



CHAPTER 6 - MACHINERY AND EQUIPMENT FOR UTILIZATION OF CROP RESIDUES AS FEED

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Technology flow and equipment

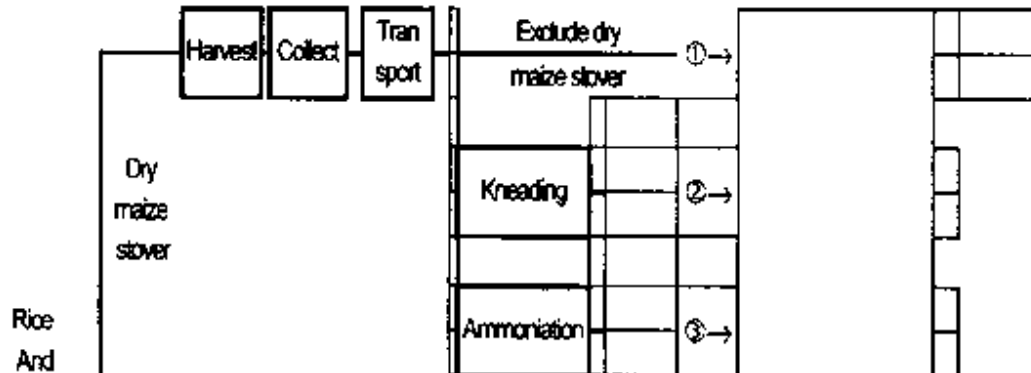
The handling of straw for feed on individual farms in China has mostly been done manually, with the aid of little machinery.

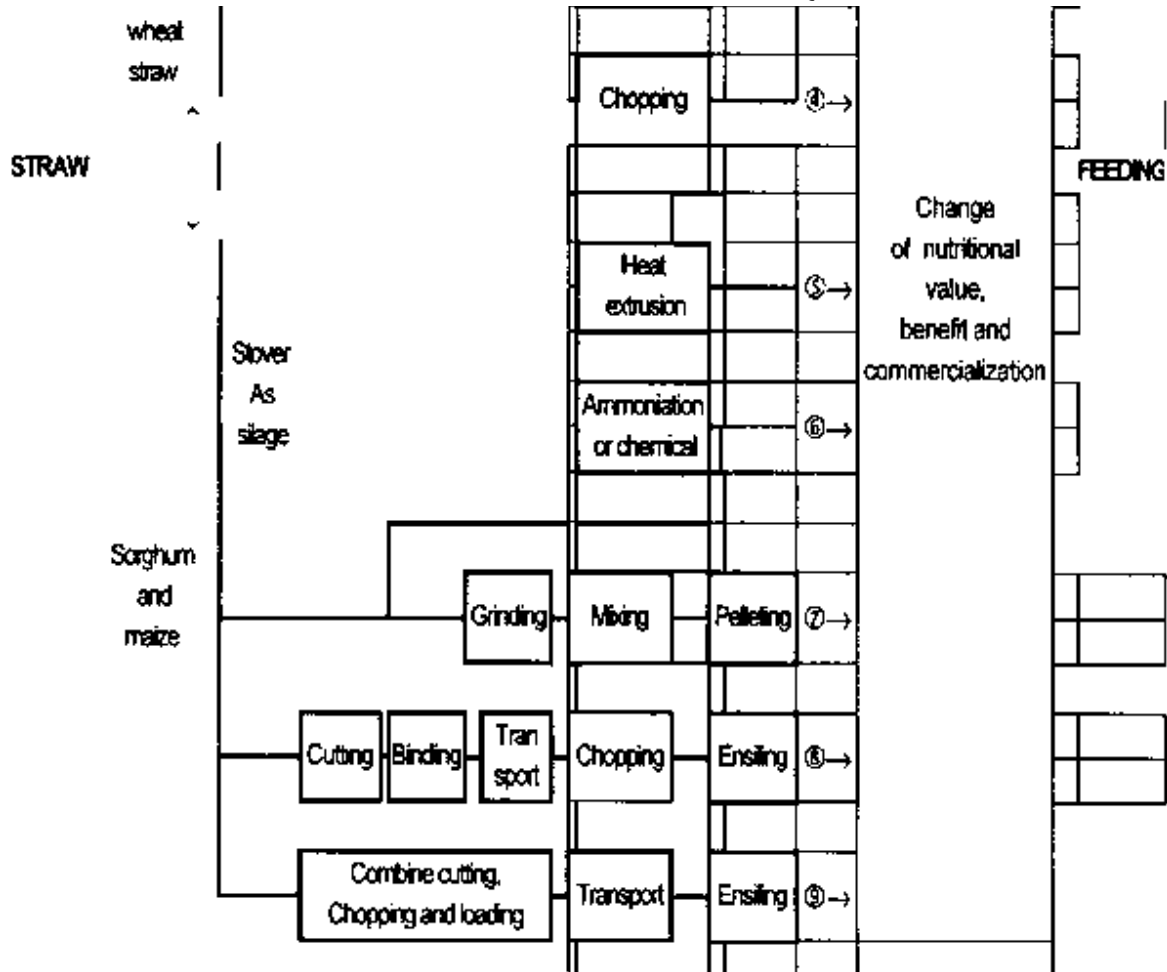
However, with increased scales of production and reduced labour force as town enterprises develop and attract away workers, it is inevitable that there will be a gradual move towards mechanization of animal husbandry. Of course, the process will take a long time

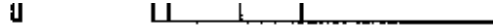
considering the situation in the country. The purpose of this chapter is to introduce machinery and equipment suitable for different levels of mechanization of straw feeding. It will present types, uses and selection principles of machinery and equipment for upgrading and utilizing straw as feed.

The technical flow from straw collection and processing to feeding could take many routes, from simple to complex, depending on the level of upgrading, the nutritive value of the straw, and commercialization of straw products (Figure 6-1).

Figure 6-1. Technical flow chart of residue processing







Flows 1 and 4 are manual handling systems, some elements of which can be replaced by machines nowadays. Flow 2 is the best processing method to increase intake and utilization of an entire crop without further treatment than the kneading into thread-like pieces. This is appropriate for maize stover of high nutrient value. The final process of flows 3 and 6 is ammonia treatment. The difference between flows 3 and 6 is that 3 is used for whole straw, such as rice and wheat straw, while 6 is suitable for maize stover. The final step of flow 5 is heat extrusion. Its key part is the heat extrusion equipment. Flow 7 shows that, after ammonia and chemical treatment, straw needs to be ground and mixed with nutrients, and finally pelleted or wafered. Straw treated by this method has the advantages of being of high density, easy to store and transport (marketing), reduces waste at feeding and avoids diet selection by the animal.

Both flows 8 and 9 are suitable for ensiling maize or sorghum stover. In flow 8, harvesting, bundling, transporting, chopping and loading into a trench silo are performed separately, and most of

them can be done manually, but the chopper or so-called "silage cutter" is absolutely necessary. In flow 9, the residues are harvested, chopped and loaded into the wagon using a combine, then transferred to a silo.

The processes used for upgrading of straw for feeding and the machinery options are listed in Table 6-1.

Table 6-1. Machinery selection for various technical processes in upgrading straw

Process	Machine type
Straw collection	Rectangular baler; round baler; stacker; stationary baler.
Loading and transport	Bale loader mounted on wagon or trailer; round bale wagon; stack-mover; wagon; trailer.
Kneading and cutting	Kneading and cutting machine.
Chopping	Cylinder chopper; flywheel chopper.
Heat extrusion	Heat-extrusion equipment

Heat extrusion	Heat extrusion equipment.
Ammonia treatment	Ammonia treatment equipment at normal temperature; heated ammonia equipment; ammoniation tank; ammoniation oven.
Grinding	Hammer mill; fixed head mill; claw-type mill; double roller mill.
Pelleting or wafering	Pelleting equipment; wafering equipment.
Silage cutting, chopping and loading	Silage combine and trailer.



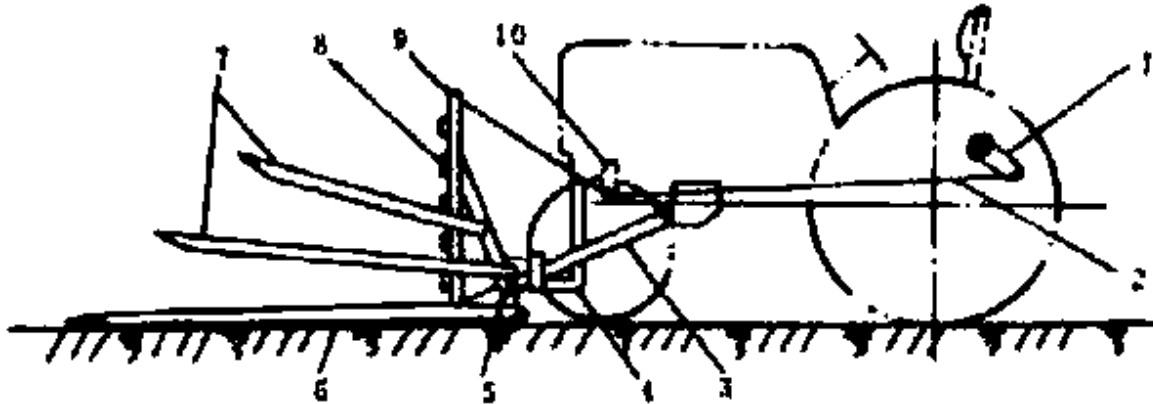
Collection, loading and transport equipment

Collection, loading and transport equipment for long and loose straw

Straw collector

It is used to collect straw into small stacks, or to bring them to a large one. It consists of a collecting platform, left and right handspikes, a frame and a pulley support (Figure 6-2). The collecting platform includes a collecting fork, a side bar and a fence.

Figure 6-2. Straw collector



KEY: 1. Hydraulic arms; 2. Steel cable; 3. Handspike; 4. Frame; 5. Suspension spring; 6. Collecting fork; 7. Side bar; 8. Fence; 9. Supporting frame; 10. Pulley support.

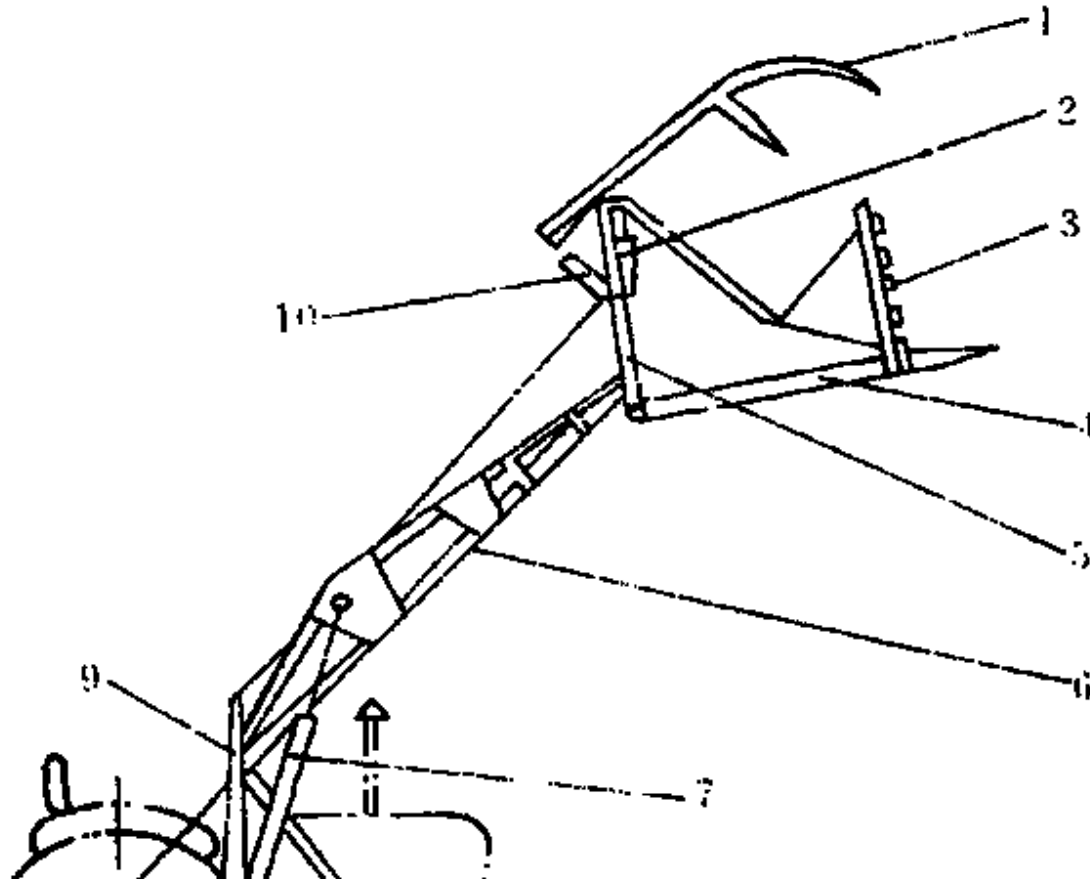
The machine slides forward, with an angle of 5-7° from the ground, to collect straw with the fork. When the fork is full, hydraulic arms are engaged to lift it about 30 cm high from the ground. Then the tractor moves straw to the stack. After lowering the platform, the tractor is backed to unload the straw. There is no stereotype for this machine. Because of its simple structure, users can construct them themselves.

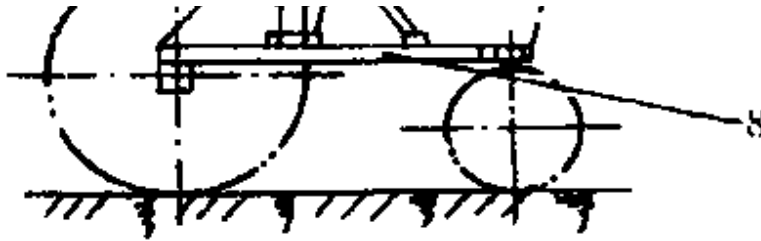
Stacker

There are many types of stacker, including derrick stackers, fan stackers, conveyor belt stackers, slide stackers and hydraulic stackers. For a hydraulic stacker (Figure 6-3), the operation is the following:

- (i) the collecting platform is lowered;
- (ii) the straw-pushing board (3) is moved back by the hydraulic cylinder (2);
- (iii) the collecting fork is used to gather the straw until it is full;
- (iv) the large arm (6) lifts it;
- (v) a hydraulic cylinder opens cover (1);
- (vi) the hydraulic cylinder (2) moves the straw pushing board (3) forward and pushes the straw out.

Figure 6-3. Straw hacker





KEY: 1. Cover; 2. Hydraulic piston for pushing straw board; 3. Pushing straw board; 4. Collecting forks; 5. Vertical arms; 6. Large arms; 7. Main hydraulic cylinder; 8. Main frame; 9. Vertical pole; 10. Hydraulic cylinder for cover.

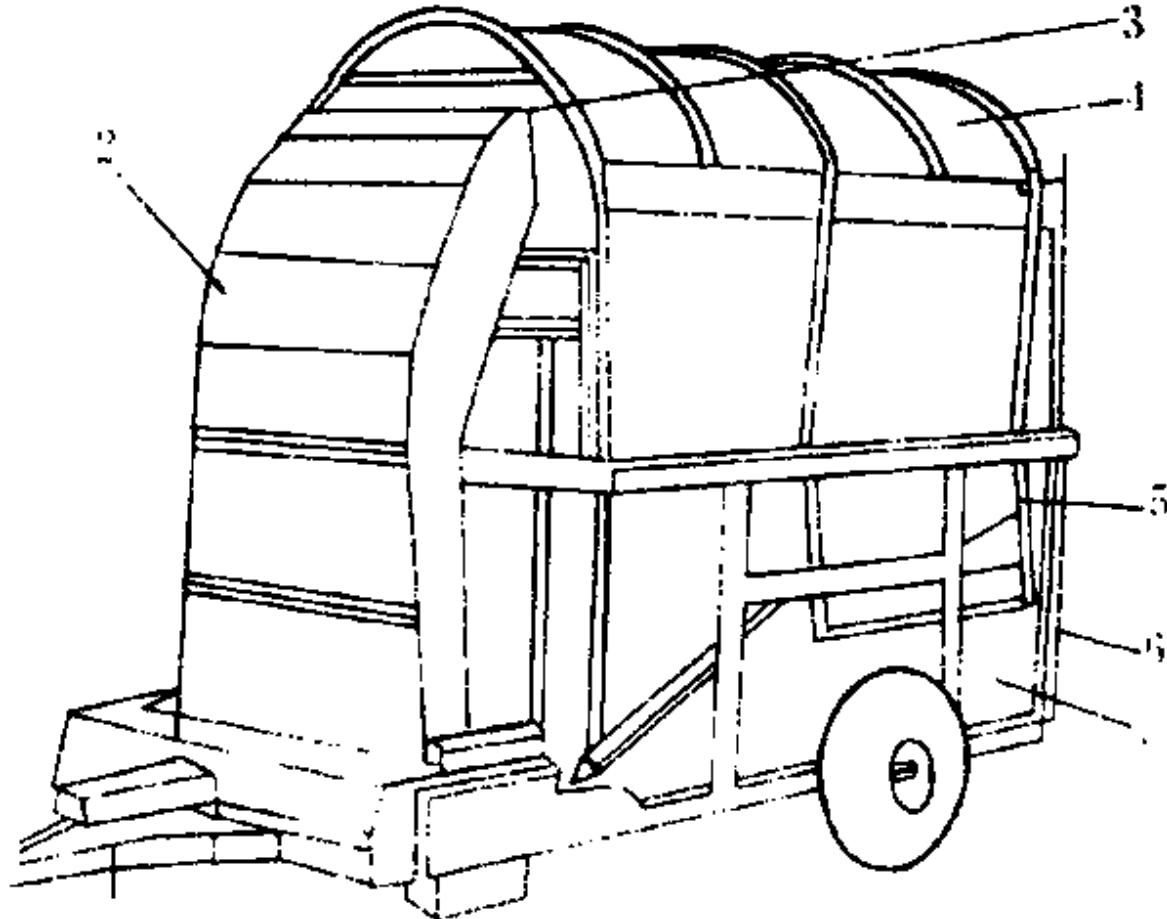
Pick-up-and-press stacker

This consists of a flail-type pick-up chopper, a blower tube with rectangular cross section, a directing cover, a movable top cover, a chamber, a chamber rear door, and a chain conveyor for discharging (Figure 6-4).

The flail type pick-up chopper is used to pick up and chop straw. The airflow, generated by the high-speed rotation of the chopper,

blows straw into the chamber through the tube and directing cover. When the chamber is full, the tractor stops moving forward. The top cover is moved down by the compression mechanism to press the straw into the chamber, then the top cover is lifted again. The machine continues to go forward picking up straw again. Generally, a stack can be formed by repeating the above process two or three times. In order to discharge (unload) the stack, the tractor is stopped, the rope is pulled to unlock the chamber's rear door, the hydraulic piston is activated to lift the top cover to its highest position. The chamber's rear door and the top cover open automatically at the same time and the chain conveyor is engaged automatically to move the stack out. When the stack touches the ground, the tractor is driven forward slowly so as to unload the stack on the ground.

Figure 6-4. Pick-up-and-press stacker



KEY: 1. Flail-type pick-up chopper; 2. Rectangular blower tube; 3. Directing cover; 4. Movable top cover; 5. Compression mechanism; 6. Rear chamber door; 7. Chamber.

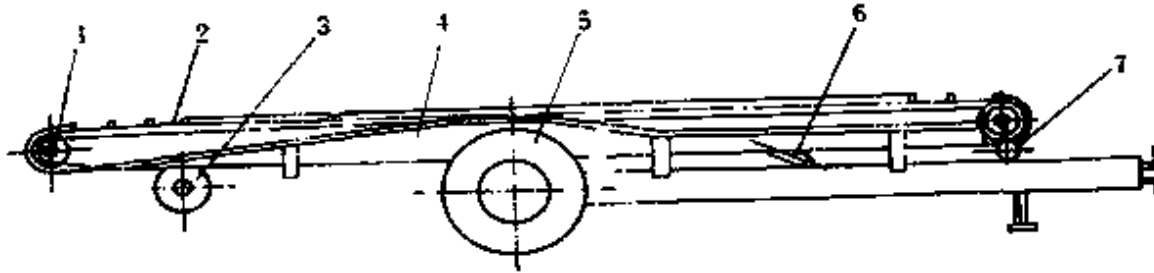
The technical parameters of the 9JD-3.6 pickup stacker made in Qiqihaer agricultural and livestock machinery plant are:

- Overall dimensions (cm): length, 724; width, 398; height, 458.5
- Net weight: 4 200 kg
- Chamber volume: 33 m³
- Power source: 44.4-73.5 kW tractor
- Working width: 198 cm
- Stack dimensions (cm): length, 430; width, 260; height, 300
- Stack weight: ca 3 000 kg
- Stack density: 70-110 kg/m³

Stack wagon (stack conveyer)

When the straw stack made by the pick-up-and-press stacker is to be used, it needs to be transported to the feeding site by the stack wagon. The stack wagon (Figure 6-5) is a large platform supported by wheels. On the platform, there are three conveying chains with claws driven by a hydraulic motor fitted at the rear of a pick-up roller and a supporting roller. In operation, the wagon is backed up to the stack. The platform is tilted by the hydraulic cylinder so that the rear roller touches the ground. Then the pickup roller is inserted under the stack. The stack is moved up onto wagon by the combined action of the pickup rollers and reversing of the tractor. When the stack is on the wagon, the platform is returned to the horizontal position and can move off with the stack. After arriving at the feeding site, the platform is tilted again; the chain conveyors are driven in reverse to unload the stack.

Figure 6-5. Stack wagon



KEY: 1. Pick-up roller; 2. Conveying chains with claws; 3. Supporting roller; 4. Large platform; 5. Road wheels; 6. Hydraulic cylinder; 7. Hydraulic motor.

The technical parameters of the 7DY-3.6 stack wagon made in Qiqihaer Agricultural and Livestock Machinery Plant are:

Overall dimensions (cm): length, 705; width, 277; height, 95

Overall weight: 1 200 kg

Power source: 20 kW from tractor

Carrying capacity: 3 600 kg

Road speed: 25 km/hour

Balers

A baler is a machine used to compress hay or straw into bales for easy transport and storage. A bale is the simplest minimum package for marketing.

Balers are divided into stationary balers and field balers. They are further classified into rectangular balers and round balers according to the bale shape produced. According to density of bale, they could be high (200-350 kg/m³), medium (100-200 kg/m³) or low density (<100 kg/m³) balers.

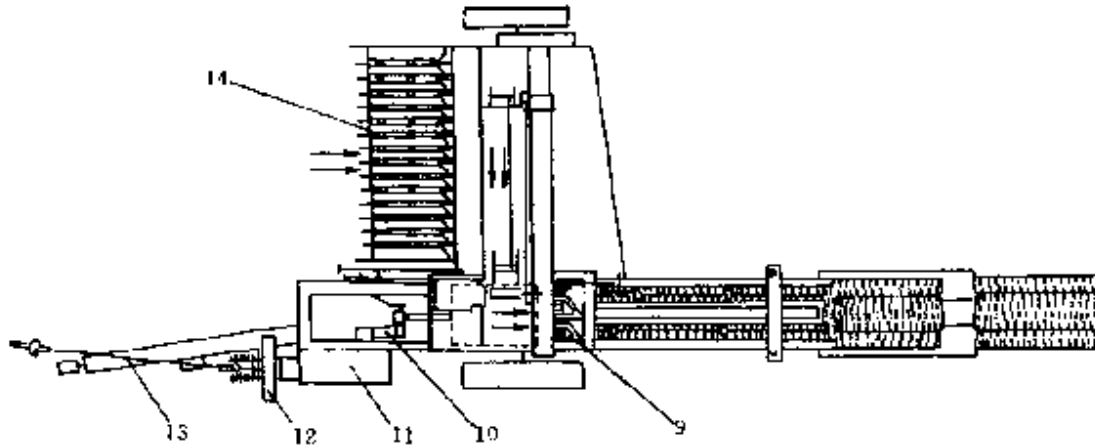
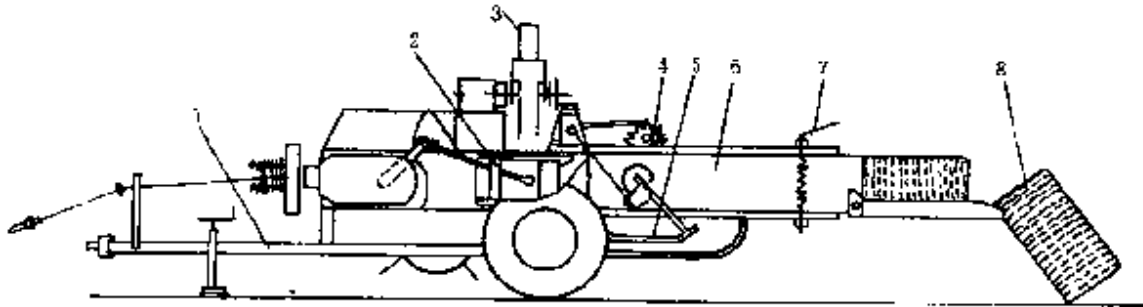
Rectangular pick-up baler

The 9KJ-1.4A rectangular pick-up baler (Figure 6-6), made by the Inner Mongolia Baochang Livestock Machinery Plant, is used as an example for the general structure and function of rectangular pick-up balers. It makes bales from the straw windrow left by the combine. The machine consists principally of a pick-up reel, a conveying and feeding system, a compressing chamber, a bale

density adjuster, a bale length controller, a needle-and-tying mechanism, a crank-linkage mechanism, a power transmission, and hauling system.

It is powered from the power take-off (PTO) of the hauling tractor. The straw windrow is lifted from the ground by a pick-up reel having spring teeth (14) and transferred continuously to a conveying and feeding mechanism (3) as the baler moves forward along the windrow. The conveying and feeding mechanism (3) pushes individual charges of hay into the bale chamber (6) from the side at intervals when the piston (2) is withdrawn. The piston reciprocates under the function of the crank-linkage mechanism to press the material into the bale. When the bale reaches the required length, the needle-and-tying mechanism is engaged automatically to bind the bale, which is then pushed out from the chamber by successive bales and is discharged to the ground.

Rectangular bales can be lifted and loaded either by hand or by a loading machine mounted on the side of a truck or trailer and driven by a ground wheel. The Jilin Baicheng Agricultural and Livestock Machinery Factory also make this kind of baler, model 9JKC-2.7.

Figure 6-6. Structure and operation of a 9KJ-1.4A baler

KEY: 1. Tow beam; 2. Piston; 3. Conveying and feeding equipment; 4. Bale length controller; 5. Needles; 6. Compression chamber (bale chamber); 7. Bale density adjuster; 8. Bale; 9. Needle-and-tying mechanism; 10. Crank; 11. Main gear box; 12. Flywheel; 13. Universal joint gearing axis; 14. Pick-up reel.

