Chapter 13
Food Losses in Rice Milling

Ye Aung

13.1 Introduction

Our world is approaching the inevitable food scarcity problem as food insufficiency is becoming eminent in certain parts of the world, mainly in Africa, Asia, and South America (Buerkle 2006). Furthermore, for major cereal crops of the world, there has been a steady decline in the rate of growth in yield (FAO 2015). This may lead to food chaos that could possibly occur within the next 30 years if food security-related issues are not properly addressed. Among the many reports on this issue, the report from the United Nations' Food and Agriculture Organization is more precise. According to the report, world's population is expected to exceed 9 billion people by 2050 and it was affirmed that agricultural output needs to increase by 70% in 40 years to feed the global population, therefore countries of the world were urged to reverse a 20-year decline in investment and put back into agricultural section (FAO 2009).

Rice is one of the main staple foods for the people of the world. More than half of the global population consumes it. Demand for it is steadily increasing along with the population growth. It is interesting to note that rice demand in the European countries has risen up recently (Ferrero and Tinarelli 2007). Fresh data are showing that internationally traded volume of the rice has increased more than 10 million tons compared to the time when our world was turning into the twenty-first century (The World Bank 2014). This rising trend seems to be continuing at least for some time.

The surge of demand also highlights the loss that occurs presently in the postharvest sector of rice. The loss has already reached to an alarming level if carefully calculated. In 1975, the United Nations in its 7th Special Session stressed for efforts to reduce postharvest food losses in developing countries to be given priority.

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While the world body is keeping caution on the quantity, more losses came from the corner of quality. The interest in milling quality rice has increased since then. Instead of focusing on waste-control as a response to the world body, the industries had shifted its focus to the beauty of rice which leads to more rice losses. With an awareness of this trend, one food monitoring organization has announced in 1978 the importance to focus on recommendation for the efficiency of rice production system and to reduce losses (National Academy of Sciences, Washington DC, 1978). However, the thirst for beauty still goes on.

13.2 State of the Paddy at Harvest

Rice originated from a wild grass called *Oryza sativa.* It is a seasonal crop and usually grown in tropical countries which receive sufficient sunshine. The plant can be grown on muddy soil with little water dwelling on it. The plants are of various heights producing numerous leaves and branches. Paddy grains are developed on a long and thin panicle hanging out from the branch. A panicle can carry many grains and there are a number of panicles on a plant.

Most paddy varieties mature just over hundred days and ready for harvesting. Harvesting is carried out by cutting upper part of the plant where the panicles are hanging out. Manual harvesting uses sickle or a special knife cutter that cuts a handful amount of the branch batch by batch. Harvested branches are bound into bundles for threshing. Modern combined harvester can deliver threshed paddy simultaneously in the time of harvesting (Liang et al. 2017). Deciding the right time to harvest is very important to avoid immature and cracked grains. Early harvest may collect more immature grains while late harvest will collect cracks.

Threshing of harvested branches is required to receive paddy seeds separately. Traditional threshing method is carried out by beating the bundles across a grate or stamped over by a team of buffalos. Paddy seeds are collected always with plant parts like stems, leaves, panicles, and also with earth pieces. Hence, cleaning of threshed paddy is required. Farmers themselves clean it to a certain extent by manual or natural winnowing. Along the steps, losses occur and the amount is from 5 to 15%. Manual harvesting leads to more losses than mechanical harvesting.

13.3 Deconstructing a Rice Grain

Outer piece of the rice is the husk formed by two leaves covering the entire rice (caryopsis) loosely. The two has joined at opposite sides by overlapping folds extending the entire length (Figs. 13.1 and 13.2). The leaves are mostly fiber and supported by hard spines. Short or long tiny hairs are always found on the surface. Hairs are somehow hard, straight, and pointed. Therefore rice is called spikelet in the botanical term.

