaline gel length	100 mg of flour is shaken with 4 ml of 1.25% KOH and centrifuged (or allowed to stand for 30 min). The gel length increases with increasing severity of parboiling.
Dimethyl sulfoxide gel length	Similar to alkaline gel test.
Gel mobility	90-130mg of rice flour is dispersed in 2.0 kL of 0.2N KOH in a 13 ×150 mm test tube. The length (mm) of gel flow after 1 hr, when the tube is laid horizontally, increases with severity of parboiling.
Canning stability	5 g of rice is cooked under pressure in excess water and strained. Loss of solids decreases with severity of parboiling.
Near-infrared (NIR)	The near-infrared spectrum is obtained and examined for its defining characteristics.

Check Your Progress 10

Note: a) Use space given below for your answers.

b) Check your answers with those given at the end of the unit.

1. What is the meaning of EMCS? Describe the test procedure.

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2. Describe the procedure to determine degree of parboiling?

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3. Describe the procedure to determine canning stability?

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3.11 EFFECT ON COOKING QUALITY AND TEXTURE

Parboiled rice needs a longer time to cook than raw rice; however, it retains better shape, is fluffier and less sticky, and loses less solids into the cooking water. Soaking paddy at temperatures up to 60 °C has little influence on the water uptake of the resultant milled rice during its subsequent cooking, but the value decreases if the paddy was soaked at 70 °C or more, even without steaming. Steaming or heating of soaked paddy causes a drop in water uptake, a progressive decline with increasing severity of heating,

and a simultaneous decrease in loss of solids during cooking. The combined heat treatment during soaking and streaming determines to what extent the cooking quality is affected. In parallel with its slower cooking, cooked parboiled rice is firmer in texture than the cooked raw rice. Although definitely slightly coloured after being parboiled, the rice becomes virtually as white as raw rice after cooking. Parboiled rice expands less in length but more in breadth during cooking compared with raw rice. For this reason, parboiled rice appears more stocky and round after cooking.

Check Your Progress 11

Note: a) Use space given below for your answers.

b) Check your answers with those given at the end of the unit.

1. List out the changes in cooking quality of parboiled rice?

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3.12 LET US SUM UP

Parboiling of paddy is perhaps the only method of increasing the milling recovery and reducing milling losses to a great extent in addition to increasing the nutritive value and improving the cooking quality of resultant rice. Hot water soaking reduces the total period time of parboiling process and removes the foul smell commonly found in rice produced by cold soaking methods. Steaming of soaked paddy is by far the most efficient method of gelatinization of rice during parboiling but sand roasting of soaked paddy may provide better alternative of both gelatinization and partial drying of paddy.

3.13 KEY WORDS

Parboiling : It is a hydrothermal given to paddy, to withstand the pressure exerted during dehusking and whitening in milling process.

Gelatinization temperature : The gelatinization range refers to the temperature range over which all the starch granules are fully swollen irreversibly.

Soaking (or) steeping (or) Imbibation : The process of water absorption by paddy is known as soaking.

EMCS : Equilibrium moisture content attained by rice when soaked in ambient water.

3.14 SOME USEFUL REFERENCES

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5. Pillaiyar, P. 1988. Rice Post Production Manual, The Wiley Eastern Limited, West Patel Nagar, New Delhi.

3.15 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. During milling, considerable amount of breakage of kernel occurs. To withstand the pressure exerted during dehusking and whitening, the kernel may be hardened by a conditioning technique known as parboiling. Parboiling is essentially cooking rice in paddy form.

2. The process consists of following three unit operations:

   Soaking or steeping of paddy; heat treatment to raise the temperature of wet grains beyond the gelatinization temperature, and drying of grains to 14% moisture content.

3. The most suitable change brought by water and heat, is gelatinization of starch and disintegration of protein bodies in the endosperm which expands to fill al the gaps and pressing the starch granules together thus sealing all cracks and abnormalities in the grain.