Basic specifications of the 9KJ-1.4A rectangular baler:

- Overall dimension (cm): length, 480; width, 270; height, 145
- Power source: 22 kW from tractor PTO
- Working speed and output: 5 km/hour; 5 000 - 7 000 kg/hour
- Piston frequency: 70-80 strokes per minute
- Feed rate: 1.5-2.5 kg per cycle
- Nominal pick-up width: 141.4 cm
- Working width: 160 cm
- Bale size (cm): Length, 60-120; width, 46; height, 36
- Bale weight and density: 15-25 kg; 100-180 kg/m³
- Baler net weight: 1 480 kg

High density baler

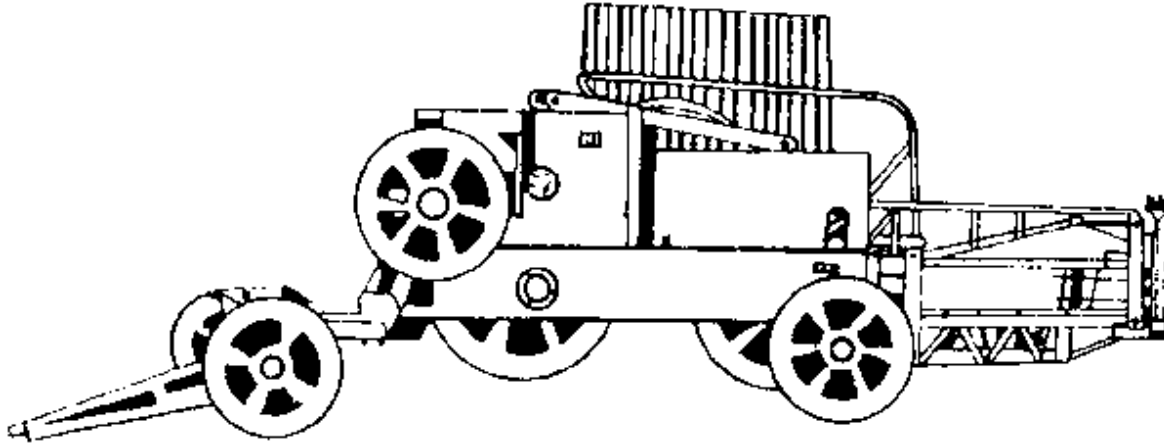
The 92FY-300 high density baler (Figure 6-7) manufactured by the Inner Mongolia Yakeshi Forestry Machinery Plant is taken as an example to describe basic structure and working process. It is a stationary baler equipped with front and rear wheels. It can be hauled to the working site by a tractor. The density of the bale reaches 300 kg/m^3 . An electric or diesel motor or the tractor's PTO can supply the power (17 kW). A belt, a chain and a gear by a linkage mechanism drive an eccentric axis that moves the piston back-and-forth. At the same time, the conveying mechanism moves up-and-down to feed the straw into the compression chamber. The bales are fastened with three steel wires (diameter, 2 mm; length, 210 cm).

Basic specifications are:

- Overall baler dimensions length, 77; width, 150; height, 254 (cm):

- Net weight of the baler: 4 tonne.
- Bale size (cm): length, 50-65; width, 36; height, 46
- Bale weight: 30-35 kg.
- Piston displacement; 62 cm
- Piston frequency: 30 times per minute
- Output: 50-80 bales per hour
- Reference price: ¥ 35 000

Figure 6-7. High density baler



Round baler

The round baler is a new kind of pickup baler. The bales are round, 90-200 cm in diameter. It has the advantages of simple structure and convenience for adjusting and use. The round bales resist the rain, are convenient for feeding and adapted to outside storage. They also save on wire. As a result, they are being increasingly used.

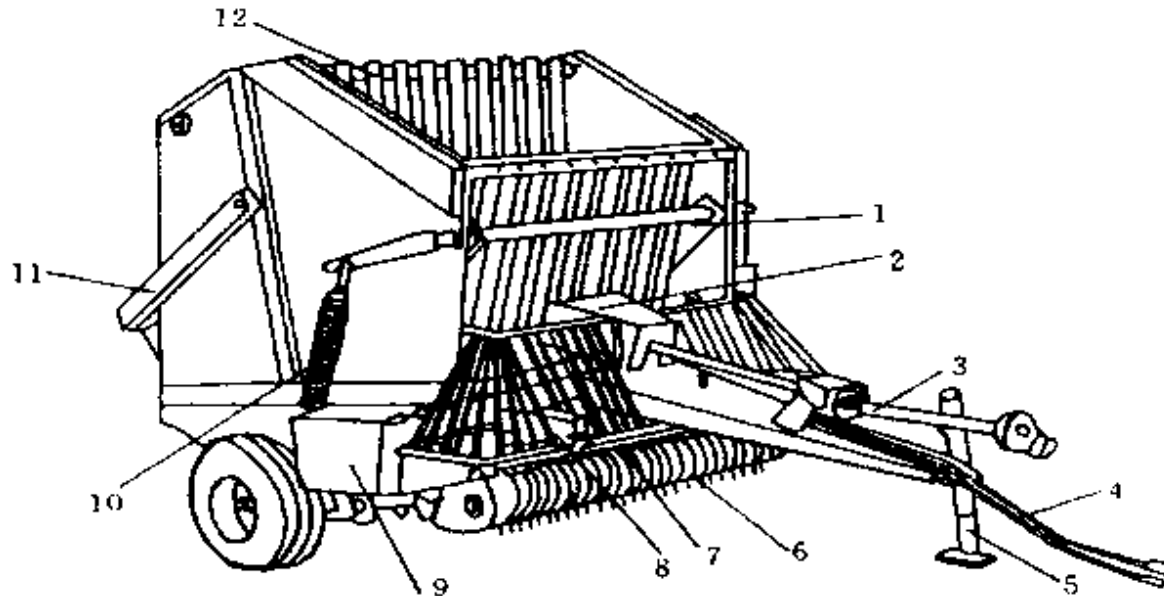
Based on the form of working unit, round balers can be classified

into long-belt type, short-belt type, chain type and roller type. They are also classified into inside winding type and outside winding type by their working principle. Long-belt and chain types are inside winding; short-belt and roller types are outside winding.

Figure 6-8 illustrates a belt, inside winding pick-up baler that consists of a pick-up reel, a conveying and feeding mechanism, a wrapping and pressing mechanism, a rear door for unloading, a transmission mechanism and a hydraulic operating mechanism. Its working process is shown in Figure 6-9. The windrow is lifted by a pickup reel (4) and rolled up to double smooth rollers (3) where it is pressed into a flat layer, then conveyed to the baler chamber. With the upper belt the straw moves upward by friction to a certain height, then rolls down to the lower belt by gravity to form the core of the bale, which continually rolls, increasing the diameter. When the bale reaches the desired size it is discharged from the lower belt. The springs fixed in the swing arms in the two sides of the bale chamber maintain the pressure of the belt on the bale's surface. The pressure increases with bale size, resulting in low density on the inside of the bale but high density on the outside.

Inside wrapping means that the volume of the wrapping and pressing chamber enlarges during pressing to keep a constant pressure on the bale. The bales formed by inside wrapping have much higher density than by outside wrapping and keep their shape for longer during storage. However, the structure of an inside wrapping baler is more complicated. When the bale reaches the desired size, an indicator alerts the driver to engage the hydraulic distributor in order to activate the binding mechanism. The twine is passed by the tube and fed with straw to the chamber. The twine is wrapped around the circumference of the bale, then cut by a blade. The rear door is lifted hydraulically. The bale is then discharged to the ground.

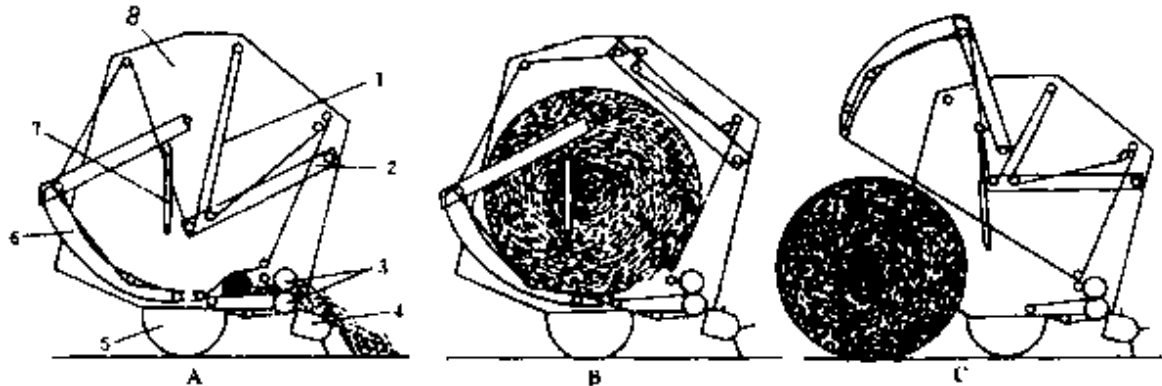
Figure 6-8. Inside wrapping pick-up round baler



KEY: 1. Swing arms; 2. Gear box; 3. Gearing shaft; 4. Hydraulic power supply tube; 5. Support frame; 6. Pick-up reel; 7. Tube for the twine; 8. Twine cutter; 9. Twine box; 10. Tension spring; 11. Rear discharge door; 12. Belt of wrapping and pressing chamber.

Figure 6-9. Operating principle of the wrapping and pressing

mechanism



STAGES: A. Forming of the core of the bale. B. Making the bale. C. Discharging the bale KEY: 1. Upper belt; 2. Swing arms; 3. Smooth rollers; 4. Pick-up reel; 5. Road wheels; 6. Rear door for discharging; 7. Hydraulic cylinder; 8. Side walls.

The round baler manufactured by the Jilin Baicheng Agricultural and Livestock Machinery Plant belongs to this type. Its specifications are:

- Overall dimensions (cm): length, 485; width, 245, height, 243
- Net weight: 1 900 kg
- Power source: 40.4 kW from tractor hydraulic system
- Working speed and output: 5 km/hour; 8-12 bale/hour
- Bale weight: 450-500 kg
- Bale diameter and width: 180 cm; 150 cm
- Width of pick-up: 140 cm

Round bales must be loaded, transported and unloaded by machine due to their heavy weight. The 7KY-4 round bale transporting wagon made in China is hydraulically driven and equipped with an automatic pickup mechanism. It can pickup and load round bales with flexibility and accuracy. Four bales can be transported simultaneously.

Harvesting machine for maize silage

Several new cultivars of maize have been popularized in large areas of China, and some of these cultivars have a green stalk at harvest, so they are fit for ensiling. Stover can be harvested, chopped and loaded by a long-stalk cutting platform fitted to a silage harvester (also called a silage combine), and then put into the silo. The 9SQ-10 cylinder-type forage harvester made by the Chifeng Livestock Machinery Plant belongs to this type. When the machine is equipped with a long-stalk cutting platform, its parameters are as follows:

- Dimensions (cm): length, 620; width, 310; height, 288.6
- Weight: 1 180 kg;
- Power supply: 40.4-58.8 kW from tractor
- Cylindrical chopping device:
 - cylinder rotation speed: 1 120 rpm;
 - cutting blades: 6
 - harvesting rows: 2

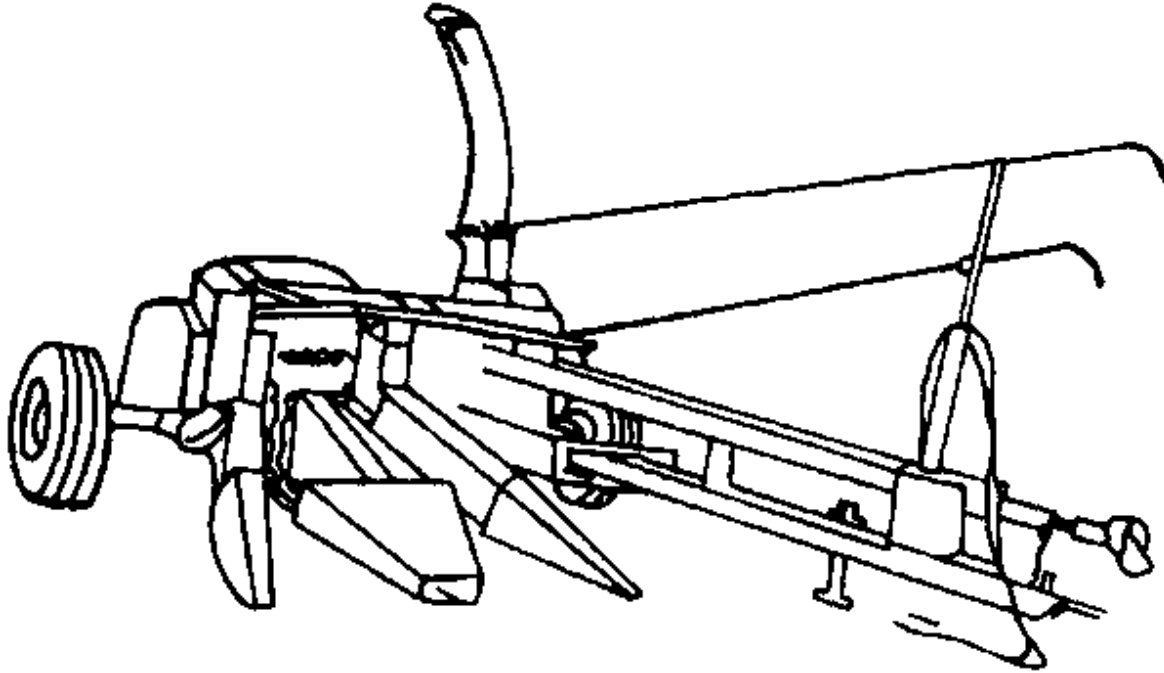
 - distance between rows: 60 or 70 cm

stalk cutter:

double disc-type

The Beijing Combine Factory has designed a self-propelled maize harvester (model 4YZ-4) that accomplishes picking, husking, ear collecting, stover and leaf chopping, and returning to the ground or throwing into a trailer as a single-pass operation. It is well suited to harvest maize before sowing wheat. It harvests four 70-cm rows with an efficiency of 1-2.5 ha/hour. The engine power is 110.25 kW, and its weight is 9 tonne. The reference price is ¥ 150 000.

Figure 6-10. Cylinder-type silage harvester with thrower



Crop residue processing machines

Choppers

The chopper is mainly used for stalk forage, such as rice straw, wheat straw, maize stover and maize for ensiling. Straw choppers can be classified by size into small, medium and large. The small-size chopper is mainly adapted for chopping dry straw or silage on small-scale farms. The large chopper - also called a silage chopper - is mainly used for silage on cattle farms. The medium chopper is normally suited to cutting dry straw and silage, so it is called a straw-silage chopper.

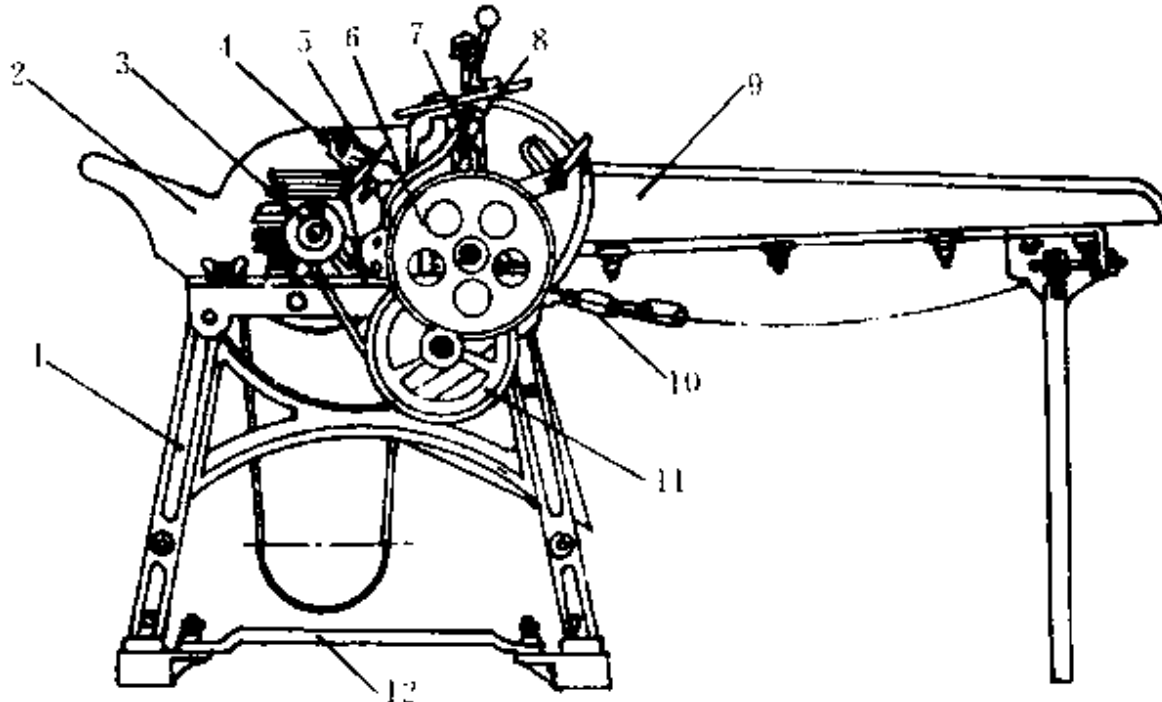
Choppers can be divided into cylinder or flywheel types, according to the mode of cutting. Large- and medium-size choppers are generally flywheel types, to facilitate throwing silage, but the majority of small choppers are cylinder type. Large and medium choppers are usually equipped with road wheels for easy movement, while small-size choppers are normally stationary.

Cylinder choppers

There are many types of cylinder chopper. The 93ZT-100 chopper (Figure 6-11), made by Wulanhaoite Livestock Machinery Factory in Inner Mongolia, is taken as an example to describe the structure of a chopper.

The machine consists primarily of mechanisms for feeding, chopping, and throwing, with a transmission, a clutch and a frame. The principles of operation are illustrated in Figure 6-12.

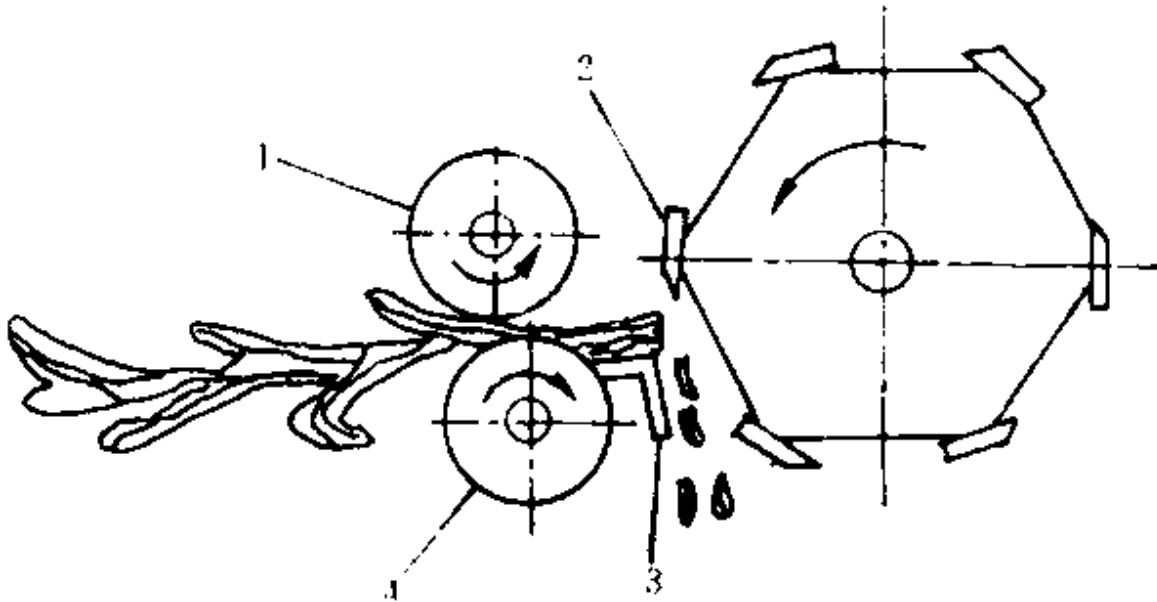
The main parts of the feed mechanism are a chain conveyor, pressing rollers, and upper and lower feed rollers. For the upper feed roller, springs are used for pressure, with a cross-groove shaft coupled with a compact structure for driving. The chopping and throwing mechanism is in one unit, which consists of a main shaft, a blade rotor, rotating blades, a throwing vane and stationary blades. Gear teeth are 13, 22, 65 or 56. By changing the gear used, the speed can be adjusted to obtain various cutting lengths.

Figure 6-11. 93ZT-1000 straw chopper

KEY: 1. Frame; 2. Throwing cover; 3. Small single-groove sheave; 4. Blades disk; 5. Movable blade; 6. Changeable

gear; 7. Wheel-tension clutch; 8. Suspension bracket; 9. Feeding groove; 10. Chain; 11. Large single-groove sheave; 12. Supporting plate for motor.

Figure 6-12. Chopping action of cylinder-type straw chopper



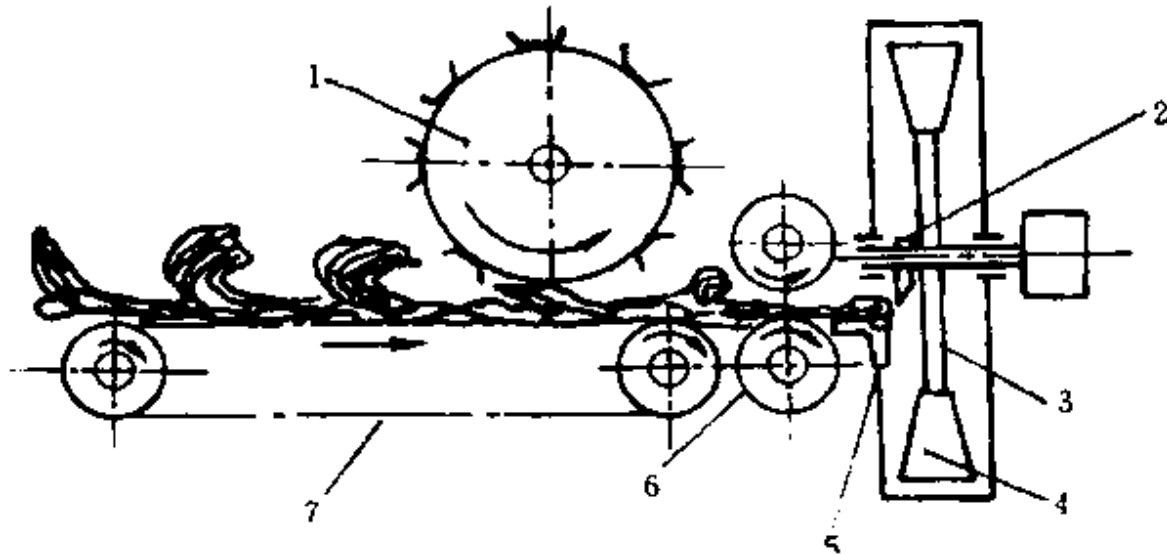
KEY: 1. Upper feed roller; 2. Cylinder blade. 3. Stationary

bottom blade; 4. Lower feed roller.

Flywheel choppers

Flywheel chopper operation is illustrated in Figure 6-13, showing a feed chain, upper and lower feed rollers, a stationary lower blade, a cutter and a throwing fan. The straw is fed via the feed chain into the feed rollers, pressed and moved forward by them, then cut into pieces by the combination of upper and lower blades, and it is finally blown by the fan to the storage site or silo.

Figure 6-13. Chopping action of the disk chopper

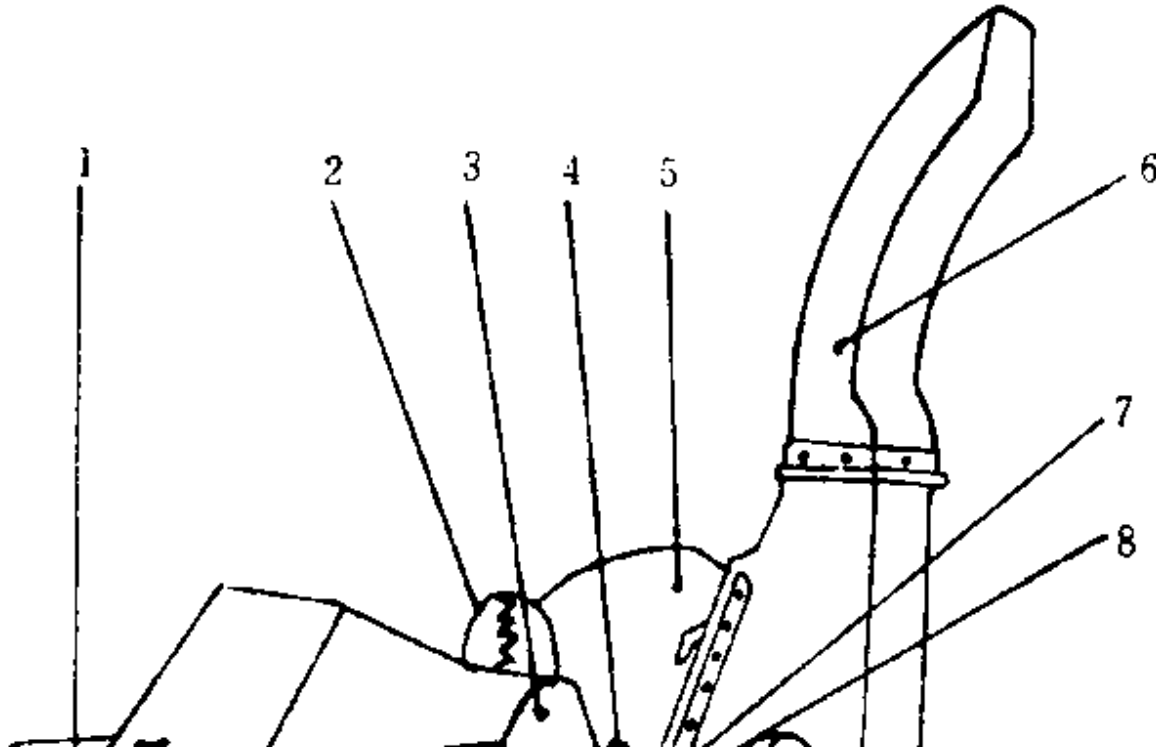


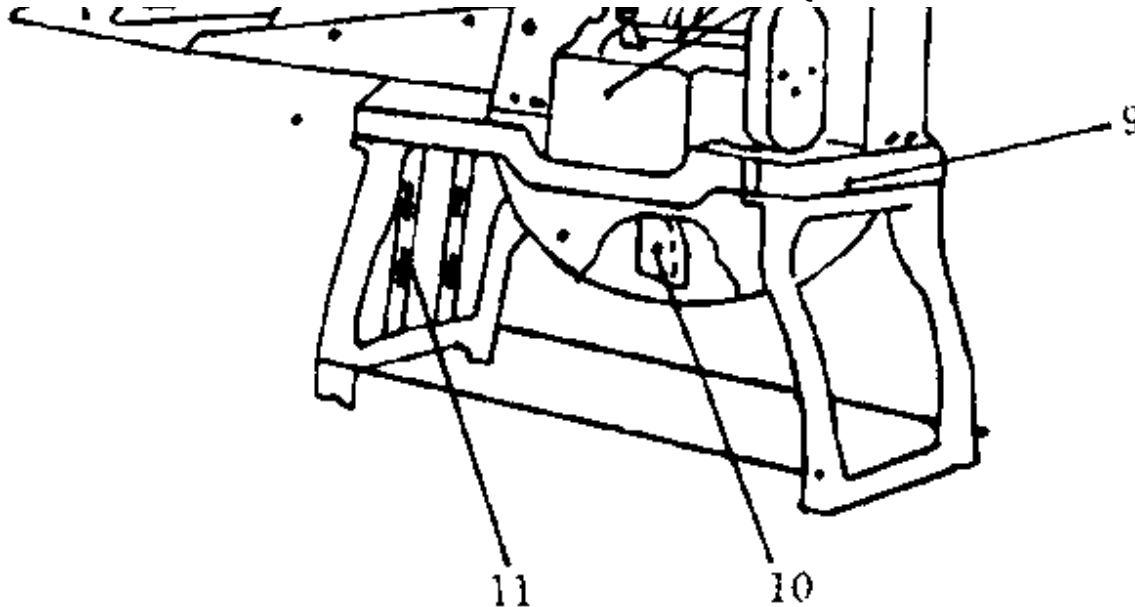
KEY: 1. Feed roller; 2. Blade; 3. Disk; 4. Blower fan; 5. Stationary bottom blade; 6. Feed roller; 7. Feed chain

Figure 6-14 shows the outline of a 93ZP-1000 straw chopper produced by the Liaoning Fengcheng Donsfeng Machinery Factory. Its output is 1 000 kg/hour, the length of chopped pieces are 15 mm or 35 mm and the rotary speed of the main shaft is 8 000 rpm. It has 2 movable blades, a power supply of 3 kW from an integral

motor, weighs 110 kg, and its overall dimensions are 95 cm long, 98 cm wide and 140 cm high.

