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EDITORIAL

Season's Greetings to Everyone!

AMA's Winter issue such as the present one, inevitably coincides with the Christmas and New Year holidays for which reason the entire AMA staff takes time to extend to everyone, particularly our readers and contributing editors, a joyous Season's Greetings!

As we bid the outgoing year adieu and welcome the coming year, we are confident that our readers' problems, if any, are few and small and that the coming years will be more blessed with glad tidings.

This editorial takes the opportunity to make three brief observations worth mentioning considering their timeliness. The first one concerns the current Uruguay Round affecting agriculture in both developed and developing countries, i.e., an agreement that assures free trade of agricultural products from developed countries to developing ones. This free trade will likely increase in volume but will also likely be disastrous to the developing countries in terms of reduced prices for their agricultural products when exports start coming in. One can only hope that the Uruguay Round on agriculture has fully considered the provisions of policies in the interest of governments of developing countries.

The second observation pertains to the drama now taking place in Somalia wherein the United States has taken the lead to provide expeditionary military forces to secure the delivery of much needed food and medicines to the starving Somalians in concert with the United Nations decision to provide military protection. Already, the UN Secretary-General has expressed the desire that the US forces also disarm the warring factions in Somalia to ensure that peace and order will be restored after the US troops pull out. Whether a disarmament takes place or not, it is imperative that the once productive farms of the country be cleared of land mines and be converted instead to the production of food crops because the current food aid is nothing more than a temporary solution to the starvation taking place in the country. This is where aid-givers should consider extending expertise and farm machineries to Somalia in order to engage in a massive redevelopment of productive farms.

The third observation asks AMA readers to take note of an interesting report from IRRI and University of the Philippines economists on page 45 of this issue citing in more graphical terms that "...With an increase in demand, national income will increase at a higher rate in mechanized farm than in non-mechanized farm. This is mainly due to high efficiency in the use of inputs by farmers in mechanized farms." In short, the economists have developed a model to show that, indeed and in fact, agricultural machineries do not necessarily replace labor. And they have empirical evidences to prove their points. This and previous AMA contributions further support AMA's stand from the start that agricultural mechanization is the right option for governments of developing countries to take if they intend to increase agricultural productivity.

Once more, here's wishing everyone the best of the Holiday Season!

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
January, 1993

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Development of Seed Drill for Rain-fed Farming

by
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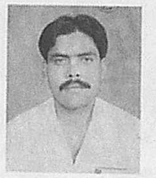

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Abstract

A drop type two to six row tractor-drawn semi-automatic cereal, legume seed drill with an adjustable row spacing of 30-90 cm has been developed. It has a rotating spindle (small drum) for uniform seed placement. The seed drill opens the furrows, places seeds, fertilizer, chemicals and covers them. A tractor operator and one other person are required for its efficient and smooth operation. Its effective field capacity is 1.41 acres/h and it has a forward speed of 2-3 km/h depending upon soil type and seedbed preparation.

Introduction

Soil moisture is a major factor limiting rain-fed crop production. The seed drill was developed to form ridge-furrow systems in order to capture rainwater in place to facilitate infiltration into the soil. This system facilitates the successful production of crops in low rainfall areas.

The semi-arid region of south-east Asian countries receive 250 to 400 mm average annual rainfall and the rainfall often has a highly irregular distribution (Tanji et al., 1987). A minimum of 300 mm of rainfall is required for a successful crop production (Watt, 1948). More than 30 million ha of land in Pakistan consist of arid and semi-arid regions where rainfall is not adequate for successful agriculture. The annual rainfall probabilities in arid and semi-arid areas of Baluchistan are shown in **Table 1**.

The annual rainfall in barani winter-cropped areas of Baluchistan is insufficient to produce good winter crops (Kidd et al., 1988). Principal barani crop production activities pertain to winter wheat, barley, some lentils and forages. Traditionally, farmers of this area adopt a number of rainwater collection or water harvesting techniques such as small dams, *wadis* or tide ridges (Perrior, 1986), to get better crop growth. The most common technique is the formation of a ridge-furrow system which is a series of lateral ditches which collect rainwater very effectively (Billy, 1980). This technique has been used in most of the rain-fed agricultural regions to retain rainwater (Hudson, 1971). Using this technique increases the retention of rainfall (Garduno, 1980) and thus reduces the risk of crop failure due to drought (Jorge et al., 1980).

Winter wheat, barley and summer sorghum are the major crops in the region. They require different planting methods and systems. Basically, all the planting methods consists of opening of the soil for the placement of seeds, fertilizer application at the required depths and the covering of the seeds with the soil.

Traditionally, cereal crops have been planted by draft animals and this practice continues in the rain-fed dry farming areas of the region. However, there are several cereal planting machines available in the world, but they are basically designed and used for irrigated agriculture and do not

Table 1 Rainfall Probabilities Analyzed for 40 Years of Rainfall Data of Different Stations of Upland Baluchistan

District		Exceedance probability								
		90%	80%	70%	60%	50%	40%	30%	20%	10%
Kalat	Annual	107	127	142	158	174	191	211	239	282
	Winter	54	75	94	113	132	155	181	212	264
Kovak	Annual	88	102	113	124	135	146	161	178	206
	Winter	34	51	67	87	100	118	140	174	224
Mastung	Annual	105	123	138	152	165	180	198	222	259
	Winter	71	92	108	127	143	161	183	210	252
Quetta	Annual	134	157	176	193	210	227	250	281	327
	Winter	91	119	143	165	185	208	240	274	330
Dasht	Annual	48	65	82	98	115	137	165	205	278
	Winter	42	60	78	94	108	126	147	177	223
Khuzdar	Annual	92	116	138	158	178	204	235	274	344
	Winter	27	44	58	71	84	100	118	139	175

fulfil the requirements of rain-fed agriculture.

There was a need to develop a planter for dryland agriculture to place the seeds, apply the fertilizers and chemicals at required depths and also to form a water catchment to capture rainwater effectively (such as furrows or ridges to keep water in place) (Perrior, 1986).

Therefore, a seed drill was designed keeping in mind these requirements of the local farmers, ecological conditions and the socio-economic situation of farmers (Garduno, 1980). Local farmers in rainfed areas of Baluchistan use animal drawn plow-cum-drill (**Fig. 1**). This instrument when engaged into the soil, pushes the loose soil to either side to form a ridge-furrow system (**Fig. 2**) to capture rainwater in place. The ridges increase the storing capabilities of soils by forming a trap for the runoff. These ridges increase the potential for infiltration and storage of water into the soil profile (Bao, 1966).

Development of the Planter

The seed drill was developed in the Arid Zone Research Institute, Quetta. It is useful in planting large farms as well as small plots. It can place seeds of up to 4 mm in diameter at a seed rate of 20 to 240 kg/ha applying fertilizer and chemicals at the same time.

Of the several methods of cereal planting, row planting is highly recommended. The local farmers of Baluchistan also plant in row with an animal-drawn plow-cum-drill. Spacing of rows with winter cereals varies from 15 to 40 cm. However, spacing has no effect on grain yield (Singh and Atam, 1986). In this region farmers plant lentils at a row spacing of 30 to 40 cm and at a seeding rate of 40 to 70 kg/ha (Sharma et

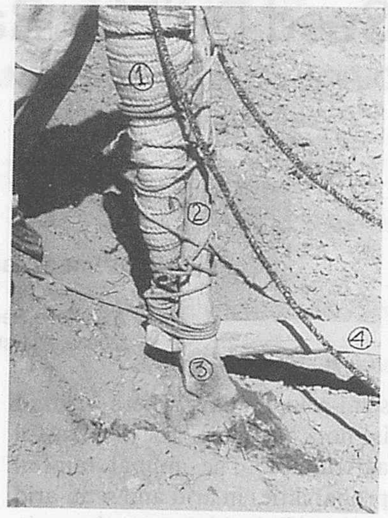

Fig. 1 Seed distribution system and shape of local drill: ① Seed metering system; ② Handle; ③ Share; ④ Beam connects with camel.

al., 1986). The seed rate of wheat and barley is 40 to 100 kg/ha (Aslam et al., 1986). Aslam and Saleem (1985) reported that in the case of high quantities of well distributed rain, grain yield decreased due to lodging, beyond the seeding rate of 100 kg/ha. The local farmers of Baluchistan use 70 to 90 kg/ha of wheat and barley because of the low germination rate in rainfed farming.

Mechanical Details of the Planter

The planter consists of a main frame with 2 to 6 furrow openers and has a vertical rotating spindle (small drum). The seed distribution system is similar to those of most other seed drills available and used for irrigated farming (**Fig. 3**). Inter-cropping with this seed drill is very easy by making some small adjustments. It consists of one operator seat; chain and sprocket drive from ground wheel; and belt drive to spindle from a seed rate adjusting pulley driven by ground wheel. The main frame is made of an iron channel of 7 × 3.5 cm. The total length of

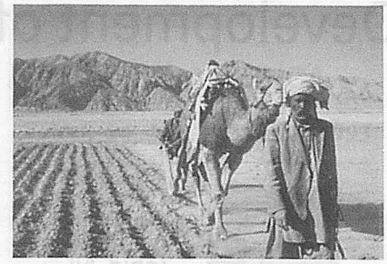

Fig. 2 Construction of ridge-furrow system and the placement of seeds by local plow-cum-drill.

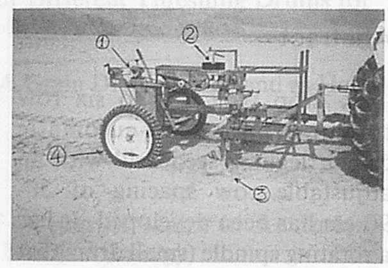

Fig. 3 Two-to-six row tractor-drawn mounted type semi-automatic seed drill. ① Seed rate adjusting pulley. ② Small rotating spindle (drum). ③ Coulter designed to make ridge-furrows. ④ Ground wheel provides main drive.

the machine is 1.8 m, the width is also 1.8 m and the height is 1 m. The diameter of the ground wheel is 68 cm, the diameter of the rotating spindle is 27 cm and the height is 8 cm. The shares are designed according to the shape of the shares on the locally used plows with a height of 19 cm and a length of 26 cm (**Fig. 5**).

Field Performance

The machine was tested at three cropping seasons each in 1984, 1987 and 1988 at different locations and soil types in Baluchistan: Khuzdar, Kallat, Kovak, Dasht and Rangita. The machine opened the furrows, placed the seeds, fertilizer and covered the seeds with soil (**Fig. 4**). For field evaluation, wheat, barley, lentil and some vicia species were planted. The plant growth of the vicia species and local lentil, three months after sowing, is shown in **Fig. 6**.

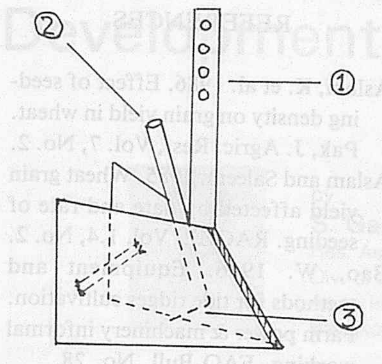

Fig. 5 Planter coulter designed to make ridge-furrows. ① Seed depth. ② Seed metering pipe connects to machine by plastic pipe. ③ Inclined seed metering modified to prevent from seed blocking by soil.

Fig. 4 Field performance of the seed drill showing the placement of seeds and the construction of the ridge-furrow system.

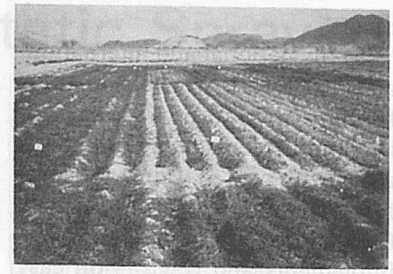

Fig. 6 Growth of Vicia and Lentil as forages after 3 month of planting.

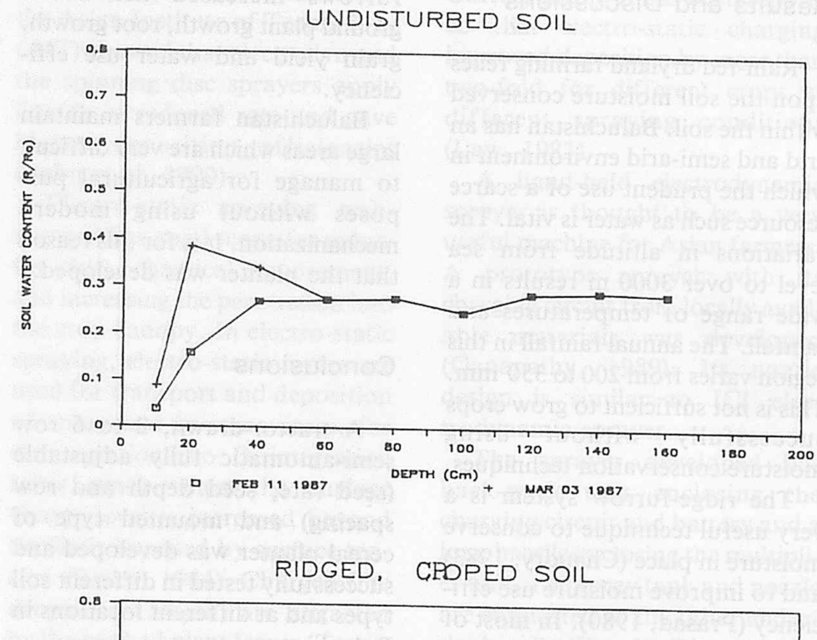

Fig. 7 Soil water content, profiles (R/RO-neutron probe rate count as a fraction of shield count) before and after 47 mm rainfall between Feb. 11 and March 3, 1987.

The machine was drawn by a 65 hp tractor. This tractor is common among the farmers of Baluchistan. Two persons, including a tractor operator, are required for the efficient and smooth operation of the machine. The planter was continuously used until the end of planting at each site for 4 to 6 h a day. It was observed during the operation that a vertical seed metering system several times blocked the flow of seed into the soil. To solve this problem an inclined metering system was developed and successfully used.

During planting the seed drill constructed ridges 16 cm high with a 40 cm distance between each ridge. This 40 cm distance was the row spacing adjusted on the seed drill for wheat and barley. The effect of ridging to increase the amount of moisture is graphically shown in **Fig. 7**.

Response of Farmers

Local farmers liked this planter very much because during planting it shapes the soil surface in the same way as a local plow-cum-drill does (**Fig. 4**). According to an informal survey conducted in the community of farmers where trials were conducted, this planter has the ability to increase the cultivated area in the rain-fed areas of the region.

There are several companies in Pakistan that manufacture agricultural implements. The developers of the seed drill have contacted them to encourage manufacture of this machine at a cost which the local farmers can afford.

Many national and international agencies are working in these farming areas to provide agricultural implements on a rental basis along with related training to local farmers. Also, farmers are offered the opportunity to purchase new implements and tractors on easy installment basis.

Results and Discussions

Rain-fed dryland farming relies upon the soil moisture conserved within the soil. Baluchistan has an arid and semi-arid environment in which the prudent use of a scarce resource such as water is vital. The variations in altitude from sea level to over 3000 m results in a wide range of temperatures and rainfall. The annual rainfall in this region varies from 200 to 350 mm. This is not sufficient to grow crops successfully without using moisture conservation techniques.

The ridge-furrow system is a very useful technique to conserve moisture in place (Chaudry, 1983) and to improve moisture use efficiency (Prasad, 1980). In most of the irrigated areas of Pakistan farmers use the ridge-furrow system to grow cotton and vegetables. Farmers of rain-fed areas of Baluchistan also use alternate ridge-furrow system. The main difference of planting patterns between irrigated and rain-fed areas is that the farmers in irrigated areas grow crops on the ridges while the farmers in rainfed areas of Baluchistan plant in the bottom of furrows (**Fig. 6**) thereby increasing the water use efficiency (Reddy et al., 1978).

The construction of the ridge-furrows and planting on the ridges is a very laborious, expensive and time consuming job which can be economically justified under the irrigated farming system. However, in the rainfed areas, where annual rainfall is low and uncertain, it is almost impossible to plant in hand-constructed, ridge-furrow systems. Therefore, the farmers plant crops with an animal drawn plow-cum-drill (**Fig. 1**), which pushes the soil on either side of the plow, places the seed deep into the moist soil and constructs an alternate ridge-furrow system (**Fig. 2**). Chaudhry (1985) reported that water through furrows increased the above ground plant growth, root growth, grain yield and water use efficiency.

Baluchistan farmers maintain large areas which are very difficult to manage for agricultural purposes without using modern mechanization. It is for this reason that the planter was developed.

Conclusions

A tractor-drawn, 2 to 6 row semi-automatic fully adjustable (seed rate, seed depth and row spacing) and mounted type of cereal planter was developed and successfully tested in different soil types and at different locations in Baluchistan.

