UNAPCAEM

Rice Harvesting & Post-harvest Technologies in Myanmar

A Training Manual

Pilot project on capacity building to improve post-harvest technologies and reduce post-harvest losses in rice production in Asian and Pacific countries, October – December 2010

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Foreword

Rice is the major crop for millions living in Asia and the Pacific, and 90 percent of the world's output of rice is produced and consumed within Asia. Millions grow their own rice and are dependent on sales of surplus rice to provide them with cash to purchase other necessities. Although most Asian rice farms are small holders, they employ intensive labor practices in place of mechanization. With limited land, huge population and food insecurity exacerbated by the lingering effects of the global financial crisis and climate change, a viable option is to create food surpluses by increasing land productivity and reducing post-harvest losses through the introduction of efficient and adaptable small-scale machinery into rice production farming systems in the region.

Post-harvest grain losses across all Asian countries have been estimated at 10–15%, and when combined with the loss of quality, represent a potential loss in value between 25–50% at the market. Conservatively, this equates to a value of $50 per ton of rice that farmers are losing. The past studies by IRRI in Cambodia, the Philippines, and Indonesia, have found that post-harvest losses occur mainly because of spoilage and wastage at the farm level, poor storage, reduced milling yields, and grain quality reduction during processing. These losses result in lower quality rice for consumption or sale, smaller returns to the farmer, higher prices for consumers, and greater pressure on the environment as farmers try to compensate for it by growing more rice. Small landholders suffer most from the lack of information and poor post-harvest technology, since up to 95% of their grain is initially dried and stored on-farm. Because these farmers have limited access to knowledge of the appropriate technologies for drying, storage, and milling, they end up with less after milling. If they don't sell immediately after harvest, the grain further deteriorates at a rapid rate and loses more value and, if they do sell, they have less bargaining power, as they are often selling into a restricted or oversupplied market.

In response, UNAPCAEM formulated a pilot project to strengthen the participating country's agricultural engineering and mechanization capacity by focusing on developing a package of suitable on-farm post-harvest technologies, including locally adaptable machineries and good agricultural practices. This technical assistance project was first rolled out in Myanmar.

From 16-20 December 2010, in collaboration with the Ministry of Agriculture and Irrigation of Myanmar, UNAPCAEM organized a training workshop on rice harvesting and post-harvest technologies in Myanmar. Fifty technicians, engineers, extension workers, as well as representatives from the research institutes, the private sector and rice miller associations from across the country joined the week-long training. The training covered drying, storage, processing as well as harvesting technologies in rice production.

This training manual is prepared by Dr. Athapol Noomhorm of the Asian Institute of Technology of Thailand (AIT) and Dr. Shuren Chen of Jiangsu University of China, and is designed for trainers from national institutes responsible for agricultural mechanization and transfer of technology on rice production, agricultural extension workers and government policy makers.

UNAPCAEM is very grateful for the technical support from AIT and the Jiangsu University in the implementation of the project. A special thanks to the Ministry of Agriculture and Irrigation of Myanmar, Agricultural Mechanization Department (AMD) in particular, for providing the data and information on farm mechanization and post-harvest technologies in Myanmar. Inputs are also gratefully received from Mr.Tin Htut Oo, former Director General of the Department of Agricultural Planning of the Ministry of Agriculture and Irrigation of Myanmar, Mr. Imran Ahmad of AIT and Mr. Rabi G. Rasaily, an intern of UNAPCAEM. Mr. LeRoy Hollenbeck, Director of UNAPCAEM and Ms.Yuxin Ai, Senior Expert of UNAPCAEM, also contributed to the editorial work. Logistical assistance from Mr. U Win Myaing, Assistant Director of AMD, Mr. Yuemin Shen, Programme Assistant and Mr. Zhen Wei, IT Assistant of UNAPCAEM are also gratefully acknowledged. This training manual also benefited from presentations made by local participants during the training workshop held in Myanmar.

Introduction

Myanmar is considered an agrarian economy with agriculture contributing to 34% of the total GDP, and 15.44% of total export earnings. Net cultivated area is about 17.68% of total land area and 12 million hectares are agricultural land. The main crops are paddy, pulse and bean. Myanmar is a rice growing country with a relatively small population and abundant land and water resources. Yearly cultivated area of paddy including summer crop is over 20 million acre (8.1 million ha) and produce about 27.18 million tons which gives the average yield of 3.35 tons per hectare, which is very low in comparison with other countries. Myanmar also faces the acute challenge of mechanizing its agricultural sector to increase productivity and reduce post-harvest losses. [1] According to the fact-finding mission conducted by UNAPCAEM prior to the training workshop, the post harvest losses in rice production in Myanmar stand at 10-20%.

The government of Myanmar has made development of agriculture through mechanization and application of modern agro-technologies a priority in the overall national economic development. However, the present capacity of the Government's Agricultural Mechanization Department (AMD) is limited, at the same time, the role of Myanmar's burgeoning private sector that produces agricultural machinery needs exposure to the latest technological developments. Enhancing the capacity of both will assist Myanmar in achieving its targets to mechanize the agricultural sector.

In general, adoption of post-harvest technologies in Myanmar is beset with several constraints and challenges. Most of the farmers still rely on traditional farming techniques and manual labor and draft animal power in subsistence farming of rice. Agricultural extension services have traditionally focused on seeding, land preparation but not post harvest technologies, and extension services and training programmes provided by the Ministry of Agriculture and Irrigation are not sufficient. Because of a weak information system nationwide to disseminate proper knowledge of post-harvest technologies and good agricultural practices, farmers have little information on proven technologies, machineries and their prices. In addition, constrained by low income and limited access to financing, farmers usually can't afford machineries, and there is no incentive mechanism afoot to encourage farmers to adopt best practices in post-harvest process. Underdeveloped rural infrastructure, small land holding size, and limited research and development and manufacturing capacity also restrict mechanization in rice production. [2]

However, the use of farm machinery is growing in Myanmar due to the changing cropping system and expansion of cultivated area (Table 1). Farm mechanization is becoming more important not only in land preparation but also in harvesting and other post-harvest processes such as threshing, drying, milling. While most of the agricultural machineries are imported, some of the machineries are produced locally like tractors, power tillers, threshers, water pumps and mechanical reapers. Now mechanization is widely used in land preparation. In double or triple cropping areas, because of the short harvesting period, timely harvest is crucial where adoption of combine harvesters or mechanical reapers are in great need. The efficiency of rice mills is low due to old milling facilities

[1] Presentation made by Agricultural Mechanization Department of Ministry of Agriculture and Irrigation of Myanmar.
[2] Ditto

and shortage of power supply. Post-harvest technologies play an important role in reducing losses in rice production, and improving the quality of rice.

Table 1: Utilization of Machineries and Farm Implements in Myanmar (2009-2010)

Type of Machinery	Units
Tractor	11, 784
Power Till	145, 548
Threshing machine	23, 349
Thresher	7, 927
Dryer	549
Inter-Cultivator	226, 116
Seeder	46, 354
Harvester	3, 220
Water Pump	173, 224

Source: Agricultural Mechanization Department, Ministry of Agriculture and Irrigation of Myanmar

Considering the present status on utilization of post-harvest technologies and machineries, dissemination of good agricultural practices and training of experts in all processes of paddy production especially in post-harvest processes are in urgent need. Research and development capacity in post-harvest handling should be strengthened with increased government support. Meanwhile, technical collaboration with the private sector and institutions and organizations outside of the country will help speed up the adaptation rate of appropriate technologies.

Part I – Threshing and Harvesting Technology

1.1 Mechanical reaping technology

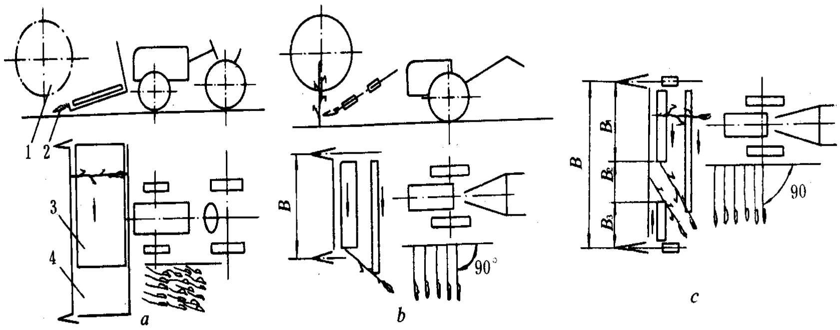
A mechanical reaper is an agricultural device which reaps crops mechanically and lays down the stems into small bundles, providing an alternative to using laborers to gather in crops by hand at harvest time.

Mechanical reapers can be classified into two types according to the positions of cutting table and conveying devices. One is called horizontal conveying reaper, the other is called vertical conveying reaper. See Figure 1.

Fig.1 Different types of reapers

1.1.1 Horizontal conveying reaper

Featuring a horizontal cutter and bigger cutting width, the horizontal conveying reaper has good operational reliability. Most reapers with big cutting width adopt this configuration. Horizontal conveying reapers can be further classified into several models, namely, single conveyor belt, double conveyor belt and multi-conveyor belt as the number of conveyor belts varies. See Fig.2. Their basic structures are the same, consisting of cutter, reel, conveyor, machine frame and conveying devices.



a. single conveyor belt b. double conveyor belt c. multi-conveyor belt

Fig.2 Schematic diagram of horizontal conveying reaper

Operational principle of horizontal conveying reaper

When horizontal conveying reaper operates, the reel, conveyor belt and cutter are driven by the engine. Guided to the cutting area by grain divider and backward movement of reel, the paddy is cut, with the straw piled in field via conveyor belt.

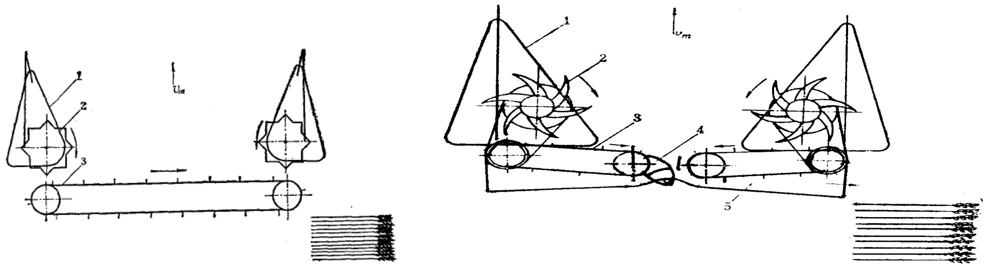
Main performance parameters of horizontal conveying reaper are listed in Tab.1.

Tab.1 Main performance parameters of horizontal conveying reaper

Machine type	**4GW-1.4**	**4GW-1.7**	**Qingfeng4G-2.5**	**4GX-3.8**
Suspension type		front- mounted		
Cutting width(m)	1.4	1.7	2.5	3.8
Stubble length(cm)	4~8	5~7	5~8	6.5~30
Productivity(hm^2/h)	0.27~0.4	0.4~0.53	0.73~1.2	2.53
Weight (kg)	135	150	278	375
Tractor engine Power(kW)	8.8	14.8~18.5	18.5	40~55.5

1.1.2 Vertical conveying reaper

Vertical conveying reaper is a mechanical reaper whose cutting table position is vertical. When the vertical cutting table works, the standing paddy is cut, then transported by conveyor and finally laid down in field. It has the characteristics of light weight, compactness and high mobility, therefore suitable to use in scattered small fields while inappropriate for harvesting lodging paddy. Vertical conveying reaper can be classified into side-delivery and back-delivery reaper. See Fig.3.



1. grain divider 2. star wheel 3. conveyor belt
1. grain divider 2. stalk lifter 3. conveyor belt 4. commutating valve

Fig.3 Schematic diagram of side-delivery and back-delivery reaper

1.2 Threshing technology

Thresher is a machine that separates rice grain from paddy stem, or the machine can separate and clean grain from the impurities.

1.2.1 Technological requirements for thresher

Highly productive, the mechanical thresher consumes small amount of power. Threshing performance refers to the percentage of threshed rice grain obtained from the fed paddy. The percentage of grain damage and total loss should be less than 1.5%, including loss of unthreshed grains, loss of entrapped grains, grain loss of cleaning and spattered grains. Threshing performance and clean rate for paddy can get 99% and 98% respectively.

The thresher should meet different grain-threshing demands and keep the straw integral. The thresher should be used reliably and safely, and be convenient to adjust and maintain.

1.2.2 Threshing principle

The key to threshing the paddy is to separate the grain from the stem. Threshing modes include impacting, kneading, grinding and combing.

Impact threshing

The grains are threshed through the interactive impact action with the threshing component. i.e, nail tooth. High nail tooth impact speed can enhance threshing productivity and cleaning rate while increasing grain damage rate at same time. This model of thresher has a stronger ability to snatch straw and good adaptability for asymmetrical feeding and moisture crop. See Fig.4. The ensuing broken paddy stalk will generate difficulty in the separating and cleaning process.

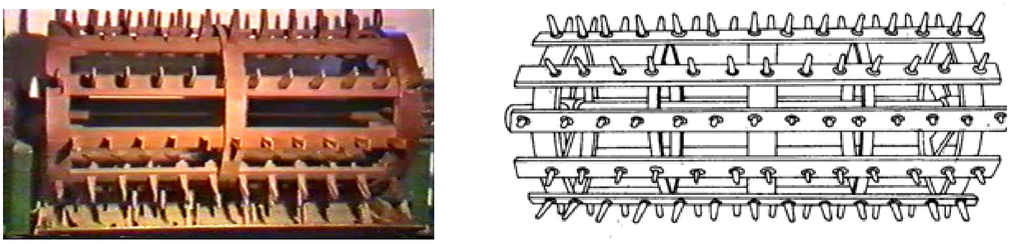
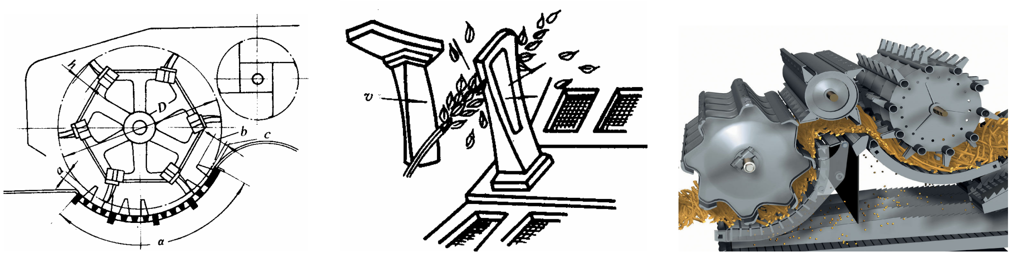


Fig.4 Nail tooth threshing cylinder



a. threshing device of nail tooth cylinder b. action of nail tooth c. model of nail tooth cylinder

Fig.5 Schematic diagram nail tooth threshing structure

Nail teeth are fixed on the tooth bar according to screw line. The shapes of nail include plate knife tooth, wedge tooth and bow tooth. Since plate knife tooth is thin and long, it can snatch up and comb grain better, which means better threshing effect than wedge tooth.

Knead threshing

The principle of knead threshing is that rice grain is threshed by the friction between threshing component and grain. Enhanced knead action can improve, the productivity and clean rate while increasing grain damage rate. If the clearance between cylinder and concave plate are adjusted, the action of knead will also change. This model can satisfy the requirement of threshing. See Fig.6.