Figure 6-14. Structure of a 93ZP-1000 type chopper





KEY: 1. Feed channel; 2. Bow shape frame; 3. Supporting frame for rollers; 4. Handle for changing position; 5. Cover; 6. Outlet for straw; 7. Connecting shaft; 8. Gearbox; 9. Chassis; 10. Movable blade; 11. Motor frame.

Some types of straw choppers, their technical parameters and

their manufacturers in China are shown in Table 6-2.

Grinders

Grinding methods and grinder types

There are four main grinding methods: impacting, grinding, crushing and sawing (see Figure 6-15). Impacting is suitable for hard and brittle raw materials, such as maize feed; sawing is better for large and fragile feed; and crushing and grinding are used for tough feed.

Table 6-2. Some chopper types, their technical parameters and manufacturers in China

Model	Type & Cutting Speed (rpm)	Cutting length (mm)	Power (kW) & Capacity (kg/hour)	Weight (kg) & Price (¥)	Maker
93ZP-400 Straw	Flywheel	15.35	0.75	33	(1)

chopper (Feima)	900	400	70à55à50		
93ZP-1000 Straw	Flywheel	3.0	110		
		15, 35		1 190	(1)
chopper (Feima)	800	1 000	95à98à140		
93ZP-1600 Straw	Flywheel	4.0	115		(1)
		15, 35		1 235	
chopper (Feima)	800	1 600	n.a.		
93ZQ-400 Straw					(1)
	Flywheel	0.75	35		
and vea.		5. 7.		757	

chopper

15, 35

900

400

70à55à50

(Feima)

9QF-45
Silage

Flywheel

7.5-11

200

16

2 (1)
927

chopper
(Feima)

1000

1 500

152à99à80

9ZP-4.0
Straw

Flywheel 15, 22,
35, 50

13.0

515

6 (2)
300

chopper
PC C-60
Silage

700

4 000

253à248à1773

Flywheel

10.0

1000

6-106

6 (2)

chopper 9ZP-1.6 Straw	450		9 000 3.0	284à177à205	300	
		Flywheel			n.a.	
and veg. chopper		15, 20, 35	Grass 2 000			(3)
					n.a.	
(Fenglei)			Straw 3 000 4.0			
9DQ-100 Silage				Flywheel	335	
		9, 20, 28, 60	Straw 2 500			1 (4)
chopper (Wuye)	600				150à55à126	680
			700-6			

93ZT-1000			500			
Straw						
			3.0	190		
chopper		13, 26			1	(5)
					188	
			1 000	175à60à110		
<i>(Xing'anling)</i>						
			5.5			
9Z-4 Straw	Cylinder			280		
		15-20	Grass 6		4	(6)
			000		100	
chopper	1200			n.a.		
			Straw 1			
			500			
			n.a.			
9Z-8 Straw	Flywheel					
		15, 14	Grass 12			(6)

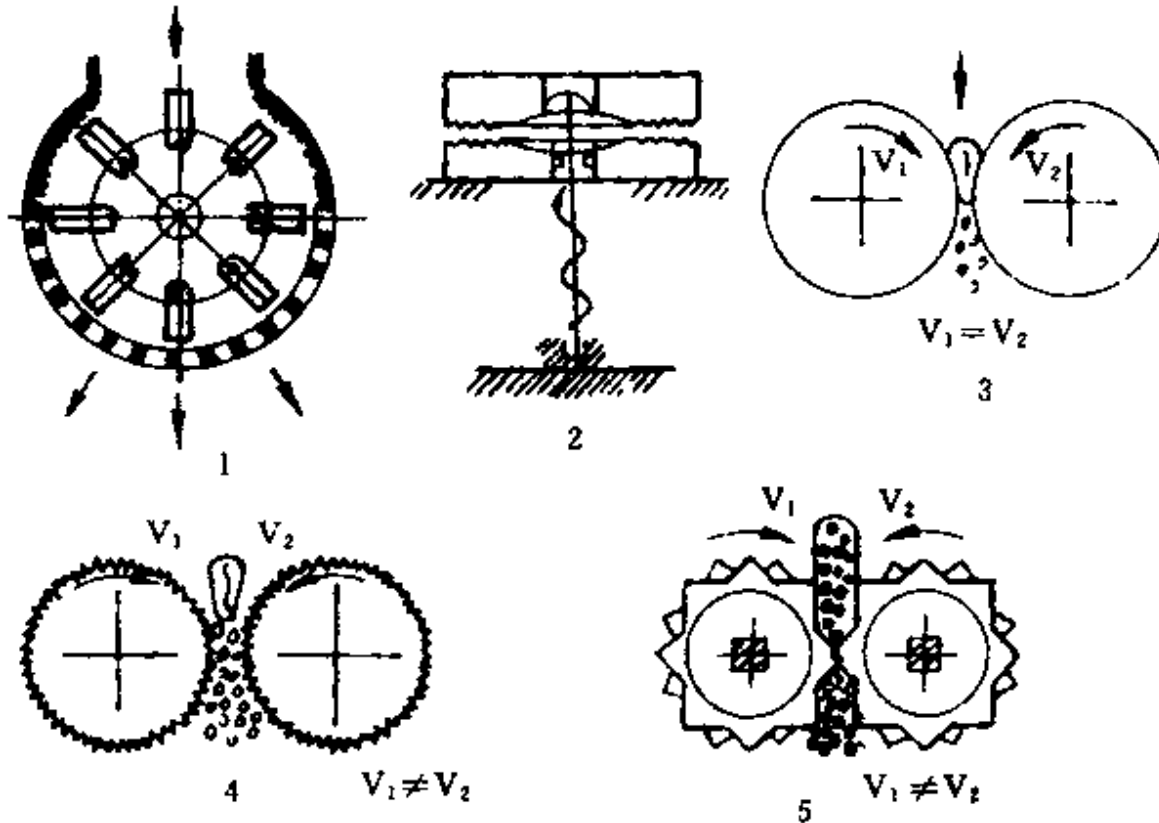
chopper (Ximmu)	600		000		
			Straw 3 000		
9ZCA-1.0 Straw	Cylinder		3.0	195	
		13, 26			800 (7)
chopper 9ZC-6 Straw	775 Cylinder		1 000 10.0	175à60à110 1000	
		6, 13, 25			5 (8) 700
chopper	650		Silage 6 000	250à180à195	
93ZP-2500 Straw	Flywheel		7.5	320	
		8-25			(9)
chopper	850		2 500	238à134à173	

(*Ximmu*)

NOTE: n.a. = information not supplied.

KEY TO MANUFACTURERS: (1) Liaoning Fengcheng Dongfeng Machinery Plant. (2) Beijing Linhai Agricultural and Livestock Machinery Plant. (3) Beijing Yanjing Livestock Machinery Co. (4) Shijiazhuang Agricultural and Livestock Machinery Plant. (5) Inner Mongolia Wulanhote Livestock Machinery Plant. (6) Shandong Feicheng Chopper Plant. (7) Henan Fugou Scientific Instrument Plant (MOA). (8) Shanxi Xi'an Livestock and Milk Machinery Plant. (9) Xinjiang Livestock Machinery Plant.

Many mills combine different methods. Those commonly found are hammer, fixed head, claw and roller mills. The hammer mill is well suited for straw feed. The roller mill uses a pair of opposed toothed rollers that rotate simultaneously in opposite directions and at different speeds to grind the feed. Roller mills are mainly used for grinding oil cakes. The principles of operation are illustrated in Figure 6-15 (5).

Figure 6-15. Grinding methods for feed

Key: 1. Impacting; 2. Grinding; 3. Pressing; 4, 5. Sawing.

Hammer mills

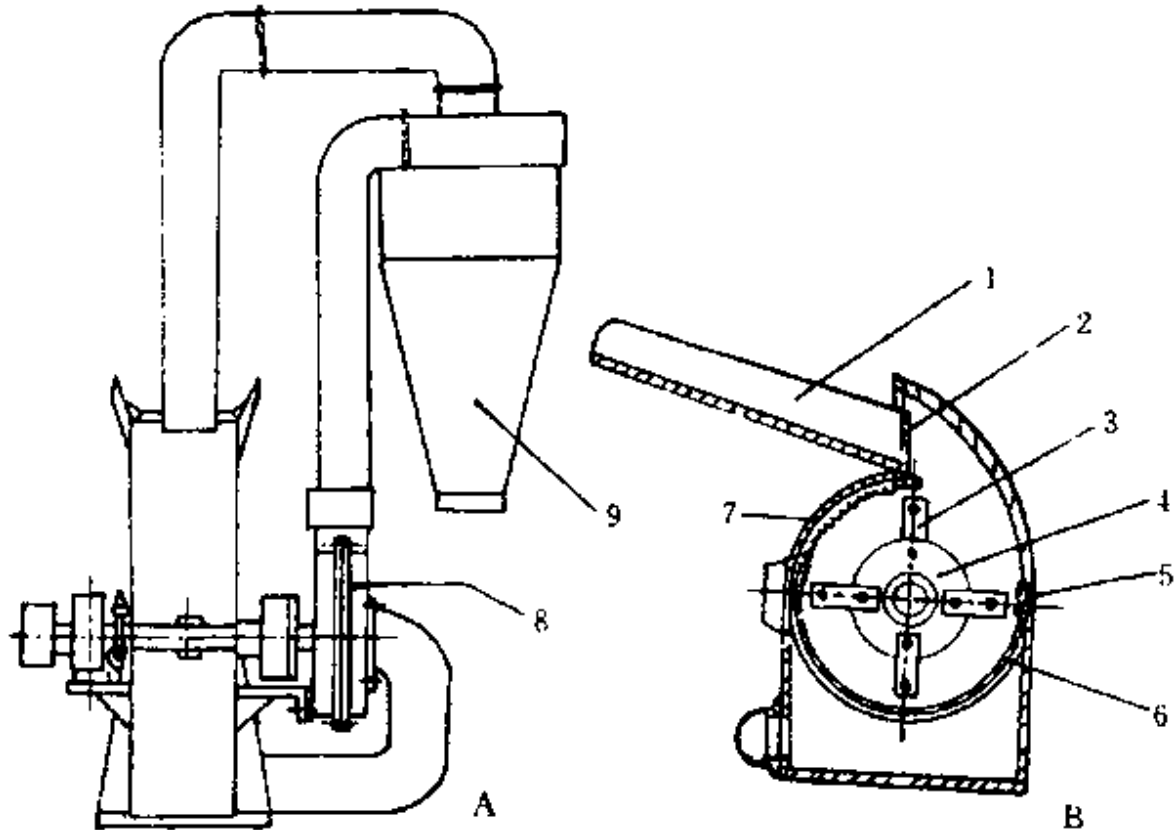
Hammer mills grind material by the impact of a high-speed rotary hammer. Hammer mills are either tangential-feed or axial-feed types, according to their structure.

Figure 6-16 shows the structure of the 9FQ-50 tangential-feed mill made by the Hongxing Machinery Factory in Jiangxi Province. The mill comprises a feeding part, a grinding chamber and a collector. The feeding part comprises a feed hopper and a feed control flap. The grinding chamber consists of a rotary disk, a hammer, a serrated plate and a screen. The major parts of the collector include a fan, a feed conveying tube and a collection hopper.

Fed from the feed hopper in a tangential direction, the material is impacted and driven to the grinding chamber by the rotating hammers with high speed. The material in the grinding chamber is firstly hit and ground to some extent by hammers, and then thrown at high speed at the serrated plate and the peripheral screen fixed

inside the chamber to be further ground through impact with the serrated plate and friction with the screen.

Figure 6-16. Tangential-feed grinder



KEY: 1. Feed hopper; 2. Feed control; 3. Swinging hammer; 4. Rotary disk; 5. Small serrated plate; 6.

Peripheral screen; 7. Large serrated plate; 8. Fan; 9. Feed gathering (collection) hopper.

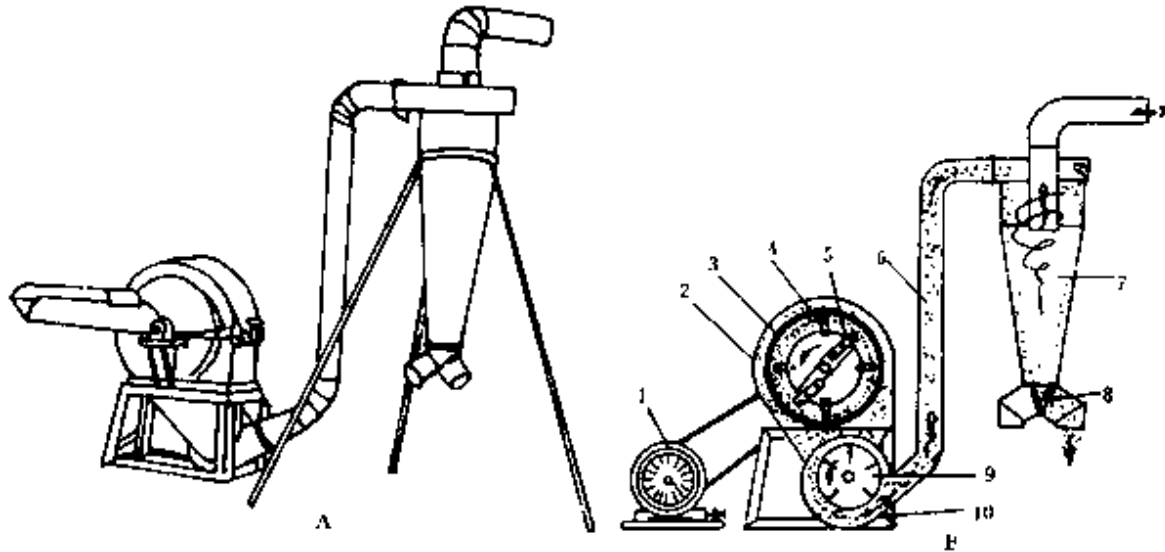
The process then repeats until the particles pass through the screen and are discharged from the grinding chamber. The process inside the grinding chamber includes the functions of impacting, shearing and kneading, which improves the efficiency of grinding. The feed product is sucked from the discharging door to the conveying tube by a fan, then enters the collection hopper, and is finally discharged from the collection hopper after the meal settles out from the air stream.

The axial-feed mill (Figure 6-17) differs from the tangential-feed mill in both the direction of feeding and in primary cutting action. Straw fed from the axial-feed hopper is firstly chopped into small pieces by the primary cutting mechanism fixed in front of the grinding chamber, and these pieces then fall into the grinding chamber. Thus the load on the grinding chamber is reduced; and the feeding capability and efficiency of processing improved. The axial-feed mill is especially suited to grinding straw with high moisture content.

The advantages of the hammer mill are high productivity, wide application and fine particle output. It can be used to mill maize, concentrate feed, green grass and various straws with high moisture and fibre content, so it is also called a "grass powder miller." However, energy consumption is high.

The fixed-head mill differs from the hammer mill in that its blade is fixed to the rotary disk rather than connected to it by a pin, so it has much higher grinding capacity.

Figure 6-17. Axial feed mill. A. Outline; B. Operation



KEY: 1. Motor; 2. Housing; 3. Ring screen; 4. Hammer; 5. Primary cutter; 6. Conveying tube; 7. Feed collection (gathering) hopper; 8. Discharging door and tube; 9. Fan; 10. Frame.

Claw mills

Claw mills hit and grind material with claws fixed in a rotating disc,

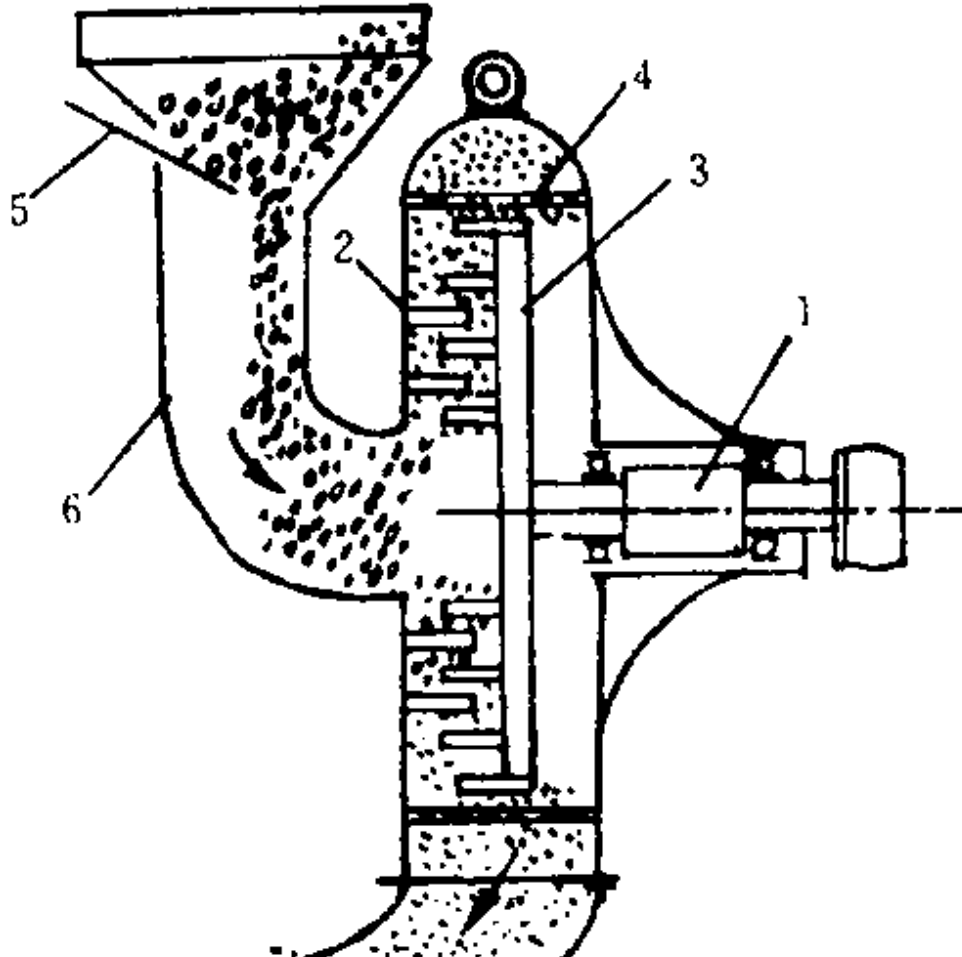
and are suitable for concentrate grinding because of compact structure, small volume and light weight.

Figure 6-18 illustrates the structure of a claw mill with its feeding, grinding and discharging parts. The feeding includes a feed hopper, a feed control door and a feed tube. The grinding part consists of a rotary serrated disk, a stationary serrated disk and a ring screen. Claws are fixed on the rotary and the stationary disks alternatively. The discharging part is a tube situated in the bottom of the machine.

After flowing into the grinding chamber from the feed hopper via the feeding door, the material is impacted, sheared, kneaded and gradually rubbed by claws into powder. At the same time, the airflow formed by high-speed rotation of the rotary serrated disk blows the powder out through the ring screen.

Figure 6-18. Claw mill







KEY: 1. Main shaft; 2. Stationary serrated disk; 3. Rotary serrated disk; 4. Ring screen; 5. Door to control material input rate; 6. Feed tube.

Factors influencing the effects of grinding

- (i) **Type of material to be ground.** The grinding output with the same energy consumption differs according to raw material. Output with cereal feed is higher than with roughage. With a screen hole diameter of 1.2 mm and a moisture content below 15 percent, the output in kg/kW is 45-60 for maize and sorghum; 17-22 for chaff; 12-16 for sweet potato vines; 8-12 for maize stover; 7-12 for sorghum stover; 6-10 for legume straw; and 3-4 for maize cobs (2 mm screen hole diameter).
- (ii) **Moisture content.** The higher the moisture content, the lower the output and the poorer the energy efficiency. Generally,

moisture content should not be higher than 15 percent.

(iii) **Rotary speed of main shaft.** Each type of mill has a range of rotary speeds for the main shaft to obtain high output and low energy consumption for each feed. If the rotary speed is too low, the grinding capacity is decreased and feed discharge is hampered, so productivity is also reduced. In contrast, if the rotary speed is too high, idle energy consumption is increased, as well as wear, tear and vibration, and the total energy consumed is higher. The line speed for hammer mills made in China in recent years is about 70 -90 m/sec.

(iv) **Feed rate.** If the feed rate is too high, ground feed can not be discharged from the grinding chamber at the same rate, which results in clogging, which affects capacity. In contrast, if the feeding rate is too low, the milling capacity is not fully used and efficiency decreases.

The main mill types made in China are listed in Table 6-3.

Kneading machines

The kneading machine is a new kind of straw processing technique developed in China, combining chopping with grinding. The machine processes residues, especially maize stover, into thin thread segments of 8-19 cm, completely destroying its node structure. Palatability is greatly improved, and the intake of the entire crop is also increased to 95 percent from the original 50 percent. The structure of the kneading machine is shown in Figure 6-19. In operation, the rotor, diameter 40 cm, rotates at a high-speed (2 856 rpm) driving 16 hammers arranged in 4 groups, which impact the straw fed continually. A tilted serrated plate, whose teeth are arranged helically and with changeable height, and 6 stationary blades are fixed to the concave plate of the machine, in order to keep the impacted straw moving in axially with the help of a fan. Taking the 9RC-40 kneading machine, made by the Beijing Linhai Agricultural and Livestock Machinery Plant, as an example: the power supply is 7.5 -13 kW (the machine can also be driven by 8.82 -11.0 kW from a four-wheel drive tractor) and the output of model I is up to 1 000 kg/hour, with 2 000 kg/hour from model II.

The kneading machine can increase straw utilization considerably

simply by physical processing and it is well suited for maize stover, which already has high nutrient value. Energy consumption is high, 1 to 2 times that of a normal chopping machine of the same output, because the final particles are finer. Because straw can also be softened during ensilage or ammoniation, this chopper can meet animals' requirements when they do not directly eat straw.

The main types and technical parameters of the kneading machines made in China are shown in Table 6-4.

Table 6-3. Characteristics of some grinders produced in China

Model and Type*	Speed Rotor D (mm) Screen (mm)	Output - Maize - Straw (kg/kWh)	Capacity - Maize - Straw (kg/hour)	Power (kW)	Weight (kg) Size (l à w à h; cm)	Price (¥)	Maker
9FQ-40B	3800	95	800	7.5	150	790	(1)
	1000	90	1000		200×70×200		

VIII

400; -

ZZ

100

83a79a90

(Fenglei)

[H]

9QF-50B

3250

95

1300

13.0

240

1

(1)

Feed

rpm

600

mill

500; -

20

260

107à106à99

(Fenglei)

[H]

6FC-308A

3800

n.a.

600

5.5

120

760

(2)

Feed

rpm

mill [Fixed
head]

308; -

-

75à56à120

9FQ40 -20

n.a.

n.a.

1000

7.5-11

170

850

(2)

Feed

mill [H]

-

90à89à81

9F-45A

3600

90

900

130

High

rpm

efficiency

feed

		10.0			865	(3)
mill (Fengshou)	450; 1.2	30	300	88à87à105		
[H]						
9F-36 Feed mill	4 500 rpm		1000	85		
		n.a.		7.5	780	(3)
(Fengshou)	360; 2		280	75à99à114		
9FQ40-20 Straw						
	3 770 rpm		1100	170		
Mill (Fengshou)		n.a.		7.5-11	850	(3)
	n.a.		Đ	99à89à81		
[H]						
9FQ-40 Feed	-	95	900	7.5-11	200	1 297

mill [H]

400;
2.0

25

200

90a57a81

9F-45A
Feed3 600
rpm

1090

n.a.

11

n.a.

n.a.

(5)

mill [H]

-; 2

Đ

9FS-45A
Feed3200
rpm

780

n.a.

11

n.a.

n.a.

(5)

mill [C]

-; 2

Đ

93FC-50
Straw3437
rpm

134

1519

Mill
(Hongxing)

15

8
000

(6)

500; 3

78

706

184à105à95

H01000

9FQ40-20

Feed

3730
rpm

130

1000

180

mill

(Hongxing)

7.6

1
200

(6)

400; 2

22

165

n.a.

[H]

9FQ-50

Feed

3440
rpm

69

884

488

mill

(Hongxing)

13

1
800

(6)

500;
1.2

13.7

175

156à61à210

[H]

9F-37-1

Feed

	4000 rpm		250		125		
mill (<i>Lingfeng</i>)		n.a.		7.5		700	(7)
	370; 1		50		69à70à68		
[H] 9F-500 Feed							
	3250 rpm	> 125	850		200		
mill (<i>Dongyue</i>)				11		1 320	(8)
	500; 3.5	> 20	400		154à97à154		
[H] 9F-400 Feed							
	3000 rpm	> 142	600		150		

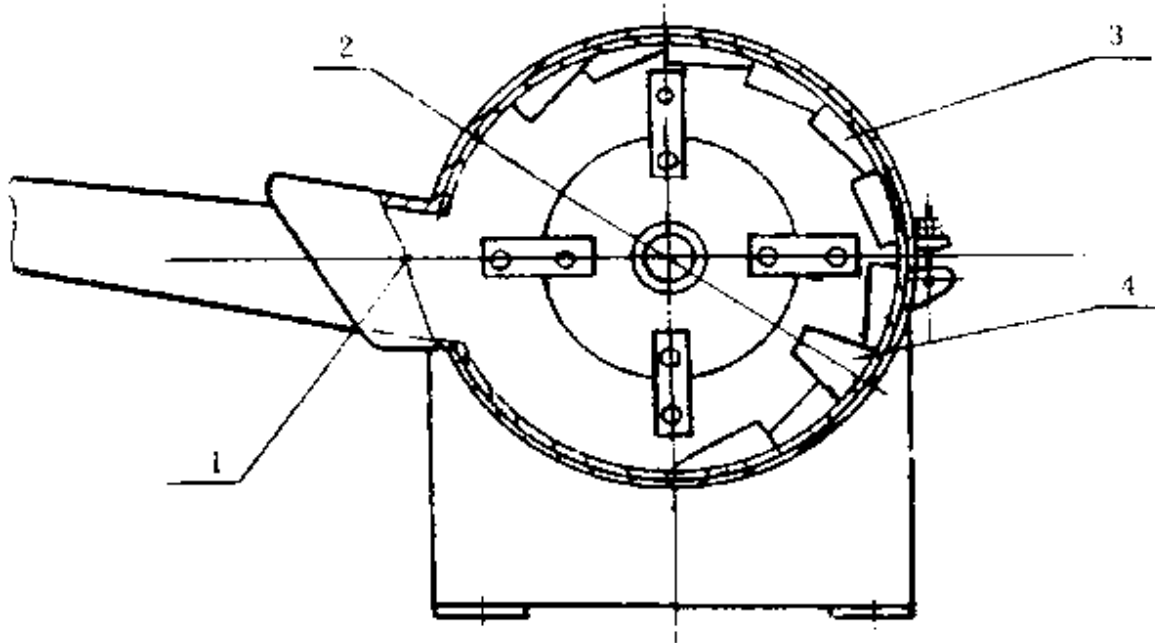
mill (<i>Dongyue</i>)				7.5		1 100	(8)
	400; 3.5	> 25	250		149à99à146		
[H] 93Fc-650 Straw	2500 rpm	107	800		n.a.		
				11			(9)
Mill (<i>Xinmu</i>) [H]	650; 4	46.8	560		2157à1274à1505	3 200	

NOTES: *Types are [H] = hammer; [C] = claw. n.a. = information not provided.