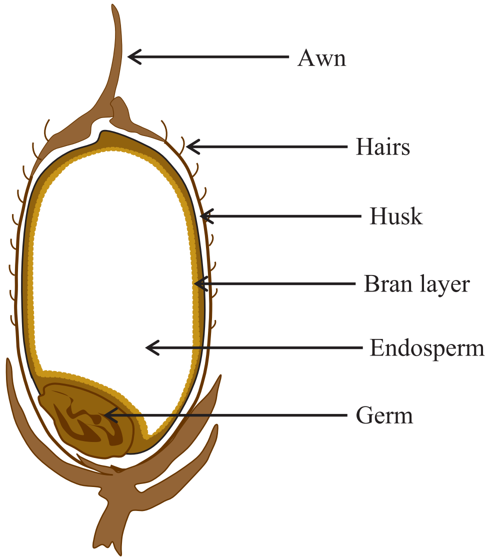

Fig. 13.1 Paddy rice

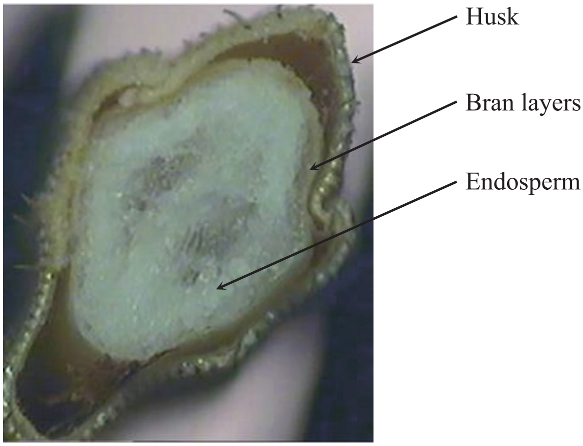

Fig. 13.2 Cross section of a paddy seed

Inside the husk lies a seed called rice containing a reproductive organ called germ. Based on the color, the rice is called brown rice. Germ is the most nutritious part of rice and people prefer to consume it. The rice is traded under the name of cargo rice. However, the germ is crushed and thrown out as by-product during the milling. The bran layers are brown in color which is second to germ in terms of nutrition. Again, these nutritious parts are removed during whitening. Based on the properties, bran layers are divided into three groups:

1. Pericarp layer: It is the outermost layer of the brown rice; a thin fibrous hard cell.
2. Tegmen layer: Just beneath the pericarp layer and less fibrous than pericarp; but relatively richer in oil. A small amount of protein also exists.

3. Aleurone layer: Innermost layer in the bran groups and genuine bran layer bordering with the endosperm. Richest in protein, vitamins, minerals, and fat.

Having different properties, the layers show off the different hardness. The outer is the hardest and gradually softer inside. There is no definite boundary between the bran layers and the endosperm. By the constituents, bran is considered empty when the weight loss of peripheral removal has reached to 8% from the initial brown rice weight. Ancient people learned to be healthier than today's rice eaters by eating brown rice as it is.

13.4 Drying of Paddy

By nature, freshly harvested paddy contains high moisture content. Generally, the content ranges from 22 to 26% depending on the regional condition around the harvesting time. Especially during rainy period, the moisture content is higher. However, rice millers will not process the paddy with this moisture range. Paddy must be dried down to 14% which is the norm and proven level of safe storage and standard milling results. Paddy with moisture content over 14% is weak to respond to the milling impacts and deteriorated in the storage. Long-term storage needs the moisture content to be a bit lower than this. Therefore, drying of harvested paddy is an unavoidable task.

Sun-drying is popular around the world and still being practiced widely. However, large and commercial rice mills prefer artificial (mechanical) dryers for quick and spaceless drying (Okeke and Oluka 2017). Any drying method can crack the paddy if correct procedures are not followed. Sun-drying comparatively offers less control than mechanical drying and as such infamous for sun-cracks. Drying cracks are serious issues for the milling because once cracked, rice is readily broken even when subjected to a light milling process.

Harvested quantity of the rice will drastically reduce by weight after drying as water evaporated away during drying. The drying loss was observed and found to be around 14% if the paddy of 26% moisture content was dried down to 14% (Wimberley 1983).

13.5 De-husking or Hulling

13.5.1 Cleaning

Paddy is always mixed with a certain quantity of impurities whenever the paddy arrived at the rice mills. The sort of impurities includes both organic and inorganic items. At the rice mills, the impurity contents range between 2 and 6%, requiring a series of cleaning processes. These include removal of seedless and very light immature grains. Impurities can block the inlet and outlet of the machine, quite often, the impurities block the screens. Even if they do not damage the machines, they can jeopardize the performance of the machines. In the worst case, they shorten the lifespan of the machinery parts.

As the impurities are of different kinds, different technologies are required in eliminating them. The standard cleaning practice is to carry out the impurity elimination process in two stages. Large and coarse impurities are first removed and the fines are removed in the second stage. The first cleaning work is called pre-cleaning, usually carried out just after receiving the paddy. The second time is in the milling line before any major operations and is called secondary cleaning. Secondary cleaning uses more précised and complicated technologies. Some people called the process fine cleaning.