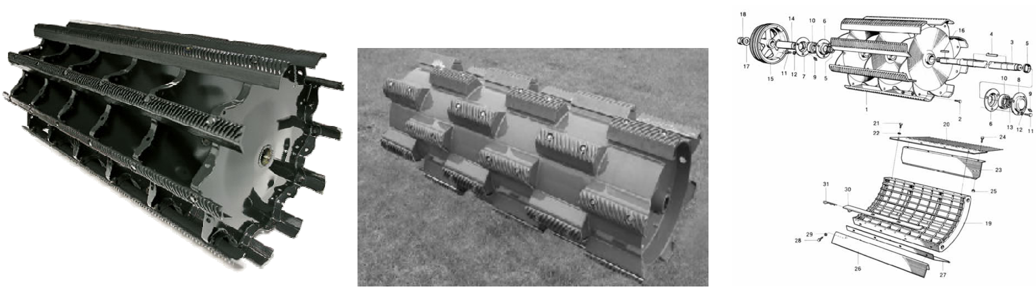


Fig. 6 Schematic diagram of knead threshing cylinder

When the impurities is fed into knead threshing device, a majority of the grain is struck and separated in front of concave. With the decrease of threshing clearance, the movement of grain in nearby concave slows down while the grain in near rasp bar moves faster. Through the high frequency vibration, the remaining grain will be threshed at last. In the overall grain threshing process, impacting is applied in the first half and kneading in the second half.

Combine threshing

The paddy is threshed via the pull force from threshing components. With bow tooth threshing, the grain is not easy to be damaged. Featuring small power consumption, it can be adapted to thresh paddy.

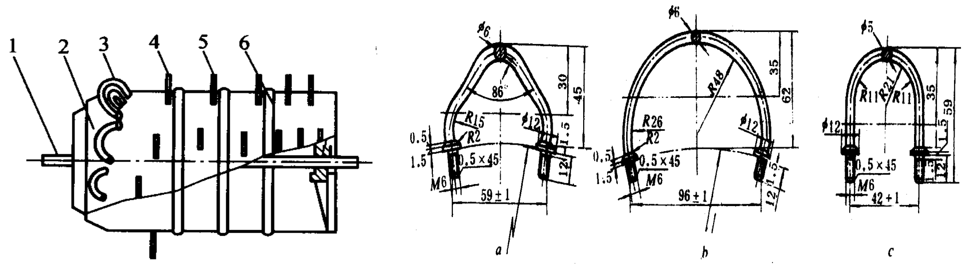


Fig.7 Schematic diagram of bow threshing cylinder and combing components

Double cylinder thresher

Double cylinder thresher works with two cylinders in series. Since the first cylinder rotates slowly, the mature grain were got off and separated on the first concave plate. At same time, the fed grain layer can be homogeneous and thin. The second cylinder rotates fast and has minor clearance, whereby the remaining rice grain can be threshed completely. See Fig.8

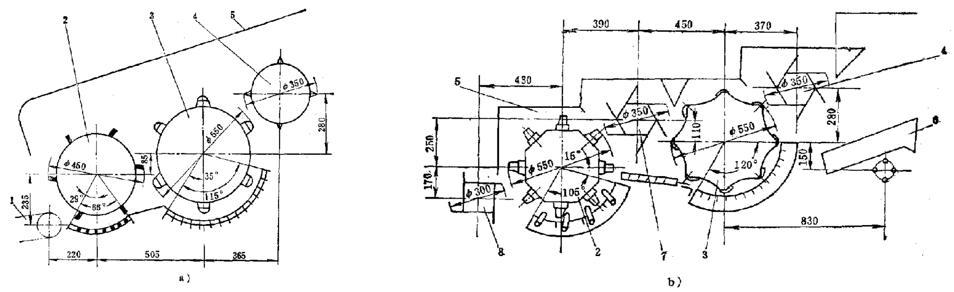


Fig. 8 Schematic diagram of double- cylinder thresher

1.2.3 Thresher structure

Threshers can be classified into two kinds: whole feed and head feed. Whole feed thresher is that the paddy is entirely fed into the threshing device, generating broken stem and impurities. Although it consumes big power, the productivity is high. When head feed thresher works, only the ear of paddy is fed into the threshing device while paddy stem is left integral. Thresher structures are presented in Fig.9.

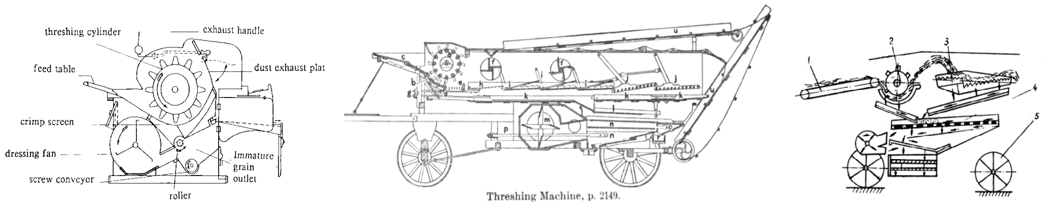


Fig. 9 Schematic diagram of thresher structures

When Axial flow threshing cylinder works, the paddy grain which is fed into the thresher, moves along axial line and rotate around tangent direction. Its characteristic is that the grain seeds can be separated from paddy stalk, so that a separating device can be omitted. The thresher is usually made of threshing device, separating device, cleaning device, conveying device and traveling wheel.

The productivity of threshing cylinder depends on the numbers of combing components. If there is only one comb in moving track, the productivity is low and the cylinder should be long. So the comb elements are arranged as multi-head screw lines.

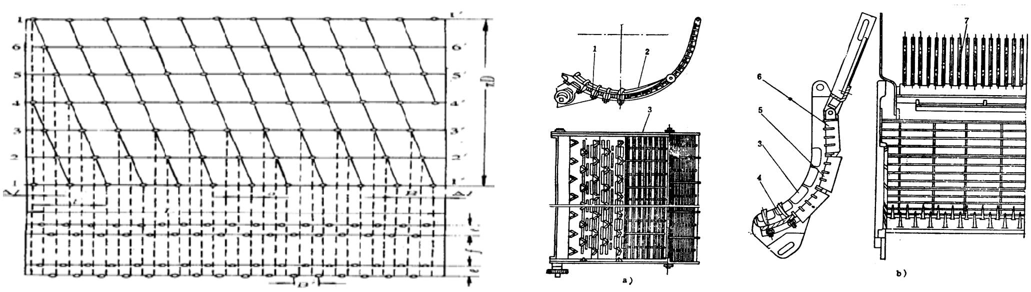


Fig.10 Arrangement of comb components and concave structure

Fig.11 Different types of threshers

1.3 Whole-feed combine harvester

1.3.1 The structure of whole-feed combine harvester

As a harvesting machine that combines four separate operations (reaping, threshing, separating and cleaning) into an integral operation process, the combine harvester, or simply combine, can be applied to harvest paddy, wheat and corn. The harvest residue abandoned in the field includes the processed stem and leaves of the crop with limited nutrient, which can be used to feed the livestock.

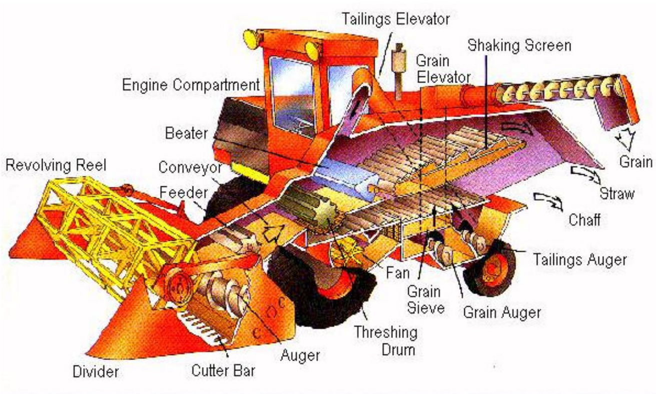


Fig. 12 Schematic diagram of whole-feed combine harvester

When the whole-feed combine works, the cut crop is conveyed to the feeder throat via a chain or flight elevator and fed into the threshing unit, which consisting of a rotary cylinder and grooved steel bars. The rasp bars thresh and separate the grains and chaff from the straw through the interaction between the cylinder and the concave (consisting of steel bars and grates).Through the concave, grain, chaff and smaller debris will fall, whereas the straw, due to its length, will be carried forward into the straw walkers. Since the grain is heavier than the straw, it falls while floating residue is conveyed from the cylinder/concave to the walkers. The cylinder rotary speed is adjustable for most combine harvesters and the distance between the cylinder and concave can be finely adjusted to achieve optimum separation and output. Additional separators can be manually fitted into the concave, which will provide extra friction to remove awns from the wheat. After the primary separation at the cylinder, the clean grain falls through the concave to the shoe, which contains the chaff and sieves. The shoe is common to both conventional combines and rotary combines.

Fig.13 Two kinds of whole-feed combine

During the Germany Hanoverian International Farm Machine Exhibition held in 2007, a 550hp super-powerful combine harvester was displayed. With a 10.5m cutter width, it can harvest 50 tons per hour. New Holland Co. also produced 591hp combine harvester which can harvest 451.2 tons of wheat within 8 hours. Having adopted advanced CTS technology- (tangent threshing cylinder and single axial flow nail tooth separating cylinder), JOHN DEERE 3316 combines can enhance the performance of threshing, separating and reduce grain damage. See Fig.14.

Fig. 14 New Holland combine harvester

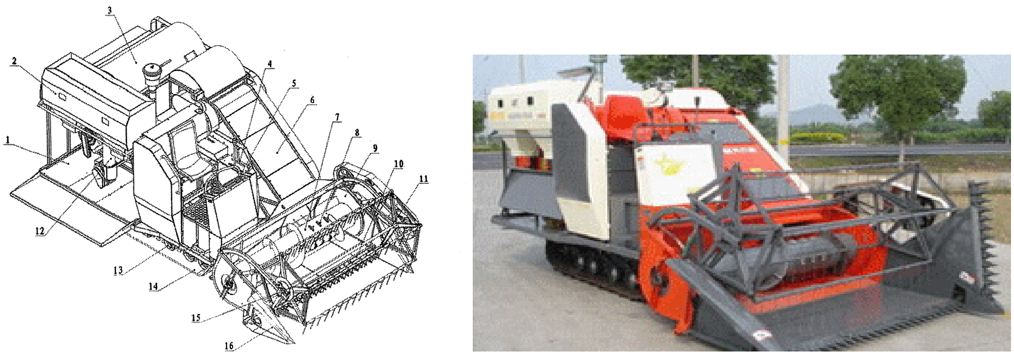
1.3.2 Self-propelled whole-feed combine harvester

Compared with the former generation of combine harvester, self-propelled whole-feed combine has advantages of high efficiency, low ground pressure and good reliability, and can fulfill functions of cutting, conveying, threshing, separating, cleaning and collecting discharged grain in water field with soil depth of 25cm and dry field, and produce grains directly. All straw and husk are spread on the field.

This kind of combine has following technological characteristics: (1) Continuously variable transmission, one-handle control, hydraulic steering make operation easy and convenient. (2) Wide track and high ground clearance are much suitable for operation in paddy fields in Southeast Asia. (3) Hanging support wheels, dual pipe supported guide wheel and wearable driving wheel are three high reliable lines of defense from mud. (4) The super high lifting height of cutting table is convenient for down slope and ridge cross. (5) The super wide conveying groove makes conveying smooth with little noise. (6) Dual threshing case with broad diameter, vibrating screen with adjustable plates and two lifting/conveying re-threshing augers guarantee the small grain loss and high cleaning rate. (7) Large volume grain tank makes grain collecting operation easy and convenient. (8) New operation cab and easy-to-open engine cover make cleaning and maintenances much easier. In a word, this machine, which has a unique structure, decent outlook, easy operation, reliability and safety, high operation capacity in paddy field, energy saving and high efficiency, is the most ideal harvest machine fort the area of paddy and wheat.

Configuration and operation principle of the self-propelled whole-feed combine harvester

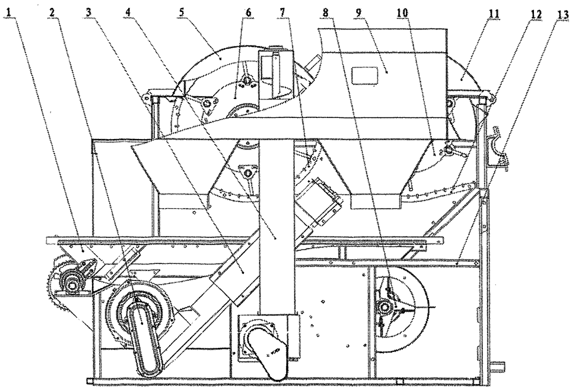
The combined harvester consists of three major units: cutting and conveying unit, threshing part and propelling unit. Located in the far front, the cutting and conveying unit consists of cutting table and conveying groove. Located in the rear part, the threshing unit consists of threshing and separating device, grain discharge device and grain case. Located at the bottom of the machine, the propelling unit consists of framework, engine, gearbox, wheels and track. In addition, there are hydraulic system, electric system and operation system etc. See Fig.15



1. receiving plate 2. grain collecting box 3. rear threshing roller 4. operation system 5. electric system 6. conveying groove 7. spiral conveyor 8. telescopic gear 9. frame for cutting table 10. auxiliary plate 11.reciprocal cutter 12. lifting auger 13. bear weight wheel 14. track 15. reel 16. divider

Fig. 15 Self-propelled whole-feed combine harvester

When the machine is in operation, the dividers (16) on both sides of the cutting table can guide crop to reciprocal cutter to be cut (11) on the cutting table with the support of the reel (15). The crop being cut is pushed by the spiral conveyor (7) and the auxiliary plate (10) to the left side of the cutting table and pushed back by the telescopic gear (8) and grasped by the scraper at the conveying groove (6) and sent to the threshing roller.



1. reciprocal vibration screen 2. re-threshed system 3. rising/conveying auger 4. rising/conveying auger 5. rear threshing roller top cover 6. rear threshing roller 7. rear concave screen 8. fan 9. grain collecting case 10. front threshing roller 11. front threshing roller top cover 12. front concave screen 13. threshing frame

Fig.16 Threshing system of self-propelled whole-feed combine harvester

As shown in Fig. 16, via the interaction between the front threshing cylinder(10) and front concave screen(12) and that between rear threshing cylinder(6) and rear concave screen (7), the crop is threshed twice. In this process, during the course grains drop down and straw is deformed. Grains are separated from some husk and short straw through the concave under the role of the centrifugal force. Light impurities are blown off the machine by blowing of the fan as well as the role of the reciprocal vibration screen while grains drop into horizontal auger and the broken fringe drop into horizontal auger. Grains in horizontal auger are sent to the grain collecting case by the lifting auger while grains in horizontal auger is re-threshed by there-threshed roller, sent by rising/conveying auger to be re-threshed again by the rear roller. Straw and leaves that do not pass through the concave are discharged from the discharge port at the rear side. Table 2 contains the technical specifications of this type of combine.