This planter constructs an alternate ridge-furrow system as a water catchment in order to increase water infiltration into the soil. It uniformly distributes and places the seeds and applies the fertilizer and chemicals into the moist soil. The cost of planting with the machine was $7.89/ha at current labor wage rates. This is about five times less than the cost of planting with animal-drawn plow-cum-drill. There are net savings of about 10 men and 10 animals per hectare per day. The planter is very easy to operate and has very few maintenance requirements. It only requires proper lubrication of its moving parts.

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(Continued on page 22)

Development of An Electro-static Sprayer

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Abstract

A prototype hand-held sprayer was developed using a high voltage circuit of an output of 15-20 kV for an input of 6 V. The charging circuitry consisted of an invertor and a multiplier. Droplets produced by the sprayer with malathion in kerosene were of size 10-250 μm. The effect of voltage and flowrate on the droplet spectrum were analyzed.

Introduction

The problems of health hazard, environmental pollution and drudgery that are associated with high volume spraying in the past decades have led to the development of a series of low volume and ultra low volume sprayers. Poor penetration through the crop canopy of chemical applied is still a major problem with this kind of sprayers.

It is important to minimize the pesticide application rates and at the same time increase the application efficiency. A study on comparative performance evaluation of conventional, spinning disc and electrodyn sprayers, conducted at the Asian Institute of Technology (AIT) showed that electrodyn and the spinning disc sprayers apply liquids at reduced rate and gave higher deposition efficiencies (Babu et al, 1990).

Electro-static spraying technique offers good scope for reducing drift, chemical requirement, and increasing the penetration into the crop canopy. In electro-static spraying, electro-static forces are used for transport and deposition of spray and in some cases, for disintegration also. Disintegration takes place when the surface charge level is increased beyond the limit imposed by surface tension (Bailey, 1984). Charged fine droplets (<50 μm) are attracted by the earthed plant leaves. Transport of charged droplets is aided by the electrical field operating between the electrode and earth. As charged droplets follow electrical field lines during transport, the nether of leaves is also covered. Deposition is further enhanced by the setting up of image charges on the targets (Marchant, 1979 and Coffee, 1981). It has been reported that electro-static charging improved deposition by more than two-fold for different crops at different spraying conditions (Law, 1983).

A hand-held electrodynamic sprayer is thought to be a very useful machine for Asian farmers. A prototype sprayer with its charging circuit from locally available materials was developed (Ganapathy, 1989). Its nozzle design is similar to ICI electrodynamic sprayer.

The sprayer developed has back-pack unit enclosing the charging circuit and battery and a long handle enclosing the multiplier unit. The spray tank and nozzle are supported at the other end of the handle (**Fig. 1**). Direct charging system is adopted in the design of the nozzle. A high voltage of 20 kV applied to the stud inside the nozzle creates a powerful field against the ground electrode outside the nozzle. This field pulls out the liquid from the tank and disintegrates it.

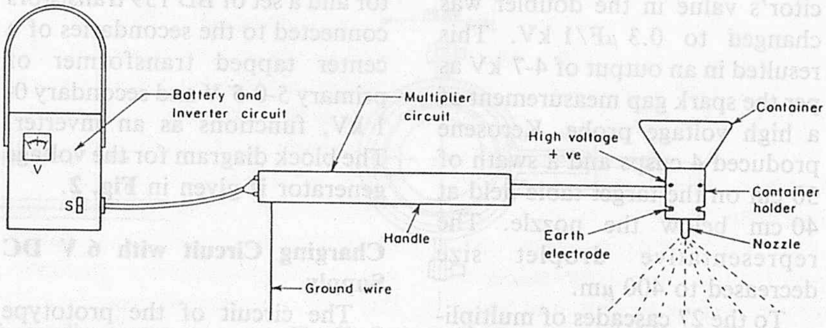

Fig. 1 Diagram of the experimental electrodyn sprayer.

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Development of Charging Circuit

Charging Circuit with 230 V AC Supply

For laboratory testing, a circuit which delivers 15-20 kV DC for a supply input of 230 V AC was used. The development of charging circuit went through four important stages each of which was an improvement over the former one in output. In all the stages of development of charging circuit, the essential functional units remained unaltered except the multiplier unit.

Development of Multiplier

The multiplier consists of cascaded stages of half-wave doubler. The output of the transformer is supplied to a specific number of cascades depending on the output of the circuit needed. In each cascade, the voltage is added to give the final output in kV.

The first stage of development resulted in a voltage output of 2-4 kV as estimated by the spark gap measurement with a high voltage probe. The kerosene dispersed at the first stage was observed to have 3 cusps and the swath width on a target table held 40 cm below the nozzle was measured to be 20 cm. The droplets collected on glossy papers were 500 μm in size. The circuit of the first stage multiplier unit had 27 sets of diodes (1N 4001) and capacitors (47 μF/600 V).

In the second stage, the capacitor's value in the doubler was changed to 0.3 μF/1 kV. This resulted in an output of 4-7 kV as per the spark gap measurement of a high voltage probe. Kerosene produced 4 cusps and a swath of 30 cm on the target table held at 40 cm below the nozzle. The representative droplet size decreased to 400 μm.

To the 27 cascades of multiplication, 10 more cascades of

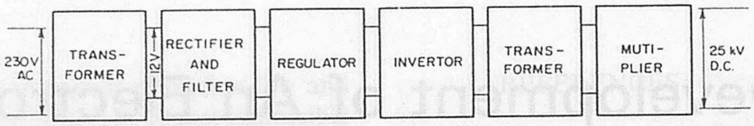

Fig. 2 Block Diagram of high voltage generator.

0.25 μF/200 V capacitors and diodes were added to the circuit in the third stage. This finally resulted in a 7-12 kV output. Dispersion of kerosene occured in 6 cusps and the swath width on target table at 40 cm below nozzle was 40 cm. The representative droplet diameter of the spray was 300 μm.

In the fourth stage, a set of 31 cascades composed of 0.25 μF/1000 V capacitors and 1N 4007 diodes were coupled to the transformer secondary. A voltage output of 20-25 kV was achieved at the high voltage stud of the nozzle holder. The number of cusps increased to 8-12 whereas the swath width increased to 60 cm and the droplet diameter decreased to 150-200 μm. The dispersion and droplet formation in kerosene and coconut oil were considered to be satisfactory for electro-static spraying.

Development of Oscillator and Inverter Circuits

A step-down transformer of 230/12 V rating, supplies 12 V input to the rectifier and filter unit. The rectifier is a full wave bridge rectifier. A capacitor of 2200 μF rating serves as a filter. The regulator used is LM 317 whose function is to give a stable output of 1.2-5 V for an input of 9 V against any variations in the load. An IC 555 serves as oscillator and a set of BD 139 transistors connected to the secondaries of a center tapped transformer of primary 5-0-5 V and secondary 0-1 kV, functions as an inverter. The block diagram for the voltage generator is given in **Fig. 2**.

Charging Circuit with 6 V DC Supply

The circuit of the prototype field sprayer is to be operated on 6 V supplied from four dry cells of 1.5 V each. Efforts were made to alter the input from 230 V AC to 6 V DC wet battery for the circuit developed. The rectifier, filter and regulator units were removed from the original circuit. The input voltage was applied to the inverter unit directly (**Fig. 2**). Two transformer (T1 and T2) of different frequencies, namely; 100 Hz and 5 Hz, including the one used for the circuit operating on AC input, were tested in the invertor assembly. The frequency of the transformer determines its size and hence the size of the sprayer handle.

Open circuit core loss tests were conducted for both inverter circuits. The trend of increase in primary current with the increase in the applied voltage was illustrated. As the applied voltage is directly proportional to the flux density developed, the operating range of magnetic flux density for the transformers tested could be studied using the information given in **Tables 1** and **2**.

The operating conditions of transformer T1 for an output of 720 V corresponds to a maximum magnetic flux in the circuit. In the case of transformer T2, the entire operating zone is beyond the maximum magnetic flux region marked by drastic current increase for a small increase in magnetic flux and hence the applied voltage. This explains why the input voltage could not be increased beyond 3.6 V and for the noise created by the huge core losses in the transformer.

The turns ratio being as high as 200, insulation in the transformer winding break-down was often. For the designed charging circuit, the number of multiplier cascades were optimized at 31.

Table 1 Open Circuit Core Loss Test for Transformer T1

No.	Input V	Input A	Output V
1	3.5	0.055	500
2	4.0	0.060	620
3	4.5	0.080	720
4	5.0	0.100	800

Table 2 Open Circuit Core Loss Test for Transformer T2

No.	Input V	Input A	Output V
1	2.0	0.20	25
2	2.5	0.47	55
3	3.0	0.68	80
4	3.5	0.82	95
5	3.6	0.85	100

Table 3 Sparkover Voltage for Rod Gaps

Gap spacing (cm)	Sparkover voltage (kV)
0.1	3
0.2	5
0.5	8
1.0	13
2.0	22

Design of System for Charging Droplets

The direct charging method was investigated with Electrodyn and spinning disc sprayer in the performance evaluation tests.

If the total surface charge "q" of a drop is increased to a level where the outward electro-static force equals the binding surface tension, then any further increase in charge above this level results in disruption of the drop into charge fragments (Lord Raleigh, 1879) as given by the following equation:

$$q = 8\Pi\sqrt{\epsilon_0 \sigma r^3}$$

where

q is the limiting surface charge on a drop, C

ϵ_0 is the permittivity of air, C^2/Nm^2

σ is the surface tension of spray liquid, N/m

r is the diameter of the droplet, m

Electrodyn and Experimental Electrodyn Sprayer

In the electrodyn sprayer, a stud which is in contact with the nozzle serves as positive electrode and a copper wire of 8 cm diameter encircling the nozzle tip serves as earth electrode. The electrodes are separated vertically by a distance of 4 cm.

A nozzle holder made of nylon with electrodes positioned as in electrodyn nozzle, was used in the experimental sprayer. Two plastic nozzle heads were designed to have different flow rates of the liquid.

Spinning Disc Contact Sprayer

The design of contact charging system for spinning disc sprayer is illustrated in **Fig. 3**. High voltage was applied to the liquid through a mild steel coupling placed in the flow path of the liquid from the tank to the atomizing disc. The sprayer tank is supported by a PVC hard pipe which houses the high voltage cable. High tension supply to the coupler is through a screw centered in a clamp holding the sprayer tank. The screw is perfectly insulated by a layer of polypropylene sandwiched between the screw head and the clamp. The other end of the screw passes through a polypropylene collar and its end is connected to the high voltage cable. The polypropylene collar supporting the electrode and clamp is press-fitted into a PVC hard pipe. The motor housing is well insulated by a rubber casing.

Experimental Procedure

The electrodyn sprayer supplied by ICI, spinning disc sprayer supplied by American Springs and Pressing Works Ltd., India and experimental electrodyn sprayer developed were the sprayers used in the performance evaluation studies.

The parameters selected for the evaluation of different electrostatic sprayers are voltage output at the electrode, charge carried by the droplets, and droplet size and spectrum.

Measurement of Voltage at Electrode

A uniform field spark will always have a spark over voltage within a known tolerance under constant atmospheric conditions. The sparkover voltage for rod

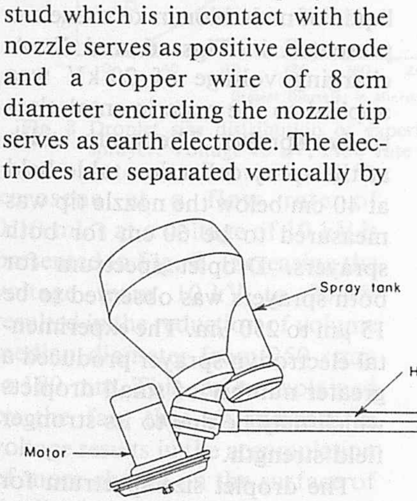

Fig. 3a Schematic diagram electrostatic spinning disc sprayer.

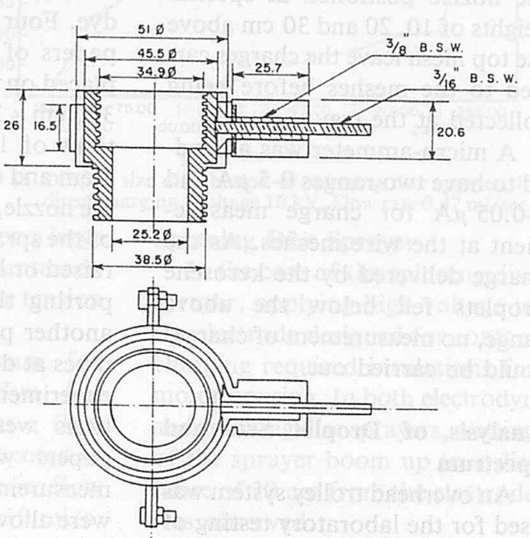

Fig. 3b Contact charging system in spinning disc sprayer.

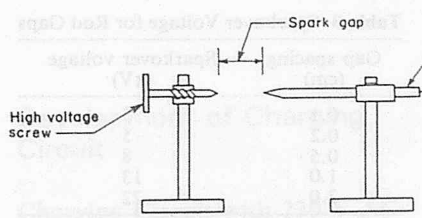

Fig. 4 Spark gap measurement device.

gaps at an atmospheric temperature of 27°C are given in **Table 3** (Naidu and Kamaraj, 1982).

The spark measurement device with the high voltage probe is shown in **Fig. 4**. A high voltage probe supported on a stand served as grounded electrode. High voltage was applied to a long screw well insulated and supported on a stand with a disc of nylon at its tail end. The linear spark gap was measured from the rotations given to the disc. The high voltage cable was well insulated and so positioned as not to influence the electric field between the electrodes.

Measurement of Charges on Spray Droplets

A Faraday cage (**Fig. 5**) made of acrylic 30 cm × 30 cm, with slides to receive three wiremesh frames, was used in the measurement of charge on spray. A tray was provided below the bottom most mesh to collect the spray liquid passing through the meshes. The spray liquid emanating from the nozzle postioned at specific heights of 10, 20 and 30 cm above the top mesh leave the charges carried to the meshes before being collected at the tray.

A micro-ammeter was amended to have two ranges 0-5 μA and 0-0.05 μA for charge measurement at the wire meshes. As the charge delivered by the kerosene droplets fell below the above range, no measurement of charges could be carried out.

Analysis of Droplet Size and Spectrum

An overhead trolley system was used for the laboratory testing of sprayers. The trolley had three different speeds, 0.53, 0.67 and 0.83 m/s. Malathion, in a carrier of kerosene, was used as a spray solution in two flow rates of 0.10 ml/s and 0.19 ml/s.

The technique used for the measurement of droplets involved the incorporation of a dye into the spray liquid and the collection of droplets on a highly contrasting surface which stained when a droplet impinged. About 10 g of a pigment base was treated with 30 ml of oleic acid in water bath and the resulting salt solution was filtered out and used as dye for oils. Victoria blue base and rodamine-b were the pigment bases tried in the preparation of dye. Four high quality glossy art papers of size 7 cm × 5 cm were placed on a wooden board of size 300 cm × 15 cm, at selected positions of 15 cm and 30 cm away from and either side of the path of the nozzle, thus covering the swath of the spray. The boards could be raised or lowered as the pipe supporting the board moves inside another pipe and a pin locks the pipes at desired heights. For each experimental set up, five replications were taken. The sample papers were collected for the measurement of stain sizes. Stains were allowed a few hours to stabilize before measurement.

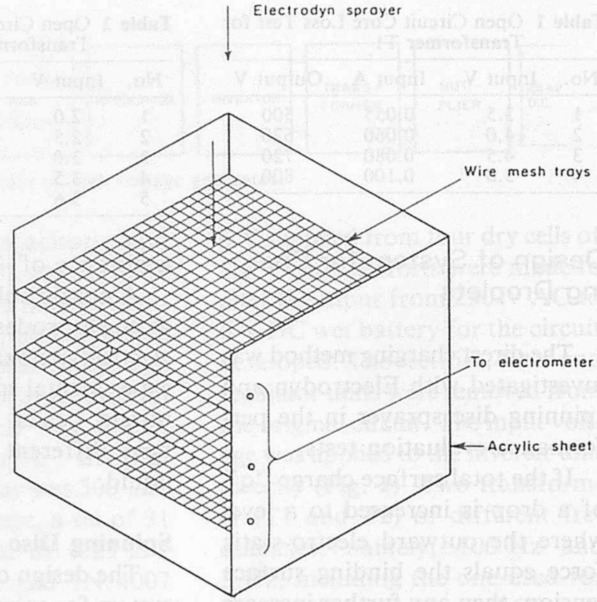

Fig. 5 Faraday cage without door for measurement of charges.

Olympus series BH system microscope with a built-in light source was used to analyse the size of the droplets. The head unit with the eye piece received signals from the particle size micrometer and analyzer. The droplets were analysed in two size ranges, i.e., 1.0-200 μm and 0.5-250 μm using this micrometer.