13.5.2 Hulling Machine (Huller)

De-hulling or hulling is the first operation in which rice is broken for the first time. In earlier days, de-hulling is carried out by disc huller made of iron with partial stone coating (Bhattacharya and Ali 2015). Stones are emery grains firmly coated around circumferential areas of the discs. There are two discs in one machine assembled in parallel by keeping stone coated surfaces inside. Lower disc is attached to a shaft and rotates during operation while the upper one is fixed and remained stationary. Paddy is fed through the hole made at the center of the upper disc and let spread onto the lower disc. Fed paddies spread in all directions by the influence of the rotating surface and reach between the stone coated areas. By the rough surface, the stones crush the paddy and husks are split into pieces. The admixture of brown rice, husks, and unhusked paddies instantly reach out of the discs after hulling. The products are first dropped through an aspiration box to blow the husks out and the rests are sent to another machine called paddy separator.

Later, rubber-rolls are used to replace the iron discs (Bhattacharya and Ali 2015). Hulling breakage significantly reduced since then. Rolls are cylindrical-shaped rubber shoes lying in parallel with different rating speeds. One roll is movable forward and backward enabling adjustment of the clearance between the two. Paddy is fed into the clearance and the husk is sheared off by the different speeds. Hulled rice are pushed out simultaneously along with the husks.

Working principle of the rubber roll was invented in view of exploiting loosened wrapping and joining pattern of the husk leaves. Overlap-folding of the husks indicates the way of sliding them (Fig. 13.2). Elasticity of the rubber, clearance between the husk and rice, and the folding pattern, all contribute in the removal of the husks with little damage to the rice.

The machine was modified subsequently by adding a feeding system in which paddies are guided to dive into the rolls vertically (Bhattacharya and Ali 2015). The invention further improves the performance of the machine both in efficiency and capacity.

Whatever the model and type, performance of a huller is always judged by the two fractions in its output, the unhusked paddies and the broken ones.

Lesser unhusked paddies translates into a high degree of hulling requirement while small amount of broken rice means good performance as well as good rice quality. A huller is considered the best if the percentages of both unhusked paddies and broken rice it produced is the lowest. The weight contributed by the husks to the paddy at 14% moisture stands from 18 to 23% depending on the variety. Most long grains show 21% husk content at the said moisture.

13.5.3 Separating Unhusked Paddies

It is a common understanding that not all of the paddies fed to a huller will have the husk removed. A certain quantity will always be left unhusked. Unhusked paddies are in fact thin grains that escaped out of the clearance set for the majority of the grains. The amount of unhusked paddy is high when hulling is done on early-harvested paddy. Timely harvested paddy will have the minimum amount. This is because not all paddies matured at the time of harvest. In the real situation, paddies are not uniformed even on the same panicle as they do not flower at the same time. There are always early and late bloomers on a paddy plant. Hence, the stock contains immature grains. Therefore, hulling is always set for the majority of the grains and the thin grains are let to go free. When it is set for thin grains, the majority of the grains are likely to be broken in a massive quantity.

Unhusked paddies are not allowed to proceed for further processing, especially to the whitening machines for fear of wear and tear. Whitening machine works with compressive force in which paddy with its abrasive nature could erode machine parts. Paddy separator segregates the paddies and brown rice by exploiting different surface properties between the two. Paddy is rough and brown rice is smooth. Separated paddies are discharged separately and sent back to the hulling section while brown rice including broken rice is being forwarded to the whitening section. Purity of the products is adjustable by changing machine inclination, number of frequency, and length of the stroke. Determination is done by examining the products especially in brown rice fraction.

13.5.4 Recovery of Brown Rice

Keeping record of brown rice recovery is uncommon in small and conventional rice mills. However, the practice is necessary for large and commercial-scale mills because the data highlights the impurity content after hulling and also the losses during whitening. Based on the husk weight from the standard content and brown rice weight, content of the impurity can be easily discovered by deducting brown rice recovery from the input paddy quantity. Modern rice mills include a weighing machine before whitening for this purpose.

In most major rice producing countries, 75% of brown rice recovery is generally accepted (Baradi and Elepaño 2012). This leaves impurity content at 5% including dusts, chaffs, seedless grains, and very light immature grains. However, the data should be considered as a bottom line as some rice mills that count starting from cleaned paddy take 78% as the acceptable brown rice recovery.