Table 2: Technical specifications of self-propelled whole-feed combine harvester

S/N	Item	Unit	Size	
1	Structure Style	/	Track Self-propelled whole-Feed	
2	Applicability For Crop(Physical Height)	mm	Paddy, wheat: 500-1 200	Cole: 601-700
3	Power/rotary speed	kw/rpm	45/2400	
4	Productivity of Pure Working Hour	hm^2/h	Paddy, wheat: 0.2-0.47	Cole: 0.1-0.3
5	Fuel Consumption per Hectare	kg/hm^2	<28	Cole≤30
6	Dimension (L×W×H)	mm	4650×2350×2300	Cole: 5020×2450×2160
7	Structural Weight	kg	2400	Cole: 2500
8	Reaping Width	mm	2000	

9	Feed Volume	t/h	7.2	Cole: 4.32
10	Minimum Gap of Off-Ground	mm	240	
11	Style of Swerve	/	Hydraulic Style	
12	Shift Modality	/	Automatic Mechanical Transmission +HST Hydraulic Continuousive Variable Transmission	
13	Speed of Operation Forward	m/s	0-0.8、0-1.26	
14	Stroke of Cutter	mm	76.2	
15	Auger Style of Cutting Table	/	Spiral Conveying	
16	Outer Diameter of Auger of Cutting Table	mm	φ470	
17	Style of Reel	/	Eccentric Style	
18	Diameter of Reel	mm	φ900	
19	N0. of Plates of Reel	PCS	5	
20	Conveyor Belt Style	/	Rake-Teeth Style	
21	Threshing Roller Style	/	Spike-Teeth Stylex2	
22	Size of Threshing Roller (O. D. ×L) Front Roller	mm	φ540×650	
	Rear Roller	mm	φ540×1285	
23	Concave Style	/	Grid Screen×2	
24	Angle Range of Concave	(°)	227°	
25	Fan Style	/	Centrifugal	
26	Diameter of Fan	mm	φ328	
27	Diameter of Grain Discharge Argue	mm	φ123	
28	Crew Distance of Grain Discharge Argue	mm	105	
29	Re-Threshed Style	/	Blade Revolving Style	
30	Grain Receiving Style	/	Manual	
31	Clearance between Argue of Cutting Table and Base Plate	mm	15-18	
32	Track	mm	400(or450)×90×48	

1.3.3 Tangent flow combine harvester

The tangent-flow cylinder is usually used in the machines with low capacity due to limited cylinder length. The machine works well in harvesting high-stubble crops. However, the high stubble height hinders the commonplace rotary tillage in rice production and reduces the straw harvest. If the machine is used to harvest the low-stubble crops, the long straw fed into axial cylinder may very likely to get the cylinder tangled, causing the blockage and increased grain loss in separation, especially when the straw is wet. Revolving around the axial cylinder, the straw is rubbed and shortened. Since the discharged straw decays quickly, it can be directly absorbed into the soil by plowing in double cropping rice area. The tangent-flow cylinder harvester has simple structure, small size, light weight and high mobility in paddy field, making it suitable for use by small and medium scale rice growers or harvesting service contractors.

The main drawback is its poor performance in harvesting heavily lodged rice, typical in coastal typhoon-struck areas. It is one of the major types of combines developed in China. The suggestions to improve this model include optimize the design of the header to improve its performance in harvesting the lodged rice, enhancing its power output and adding the straw chopper. Compared with the self-propelled model, the mounted combine harvester saves cost because the self-propelled have the chassis and track idle for most of the year. But the mounted type has less mobility in wetland, narrower field of vision and poorer steering capability than the self-propelled one.

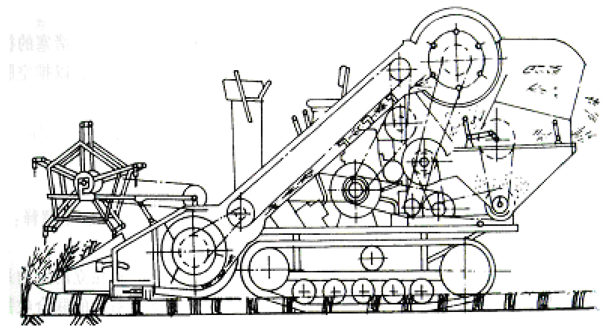


Fig.17 Tangent flow combine harvester

1.3.4 Axial flow rice combine harvester

As shown in Fig.18, the 1480-axial flow whole feed rice combine harvester is made in the U.S. Since the axial-flow threshing cylinder is laid in the longitudinal direction, when the cylinder revolves, the paddy is fed from one end of the axial-flow cylinder and moves forwards in a spiral line. The threshed grain falls into a cleaning device via grain auger. Then the stem is discharged from the other end of cylinder into the field.

1.revolving reel 2. cutter auger 3. conveyer groove 4. axial flow cylinder 5. concave sieve 6. cylinder beater 7.scatter implement 8. mixed auger 9.down sieve 10. up sieve 11. grain auger 12. fan 13. conveyer auger

Fig.18: Axial flow whole feed rice combine harvester

1.3.5 Revolving reel

The function of revolving reel is to lead paddy stem to cutter, support the stem, push the cut paddy into conveyer belt, clean the cutter table, prevent the cut stem from accumulating on the cutter knife. Revolving reel is divided into two kinds, the normal one and the acentric one. Acentric revolving reel adopts press layer and spring tooth. See Fig.19.

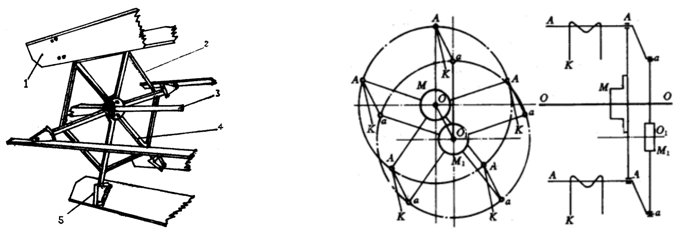


Fig. 19: Normal and acentric revolving reel

Acentric revolving reel consists of wheel axle, spoke, tendon, chain wheel, press layer and spring tooth. The trochoidal-curve motion path of reel bat is composed of revolving circle speed Vb and combine forwards speed Vm.. See Fig.20. The motion trace depends on the ratio λ of Vb to Vm. Only when the $\lambda>1$, the motion trace has the trochoidal-curve ouch. There is the backwards horizontal speed under the trochoidal-curve for pushing the paddy action. So the necessary condition is $\lambda>1$ for the revolving reel working normal.

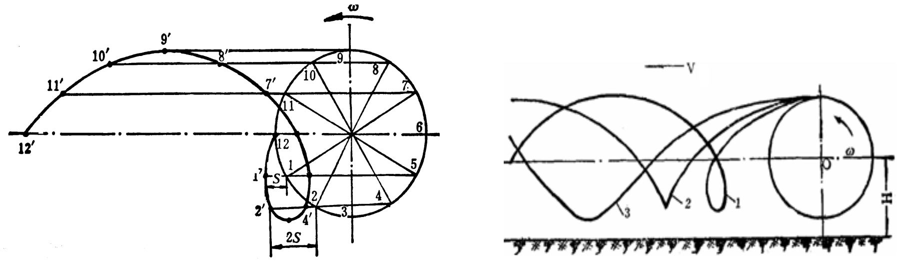


Fig. 20: The motion trace of reel bat

1.4 Head-feed combine harvester

1.4. 1 The structure of head-feed combine harvester

A typical head-feed combine harvester includes vertical cutter header, conveying-and-feeding unit, intermediate gripping chain, threshing cylinder, cleaning unit, walking unit and engine. See Fig.21.

Fig. 21 Head-feed combine harvester

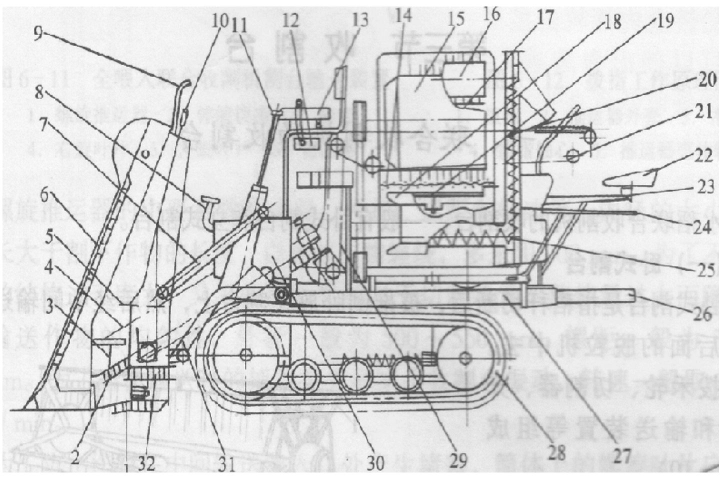
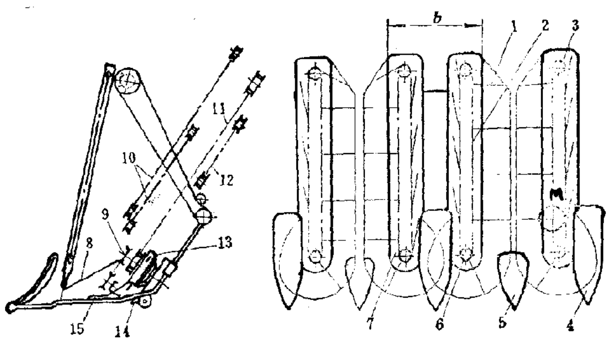


Fig.22 Schematic diagram of head feed combine harvester

During the working process, head-feed combine can uphold lodged paddy and, push it against the cutter header, via star wheel clasp. Then the rice straw is cut and delivered to the end of cutter header by conveying belt. The cut paddy is transported to intermediate conveying device. The middle gripper chain changes vertical rice straw into horizontal state, and feed them into threshing cylinder whereby the long rice straw is discharged from the back of combine and laid down in the field orderly. Passed through the wire gauze sieve and dithering board, cleaned by fan, the kernels are carried into grain collecting box by conveying auger at last. See Fig.22.

The head-feed combine operates as follows. The cut paddy straw should be kept integral. Then, the straw is clasped and transported via long chains. Subsequently, the whole paddy is sent to the threshing chains via the intermediate delivery. The paddy ear head clasped by clasping chain is threshed through the action of threshing cylinder. Because the paddy stem was clasped by clasping chain, the paddy can be preserved orderly. Since the straw is not processed through the cylinder, the straw is retained undamaged and the power requirement is low. It doesn't need an independent separating device. As a result, the machine is a mini-combine harvester and could not have high productivity.

Adopting a pick-up and head-feeding device, this type of machine has an excellent performance in threshing and separating grain, even harvesting heavily lodged rice. It can process rice straw in different ways: windrow them in an orderly manner or cut them in even length and spread them on ground. The main drawback of this model is that it is too expensive for farmers. In addition, the pick-up device for lodged crops may cause grain damage and loss, amounting to 5% in the later harvesting period. It is suitable for economically developed areas, areas where government subsidies are available, and areas where crop lodging occurs frequently. If good quality straw is expected for other valuable purposes, this model is recommended.



1. crop lift finger 2. lifting finger chain 3. up chain wheel 4、5. divider 6. down chain wheel 7. chain box 8. leading frame 9. rubber finger conveyer 10. middle conveyer fringe grasping chain 11. middle conveyer root grasping chain 12. feeding depth adjust grasping chain 13. stretch and withdraw lifting finger 14. cut knife 15. portrait guide pole 16. guide rail 17. axle pin

Fig. 23: Vertical header of head feed combine

1.4.2 Vertical header of head feed combine

The head-feed combine harvester usually attaches a crop lifting device to the vertical header. The crop lifting device consists of chain transmission assembly, chain box, crop lifting finger and guide rail. The inclined crop lifting device is installed in front of head feed combine. Hinged with chain, the lift finger, whose motion is guided by guide rail, moves with chain in synchronization. While working, the lift finger will extend to grasp and hold up paddy, and then retreat into chain. See Fig. 23.

1.4.3 Thresher of head-feed combine harvester

To shorten the development cycle, reduce the dependence on physical prototype and save development cost, the digitalized design has become an important means of designing the product. The structures and parameters of the threshing and separating unit for paddy should be defined firstly. Based on the feature-parameter model technology, the digital simulation of short-rasp-bar tooth threshing drum, grid concave and overlap are established and virtual assembly is utilized.

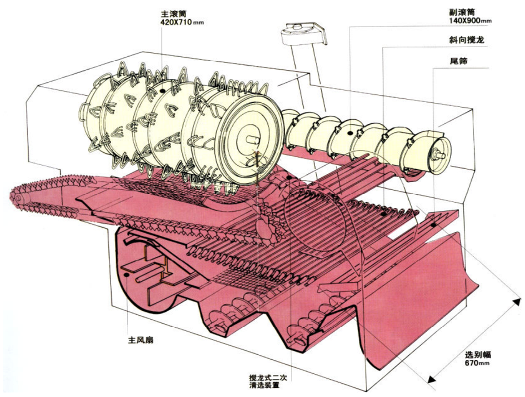


Fig. 24: Thresher of head-feed combine harvester

Dealing only with the panicles of the rice bundles, a head-feed thresher is composed of arch tooth cylinder, auxiliary cylinder and rear concave screen. The cut paddy is clamped by feeder chain, and the panicles are passed through the main cylinder from one axial side. Threshed rice grain is further separated via the concave screen. Finally, the straw is discharged from the other side of main cylinder. Moved from main cylinder to auxiliary cylinder, the short straw and broken panicles are re-threshed to outside. See Fig.24.

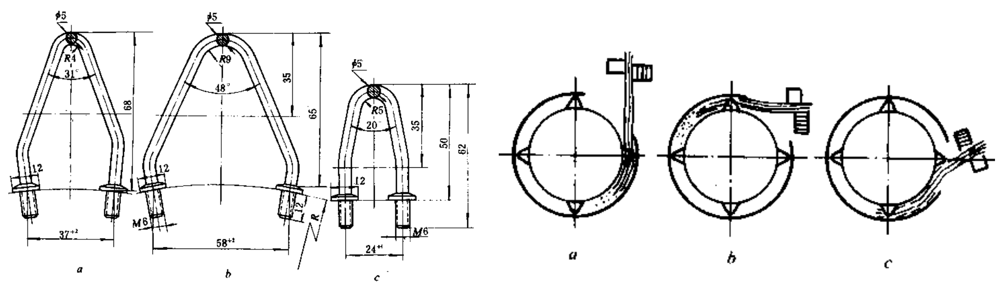


Fig. 25 Head-feed threshing tooth and mode

In the main threshing cylinder, there are four head spiral lines, along which comb tooth, reinforced tooth, threshing tooth and impact board are arranged. The comb tooth is installed at the entrance of thresher, whose action is to snatch the paddy and guide it into cylinder so as to be combed and threshed gradually. Following the comb tooth, the reinforced tooth can improve the capability of threshing grain, and prevent straw from passing through tooth. In this way, broken stem and tangled straw can be avoided and impact time for panicle will be extended. Convex and sharpened, the threshing teeth have stronger capability to break bigger link force.

Auxiliary threshing cylinder can re-thresh tailings, separate grain from residue and discharge impurities. With the help of concave sieve, threshing tooth at the front of auxiliary cylinder can re-thresh tailings. The oriented plate inside of auxiliary cylinder up-cover can control the impurities axial flow velocity, to thresh and separate grain.