Performance Evaluation

Electrodyn and Experimental Electrodyn Sprayer

Droplet spectrum for the electrodyn and experimental electrodyn sprayers, tested at a flow rate of 0.10 ml/s with a spray liquid of malathion in kerosene are presented in **Figs. 6** and **7**. A charging voltage of 20 kV was applied to the experimental electrodyn sprayer. The swath width at the spray collection table held at 40 cm below the nozzle tip was measured to be 60 cm for both sprayers. Droplet spectrum for both sprayers was observed to be 15 μm to 250 μm. The experimental electrodyn sprayer produced a greater number of small droplets which may be due to its stronger field strength.

The droplet size spectrum for experimental electrodyn sprayer for a spray liquid of malathion in

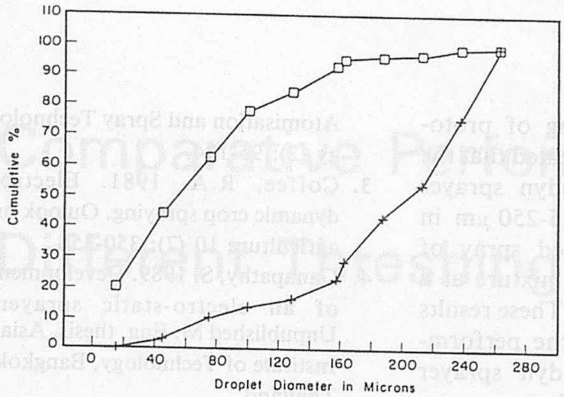

Fig. 6 Droplet size distribution of electrodyn sprayer. Voltage 20 kV, Flow rate 0.10 ml/sec.

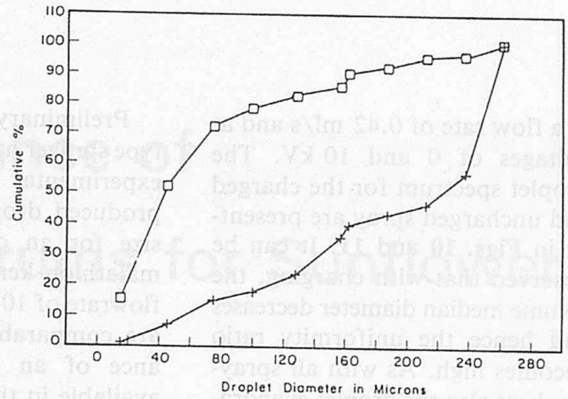

Fig. 9 Droplet size distribution of experimental electrodyn sprayer. Voltage 20 kV, Flow rate 0.19 ml/sec.

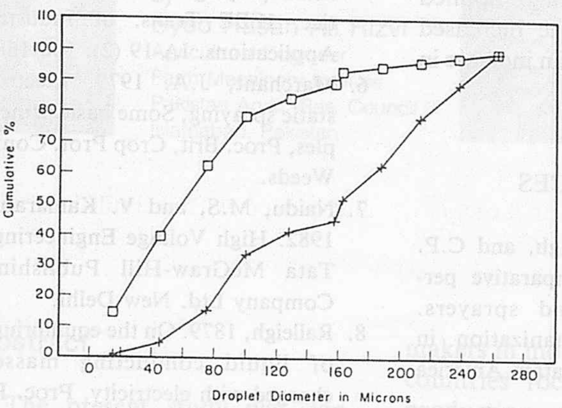

Fig. 7 Droplet size distribution of experimental electrodyn sprayer. Voltage 20 kV, Flow rate 0.10 ml/sec.

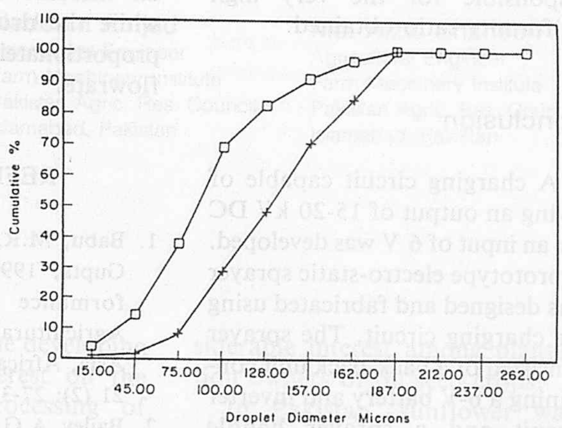

Fig. 10 Droplet size distribution of spinning disc sprayer uncharged. Flow rate 0.42 ml/sec.

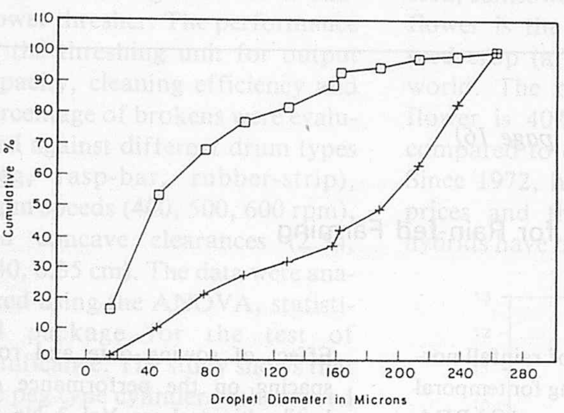

Fig. 8 Droplet size distribution of experimental electrodyn sprayer. Voltage 10 kV, Flow rate 0.10 ml/sec.

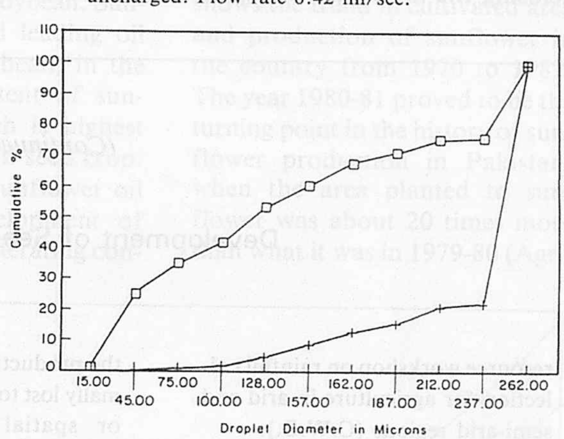

Fig. 11 Droplet size distribution of spinning disc sprayer, in direct charging. Voltage 10 kV, Flow rate 0.42 ml/sec.

kerosene at a flow rate of 0.10 ml/s at a voltage of 10 kV is presented in **Fig. 8**. Increasing the voltage from 10 kV to 20 kV resulted in the reduction of volume median diameter from 250 /mm to 180 mm. This can be explained by the fact that an increase in voltage results in the accumulation of more charge on the surface of the liquid and thereby leading to the dispersal of small droplets. The increased field force on a large number of droplets is counteracted by an increased surface tension force of small droplets.

Droplet size spectrum for experimental electrodyn for malathion in kerosene at a flow rate of 0.19 ml/s is presented in **Fig. 9**. For the increase in flow rate from 0.10 ml/s to 0.19 ml/s, the volume median diameter increased from 180 μm to 230 μm.

Spinning Disc Sprayer

In the case of the spinning disc sprayer, applying high voltage to the electrode designed for contact charging required insulations for motor housing. In both electrodyn and spinning disc sprayers, wetting of the sprayer boom up to a distance of 30 cm from the electrode was observed.

The spinning disc sprayer was tested with malathion in kerosene at a flow rate of 0.42 ml/s and at voltages of 0 and 10 kV. The droplet spectrum for the charged and uncharged spray are presented in **Figs. 10** and **11**. It can be observed that with charging, the volume median diameter decreases and hence the uniformity ratio becomes high. As with all sprayers, here also the droplet evaporation and drifting are the factors responsible for the very high uniformity ratio obtained.

Conclusion

A charging circuit capable of giving an output of 15-20 kV DC for an input of 6 V was developed. A prototype electro-static sprayer was designed and fabricated using the charging circuit. The sprayer consisted of a back-pack unit containing a 6-V battery and inverter circuit and a sprayer handle enclosing the multiplier unit.

Preliminary testing of prototype sprayer has indicated that the experimental electrodyn sprayer produced droplets 15-250 μm in size for an oil based spray of malathion kerosene mixture at a flowrate of 10 ml/s. These results are comparable to the performance of an electrodyn sprayer available in the market.

The droplet size decreased with an increase in voltage applied while the droplet size increased proportionately with an increase in flowrate.

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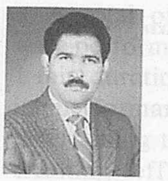
Comparative Performance of Different Threshing Drums for Sunflower



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Abstract

The present study was conducted in order to determine a better threshing unit for a sunflower thresher. The performance of the threshing unit for output capacity, cleaning efficiency and percentage of brokens were evaluated against different drum types (peg, rasp-bar, rubber-strip), drum speeds (400, 500, 600 rpm), and concave clearances (2.54, 4.40, 6.35 cm). The data were analyzed using the ANOVA, statistical package for the test of significance. The study shows that the peg type cylinder with a speed range of 400-500 rpm and a concave clearance range from 2.54-3.00 cm may be used for developing a threshing unit for a sunflower thresher.

Introduction

The current emphasis on energy conservation and utilization in many countries has prompted agricultural policy makers to reset priorities in agriculture. Consequently, policy makers in most of the developing countries focus interest on the production and processing of oilseed crops like mustard, rape seed, sunflower and soybean. Sunflower is the second leading oil seed crop (after soybean) in the world. The oil content of sunflower is 40% which is highest compared to other oil seed crop. Since 1972, higher sunflower oil prices and the development of hybrids have been generating considerable interest among plantation owners of oil seed crops.

In Pakistan, sunflower was introduced in the late 1960s. Fig. 1 shows the trend in cultivated area and production of sunflower in the country from 1970 to 1987. The year 1980-81 proved to be the turning point in the history of sunflower production in Pakistan, when the area planted to sunflower was about 20 times more than what it was in 1979-80 (Agri.

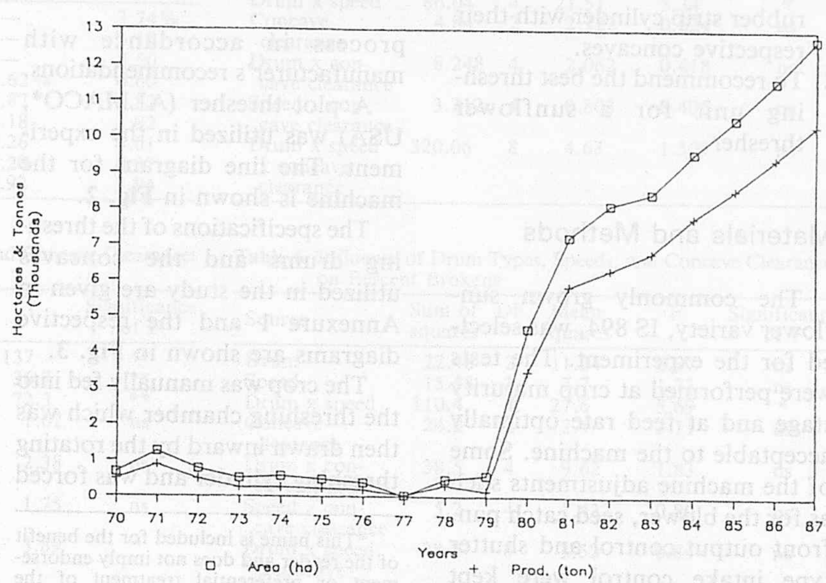

Fig. 1 Area and production of sunflower in Pakistan.

Stat. of Pakistan, 1987). As expected, the production also increased proportionately. This has been made possible largely due to the encouragement and establishment of infrastructure by the government in the Sixth Five-Year Plan, 1983-88.

Sunflower is a short duration crop which matures in a period of 90 to 100 days. The average yield in the country is 6 880 kg/ha. This means that a farmer can expect earning about Rs. 5 000 per hectare in a short period of 3 months (Baig and Nazir, 1982).

The preceding statistics have highlight the importance of sunflower in the national economy as a major source of oil. Its nutritional qualities continue to make its demand grow further. Hence, in order to cope with the increasing production of sunflower, the development of a sunflower thresher has become of paramount importance. The threshing unit plays a key role in determining the performance of a thresher. Therefore, the study was conducted with the following objectives:

1. To asses and evaluate the performance of different types of threshing units, i.e., spike/peg tooth, rasp-bar and rubber strip cylinder with their respective concaves.
2. To recommend the best threshing unit for a sunflower thresher.

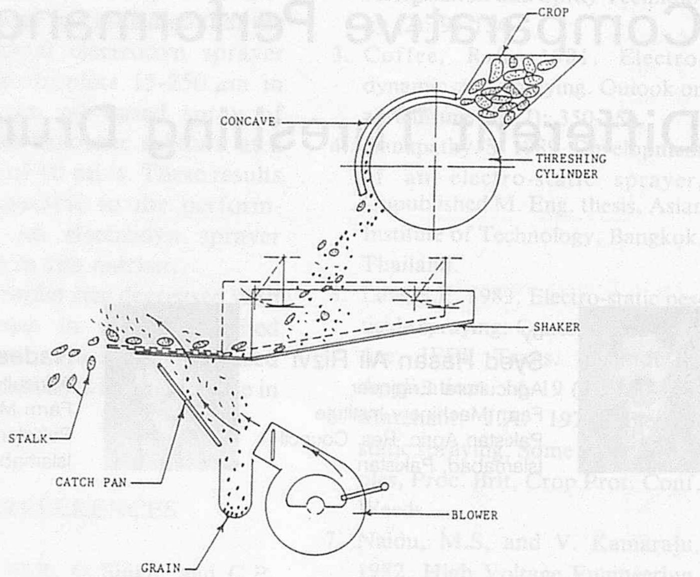

Fig. 2 Line diagram of the thresher.

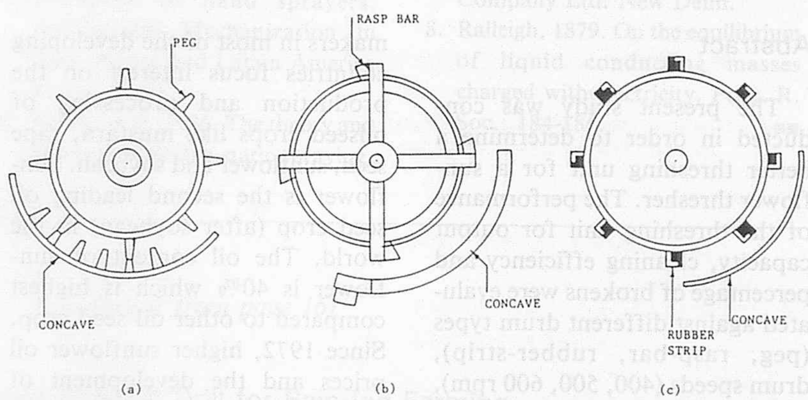

Fig. 3 Drum types and concave used. (a) Peg tooth; (b) Rasp-bar; (c) Rubber strips.

Materials and Methods

The commonly grown sunflower variety, IS 894, was selected for the experiment. The tests were performed at crop maturity stage and at feed rate optimally acceptable to the machine. Some of the machine adjustments such as for the blower, seed catch pan, front output control and shutter type intake control were kept constant throughout the testing process in accordance with manufacturer's recommendations.

A plot thresher (ALMACO*, USA) was utilized in the experiment. The line diagram for the machine is shown in **Fig. 2**.

The specifications of the threshing drums and the concaves utilized in the study are given in Annexure 1 and the respective diagrams are shown in **Fig. 3**.

The crop was manually fed into the threshing chamber which was then drawn inward by the rotating threshing cylinder and was forced against the adjustable over-shot type concave. A rotating straw puller was fitted on the unit to prevent excessive seed rebounding and to assist in material's movement through the machine. The threshed grain and straw were discharged onto a fixed stroke shaker pan where the straw was separated from the grain by the action of the shaker and was moved outward to the rear of the machine. The grains fell through the openings in the tail stream into the adjustable seed catch pan and were then delivered through the seed delivery pan to a catch bucket on the side of the machine.

The following parameters were

*This name is included for the benefit of the reader and does not imply endorsement or preferential treatment of the product by the authors.

varied in the perrformance tests;

1. Threshing drum types: i) peg tooth (PT); ii) rasp-bar (RB); and iii) rubber-strip (RS).
2. Threshing drum speeds: i) 400 rpm (S1); ii) 500 rpm (S2); and iii) 600 rpm (S3).
3. Concave clearances: i) 2.54 cm (C1); ii) 4.40 cm (C2); and iii) 6.35 cm (C3).