KEY TO MANUFACTURERS: (1) Beijing tonnexian Grinder Plant. (2) Shanxi Huguan Farm Machinery Plant. (3) Inner Mongolia Ningchen General Machinery Plant. (4) Liaoning Fengchen Machinery Plant. (5) Helongjiang Anqing Farm and Livestock Plant. (6) Jiangxi State

Running Hongxing Machinery Plant. (7) Gangxi Hoxian
Agricultural Machinery Plant. (8) Shandong Taishan Farm
and Livestock Machinery Plant. (9) Xinjiang Livestock
Machinery Plant

Figure 6-19. Illustration of kneading machine structure



KEY: 1. Smooth plate; 2. Hammer rotor; 3. Unequal height teeth; 4. Stationary blade.

Table 6-4. Characteristics of some kneading machines in China

Model	Rotor \AA	Power	kg/kWh	Weight	Price	Maker
-------	--------------------	-------	--------	--------	-------	-------

type*	(mm) Speed (rpm)	(kW) Capacity (kg/hour)	(kg) Size (l x w x h; cm)	(.)
93RC-40 Straw Kneading	400	7.5-10	120	
			100	1 (1) 640
Machine [H]	2500	1000	13712669	
93RC-40 Straw Kneading	400	7.5-13	130	
			n.a.	2 (2) 500
Machine [H]	2610	2000	15366127	
K-67-50 Straw Kneading	500		n.a.	

		n.a.	n.a.	2 000	(3)
Machine [H&B]	n.a.		n.a.		
9RS -1.5 Straw Kneading	n.a.	17-22	n.a.		
			n.a.	2 800	(4)
Machine [H&B]	1400	1500	16050122		
9RS -0.7 Straw Kneading	n.a.	5.5-10	n.a.		
			n.a.	1 800	(4)
Machine [H&B]	2000	700	1323783		

	Chopping 900				
9RSL -50 Multi-function feed		7.5		195	
	Tearing 2000		n.a.	1 500	(5)
Kneading Machine [H&B]		5000		21554150	
	n.a.				
9RC-40 Straw Kneading		7.5		160	
	n.a.		n.a.	n.a.	(6)
Machine [H]		1000		n.a.	
9FRQ-40B Straw Kneading				n.a.	

	n.a.	n.a.	n.a.	750	(7)
Machine [D]				n.a.	
93F-45 Straw Kneading	450	4		600	
			50	3	(8)
				200	
Machine [H]	2500	200		18080105	

NOTES: * machine types are [D] = disc; [H] = hammer;
[H&B] = hammer and blade.

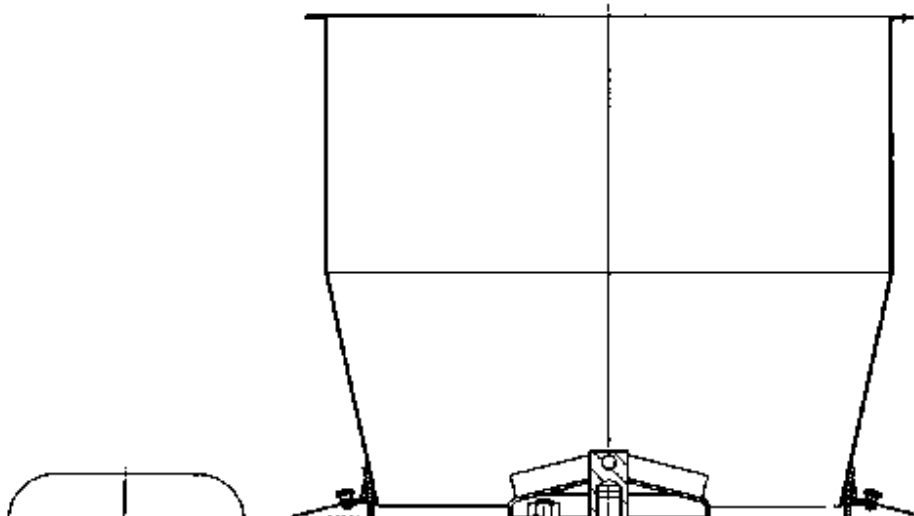
n.a. = information not supplied

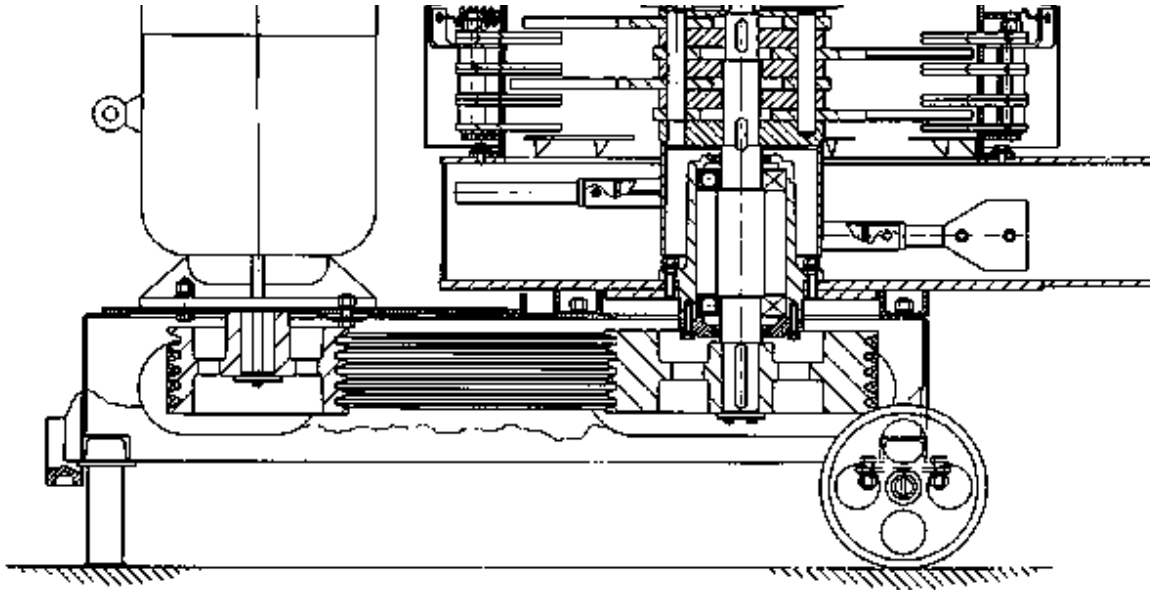
KEY TO MANUFACTURERS: (1) Liaoning Fengchen
Machinery Plant. (2) Beijing Linhai Farm and Livestock
Machinery Plant. (3) Helongjiang Achen Huajianuy Metal
Structure Plant. (4) Inner Mongolia Chifeng General
Livestock Plant. (5) Helongjiang Anda Livestock
Machinery Plant. (6) Helongjiang Achen and Mechanical
Electrical Equipment Plant. (7) Jilin Jutai Farm Tool Plant
(8) Shanxi Xi an Livestock and Milk Equipment Plant.

Kneading and cutting machines

Kneading and cutting machine models 9LRZ-80 (Figure 6-20) and 9RZ-60 (Figure 6-21) were designed by the Non-conventional Feed Institute, China Agricultural University. They passed appraisal by MOA in 1998. The appraisal said that the machines were an innovation in China, with world-leading performance.

Figure 6-20. Type 9LRZ-80 kneading machine



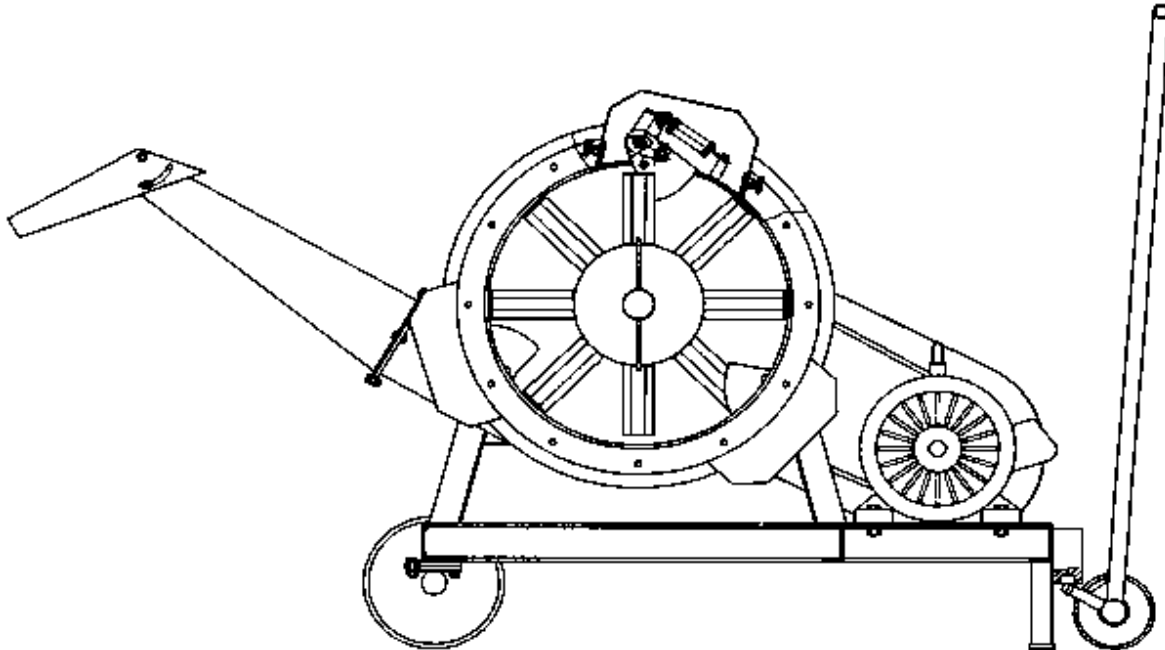


Kneading and cutting machines combine cutting, kneading and mixing in one operation. Maize stover, wheat and rice straw, bean vine and tuber vine can be processed to thread-like soft material.

The future developments of the series include the replacement of the cutting blades in the chopper by running blades; and the incorporation of a hammer in the kneading machine and of a mixing

rotor in the mixer. There are now 16 running blades and 6 sets of fixed blades. Changing the number of running blades and fixed blades will alter the cutting length and softness. The material will be thrown to the inner region of the cylinder, and will be chopped, cut and kneaded to thread-like form. When tubers and concentrate are fed into the machine together, material will be cut and mixed.

Figure 6-21. Type 9RZ-60 kneading machine



The new series has the following advantages:

- The new axle structure increases the feeding capacity.
- In the working cylinder, the running and the fixed blades will cut and knead at same time, so that energy can obviously be

reduced.

- By simply changing blade numbers, different lengths and softness can be obtained. It is suitable for green and dry materials, and especially for wet and tough material (such as palm nut shell, reeds, and chaste tree twigs).
- It is suitable for maize stover silage. The processed material can be compacted easily. Without nodes remaining, the whole stalk can be eaten by the animal.

The 9LRZ-80 is appropriate for large farms. It requires a power source of 22-30 kW, and has a capacity of 6-8 t/hour, and an output of 0.39 tonne/kWh. Its node breaking efficiency is 99 percent.

The 9RZ-60 kneading and cutting machine can be equipped with a 15 kW electrical motor. The 9RZC-60 has an 18 hp diesel engine. Both have an output of 3-4 t/hour, and are suitable for medium-sized farms.

Table 6-5. Specifications of kneading and cutting machines

	9LRZ-80		9RZ-60
Power (kW)	22		11-15
Productivity (t/hour)			
With 14-40% moisture	3-5		2-3
With 40-70% moisture	6-8		3-4
Grade of processed material			
< 50 mm		ca 78%	
50 - 100 mm		ca 20%	
> 100 mm		ca 2 %	
Node breaking efficiency		> 99 %	

Compared to a chopper, the 9LRZ-80 can save 2 160 kWh and 1 080 work-days for processing 6 000 tonne of green stalks. Total savings are about ¥ 3 000.

Pelleting equipment

After being ground into meal, having had concentrates and other nutrient elements added, straw makes a complete feed, and can be pressed by a pelleting machine. The pelleted feed, containing all nutrients, increases palatability and intake, and at the same time decreases feed waste and reduces feeding time. However, the cost of equipment for pellet processing is high. The machine consists of a pelleting device, a steam generator, an oil and molasses doser, a cooling device, a separator and a sieve.

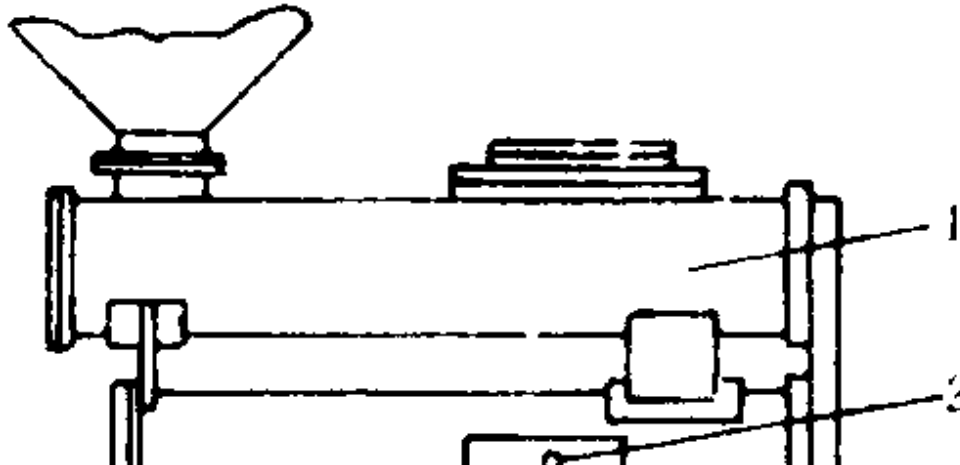
There are two types of pelleters: disk die and ring die pelleters.

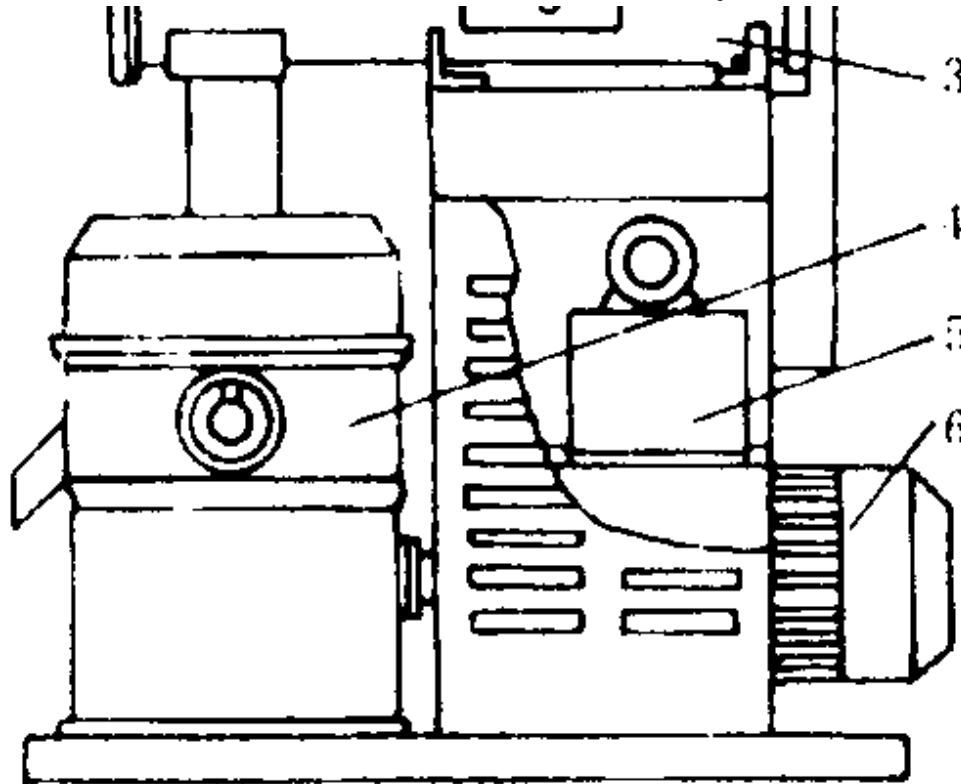
Disk die pelleter

Several disk die pelleters have been made in China. Figure 6-22 shows a disk die pelleter, comprising a screw conveyor, a gear-box, a stirrer and a pelleting device. The screw conveyor, whose rotary speed is adjustable, is mainly used to control the charging rate. The stirrer situated under the conveyor stirs the material, admitting steam through a side hole to heat and cook the material while it is transferred to the pelleting device. Inside the die there are 2 to 4 press rollers and a disk with many holes (shown in

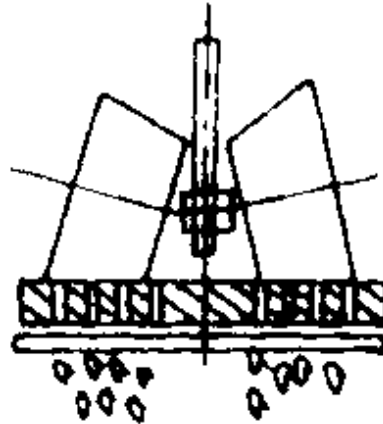
Figure 6-23). In operation, the disk rotates at a speed of 210 rpm. After falling onto the disk die, the cooked meal is distributed evenly by a spade and forced through the round holes of the die by the press. The cylindrical pellets from the die are then cut into pieces 10-20 mm long by a blade under the disk. Disk presses can be classified into three types: movable die, movable roller and movable die and roller types. Hole diameter in the die can be 4, 6 or 8 mm. The diameter of the roller ranges from 160 to 180 mm.

Figure 6-22. Pelleter with disk die





KEY: 1. Screw conveyor; 2. Steam inlet; 3. Stirrer; 4. Press; 5. Wormwheel box; 6. Motor.

Figure 6-23. Operation of the disk die***Ring die pelleter***

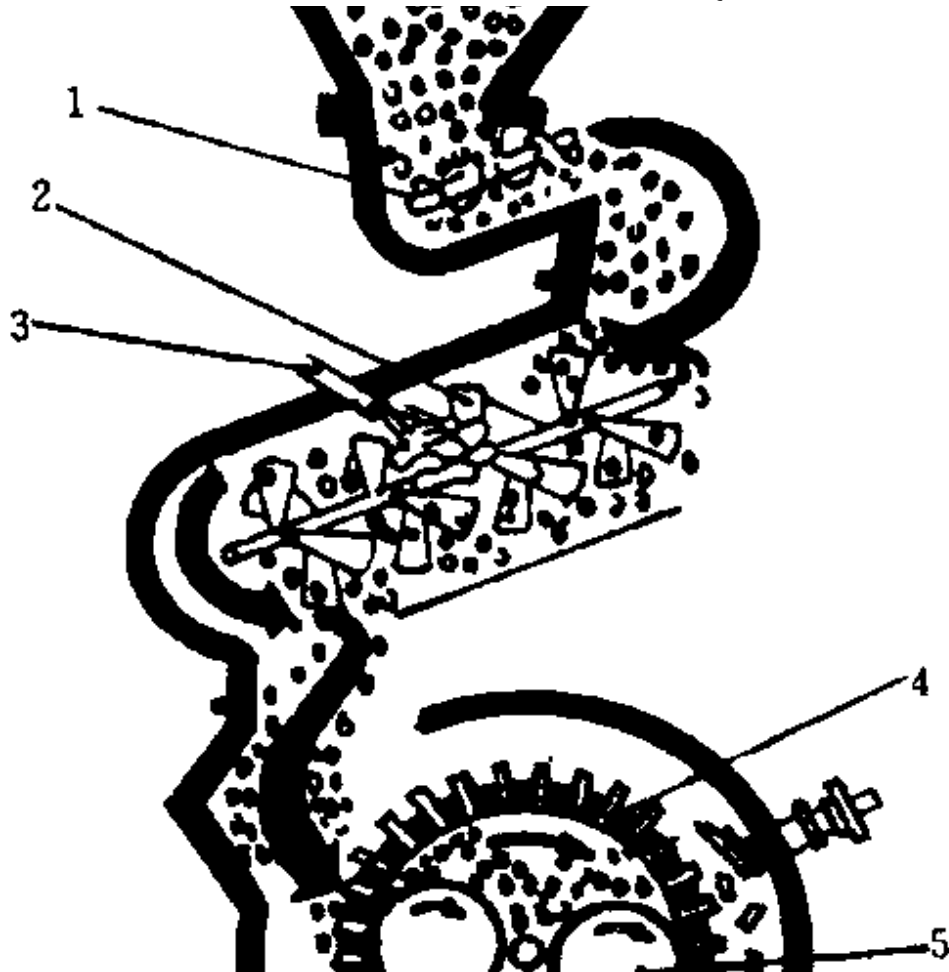
The ring die press has been widely used in engineering. Figure 6-24 is an illustration of its operation. The main parts are a screw conveyor, a stirrer, a pelleting device and a drive mechanism. The screw conveyor, whose rotary speed can normally be changed gradually in the range of 0-150 rpm, is used to control the loading rate. A side opening to the stirring chamber allows steam to be

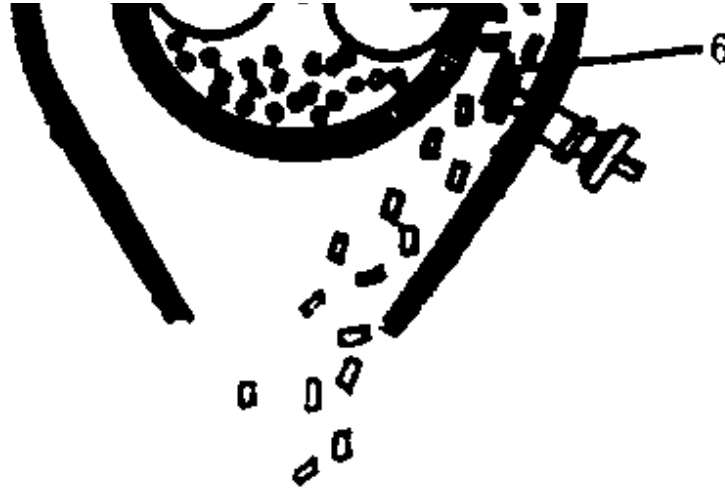
injected. In the stirring compartment, the meal is mixed with over-saturated high-pressure steam. Sometimes oil, molasses and other additives are added during mixing. When ideal conditions can not be met, water can be used instead of steam, but in this case mixing is poor, output is decreased, and energy consumption and friction are increased.

The mixed meal goes into the pelleting device, which consists of a ring die and pressing rollers. In operation, the ring die rotates, making the rollers turn and press the material through the cylindrical holes of the ring die. The cylindrical pellets rotate with the ring die, and are cut by a blade. The larger the hole diameter, the higher the output of the machine and the lower the energy consumption. Hole diameter is determined by animal requirements.

Figure 6-24. Operation of a pelleter with ring die







KEY: 1. Screw conveyor; 2. Stirrer; 3. Steam or air inlet;
4. Ring die; 5. Rollers; 6. Cutter.

Wafering machinery for roughage

Wafers are about ten times the size of pellets. The wafering machine made by the Guangdong Huada Machinery Factory can make rectangular wafers 25 ¥ 25 mm or 30 ¥ 30 mm, and also cylindrical wafers of 8-30 mm in diameter. The density varies from

0.6 to 1.0 g/cm³, and the bulk weight from 0.4 to 0.6 tonne/m³. The output is 600-1 000 kg/hour. Five operators are needed.

The 93KWH-40 waferer and the 93KWH complete wafering set have been developed by the Jiangxi Hongxing Machinery Plant. The rotary speed of the main press shaft is 167 rpm, the output is 300-600 kg/h, and the power needed 37 kW. The whole system's energy needs are 62.5 kW.

After milling and addition of concentrates, chemical additives and other minerals, the straw is wafered to increase nutrient value, intake and digestibility. The wafered feed is not only easy to transport, to store and to feed, but also very convenient for marketing due to its high density.

The wafering process is shown in a flow chart (Figure 6-25). After size reduction (chopping, grinding) to a specified size, controlled by the screen holes, roughage such as rice straw, wheat straw, maize stover, bulrush and sunflower stem is transported by forced air to the cyclone (2) and then to the buffering bin (3). The material from

the bin (3) is conveyed via a double-screw conveyor (4) and a rationing conveyor (5) to the mixer (8), where chemical additives and concentrates are added separately at prescribed rates from hoppers (6 and 7). At the same time, water and steam are also added to the mixer. The uniformly mixed material falls to the wafering machine (11) to be made into cubes. The cubes are transferred to a horizontal cooler (13), and then drop to the packing machine.



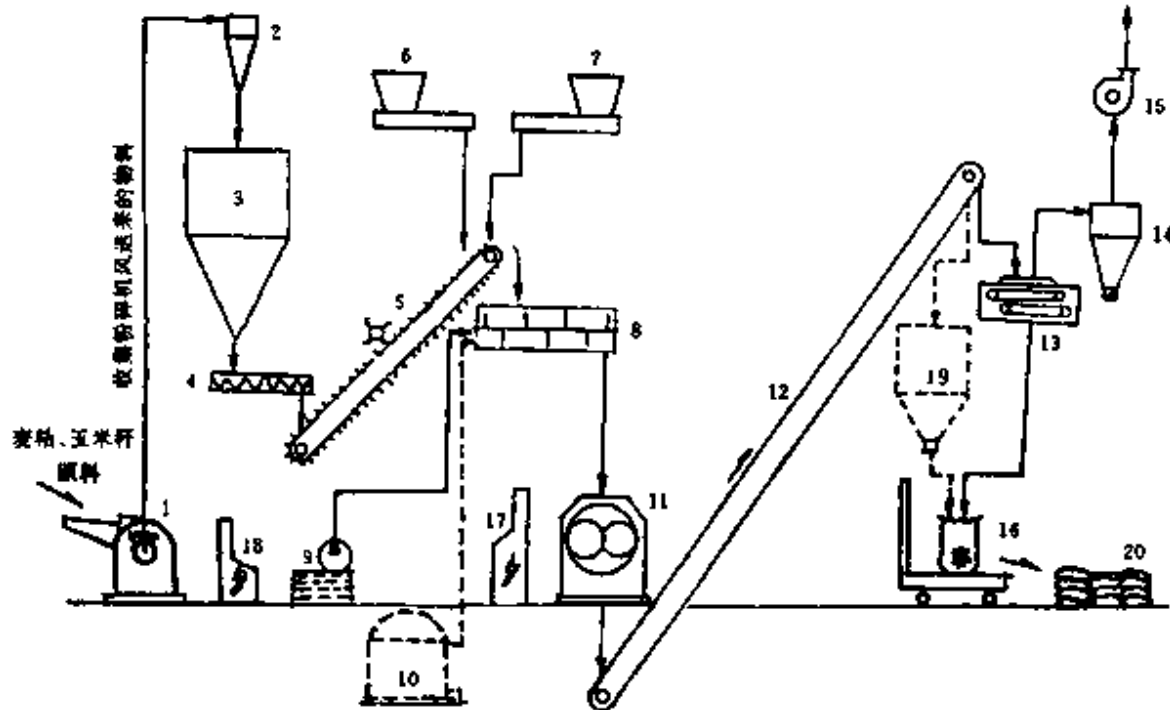
Straw treatment equipment

Ammoniation equipment for ambient conditions

The ammoniation reaction occurs at temperatures above 0°C. Reaction speed increases with temperature. There are many methods for ammoniation under normal temperature, such as stack ammoniation and use of an ammonia silo. Straw ammoniation can be carried out using various sealable containers.