New threshing cylinder

As a key component, the design of threshing drum has an important impact on the harvesting performance. The threshing unit consists of short-rasp-bar tooth and plate teeth, as shown in Fig.26. The bench test shows that the short-rasp-bar tooth threshing drum is more effective than spike-tooth cylinder in the harvesting the paddy. Installed at the hypotenuse of short-rasp-bar drum, the plate teeth can push the motion of paddy in threshing space, reduce the residence time of paddy in threshing room, crush panicles and stems and decreases impurities significantly, thus reducing subsequent stress on cleaning and improving the performance of cleaning. The threshing components are distributed along spiral line, as shown in Fig.27.

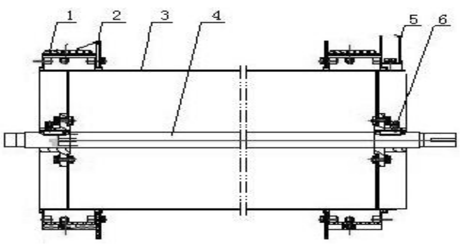


Fig. 26 Structure of cylinder

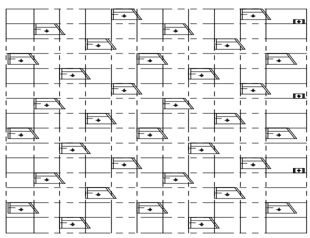


Fig. 27 Threshing component arrangement

Drum diameter has an impact on threshing and separating. If the drum diameter is bigger, the feed rate will increase and the threshing and separating capability will become more powerful. However, big diameter results in large structure size and heavy weight. To avoid the drum being worn by the grasses, the circumference of root circle should exceed the length of crop stem.

Concave sieve

The concave enveloping angle affects how well the paddy is separated. If the angle is big, the separating area is large, which means a good separation effect. Meanwhile, the length of drum can be properly shortened, and then concave enveloping angle is determined as 235°. Consisting of wire and flat steel, the grid sieve makes up the concave. In order that the threshed stuff from the concave sieve could distribute along axially, the wire is arranged densely at the front and sparsely in the back. The diameter of wire is 3mm, the wire center distance is 8mm from the entrance and from the exit and the center distance is 12mm. This kind of concave sieve is beneficial to threshing and separating. Featuring a simple structural and cheap price, it is sturdy and durable. The horizontal strip may be increased 6mm to achieve desirable threshing and separating capability, meanwhile, a clearance of 15mm between the tooth tip of threshing drum and the concave sieve should be maintained.

Overlap

The circular threshing room consists of the drum overlap and the concave sieve. For the rotary motion of paddy, five rotary plates are installed inside the overlap. The spiral angle of four initial plates is 15° in order to induce axial movement speed of the rice. The spiral angle of the last plate is lessened so that the unnecessary stuff is pushed off the outlet. See Fig.27.

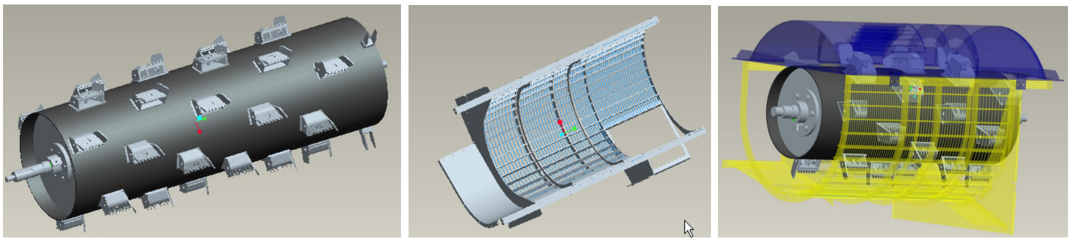


Fig.27 New threshing and separating unit for paddy

The height of guide plate has an impact on the axial motion of paddy. If the height is too low, the guide plate can't completely make the paddy move spirally. The paddy thickness exceeding the height of guide plate, the paddy can't be guided fully, the axial movement speed is reduced and increases the time of retention in threshing room and finally leads to blockage. The unreasonable height of guide plate will make the threshing space so large that the function of kneading and striking is compromised, which affects the threshing rate. Therefore, the height of guide plate should be set at 30mm and the shortest distance between plate tooth and guide plate is 25mm.

1.5 Combine harvester technologies in China

China is a major rice producer. Based on the climatic conditions and cropping practices, its production areas can be divided into three major geographical areas: double rice cropping area, rice-wheat two cropping area, and single cropping area. Special requirements are imposed on the harvesting machines in different areas. Mechanization of rice and wheat harvesting is developing very rapidly in China. Development of trans-regional harvesting service was commonplace in the past several years, creating very positive impact on the development of farm mechanization. Both domestically-made and imported combine harvesters are being used. Normally, the domestically-made machines are significantly cheaper than the imported ones. Rice is the major staple food in China. In 2000, China produced 190 million tons of rice, accounting for 31.4% global rice production. The 18% of rice was harvested mechanically.

Axial rotor of whole-plant feeding

Featuring relatively large clearance, moderate threshing speed, gentle and repeated threshing action, this type of machine can better solve the problem of effective threshing with small grain damage. The spiral movement of the crop in the threshing room, the use of the centrifugal force instead of gravity in the straw walker, and the prolonged time for threshing contribute to good grain separation rate from straw. It demonstrates that in whole-plant feeding the axial rotor harvester will surpass the combination of tangential threshing cylinder and straw walker in terms of harvesting.

Lengthwise axial rotor

The typical harvesters that use lengthwise axial rotors are Case 2388 and IH1460, which are rarely used in China. Since the rotors do not have limited length and suit the machines of larger capacity, threshed crop can be distributed evenly on the chaff. The drawbacks are the complicated transmission of the rotor and the propeller at its front end which feeds the material into the rotor and subjects to heavy wear. These machines work well both for threshing and keeping the grain integral. But their specific energy consumption is high (280 Hp for Case 2388). They can bear the risk of being blocked by long and wet straw when harvesting with low stubble. So it is a common practice to use such machines to harvest with high stubble in order to achieve high efficiency. All the lengthwise axial rotor combine harvesters are used in large farms in China.

Tangential threshing cylinder and lengthwise axial rotor for separation

The typical example of the machines that use tangential threshing cylinder and lengthwise axial rotor for separation is "JD-CTSⅡ", which features the twin counter-revolving axial rotors bearing the robust tines for energetic separation of grain from the long straw. The rotors are acentric with its concaves, thus the materials get a press-release alternative action, freeing trapped grain and reducing grain loss. In fact, the threshing action can be alleviated by enlarging the threshing clearance in the tangential cylinder to reduce grain damage. The remaining threshing functions can be performed by the axial rotor. However, its power consumption and weight are increased (275HP, at max. 315 HP delivered; 13t. and header not included). It is a good model to be followed by Chinese large farms who own large size combines like "JD 1075". The new machine is modified with two axial rotors replacing the straw walker to improving rice separation and has shown satisfactory results.

1.6 Trend of combine harvester technologies

Self-propelling and high efficiency

All head feed combine harvester are self-propelled. The self-propelled small and medium combine are developing very fast. They have high performance, good work efficiency and reliability.

Driving with static hydraulic transmission device

Driving with static hydraulic device has lot of advantages, such as continuously variable forward velocity of the combine, simplification of the transmission device, and flexible configuration transmission component. This kind of combine can be operated more easily.

New threshing and separating device

The latest development of new threshing and separating device in modern combine harvester can improve the work efficiency and reduce paddy losses. Double threshing cylinder with axial-flow thresher and double cylinder longitudinally mounted thresher separating configuration have been applied extensively.

Straw disposal device

Combine harvesters usually don't have a straw box. The straw is gathered by bundling machine. Some combines can cut straw and discharge them into field via a straw disposal device.

Part II – Post-harvest

2.1 Moisture content determination

Moisture content is one of the essential factors affecting grain quality and its storability. It is generally accepted as a tool in determining the prices of agricultural commodities such as grains. Thus, the knowledge of moisture content determination of any product is indispensable since moisture content influences the price and storability of the produce. Therefore, it is important to study the different methods of determining the moisture content of agricultural crops. In grain industry, rapid moisture determination is important. Several moisture meters, either resistance or capacitance types, have been developed for this purpose. These moisture meters should be tested and calibrated with respect to the AOAC standard before using since moisture content readings from different moisture meters vary.

The term 'grain moisture content' normally denotes the quantity of water present in a sample per unit mass of dry matter and moisture combined. That is it is expressed on a wet weight basis. The alternative and rarely used dry weight basis compares the moisture present with the weight of dry matter in the grain. For example, if 100 kg of moist grain contains 25 kg water and 75 kg dry matter:

Percentage moisture content wet weight basis:

$$\frac{weight\ of\ water\ x\ 100}{weight\ of\ undried\ grain} = \frac{25g\ x\ 100}{100\ g} = 25\%\ \text{moisture content}$$

Percentage moisture content dry weight basis:

$$\frac{weight\ of\ water\ x\ 100}{weight\ of\ dry\ matter} = \frac{25\ g\ x\ 100}{75\ g} = 33\%\ \text{moisture content}$$

Percentage moisture content wet basis is universally used by farmers, traders and agriculturists while dry basis is more popular among researchers. To convert moisture content percentage from a wet basis (Mw) to a dry weight basis (Md):

$$\text{Ma} = \frac{100\ x\ M_W}{100 - M_W}$$

For example, the percentage moisture content wet basis of a sample of wheat is 18%. What will be its percentage moisture content dry basis?

$$M_a = \frac{100\ x\ 18}{100 - 18} = 21.95\%$$

To convert moisture content percentage from a dry basis (Md) to a wet basis (Mw), use the following formula:

$$M_w = \frac{100\, x M_d}{100 + M_d}$$

For example, the percentage moisture content dry basis of a sample is 22%. What is the percentage moisture content wet basis?

$$M_w = \frac{100\, x\, 22}{100 + 22} = 18\%$$

Determination grain moisture content accurately is important before making decision of harvesting, storage and milling (Table 3).

Table 3: Importance of measuring moisture content (courtesy: IRRI)

Operation	Desired Moisture Content (MC)	Primary losses
Harvesting	20-25 %	Shattering if grain is too dry
Threshing	20-25% for mechanical threshing <20 % for hand threshing	Incomplete threshing Grain damage and cracking/breakage
Drying	Final moisture content is 14% or lower	Spoilage, fungal damage Discoloration
Storage	<14% for grain storage <13% for seed storage <9% for long term seed preservation	Fungal, insect & rat damage Loss of vigor Loss of vigor
Milling	14%	Grain cracking and breakage Over milling

Moisture content of grain can be measured by using a drying oven, or by using a commercial moisture meter.

Standard method of determining moisture content:

10 grams of sample of each moisture level was dried in an air oven for 16 hours at 130° C.

Method

1. Pre-heat the oven at 130°C (Fig. 28);
2. Weigh three paddy samples of 10 grams each and place them inside the oven;
3. Remove the samples after approximately 16 hours, and obtain the final weight of each sample;
4. Compute the MC for each sample : MC = (10 - Final weight of dried sample in grams)*100/(10);

Compute the average MC of three samples

Fig. 28: Hot air oven

Most commonly used commercial moisture meters are built on electrical methods. The electric meters are not suitable for the determination of the very high moisture contents which can be measured with infra red and acetylene methods, their speed and ease of operation together with consistent accuracy; make them the first choice of most formers.

The electrical moisture meters measure moisture content 'indirectly' as the instruments are calibrated with the electrical properties of grain. Electrical moisture meters can be divided into two categories according to the characteristic of grain which they measure:

Capacitance type moisture meters

A sample is poured into an enclosure with walls that form the plates of a condenser activated by a high-frequency current. Precise weighing and correction for temperatures differing from 77○F are required for accurate measurements. A calibration chart is needed for every grain type. Capacitance meters are generally more accurate over a wider range of moistures than resistance meters. The normal moisture content range is 5-40% but this can be extended by recalibration of instrument. The sample size is 250 grams and the chained accuracy is 0.2% (Fig. 29).

Dole moisture meter

Borrow Moisture meter

Fig. 29: Capacitance type moisture meters

Resistance measuring moisture meters

This type of moisture meter measures the electrical resistance of a grain sample to an electrical current (Fig 30). The value of the resistance is measure of moisture content. A whole grain sample is placed between two electrodes in a compression cell. The sample must be compressed to a known and constant value for accurate measurements. A grain temperature correction is sometimes used. An example of this type of meter was recently tested with cereals in the range 12 to 20%. The meter readings varied from 0 to 0.3% high with wheat to 0 to 1.8% low with barley. Oil seed rape was tested in the range 8 to 15% moisture content when the results were found to be 0.5 to 5.2 low. However, in all cases, the meter was consistently most accurate at the moisture content which is required for prolonged storage of the species in bulk. A sampled could be ground and it moisture content determined in approximately one minute.

Satake Moisture meter

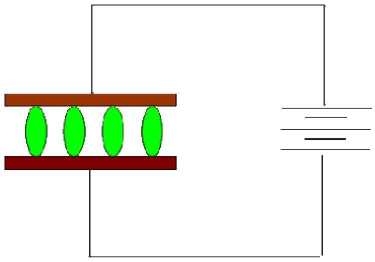


Fig. 30: Resistance type moisture meters

The accuracy of resistance meters is dependent upon a normal distribution of moisture throughout the grain. Hence recently dried grain may tend to give low readings if the surface of the grain is disproportionately dry. Conversely, grain which has recently wetted may give high readings. A resistance type meter has been specified for use by the US Department of Agriculture for the determination of moisture content of grain for which standards have been established.

Exercise to determine moisture content and calibration of moisture meters

Learning Objectives

1. To familiarize with the commonly used moisture meters in the grain industry and to know how to use these moisture meters;
2. To calibrate selected moisture meters with respect to AOAC Standard method using the hot air oven, and
3. To determine the accuracy, allowable quality limits, precision and reproducibility of

selected moisture meters.

Determination of Moisture Content (% wet basis)

1. Familiarize with different moisture meters. The moisture meters to be used in this exercise are as follows: Satake (Resistance type), Dole (Capacitance type) and Burrows 700 (Capacitance type).

2. There are 5 paddy samples corresponding to the 5 moisture levels to be used in the experiments. The Burrows 700 requires a 250 g sample, the Dole requires approximately 200 g depending on the moisture content and the Satake requires only a few grains.

3. Determine the moisture content of the paddy samples. Ten measurements will be made per meter per sample.

4. For your control, prepare a 30 g sample in triplicate and dry in an oven set at 130^{o}C for 16 hours. The samples must be cooled in desiccators before weighing.

5. The precision and reproducibility of the moisture meter need 10 samples. Each group will determine these parameters for a selected moisture meter (Satake TA-5).

6. Do the statistical analysis (one-way ANOVA) on the moisture content obtained from the different moisture meters with AOAC Standard (Oven) method as control.

B. Moisture Meter Calibration

1. Select a moisture meter to be calibrated. Then, prepare three samples at 30 g per sample for five moisture levels. Dry the samples in the hot air oven set at 130^{o}C for 16 hours. Cool down the dried samples in desiccators before weighing.