A total of 81 different tests were performed. Each test was of 1 min duration. For each threshing performance test, the data for determining the machine output, cleaning efficiency and grain damage was recorded. Machine output was defined to be the weight of total material (W1) collected per unit time at the main grain outlet. Cleaning efficiency was defined to be the weight of whole grain per unit time received at the main grain outlet divided by W1 and was expressed in percent. The grain damage was defined to be the ratio of weight of damaged grain to the sum of weights of the whole and damaged grain collected per unit time at the main outlet, expressed in percent (RNAM Test code 1983).

Results and Discussions

The performance of the thresher for output capacity, broken grain and cleaning efficiency were evaluated against different drum types, speeds and concave clearances. **Tables 1** to 3 summarize the data obtained from the field tests. The data were analyzed using the ANOVA, a statistical package for the test of significance.

Output Capacity

Comparing the performance at a particular set of operating conditions, the cylinder showed the highest output capacity **(Fig. 4)**. The raspbar did not work at 400 rpm with all concave settings. **Table 1** also indicates that the output capacity increased with drum

Table 1 Comparative Mean Output of Drums (Unit: kg/min)

Speed	Concave clearance (cm)	Drum type		
		Peg	Rasp bar	Rubber strip
400	2.54	4.4	—	3.92
	4.4	6.41	—	3.67
	6.35	6.67	—	3.22
500	2.54	5.67	5.41	1.75
	4.4	6.67	5.67	3.63
	6.35	6.92	5.67	3.17
600	2.54	7.12	4.08	4.25
	4.4	7.50	4.87	3.75
	6.35	8.0	4.75	4.75

Table 2 Comparative Mean Cleaning Efficiency of Drums

Speed (rpm)	Concave clearance (cm)	Drum type		
		Peg	Rasp bar	Rubber strip
			%	
400	2.54	75.74	—	59.60
	4.4	64.55	—	74.20
	6.35	69.97	—	60.52
500	2.54	69.94	72.72	72.93
	4.40	70.83	65.30	69.15
	6.35	63.22	70.93	62.00
600	2.54	58.8	78.83	83.02
	4.40	64.53	73.42	71.15
	6.35	60.92	90.63	66.23

Table 3 Comparative Mean Percent Brokens of Drum Type

Speed (rpm)	Concave clearance (cm)	Drum type		
		Peg	Rasp bar	Rubber strip
400	2.54	2.94%	—	3.74%
	4.40	4.25	—	3.10
	6.35	3.23	—	8.50
500	2.54	1.94	4.62%	6.60
	4.40	3.74	4.87	6.82
	6.35	3.78	4.18	3.92
600	2.54	4.17	4.26	4.01
	4.40	2.91	3.20	6.87
	6.35	4.80	3.92	3.94

Table 4 Influence of Drum Types, Speeds, and Concave Clearances on Output Capacity

Source	Sum of squares	DF	Mean squares	F	Significance of F
Drum	220.53	2	110.26	66.14	**
Speed	93.66	2	46.83	7.57	*
Drum x speed	86.04	4	21.51	5.34	*
Concave clearance	4.84	2	2.122	0.624	ns
Drum x concave clearance	8.248	4	2.062	0.418	ns
Speed x concave clearance	3.212	4	0.803	0.406	ns
Drum x speed x concave clearance	320.06	8	4.63	1.509	ns

Table 5 Influence of Drum Types, Speeds, and Concave Clearances on Cleaning Efficiency

Source	Sum of squares	DF	Mean squares	F	Significance of F
Drum	5 941.4	2	2 979.7	137	**
Speed	11 495.4	2	5 747.7	36.7	**
Drum x speed	22 606.2	4	5 651.5	72.3	**
Concave clearance	196.3	2	98.16	1.02	ns
Drum x concave clearance	798.7	4	109.6	2.38	ns
Speed x concave clearance	244.4	4	61.1	1.75	ns
Drum x speed x concave clearance	1 232.3	8	154.0	3.89	*

Table 6 Influence of Drum Types, Speeds, and Concave Clearances on Percent Brokens

Source	Sum of squares	DF	Mean squares	F	Significance of F
Drum	22.48	2	11.24	0.87	ns
Speed	15.58	2	7.7	1.73	ns
Drum x speed	110.4	4	27.6	5.69	*
Concave clearance	24.9	2	12.4	3.11	ns
Drum x concave clearance	38.5	4	9.62	1.83	ns
Speed x concave clearance	5.2	4	1.43	0.80	ns
Drum x speed x concave clearance	28.2	8	3.52	0.84	ns

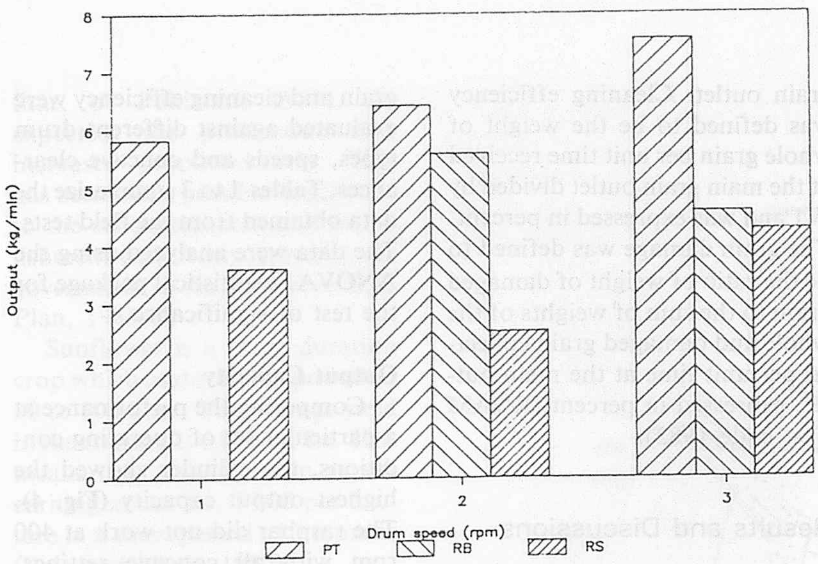

Fig. 4 Effect of drum speed on output capacity of threshing unit.

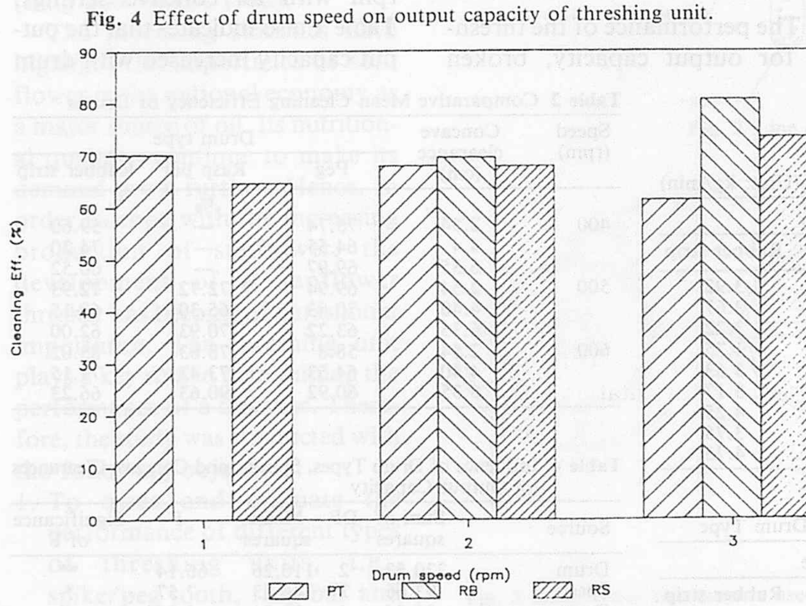

Fig. 5 Effect of drum speed on cleaning efficiency of threshing unit.

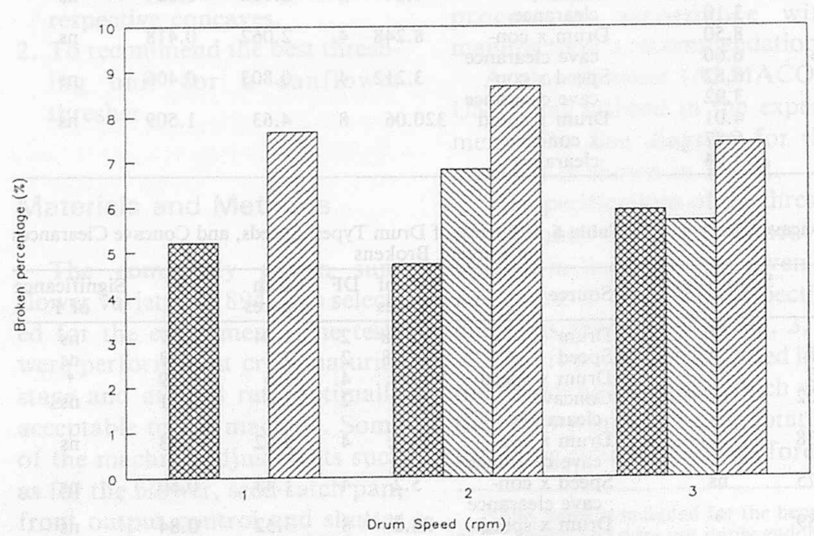

Fig. 6 Effect of drum speed on grain breakage of threshing unit.

speed and concave clearance with peg type, but this trend was not found in the other two drum types. The type and speed of the drums tested were significant ($p<.05$) affecting the output of thresher **(Table 4)**. The concave clearance by itself and in relation with speed and type of drum had no effect on output. The least significant difference (LSD) test also showed that the peg and rasp-bar are significantly different ($p<.05$) from the rubber-strip. The maximum output (422 kg/h) was recorded with PT at C2 and S3 settings. The minimum was with RS at C1 and S1.

Cleaning Efficiency

Table 2 shows that the performance of peg was better than the rasp-bar and rubber strip at a lower drum speeds. However, the trend was not consistent at high speeds **(Fig. 5)**. The statistical analysis shows significant differences in cleaning efficiency of the threshing unit with the type and speed of the drums **(Table 5)**. The drum and speed interaction was also highly significant. The concave clearance and its interaction with drum and speed showed no effect on cleaning efficiency. The best results for cleaning efficiency (79%) were observed with RB at C3 with S3.

Percent Brokens

The component of grain damage was highest for the rubber-strip, followed by rasp-bar and peg **(Table 3)**. For the peg type, as the speed increased the percentage of broken grain increased. But in case of the rubber strip percent brokens increased at 500 rpm but again decreased at a higher speed. The same was true for the rasp-bar **(Fig. 6)**. The type of the drums, relative speeds of the drums and concave clearances failed to show significant effect on grain breakage **(Table 6)**.

However, the speed and drum, in combination, did influence the breakage of the grains. Maximum breakage (6.5%) was observevd in Rs at C2 with S1 and S3. The lowest values were recorded with PT at C1 with S1 and S2.

Summary and Conclusion

1. The drum types influenced the output capacity of the thresher and the peg cylinder had the best output and the least breakage of grains.
2. The lowest output was observed at 400 rpm for the peg cylinder, but the same was not true for the rasp-bar and rubber-strip. Cleaning efficiency was better at 600 rpm with the peg type.
3. The concave clearances had no significant effect on output and cleaning efficiency of the threshing unit. But the mean values showed better performance at 6.35 cm opening, both for the cleaning efficiency and percent brokens in all types of drums.
4. The peg cylinder has showed the highest cleaning efficiency and the least percentage brokens at 400 rpm with 2.54 cm concave clearance.
5. The rasp-bar cylinder performed satisfactorily throughout the test with the 6.35 cm concave setting and 500 rpm of the drum, except for cleaning efficiency which was better at 600 rpm.
6. The rubber-strip cylinder showed the best results for output and percent brokens at 6.35 cm concave setting with 600 and 500, rpm, respectively. However, the cleaning efficiency was relatively good at 2.54 cm with 600 rpm.

Recommendation

It is recommended that the peg type cylinder, with a speed range from 400-500 rpm and the concave clearance range from 2.54-3.00 cm may be used for developing a threshing unit for sunflower variety thresher.

Annexure 1

Specifications

1. Threshing drum
   Peg/rasp-bar/rubber-strip
   (i) Type
   A. Peg: Pegs of equal length are attached on the periphery of the cylinder in tandem fashion.
   B. Rasp-bar: Equidistant stationary bars built on the periphery of cylinder in parallel orientation.
   C. Rubber-strip: Rubber strips are fixed equidistant in parallel orientation.
   (ii) Diameter: 43.2 cm
   (iii) Length: 56 cm
   (iv) Speed: 400-1 500rpm
   (v) Peripheral speed: 9-34 m/sec
   (vi) No. of peg/rasp/strips: 75/4/8
2. Concave
   (i) Type and material: Peg/Rasp/Rubber cast, mild-steel & rubber
   (ii) Recommended concave clearances: Not specified
   (iii) Method of clearance adjustment: Adjustment lever and locking screws

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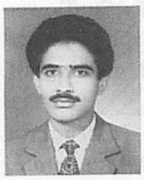
Design and Development of A Grain Dryer Using Sand as Heat Medium

by



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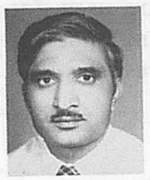

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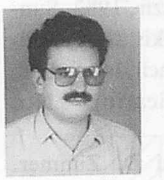

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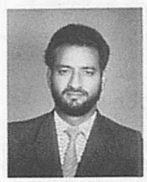

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Abstract

The increasing population rate in Pakistan demands saving of agricultural products for a longer period. Grain crops are considered as food and cash crops. Food, fibre and shelter are the main necessities of life. Food grains represent most of the food crops. Therefore, due attention is required in saving the grains after harvest. As high as 20% losses have been recorded during sun-drying and storage of grains. To avoid such a big loss, a grain dryer was designed which can save drying and storage losses. Drying of grains using this dryer is easy and time saving. The moisture removed by this dryer is proportional to the initial temperature of heat transfer medium (sand). Moreover, moisture removal rate and the drying efficiency of this dryer is maximum at 6.0 sand-to-grain-mass-ratio (SGMR).

Introduction

In underdeveloped countires, priority is normally given to crop production efforts but not to handling the crops after harvest. Much of the waste and loss of foodgrains takes place after harvest, i.e., storage due to fact that the freshly harvested crops are more susceptible to insect attack because of high moisture content on grains when stored.

Generally, grain crops are harvested at moisture content levels ranging from 15 to 30% wet basis (w.b.). If the grains are not dried to about 12 to 13% moisture content level (w.b.), favourable conditions will be available for the development of molds and fungus during storage which cause the deterioration of quality of the product (Noomhorm, 1986).

There is a sizable loss of grain every year due to storage of grain at high moisture content (Brooker et al., 1974). Hence, grains must be dried to proper moisture content level to prevent deterioration. In order to maintain quality in storage, the crop must either stand longer in the field or it must subsequently be dried. If the crop is allowed to stand longer in the field, there is a considerable risk of grain damage by wind, hail storm, heavy rains and birds. It also places time constrains for agricultural operations such as post-harvest tillage for the next crop. The traditional method of drying threshed grains in Pakistan is to spread the grain in the sun. This method is only applicable in dry weather and requires sufficient dry area exposed to the sun and adequate available labor for spreading, stirring, tending and collecting the grains. Small quantities of threshed grains are also spread on woven mats. Large lots are spread on drying floors of different types. A report based on the work done at the University of Agriculture, Faisalabad (Chaudhry, 1970) shows that about 3.2% losses occur during floor-drying of corn. Mphuru (1982) cites an average of 20% post-harvest losses for most grains. This necessitates proper measures to reduce these losses.

At present, few dryers using hot air as heat and moisture transfer medium are reported in Pakistan. But air drying has been described as an inefficient process (Foster, 1973).

In view of the foregoing, a prototype of a simple grain dryer employing sand as heat transfer medium was designed and developed. The dryer is technically suitable and economically feasible.

Granular texture of sand permits uniform heat transfer to grain kernels by conduction. Sand possesses semi-fluid characteristic which facilitates easy separation from grain during the drying process. The heat transfer associated with contact between sand particles and grain kernels enhances the drying rate (Mittal and Lapp, 1984). Heat energy from the sand mass is transferred directly from the surface of sand to the surface of grain.

Design and Development of Dryer

The machine (**Fig. 1**) which is the subject of this report was fabricated from locally available materials. A brief description of the major parts comprising the dryer is given below:

The main component of the dryer is a rotary cylinder 61 cm in diameter and 76 cm long, made of 15 gauge M.S. sheet. A helix made of 18 gauge M.S. sheet is welded inside the drum for conveying and mixing the hot sand and grain. The development of the helix is shown in **Fig. 2**.

A conical feeding end of the cylinder facilitates the pouring of grain into the cylinder. The conical mouth of the cylinder has 30.5 cm diameter. At the exit end of the cylinder access ports were provided for discharging sand-grain mixture after the drying operation.