The sources of ammonia for straw treatment are anhydrous ammonia, aqueous ammonia, ammonium bicarbonate and urea. When using aqueous ammonia, ammonium bicarbonate or urea, water should be added at a prescribed rate. Straw uniformly mixed with the ammonia source is sealed in the container for the ammoniation. Anhydrous ammonia is kept as a liquid under high pressure and therefore pressure containers are required to transport and store it. A minimum set of equipment, including perforated metal pipe (ammonia injection spear), volume meter, ammonia pressure meter and some safety equipment, are required for ammonia injection. Because anhydrous ammonia is a potentially dangerous and toxic material, stringent safety measures need to be taken.

Figure 6-25. Flow chart of 93KCT-1000 complete roughage wafering set operation



KEY: 1. Grinder; 2. Cyclone; 3. Buffering bin; 4. Double-

screw conveyor; 5. Rationing conveyor; 6. Chemical additive dosing mechanism; 7. Concentrate adding mechanism; 8. Mixer; 9. Water adding mechanism; 10. Heat source for cooking; 11. Waferer for coarse silage; 12. Tilt conveyor; 13. Horizontal cooler; 14. Cyclone; 15. Fan; 16. Packing machine; 17. Electronic control console; 18. Grinder control console; 19. Final product bin; 20. Product.

Heating equipment for ammoniation

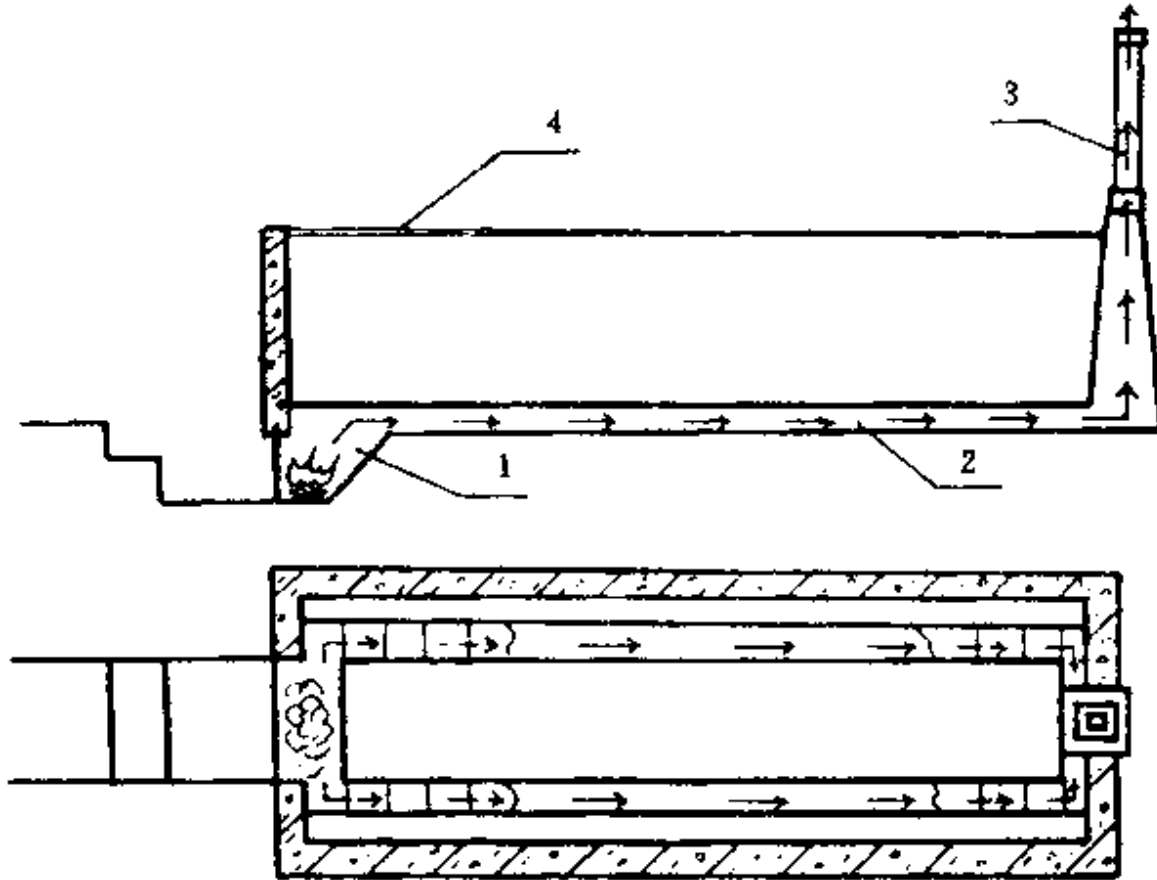
To the north of the Yellow River, the temperature is usually below 0°C in winter, and thus the ammoniation reaction can not happen. In order to deal with this problem, some new ways for ammoniation were developed in these areas.

Heated ammoniation-bunker method

The traditional method for heating material using the smoke channels of a stove - a procedure widely used in rural areas to cultivate sweet potato seedlings in early spring - is used for straw

ammoniation. It is called the heated ammoniation-bunker method. The structure of the bunker is shown in Figure 6-26. The operating steps are as follows: a bunker is constructed with brick and concrete, half underground. A stove is built at one end of the bunker, under which there are two smoke channels connected to a chimney at the other end of the stove. Firstly, the straw, mixed with the urea or ammonium bicarbonate solution at recommended doses, is placed into the bunker and sealed. Next, the straw inside the stove is ignited to heat the treated straw during half a day at a temperature of 30°C. The amount of straw burnt is equivalent to 5-10 percent. After a week, the treated straw can be fed. Longer heating times or higher temperature can shorten ammoniation time.

Figure 6-26. Ammoniation bunker for heating



KEY: 1. Stove; 2. Heat channel; 3. Chimney; 4. Plastic

sheet

Ammoniation in tobacco curing houses

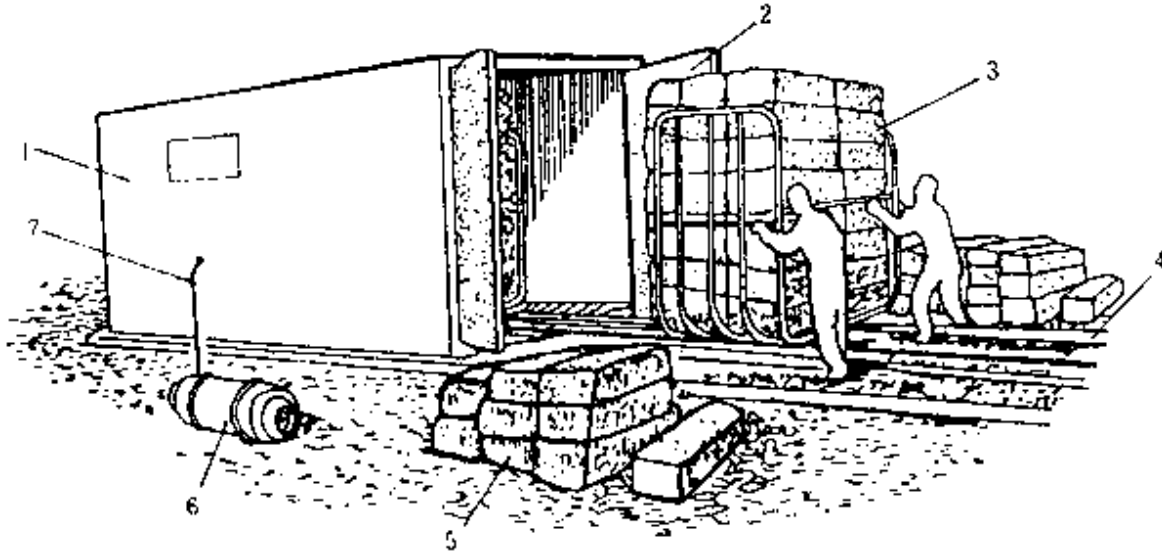
Tobacco curing houses are usually empty in winter. The straw is placed into the tobacco house, a urea or ammonium bicarbonate solution added, the straw well sealed, and then heated by burning coal. The house is kept at 40-50°C for 3-4 days for the ammoniation to be completed. This is a practical method in tobacco-growing areas.

Ammoniation in ovens

The ammoniation oven has proved to be an efficient item of equipment for livestock farms where straw ammoniation needs to be industrialized and delivered regularly according to a plan. Figure 6-27 outlines an oven with a straw trailer that can be pulled in and out. The source of ammonia can be anhydrous ammonia or ammonium bicarbonate. In Figure 6-27, anhydrous ammonia is used. Of course, anhydrous ammonia needs to be transported and stored in pressure containers. Urea is not suitable for oven

ammoniation, with its temperature as high as 90°C, because the ureases required to break down urea are destroyed at these temperatures. There are three heating options: electricity, steam or coal. The oven may be a metal box or of brick construction. The parameters for a 30 m³ metal box-oven heated by electricity are listed in Table 6-5.

Figure 6-27. Oven for ammonia treatment of straw



KEY: 1. Oven; 2. Door; 3. Straw trolley; 4. Track; 5. Straw baler; 6. Ammonia bottle; 7. Perforated metal pipe for ammonia injection (ammonia spear).

When an electric element is used to heat the oven, the temperature and heating time can be automatically controlled using a thermostat and timer. This oven has the advantages of simple operation, time

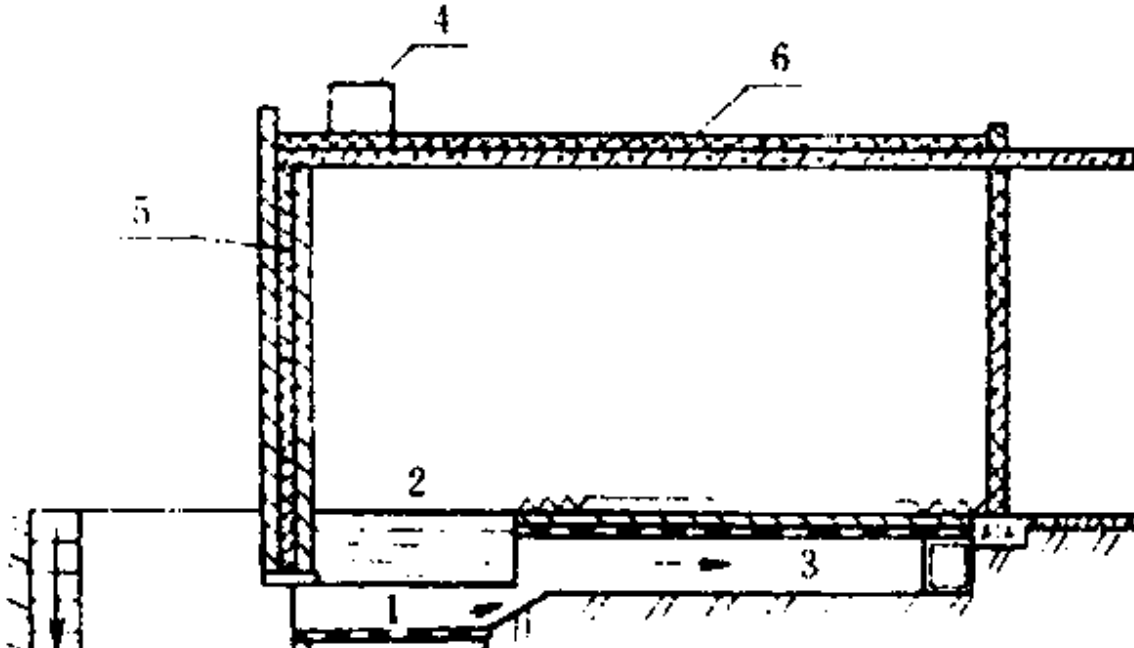
and labour saving and high level of automation. A 30 m³ oven can treat 1.5 tonne of straw within 24 hours. The energy consumed per tonne of straw is less than 100 kWh, with a cost of ¥ 29 (in 1990), equivalent to the daily wage of two persons.

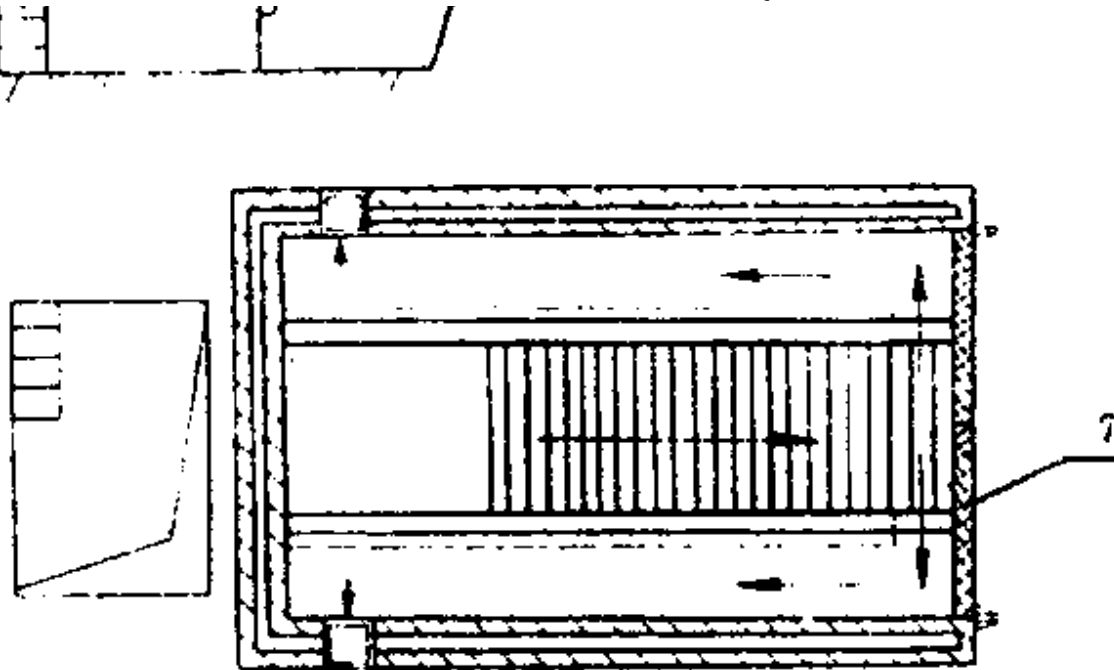
Steam is a convenient source of heat on cattle farms equipped with steam sterilizers. Oven temperature depends on steam pressure and supply time. Generally, oven temperature is maintained with steam at 70°C for 10-12 hours, then the straw is kept in the oven for a further 22-24 hours. Considering only the coal used, the cost of steam is only 40 percent of electricity.

A built up oven, heated with coal and steam, is shown in Figure 6-28. Its walls, top and bottom are constructed with bricks, cement and insulating material. The straw trolley can be pulled in and out. At one end of the oven, a stove is built in a pit. The tank, situated above the stove, provides the water for steam generation. The hot air flows through the main channel (3) from one end to another, turns to the second channel, returns to the main channel again and is finally released via the chimney (4). The oven is equipped with a

straw trolley, wheel tracks and hard rubber wheels. When hard rubber wheels are used, the straw trolley is easily moved for loading/unloading. Rails are used for guiding when loading and unloading.

Figure 6-28. Ammoniation oven heated by coal and steam





KEY: 1. Stove; 2. Water tank; 3. Smoke channel; 4. Chimney; 5. Insulation; 6. Insulated top; 7. Insulated door.

In coal producing areas such as Shanxi province, heat from coal is ten times cheaper than from electricity. It is a convenient fuel for

regions with sufficient supplies and cheaper labour.

Heat-explosion equipment

The principles of heat-explosion combine heat reaction and mechanical processing. Under the action of steam at 170°C, straw lignin is broken down and partly hydrolyzed. During the explosion, the particles impact each other inside the tube and at the same time the water trapped within cells rapidly expands to a gaseous state and physically tears apart the brittle cell wall. Straw is shredded into fine particles, greatly increasing its surface area. The quality of the treated straw is considerably improved. Equipment and a flow chart of the technology is shown in Figure 6-29.

After cutting by the chopper (1), the material is transported via the storing bin (2), the hopper (3) and charging valve (4) to pressure container (5). After being sealed, the container (5) is injected with low or medium pressure steam to a pressure of 0.5-1.0 MPa, supplied by the burner (6) and controlled by the discharge valve (7), and maintained at this high pressure for some time (from 1 to

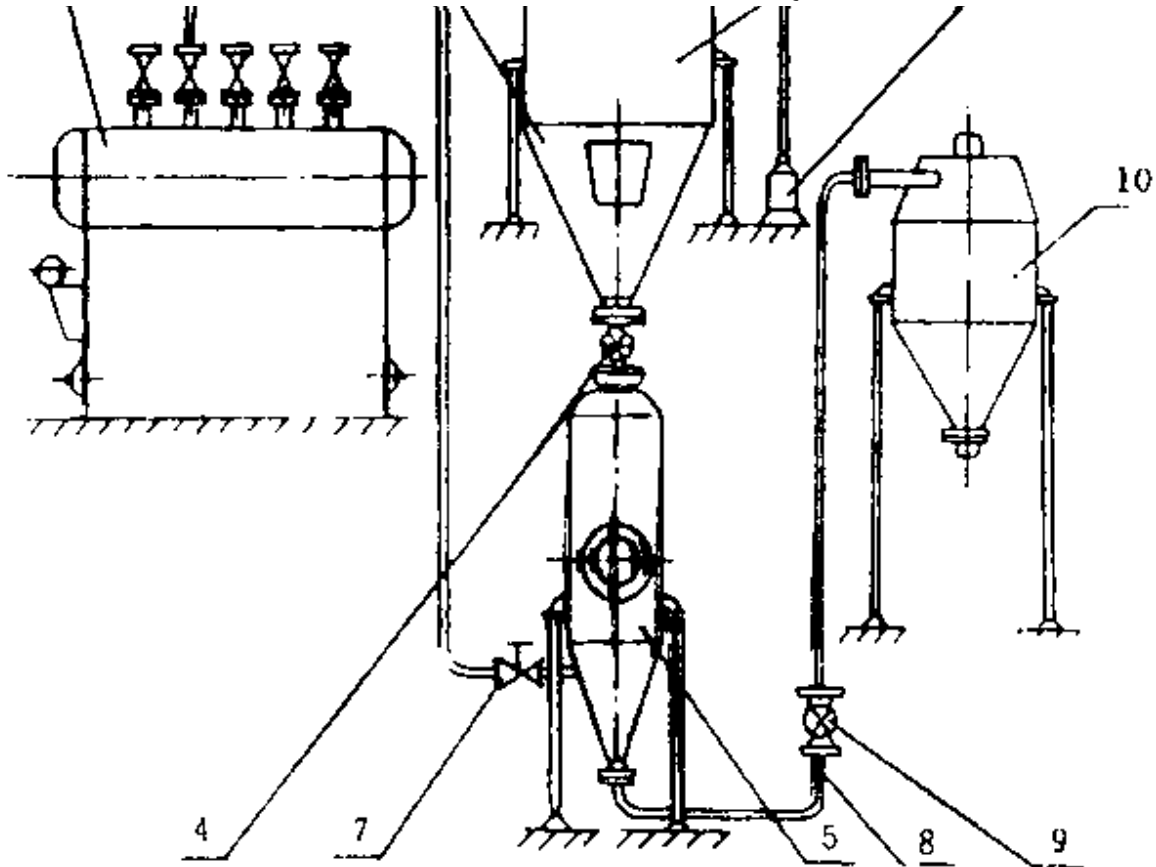
30 minutes). The pressure is then abruptly released through the rotating ball valve (9), and the material discharged into container (10) through tube (8), for subsequent direct feeding or pelleting.

The cost of this equipment was ¥ 65 000 in 1990. The volume of the pressure container is 0.9 m³. Straw output is 300 - 400 kg/hour, coal consumed is ca 50 kg/hour, and the cost for treating 1 kg of straw is about ¥ 0.02.

After heat-explosion, the physical properties of the straw have been changed, and the intake of the entire crop is increased by 50 to 90 percent. The digestibility is increased more than 50 percent. The heat explosion treatment can eliminate the toxins of colza (rapeseed) and cottonseed cakes, and sterilize the faeces of chicken, duck and cattle to odourless materials.

Figure 6-29. Heat-explosion equipment





KEY: 1. Chopper; 2. Storage bin; 3. Feed hopper; 4.

Feed valve; 5. Pressure container; 6. Boiler; 7. Inlet steam valve; 8. Discharge tube; 9. Discharge valve; 10. Storage container.



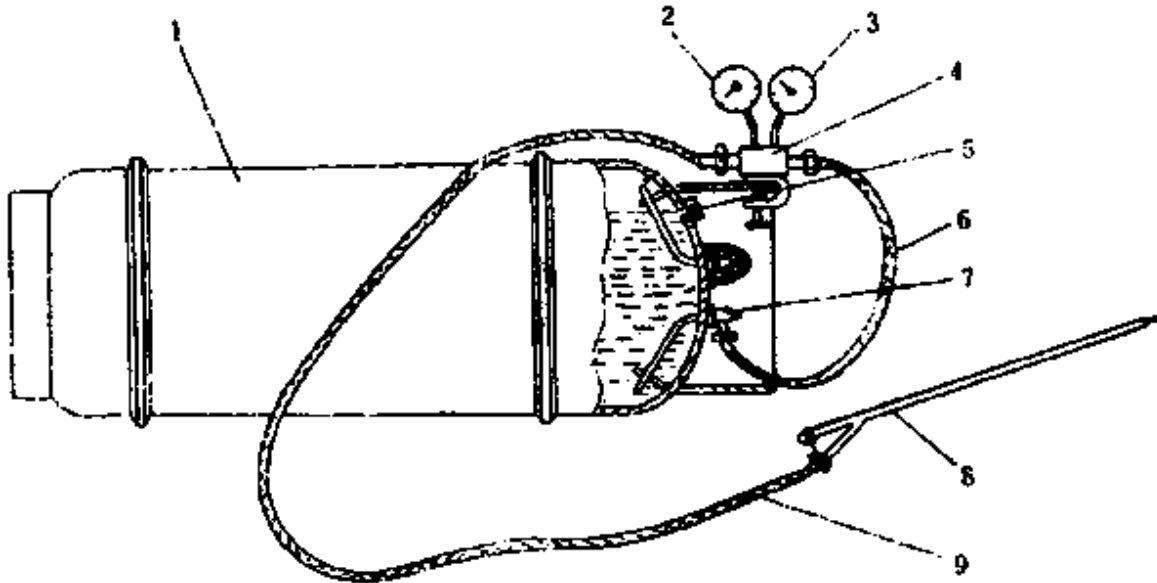
Ammoniation with anhydrous ammonia

Injection equipment

The full set of the ammonia injection equipment (Figure 6-30), developed by the Non-conventional Feed Institute of China Agricultural University, consists of an ammonia bottle, a high pressure hose, a flow meter, a low pressure hose (rubber hose) and an ammonia spear. Protective equipment (gas mask, rubber

gloves and boots) must be used.

Figure 6-30. Ammonia application equipment



KEY: 1. Ammonia bottle; 2. Low pressure meter; 3. High pressure meter; 4. Flow meter; 5. Safety plug; 6. High pressure hose; 7. Valve; 8. Injecting spear; 9. Low

pressure hose.

During treatment, the ammonia bottle should be laid horizontally, keeping vertically the line connecting the two valves: the upper for gas and the lower for liquid. One end of the high-pressure hose is connected to the lower valve and the other end to the high pressure end of the flow meter. One end of the low pressure hose is connected to the low pressure end of the flow meter and the other end to the ammonia spear.

After connecting the full set, operators should first put on their protective equipment: gas mask, rubber gloves, boots and suit. Second, the ammonia spear is inserted into the straw stack, about 0.5 m from the ground. Third, the lower valve is slowly unscrewed to inject the appropriate dose of ammonia according to the amount of straw. When finished, the valve is closed, but the spear kept in place for 4-5 minutes to allow ammonia left in the hose and spear to flow to the straw. Finally, the spear is pulled from the stack and the injection hole sealed with glue or tied with a string.

Using the flow meter, ammonia can be injected into the stack

directly from an ammonia truck, avoiding ammonia transfer from tank to bottle. As a result, working efficiency is increased.

Construction of an ammoniation station

Anhydrous ammonia is the cheapest ammonia source, and, for this reason, treating straw with anhydrous ammonia has been advocated. However, aqueous ammonia is toxic, volatilizes easily and causes burns, thus pressure containers are required for transport and storage. It is necessary to build an anhydrous ammonia supply system. Considering the practical radius of service and amount to be used, a county-level ammoniation station might be needed. Functions of the station are to obtain ammonia in large quantities from chemical (usually fertilizer) factories in tank trucks, store it in large containers, distribute it in bottles and also to perform the injection into the straw at farmer level. At the same time, the station also can market other ammonia sources (e.g. urea) and ammoniation equipment.

Selection of equipment for transport and storage

Many types of transport and storage facilities for anhydrous ammonia have been manufactured in China, including ammonia tank trucks, containers and bottles, some of which are listed in Table 6-7. The 3-ton Dongfeng truck tank and the 7.2-ton Hongyan 19 truck tank have been selected as the main models to meet requirements in a flexible manner. Anhydrous ammonia containers are mainly used in ammoniation stations connected with an ammonia supply system. When selecting ammonia containers, cost and uniformity of ammonia delivery should be taken into account. Because anhydrous ammonia can be transferred directly from a tank placed on a truck body into bottles, tanks may not be required for a county-level ammoniation station if funding is adequate.

Table 6-7. Equipment sizes for ammonia transport and storage

Category	Type	Capacity
Anhydrous ammonia tank trucks	Dongfeng	3.0 t
	Dongfeng-13	5.1 t
	Hongyan-19	7.2 t
	Hongyan-30	12.0 t

Anhydrous ammonia containers	6 m ³	3 t
	16 m ³	8 t
	25 m ³	12.5 t
	50 m ³	25 t
Bottles	800 litre	400 kg
	400 litre	200 kg
	40 litre	20 kg

When selecting ammonia bottles, the first factor to be considered is convenience for loading and unloading. Because hand tractors or small carts can easily transport a 400-litre (200 kg) ammonia bottle, they have been selected as the main type. The 40-litre (20 kg) bottles are well adapted for farmers ammoniating straw in stacks, because of their easy transport, loading and unloading. One 40-litre bottle can treat 700 kg of straw in a stack, avoiding weighing and other complex procedures, and it can be transported

by bicycle. The Non-conventional Feed Institute of China Agricultural University and relevant factories have promoted the "one bottle, one stack" concept based on this small bottle, as recommended by FAO experts.

Ammonia transfer

One of the important roles of the ammoniation station is to transfer anhydrous ammonia from the truck tank to bottles. If the liquid level in the tank is nearly equal to that in the bottle, ammonia can not flow by gravity and a compressor is needed. Ammonia compressors are available in Denmark. In China, an ammonia compressor has been obtained by redesigning the corrosion-prone parts of an air compressor.