Actual weight of the husk is occasionally checked in some rice mills where frequent variety changes take place. Standard procedure is comparing 1000-kernel weight between the paddy and brown rice, whole grain. The same method is sometimes applied for determining the loss of moisture content.

Brown rice is usually checked for head rice and broken rice contents, so that necessary adjustments can be done to salvage the broken rice.

13.6 Whitening

13.6.1 Brown Rice and Digestibility

Whitening became a principal part in the rice milling since people ate white rice. Whitening is not part of the primitive milling method but the primitive way includes hulling. Rice milling in the ancient time involved pounding the paddies in a mortar by a pestle. The primary objective then was only to remove the husk. Pounding was stopped because only a small amount of paddy was able to be unhusked. A lot of broken rice was produced after pounding. If the amount was deemed too much, the stock was screened out in a bamboo tray before consumption, otherwise, taken as it is.

Nowadays, a rice mill without a whitening machine is not regarded as a rice mill. Some countries even issued regulations for the inclusion of this machine. One rationale is that eating quality of the brown rice is inferior to white rice. However new studies showed that brown rice contain more essential nutrients compared to milled rice (Pan et al. 2017).

Whitening operation changes the brown color into white. The degree of whiteness increases with the whitening time as more bran is being removed. Exposure of the endosperm indicates that the whiteness has reached the highest level.

13.6.2 Structure of a Whitening Machine

Whitening of rice is performed by the abrasion produced on the rice surface using the stone specially fabricated for this purpose. The rice is rubbed with the stone by which abrasion is created that is just sufficient for dismantling the rice surface. The rubbing speed supports the effectiveness of the abrasion. The stone is made of emery grains with crystalized multiple corners forming sharp edges. Stones made of larger emery grains produced rough abrasion whereas smaller grains are for fine abrasions. Whatever the degree of abrasion that is made, uniformity of the grains is important in order to prevent the rice from breaking.

Stone made for conventional whitening machine is conical in shape and made in one solid piece. Modern machines use smaller discs and a number of discs are used in one machine. The discs are assembled on a single shaft that rotates all the stones simultaneously. A cylindrical screen surrounds the stones with a distance from the stone surface providing the space for rice to come into. The clearance of the space was predetermined citing whitening effects. Then, circular hollow area is formed into segments by inserting vertical bars (brakes). The brakes are in equal distances and attached to the screen leaving a narrow gap towards the stones. The configuration in cone-type machine is the same. Both models have openings at the top and bottom for rice feeding and discharging, respectively. However, discharging rate is controllable based on the desired period for the rice to be maintained inside the machine.

While the machine is running, the rice is fed from the top and guided to fall equally into each chamber. Disc type uses mechanical feeding whereas cone type uses gravity feeding. The rotation process enables the running stones to rub the rice while slowly moving downwards and being blocked by brakes from running around. Surface of the rice is scratched and bran layers are removed. The brans that are disintegrated into pieces are screened under the influence of the rotation of the stone. Residual period is regulated by the discharge apparatus. Rice whitening cannot be carried out without breaking the rice because the brans are integral parts of the rice (caryopsis) and bound organically to the endosperm.

13.6.3 Heat and Breakage

Rice is always warm during whitening and if the warmness is high, self-breaking of the rice occurs leading to high whitening breakage. Rice temperature increases along with the time of whitening and the pressure applied on it. Once warmed, lateral pressure increased and creates thermal stress inside the rice causing cracking. Cracked rice could not withstand the milling stresses and breaks easily. Thermally stressed rice breaks easily though cracks are yet to be visible. In order to minimize breakage, the whitening operation is carried out in multiple passes to minimize heat generation.

The most popular concept is the 3-pass whitening system corresponding to the number of bran groups. Stones are set as coarse, medium, and fine starting from the first pass. The same way is applied for the peripheral speeds, which are fast, medium, and slow. By having intervals between the passes, it is possible to limit the level of warmness leading to reduction in breakage.

13.7 Polishing

Polishing is the follow-up process to the whitening as a complementary work to make the rice attractive. Rice looks coarse after abrasive whitening due to the scratches inflicted by the stone. Polishing sealed it by filling with loose bran particles on the rice. The rice becomes neat and tidy after the scratches have disappeared.

Friction polisher gives better surface finish to the milled rice (Koga 1969). Further passes of polishing hardens the fillets and smoothens the surface.

This kind of facial improvement misled the rice millers to apply more passes of polishing with the hope of having a better look to fulfill the consumers' demand. In fact, polishing is simply a beauty-making process and no evidence has been found that rice gives better taste by intensive polishing.