2. Using the results from part **A**, plot the moisture content obtained from the meters versus Oven method and determine the calibration equation by simple linear regression.

Questions:

Which moisture produced accurate results? Which type of moisture meter is suitable for high moisture content and for low moisture content? Which meter would you recommend to farmers? and why?

2.2 Paddy Drying System

Drying is a process of simultaneous heat and mass transfer. It refers to the removal of moisture from the product naturally or artificially to prevent the action of spoilage causing organisms. It is one of the most important activities in the post-harvest system. The natural drying process utilizes heat from the sun, while artificial drying uses devices for bringing the heat from the source to the product. In drying of biological products under constant external conditions, two distinct periods prevail. These periods are the constant-rate moisture loss during the initial drying period followed by the falling-rate period. Most cereal grains usually dry entirely within the falling-rate period. The drying operation analysis, especially in deep bed dryer, is a complex process. To avoid this complicated process, the total depth is divided into several thin layers. Through this, the factors affecting the drying process can be quantified, thus making the analysis simpler, easier and quicker.

As the rice combine harvester works at less loss of paddy, the potential shortcoming is that the paddy must be harvested at high-moisture content, i.e., >28%. This high moisture content is conducive to rapid deterioration in quality such as discoloration, yellowing, germination, and damage to milling quality.

The only practical means of preventing grain quality deterioration is immediate drying of high moisture paddy, as sun drying, the conventional method, is inadequate to guarantee the quality and quantity of the produce, thus there is a high demand for mechanical drying facilities.

However, before introducing mechanical dryers, it seems appropriate to discuss shade drying and sun drying given the fact that both methods remained the most popular practice in most farmers' communities.

Shade Drying

Shade drying is the process of removal of water from grain to ambient air at low temperature. Head rice yield from shade drying is highest. Shade drying is not used for commercial purpose, as it needs large area and longer drying time hence making it inefficient. Quality of rice does not change much when dried at low grain temperature.

Commercial sun drying

Sun drying at commercial level can produce good quality paddy if recommended practice and proper tools are used. These tools are less capital intensive and can be used with unskilled labor. Basic requirements for sun drying are:

1. Paved even area (as big as a basketball court) without trees and big buildings in vicinity.
2. Moisture meters and thermometers to check moisture content and paddy temperature frequently

3. Power mower and hand mowers for mixing and spreading the paddy
4. Plastic sheets and fences for covering during (i) over heating (ii) raining and heavy wind (iii) mixing with other materials, and, (iv) contamination from birds and animals
5. Spread the grains in thin layers, ideally 2-4 cm.
6. Turn the grain at least once per hour.

Mechanical dryers

Most mechanical dryers available are suitable to rice millers and farm cooperatives that handle thousands of tons of paddy. Small-scale dryers were developed for farm use as fixed-bed dryers and solar rice dryers, which are appropriate at farm level. However, those have not been widely accepted due to their potential inconvenience.

Accelerated drying of high moisture paddy using conduction heating with a rotary dryer is becoming popular which allows the use of high temperatures for quick drying without significant damage to the grain. This technique has been reported to be promising from the energy consumption point of view.

A rotary dryer based on conduction and natural convection heating can effectively reduce moisture content from 23–16% (w.b.), using a pipe heat exchanger at surface temperatures of 170–200°C with a residence time of 30–70 seconds. Rapid drying and good milling quality of the paddy could be achieved with such a dryer.

The combination of conduction and convection heating type rotary dryers was developed for on-farm drying as a first stage drying process. It consisted of double cylinders: the external cylinder with 500 mm diameter, attached to the inside surface with straight flight; and an inner cylinder, hexagonal in shape with an outer tray and firing device installed inside as a part of inlet cylinder. The grain was cascaded into the external cylinder with a concurrent flow of air. The experimental results showed that about 3% of moisture content could be removed with a single pass with small reduction in milling quality.

A further improved prototype of combined conduction-convection type rotary drum dryers is the provision of ambient air, which was forced into the drum in a counter-flow direction to the cascading grains. The grain was heated by conduction heating as drying proceeded and followed by convection heating as cooling occurred of the heated grain. The results showed that its partial drying capacity increased approximately to double that of the pre-dryer developed by IRRI, requiring only a single pass operation. Neither drum surface temperature nor ambient air velocity and their interaction influenced total milling recovery and head rice recovery.

Combined conduction-convection heating rotary dryer

A combined conduction and convection heating rotary dryer for 0.5 ton-hr-1 capacity using LPG as a heat source suitable for drying high moisture paddy at farm conditions. This type of dryers is an affordable way to dry field paddy on the day of harvesting to facilitate handling and for higher returns of produce for the farmer. The operation details below describe the operating conditions in which moisture up to 3% can be removed in a short time while grain quality should be close to fresh paddy. Performance of the rotary dryer in terms of moisture removal, residence time, energy consumption, and milling quality is also given.

This prototype rotary dryer, designed with a concurrent flow system, comprised of two primary parts, a double cylinder and a discharge cover, as shown in Fig. 31. Forward movement of paddy takes place by the inclination angle and rotary motion of cylinder, while air is blown through the cylinder by the suction fan located on top of the discharge cover. A 1-horse-power motor with a 1:60 reduction gear was used to drive the rotary dryer. The LPG lamp on the entry end heats up the air and heated air moves to other end due to suction fan. During forward motion, paddy first contacts the outer surface of inner cylinder where conduction heating takes place followed by a cascading action along the inside of the external cylinder resulting in convection heating. The paddy then falls on to the discharge cover and out of the dryer, while the suction fan sucks out the moist air.

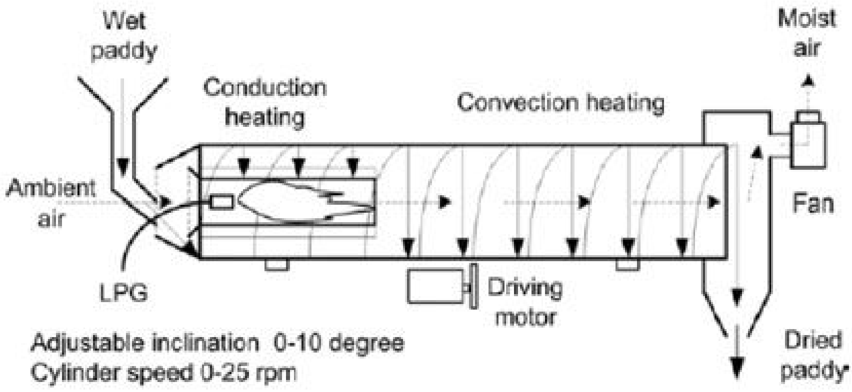


Fig. 31: A Schematic drawing of combined conduction and convection type rotary dryer

Relatively less moisture was removed during the last (third) pass at temperatures of 100 and 110°C, that is, 1.5 and 1.7%, respectively. While at 120°C, moisture content of 2.1% could be removed. Obviously, this is due to the fact that less free water was available at the third pass of drying.

The conduction and convection zones are shown in Fig. 32, along with the inlet and outlet temperatures of grain and hot air. It can be seen that high temperatures in the conduction zone can remove higher amounts of water than the convection zone which is, in turn, sucked out by hot moist air. It can also be observed that outlet grain temperatures were dropped to the safe range (max. 52°C) within a very short time (2–3 min.).

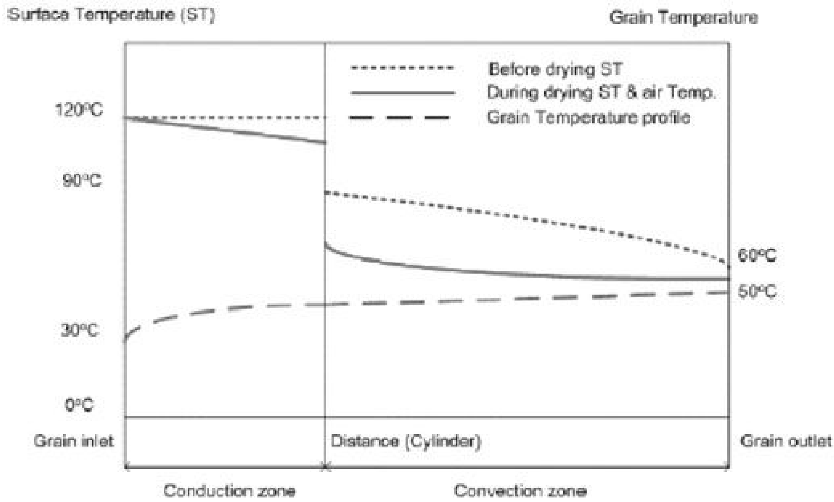


Figure 32: Temperature profile during conduction and convection

This demonstrates the dryer's heat exchange efficiency. The comparison of the effects of conduction heating and convection heating on moisture removal showed that the major moisture content of paddy was removed by conduction heating for all temperatures, while the convection heating could remove moisture at less than 0.4%. Being designed as the mobile unit for drying paddy in the field, energy consumption is one of the most important aspects to consider.

The difference in weight before and after running a pass was recorded. Statistically, insignificant difference was found in weight of LPG consumed at all temperatures. However, the average power consumption was 0.6 KWh and power of 0.46 kg/hr LPG.

It was estimated that the operating cost to remove up to 1% of moisture content of 1 tonne paddy was 0.23$ in the first pass. The cost will increase up to 0.33$ in the second pass and subsequently increase in the third pass, depending on availability of free moisture.

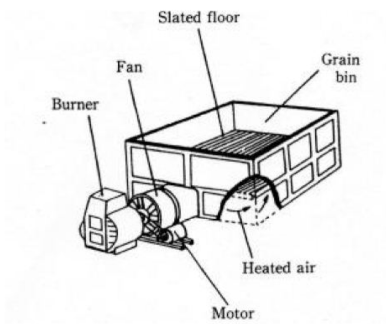


Fig. 33a: Flat bed dryer

Design of various types of dryers

Following is a list of commonly used dryers, basic design principle and components, capacity and energy requirement is summarized. For detailed information on each type of dryer, the reader is encouraged to IRRI's manual on dryers.

Static type: drying without moving grain while drying.

The static type dryer was used in practice 30 years ago in Japan. The uneven drying is the weak point of this type of dryer (Fig. 33a, b). Its characteristic features are:

1. Capacity : 0.7 – 1.5 to (paddy)
2. Layer thickness : 20 – 60 cm
3. Heated air temperature : <50oC
4. Air quantity ratio : 0.5 – 1.0 m3/ sec-ton
5. Drying speed : 0.5%/hr

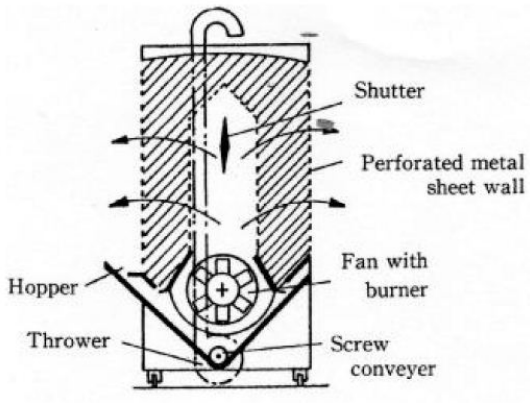


Fig. 33b: Vertical type static dryer

Circulation type dryer (tempering drying): designed for farmer and facility use

Effective drying takes place as the uneven drying is eliminated in this design (Fig 34a). The ratio of air quantity to paddy is very effective. The characteristics are:

1. The holding capacity is 1 to 10 tons.
2. Heated air temperature : 40 -55oC
3. Drying speed : 0.6 – 1.0%/hr

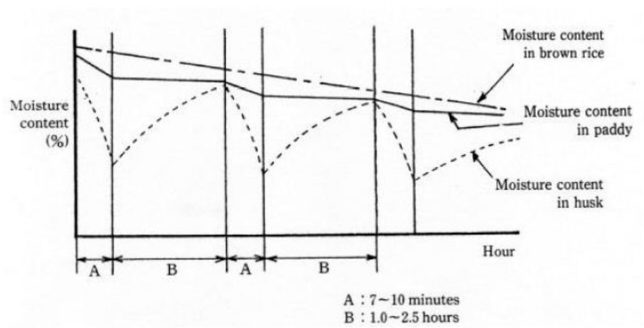


Fig. 34b: Tempering process

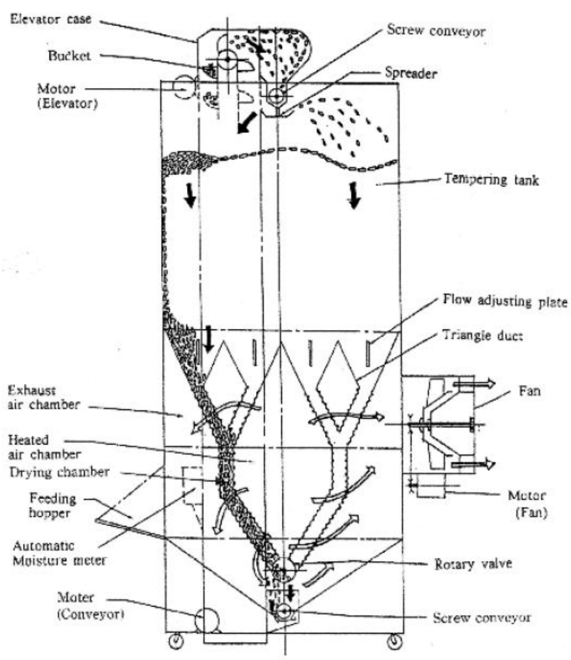


Fig. 34a: Circulation type dryer

Tempering during drying process

First the moisture in the husk is reduced while the paddy passes through drying chamber for a short time (A). After that, the paddy is tempered in tempering tank for a few hours (B) (Fig. 34b). During the tempering process, the moisture in the brown rice gradually shifts to the husk. Thus the moisture of the husk and the brown rice equalized. By repeating this process, the paddy is dried evenly. Thus, the paddy is dried safely without crack.

Continuous type dryers:

Paddy is continuously fed at the inlet and discharged from the outlet. Paddy passes through the dryer several times and in between each drying, paddy is tempered in the tempering tank at each drying process (Fig. 35).

Columnar Type

1. Capacity: 15 – 20 ton
2. Drying time for one pass: 30 min
3. Reduction of moisture content by one pass: 2%
4. Heated air temperature : 60 - 80°C
5. Air quantity ratio: 2.5 m^3/sec-ton
6. Air volume: 2250 – 3000 m^3/min, Tempering time: 3 -8 hr

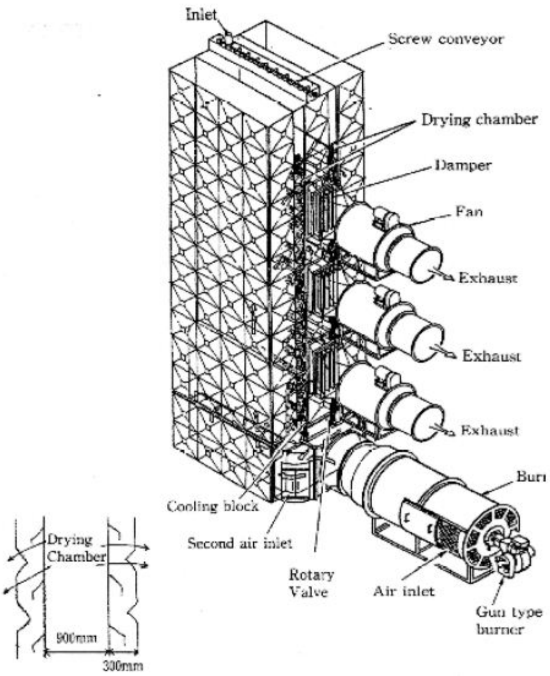


Fig. 35: Column type dryer

Mixed Flow Type (LSU Dryer)

Heated air enters through the unique air intake channels passes between grain to absorb dust and moisture, and is discharged through exhaust channels to be sucked up by the cyclofan (Fig. 36). With this suction system, airflow is smooth and even.