A cast iron stand was used for mounting the drum, electric motor and other accessories. A rotating shaft, 3.175 cm in diameter, that passes through the drying drum is supported by two UDC 206 ball bearings at its two ends. A 950 rpm, 1 HP electric motor was installed to rotate the cylinder a thorough matched pair of step pulleys and a V-belt.

Speed Reduction Mechanism

First reduction in speed was done with the use of step pulleys having diameters of 5.40, 7.94 and 10.64 cm mounted on the shaft of the motor. Another set of pulleys with diameter of 13.00, 14.48 and 7.96 cm are mounted on the shaft of the worm. A single thread worm with 10 mm pitch and a worm wheel with 44 teeth was used to obtain second reduction in speed. With these arrangements the rotational speeds of the cylinder could be adjusted at 11, 14, 18, 23 and 28 rpm.

Two cast iron spur gears, each with 104 teeth and 9 mm pitch were used to transmit the drive from the worm wheel to the drying cylinder. These gears provided positive power transmission system.

Operation

Two men, one for pouring the hot sand and the grains into the drum and the other for sieving and handling the dried grains were required to operate the machine. The required quantity of sand was heated to the desired temperature. As soon as the desired temperature of sand was reached, it was transferred quickly into the rotating drum. A temperature drop during transfer of hot sand into the drum was compensated by heating the sand a little more than the required drying temperature.

After the heated sand was transferred to the cylinder, a weighed sample of grains, according to sand grain ratio, was poured quickly into the cylinder to move the mixture of grains and the hot sand within the rotating cylinder towards the exit end. As soon as the mixture of sand and grains was discharged by the dryer, the grains were separated from the sand by a sieving process. Block diagram of the drying system is shown in **Fig. 3**.

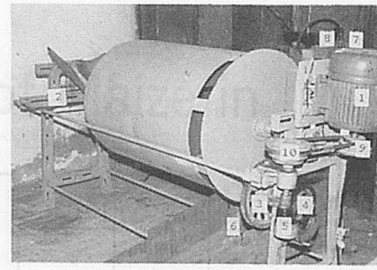

Fig. 1 Grain dryer. ① Electric motor; ② Iron stand; ③ Spur gear; ④ Worm wheel; ⑤ Worm; ⑥ Sieve; ⑦ Gas meter; ⑧ Sand heating pan; ⑨, ⑩ Step pulleys.

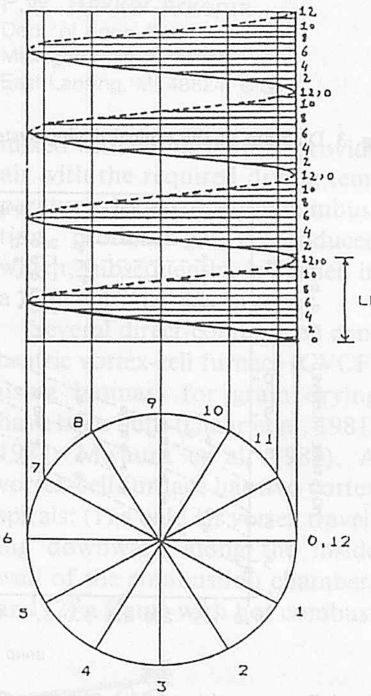

Fig. 2 Development of helix.

Fig. 4 shows that the percent moisture removed is proportional to the initial sand temperature. Moreover, the reduction in moisture content of the grain increased up to a 6.0 sand-to-grain-mass-ratio (SGMR) and a decreasing trend was shown when the SGMR were higher than 6.0.

Fig. 5 also shows that an SGMR of 6.0 gave higher drying efficiencies at all initial temperatures of the sand. The lowest drying efficiency was 34.40% for

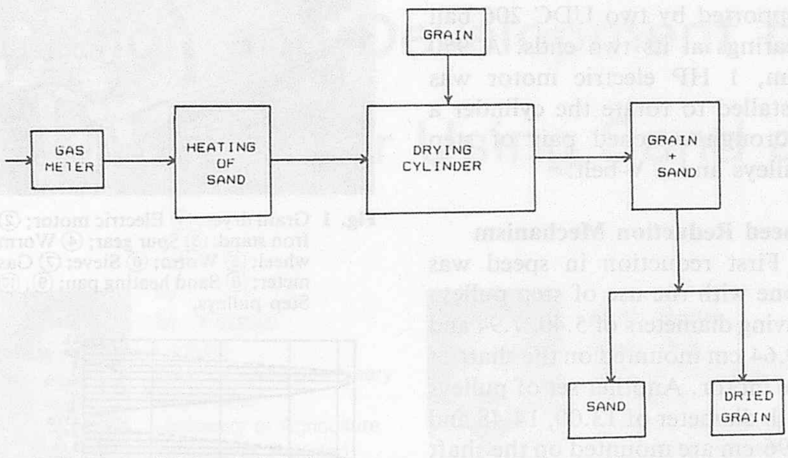

Fig. 3 Diagram of the typical drying system.

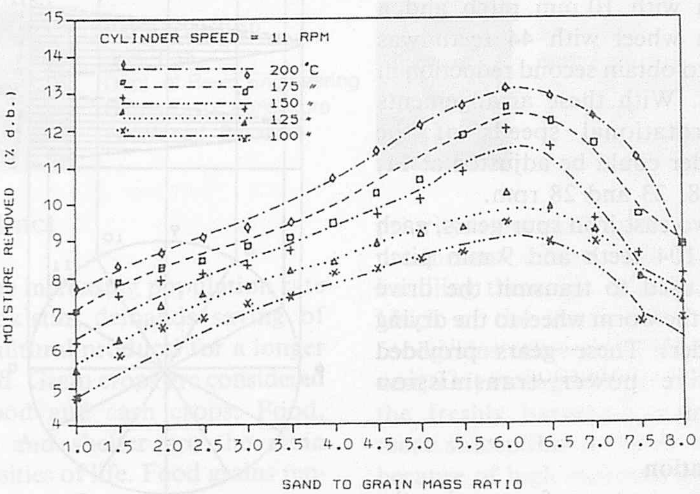

Fig. 4 Percent moisture removed from corn at different SGMR and sand temperatures.

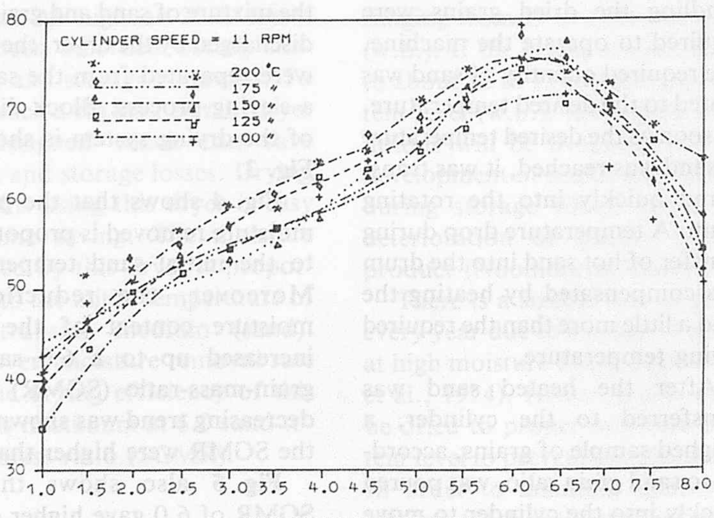

Fig. 5 Percent drying efficiency of corn at different SGMR and sand temperatures.

an initial sand temperature of 100 °C and 1.0 SGMR whereas 79.85% efficiency was obtained with initial sand temperature of 200 °C and a 6.0 SGMR.

Drying of grains by this method was found easy and time-saving. Drying by a traditional method requires large open spaces for spreading the grains for sun drying, causes grain losses and needs more time for achieving the desired moisture level of grains for storage. The grain dryer developed and reported in this paper offers attractive features to grain farmers.

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Performance Evaluation of Drying of Maize in An In-bin Counterflow System Using Biomass Energy

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Abstract

Approximately 140 t of wet maize was dried during the testing of the concentric vortex-cell furnace/in-bin counterflow drying system. The results demonstrate that the CVCF biomass is a technically viable alternative to conventional fossil fuels. The drying capacity of the CVCF/IBCF system is 90% of the LP fueled system. The CVCF/IBCF system operates at about 70% efficiency in converting biomass into energy for grain drying. A CVCF simulation model was used to analyze the effect of different operating conditions. Ambient temperature, feed moisture and excess air are factors which most affect the system efficiency.

Introduction

Energy is an important input in agricultural crop production systems. Of the total energy used for maize production, 33% is used in the United States for maize drying (Nelson et al., 1974). Nearly all high-temperature on-farm dryers use liquid propane or natural gas. Fossil fuels have increased in costs during the past decade and are expected to decrease in availability in the future. Agricultural crop residues and biomass crops are viable energy sources because they are readily available and renewable.

Incineration of biomass for grain drying requires a well-designed furnace to ensure complete combustion. Incomplete combustion may cause undesirable odors, discoloration and crop contamination if direct heating of the air is used (Anderson et al, 1981).

Two main categories of combustion are found: direct combustion and gasification combustion. In direct combustion, the energy from the burned biomass is transmitted to an airsteam which is mixed with ambient air to provide air with the required drying temperature. In gasification combustion, producer-gas is produced which, subsequently, is burned in a conventional gas heater.

Several direct-combustion concentric vortex-cell furnace (CVCF) using biomass for grain drying have been built (Claar et al, 1981, 1987; Mwaura et al, 1989). A vortex-cell furnace has two vortex spirals: (1) a cold air vortex traveling downward along the inside wall of the combustion chamber, and (2) a flame with hot combus-

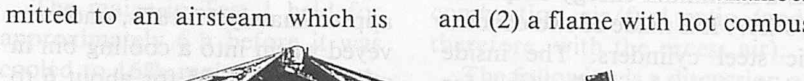

Fig. 1 Cut-away portions of the in-bin maize dryer.

tion products traveling upward in an inner spiral at the center of the combustion chamber. The vortices cause thorough mixing of the air with the volatile gases to increase the combustion rate and the completeness of combustion.

This paper discusses the drying of maize in an on-farm, in-bin dryer using a CVCF biomass furnace (**Fig. 1**). The furnace has been integrated into a commercial in-bin counterflow (IBCF) maize-drying system. The effects of various operating conditions on the performance of the system are determined. A simulation model was employed for an in-depth analysis of the system.

The Experiment

Fig. 2 is a schematic presentation of the CVCF/IBCF system. Details of the MSU CFCF furnace are described in Mwaura et al (1982). The furnace is 1.2 m in diameter and 3.7 m in height, and has a maximum energy output of 690 kW. It is made of two concentric steel cylinders. The inside cylinder is lined with firebricks for insulation.

The drying system consists of an in-bin counterflow drying system manufactured by Shivvers Inc., Corydon, IA. The drying bin and the final-drying/cooling bin are both 5.5 m in diameter and 3.7 m in height. The grain depth varied during each test since grain was removed continuously from the bottom of the grain bed. In a IBCF drying system, wet grains are loaded into the drying bin while hot air is forced through the perforated floor. A temperature-sensing element controls the activation of the sweep auger. As drying progresses, less evaporation occurs in the bottom layer and the drying air temperature increases at the sensing point. When activated, the tapered sweep auger makes one complete sweep around the bin, removing a layer (13-18 cm) of dried maize. The wet grain above moves down and the process is repeated.

Employed as fuels were wood chips at 14, 19 and 45% moisture content (w.b.), and maize cobs at 10 and 12%. Shelled maize was dried from different initial moisture contents (22-27%) to approximately 17-18%, and conveyed warm into a cooling bin in which it was held for about 6 to 12 h before cooling to ambient at a low airflow rate (0.5-1.0 m^3/min-m^2). The moisture content of the grain after the cooling process varied from 14 to 16%. The airflow rate in the drying bin varied from 11 to 13 m^3/min-m^2 depending on the height of the grain bed; the drying air temperature was 65 to 94°C.

The maize and fuel moisture contents were determined using the standard oven methods (ASAE 1984). The energy input to the furnace was calculated by multiplying the fuel feed rate (kg/h) by the heating value of maize cobs and wood chips (Claar et al, 1980; Holmes, 1978).

Results and Discussion

Experimental Results

Tables 1 and **2** show the experimental results. The ambient conditions, drying conditions, fuel moisture content, furnace heat loss and the experimental and minimum fuel feed rates are listed for seven tests in **Table 1**. The minimum fuel feed-rate is defined as the rate at zero heat loss from the furnace/drying system. **Table 2** presents the drying rates and energy consumption rates.

In Test 1, maize was dried from an initial moisture content of 26.2% to an intermediate moisture

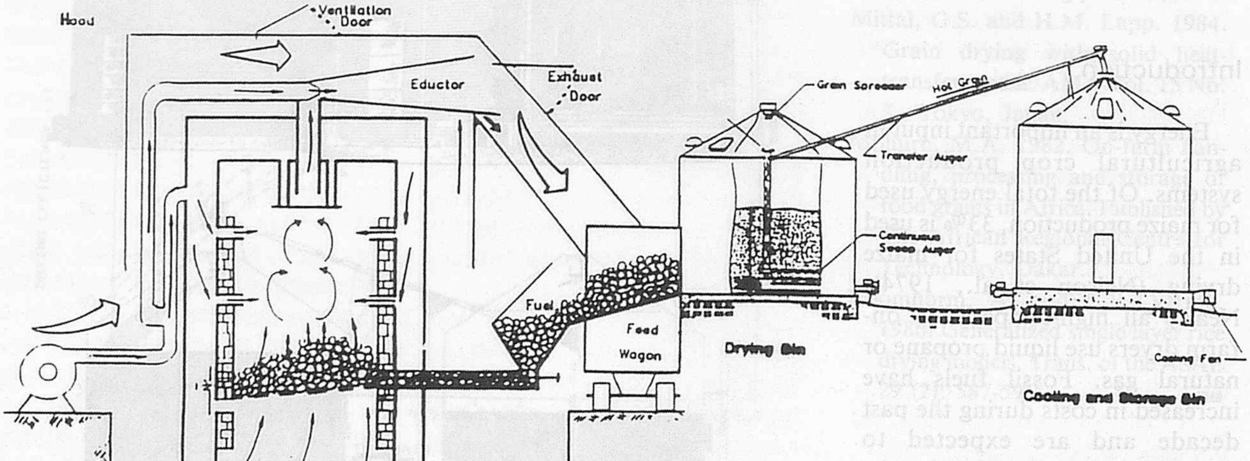

Fig. 2 Schematic diagram of the CVCF/IBCF drying system.

Table 1 Experimental Fuel Consumption Rates, Heat Loss and Furnace/System Efficiency at Different Ambient Conditions and Different Drying air Temperatures for a CVCF/IBCF System Drying Maize

Test No.	Average ambient conditions		Experimental drying conditions			Fuel*	Furnace heat loss	Fuel feed rate	
	Temp. (°C)	RH (%)	Temp. (°C)	Airflow (kg/h)	Energy (MJ/h)	MC (%)	(MJ/h)	Exp. (kg/h)	Min.+ (kg/h)
1	12.4	84	77	18781	1213	14.6-W	422	85	78
2	13.5	100	89	19450	1468	14.6-W	556	110	82
3	2.0	76	78	18868	1434	12.1-C	664	115	87
4	5.8	70	88	17639	1450	12.1-C	524	100	88
5	0.9	87	82	18256	1513	19.3-W	499	120	89
6	13.3	90	93	15828	1261	10.1-C	540	100	75
7	0.6	93	82	16879	1374	45.0-W	810	178	119

* W = wood chips, C = maize cobs
\+ Minimum = theoretical fuel consumption at zero heat loss

Table 2 Actual Drying Rates and Energy Consumption Rates for Tests 1-7 Given in Table 1 for a CVCF/IBCF System Drying Maize

Test No.	Moisture content* (% w.b.)			Fuel feed rate**	SECO*** ($kJ/kg\text{-}H^2O$)		Drying capac.	Efficiency+ (%)	
	In	Int	Fi	(kg/h)	H	AC	(t/h)	F	S
1	26.2	18.8	16.0	85-W	5092	3821	2.7	94	74
2	23.5	17.0	14.1	110-W	7703	5461	2.5	95	75
3	22.6	16.5	14.4	115-C	9169	6992	2.2	95	75
4	22.2	14.2	14.2	100-C	6672	6672	2.4	96	73
5	26.4	16.7	15.9	120-W	6668	5422	2.0	96	75
6	25.8	14.7	13.1	100-C	5555	4946	1.8	95	71
7	27.4	14.6	14.6	178-W	6287	6287	1.5	97	77

* In = initial; Int = intermediate; Fi = final
** W = wood chips: C = maize cobs
*** SECO (net specific energy consumption); H = heating; AC = after cooling
\+ simulated efficiency: F = furnace; S = system

content of 18.8% in the high-temperature IBCF and dumped hot (about 60°C) in the dryeration bin.