13.7.1 Structure of a Polishing Machine

Unlike the whitening machine, polishing machine works horizontally. The rice is fed from one end and discharged at the opposite end. Being a horizontally working machine, rice is fed mechanically and moved forward by the feeding force. There is a counter force from the discharge side to hold the rice tightly. The working chamber is formed by screen-baskets keeping cam-rotor in the middle. Unlike the whitening machine, the screens are folded in design to create resistance to the rice which is supposed to be moving around with the cam-rotor. While rotating, the tips of the cam beat the rice enabling rice kernels to be displaced repeatedly. The moment of displacement together with the tightly packed conditions prompts the rice to rub each other. This is called self-frictioning and the polishing machine is called frictioning machine. Rice is warmer than when it was in the whitening machine.

Subsequently, the polishing method was further developed to include water addition. Water mist is blown in during the operation via a central shaft and openings of the cam. The rice is wet and the surfaces are softened by the water. Polishing heat cooks the rice immediately resulting in the surface layer to form a coating. The coating is very thin and looks like a silk layer. The rice from wet polisher is called silky rice. The rice kernels are brighter than that produced by dry-polishing.

13.8 Losses

13.8.1 Physical Losses

White rice that has been subjected to a high degree of polishing produces slippery surface and better reflective quality that stands better in today's market. These attributes are only determined by personal judgments, and as such there are frequent disputes. For fear of disputes, millers often carry out the whitening and polishing processes to a greater extent. Unfortunately, the practice intensifies further the losses that occur.

Food loss is particularly boosted during the smoothening process in which rice parts are cut off. If we look at the cross section, it can be seen that the rice body is uneven and undulating. There are six numbers of ridges and furrows (Fig. 13.3a). The undulating body is due to the grooves on the rice surface that formed during

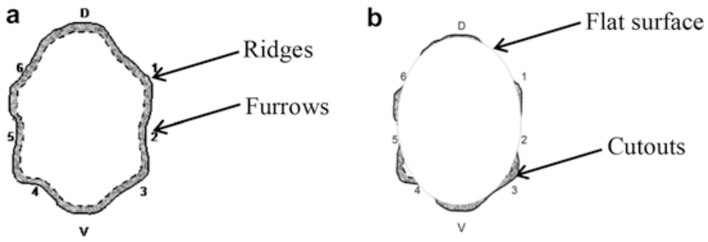

Fig. 13.3 (**a**) Cross section of rice. (**b**) Cross section of grounded rice

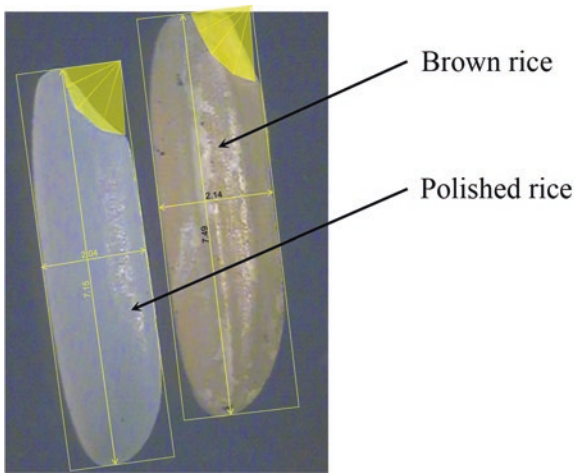

Fig. 13.4 Brown rice and the smaller highly polished rice

growth of the seeds (Bhattacharya 1980). The depth of the grooves varies from 1 to 88 μm (Bhashyam and Srinivas 1984) depending on the growing location.

Smoothening rice surface requires flattening the ridges to the level of the furrows (Fig. 13.3b). In this procedure, rice with deep grooves requires more grinding; however, this leads to additional losses.

In order to get rid of the ridges, whitening must be aggressive, prompting rice to be broken extraordinarily. In this scenario, whitening operation eventually becomes a size-reduction process (Fig. 13.4). Massive rice parts are found in the discarded bran in this kind of whitening condition (Fig. 13.5).

An analysis of the size reductions on a Thai premium rice that has been milled until 11% of weight loss from brown rice.