1. Capacity: 15 – 20 ton
2. Drying time for one pass: 30 min
3. Reduction of moisture content by one pass: 2%
4. Heated air temperature: 60 - 80 °C
5. Air quantity ratio: 1.3 m^3/sec-ton

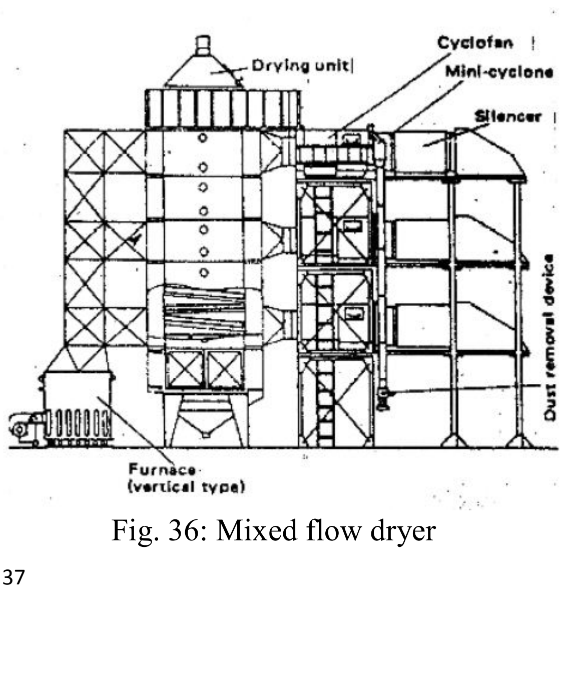


Fig. 36: Mixed flow dryer

6. Air volume: 1170 – 1560 m^3/min,
7. Tempering time: 3 -8 hr

Exercise for the determination of optimum drying temperature and evaluation of rice dryer

Learning Objectives

The general objectives of this experiment are to gain insights into the drying principles of selected biological products and to analyze the drying characteristics using the existing drying models. The specific objectives are:

1. To study the drying characteristics of grain (rough rice) using heated air at different temperatures and determine the factors affecting the drying process,
2. To evaluate dryer performance.

Drying

1. Prepare the grain sample by soaking it overnight and then drained for some for removing surface moisture. Weigh 300 g sample in replicate for each sample per treatment. The samples will be placed in wire mesh containers so as to provide better exposure to the drying medium.
2. Dry paddy at four temperatures, i.e., 60, 70, 80 and 90°C.
3. When the drying temperatures is stabilized, place the samples into the ovens and record weight of each sample at 5 min. interval in the beginning upto 3 h and then at 15 min. interval until constant weight is attained.
4. Monitor also the relative humidity during drying with the help of wet and dry bulb thermometers placed inside the oven. Five to seven readings will be taken for the entire drying duration and the average will be used for equilibrium moisture content determination.
5. Monitor also the drying temperature throughout the drying duration. As much as possible, maintain a constant temperature.

B. **Initial Moisture Content Determination**

6. The initial moisture content of the samples used in **A** must be determined. Separate oven will be used for this purpose.
7. For grain, at least 20 or 30 grams in three replications will be dried using the air oven at 130°C for 16 hours. After drying, the samples will be cooled down in desiccators before weighing.

C. **Evaluation**

Determine drying rate i.e., rate of moisture removal with relation to drying temperature and %RH.

Determine effect of drying temperature on quality of paddy (discussed in section 2.4 and 2.5).

2.3 Grain storage

Moisture content and temperature affect the storability of rice to great extent. As the moisture content increase and the temperature rises, respiration becomes more active, consuming more nourishment, advancing the deterioration of quality and promoting the growth of molds and insects, thus inducing the degeneration of the rice.

Paddy is usually stored in bags which are stacked inside warehouses. Some are stored in bulk on floor or platform with built-in ducts for heated air drying and subsequent aeration or using bins or silo associated with the drying and milling operations. Fumigation, aeration and the maintenance of clean warehouses are considered good warehouse management practices.

Milled rice wholesalers usually store their product in sacks which are stacked in secured warehouses using one or a combination of sandwich, window or block stacking technique to permit maximum air flow through the spaces and maintain aeration. This is to prevent rice from deteriorating in quality due to moisture absorption. Rodent traps and other means of controlling them and insect pests are also instituted by necessity.

Types of Grain Storage systems

Grain storage systems can be classified as either bag or bulk as recommended by the IRRI.

Open Bag storage system

Grain is stored in 40-80kg bags made from either jute or woven plastic (Frg.37). Depending on the size of storage, these bags are normally formed into a stack. Some farmers use bag storage in outside granaries, which have been constructed from timber or mud/cement or large woven bamboo or palm leaves.

Hermetic Sealed storage

Sealed or hermetic storage systems are a very effective means of controlling grain moisture content and insect activity in tropical regions. These systems vary in size from 1-300tons.

- Reduces insect activity (1/kg)
- Constant grain moisture content
- Increases the life of seed from 6 months to 12 months
- Maintains milling quality

(Rickman and Gummert, IRRI)

Fig. 37: open bag storage system (above), hermetic sealed bag (below)

Smaller 50kg hermetic bags which fit inside the traditional bags are also available.

Household metal silos

The household metallic silo is a simple storage technology recommended by FAO for small and medium-scale grain farmers (Fig.38).

Fig. 38: Household metal silos

Bulk storage

Granaries

At farm level grain is often stored in bulk in small outside granaries or in woven baskets or containers made from wood, metal or concrete, which are located under or inside the house. These storages vary in capacity from 200-1000kg. Losses from insects, rodent, birds and moisture uptake are usually high in traditional bulk storage systems.

Silos

The large export mills and collection houses sometimes use metal or concrete silos. These silos range in size from 20-2,000 ton capacity. Silos have the advantage that they can be more easily sealed for fumigation and less grain is spilt or wasted. Bulk storage warehouses are not very common in Asia.

Silo design and aeration system

Aeration is a process of forcing air through grain or stored paddy at low flow rates to reduce its temperature and maintain its quality. It is a very useful storage management tool which can preserve grain from deterioration, especially where the moisture content of the grain is above its safe level. The objectives of a good aeration system are:

- To remove generated heat and water from grain
- To maintain a uniform temperature in the grain bulk or equalizing temperature throughout the grain bulk
- To keep that temperature to a low level as practical
- Creating low temperature in the grain bulk
- Removing or reducing odors from grain
- Equalizing grain moisture
- Removing dryer heat

- Reduce moisture accumulation
- Fumigant application

General requirements for ambient aeration for storage design are (i) some form of perforated ducting on the floor through which air can be blown into the grain, and (ii) venting above the grain for air exhaust with downwards aeration the floor ducting is used for exhausting the air and the roof opening is the air inlet.

The components of aeration system basically consist of the following:

- Aeration ducts
- Air supply duct
- Fan (blower)
- Fan operation control equipment or controller
- Storage bin

Storage bin

A structure designed primarily to maintain grain quality. For the use of aeration technology grain must be stored in bulk (Fig. 39).

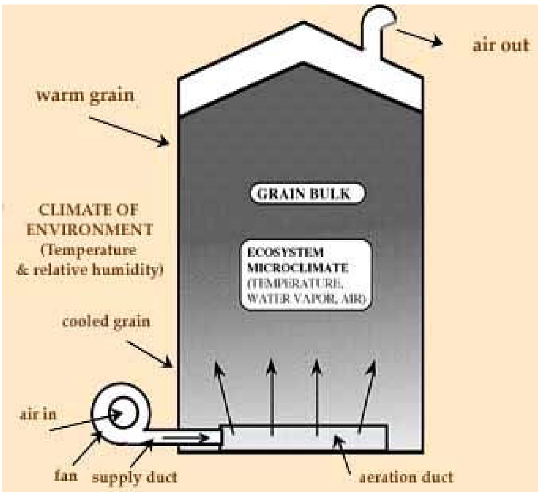


Fig. 39: Storage bin with aeration system

The storage structure can be vertical or horizontal. Vertical (upright) storage is any structure where the height is greater than the diameter or width, whereas horizontal (flat) storage is any structure where the height is less than the diameter or width

There are three principal considerations in the design of aeration systems.

1. Airflow rate

This is the volume of air desired to maintain uniform conditions in the stored bulk and to remove the generated heat and water.

The recommended rate depends on the purpose of aeration, the type of grain being aerated, the size and type of storage structure, and climatic conditions.

2. Fan selection

The selection of fan is normally based on the airflow rate used for a particular grain, the kind of grain handled and the grain depth.

These factors determine the resistance of grain to airflow and the static pressures against which the fan must deliver the required airflow.

Two types of fan are used for aeration. These are the centrifugal and the axial flow fan. Generally, the axial flow fan will deliver more air than centrifugal fans at static pressures up to about 4 inches of water (1,000 Pa). For higher static pressures, the centrifugal fans are recommended.

3. Air distribution

This includes the ductings, false floors, etc. which are used to move the air to the desired points (Fig. 40).

The proper sizing of the ducts, the sizing and spacing of the openings in the ducts to let the air move between the duct and aerated grain, the layout of the duct system are important to maintain the entering (or exiting) air at an acceptable velocity and provide uniform airflow through the grain.

Modern aeration systems are also equipped with automatic controls which are now widely used.

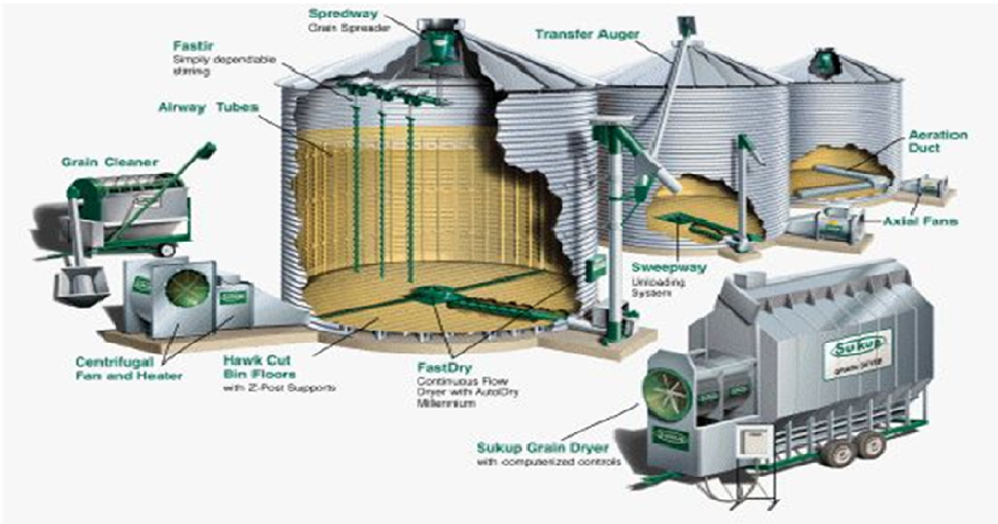


Fig.40: Duct system for round or rectangular bins

There are 10 Steps in the design of aeration of bulk storage

Step 1	:	Select design moisture
Step 2	:	Calculate the generated heat
Step 3	:	Select a design day
Step 4	:	Calculate equilibrium humidity
Step 5	:	Determine hours of operation per day
Step 6	:	Calculate kilogram of air needed per day
Step 7	:	Determine air volume and pressure
Step 8	:	Select fan
Step 9	:	Design the air distribution system

Step 10 : Design the power and controls

Be referred to training materials given during the workshop for detail calculation on each step.

Exercise for the Determination of Frictional Properties and Flow of Granular Materials

Learning Objectives

1. To determine the angle of internal friction and angle of repose
2. To determine flow factor using Jenike's method for a product such as wheat flour.
3. To evaluate the effect of height of material above the orifice opening in a conical hopper on its flow rate.
4. To study the relationship between the orifice opening size and flow rate

Equipment and Materials

Coefficient of friction and angle of repose measuring set up; a transparent model bin; a conical hopper with changeable orifice openings, and Jenike's setup.

Tasks

1. Determine the coefficient of friction of grains on selected surfaces and evaluate the effect of increase in moisture content and normal load.
2. Determine the angle of repose for the materials used in step (1) and compare it with the angle of internal friction.
3. Determine the yield locus for wheat flour for at least 3 compaction levels and determine the flow function.
4. For any selected orifice opening size, determine, the material flow rate out of the hopper using different filling heights. Evaluate the effect of material height on its flow rate.
5. Determine the flow rate of selected grain using different orifice openings and fixed amount of material. Develop a log-log plot of flow rate as a function of orifice opening and interpret the results.

2.4 Milling and Parboiling

The processes of converting paddy into rice involve removing the husk from the paddy and removing all or part of the bran layer. The milling of rice involves at least two basic operations as dehusking and whitening process. The factor of milling as variety of paddy, condition of paddy during milling, degree of milling required, the kind of rice mill used, the operators, insect infestation and others. Important points in the rice milling process;

1. Selection of raw rice
2. Important points for rice milling
    a. Rice milling machine
    b. Milling degree and whiteness of brown and milled rice
    c. Temperature rise, broken rice, and milling loss
3. High quality, high efficiency, and accessories
4. Effective processing of byproducts
5. Rate of utilization

The large scale rice mill is higher technology to control milling operation more than the small scale therefore, the results is more grain recovered, more whole grains and less broken (The Food Agency, 1995 and Lantin, 2003).

Rice milling system

- One step process
- Two step process
- Multi stage process

In a one step milling process (Engleberg mills), husk and bran removal are done in one pass and milled or white rice is produced directly out of paddy. This mill is a steel friction type mill and uses very high pressure to remove the hull and polish the grain. This results in many broken kernels, a low white rice recovery of 50-55% and head rice yields of less than 30% of the total milled rice. The fine brokens are often mixed in with the bran and the ground rice hull and this is used for animal feed. The poor performance of the Engleberg mill is discouraged to use in commercial mills.

In a two step process, removing husk and removing bran are done separately, and brown rice is produced as an intermediate product. These mills have a capacity of between 0.5 to 1 ton per hour paddy input and are often used for custom milling in the rural areas. The milling performance of the compact rice mill is superior to the single pass Engleberg huller with milling recoveries normally above 60%.

In multistage milling, rice will undergo a number of different processing steps that produces higher quality and higher yields of white rice from paddy or rough rice. The process involves:

1. Pre-cleaning the paddy prior to milling
2. Removing the husk or outer layer from the paddy
3. Polishing or whiting the brown rice to remove the bran layer
4. Separating the broken grains from the whole kernels
5. Bagging the milled rice
6. Managing the by-products.