Also, in Test 1, the in-bin counterflow drying system was operated at bed depth of 2.0 m and an airflow rate of 12.7 kg/h. The initial moisture content was 26.2%, the intermediate, 18.8%; and the final 16.0%. The drying temperature was 77°C; the ambient temperature, 12.4°C. The minimum energy input was calculated to be 1,213 MJ/h (not including the heat losses). The experimental energy requirement was 1,635 MJ/h. Thus, the heat losses are equal to 422 MJ/h. The furnace/dryer system efficiency was, therefore, 74% (100 × 1213/1635). Using a heating value of 20.97 MJ per kg of 14.6% moisture content wood chip, the theoretical fuel feed-rate is 83 kg/h and the experimental feed rate is 85 kg/h of wet wood chips. The conditions for the other tests have been likewise evaluated.

The maize in Test 1 held for approximately 6 h before it was cooled to 16% moisture content. During Tests 4, 6, and 7 the maize was dried directly to the final moisture contents in the IBCF system.

The specific energy consumption (SECO, kJ/kg of water removed) varied from 5,092 to 9,169. The average net SECO of the biomass fueled system is about 6,700 kJ/kg compared to 4,700 kJ/kg for the same system fueled by propane (Silva, 1980). The difference is due to the heat losses from the furnace and from the duct linking the biomass furnace to the dryer.

The average drying capacity in the temperature range of 77 to 92°C for the seven tests was 2.2 wet ton per h in drying from 25% to 15% moisture. The drying capacities for Tests 6 and 7 were lower than for the other tests because the maize was dried to a lower moisture content in the high-temperature phase. If Tests 6 and 7 are excluded, the average capacity of the CVCF/IBCF drying system is 2.4 wet t per h. This compares with a capacity of the IBCF propane-fueled system of 2.6 wet t per h in drying from 26% to 17% at a drying temperature of 71°C (Silva, 1980). Thus, there appears to be a small loss in drying capacity when the IBCF is operated with biomass fuel. The decrease in dryer throughput is due to a reduction in airflow because the air is heated before it enters the fan rather than after the fan as is the case in a fossil-fueled burner.

System Performance

The fuel consumption rate depends on the heat required to raise the drying air from ambient to the drying temperature, on the heat losses from the system, on the fuel heating value, and on the fuel moisture content. The fuel consumption varies slightly with the combustion air/fuel ratio (and, therefore, with the excess air).

The following is a discussion of the effect of ambient temperature, feed moisture content and excess air on the system performance. The results are obtained by applying the simulation model of the CVCF/IBCF system developed by Mwaura (1984). The reader is referred to Mwaura (1984) for details on the simulation program.

Effect of ambient temperature—The fuel feed rate, heat loss and the furnace/dryer efficiency at varying ambient temperature, at a constant drying air temperature of 80°C, are presented in **Fig. 3**.

The heat loss from the furnace/dryer system increases linearly with a decrease in ambient temperature. A 1°C decrease in ambient temperature results in an average increase of 7.5 MJ/h in heat loss. The fuel feed rate increases by approximately 2 kg/h (equivalent to 33.5 MJ/h). Therefore, the increase in energy input in the form of fuel is higher than the increase in the heat loss. The increase in the fuel consumption is mainly due to the energy required in heating the drying air from a lower ambient temperature. Additional energy is utilized in preheating the combustion air and the fuel. The energy required to counterbalance the heat loss is approximately 22% of the total fuel rate consumption increase.

The heat loss varies from 377 to 482 MJ/h when the ambient temperature decreases from 14 to 0°C. According to Silva (1980), the heat loss from the IBCF drying system is 351 MJ/h at an ambient and drying temperature of 10 and 71°C, respectively, with a system efficiency of 71%. The simulated heat loss from the entire CVCF/IBCF system is 403 MJ/h at an ambient and drying temperature of 10 and 80°C, respectively, with a system efficiency of 75%.

The furnace and the system efficiencies are nearly constant for the temperature ranges shown in **Fig. 3**. The furnace efficiency is 95.9% at 0°C and 95.7% at 14°C. The system efficiency varies from 75% at 0°C to 74.2% at 14°C. The change is due to the fact that

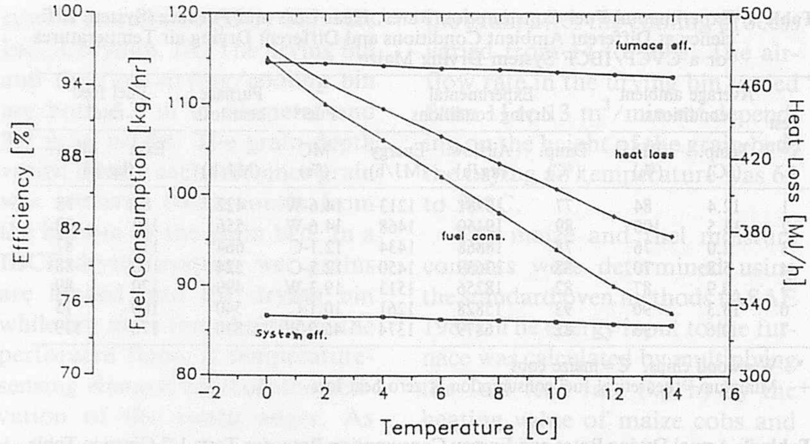

Fig. 3 Effect of ambient temperature on the fuel consumption, furnace and system efficiency, and heat loss from the CVCF/IBCF drying system (drying air temp = 80°C, drying airflow = 12.3 m^3/min-m^2, ambient relative humidity = 75%).

the drying temperature is constant and, therefore, the heat loss increase is compensated by an increase in the fuel feed rate. The furnace efficiency is approximately 95% for the conditions shown in **Fig. 3**. Thus, the furnace heat loss is only 5% of the total heat loss.

Effect of fuel moisture on fuel consumption—The moisture content of the fuel greatly influences the performance of the CVCF and the required fuel consumption rate at a specific heat output. The moisture in the fuel reduces the net heating value of the fuel and the flame temperature, and, therefore, results in a high fuel consumption. Incomplete combustion is an additional undesirable effect of low flame temperature.

Figs. 4, 5 and **6** present the simulated fuel consumption rate, furnace/drying system temperatures and efficiencies when employing wood chips at different moisture contents and different drying air temperatures. The simulations are based on an airflow rate of 13 m^3/min-m^2, and an ambient temperature of 4°C.

Fig. 4 shows the fuel consumption rate for different fuel moisture contents at three drying temperatures. The fuel feed rate increases exponentially with the fuel moisture content due to the reduced dry matter of the fuel, and the extra energy required to

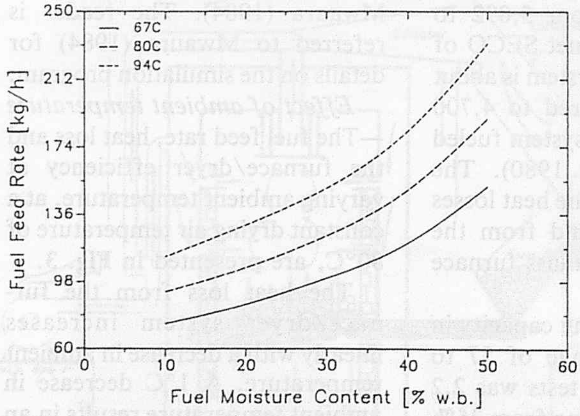

Fig. 4 Fuel feed rate (kg/h) as a function of fuel moisture content (% w.b.) and drying air temperature (ambient temp = 4°C, airflow rate = 13 m^3/min-m^2).

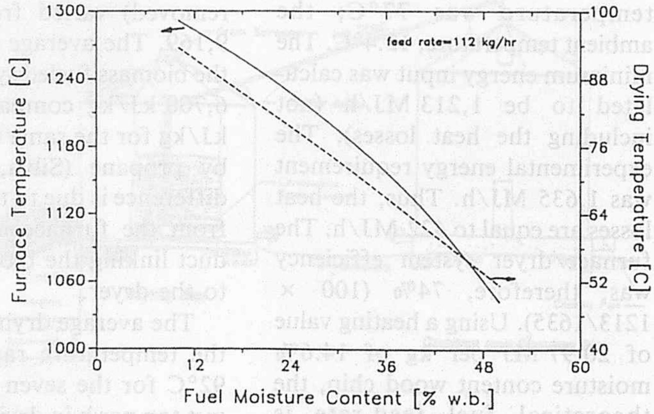

Fig. 5 Furnace temperature and drying temperature as a function of fuel moisture content (% w.b.) (ambient temp = 4°C, airflow rate = 13 m^3/min-m^2).

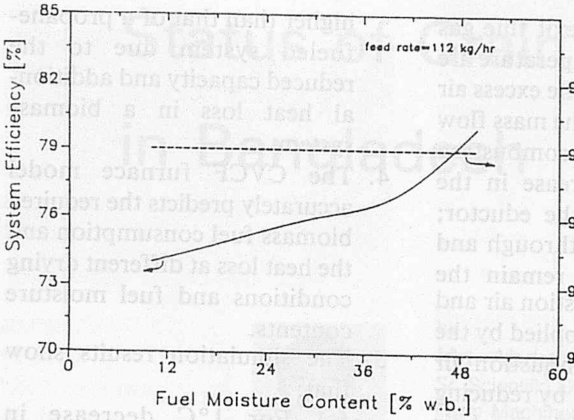

Fig. 6 Furnace and system efficiencies as a function of fuel moisture (% w.b.) content (ambient temp = 4°C, airflow rate = 13 m^3/min-m^2).

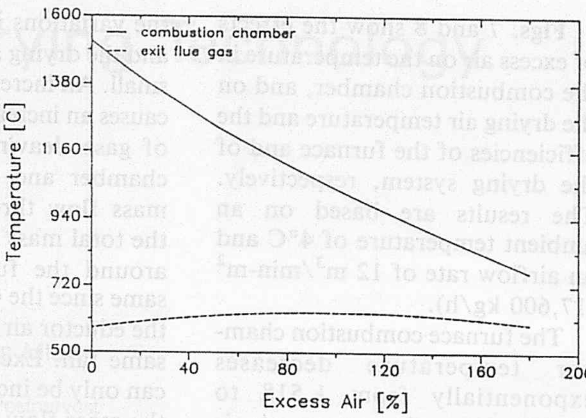

Fig. 7 The effect of the excess air on the temperature in the combustion chamber and on the temperature of the exit flue gas (ambient temp = 4°C, airflow rate = 12.5 m^3/min-m^2).

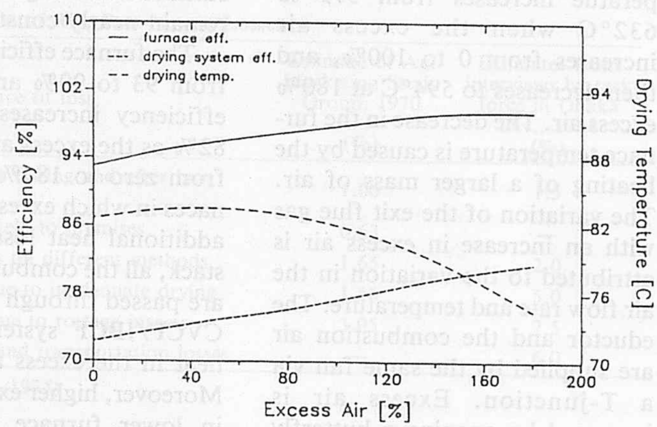

Fig. 8 The effect of the exces air on the furnace efficiency, system efficiency and drying air temperature (ambient temp = 4°C, airflow rate = 12.5 m^3/min-m^2).

evaporate the moisture from the fuel. The increase in the fuel dry matter feed rate at a constant drying air temperature is relatively small compared to the increase in the wet fuel feed rate. At a constant drying air temperature of 67°C, the wood chips dry matter consumption increases from 67 kg/h (at 10% moisture) to 76 kg/h (at 50% moisture).

Fig. 5 illustrates the effect of the fuel moisture content on the furnace performance at a constant fuel feed rate of 112 kg/h. For every 10% increase in the fuel moisture content, the furnace temperature decreases an average of 62°C, and the drying air temperature 11°C. This is due to the decrease in the fuel heating value since higher moisture fuel contains less dry matter and, therefore, less net energy than the same quantity at a lower moisture fuel.

Fig. 6 shows that the furnace efficiency remains constant, but the system efficiency inccreases (at constant feed rate) with an increase in the fuel moisture content. The duct heat losses decrease at high fuel moistures since the drying (and, therefore, the duct) temperature decreases. The increase in the system efficiency is 6% when the fuel moisture content increases from 10 to 50%.

Effect of excess air on furnace performance—Excess air is the quantity of the combustion air in excess of the stoichiometric air required for complete combustion. Some excess air is necessary in biomass furnaces to ensure complete fuel combustion (Babcok and Wilcox, 1978; Buchele et al, 1981). If the combustion air is limited to the stoichiometric quantity, incomplete combustion may result due to the lack of thorough mixing of the fuel and the air. High moisture fuels require high levels of excess air prior to combustion (Tillman et al, 1981).

An excessive amount of air slows down the combustion reaction by excessive cooling of the combustion chamber in the furnace. More importantly, the excess air increases the pressure in and the mass flow from the combustion chamber. This results in backfiring of the feed system and in an increase of the furnace gas velocity. Unburned entrained materials are carried out of the furnace into the drying bin under such conditions (Mwaura, 1984).

In the MSU CVCF biomass furnace, the combustion and the educt (i.e., a jet pump in which a high velocity fluid is forced through the nozzle) air are supplied by the same fan. Increasing the excess air reduces the educt air flow. Consequently, the eductor develops less vacuum in the chamber, causing backfiring and smoke-escape through the feed hopper.

Figs. 7 and 8 show the effects of excess air on the temperature in the combustion chamber, and on the drying air temperature and the efficiencies of the furnace and of the drying system, respectively. The results are based on an ambient temperature of 4°C and an airflow rate of 12 m^3/min-m^2 (17,600 kg/h).

The furnace combustion chamber temperature decreases exponentially from 1,518 to 763°C when the excess air is increased from zero to 180% (Fig. 7). The exit flue gas temperatue increases from 579 to 632°C when the excess air increases from 0 to 100%, and then decreases to 594°C at 180% excess air. The decrease in the furnace temperature is caused by the heating of a larger mass of air. The variation of the exit flue gas with an increase in excess air is attributed to the variation in the air flow rate and temperature. The eductor and the combustion air are supplied by the same fan via a T-junction. Excess air is increased by opening a butterfly valve. An increase in the combustion air flow results in a decrease in the flow rate and vice versa. If the combustion airflow increases (with an increase of excess air), the temperature of the flue gas existing in the combustion chamber decreases. However, the mass flow rate of the flue gases increases.

The drying air temperature varies directly with the exit flue gas temperature if the ambient temperature remains constant (Fig. 8). Therefore, the curve of the drying air temperature versus the percentage excess air has a similar shape as the exit flue-gas temperature curve. The drying air temperature decreases faster than the exit flue-gas temperature (excess air greater than 100%) due to the heat losses between the furnace and the drying bin.

Fig. 7 and 8 also indicate that the variations in the exit flue gas and the drying air temperature are small. An increase in the excess air causes an increase in the mass flow of gases leaving the combustion chamber and a decrease in the mass flow through the eductor; the total mass flows through and around the furnace remain the same since the combustion air and the eductor air are supplied by the same fan. Excess combustion air can only be increased by reducing the mass flow. Since the total air flow through the furnace remains constant, the drying air and the furnace exit flue gas temperatures remain nearly constant.

The furnace efficiency increases from 93 to 99% and the system efficiency increases from 72 to 82% as the excess air is increased from zero to 180%. Unlike furnaces in which excess air results in additional heat loss through the stack, all the combustion products are passed through the grain in a CVCF/IBCF system. Thus, the heat in the excess air is utilized. Moreover, higher excess air results in lower furnace temperatures, and, subsequently, in reduced radiation and convective heat losses from the furnace.

A 50% excess air was used in simulating the furnace performance. The 50% excess air is equivalent to an air/fuel ratio (dry basis) of 9.5 for wood chips and 8.3 for maize cobs.

Conclusions

1. The concentric vortex-cell biomass furnace is a technically viable alternative to propane for grain drying.
2. The drying capacity of a CVCF/IBCF grain dryer is about 90% of a propane-fueld IBCF system.
3. The average net specific energy consumption of a CVCF/IBCF system is about 30% higher than that of a propane-fueled system due to the reduced capacity and additional heat loss in a biomass system.
4. The CVCF furnace model accurately predicts the required biomass fuel consumption and the heat loss at different drying conditions and fuel moisture contents.
5. The simulation results show that:
   - 5.1. For 1°C decrease in ambient temperature, the energy input is about four times higher than the increase in the heat loss of the system. The system efficiency is not greatly affected by a change in the ambient temperature.
   - 5.2 For every 10% increase in the fuel moisture content, the furnace temperature decreases by about 60°C, and the drying air temperature by 10°C. The increase in the system efficiency is 6% when the fuel moisture increases from 10 to 50%.
   - 5.3 The furnace combustion chamber temperature decreases exponentially when the excess air is increased from 0-180% while the exit flue gas temperature first increasing and then decreasing; the system efficiency increases from 72 to 82% with an increase in excess air from 0 to 180%.