Reduction in length: 4.5%,
Reduction in breadth: 5.1%, and
Reduction in thickness: 6.9%

Higher reduction on the thickness is observed because of the fact that rice mostly has kernel whose shape is somewhat flat. Among them, the length reduction is the most risky finding as rice could be broken when its tips are trimmed. Besides,

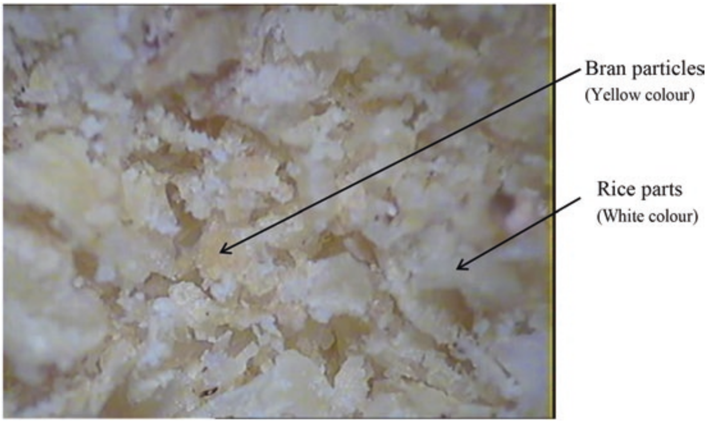

Fig. 13.5 Rice cells in the bran after aggressive whitening

shorter length could bring down the price it usually fetches. Overall volume loss in such case amounted to 15% which could lead the people to consume more rice for satisfaction.

13.8.2 Nutritional Losses

Apart from physical losses, overly milled rice lost nutrition too. Proteins, fats, vitamins, and minerals are present in greater quantity in the germs and outer layers than in the starchy endosperm (Heinemann et al. 2005). The rates of nutritional reduction are further examined on the white rice. White rice that has been milled at 7–8% bran removal showed nutrient losses as 29% proteins, 79% fat, 84% lime, and 67% iron. Towards these findings, FAO published this notification in its publication, *"Highly polished rice produced in modern mills further increases the incidence of beriberi and other deficiency diseases such as keratomalacia, stomatitis, glossitis, cheilosis, and hepatic cirrhosis"* (FAO 1948). Rates of the losses seem more critical now with respect to the higher degree of milling (Abbas et al. 2011).

13.9 Grading

The responsibility of the grading operation is to fix the broken rice in the finished rice as per specifications. The operation selects the correct sizes of broken rice that are present. Sizes of the broken rice in a rice quality measurement are generally identified by decimal numbers on tenth basis of the rice length. For example, 0.8, 0.75, 0.65, 0.5, 0.4, 0.3, 0.2, and 0.1. Some use fractional whole numbers by eighth basis such as 10/10, 9/10, 8/10, 7/8, 6/8, 5/8, 4/8, 3/8, 2/8, and 1/8. In general, 3/4 of the rice length is regarded as head rice. However, top quality long grain types of rice are always larger than this ratio. As accuracy of content and size are very critical in price negotiation, grading is carried out in several steps in a specified sequence by using different methods of segregation.

13.10 Recovery of Head Rice in the Milled Rice

The rice received after whitening and polishing is called milled rice representing the whole mass including the broken rice. Of the two, head rice is the deciding factor for the final yield of finished rice. The ratio of the head rice must be the highest possible in the milled rice. The type and design of the milling machinery influence the milling results (Bhattacharya and Subba 1966; Appiah et al. 2011). However, other factors such as plant design, processing method, and ambient conditions also play a role and affect the rate of broken rice. From the material side, immature grains and cracked kernels are serious factors and effectively bring down the head rice recovery.

13.10.1 Double Losses in High Quality Rice

Every time when high-quality rice is produced, the process involves a certain rate of bran removal followed by consequential damages leading to production of broken rice. In the past, so-called high-quality rice are made up of 7–8% bran removal (7–8% weight loss from input paddy). Nowadays at 11% weight loss, the head rice recovery in the milled rice has reduced substantially, much lower than that of the past (Fig. 13.6). In today's milled rice, head rice is hardly found at 65% while in the past it was 75% or more (Table 13.1). The disappearance of 10% head rice in the milled rice is the clear reason for the yield loss for the same quality of milling in the current scenario.

13.11 Rice Specifications

Rice specification describes details what a certain rice quality wants and what are not part of its specification. The contents of head rice and broken rice are the main criteria. A rice quality is formed based on these two components in which the former is the principal fraction and stands as the higher portion. The higher the quality grade, the higher is the content of the head rice. Given below are important quality descriptions which affect the price and consumers' perception.