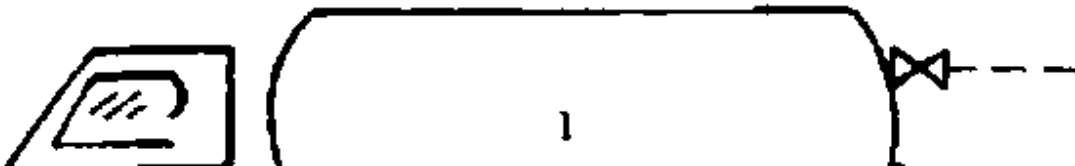
The Non-conventional Feed Institute of China Agricultural University has successfully developed an anhydrous ammonia flow meter. The system of transferring ammonia from truck tank to bottle is shown in Figure 6-31. The ammonia transferring procedure is:

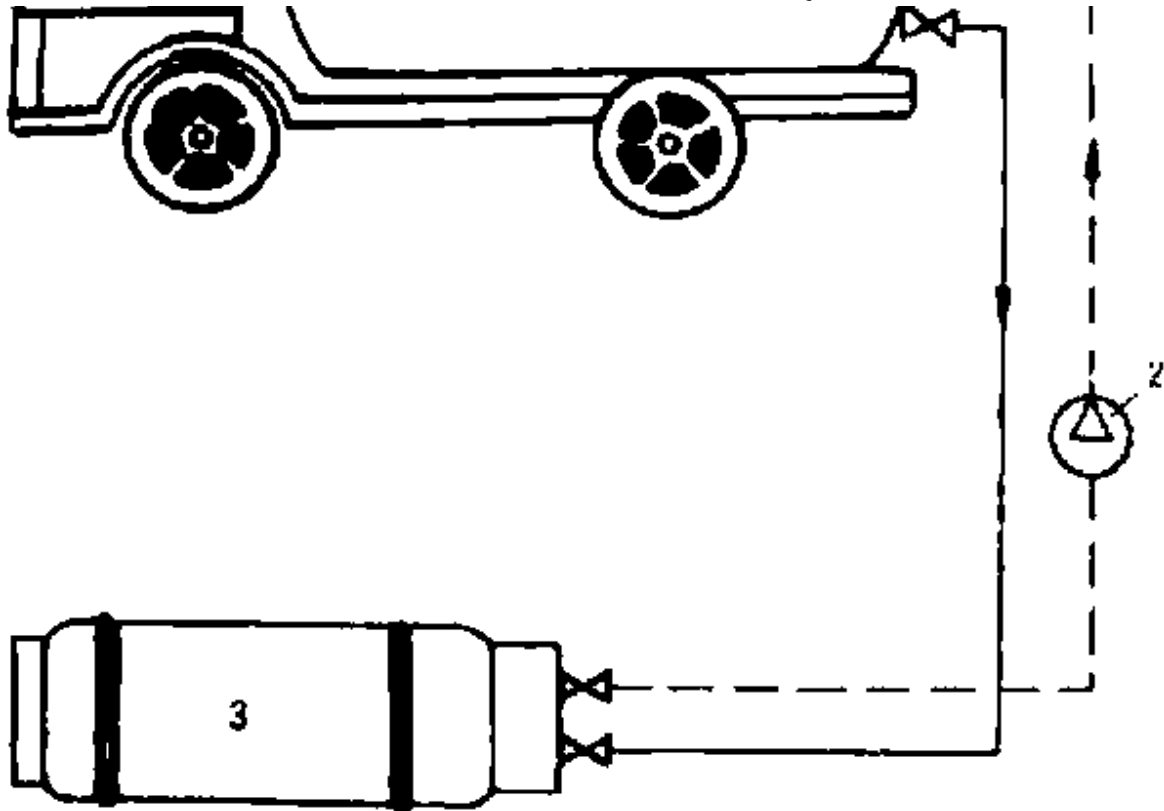
- A high-pressure hose is attached between the liquid valve on

the truck tank and the bottles. A gas hose is attached between the gas valve on the truck tank and bottle through the compressor.

- The gas valve on the truck tank is opened and checked for any leakages (splits or cracks along the hose).
- The bottle's gas valve is opened, then the truck tank's valve, and a check is made for leakage along the hoses.
- The liquid valve on the bottle is then opened.
- The compressor to transfer ammonia from the truck tank to the bottle is started before the liquid is released into the hose.

Figure 6-31. The transfer system from the truck tank to the ammonia bottle





KEY: 1. Ammonia truck tank; 2. Ammonia compressor; 3. Ammonia bottle.

It is better to place an ammonia pressure meter on the bottle's gas valve, and to compare its value with that on the tank. If the pressure of the tank is consistently more than that of bottle, this means the system is working fine.

Layout of ammoniation station

Determining service scale and equipment. The technology of treating straw with anhydrous ammonia is already mature. The ammonia dosage should be 3 percent of the straw dry weight. It is estimated that 1.5 tonne of ammoniated straw are enough for one head of cattle a year. Table 6-8 is based on an assumption of 1.5 tonne per head per year, and 300 working days for the ammoniation station a year. Table 6-7 indicates that a farm with 10 000 beef cattle needs 15 000 tonne of ammoniated straw, requiring 450 tonne of anhydrous ammonia annually. The quantity of ammoniated straw and ammonia for other animal species can be estimated by converting other livestock units into cattle units. The type and number of ammoniation facilities are determined by the quantity of anhydrous ammonia needed per year. The number of

trips is estimated based on truck tank size and distance between the station and the fertilizer factory.

Table 6-8. Relationship between cattle member, straw amount, anhydrous ammonia and facilities required

Cattle	Treated straw (ton/yr)	NH ₃ need(1) (ton/yr)	Trips of 3-ton tank truck		Trips of 7.2-ton tank truck		No. of 200 - kg bottles needed
			Per year	Per day	Per year	Per day	
10 000	15 000	450	150	0.5	62.5	0.200	15
20 000	30 000	900	300	1.0	125.0	0.420	30
30 000	45 000	1 350	450	1.5	187.5	0.625	45
40	60 000	1 800	600	2.0	250.0	0.830	60

50 000	75 000	2 250	750	2.5	312.5	1.040	75
60 000	90 000	2 700	900	3.0	375.0	1.250	90
70 000	105 000	3 150	1 050	3.5	437.5	1.460	105
80 000	120 000	3 600	1 200	4.0	500.0	1.670	120
90 000	135 000	4 050	1 350	4.5	562.5	1.875	135
100 000	150 000	4 500	1 500	5.0	625.0	2.080	150

NOTES: (1) As anhydrous ammonia.

The total volume of bottles should be double that of the tank to ensure thorough discharge. That means that half of the bottles will be with farmers and the other half on station. The bottles should be recycled to accelerate turnover and improve working efficiency. In

addition, small ammonia bottles holding 40 litre (20 kg) should also be available to facilitate farm work. At the station, ammonia is transferred from the truck to bottles through a hose controlled by a platform scale. Because the amount of ammonia remaining in each bottle varies, it is impossible to estimate the total amount transferred by a flow meter. At the same time, the amount in each bottle is an important consideration for safe transport, so flow meters are unsuitable for stations.

Equipment and its cost. Equipment and its cost in a typical ammoniation station serving 20 000 beef cattle are listed in Tables 6-8 and 6-9. The ammoniation of 30 000 tonne of straw requires 900 tonne of anhydrous ammonia, which can be transported by a 3-ton truck tank once daily (Table 6-7). At the same time, 30 small bottles with 200 kg and other facilities, such as a farm vehicle, a small four-wheel tractor and trailer, are also needed. Appropriate schemes can be planned for various sizes of ammoniation stations, based on the data in Table 6-9.

Table 6-9. Equipment and cost for an ammoniation station serving

20,000 cattle

Equipment item	Number needed	Cost per unit (¥ 10 000)	Total cost (¥ 10 000)
3-ton truck with ammonia tank	1	6.95	6.95
200-kg anhydrous ammonia bottle	30	0.20	6.00
Farm vehicle	1	4.50	4.50
Weighing scale (500 kg capacity)	1	0.05	0.05
Loading and unloading frame	1	0.20	0.20
Small four-wheel tractor	1	0.70	0.70
Trailer for small four-wheel tractor	1	0.25	0.25
Hand trolley	1	0.05	0.05

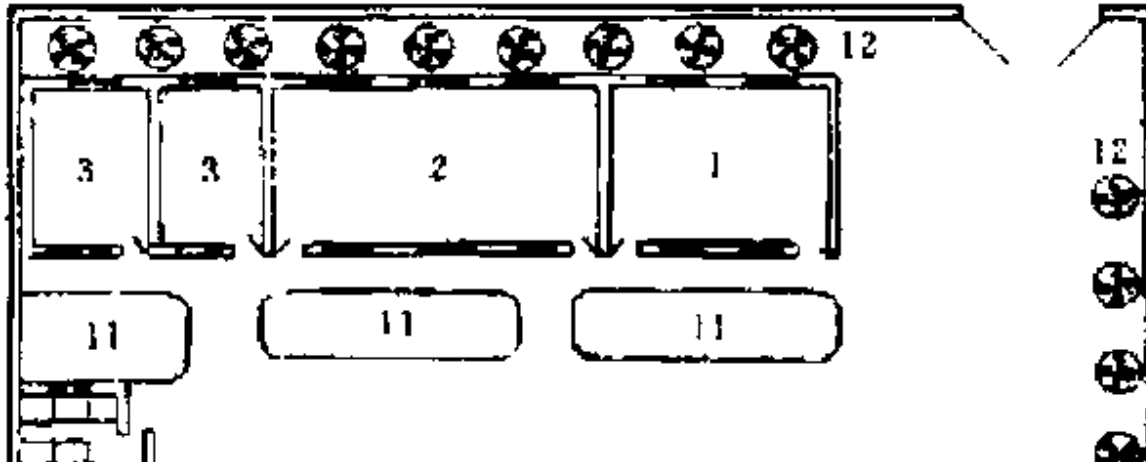
Other			0.50
Total			19.20

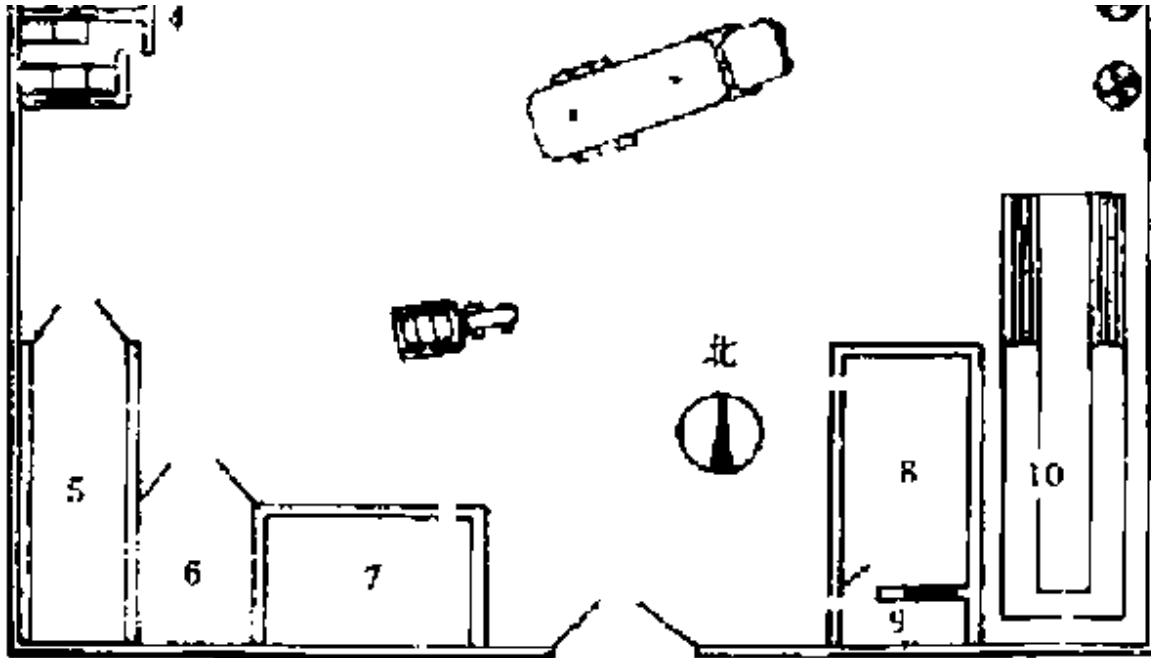
Personnel. For a typical ammoniation station serving 20-50 000 cattle, 5-7 persons are needed (1 manager, 2 drivers, 2-4 operators).

Construction requirements and plan layout. Each ammoniation station should be designed specifically for the service scale and land and equipment available. An ammoniation station for a 20-50 000-cattle catchment (typical county level) shows typical construction requirements and layout (see Figure 6-32). The area is 40 × 40 m (1 600 m²). In order to quickly transfer ammonia from the tank truck to bottles, the difference in height between tank and bottle should be adequate. Thus, a 1-m platform (10) is suitable for loading and unloading. It has an inspection pit for checking or repairing vehicles. The platform can also be used for general loading and unloading operations. A shed beside the platform (8) holds 125 ammonia bottles (200 kg each), standing vertically. At the end of shed (8) there is a storeroom (9) with a separate wall. A

tractor can be driven close to shed (8). One person can load and unload with the aid of a movable gallows frame. The office (1) is used as a check point and for sales (urea, ammonia filling equipment and plastic sheets). The other rooms are an office (2), a meeting room and manager's office, living rooms (3), toilet (4), large (5) and small (6) garages and stores for urea, ammonia filling equipment and plastic sheets (7). (11) are flower beds, and (12) are trees.

Figure 6-32. County-level ammoniation station





The living and administrative areas are located at the corner opposite to the ammonia source to minimize effects on people. Doors on opposite sides of the compound facilitate access of trucks and tractors. The whole yard is large enough for vehicles to turn around without the need to reverse.

A typical budget for the construction of a county-level ammoniation station is given in Table 6-10.

Table 6-10. Budget for construction of a county-level ammoniation station

Building	Size (m)	Unit price (¥)	No.	Total cost (¥)
Office and dormitory	3.0 × 6.0	3 000	7	21 000
Truck garage	3.5 × 11.0	5 000	1	5 000
Car garage	4.5 × 6.5	3 500	1	3 500
Shed for urea storage	9.0 × 6.5	6 000	1	6 000
Platform for loading and unloading	15.0 × 4.0 × 1.0	3 000	1	3 000
Shed for ammonia bottles	3.0 × 11.0	5 000	1	5 000
Toilet	4.5 × 6.0	1 000	1	1 000
Road, water and electricity				10 000

facilities				
Total				54 500

Economic assessment. The cost estimation is done taking into account the following factors:

- Depreciation of equipment and buildings over 10 years
- Wages at ¥ 250 per person per month
- Transport costs of ¥ 0.03/ton/km
- 5% profit on turnover
- Aqueous ammonia cost of ¥ 1.4/kg

The economics of a county-level ammoniation station serving 20 000 cattle are presented in Table 6-11. The price of aqueous ammonia reached ¥ 0.1434/kg after transport, storage and distribution by the ammoniation station. Except for personnel wages and transport fees, other costs were ¥ 87 050 per year.

Investment in equipment and building construction was ¥ 24 500. It is estimated that 3 years are needed to recover the investment. The cost of buying the land and electricity also should be taken into account. In addition, possible additional income from sales of urea, ammonium bicarbonate and ammonia equipment is not considered.

Table 6-11. Economics of a county-level ammoniation station for 20,000 cattle

Cost	Yearly depreciation		Wages	Transport cost	Profit	Total
	Equipment	Buildings				
Total	45 250	4 850	21 000	67 500	157 000	
Per kg of aqueous ammonia	0.1213	0.0054	0.0167	0.0300	0.0700	0.1434

NOTE: (1) Aqueous ammonia sold annually is 900 tonne.

(2) All values are in ¥

County-level ammoniation station in parallel to the ammonia supply system in a fertilizer factory. Such a station can be built on an empty area inside or close to the fertilizer factory. A tank, with a volume 5 times that of expected daily use, can be connected to the ammonia source in the factory. The capacity for ammonia delivery can be increased with a larger tank, but the cost also increases. For a station serving 20 000 cattle, a 12.5 tonne tank is preferred. It costs about ¥ 52 000. Having a station associated with the fertilizer factory saves not only on transport but also on wages and building cost. The economic assessment can be done on a similar basis to that above.

Township-level ammoniation station. Such an ammoniation station would be responsible for supplying ammonia for straw ammoniation. It can be part of the agricultural machinery service system or can be contracted to a professional farmer. Most of the equipment required, listed in Table 6-12, can be shared with the agricultural machinery station.

Table 6-12. Equipment for a township-level ammoniation station

Equipment item	No. needed	Unit cost (¥)	Total cost (¥)
Small four-wheel tractor	1	7 000	7 000
Trailer for tractor	1	2 500	2 500
200 kg ammonia bottle	2	2 000	4 000
Ammonia filling and protective equipment	1	750	750
Weighing scale (500 kg capacity)	1	500	500
Total			14 750

The village-level ammoniation station requires 3 persons (¥ 200/month each). The running cost for a small four-wheel tractor is ¥ 30/day. Anhydrous ammonia sales are 400 kg a day, or 120 tonne a year. The depreciation of equipment is calculated over 10 years. Cost of anhydrous ammonia handling is ¥ 0.147/kg.

Assuming that the cost for transport and storage of anhydrous ammonia is ¥ 0.227/kg for county and township-level ammoniation stations, and that 1 kg of anhydrous ammonia can treat 33.3 kg of straw, then the cost of treated straw is ¥ 8.3/ton. This estimation is based on general 1998 prices. When planning an ammoniation station, the economic assessment should be based on local costs.



Safety operation of anhydrous ammonia equipment

Treating straw with anhydrous ammonia has many advantages, such as high efficiency, low cost, simplicity of operation and elimination of parasite eggs and weed seeds. However, anhydrous

ammonia is toxic and explosive, so pressure containers are required for transport and storage. It is very important to follow relevant national regulations for safe operation. The basis of these regulations should be well understood. Explosions of ammonia containers happen occasionally and have resulted in persons injured or even killed. All persons working with ammonia must learn from these accidents.

Physical and chemical characteristics of ammonia, and safe operation

Ammonia is a colourless gas with suffocating and penetrating odour. Under pressure or at low temperature (-33 °C) it condenses to a clear liquid. The physical and chemical characteristics of ammonia are:

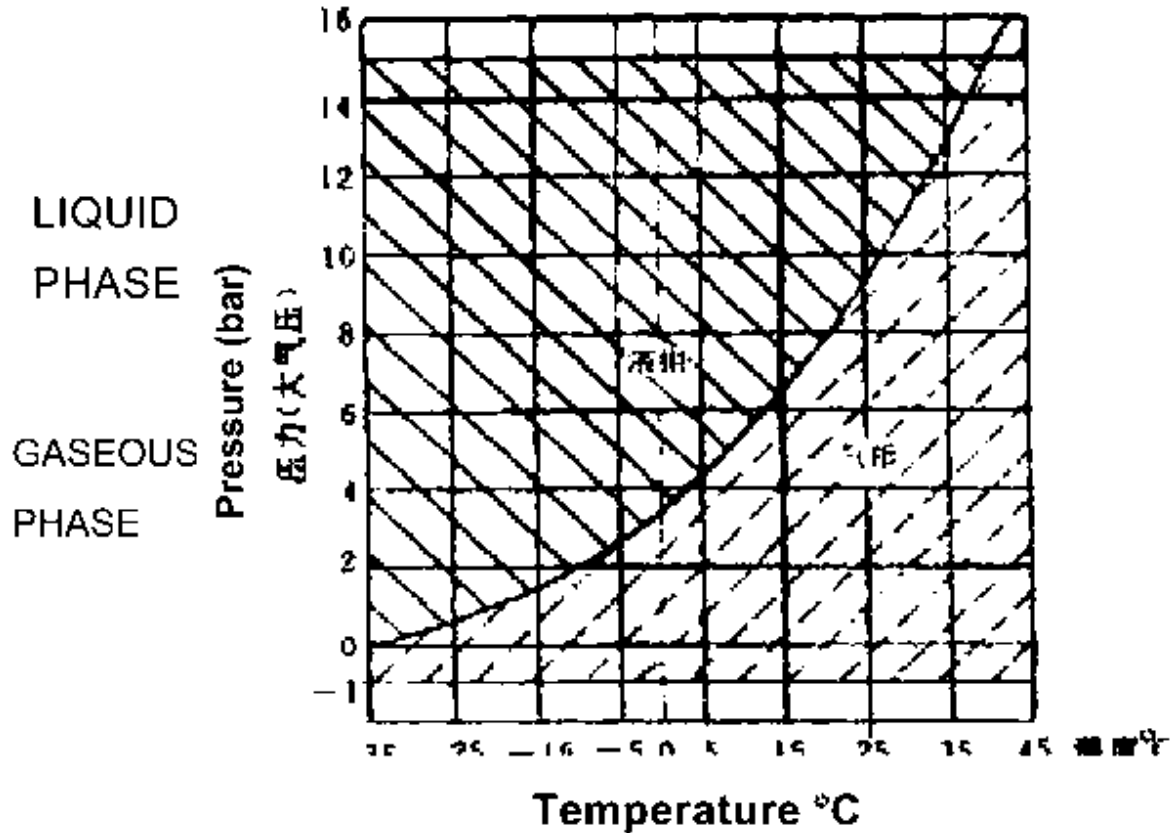
· Chemical formula	NH ₃
· Boiling point (at atmospheric pressure)	-33.4°C
· Density of ammonia	0.596
· Density of anhydrous ammonia	0.617 (at 20°C)

- Solubility in water (at 15°C) 60 g/100 g H₂O
- Vapour from 1 litre of anhydrous ammonia 1 000 litre
- Solubility of gas in 1 litre of water 700 litre (20°C)
- Explosion limits 15-28% (volume)
- Safe concentration 0.0001 mg/litre
- Toxic concentration 0.2 mg/litre

In the presence of water or steam, copper, zinc and aluminium, and alloys containing these metals, will be corroded by ammonia. These metals are therefore not to be used in ammonia equipment.

The pressure change in an ammonia container according to temperature is illustrated in Figure 6-33.

Figure 6-33. Ammonia pressure change with temperature



The chemical and physical characteristics of ammonia are the

basis of the selection of ammoniation equipment and for safe operation:

- From Figure 6-33 it can be seen that the ammonia pressure is 2×10^5 , 5.3×10^5 and 14.8×10^5 Pa for temperatures of -10 , 10 and 40°C , which correspond to normal winter, spring and autumn temperature in Beijing, respectively. According to regulations, the ammonia should not be used at temperature over 50°C , equivalent to a pressure of 2.07×10^6 Pa. Other factors are taken into account, and the design pressure for a truck tank is 2.2×10^6 Pa and 3×10^6 Pa for a bottle. Pressurized containers should not be exposed to the sun for a long period, nor be brought near fire.
- Ammonia easily dissolves in water, a very important consideration in safety protection and accidents. On handling sites, enough water should be available, preferably tap water. A sign indicating "safety water" must be clearly displayed. If ammonia gets into the eyes or on the skin, it should be rinsed immediately with abundant water. If ammonia leaks into the air, water spray should be used to "knock down" the vapour.

Spraying polluted areas with water reduces gas emission.
Covering the nose with a wet towel is an efficient method of protection.

- Ammonia's density is lower than air density. If a large amount of ammonia is released to the air, people should rapidly leave the polluted area, moving into the wind. When driving out air from an ammonia container, the gas outlet valve should be in a low position.
- The boiling point of anhydrous ammonia is -33.34°C . When anhydrous ammonia vaporizes, a great amount of heat is absorbed. If the heat source is not sufficient, the process of volatilization is slowed down; and ammonia will remain liquid for longer. If anhydrous ammonia comes into contact with the skin, temperature will decrease and water will be absorbed, causing injury. If a great amount of ammonia liquid escapes from a damaged valve, if possible a soil or sand dam or a dig pit should be made around the discharge (because the ammonia boiling off will cool surfaces to -33.34°C) to reduce

gas emission. Heat absorption from the air can be further reduced by spraying foam on the liquid ammonia, or simply covering it with a plastic sheet.

- If it is impossible to dig a hole or to make a dam, the container should be rapidly turned so that the damaged valve is uppermost (from liquid to gas position), thereby reducing the speed of ammonia release, since 1 litre of anhydrous ammonia will vaporize into 1 000 litre of ammonia gas.
- When the ammonia content in the air gets to 15-28 percent, it has reached the explosion limit. Below 15 percent, there is not enough ammonia for the explosion, and above 28 percent there is not enough oxygen. In practice, ammonia in the air or in containers should be kept below the explosion limit. For new ammonia containers or for those that have not been used for a long time, it is necessary to drive air out before using them. Adding a little ammonia into the container and opening the lower valve, the gas is pushed out into water through the hose. Repeating the process several times until there are no more bubbles in the water means that all discharged gas is

ammonia. Since ammonia dissolves rapidly and thoroughly in water, in order to prevent air from going into ammonia containers, a little ammonia should be left in the bottle: that is to say, the pressure meter should remain at 0.05 MPa (0.5 atmospheres pressure). In addition, avoid fire on the handling sites to prevent explosions and self-ignition at 630°C. Attention should be paid during welding or repairing ammonia containers: ammonia should be purged beforehand.

- Containers should not be filled to excess. Figure 6-33 clearly shows that the vaporizing pressure increases with temperature. If the container is completely full of ammonia, with no empty space for liquid expansion with increasing temperature, the pressure will increase at the rate of $1.5 \times 10^6 \text{ Pa/}^\circ\text{C}$. If the temperature increases by 5°C , an explosion will occur. The amount of ammonia to be put in a container (G) should be calculated using the formula: $G = 0.53V$, where V represents the real volume of the container (in litres) and 0.53 is the maximum filling factor (kg/litre).

Safety supervision of ammonia containers

In order to emphasize the management of pressure containers with explosion risk, *Safety supervision regulations for gas bottles*, *Supervision regulations for pressure containers*, and *Management regulations for liquefied gas tank trucks* have been promulgated by the National Council, the Ministry of Work and Personnel, and the Ministry of Chemical Industry. Clear regulations have been established for the design, manufacture, installation, usage and inspection or repair of pressure containers, as well as for reporting accidents.

Ammonia tank trucks and bottles are classed as medium-pressure container transport. As ammonia is very toxic, a container of more than 440 litre volume is a class II container, which can imply serious consequences in an explosion.

According to national regulations, the following points should be observed when using pressure containers:

- ***Inspection and acceptance.*** The design and manufacturing

company must have a Certificate of Approval from the appropriate authorities, and the products must have a quality certificate.

- **Keeping technical records.** Detailed records should be kept, including dates, inspections, repairs, measures taken to resolve problems, and so on.
- **Personnel training.** Operators must be trained, and receive the required qualification after passing an examination.
- **Care in handling.** Valves should be opened slowly to prevent pressure from rising or falling too quickly.
- **Avoid overfilling.** Do not overfill, to avoid high pressure and temperature.
- **Regular inspection.** According to the specifications of the pressure containers, they should be inspected externally once a year and internally once every two years by the relevant authorities. After inspection, a visible and permanent label of

the authority, with the year of inspection, must be affixed to the container.

- ***Safe transport.*** Ammonia containers should be protected from impacts or overturning. Valves should be closed and caps well screwed on during transport. Loading and unloading must be done slowly. Ammonia containers should never be placed together with other containers, especially oxygen bottles. Fire extinguishers must be available.
- ***Regular maintenance.*** Pressure containers must be repaired and maintained regularly to prevent leaking. They should be kept in dry areas when not used.
- ***Qualified drivers and operators.*** The drivers and operators of tank trucks must be trained and qualify by passing an examination. Moving and stopping ammonia tank trucks should respect not only normal traffic regulations but also special conditions. The relevant regulations should be written and displayed in the appropriate position in or on the vehicle.

- ***Accident reporting.*** Any accident should be reported immediately to the relevant administration, police and labour department.

Regulations for safety in straw ammoniation

Ammonia is toxic and may explode under certain conditions. The ammonia containers are classed as "pressure containers with risk of explosion." Treating straw with anhydrous ammonia can endanger life and health if not done correctly. It is therefore necessary to follow the precautions and regulations made by the Bureau of Animal Production and Health (MOA, 1990):

Safety operation regulations for straw ammoniation

- Operators must have the necessary training, pass the examination and obtain their qualification.
- Safety equipment available at the working site should include:
 - an abundant supply of fresh water;

- filter masks with ammonia filters;
 - gloves and boots made of rubber or another suitable material; and
 - fire extinguishers.
-
- Each new ammonia container must have an accompanying quality certificate that is properly filed.
 - Never overfill whenever adding ammonia to a container.
 - In summer, do not put ammonia containers in the sun. In winter, if ammonia flow is low, move containers to a warm place. Never heat them with fire.
 - During ammonia transport, storage and straw ammoniation, check containers and hoses for leakage or swollen parts. Stop operation to make appropriate repairs to damage if found.
 - Ammonia bottles must be firmly secured to the vehicle during

transport to prevent them from falling due to movement.