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(Continued on page 41)

Status of Grain Drying Technology in Bangladesh

by
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Introduction

Bangladesh is an agricultural country. About 10.5 million ha land is used for rice cultivation and the annual production amounts to nearly 16 million tones of rice. The country is not self-sufficient in food and the shortfall can reach up to 2 million tons in a bad-weather year. Bangladesh has a humid tropical climate and experiences three clearly defined seasons in a year, namely; winter (Nov. to Feb.), summer (March to May) and the monsoon or rainy season (June to October). The average annual rainfall is about 1900 mm. The average lowest rainfall is 1198 mm, and the highest 5644 mm. During the monsoon period, the intensity of rainfall is high and the relative humidity is also very high which ranges from 70-90%.

In Bangladesh the harvesting period of Boro is April to May, Aus is August to September and Aman is November to December. The wheat harvesting period is April to May. The production and post-production processes are traditional with the possibility of large grain losses (both quantitative and qualitative) from harvest to storage. Post-harvest losses of paddy is estimated to be as high as 22% (**Table 1**). These losses mostly occur in Aus and Boro paddies as the harvest is done during the rainy season. The FAO (1986) reported that the post-harvest losses in Bangladesh is about 14%.

Table 1 Estimates of Rice Post-harvest Lossess

Source of loss	Estimate of Ag. Marketing Study Group, 1970 (%)	Estimates from interviews by task force in Dhaka Div., 1974 (%)
Shattering losses during and after harvesting	1.06	1.5
Carrying loss, field to premises	0.63	—
Threshing losses on different methods	1.65	2.0
Drying losses due to inadequate drying	1.56	5.0
Storage losses due to rottage insects	3.05	7.5
Total handling and transportation losses	—	6.0

(Source: Farouk, 1975)

The two common methods of drying paddy are sun drying and artificial drying. The former is widely used by Bangladeshi millers and farmers. In the rural areas, on sunny days, farmers use mud floors for drying. From mud floors grain losses occur through various reasons such as devouring by birds and rodents, and contamination. Exell and Kornsakoo (1978) reported that these losses may range from 10-25% during sundrying. A large quantity of paddy during drying is eaten by chickens (**Fig. 1**). During porlonged rainy days people cannot dry their grains outdoors, so they use covered spaces for drying paddy but by this process, drying does not occur quickly enough to prevent fungal growth. In areas where electricity is available ceiling fans are sometimes used for drying but the results are not very encouraging due to high equilibrium moisture content and relative humidity.

Fig. 1 Poultry birds are causing grain loss by eating.

To minimize grain losses in the wet season, different types of artificial driers have been developed. Mollah (1981) reported that artificial drying below 50°C has no adverse effect on the viability of seed. Miah et al (1987) reported that rice hull fired drier does not affect the germination of paddy if the drying temperature ranges from 45°C to 52°C.

Drying Principles of Cereal Crops

The purpose of grain drying is to reduce the grain moisture content to a certain level which is at equilibrium with the normal atmospheric air in order to preserve its quality for food and seed purposes. Drying is a process of heat and mass transfer. It is dependent on the available moisture of surrounding air.

There are two major periods of drying, namely; the constant rate period and falling rate period. During the constant rate period, drying takes place from the surface of the grain and evaporates from a free water surface. Final drying occurs in the falling rate period.

The falling rate of drying is controlled by the product and involves the movement of moisture within the material to the surface by liquid diffusion and removal of moisture from the surface.

Drying up to 20 cm depth of grain on the floor, is referred to as thin layer drying which is entirely exposed to the air moving through the product.

(a) The drying rate is independent of air velocity; (b) At a given relative humidity, the drying rate is proportional to the difference between grain moisture content and equilibrium moisture content (dry basis); and (c) The rate of drying is proportional to the difference between vapour pressure of grain and vapour pressure

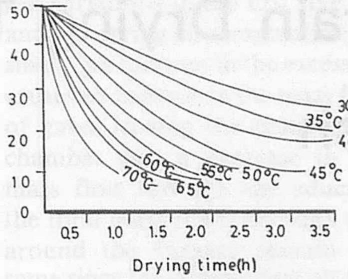

Fig. 2 Effect of temperature on exposed rate of drying. (Source: Ojha, 1974)

of drying air.

The movement of moisture during drying is represented by the following equation:

$$\frac{dM}{dt} = -K\,(M-Mc)$$

integrating the equation

$$\int_{Mo}^{M} \frac{dM}{M-Mc} = -\int_{to}^{t} K dt$$

$$\text{or } \frac{M-Mc}{Mo-Mc} = e^{-kt}$$

where, $\frac{dM}{dt}$ = rate of drying per h

M = Moisture content (dry basis) of grain at any time, t

Mo = Original moisture content (d.b.)

Mc = Equilibrium moisture content

t = Time in h

k = Drying constant

$\frac{M-Mc}{Mo-Mc}$ = Moisture ratio.

The effects of temperature in drying exposed grain are shown in **Fig. 2**.

Sundrying

Sundrying is most widely practised by the farmers and millers in the country. It is a traditional method that is widely practiced in the tropical countries like Bangladesh, India, Indonesia, Burma and most other Asian countries. People in some parts of Africa also use the sundrying method.


Fig. 3 Natural sun drying.

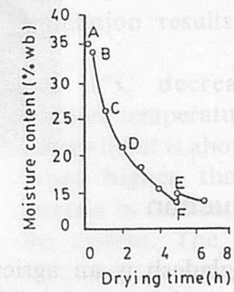

Fig. 4 Variation of moisture content of paddy with drying time. (Sun dring). AB = heating period; BC = constant rate period; CD = first falling rate period; EF = tempering for 2.5 h. (Source: Aroulla et al, 1976).

Trim (1982) reported that in 1968, about 255 million tons of agricultural produce were sun-dried. This drying starts before or after threshing. After harvest the paddy bundles are left in the field for several days in the open air for drying.

After threshing, the wet paddy is usually spread over the drying floor to a thickness of 3-4 cm with the help of wooden plate or human feet. During the operation the paddy is continuously stirred and turned for uniform drying (**Fig. 3**). Usually, the total drying time is about 6-7 h during summer and about 9-10 h during winter. The variation in moisture content of paddy with drying time is shown in **Fig. 4**. The drying floors vary in size from one place to another in the country. These floors are usually made of clay, and occasionally of concrete. Generally, the thickness of the floors is 5 to 10 mm. In some places public roads are also used as drying floors.

Shade Drying

During the monsoon period when sunshine is rarely available, people use thinsheds, verandahs and thatched shed for grain drying. The grains are stirred and mixed several times for uniform drying (**Fig. 5**). However, due to the very high relative humidity of the air (80-90%) moisture does not migrate quickly from the grain to the atmosphere and this encourages fungal growth in the grains.

Ceiling Fan Drying

In areas where electricity is available, ceiling fans are used for drying. In this method, the grains are spread on the floor and agitated several times by human feet or wooden plates (**Fig. 6**). This method is better than shade drying.

Roadside Drying

In many parts of Bangladesh, people dry the grains on parts of concrete of public roads that pass by their villages. Drying on public road is shown in **Fig. 7**. This, however, causes problems for the road traffic and is risky for the persons engaged in spreading and sifting the grains.

Millers Drying Yard

In Bangladesh there are three categories of rice mills: large, medium and small rice hullers. Each mill has its own drying yard according to its milling capacity. The paddy is dried in the sun on concrete drying floors. Like the farmers, the millers also spread the paddy on the floors throughly in the morning. A large number of workers constantly turn and mix the paddy with wooden implements to achieve rapid and uniform drying (**Fig. 8**). Usually the paddy is uniformly levelled by feet. The operation is carried out until the grain moisture content is reduced to about 18-20% (**Fig. 9**), then the grains are heaped and covered with mats for about 2-3 h for proper tempering. The heaped paddy is again spread over the floor and dried for about 2-3 h in the evening until the moisture content is down to 14-16%. **Fig. 10** shows the rate of moisture removal with respect to drying time. In the evening, the paddy is again heaped together and covered

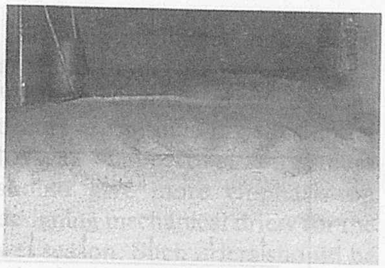

Fig. 5 Shade drying (inside the room).

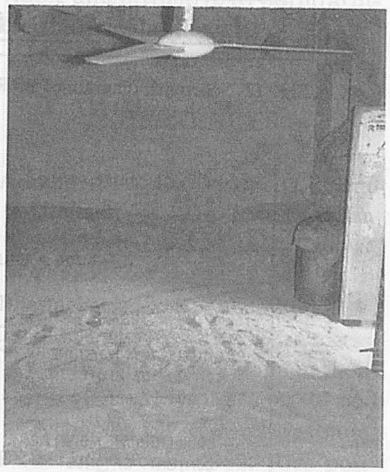

Fig. 6 Ceiling fan drying (inside the room).

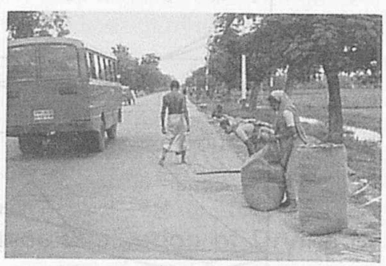

Fig. 7 Roadside drying.

Fig. 8 Spreading of paddy on drying yard with wooden plate.

Fig. 9 Mixing and levelling of paddy by human feet.

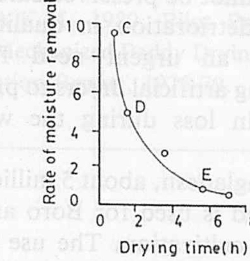

Fig. 10 Variation of drying rate with drying time (Sun drying): CD = first falling rate period; and DE = Second falling period. (Source: Araulla et al 1976).

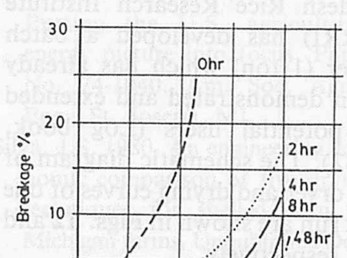

Fig. 11 Milling yield of parboiled paddy in relation to moisture content of grain and length of conditioning periods. (Source: Bhattacharya, Subba Rao and Swamy, 1966).

with mats. During night time the remaining moisture spreads evenly throughout the grain and this tempering process makes the paddy suitable for maximum milling outturn. The milling outturn of parboiled paddy in relation to grain moisture content and duration of tempering period is shown in **Fig. 11**.

Artificial Driers

The use of artificial driers in Bangladesh is limited. Aus, Boro and early maturing high yielding rice varieties are usually harvested during monsoon when little sunshine is available to dry the grains. The harvested paddy during the wet season contains high moisture (23-30%) and the paddy cannot be preserved safely without detrioration in quality. There is an urgent need for developing artificial dryers to prevent grain loss during the wet season.

In Bangladesh, about 5 million ha of land is used for Boro and Aus rice cultivation. The use of dryers during the harvesting period of these two paddies is vital. To overcome the drying problem in the wet season both for farmers and millers, the Bangladesh Rice Research Institute (BRRI) has developed a batch dryer (1 ton) which has already been demonstrated and extended to potential users (Log book, 1982). The schematic diagram of the dryer and drying curves of one test run are shown in **Figs. 12** and **13**, respectively.

Moreover, the Danish International Development Agency (DANIDA) and the Bangladesh Academy for Rural Development (BARD) have developed an artificial drier. These driers are installed in the Hoar (low lying) area of Bhairab Bazar, Sunamganj and Comilla districts. In the areas,

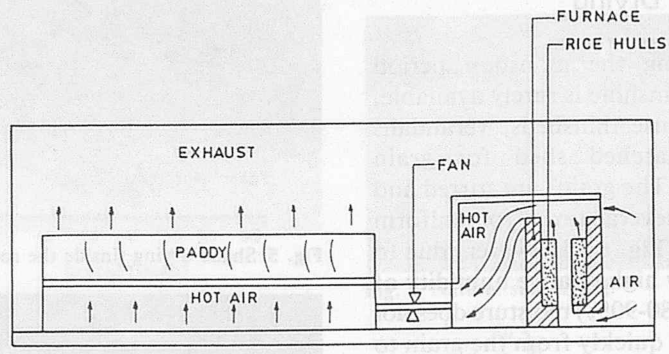

Fig. 12 Schematic diagram of BRRI Rice hull-fired batch dryer. (Source: Miah et al, 1987).

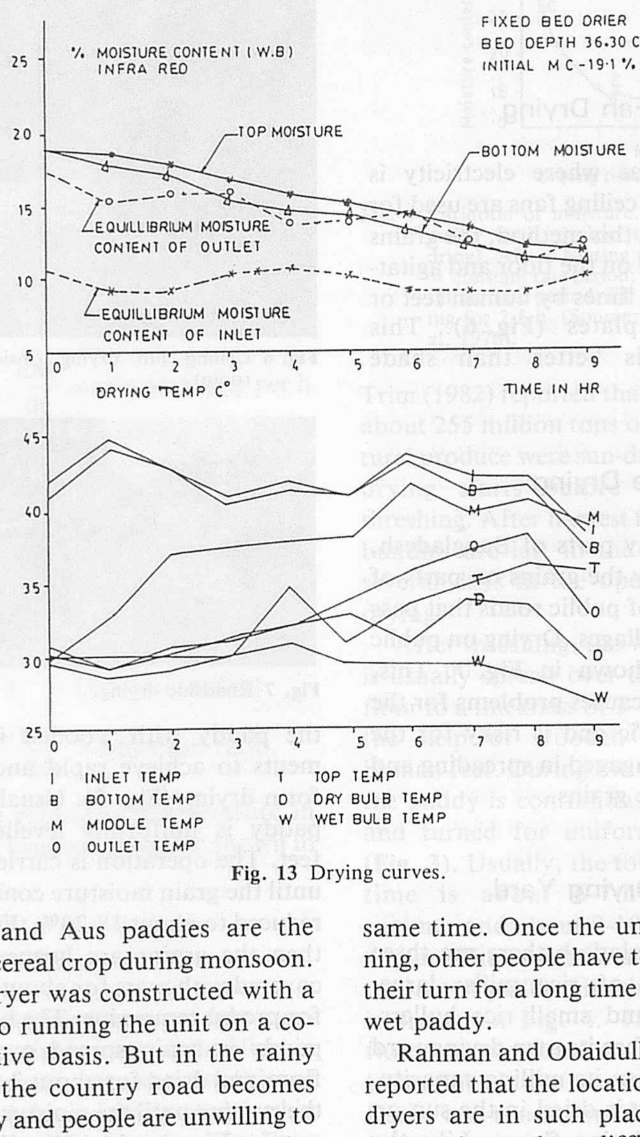

Fig. 13 Drying curves.

Boro and Aus paddies are the main cereal crop during monsoon. The dryer was constructed with a view to running the unit on a cooperative basis. But in the rainy days, the country road becomes muddy and people are unwilling to bring their wet paddy to the drier house. Besides, many farmers use many different varieties which makes it very difficult to mix various varieties in the dryer at the same time. Once the unit is running, other people have to wait for their turn for a long time with their wet paddy.

Rahman and Obaidullah (1980) reported that the locations of the dryers are in such places where farmers have a long difficult route to transport their paddy. They suggested that the driers should be installed in such a place where the farmers have easy and inexpensive access. However, during monsoon (rainy days) poor supply of wet paddy and high transport cost raise the ultimate drying cost. There are 25 automatic rice mills in the country. Every mill has one drying unit. Rice husk is used as fuel to run the unit.

Conclusions

Both sundrying and artificial drying have advantages and disadvantages from the technical and economical points of view. Direct solar heating may cause grain cracks and sudden rains may re-wet the grains. Also, birds and cattle cause grain loss. However, this method is easy to practice and is economical, and so it is widely used in the tropical countries. During sunny weather, the use of artificial dryers are not economically feasible (except in automatic rice mill).

During prolonged rainy days, artificial dryers are very essential. Without drying, grain damage occurs resulting in substantial losses. Therefore, engineers should give more emphasis on designing mechanical driers for the wet season. Such driers should be technically sound, economically viable and attractive to both farmers and rice millers.