1. Content of head rice
2. Content of whole kernel (part of head rice)
3. Content of broken rice
4. Size of broken rice permitted

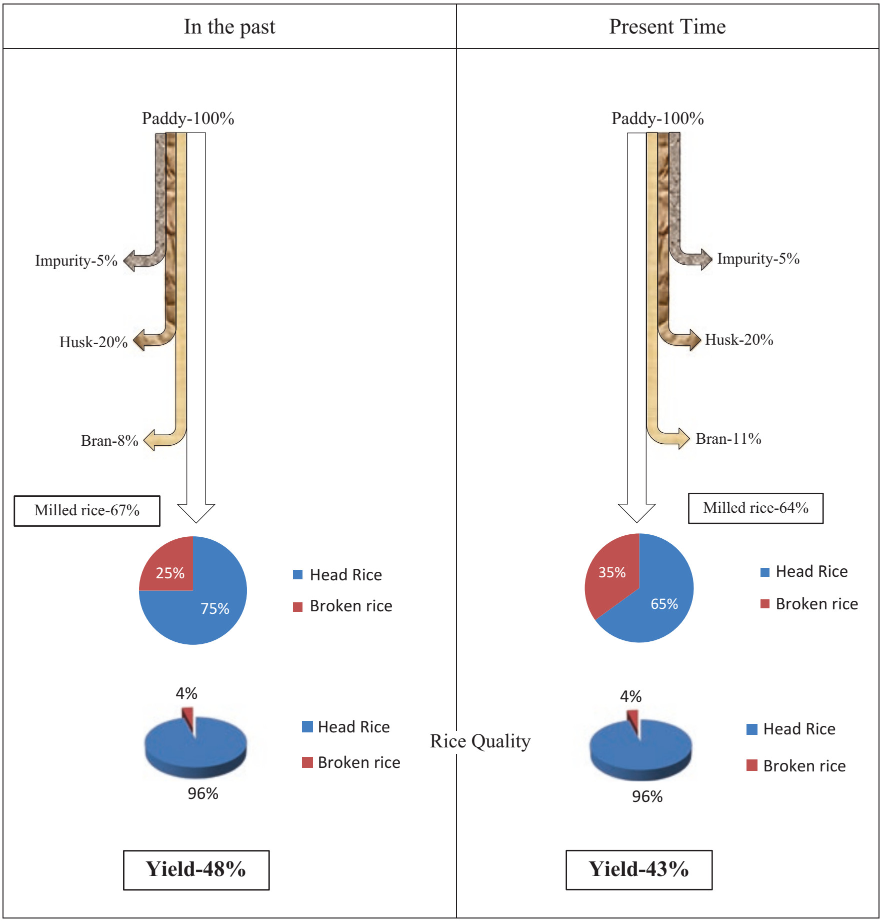

Fig. 13.6 Yield comparison between milled rice from the past and present

Table 13.1 Head rice recoveries for the same high-quality rice in the past and at present

Input paddy (%)	Impurity (%)	Husk (%)	Bran (%)	Milled rice (%)	Broken rice (%) in milled rice
Past 100 % Rice Quality	4.0	21.0	6.5	68.5	*75 (25)*[a]
Present 100% Rice Quality	-Same-	-Same-	+11.0	65.0	*65 (35)*[a]

[a]Ratio of broken rice in the milled rice the two figures make 100%.

Qualities of the rice are named based on the content of the broken rice. The system enables immediate determination to compare the price and quantity of broken rice in finished rice. This is because the broken rice is a cheaper item compared to the head rice.

Table 13.2 Specifications of three high-quality grades of rice

High-quality grade	Head rice (%)	Broken rice (%)	Size of broken rice (of average length, whole kernel)
Rice grade, 100%	+96	−4	0.5–0.8
Rice grade, 5%	+93	−7	0.4–0.8
Rice grade, 15%	+83	−17	0.3–0.7

Notification of Commerce, Thailand B. E 2540 (1997)

Table 13.3 Finished rice yields and the percentages of extracted broken rice

	100% Rice		5% Rice		15% Rice	
Bran removal	Yield (%)	Broke rice extracted (%)	Yield (%)	Broken rice extracted (%)	Yield (%)	Broken rice extracted (%)
8.0	50.0	*14.0*	52.0	*12.0*	55.0	*5.0*
11.0	41.0	*22.0*	43.0	*19.0*	51.0	*10.0*

Remark: Bran removal rate of 15% rice grade is generally at 7% (paddy basis)

Universally known rice qualities are:

1. 100% rice, meaning full of head rice. However, the rice still allows 4 to 6% broken rice of the largest sizes.
2. 5% rice, 10% rice, 15% rice, 25% rice, and 35% rice. All the percentages mean broken rice contents.