- Be sure not to hit or to roll ammonia bottles during loading and unloading, which should be done slowly.
- Screw and tighten valves during bottle transportation and storage.
- Transport of anhydrous ammonia and oxygen in same wagon and storage in the same shed is strictly prohibited to avoid danger of explosion.
- If there is still pressure in a container, do not repair or fasten any part under pressure.
- When ammoniating straw, first place the spear into straw, then open the valve.
- Open and close ammonia-injecting valves slowly. During ammonia injection the gas pressure must be below 0.8 Pa. Do not hit the ammonia bottle with any tool.

- Ammonia flow should stop when pressure drops to 0.05 Pa.
 - The ammonia containers can not be used to store any other material without the written consent of the working department.
 - Ammonia containers must be checked regularly.
 - The operators must wear protective equipment, including rubber gloves and protective suit, and stand upwind from the ammonia source.
 - If ammonia leaks to the air, people should lay down on the ground, cover their noses with a wet towel and move upwind.
 - Fire is forbidden in the vicinity of the ammonia station and the site of straw ammoniation.
 - If an accident occurs, it should be immediately reported to administration and labour departments.
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CHAPTER 7 - ECONOMIC ANALYSIS OF ANIMAL PRODUCTION BASED ON CROP RESIDES

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Introduction

The economic benefits of using untreated and treated crop residues as feed for ruminants mainly depends on the source and cost of crop residues, cost of treatment, cost of urea or other ammonia source, on the price of protein supplements, as well as on agricultural production and technical levels and other factors. In

relation to the potential of crop residue use, countries can be divided into four types:

Type 1 are developing countries and regions with a high population density. Most countries in the Far East and part of the Middle East belong to this group. Crop residues in general are used as the major feed for ruminants. Treated crop residues may result in very good economic returns.

Type 2 are developing countries and regions with low population density. Most countries and regions in Africa and Latin America where land use is not restricted belong to this type. Feed supply comes from various sources, but cattle production relies, in general, on natural pastures. Crop residues, treated or untreated in emergency situations, especially in the dry season, become an important feed resource.

Type 3 are developed countries and regions with an ample grain supply. The USA, Canada and France belong to this type. In addition to roughage, ruminants are fed with large quantities of concentrates to obtain high yields of animal products. Untreated

crop residues are sometimes used as a source of fibre substituting hay or silage. Under these conditions, treated crop residues might give fairly good economic benefits. However, it might not be economical to utilize crop residues in areas where the production of hay or silage is high.

Type 4 are the developed countries and regions with small land area per capita. Most countries in north Europe belong to this type. In order to achieve self-sufficiency in food, the governments of these countries attach great importance to the utilization of crop residues so as to increase food output from the limited land. Among north European countries, Denmark and Norway use the highest proportion of crop residues as feed.

In China, the broad agricultural region, characterized by huge population with limited land, belongs to Type 2. It has good prospects for developing animal husbandry based on crop residues.

Status of the utilization of crop residues in China

In general, straw is used for burning, composting, paper making and animal husbandry. For a long period in the past, due to limited economic development and way of life, it was very popular to use straw as fuel for cooking. It is estimated that 70 percent of total straw was used as fuel. With the improvement in the rural economy and farmers' living standards, rural energy has become diversified to coal, natural gas, biogas, electricity, etc., so the amount of straw used as fuel has been reduced to less than 50 percent. Direct straw application to soils is also practised, but this operation increases the cost by about ¥ 10 per mu (¥ 150/ha). At the same time, it takes time for straw to fully decompose, thus interfering with germination and growth of the next crop. This is particularly true in regions with intensive agriculture because it increases the difficulties for crop rotation. In addition, returning straws directly to the field may have hidden dangers in terms of insects and diseases, so this utilization has its limitations. Returning straw to fields wastes the energy, decomposed by micro-organisms, while crops can only utilize part of the N, P, K and other inorganic nutrients after decomposition.

Another use for straw is as raw material for paper making. It is estimated that 2-2.5 tonne of rice straw can be processed into 1 tonne of paper. However, it is difficult to collect due to the large volumes involved and its disperse distribution, and only part of the rice straw can be utilized. Since 1995, the State has shut down many medium- and small-sized local paper plants due to environmental pollution. The closure has led to a surplus of straw.

In many regions of China, large amounts of unused crop residues are piled up by field edges and road sides, and extensive burning of straw by farmers in the fields occurs every autumn at harvest. This has caused a drop in soil organic matter, hardening and producing impervious soils with low moisture holding capacity. It has also caused atmospheric pollution and poor air visibility. In May 1997, due to smoke produced by burning of wheat straw, the Chengdu Shuangliu Airport was closed for 4 hours. Visibility had dropped below the minimum safety limits required for flying. Twenty-two flights had to be diverted to another airfield and eight flights were delayed. At Hebei Shijiazhuang Airport there were also flight delays, and on the Jinan-Qingdao motorway there was an

increase in traffic accidents, both due to the burning of crop residues. Therefore, each province has set regulations strictly prohibiting the burning of straw, but straw burning still occurs, despite regulations and repeated disciplinary action. It is estimated that about 40 to 45 percent of the crop residues are still used as fuel or burned on the hillsides yearly, equivalent to over 1.2 million tonne of N, 280 000 tonne of P and 2.8 million tonne of K (Table 7-1), resulting in both environmental pollution and energy waste. In these regions, straw has become a significant cause of environmental pollution.

Table 7-1. Nutrition elements in straw

Year	Straw output ($\times 10^6$ tonne)	Nitrogen ($\times 10^4$ tonne)	Phosphorus ($\times 10^4$ tonne)	Potassium ($\times 10^4$ tonne)	NPK as proportion of total chemical fertilizer output of China
1997	600	300	70	700	25 %

SOURCE: Lu Ming, 1998.

One of the best methods to prevent environment pollution caused by straw is to develop livestock production based on straw and to return manure to the fields. In other words, turn the organic and inorganic nutrients contained in straw into high quality products (meat, milk, skin, wool) and bio-energy (animal power) via ruminants. The manure, which can not be directly utilized by humans, can be returned to farmland. Most of the nutrients needed by crops can be met by animal manure. Long-term applications of manure can increase soil organic matter and improve soil structure and fertility, which are beneficial for the establishment of a highly efficient virtuous circle of agricultural production and ecology. If manure is used to generate biogas via fermentation as a source of rural energy, and the effluents returned to farmland, the energy flow would become even more rational.

Chinese farmers have a tradition of using straw to feed herbivores, for example, chopped straw for cattle. However, scientific experiments have shown that chopping or milling can not improve

straw digestibility: it can only increase intake and reduce feeding losses. In the past, most cattle farmers used animal traction and fed straw and other roughage during slack seasons and some concentrates during busy seasons. In this case, cattle could not develop strong body condition and used to be called "old yellow cattle" at the end of their lives. Cattle with less flesh was a direct result of this production method. At present, animal draft power has been gradually replaced by machinery and animal numbers. However, the improvement of cattle should not only be put on the agenda, but also on the work plans, since it is absolutely possible to obtain meat from cattle.

Turning draught cattle into beef cattle is not simply a change in the feeding objective; matched feeding methods must be implemented. The recently proposed strategy of "relying on science and technology for the utilization of straw at a higher level for the development of herbivorous animals" depends on innovative feeding methods. The two projects on developing cattle production based on straw as the major feed, undertaken by FAO in 1990 and 1992, achieved their desired objectives.

Experts from FAO recommended cattle production based on straw as a low-concentrate and long-cycle feeding system. In other words, it aimed to take advantage of the digestion characteristics of ruminants, and particularly the fact that straw in China is a non-commercial feed in most cases, to use more roughage and less concentrates to obtain a market animal through a long-cycle finishing process. Straw was used as roughage, and processed and treated with ensiling and ammoniating technologies as major methods. It was essential to profit from this opportunity to develop a new alternative for straw utilization work in China.

With the intention of taking advantage of the rich straw resources of the country, the State started the demonstration projects *Developing livestock production with straw and returning manure to fields, after digestion by livestock* in the large agricultural regions in 1992. The project had found a practical way to reduce straw burning. In the short period of 8 years, important advances were achieved. The extension of ensiling and ammoniating technologies has obviously accelerated the rate of straw utilization in China. In general, once crops mature, the straw has become dry

and inappropriate for making silage. In this case, ammoniation is the way to improve the nutritional value of straw. China started late in the extension of straw ammoniating technology (1985) and did not undertake the basic research and experimentation until the early 1980s, but in comparatively few years the country made significant progress in straw ammoniation. Thus, total straw feeding increased from 20 percent in 1992 to 28 in 1996. The utilization of treated straw rose from 4.2 to 9.5 percent. In 1996, a total of 85.2 million tonne of silage and 80.5 million tonne of ammoniated straw were made in China. Based on the equivalence of 5 kg of ammoniated maize stalk or 2.5 kg of ammoniated wheat straw in N content to 1 kg of maize, more than 20 million tonne of grain had been saved. The feeding rate of straw in Hebei Province reached 49 percent in 1997. This included 6.93 million tonne of silage (fresh weight) and 2.45 million tonne of ammoniated straw. In other words, about half of the straw in the whole province was utilized for livestock. This played an important role in alleviating environmental pollution caused by burning. Table 7-2 shows the situation of straw utilization in pilot counties and villages.

Table 7-2. Straw utilization in pilot counties and villages

Place	Year	Farm area (x 10 ³ <i>mu</i>)	End-of-year population (x 10 ⁴)	Cattle marketed (x 10 ⁴ y/r)	Straw dry matter (x 10 ⁴ tonne)			Fed as % of all straw
					Output	Fed	Ensiled & treated	
Shandong Province								
Yucheng county	1997	803.3	22	12	100	40	33	40
Maozhuang village	1997	1.2	0.06	0.03	2.08	1	0.04	48
Tangwang village	1997	1.6	0.08	0.04	2.77	1.2	0.04	45
Hebei Province								
All province	1997	98 000	661.7	429.6	3 000	1 470	200	49
Senba	1998	520	11.12	17.10	66	21.5	20	52

Sanhe county	1990	330	11.13	17.19	00	34.3	20	32
Henan Province								
Huaiyang county	1992	951.1	22.6	6.45	118.4	54.4	1.32	46

SOURCES: The Animal Husbandry Bureau of Yucheng County; the Animal Husbandry Bureau of Henan Province; Animal Husbandry Bureau of Sanhe County.

Progress on development of Straw for ruminant feed in China

The development of cattle production nationally and in the Central Plain Provinces of Henan, Shandong, Anhui and Hebei in recent years reflects the current status, the prospects and the economic benefits of the development of livestock production based on straw in China. In these provinces, there are important agricultural regions for grain and cotton, rich in straw and cottonseed. Since 1978, when the country started to implement the open and reform

policies, but especially since 1987, these provinces have extended, in a large manner, the technologies of straw ammoniating and ensiling, as well as the necessary matching feeding techniques, which has greatly promoted cattle production development.

Shandong Province, for example, had invested a total of ¥ 200 000 million and 40 000 tonne of urea, and produced a total of 3.44 million tonne of ammoniated straw by 1993. Cattle have shown the fastest population growth of all animals except poultry, and these four provinces had the fastest increase. This shows that cattle production based on straw is profitable. At national level, the cattle population reached 124 million in 1998, a 73 percent increase from 1980. During the same period, the cattle population in Henan, Shandong, Anhui and Hebei Provinces nearly doubled, an increase of 15.4 percentage points in the nation (Table 7-3).

Table 7-3. Cattle population in the Central Plain Provinces 1980-1998 (x 10⁴ head)

	1980	1990	1998	1990/1980	1998/1980
All China	7	10	12	1.44	1.74

	169	288	435		
Henan	340	893	1 301	2.63	3.83
Shandong	218	512	912	2.35	4.19
Anhui	241	501	627	2.08	2.60
Hebei	121	208	665	1.72	5.51
The four provinces	919	2 133	3 504	2.32	3.81
As proportion of all China (%)	12.8	20.5	28.2	-	-

SOURCE: China Statistical Yearbook, 1997 and 1999

Second to poultry meat, beef showed the largest increase within total national meat output. China had a beef output of 4.8 million tonne in 1998, 17 times that of 1980. Beef output was 26 000 tonne in 1980 in Henan, Shandong, Anhui and Hebei Provinces, only 9.7 percent of the nation; by 1998, it had reached 2.3 million tonne, or 47.7 percent (Table 7-4), an increase of 87 times compared to a 10 times increase nationwide. This fully demonstrates the efficacy of extending the technology of developing livestock

production with straw and returning manure to fields, after digestion by livestock in the four provinces.

Table 7-4. Beef output in the Central Plain provinces during 1980-1998 (x 10⁴ tonne)

	1980	1990	1998	1990/1980	1998/1980
All China	26.9	125.6	479.9	4.7	17.8
Henan	0.7	18.2	76.7	26.0	109.6
Shandong	0.9	17.6	60.1	19.6	66.8
Anhui	0.6	9.8	34.3	16.3	57.2
Hebei	0.4	5.6	58.0	4.7	145.0
Total for four provinces	2.6	51.2	229.1		
As proportion of all China (%)	9.7	40.8	47.7		

Extraction rate, average carcass weight and annual beef yield per head in China have much increased since 1980. In that year,

extraction rate was 4.7 percent, carcass weight was 81 kg and annual yield per head was 3.8 kg. In 1990, these parameters were 10.8 percent, 115 kg and 12.5 kg, respectively, and by 1998 they were 30.7 percent, 133.5 kg and 41 kg. In 1980, the corresponding values for the four provinces were below the national average, but by 1990 they were already above (Table 7-5). These data demonstrate that the extension of technology for cattle production based on straw greatly improved production in the four provinces.

Compared with other countries, cattle production in China still has a long way to go. Dressing percentage of cattle in China is lower than in the developed countries, indicating the potential for improvement.

Table 7-5. Change in beef production level in the Central Plain provinces (1980-1998)

	Marketing rate (1) (%)	Average carcass weight	Beef yield per cattle(2)
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				(kg)			(kg)		
	1980	1990	1998	1980	1990	1998	1980	1990	1998
All China	4.7	10.8	30.7	81.0	115	133	3.8	12.5	41.0
Henan	2.9	19.1	42.5	70.7	108	139	2.1	20.7	59.1
Shandong	4.0	23.3	45.9	100.9	160	169	4.1	37.2	77.7
Anhui	3.6	17.5	38.1	76.5	112	143	2.8	19.5	54.4
Hebei	4.2	22.2	61.6	74.9	124	152	3.1	27.6	93.7
4 provinces	3.5	20.0	46.0	81.8	125	150	2.8	24.9	69.0

NOTES: (1) Marketing rate = Number of cattle marketed in the year/cattle population by the end of previous year.
 (2) Beef yield per head = Beef output in the year/cattle population at the end of the previous year.

Economics of cattle production on ammoniated crop residues

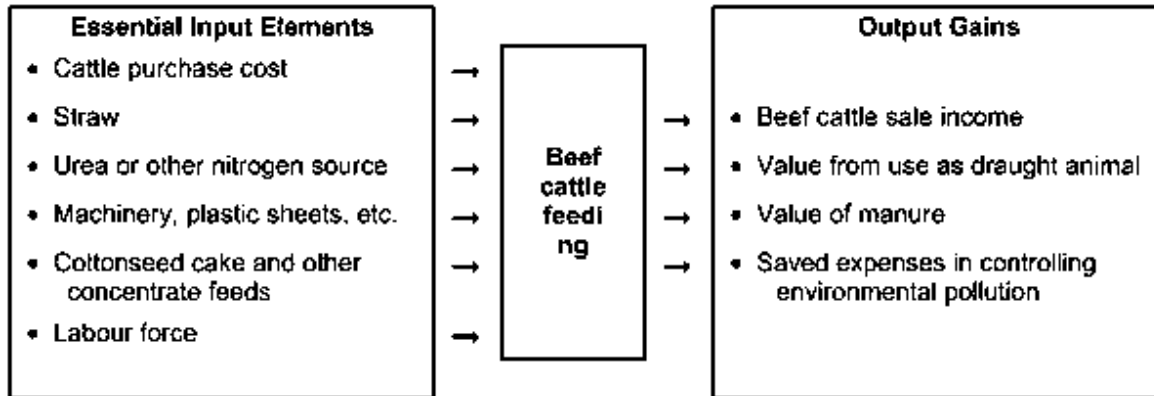
Cattle production based on straw is only one of the methods of cattle feeding, with certain scope and application conditions.

Objective economic analysis of cattle production based on straw usually considers the factors discussed below.

Basic factors influencing the economic benefits

As a complete production system, cattle rearing based on straw has the general nature of an economic activity, i.e., inputs are first, and the comparison between input and output. Only when output is greater than input is there economic efficiency. Figure 7-1 shows the basic input and output factors in cattle production based on straw.

Figure 7-1. Analysis of input-output relations in cattle production based on straw



Implications of major input and output elements and their value

In order to have a complete and accurate understanding of the implications of various essential components during the process of economic analysis, the actual calculating methods for various targets are detailed below.

The benefits obtained from cattle feeding with ammoniated straw can be broken down into direct and indirect benefits. The direct benefits can be further broken down into three.

Income from beef cattle sales

The main income of cattle production is the sale of finished cattle. The key factors are dressing percentage and beef price. The former can be obtained from average values at slaughter, while the latter comes from the market. In the case of live cattle sales, the actual income is used for calculation.

Value of draught cattle

This can be calculated from the days used as a draught animal and the local daily rates; in other words, daily rate (¥/day) multiplied by the time used as draught animal (days).

Value of manure

Manure is a sort of by-product and its value should be estimated. However, it is difficult to do it in practice. After comparisons made in most areas, it is assumed that manure value is offset by labour costs.

Indirect or macro-benefits

They are savings from reduced and controlled environment pollution, reflected in social benefits. The value of these benefits has not been included in the calculations.

There are many essential inputs for cattle production based on ammoniated straw. Some of them are:

- *Cattle purchases.* It refers to the actual expense to purchase calves or cattle. In the case of calves produced by owner himself, the feed cost of the cow should be computed.
- *Cost of straw.* In general, straw cost was not included in the past. Considering the various alternative uses of straw in China, the cost of straw should be determined by the price paid by paper mills or the negotiated price during purchase.
- *Cost of urea or nitrogen source.* This cost should be derived from the actual purchase price.

- *Cost of concentrate.* When feeding ammoniated straw to cattle, some supplementary concentrate (cottonseed cake, wheat bran, etc.) is added. This cost is computed from the market price.
- *Cost of labour.* In general, surplus or slack labour is used for cattle production, and for this reason it is not included. In the case of specialized cattle raising households, the cost of labour must be included according to the wages of local agricultural labourers.
- *Cost of equipment and other items.* The investment for a cattle shed, machinery, equipment and plastic sheeting used for ammoniation should be included in production costs. It can be calculated using the formula:

$$\text{Depreciation cost} = \text{Total investment} / \text{usable years}$$

The above standard inputs and outputs provide a basis for calculating the economic benefits of cattle production based on straw, but there might be differences in application. For example,

the cost or value of straw will change greatly according to time and place. In some regions, straw is regarded as waste with nearly no value, but one has to pay for harvesting, transporting and burning. In other regions, the opposite occurs. In the case of energy shortages and when there is an industrial demand, straw could be used as fuel. With the development of science and technology, straw will be attractive in new building materials and as a raw material for paper making. Therefore the opportunity cost of straw should be considered.

Estimation of economic benefits of use of crop residues for ruminants

In order to simplify the analysis of the economic benefits of cattle production with straw, the input/output ratio has been used to express the critical value of cattle production based on straw. Only when this value is greater than 1 can one can say that cattle production based on straw is effective. The larger the value, the greater the benefit. Any change in quantity or price of one of the essential factors will change the value of the input/output ratio.

On the basis of the above value, it is possible to calculate the total and daily net income per head of cattle, where:

$$\text{Net income per cattle} = \text{Total income per cattle} - \text{Total input cost per cattle.}$$

Cases influencing input/output ratio

Beef market objective

For international markets and domestic high-grade consumption, special attention should be given to beef quality. In general, this quality beef needs high-concentrate low-roughage diets for rapid finishing. Beef quality from cattle mainly fed straw will differ a lot from that produced from concentrates. The former can meet beef quality requirements of the common market, while the latter uses very little straw, just to provide the fibre needed for normal rumen function and it does not have to be chemically treated. Trade in high-grade beef is only 2-3 thousand tonne/yr; it is not discussed further here.

For the domestic market, the common cooking method is stewing (red-cooked beef, beef cooked in soy sauce, etc.), which does not require very tender beef. Therefore, this demand can be satisfied with beef coming from low-concentrate, high-roughage systems with a long finishing period. In this case, the roughage can be mainly straw, with better results if chemically treated. Only in this case does the input/output ratio have any significance.

Processing and treatment methods

There are many straw processing and treatment methods, which can be broadly divided into physical, chemical and biological. Economics should be considered when choosing the treatment method. Among the physical methods, chopping is most economical, but does not improve the nutritional value of straw. Among the chemical treatment methods, the alkalization (NaOH) method gives the best results, but the price of NaOH is high. Ammoniation also gives good results and provides non-protein nitrogen, improving the protein level of the straw. Therefore, in the situation of a general shortage of protein resources in China, the

ammoniation treatment has its value. In ammoniation, anhydrous ammonia, urea or ammonium carbonate are the major ammonia resources. Anhydrous ammonia is used on large farms all year round. There are great differences in the nutritional value of untreated and ammoniated straw, as well as between ammonia sources. The price of ammonia and the benefits obtained should be carefully considered. It is essential to determine which treatment method gives the best economic benefits.

Age, body weight and breed of finishing cattle

In general, as age and size of finishing cattle increase, daily gain also increases (Table 7-6). From an economic point of view, it is an important issue to select the optimal finishing period.

Table 7-6. Relationship among initial weight, final weight and daily gain

	Daily gain (g)	Initial weight (kg)	Final weight (kg)
All test groups	713 + 90	174	368

Group	Weight (kg)	Number	Weight (kg)
Best 10 cattle	894 ± 49	173	418
Heaviest 10 cattle	804 ± 100	234	453

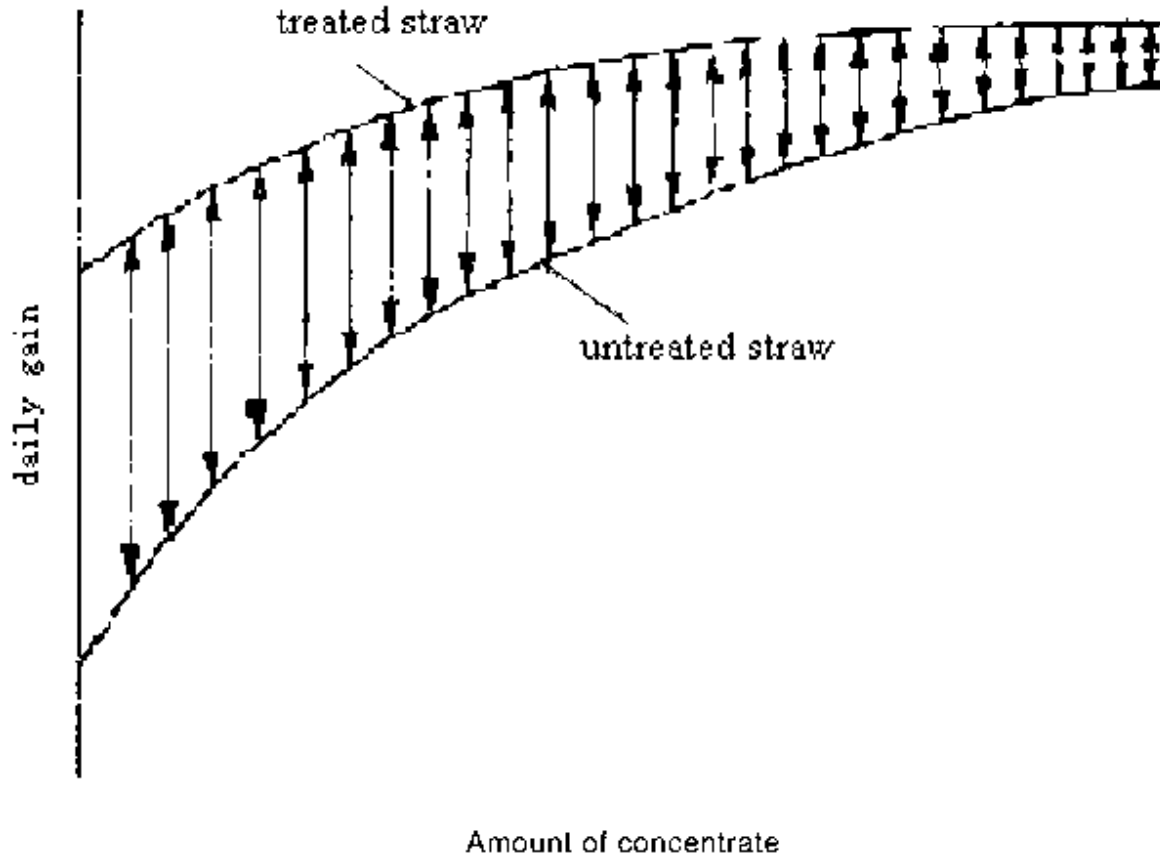
Native yellow cattle in China have better roughage acceptance, and are more suitable for low-concentrate, high-roughage diets and long finishing periods. However, imported cattle breeds have faster growth rates and high feed requirements, and are therefore more suitable for high-concentrate, low-roughage diets for faster finishing.

Protein supplements

When adopting the low-concentrate, high-roughage route, in addition to feeding treated straws, certain levels of a protein supplement should be given to meet the growth requirement of finishing cattle. In the central plain region, cottonseed cake is an optimal protein supplement feed. This is because cottonseed cake does not need detoxification when fed to cattle and it will not compete for demand by other livestock and poultry. However,

feeding too much cottonseed cake becomes uneconomical. Figure 7-2 shows the relationship between the amount of protein supplement and weight gain.

Figure 7-2. The feeding effect of treated straw vs. concentrate amount



Comments on production studies

During the period 1990 to 1992, FAO conducted studies and extension work with cattle fed on straw in Henan and Hebei Provinces. Some general comments can be made on the economic benefits of cattle production based on straw, summarizing research reports, data obtained from studies in Henan Province and related economic parameters.

Design of the study

The design of the study was feeding with ammoniated straw *ad libitum*, with different levels of protein supplement (cottonseed cake (CSC)) for native Yellow cattle, with daily gain changes observed. Table 7-7 gives the results of the experiment.

Table 7-7. Basic data of the study

Amount of cottonseed meal (kg/day/cattle)		0	1	2	3	4
Number of cattle		8	8	8	8	7
Initial weight	(kg)	182	183	183	183	183

Final weight	(kg)	205	237	242	258	262
Daily gain	(g/d)	250	660	750	845	883
Straw intake	(k g/d)	10.0	9.6	8.0	7.3	5.0

SOURCE: Dolberg and Finlayson, 1995

Analysis of economic benefits

The analysis was conducted based on input and output data of cattle raised during the finishing period (from 180 to 450 kg). The analysis was as follows according to different prices of inputs:

Case 1: CSC@ ¥.04/kg and straw free

CSC ration	(kg/day)	0	1	2	3	4
Finishing weight	(kg)	270	270	270	270	270
Finishing period	(days)	1 080	450	360	320	306
Net feed consumption	(kg)	0	450	720	960	1 224
Straw intake	(tons)	1 08	4 32	2 88	2 34	1 53

Straw intake	(t/15)	1.00	1.02	1.00	1.04	1.00
Income per cattle	(¥)	1 710	1 710	1 710	1 710	1 710
Cost per cattle	(¥)	1 558	1 186	1 202	1 259	1 327
a. Concentrate cost	(¥)	0	180	288	384	480
b. Roughage cost	(¥)	618	246	146	133	87
c. Other costs	(¥)	940	760	768	742	760
Net income per head	(¥)	152	524	508	451	383
Net income per day	(¥)	0.14	1.16	1.41	1.41	1.25
Input/output ratio		1.10	1.44	1.42	1.36	1.29

NOTES:

- (1) Finishing weight = final weight (450 kg) minus initial weight (180 kg).
- (2) Finishing period is obtained by finishing weight divided by daily gain.
- (3) Live cattle sold at ¥ 3.8/kg.
- (4) Cattle bought at ¥ 3.6/kg; Concentrate = cottonseed cake at ¥ 0.4/kg. For roughage, the cost of straw is not

computed for the time being, only the cost of urea and plastic film used in ammoniation. The cost of urea is ¥ 0.050/kg and the cost of plastic film and labour are ¥ 0.007/kg. Other costs include: cost for buying cattle, disease control and depreciation of cattle sheds.