For details on each strep of commercial milling, IRRI training manual should be consulted. Main points of each step are summarized here:

1. Pre-cleaning

When paddy comes into the mill it contains foreign material such as straw, weed seeds, soil and other inert material. If this is not removed prior to hulling the efficiency of the huller and the milling recovery reduced. The capacity of the paddy pre-cleaner is normally 1.5 times milling capacity.

2. Removing the husk (dehusking or dehulling)

Brown rice is produced by removing the husk from the paddy rice. The husk is removed by friction as the paddy grains pass between two abrasive surfaces that are moving at different speeds. After dehusking, the husk is removed by suction and transported to a storage dump outside the mill. Husk accounts for 20% of the paddy weight and an efficient husker should remove 90% of the husk in a single pass.

3. Paddy separation

The paddy separator separates unhusked paddy rice from the brown rice. The amount of paddy present depends on the efficiency of the husker and should not be more 10%. Paddy separators work by making use of the differences in the specific gravity, buoyancy and the size difference between paddy and brown rice.

4. Whitening or polishing

White rice is produced by removing the bran layer and the germ from the paddy. The bran layer is removed from the kernel either abrasive or friction polishers. The amount of bran removed is normally between 8-10% of the total paddy weight. To reduce the number of broken grains during the whitening process, rice is normally passed through two to four whitening machines connected in series.

5. Separation of white rice

After polishing, the white rice is separated into head rice, large and small broken rice and “brewers” by an oscillating screen sifter. Head rice is normally classified as kernels that are 75-80% or more of a whole kernel. To attain a higher degree of precision for grading and separation a length or indent grader is also used.

6. Rice Mixing

A good rice mill will produce 50-60% head rice (whole kernels) 5-10% large broken and 10-15% small broken kernels. Depending on the countries standards, rice grades in the market will contain from 5-25% broken kernels. If rice mixing is to be done properly a volumetric mixer is necessary.

7. Mist Polishing

Mixing a fine mist of water with the dust retained on the whitened rice improves the luster of the rice (polishes) without significantly reducing the milling yield. A friction type-whitening machine, which delivers a fine mist of water during the final whitening process, is used for “final” polishing before sale.

8. Rice Weighing

Rice is normally sold as 50kg sacks which must be accurately weighed and labeled. While most rice mills use manual mechanical weighing system very accurate and fast electronic systems are also available.

Parboiling of Paddy

Paddy parboiling refers to water/heat treatment of paddy prior to its conversion into milled rice. It has been known that parboiling process can produce more head milled rice as compared to the processing of raw paddy. The breakage in milling will be less resulting in an improved quality. Moreover, resistance to spoilage during storage will also be less. The milled parboiled rice is of higher nutritional value as compared to non-parboiled milled rice as a result of favorable redistribution of nutrients, oil, minerals and fats through the grain. This treatment is done to improve the milling recovery of paddy, to improve poor quality or spoiled paddy and to meet the demands of a certain consumer preferences.

There are three important steps involved in paddy parboiling, namely: soaking (or steeping) paddy to increase its moisture content to above 30%, heat treatment of wet paddy, usually by steam, to complete the physical-chemical changes and drying the paddy to a safe moisture level before milling.

Exercise on parboiling and milling quality evaluation

Learning Objectives

The general objective of this experiment is to familiarize with the processes involved in paddy parboiling. The specific objectives are listed below:

1. To determine the effect of soaking and steaming duration on the quality of parboiled rice;
2. To evaluate the degree of parboiling using the following parameters:
   - i. Milled rice yield
   - ii. Head rice yield
   - iii. Milled rice whiteness
   - iv. White-belly grains
   - v. Heat damaged grains,
   - vi. Textural profile of cooked rice
3. To evaluate the textural parameters of parboiled rice using Back Extrusion Test. (discussed in section 2.5)

A. ***Parboiling of paddy***

1. Prepare the paddy sample and clean it thoroughly before soaking. Set aside a paddy sample taken from the same sample lot for controls. You should have **two controls**. One control will be taken from unparboiled paddy and the other will be from the soaked paddy but no steaming. Prepare 3 replicates for each control.

2. Soak the clean paddy using the hot water bath. The soaking duration will be 4 hours at 60°C. After soaking, the water will be drained out but the paddy will be left in the soaking vessel overnight for tempering as suggested by Velupillai and Verma (1982).

3. Steam the soaked paddy using an autoclave. The steam pressure will be kept at 1.0 kg/cm^2 at 3 different durations (5, 10 and 25 min.). Make 3 replications per steaming duration at 200 gram each.

B. ***Drying of steamed paddy***

1. Dry the steamed paddy until the moisture reaches to 14% (wet basis) in two stages.
2. Use 60°C for the first stage drying up to 18% MC. This part will last for 2 - 3 hr. depending upon the airflow rates of the oven. Constant monitoring of the MC using Satake moisture meter will be made after every 1.0 hr. of drying.
3. When the MC reaches 18.5 or 19%, stop the drying process and temper the samples at room temperature for 2 hours.
4. After this, check the moisture of the paddy if it is still high, proceed with the **second** stage drying. The second stage drying of the samples will be made at 45°C until the paddy moisture reach 14%.
5. Temper or cool down the paddy for at least 2 hours before milling. (Note: this is the most

critical stage in paddy parboiling; over-drying may result in poor quality parboiled rice).

C. *Milling*

1. Mill 125 g of paddy using a Satake Huller. Record weight of milled paddy.
2. Make the desired adjustment of the huller in such a way that hulling will be at 95%. Make two passes. Polish the husk paddy using a Satake Polishing machine for 1 minute and record the weight.
3. Use a grader to separate brokens. Record the weight of head rice and brokens separately.

D. *Quality Evaluation*

1. Milling yield refers to the amount of rice obtained after the milling process. This will be expressed as a percentage of the paddy (125 g).
2. Head yield refers to the head rice obtained after milling. It is the total rice less the brokens and expressed as a percentage with respect to the paddy weight. This will be done using the Satake Grader.
3. Brokens refers to the pieces of rice kernel that are less than the size of the full.
4. White-belly grains refers to the ungelatinized starch indicated by a white opaque spot at the center of the kernel. This can be done by putting the sample on the white belly detector. The weight of white belly grains will be expressed as a percentage of the total weight of the head rice.
5. Whiteness refers to the degree of whiteness of the sample surface with reference to the standard.
6. Heat-damaged grains refer to the discolored rice kernels (usually at the tip). This will be expressed as a percentage of the total weight of the head rice.
7. **%Milled rice yield** = Milled rice weight x 100 / Paddy weight
8. **%Head rice yield** = Head rice weight x 100 / Paddy weight

2.5 Physical and Chemical Properties of Rice Grain

Measuring physical properties such as size, shape, uniformity, and general appearance are of utmost importance. The chemical qualities evaluations are determined in terms of the parameter such as: amylase content, gel consistency, gelatinization temperature, alkali spreading value. These parameters are related to the acceptability of the cooked product. Therefore, these parameters should be determined to evaluate the quality of the rice grain.

Learning Objectives

1. To familiarize with the commonly used methods for quality measurement of rice grain
2. To measure the physico-chemical parameters indicating the quality of rice grain

Chemical parameters

Amylose contents

The colorimetric iodine method of amylose estimation in rice has been simplified. The flour is dispersed in alkali by heating in water bath or by overnight soaking at room temperature. The extract is neutralized before color development by direct addition of phenolphthalein and decolorizing with dilute acid.

No simplified method of defatting (including extraction by methanol at room temperature) was found satisfactory. But apparent amylose content as determined in undefatted milled rice flour was close to 86% of the true value in 46 milled rice samples tested; hence determination without defatting and multiplication of the results with 1.16 was satisfactory for routine and approximate work. The apparent amylose value was, however, dependent on the degree of polish of the rice.

Particle size of the flour within reasonable limits had no appreciable effect on the results. The extract was quite stable even when stored in the room temperature.

Amylose content was determined by iodine colorimetry method as recommended by Juliano (1971) Ground rice was passed through 100-mesh sieve and weighed 100 mg. Then, it was placed in a 100 ml. volumetric flask in duplicate. 1 ml. of 95% ethanol was added and followed by 9 ml. of 1 M. NaOH for washing down all the flour adhering to the side of the flask. The contents of flask were boiled in a water bath for 10 min. to gelatinize the starch. Then, the samples were completely cooled and distilled water was added to the flask to increase the volume to exactly 100 ml. and mixed well. The prepared solutions were stored over night at room temperature (25oC).

Above steps were also followed to prepare a blank treatment solution and kept overnight to the above procedures are followed except taking flour to the 100 ml. volumetric flask.

After kept it overnight, the flask was mixed and e ml solution was pipetted and transferred into 100 ml volumetric flask. Then 70 ml of distilled water, 1 ml of 1 M glacial acetic acid and 2 ml of I2-solution were added to the flask and volume was adjusted to 100 ml by distilled water. The sample was thoroughly mixed and left for 20 min to develop dark purple color. The absorbance of the color was measured in the spectrophotometer at 620 nm. after setting zero of the equipment for blank treatment solution. The value of absorbance is then converted back developed by potato amylase standard (Table 4).

Alkali spreading value

Six whole milled rice kernels were completely immersed in 10 mL of 1.5% KOH solution in a Petri dish and arranged so that the grains did not touch each other. The Petri dishes were then covered. After 23 h of incubation at room temperature, each grain was visually examined for its level of intactness and assigned a numerical score by 3 trained human inspectors: “1” for not affected kernel; “2” for swollen kernel; “3” for swollen kernel, with incomplete or narrow collar; “4” for swollen kernel, with complete and wide collar; “5” for split or segmented kernel, with complete and wide collar; “6” for dispersed kernel, with merging collar and “7” for completely dispersed and intermingled kernel (Fig. 41) .

For each sample, the test was repeated 4 times on 6 grains (n = 4).

Fig. 41: (a) Calibration scale (b) Non-glutinous rice (c) Glutinous rice

The alkali spreading value provides a simple means of classifying rice into high, intermediate and low gelatinization temperature types. The glutinous had the lower gelatinization temperature at 55-69oC, while non- glutinous had the high gelatinization temperature at 75-79oC. The non-glutinous had lower alkali spreading value than the glutinous and had higher gelatinization temperature than the glutinous because non-glutinous had the high amylose content lead to more temperature resistance.

Table 4: Classification of rice based on amylose content

Class of rice	%Amylose	Cooked product
Glutinous	0-2	very sticky
Low amylose	less than 19	soft and sticky
Intermediated amylose	20-25	soft
High amylose	25-34	fluffy, hard

Gel consistency

Gel consistency measures the tendency of the cooked rice to harden after cooling by measure the distance of blue color gel flour. The distance of non-glutinous (high amylase content) and glutinous (low amylase content) gel which were 54 and 48 mm, respectively. The gel distance was also related to the flow behavior of gel. It showed that the non-glutinous and glutinous had the same flow behavior, flow behavior of non-glutinous and glutinous gel were soft. Therefore, the cooked glutinous and non- glutinous rice had a high degree of tendency. In the real, non-glutinous should have the harder gel than the glutinous because the non- glutinous had the higher amylose content than the glutinous (Table 5).

Table 5: Classification based on gel consistency

Replication	Glutinous rice	Non-glutinous rice
1	50	59
2	49	52
3	46	51
Average	48.3	54.0

Evaluation of cooking quality using Back Extrusion Test in Texture analyzer

Rice cooking instructions

i. Prepare 25 g rice and place it into a 100 ml beaker. Prepare at least 2 samples per replicate.
ii. Add 45.587 g of distilled water.
iii. Cook the rice sample using a rice cooker with 400 ml of water.
iv. Cooking duration will be 20 minutes after the steam started coming out from the rice cooker.

v. Turn off the power source and leave the sample inside the cooker for 10 minutes. Remove the sample and place the beaker upside down on the screen for 45 minutes at room temperature.
vi. After cooling, put the sample in sealed plastic bags.
   a. Set up the texture testing machine for BE test. Set the crosshead speed to 1 mm/min and the chart speed to 200 mm/min. Install the back extrusion test set-up (Fig. ??). Use a spherical plunger. Set the crosshead stop button in such a way that the plunger bottom will not touch the BE sample holder base (Approximately 1 mm clearance).
   b. Fill up the extrusion cylinder with cooked rice and be careful not to compress the sample during the filling process. Place the preloading weight (150 g) on the cylinder for 30 seconds to initially compress the rice.
   c. Perform the test. After the test, remove the BE set up clean properly the extrusion cylinder and plunger.
   d. Determine the following parameters from the curve (see definitions below) Fig. 42.
      i. Hardness
      ii. Cohesiveness
      iii. Extrudability
      iv. Chewiness
      v. Maximum force
      vi. Packability

Definitions:

Hardness: the force required to attain a given deformation. This can be obtained from the average slope of the initial, approximately linear portion of the curve, and expressed in kg/cm.

Extrudability: a function of the hardness and cohesiveness. It is expressed as the average slope of the curve in Kg/cm after the onset of shear and extrusion. It is expressed as the average slope of the curve in kg/cm after the onset of shear and extrusion.

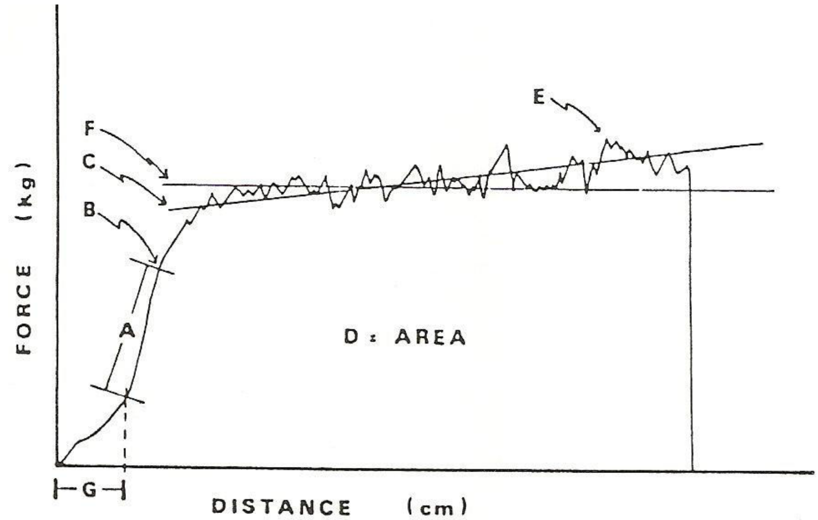
Chewiness: the energy required to masticate a solid food to a state ready for swallowing. It is measured as the area under the curve in cm^2 and represents the energy used to compress, shear and extrude the sample.

Maximum force: the maximum force is registered during extrusion.

Average maximum force: the mean force in kg during extrusion.

Cohesiveness: the strength of the internal bonds making up the body of the product. It is expressed as the force in kg required initiating shear and extrusion.

Pack ability: the distance in cm traveled by the plunger before an average linear slope is reached.



Typical force-distance curve for compression of a soy protein product in an Ottawa texture measuring system wire extrusion cell. (A) Hardness. (B) Cohesiveness. (C) Extrudability. (D) Chewiness. (E) Maximum force. (F) Average maximum force. (G) packability. (Bourne, 1982)

Fig. 42: Parameters of Textural Profile obtained in a Back Extrusion Test

Image analysis

Image analysis techniques have long been developed and commercially used for determining the quality attributes of cereals and grains linked with their size, shape, and appearance. Production of edible rice requires several processing operations such as milling, soaking, and cooking during which significant changes occur in kernel dimensions and appearance. However, little information is available in published literature on the applications of image analysis techniques for monitoring the dimensional changes in rice kernels during processing in relation to the varietal differences manifested by the physicochemical properties.