Check Your Progress 2

1. The process of water absorption is known as soaking. It is a diffusion process. The water moves inside the paddy as long as the water vapour pressure inside the grain is less than that of soak water and stops when equilibration is reached. The volume of paddy increases due to soaking. The soaking process is always accompanied by release of heat. Soaking is done to provide the starch with a quantity of water sufficient for gelatinization. The rate of soaking is also dependent on temperature of soaking. Soaking rate increases particularly at the temperature of gelatinization and higher.

2. Cold water soaking, Hot water soaking, soaking under pneumatic pressure, vapour phase soaking.

3. Cold water soaking requires longer soaking time which causes loss of vitamins, salts, and albumin from paddy into the water, which causes putrid fermentation resulting in production of toxic substances and foul smell which are absorbed by rice kernel.

4. Soaking paddy in hot water eliminates all the drawbacks of cold water soaking and reduces the time of soaking significantly.

5. Moisture content of paddy very rapidly increased by application of the pressure in the soaking tank, which results the soaking can be completed in 30 minutes to 45 minutes.

6. Moisture content of paddy can be increased very rapidly by treating paddy with steam under 0.3 to 0.5 atmosphere gauge pressure in a pressure vessel and soaking is completed in between 30 and 45 minutes.

Check Your Progress 3

1. Rice has smallest starch granules of the cereal starches, varying in size from 3 to 10μm. Starch granules are compound or polyhedral or pentagonal dodecahedron. Waxy starch granules have lower density than non-waxy granules.

2. The gelatinization range refers to the temperature range over which all the granules are fully swollen irreversibly.

3. The gelatinization temperature classified as low (55 to 69 °C), intermediate (70 to 74 °C), and (75 to 79 °C).

4. Rice is soaked in 1.7% potassium hydroxide for 23 hours at room temperature.

Rice with low gelatinization temperature disintegrate completely, whereas rice with intermediate gelatinization temperature show only partial disintegration. Rice with high gelatinization temperature remain largely unaffected in the alkali solution.

Check Your Progress 4

1. The most important change during parboiling is the gelatinisation of starch and disintegration of protein bodies in the endosperm, which results the breakage of grain during milling is minimized. The colour of the rice changes to yellow or yellowish brown. Parboiled rice takes a longer time to cook to the same degree of softness than raw rice of the same variety. The loss of protein and starch from parboiled rice in the cooling water is low. Water-soluble B-vitamins and other water-soluble nutrients diffuse into the endosperm during parboiling. The presence of vitamin E is particularly noted in parboiled rice. Slight dextrinisation and destruction of lipase occurs during parboiling. The heat treatment during parboiling causes destruction of some natural antioxidants and result in increased rancidity of parboiled rice during storage.

Check Your Progress 5

1. Partial soaking results white belly or opaque white core in the resultant parboiled rice and finally low head rice recovery.

2. The total quantity of water absorbed during the soaking operation is calculated as:

$$W = W_d (M_f - M_i) + W_p$$

3. Soaking of paddy is important during parboiling and its duration decides the total period of the process.

4. Duration of soaking mainly depends upon the soaking characteristics and the variety of paddy.

5. Drying and parboiling.

Check Your Progress 6

1. The purpose of steaming the soaked paddy is to gelatinize the starch.

2. Mild heating at 80°C in a closed box immersed in a bath; heating in a closed rotating drum by flue gases in the jacket; thermic fluid; electrical resistance; ohmic heating; microwave; hot sand or air, can be used.

3. This process may have considerable potential for parboiling paddy in India, because both heat treatment and drying are done in one step. Sun drying of parboiled paddy during rainy season (May to October) is difficult and time consuming due to overcast sky and frequent heavy rains.

4. Infrared or microwave heating yields uniformly parboiled paddy in very short duration of 20-30 seconds.

Check Your Progress 7

1. Raw paddy is dumped in the ground-level soaking tanks containing water a level of about 15 to 30 cm above the paddy and it is soaked at room temperature. In places where the consumers prefer rice with 'white belly', soaking is restricted for a few hours, and in other cases paddy is soaked for 2-3 days. At the end of the desired soaking period, the water is drained, soaked paddy transferred to steaming kettles (or tanks) for steaming and sun dried in the yard before milling.