The net income per cattle and per day mentioned above could be used as the basis for the evaluation of cattle production based on straw. Input/output ratio provides a more comprehensive reflection of the economic benefits of cattle production based on straw. To sum up, when daily feed intake was 1 to 2 kg, better economic benefits could be achieved. When daily straw intake was 1 kg, net income per cattle and input/output ratio were highest. However, when daily straw intake was 2-3 kg, the net income per day was the best.

Case 2: CSC@ ¥.04/kg and straw @ ¥ 0.06/kg

CSC	(kg/day)	0	1	2	3	4
Income per cattle	(¥)	1 710	1 710	1 710	1 710	1 710

Cost per cattle	(¥)	2 206	1 445	1 375	1 399	1 419
Net income per cattle	(¥)	-496	265	335	311	291
Net income per day	(¥)	-0.46	0.59	0.93	0.97	1.21
Input/output ratio		0.78	1.18	1.24	1.22	1.21

The results show that as the cost of straw increased from zero to ¥ 0.06/kg, a daily intake of 2-3 kg cottonseed cake gave the best economic benefits. When cottonseed cake intake was 2 kg, the best results were achieved in terms of net income per cattle and input/output ratio. However, when cottonseed cake intake was 3 kg, the highest net income per day per cattle was achieved.

The results show that as the price of CSC increased by 50 percent, a daily supplement of 1-2 kg CSC gave the best economic benefits. A daily supplement of 1 kg CSC was the best for net income per cattle and input/output ratio. A daily supplement of 2 kg CSC gave the highest net income per day per cattle. But a daily supplement of 3 kg CSC decreased the net income per day by a large margin.

Case 3: CSC increased from ¥.04/kg to 0.6/kg and straw free

CSC intake	(kg/day)	0	1	2	3	4
Income per cattle	(¥)	1 710	1 710	1 710	1 710	1 710
Cost per cattle	(¥)	1 558	1 276	1 346	1 451	1 572
Net income per cattle	(¥)	152	434	364	259	138
Net income per day	(¥)	0.14	0.96	1.01	0.81	1.45
Input/output ratio		1.10	1.34	1.27	1.18	1.09

Case 4: CSC@ ¥ 0.6/kg and straw@ ¥ 0.06/kg

CSC intake	(kg/day)	0	1	2	3	4
Income per cattle	(¥)	1 710	1 710	1 710	1 710	1 710
Cost per cattle	(¥)	2 206	1 535	1 519	1 591	1 664
Net income per cattle	(¥)	-496	175	191	119	46
Net income per day	(¥)	-0.46	0.39	0.53	0.37	0.15
Input/output ratio		0.78	1.11	1.13	1.07	1.03

The results show that when the cost of CSC increased from ¥ 0.4 to 0.6/kg and the cost of straw increased from zero to ¥ 0.06/kg, i.e., all the essential inputs had reached their maximum level, a daily supplement of 2 kg CSC gave better economic benefits. Net income per day, net income per cattle and input/output ratio were all at optimal levels.

Economic analysis of different ammonia sources

The analysis above was based on use of urea, the most extensively used ammonia resource. In practice, in addition to urea, anhydrous ammonia and ammonium bicarbonate are also used. Due to their price differences, the cost of ammoniation is significantly different. On the basis of ammonia source and amount used, it is possible to calculate the cost of ammoniation per source (Table 7-8). Based on the expenses associated with each ammonia source, plus the cost of plastic sheeting and labour, the total cost per kilogram of ammoniated straw can be obtained. Using a similar approach as in the four cases above, it is possible to estimate the economic benefits of using the various ammonia

sources.

From Table 7-8, at current prices, urea for straw ammoniation has the highest cost, followed by anhydrous ammonia, and the lowest is ammonium carbonate. As urea is a chemical fertilizer in short supply and extensively used in agricultural production, this greatly influences market prices. Anhydrous ammonia is the raw material for manufacturing urea and ammonium carbonate. Theoretically, it is estimated that 1 t of anhydrous ammonia can manufacture 1.76 t urea or 4.65 t ammonium carbonate, so the cost of ammoniation using anhydrous ammonia should be relatively low.

Table 7-8. Cost of different ammonia sources for ammoniating straw

Ammonia source	Ammonia content (%)	Amount used for ammoniation (%)	Price (¥/kg)	Ammoniated straw cost (¥/kg)
Urea	46.67	4.5	1.10	0.050
Anhydrous	82.35	3.0	1.30	0.039

ammonia				
Ammonium bicarbonate	17.72	10.0	0.30	0.030

NOTE. Only the ammonia source is considered, without the cost of facilities (or equipment). In practice, the equipment cost for ammoniation with anhydrous ammonia is fairly high.

Regardless of the ammonia source for ammoniation, the aim is to improve digestibility and palatability of straw, to supplement with non-protein nitrogen, to improve the protein content of straw and, finally, to replace part of the concentrate. Compared with the price of a predetermined concentrate, the ammonia cost that would make straw ammoniation no longer economic has become a concern of decision-makers. This relates to the upper limit of ammonia cost, which can be calculated by a simple formula:

$$p = a \times b \times x/y$$

Where:

p = upper limit of ammonia source cost

a = price of concentrate

b = proportion of ammonia source cost in total cost

x = concentrate saved per unit of ammoniated straw

y = the amount of ammonia used per total DM

A calculation was made using related laboratory data and some published papers. It was assumed that the price of concentrate (a) was ¥ 0.8/kg, and the b value was 0.6. For every kilogram of ammoniated straw, 0.2 kg of concentrate can be saved, therefore $x = 0.2$. Taking the ammonia use per source from Table 7-8, the upper cost limit of every kilogram of ammonia source can be calculated separately.

$$p_{\text{urea}} = 0.8 \times 0.6 \times 0.2 \div 4.5\% = ¥ 2.13$$

$$p_{\text{anhydrous ammonia}} = 0.8 \times 0.6 \times 0.2 \div 3\% = ¥ 3.2$$

$$p_{\text{ammonium bicarbonate}} = 0.8 \times 0.6 \times 0.2 \div 10\% = ¥ 0.96$$

In the event of exceeding the above upper price limits, from an economic viewpoint it is reasonable to feed more concentrates. In recent years, the price of urea has been below ¥ 1.3/kg. The price of anhydrous ammonia and ammonium bicarbonate are lower than the upper price limits, so the economic benefits are certain.

Case study on the economics of crop residues for ruminants at household level

The economic benefits of cattle production based on straw for rural households is influenced by a series of factors, including level of economic development, scale and technology. A comparative analysis has been made on the overall economic benefits and on those of various scales and different feeding technologies in Fuyang Prefecture. There are no grasslands in Fuyang Prefecture, but it markets more beasts than Inner Mongolia. Mengcheng, Lixin and Woyang counties in Fuyang Prefecture constitute the most concentrated area for cattle in China, and are called the Golden Triangle of cattle.

Introduction to the household survey

A survey was conducted in rural households of Mengcheng, Lixin and Guoyang counties, with the objective of analysing and studying cattle production based on straw. The method adopted was random sampling and house-to-house visits. Township and village selection was based on the economic development level and characteristics of cattle production, while the selection of rural households was at random. The time span was from July 1995 to June 1996. From a total of 120 rural households sampled, data from 119 could be obtained (39 in Mengcheng, 40 in Lixin and 40 in Guoyang). The households selected were typical and representative so that the conclusions from the data would be of general and realistic significance.

Situation of straw utilization and the cost of processing and treatment

Straw processing and utilization are the major components of cattle production based on straw. They not only influence the economics of production by rural household every year, but also determine the potential in future years. The results of the survey showed that the

average straw output per rural household was 8 624 kg, and the average purchased straw (mainly wheat straw) per household was 997 kg, for a total of 9 622 kg. Among crop residues of different crops, sweet potato vines ranked first, followed by wheat straw and finally maize stover. Their utilization rate was 38.6, 58.4 and 43.2 percent. From the total, ammoniated straws were 17.4 percent, silage 21.4 and direct feeding 47.4, with an average utilization rate of 86.2 percent and a straw treatment utilization rate of 38.8 percent (Table 7-9).

In 1995, Fuyang Prefecture as a whole had achieved a straw utilization rate for cattle production of 64 percent and a straw treatment rate of 18 percent. Although the value was higher than the national average, the trend was similar to the general trend. Compared with a survey conducted in 1993-1994, both the utilization rate and treatment rate had increased. The total straw utilization rate had increased from 76.4 to 86.2 percent.

Table 7-9. Crop residue utilization by rural households (kg)

Straw	Total	Output	Bought	Treated	Ensiled	Direct	Feeding	Treatment
-------	-------	--------	--------	---------	---------	--------	---------	-----------

type						feeding	rate (%)	rate (%)
Wheat	3 898	3 008	840	1 599	0	1 797	88.3	58.4
Barley	164	164	0	26	0	100	77.1	15.9
Maize	1 996	1 953	43	0	862	492	67.8	43.2
Rice	230	181	49	51	12	158	96.3	27.5
Soybean	323	323	0	2	0	109	49.9	0.6
Sweet potato	3 062	2 996	66	0	1 187	1 855	99.1	38.6
Total	9 622	8 624	998	1 678	2 056	4 560	86.2	38.8

Ammoniating and ensiling were technologies used widely, accounting for 71.4 and 68.1 percent of households interviewed, respectively. The cost of ammoniating and ensiling was the key factor for adoption. Most rural households used a silage-ammoniating pit for treatment, so this method was used for the

cost analysis (Table 7-10). In ammoniation, the cost of straw and of urea, the main expenses, accounted for 49.0 and 31.4 percent of total cost, respectively. For ensiling, the main cost was the crop residue itself, 72.7 percent of the total cost.

Table 7-10. Crop residue processing and treatment costs in rural households

Item	Ammoniation	Ensiling
Quantity of crop residue	500 kg	500 kg
Depreciation	¥ 50	¥ 40
Dosage of 4% urea	¥ 40	-
Depreciation	¥ 32	-
Pit cost	¥ 300	¥ 300
Depreciation	¥ 7.5	¥ 7.5
Plastic film cost	¥ 6.5	¥ 4.5
Labour	1 day	0.5 day
Value of labour	¥ 6	¥ 3

Total cost	¥ 102	¥ 55
Average unit cost	¥ 0.204/kg	¥ 0.110/kg

Overall economics at household level

The average number of cattle per household in Fuyang Prefecture was 3.6, with 2.4 marketed and an income from cattle sales of ¥ 3 190 per household. The average total output value was ¥ 5 217 per household. Households used 609.4 kg of grains with a cost of ¥ 806. The average use of concentrate per household was 648.0 kg, with a cost of ¥ 904. The average input volumes were 3 296 kg for common straw, 2 157 kg for silage, 1 991 kg for ammoniated straw and 2 305 kg for green fodder per household, with a total cost of ¥ 1078 for green fodder and roughage. Average annual net output per household was ¥ 2 172, with a net income of ¥ 1 278 and a net earning rate on costs of 32.4 percent. On average, a net earning of ¥ 360 could be obtained for every head of cattle raised; a net earning of ¥ 8.6 and net output value of ¥ 14.6 could be gained for every working day (Table 8-12).

Mengcheng county started earlier and thus it had fairly large-scale cattle production. The average number of cattle per household was 4.2, while in Lixin and Guoyang it was 3.3 cattle. In addition, the feed input type varied among the three counties. The ratio of concentrates: common straw: silage: ammoniated straw was 698:1 284:1 935:1 243 in Mengcheng; 686:1 491:690:1 822 in Lixin; and 721:2 882:809:253 in Guoyang. The concentrate input in the three counties was fairly close, but there was a large difference in straw input type. Mengcheng County had high silage and high ammoniation levels; Lixin County had low silage and high ammoniation; and Guoyang County had low silage, and low ammoniation. For these reasons, the economic benefits of cattle production based on straw in Mengcheng were higher. The average net outputs for cattle production for Mengcheng, Lixin and Guoyang were ¥ 2 448, 2 084 and 1 988; the net incomes were ¥ 1 567, 1 211 and 1 112; and the net earning rate on costs were 34.6, 32.4 and 31.7 percent, respectively. The average net earnings per cattle raised were ¥ 373, 373 and 337; the average net output values per working day were ¥ 16.7, 14.3 and 13.6; and the average net earnings per working day were ¥ 10.7, 8.3 and 7.6

(Table 7-11).

Economics of different feeding scales at household level

In Fuyang Prefecture, more than 50 percent of the rural households had 2-4 head of cattle. Households with 4-6 head were about one third. Households with 1-2 cattle were rare. The average net output with 1-2 cattle was ¥ 738; with 2-4 head it was ¥ 1 621; with 4-6 head it was ¥ 2 563; and with 6-10 head it was ¥ 5 843. The average net earnings from cattle raising for the four groups were ¥ 258, 800, 1 539 and 4 856, and the average net earning rates on costs were 13.8, 25.4, 31.7 and 64.0 percent, respectively. The average net earnings per cattle raised were ¥ 206, 287, 347 and 620; the average net output values per working day were ¥ 9.2, 11.8, 15.0 and 35.5; and the average net earnings per working day were ¥ 3.2, 5.8, 9.0 and 29.5 (Table 7-12).

Economics of different straw treatment techniques

In Fuyang Prefecture, straw processing and treatment techniques generally accepted by rural households included silage and

ammoniation. There were four technical combinations of silage and ammoniation: (1) No ensiling, no ammoniation, use of common straw alone; (2) ammoniation without ensiling, plus common straw; (3) only ensiling, without ammoniation, plus common straw; and (4) both ensiling and ammoniation, plus common straw. From the analysis of the survey, it could be seen that cattle production with common straw was the smallest group, and the economic benefits were the lowest. The larger the scale the better the economic benefits. The group of rural households using two techniques at the same time had a larger scale of operation and better economic benefits. The average net output per household of the four groups - (1) common straw; (2) ammoniation; (3) silage; and (4) silage + ammoniation - were respectively ¥ 1 492, 1 748, 2 140 and 2 362; the average net earnings per household were ¥ 581, 886, 1 222 and 1477; the average net earning rate on costs were 20.5, 26.3, 27.4 and 33.2 percent; the average net earnings per cattle raised were ¥ 187, 281, 344 and 381; the average net output values per working day were ¥ 9.8, 12.2, 14.0 and 16.0; and the average net earnings per working day were ¥ 3.8, 6.2, 8.0 and 10.0, respectively (Table 7 13).

The average concentrate input per cattle of the common straw, ammoniation, silage and silage plus ammoniation groups were 262, 308, 508 and 348 kg, respectively. The proportion of common to ammoniated straw per cattle per household in the ammoniation group was 2 198:1 260, while the proportion of common to silage straw per cattle per household was 2 663:1 383 in the silage group. The proportion using treated straw in the ammoniation and silage groups was about 35 percent for both groups. The reason for the gap in economic benefits in both groups was the large input of cottonseed cake in the silage group (an average of 948 kg per household), significantly higher than the other groups. Thus, the economic benefits were very close to those of the silage plus ammoniation group (Table 7-13).

From the rural household survey and the analysis of the production data, it is clear that the economic benefits of cattle production based on straw are significant, and influenced by various inputs, specially concentrates, ammonia source, straw, etc. The economic benefits will change with changes in prices or the cost of all these essential inputs. In order to obtain the best economic benefits,

cattle rearers must constantly adjust their diets and feeding methods to match changes in input costs.

Table 7-11. Overall economic benefits of cattle production based on straw by rural households (Units: head, yuan, 500g, working day)

	Average	Mengcheng	Lixin	Guoyang
Number of rural households		39	40	40
Average number of cattle	3.6	4.2	3.3	3.3
Number of cattle marketed	2.4	3.7	2.0	1.6
Income from cattle sales	3 190	4 260	3 119	2 218
Net weight gain	1459	1724	1386	1274
Number of working days per cattle	11.4	10.5	10.4	13.4
Manure output	30 909	34 370	29	29 198

Output value of major product	4 639	5 483	4 406	4 051
Output value of sideline products	578	619	535	572
Total output of cattle production	5 217	6 102	4 950	4 623
Amount of feed grain used	1 215	1 562	1 195	896
Cost of feed grain	806	1037	802	585
Amount of other concentrates	1 296	13 659	1 036	1 484
Cost of other concentrates	904	894	802	1 016
Amount of commons traw	6 593	5 393	4 845	5 910
Cost of common straw	297	243	223	428
Amount of silage used	4 314	8 126	2 241	2 670
Cost of silage	237	447	123	147
Amount of ammoniated	3 981	5 219	5 922	835

straw used				
Cost of ammoniated straw	406	532	604	85
Amount of green grass used	4 611	6 474	2 298	5 108
Cost of green grass	138	194	69	153
Total amount of green and roughage feed	19 499	25 212	15 306	18 123
Total cost of green grass and roughage	1 078	1 416	1 019	813
Depreciation of shed and other assets	95	97	111	77
Medicines, vaccination, breeding	161	210	131	143
Total cost of materials	3 045	3 654	2 865	2 635
Working days	149	147	145	146
Cost of labour	895	881	873	876
Total cost of production	3 940	4 535	3 738	3 111
Net output from cattle	2 173	2 448	2 084	1 988

production				
Net earning from cattle production	1 278	2 567	1 211	1 112
Net earning rate on costs	32.4	34.6	32.4	31.7
Net earning per cattle	359.9	373.0	372.6	337.1
Net output value per working day	14.6	16.7	14.3	13.6
Net earnings per working day	8.6	10.7	8.3	7.6

Table 7-12. Overall economic benefits of cattle production under different cattle numbers by rural households (Units: cattle, yuan, 500g, working day)

Group (number of cattle/household)	1-2	2-44	4-6	6-10
Number of rural households	6	69	35	9
Average cattle number	1.3	2.8	4.4	7.8
Number of cattle marketed whole	1.3	1.4	2.6	9.9

period				
Income from cattle sales	1 127	2 014	3 865	10 957
Net weight gain	577	1 093	1 782	3 596
Number of working days per cattle	2.6	11.0	14.0	10.6
Manure output	18 031	23 975	30 339	59 876
Output value of major product	1 834	3 477	5 666	11 434
Output value of sideline products	296	470	730	1 004
Total output of cattle production	2 130	3 947	6 395	12 438
Amount of feed grain used	435	859	1 556	3 176
Cost of feed grain	285	569	1 027	2 117
Amount of other concentrate	673	971	1 809	2 205
Cost of other concentrate feed	442	672	1 284	1 515
Amount of common straw	4 040	6 330	7 211	7 905
Cost of common straw	181.79	284.86	324.47	355.73
Amount of silage used	2 042	2 539	539	15 067
Cost of silage	112	140	299	829

Amount of ammoniated straw used	1 843	2 868	4 681	11 224
Cost of ammoniated straw	188	293	477	1 145
Amount of green grass used	1 830	4 522	4 618	7 120
Cost of green grass	55	136	139	214
Total amount of green and roughage feed	9 755	16 258	21 949	41 316
Total cost of green grass and roughage	537	853	1 240	2 543
Depreciation of shed and other assets	85	95	90	118
Medicines, vaccines, breeding expenses	44	137	191	302
Total cost of materials	1 393	2 326	3 832	6 595
Working days	79	137	171	165
Cost of labour	479	821	1 024	988
Total cost of production	1 872	3 147	4 856	7 583
Net output from cattle production	737	1 621	2 564	5 843

Net earning from cattle production	258	800	1 540	4 855
Net earning rate on costs	13.8	25.4	31.7	64.0
Net earning per cattle	206.2	286.6	346.7	620.0
Net output value per working day	9.2	11.8	15.0	35.5
Net earnings per working day	3.2	5.8	9.0	29.5

Table 7-13. Overall economic benefits of cattle production based on straw under with different feeding techniques by rural households (Units: cattle, yuan, 500 g, working days)

Technical type group	Common straw	Ammoniation	Silage	Silage and ammoniation
Number of rural households	21	17	13	68
Average cattle number	3.1	3.2	3.6	3.9
Number of cattle marketed	0.7	2.2	2.1	3.0
Income from cattle	942	3 045	3 093	3 970

sales				
Net weight gain	926	1 158	1 605	1 671
Numbers of working days per cattle	13.1	12.6	12. 1	11.0
Manure output	22 720	29 959	30 227	33 162
Output value of major product	2 944	3 684	5 103	5 313
Output value of sideline products	471	575	574	607
Total output of cattle production	3 415	4 259	6 577	5 921
Amount of feed grain used	697	894	1 210	1 432
Cost of feed grain	453	604	800	952
Amount of other concentrates	929	1 046	2 398	1 268

Cost of other concentrates	634	782	1 640	885
Amount of common straw	9 429	6 923	9 452	4 960
Cost of common straw	424	311	425	223
Amount of silage used	0	0	4 910	6 585
Cost of silage	0	0	270	362
Amount of ammoniated straw used	0	3 969	0	5 975
Cost of ammoniated straw	0	405	0	609
Amount of green grass used	7 698	4 685	3 930	8 475
Cost of green	231	141	118	254

grass				
Total of green and roughage feed	14 048	15 578	18 292	25 995
Total cost of green grass and roughage	655	857	813	1 449
Depreciation of shed and other assets	64.1	104.1	114.6	99.6
Medicines, vaccines, breeding	116.3	162.8	170.0	173.2
Total cost of materials	1 923	2 511	3 538	3 559
Working days	152	144	153	147
Cost of labour	912	862	917	884
Total cost of production	2 834	3 373	4 455	4 443
Net output from	1 492	1 748	2 140	2 362

cattle production				
Net earning from cattle production	581	886	1 222	1 477
Net earning rate on costs	20.5	26.3	27.4	33.2
Net earning per cattle	187.4	281.2	344. 4	380.7
Net output value per working day	9.8	12.2	14.0	16.0
Net earnings per working day	3.8	6.2	8.0	10.0



CHAPTER 8 - THE FUTURE CHALLENGE

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In 1992, the *Animal Production based on Crop Residues* (APCR) project was listed in the State Agricultural Comprehensive Development Programme (SACDP) of China. In only nine years, 13 state-level APCR prefectures and 380 APCR demonstration counties had been established, and more than 8 million farmer households were utilizing ammoniated straw to raise livestock. The implementation of the APCR project not only enabled severalfold increases in beef, mutton and milk production, but also saved more than 50 million tonne of feed grain annually. Thereby, China reduced its grain imports, making a contribution towards world grain security. The APCR project has driven the development of slaughtering and processing of meat, leather, horns, bones, blood, etc. This, together with the sale of these products, has provided employment for 20 million people in rural and urban areas, making

a contribution to farmer income and maintaining social stability. The return of manure to farmland in the APCR not only improved soil and agriculture outputs, but also reduced chemical fertilizer use and its environmental pollution, thereby reducing the generation of "red tides" and other ecological calamities. The effective utilization of crop residues also diminished air pollution caused by annual straw burning. Implementation of the APCR project in the past decade has not only generated over ¥ 70 000 million in direct economic benefits, but also generated favourable social, agronomic and environmental benefits.

Although the APCR project has already had great achievements, looking into the future, the burden is heavy and the way is still long. Strategically, Chinese agriculture confronts multiple challenges, and the situation is serious. The first challenge is population growth. China has a population of 1 300 million (22 percent of the world) that will grow by more than 14 million a year. This increase will demand at least 5.6 million tonne of food grain. However, in the past 16 years, annual grain output increased only by 4.5 million tonne. The second challenge is the pressure coming from higher

living standard since, together with economic development, the consumption of meat, eggs, milk and fish is continuously increasing. This means extra feed grain to produce them. The third challenge is continuous reduction in farmland area, worsening ecological conditions. The development of the economy requires the constructing of highways, factories, commercial centres and domestic accommodation, which occupy large areas of former farmland. In merely the last three years (1996-1999), net reduction in farmland was 13 million *mu*, equivalent to the land of 10 counties. At the same time, due to natural and mainly anthropogenic calamities, annual deterioration of pasture land has exceeded 10 million *mu*. This continuous environmental deterioration is fundamentally destroying the base for agricultural production. Most domestic and foreign scholars have predicted that in 2-3 decades, China will need to import huge amounts of grain to meet the continually rising demand. However, the grain that can be provided worldwide is also limited. If a great country with 1 300 million population imports large grain amounts, it will certainly threaten world grain security.

To solve the grain problem, "tapping new resources and economizing on expenditure" has been proposed. The "tapping new resources" implies "increasing output." If enough grain is produced, the problem is solved. But history shows that in the last 16 years grain output increases in China could not keep up with population growth. Facing this situation, the only way out is "economize on expenditure."

As mentioned before, through implementation of the APCR project, there have been annual savings in feed grain equivalent to over 50 million tonne. This is far from the maximum limit. So far, from the over 600 million tonne of crop residues annually, only about 200 million tonne are used as feed, of which less than half is treated (silage, ammoniation, etc.). Its further exploitation still has great potential. Nevertheless, crop residues can only be fed to herbivorous animals, not to swine or poultry. Only by making a great effort in developing herbivore production will full utilization of crop residues be possible. In China, herbivorous animals are a relatively weak element of the livestock industry. Beef, mutton, milk, leather, hair and feathers are all in short supply. MOA

recently formulated a policy guide for animal production restructuring, namely: "stabilize pork and poultry egg production; raise beef, mutton and poultry meat production; and intensively develop milk, quality wool and fine hair production." In other words, strive to develop herbivorous animal production.

In the first chapter it was already demonstrated that, in China, the main base for the development of herbivorous animals is the agricultural zone, the basic feed being crop residues and other crop by-products. State Council leaders have already decided that the APCR project ought to be unremittingly carried out. Therefore, MOA has already formulated a *National development scheme for a project on animal production based on crop residues 2001-2010* (henceforth called the Scheme), planning APCR work for the next decade.

According to the Scheme, in the coming 10 years, apart from consolidating the 13 current, 47 additional demonstration prefectures ought to be established. According to the State Great Development Strategy for West China, the new demonstration

prefectures and counties should be towards west China, since, in the past, most were in the Central Plain and in east China. Establishment of APCR demonstration counties in the cropping and pastoral mixed zone combines animal raising based on grass and APCR. Using a confined system instead of grazing allows for the rehabilitation of grasslands, striving for a dual goal: animal production and ecological reconstruction. Besides, the new Scheme stipulates that demonstration prefectures and counties ought to implement the guiding policy of paying equal attention to new settings and extension, and respect regional development. This consolidates the existing extension base, gradually constituting a recognized production pattern.

If Scheme targets are reached, crop residues for animal raising should reach 385 million tonne by 2010, equivalent to 55 percent of all crop residues. Of this, silage will be 250 million tonne (fresh weight) and ammoniated residues 120 million tonne. Feed grain saved will equal 126 million tonne (62 million tonne in the next decade), which will compensate for the grain demand from population growth in this period. In addition, APCR will make huge

contributions to social employment, to development of ecological agriculture and to environmental protection. The full text of the Scheme annexed to this publication.

Plate 8-1. Dr R. Orskov, a FAO expert, in China



Plate 8-2. State Councillor Mr Chen Junsheng inspects a beef cattle slaughter house



Plate 8-3. Yellow Cattle competition - the champion



Plate 8-4. Developing the beef cattle feed-lot



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