This study was aimed at investigating the changes in the dimensions of rice kernels and appearance by image analysis during milling, soaking, and cooking. In milling, the emphasis was on the estimation of head rice yield (HRY) defined as the proportion by weight of milled kernels with three-quarters or more of their original length along with kernel whiteness in terms of degree of milling (DOM). Further, the changes in kernel dimensions during soaking and cooking of milled rice were investigated in relation to their physicochemical properties. Finally, interrelationships among dimensional changes, water uptake, and physicochemical properties of milled rice kernels during soaking and cooking were developed.

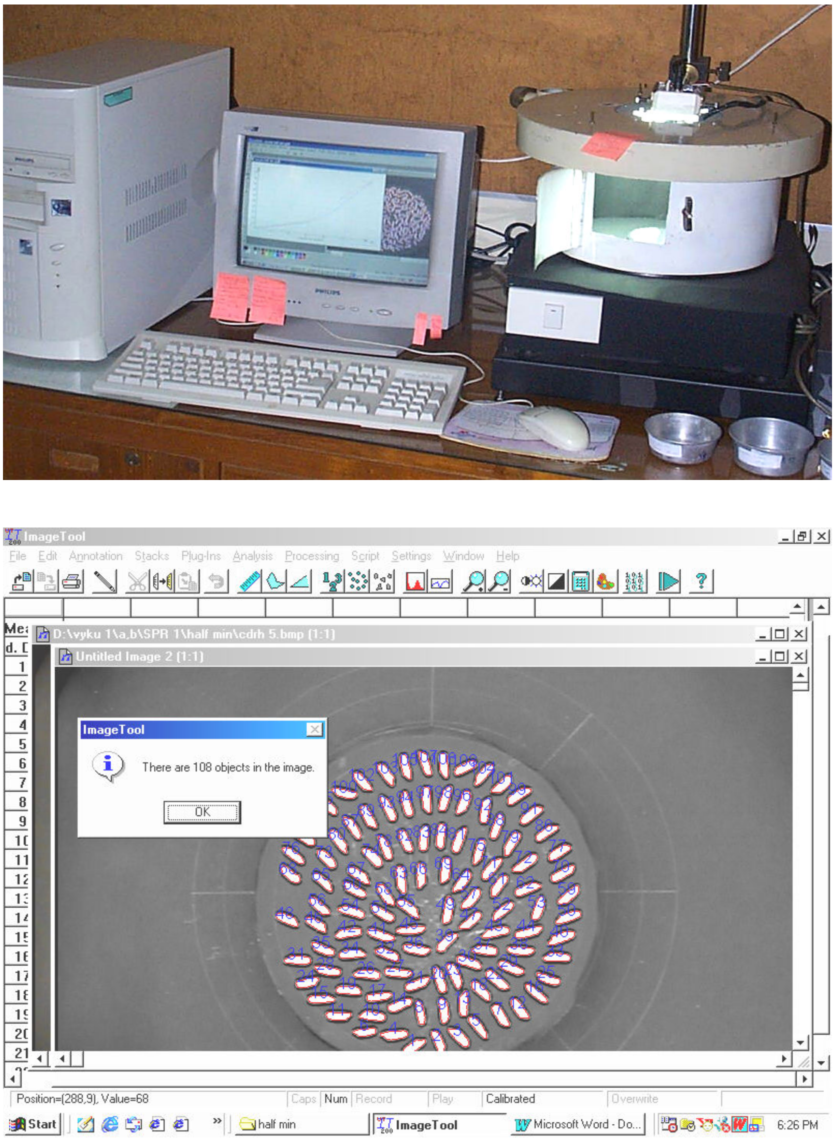


Fig. 43: Image analysis set up

At AIT, we developed a simple and robust scheme for image analysis consisting of a personal computer, frame grabber, and a color CCD camera (Fog. 43), which was used for the measurement of kernel dimensions and gray level distribution in 2-D images with Image-Tool 2.0 software available in the public domain. Ten Thai rice varieties ranging from low to high amylose content (16 to 28% d.b.) were selected for the study. Atotal of 50 samples, 5 for each variety, of rough rice weighing 200 g each were dehusked using a Satake dehusker and milled for 0.5–2.5 min at an interval of 0.5 min with a Satake polisher for obtaining various levels of AHRY and DOM. A representative sample of milled rice comprising head and broken kernels, weighing about 12 g, was placed under CCD camera manually for imaging with kernels not touching each other. Bulk samples of milled rice, which had been subjected to different degrees of milling, were imaged to determine the gray level distribution. Well-milled whole kernel rice was conditioned at three initial moisture contents (M0) of about 8, 12, and 16% (d.b.) for soaking and cooking experiments. A total of 105 kernels were imaged at each time interval to monitor the dimensional features such as length (L), width (W), perimeter (P), and projected area (Ap) during soaking, whereas a total of 32 kernels were imaged during cooking for each variety at the selected M0. Water uptake by 2 g rice kernels during soaking and cooking was determined and expressed in terms of change in their moisture contents. The physicochemical properties, namely amylose content (AC), gel consistency (GC), alkali spreading value (AS), and protein content (PC) of milled rice of different varieties were determined by standard methods.

Part III – Trends in Post-harvest and Rice Supply Chain

3.1 Good Agricultural Practice (GAP) Certification

Nowadays the consumer is becoming concerned about food quality and safety, Good Agricultural Practice (GAP) is one of system for guarantee the quality and safety from farm. They are applied through sustainable agricultural methods, such as integrated pest management, integrated fertilizer management and conservation agriculture. The GAP certificate is to ensure the safety of crop production and represents a reliable safety index for consumer's choices. Besides, the information at each stage of supply chain must be integrated for traceability. The objectives in using traceability systems are facilitation trace back for food safety and quality, differentiation and market foods with subtle or undetectable quality attributes and improvement supply management such as inventory, warehouse control.

Report of the Expert Consultation on a Good Agricultural Practices (GAP) Approach (2003) said that "The concept of Good Agricultural Practices has evolved in recent years in the context of a rapidly changing and globalizing food economy and as a result of the concerns and commitments of a wide range of stakeholders regarding food production and security, food safety and quality, and the environmental sustainability of agriculture. These stakeholders represent actors from the supply dimension (farmers, farmers' organizations, workers), the demand dimension (retailers, processors and consumers) and those institutions and service (education, research, extension, input supply) that support and connect demand and supply and who seek to meet specific objectives of food security, food quality, production efficiency livelihoods and environmental conservation in both the medium and long term."

The Food and Agriculture Organization (FAO) of the United Nations defined "Good Agricultural Practices" as a collection of principles to apply for on-farm production and post-production processes, resulting in safe and healthy food and non-food agricultural products, while taking into account economical, social and environmental sustainability.

GAP may be applied to a wide range of farming systems and at different scales. They are applied through sustainable agricultural methods, such as integrated pest management, integrated fertilizer management and conservation agriculture. They rely on four principles as follows:

- Economically and efficiently produce sufficient (food security), safe (food safety) and nutritious food (food quality)
- Sustain and enhance natural resources

- Maintain viable farming enterprises and contribute to sustainable livelihoods
- Meet cultural and social demands of society

Additional information on GAP: studies on incentives, cost, benefits can be found on FAO website:

- GAP database http://www.fao.org/prods/gap/database/index.html
- GAP website http://www.fao.org/prods/GAP/gapindex_en.htm

3.2 Good Manufacturing Practice (GMP)

Good Manufacturing Practice or GMP is a term that is recognized worldwide for the control and management of manufacturing and quality control testing of foods and pharmaceutical products. Since sampling products will statistically only ensures that the samples themselves are suitable for use, and end-point testing relies on sampling, GMP takes the holistic approach of regulating the manufacturing and laboratory testing environment itself. An extremely important part of GMP is documentation of every aspect of the process, activities, and operations involved with drug and medical device manufacture. If the documentation showing how the product was made and tested (which enables traceability and, in the event of future problems, recall from the market) is not correct and in order, then the product does not meet the required specification and is considered contaminated (adulterated in the US). Additionally, GMP requires that all manufacturing and testing equipment has been qualified as suitable for use, and that all operational methodologies and procedures (such as manufacturing, cleaning, and analytical testing) utilized in the drug manufacturing process have been validated (according to predetermined specifications), to demonstrate that they can perform their purported function (Wikipedia, 2007).

3.3 Traceability

Traceability is important in supply chain. Therefore, this section describes the traceability definition, objective of traceability, traceability system and technical instruments for traceability.

According to Webster's Dictionary, "Traceability is the ability to follow or study out in detail, or step by step, the history of a certain activity or a process".

Food traceability is the information necessary to describe the production history of a food crop, and any subsequent transformations or processes that the crop might be subject to on its journey from the grower to the consumer's plate.

Traceability can be divided into three different objectives as follows:

- Traceability to improve supply management.
- Traceability for safety and quality control.
- Traceability to market and differentiate foods.

Traceability System

We can separate the information to two basic sorts of data used within the system. The first type is information relating to a specific consignment or collection of food material; this is referred to as traceability data. The second type represents whole business information and describes the general environment in which the food material is grown or processed. Data collection starts on the farm and is done, as it is now, by the grower. We are concerned with two things as follows:

- The safety of the produce leaving the farm as a consignment.
- The quality of food production/cultivation on farm.

The data structure used should meet two conflicting criteria. First, it should be as small as possible to enhance speed and efficiency. Secondly, it must be of sufficient capacity to meet the needs of the largest data requirement. This structure meets these requirements as currently defined. In order to accommodate future knowledge or requirements, data versioning is used to allow modification or expansion.

A traceability record has five sections;

1) Location: the physical location of the food material, for example field, bin, silo, lorry or line.

2) Input: the input material itself, e.g. seed, and date of arrival at the location, e.g. drill date. It also contains links to earlier traceability records that relate to this input material.

3) Process: all processes that are carried out whilst the material is at the location, e.g. field treatments, washing or packing.

4) Monitor: all monitoring actions and their results. It also links to any process which is carried out as the result of a monitoring activity.

5) Output: records the date the material is moved from the location to another point in the food chain.

Technical instruments for traceability

Technical instrument for traceability are divided into three main groups as follows:

1) Alphanumerical codes are a sequence of numbers and letters of various sizes placed on labels, which in turn are placed on product or on its packaging. However, there are many problem associated with the large amount of managed manually data. The risk of data integrity corruption is very high.

2) Bar code system is simple visual representations of data which can be transferred to a computer via a barcode scanner. It is an automatic identification (Auto ID) technology that streamlines

identification and data collection. The benefits of using Barcodes for automated data collection are very simple: speed and accuracy. Moreover, bar code labels must be so positioned that they can be detected and identified by the reader and is easily damaged.

3) Radio frequency identification (RFID) system is an identification tool using wireless microchips to create tags that do not need physical contact or particular alignment with the reader. The reading phase is very fast and fully automated.

Among the three system, RFID is better system and more efficient. In this study, the RFID is used to investigate on data collection of rice supply chain.

3.4 Transportation

Small sized volume of paddy is transported in bags from the house storage to the small rice mill by foot, bullock carts, bicycles, motorcycles, small-sized vehicles, or public transport vehicles whichever mode is available and affordable. The paddy is harvested by combines and is handled and transported in bulk. The paddy is power unloaded from the combine by means of an auger conveyor into a waiting lorry or tractor-trailer at the field road, which is part of the infrastructure established for mechanized rice production. Paddy is unloaded from the lorry or trailer onto a floor hopper at the rice mill area for conveyance by either auger or belt conveyor to a mechanical dryer. The paddy is transported from farm to rice mill or middle man by different kind and size of vehicles depending upon the volume of the rice such as trailers, trucks and lorries. Transportation cost consisted of fuel consumption cost, driver cost, maintenance & depreciation, weighing charge, and loading/unloading charge which depend on destination, distance and vehicle type. The loading and unloading of the bags or sacks of paddy incur extra labor costs which are assumed by the trader or buyer of the paddy on site.

3.5 Utilization of by-products

Preliminary combustion studies of rice husk in a pot furnace indicated an optimum rate of combustion to be 70 kg husk/m2 hr with 60 percent excess air. The following considerations were incorporated in designing a husk-fired furnace:

1. Setting up a mixing chamber adjoining the furnace, in which the missing of the products of the products of combustion with ambient air should take place in order to attain the necessary temperature off the gas-air mixture Arresting the flying ash and sparks from going into the drying chamber.
2. An arrangement permitting the rapid change in the direction of the flue gases either to the chimney or to the drying chamber.
3. The furnace should ensure the best combustion of the fuel, as the appearance of smoke or soot in the products of combustion may cause not only the lowering of efficiency of the furnace but also deterioration in the quality of dried grain.
4. Convenience and simplicity of maintenance should be taken into account.
5. It should preferably be a portable unit.

Based on the preliminary combustion studies and the fuel properties of rice husk, a box type furnace for supplying 1,680 cubic meters per hour (1,000 cfm) at 700 C to 1200 C was designed, fabricated and tested at the Post-harvest Engineering Research Group. The furnace is equipped with an inclined grate (450 angle, 0.5 m2) consisting of the cast-iron bars in a staircase fashion. At the bottom of the inclined grate is a horizontal revolving grate which disposes off the accumulated ash at a certain interval. In between the combustion space comprising the inclined and horizontal grates and the outlet for the flue gases, there is a curtain wall throughout the width of the furnace. The height of the curtain wall is a little over the outlet so that no amount of un- burnt husk or fly ash goes into the chimney. The husk is fed at the top of the inclined grates with the help of feeding roller mounted in the hopper and powered with a 1/8 hp motor. The husk is spread in a thin layer throughout the width of the furnace and flows down the inclined grate by its gravity while combustion takes place. The burnt husk or ash is disposed off intermittently by rotating the horizontal grate. The suction end of the blower is connected with the outlet of the furnace. A secondary inlet to the blower is made to bring in the ambient air the mixture of the air and the flue gases at a required temperature is supplied by the blower either to the drying chamber or the chimney.

With the feed rate of 11 kg-hr of husk, the supply of 1,680 cubic meters per hour (1,000 cfm) of heated air flue gas mixture can be maintained at 1000 C. The furnace provides a perfect combustion with no traces of smoke in the flue gas .The flue-gas analysis shows about 3 percent CO2, 16 percent O2, 0 percent CO and the rest is inert nitrogen. It may be added that the gas-air mixture is nearly as good as the heated ambient air for drying purposes and has no bad consequences on the dried paddy.

Suggested Further Reading

1. Athapol Noomhorm, Imran Ahmad and Porntip S. Grain Process Engineering Chap. 9: In Handbook of Farm, Dairy and Food Machinery. Edited by Myer Kutz, Published by William Andrew 2005

2. Training manual of rice post production technologies developed by International Rice Research Institute (IRRI). Available at www.irri.org

3. Rice postharvest losses in developing countries. US Department of Agriculture 1985.

4. Addressing the Pre- and Postharvest Challenges of the Rice Supply Chain, Asian Development Bank 2009.