2. The process consists of soaking the paddy in water at or a little above the gelatinization temperature of the starch, for a suitable period. During soaking, the paddy absorbs moisture and heat, and the parboiling process is complete. The milling quality of the paddy produced by the RPEC method is similar to that of paddy parboiled by conventional methods.

3. The main advantage of this method is the elimination of boiler, which is one of the most costly items in a parboiling plant. The water for soaking the paddy can be directly heated by a suitable husk furnace

Check Your Progress 8

1. **Advantages:**

   The modern method of parboiling has minimized most of the inadequacies of traditional parboiling method such as long soaking time, development of certain flavour in rice kernels and high labour requirement.

   Disadvantages:

   The current practice of paddy parboiling using steam in rice processing units involves long processing time of 6 hours. This results in large amount of steam consumption per tonne of paddy and therefore energy. Moreover the resultant rice produced in the process has dark colour due to long exposure to steam.

2. The CFTRI (Central Food Technological Research Institute), Mysore method consists of upright, conical-bottom, and aboveground, mild-steel tanks, each holding 4T of paddy and fitted with steaming manifolds. Water first is taken into the tank and heated by injecting steam to ~90 °C, or hot water form a separate storage tank is pumped into the soaking tanks. Paddy previously cleaned and lifted to an overhead bin then is dropped into the water; the floating chaff is removed, and the rice is allowed to soak for 3-4 hrs at ~70 °C, with occasional recirculation of water within the tank to equalize the temperature between the top and the bottom. After soaking, the water is drained out and steam is passed through the steaming manifold, with the drain cock kept open to drain the condensate. Steaming is stopped after excess steam comes out from the bottom and the top. If the rice is dried mechanically, it is discharged onto a belt or screw conveyor and fed to the dryer through an elevator.

3. This method is an extremely simple and effective process. Its simplicity, inexpensiveness, flexibility, and absence of any patent protection have helped its fairly wide adoption even outside India, including South America, Bangladesh, Sri Lanka, Nepal, Nigeria, and Vietnam.

Check Your Progress 9

1. The current practice of paddy parboiling using steam in rice processing units involves long processing time of 6 hours. This results in large amount of steam consumption per tonne of paddy and therefore energy. Moreover the resultant rice produced in the process has dark colour due to long exposure to steam.

2. Pneumatic Pressure Paddy Parboiling method reduces the parboiling time from 6 hrs to 2.5 hrs, improves the milling quality (5-6%) and produces white coloured, and soft textured parboiled rice.

3. The process involves filling the dry paddy into the pressure parboiler after pre-cleaning and applying steam for 2-3 minutes to preheat the paddy. After preheating, hot water was poured into the pressure parboiler. After attaining desired soaking temperature, the pneumatic pressure inside the pressure parboiler is raised to required pressure, was kept for 2 hrs. When soaking was completed, the pneumatic pressure was released and soak water is drained out from pressure parboiler. After draining

out soak water, the soaked paddy was heated to above gelatinisation temperature by applying steam. The hot paddy is taken out from the pressure parboiler, dried and milled.

Check Your Progress 10

1. Equilibrium moisture content attained by rice when soaked in ambient water (EMCS). Rice is soaked in ambient water overnight. The equilibrium moisture content attained goes up from about 28% (wb) for raw rice to 50% or more for severely parboiled rice.

2. Rice kernels are put in 0.5-1.0% KOH. Extent of kernel degradation increases with increasing degree of parboiling.

3. 5 g of rice is cooked under pressure in excess water and strained. Loss of solids decreases with severity of parboiling.

Check Your Progress 11

1. Parboiled rice needs a longer time to cook than raw rice, retains better shape, is fluffier and less sticky, and loses less solids into the cooking water. In parallel with its slower cooking, cooked parboiled rice is firmer in texture than cooked raw rice. Although definitely slightly coloured after being parboiled, the rice becomes virtually as white as raw rice after cooking. Parboiled rice is that which expands less in length but more in breadth during cooking compared with raw rice.