Table 13.2 provides the specimens of specification illustrating contents and permitted sizes of all fractions included in the specific quality grade of rice. The top two qualities, 100% and 5% rice are regarded as high-quality rice and being produced under similar degree of milling. However, the 15% grade rice is produced under a lower degree of milling but it possesses whiteness high enough to attract the consumers. Comparatively, the content of the head rice is lower compared to the former two higher quality grades of rice and it allows higher content of broken rice. Therefore, the yield of the rice is higher (Table 13.3).

Although the contents of head rice and broken rice are more important for the pricing, the criteria to be considered first and of the utmost importance is the milling degree. Milling degree descriptions are given below for the respective quality grade but some degrees are entitled for two or three quality grades which are very close together.

1. "Ordinarily well-milled," for the three lowest qualities including 25% lower grade. There are 25% and 45% rice lower than 25% rice.
2. "Reasonably well-milled," from super grade of 25% rice to 15% quality.
3. "Well-milled," for the rice of 10% and 5% grades.
4. "Extra well-milled," for three grades of 100% rice such as grades, A, B, and C.

The definitions are vague and not specified by any type of measurements, therefore, over-milling usually occurs.

13.12 Yield of Finished Rice

The term yield in the rice milling refers to the quantity of finished rice in relation to the input paddy usually shown in percentages. Some countries have their own local descriptions but still convertible to percentages.

Yield can be fluctuated by the following factors regardless of the quality grade.

1. Recovery of milled rice after whitening and polishing
2. Content of head rice in the milled rice
3. Content of head rice in the finished rice

13.13 Summary

Harvested paddy should not be estimated as actual food available for the people's consumption because the quantity slides down even before milling through drying and handling losses. The amount is reduced by around 20% when it is ready for conversion into edible rice.

Further irrelevance is the ready-reckoners used for converting paddy into rice. The data 60 or 65% are in fact replica of milled rice recovery, not finished rice. Consumers' trend that tend to not eat broken rice should be drawn into consideration, as well as the actual practice of removing broken rice from milled rice. About 10–25% of input paddy quantity is being thrown out in the milling as broken rice resulting in the average yield to be less than the existing converting figure of 60%. One cause of reduction is today's milling degree which is higher than in the past. Rice eaters should know that increased whitening and polishing do not necessarily give superior eating quality (Roya et al. 2008).

The illustration below shows how much of rice disappeared from human consumption from the same quality grade comparing past and at present time. This is the present scenario. Out of this, the rice volume loss and the feedable number of population can be estimated as given below.

World paddy production	650 million per year
Standard conversion rate	0.60
Milled rice availability	390 million tons per year
Estimated high-quality rice (assumed 20% of milled rice)	78 million tons
By the average yield of 43%, paddy consumed for 84 million ton rice would be	181 million tons
If 181 million tons of paddy was milled to the same quality by the past bran removal rate of 8% and the yield, 48%, white rice would be	87 million tons
So, extra rice is (87–78)	9 million tons
Number of people that can be fed by extra rice at the rate of per capita consumption of 150 kg	60 million people for 1 year

13.14 Conclusion and Future Prospects

Practically, it is impossible to change the consumer's preference for white rice. However, the craving for rice-beauty seems to be changeable if they are convinced by the losses and the incoming food shortage. Nutritional losses and the diseases associated with highly polished rice could also be helpful. Possible reduction of the price by the lower power consumption if qualities are brought down to standard level can be considered.

On the other hand, technical solution should be sought by focusing on the breeding of thin-husked paddies and shallow undulating varieties so that weight and material losses would be less even though the present thirst for rice-beauty persists. At the same time, regulatory bodies concerning the rice quality standards should also include eating values in its regulations and standardization programs by highlighting the benefits. Therefore, optimum degree of milling could be determined on the basis of eating quality which will in turn reduce the losses.

On the other hand, eating of low-quality rice is not uncommon practice, because some countries had exercised the practice when they were facing food shortages. Government of India had once recommended 4 to 5% bran removal only (Bhole 1976).

Citing these examples, suggested efforts to save the food in the time of eminent food insufficiency would not be vain attempts. Otherwise, governments would face a time when they have to punish their own people whose behavior seems to be wasting food, even for a tiny amount. However, this kind of regulatory actions would create social instabilities and eventually diminish the peace and harmony of the world.

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