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Development of A Recirculatory Cross-flow Paddy Dryer

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Abstract

A batch-type recirculatory cross-flow paddy dryer was designed, constructed and installed in the laboratory. A husk furnace was constructed by converting an oil drum to supply heated air to the dryer. An oil drum was converted to ash separator by dividing its inner space with baffles of wire netting covered with a layer of lubricating oil. A centrifugal blower was used for delivering heated air to the dryer.

Drying tests were performed by feeding the grain into the dryer from top. Paddy was recirculated with the help of a bucket type elevator. Hot air circulated to the dryer was made to flow perpendicular to the direction of the grain flow, thereby eliminating the possibility of redeposition of moisture in the grain. Use of easily accessible low cost materials and simple technology for construction along with cross-flow air supply system made this dryer well suited to and advantageous for paddy drying under Bangladesh conditions.

Acknowledgment: The authors acknowledge the cooperation received from the Department of Farm Power and Machinery for construction and testing of the experimental unit and the Bangladesh Agricultural University, Mymensingh for financing the project.

Introduction

Drying of paddy is becoming more important in the developing countries with the increasing rate of production and increasing demand of food grains. Due to inappropriate drying facilities a considerable percentage of produced food grain is lost every year. In most parts of South and South-east Asia, the mechanical or artificial methods of drying paddy are not yet extensively used due to the fact that the available mechanical dryers are not fully suited for the tropical conditions and, generally, expensive.

Artificial grain drying is required during grain processing operations to prevent deterioration of grain quality in storage under very high ambient relative humidity. Grain cannot be stored safely at high moisture content. Paddy (i.e., whole rice with husk) is usually harvested at moisture content ranging from 22 to 28% (d.b.) and must be dried to 13 to 14% (d.b.) for safe storage. Drying of paddy is usually done in round or rectangular bins where drying air is forced into the grain through a perforated floor.

The most common traditional method of grain drying is sun-floor drying which requires large surface area and labor for spreading, stirring and collecting grain. Moreover, during rainy season, delayed and slow drying results in large quantities of loss of crop due to sprouting and other forms of spoilage. Sun drying of paddy produce grain fissures which results in low head rice yield and high bran production in milling, (Tani, 1983). Thus, it is necessary to develop some economic and readily available source of additional heat energy available for reducing moisture from the harvested grain. In the conventional dryers, air is used as the medium of heat and moisture transfer because it can be easily handled and it does not, by itself, contaminate the grains. The low heat transfer co-efficient of air, coupled with the resistance to moisture diffusion out of kernels, results into extended drying times and relatively low drying efficiencies.

In deep bed dryers, the drying air evaporates moisture from the grain and carries it away. As the air absorbs moisture, its temperature decreases and its ability to pick up more moisture decrease (Islam and Jindal, 1981). As a result, there is the possibility of moisture redeposition in upper layer during early stage of drying. In thin layer drying this problem does not arise. Since rice is consumed mostly in the form of whole grains, harvesting, drying and milling equipments are designed to provide high yields of unbroken kernel. A good quality of rice with a high yield percentage of whole kernel is needed for domestic consumption. Rice husk constitutes 20 to 22% of whole paddy weight and has a heating value of 2772 to 3276 kcal/kg (Khan, 1973).

Several research have worked on the grain dryer. Fon (1981) compared the paddy drying using one-way and reversing airflow and it was found that reversing air flow resulted in lower coefficient of variation for the final moisture content. Verma et al., (1985) determined drying constant of steamed and unsteamed rough rice as a function of temperature, velocity and relative humidity of drying air by using a vertical airflow dryer and a continous weighing system. Different effects of drying air conditions on the drying constant were observed for the steamed and unsteamed rice sample.

The main objective of this study was to design and construct a cross-flow paddy dryer and a rice husk furnace with an ash separator using locally available low-cost materials and simple technology with a view to making this drying system easily available to farmers.

Materials and Methods

A cross-flow dryer was designed for paddy drying consisting of a dryer unit, a bucket elevator, a husk furnace, an ash separator and a blower.

Flat bars, G.I. sheet and wire-net covering were used as the principal materials of construction for the cylindrical shaped experimental dryer (**Fig. 1**). The dryer was designed for drying 140 kg paddy per batch. A small cylinder made of wire net and having conical shaped ends was placed inside the dryer unit through which heated air was supplied. Grain was discharged from the dryer into a hopper for recirculation using a bucket-type elevator. Through this arrangement, a continuous recirculation of grain was maintained in the dryer.

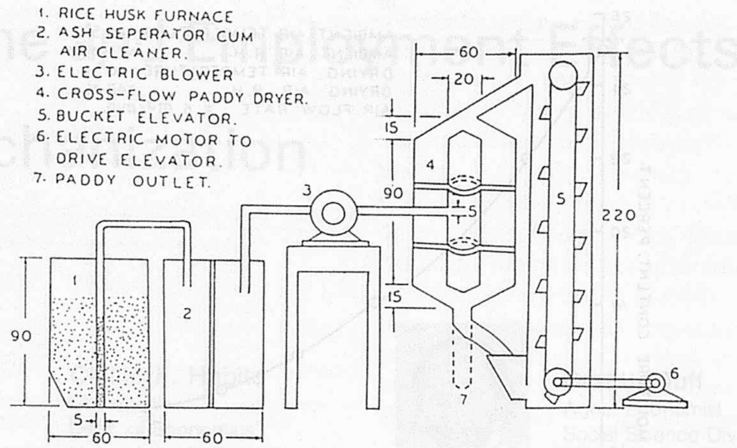

Fig. 1 Cross-flow paddy dryer with husk-fired furnace, unit: cm.

An oil drum was converted into husk furnace (**Fig. 1**). An inclined gate was constructed at the lower end of the drum by fitting inclined baffles to facilitate air flow required for burning the husk. One end of a perforated G.I. pipe (7.0 cm diameter) was placed at the center of the husk furnace and rice husk was packed around this pipe. The other end of the pipe was connected with the suction end of the blower through an ash separator.

Another oil drum was converted into ash separator by fixing a baffle into the drum (**Fig. 1**). The baffle was made of wire net and was soaked with lubricating oil for better cleaning of air.

The dryer was installed on a steel frame for convenient use. Hot air was supplied to the dryer by a blower which was installed between the dryer unit and ash separator. The ash separator and the husk furnace were installed parallel to the dryer. They were connected by a U-shaped steel pipe. The top of the dryer unit was connected with a bucket elevator for continuous feeding and recirculation of grain. The bottom of the dryer dropped into the hopper through a hose pipe.

Due to unavailability of freshly harvested paddy, dried paddy was remoistened by spraying water and mixing it thoroughly and keeping over 24 h for uniform diffusion of moisture. The moisture content of the remoistened paddy was determined by oven method and was found to be 25% (d.b.) which was considered as the initial moisture content to paddy for the test. The remoistened paddy was fed into the dryer from the top by the elevator.

Dry and wet bulb temperatures of drying air both at inlet and outlet of dryer were measured. Heated air temperature was adjusted to and made constant at 40°C before starting drying test. Grain temperature within the dryer was measured at five different places. Grain samples were collected periodically to determine grain moisture content and drying rate. Drying test was continued for 3 h (**Fig. 2**).

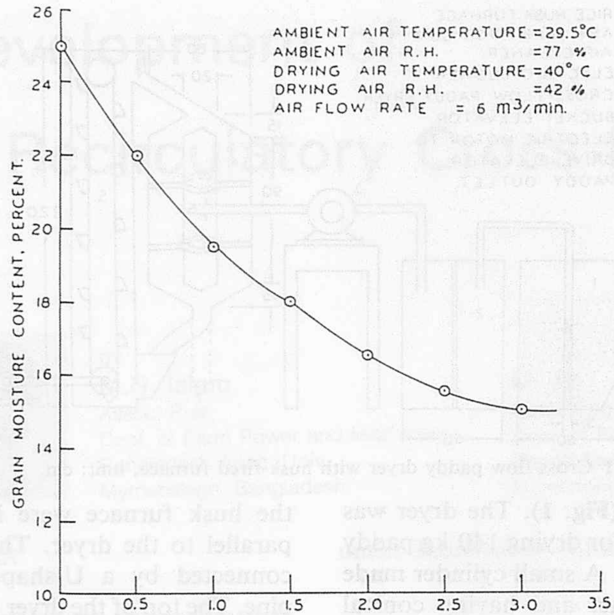

Fig. 2 Drying rate of paddy by cross-flow paddy dryer.

Results and Discussion

The dryer used for the experiment was constructed as a prototype one. As the flow of heated air was perpendicular to the direction of flow of grain inside the dryer, the absorbed moisture from grain escaped away from the dryer and resulted in faster drying and lesser scope of moisture deposition on the outer layer. Experimental results (**Fig. 2**) indicate that the rate of drying was quite high; moisture content of paddy was reduced from 25% to 15% in 3 h at 40°C drying temperature and 77% relative humidity. Both the ash separator and the husk furnace were very simple in design and construction as minimum work was involved in converting old oil drums into these two items. Hot air supplied from husk furnace was found mixed with smoke and oily substances which affected the quality of rice. On successful experimental result by developing a suitable ash separator, the unit as a whole could easily be constructed by local technician using local materials and will be useful for farmers and small scale rice processors. Cost of construction would be very low compared to imported paddy dryer.

Conclusions

The developed dryer was very useful for the farmers and small rice processors as it would improve the quality of marketed rice. The dryer was advantageous because of its simplicity in construction and operation.

The paddy dryer required minor modification for successful operation. A suitable heat exchanger should be developed for husk furnace so that smoke, ash and oily substances could be removed. The blower could be placed before the heat exchanger to reduce heat loss. Delivery pipes and heat exchanger should be insulated to reduce heat loss.

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Macro-level Income and Employment Effects of Rice Farm Mechanization

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Abstract

An input-output model was used to measure the direct and indirect effects of rice farm mechanization on employment and income in Pakistan. Results reveal that although farm mechanization decreases employment, secondary (linkage) effects are also very significant and can offset the initial decrease in employment. Most-micro-level, on-farm labor based studies over-estimated the true displacement of labor. Farm mechanization increased income both at the farm and the national level.

Introduction

In many developing countries, much research work on farm mechanization has focused on developing estimations of its farm labor displacement and income effects. These studies measured only the micro- or direct effect of mechanization on a specific farm unit, area or location. They ignored the macro-level, forward and backward indirect effects of technologies which arise from linkages between farm and non-farm sectors and between the farm and the households. The importance of these production and consumption linkages in the agricultural growth process has been emphasized by a number of scholars (Mellor[1]; Yotopoulus and Nugent[2]; Hazel and Roell[3]; Hazel and Anderson[4], and Mellor and Adam[5]). An important aspect of growth linkages to the non-farm economy is that they are predominantly due to the increases in household consumption expenditure arising from an increase in household income.

Increases in household consumption expenditures show very important aspects of growth linkages of technological change to the nonfarm economy. Ranganajan[6], reported in his study while analyzing agricultural and industrial performance in India that a 10-percent addition to agricultural growth rate stimulate an addition to the growth rate of industrial output and national income by 5 and 7 percent, respectively. Bell, et al.[7], indicated that about two-thirds of the 80 percent income multiplier in the Muda Region in Malaysia was due to increased rural household demand for consumer goods and services and only one-third was due to increased agricultural demand for inputs, processing, transport and marketing.

There are very few studies, however, where indirect or growth linkages of farm mechanization are measured. In Indian Punjab, Mudahar[8], reported that, in general, the adoption of modern farm technology, including farm machinery (except tractor and combines), led to increased labor use and employment in both the agricultural and non-agricultural sector. Another study, by Gego Atno[9], mentioned not only the importance of farm mechanization in national growth but also its role to curb rural exodus to urban centres. An increase in agricultural mechanization in combination with other measures furthering infrastructure and development services not only raise yields in developing countries but also improve employment and income, especially in rural areas.

Ahammad and Duff[10], found that the total equilibrium effect comprising subsequent production and consumption linkages for rice demand was always positive and offsets the initial decline in employment. Both consumption and production linkages account for the incremental production: rice by 81 percent; processed food by 5 percent; textiles and footwear by 3 percent; fertilizer by 2 percent and construction and trade by 3 percent of the total incremental simulated production in Indonesia.

Ahammed and Herdt[11], showed that in the Philippines the direct effect alone overestimates the true displacement of labor by 5-10 percent. They concluded that farm mechanization (e.g., power tiller and small threshers) is a sound economic measure with minimum displacement of labor.

This study, on the other hand, measured the magnitude and incidence of the direct and indirect effects of alternative rice farm mechanization strategies on the Pakistan economy.

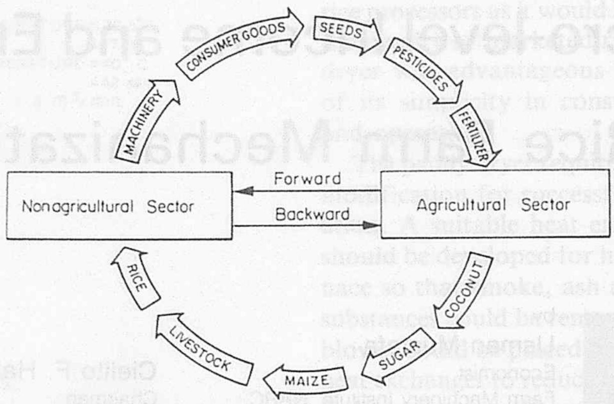

Fig. 1 Diagram of linkages (Duff, 1986).

Methodology

Farmers and agricultural laborers purchase consumer and producer goods from non-agricultural sources. Conversely, agriculture provides the non-agricultural sector with goods and products used for production and consumption. These relationships are presented conceptually by Duff, et al.[12], (**Fig. 1**).

The Leontief input-output model[13, 14], provides a framework to measure the indirect effects of farm mechanization. These indirect effects occur as a result of the interactions between the agriculture and non-agricultural sectors in production and consumption. The transactions table describes the flow of all goods and services between individual sectors of the economy. Each sector or industry depends on others since inputs of one industry are outputs of another industry and vice versa. Ultimately these mutual dependence leads to an equilibrium between supply and demand in the economy. Since the output of one industry is used by other industries as "input requirements", total industry output must be consistent with all requirements to avoid bottlenecks elsewhere in the economy.

The underlying basis of input-output analysis, given certain technological coefficients and final demand, permits each endogenous sector to find its output uniquely determined as a linear combination of multi-sector demand.

Output from the agricultural sector may be used (or demanded) as an input in food or other manufacturing sectors (grain for producing bread or cotton for producing cloth); and as a final consumption good by government or households (vegetables or grain) or as an export demand.

The input-output table can be used to quantify these direct and indirect effects. In most general formulation, we write the input-output system as $P.Q = R$ or $Q = P^{-1}.R$, where P is a given square matrix of input coefficients while Q and R are vectors of output and final demand for each production sector. The coefficient of the inverted matrix P^{-1} provides direct and indirect production requirements to meet a given increment in final demand.

The indirect impact of farm mechanization is the net effect of factors which changes employment, income distribution and saving.

The overall effect of mechanization on rice production in Pakistan was analyzed for 1983/84. Rice production systems were subdivided according to the intensity of farm mechanization. Five household classes were distinguished to describe the income distribution and consumption effects of farm mechanization. The input-output tables developed by the Pakistan Institute of Development Economics (PIDE)[15], were updated to 1984 for the study. Other secondary data were collected from some government and semi-government agencies.

Simulation of the Model

To demonstrate the macro-level effect of rice mechanization, a one percent increase in consumption of rice was simulated.

In each simulation, the additional consumption and production was fully met from a specific rice production subsection. The increase in consumption will generate an increase in direct and indirect employment, income distribution, savings, and importation. Simulation was achieved by post multiplying the inverted matrix of P with the final demand vector R, showing the one percent increase in consumption or production or rice.

There are basically two rice variety groups cultivated each year, namely: Basmati and IRRI varieties. Although the IRRI varieties gave higher yields, their average wholesale prices were lower than the Basmati varieties (Rs. 2,420 per ton vs Rs. 6,925 per ton, respectively). The one-percent production value was Rs. 124 million which was equivalent to 17.95 thousand tons of Basmati or 51.36 thousand tons of the IRRI varieties. Consumption of rice was estimated using the household income and consumption survey, Government of Pakistan[16]. One percent of total rice production was equivalent to 13.88 thousand tons.

Results of the simulation are discussed with respect to employment and income distribution.

Results and Discussion

Effect of Mechanization on Employment

Employment in rice production sectors consists of both family and hired labor. However, employment in non-rice sectors which was estimated from input-output tables and the labor force survey indicated only hired labor.

The direct effect of employment are those which occur only in rice production. These are calculated from the gross output of crops required to meet the final rice production from a specific sector divided by the on-farm output over labor ratio. The indirect effect of employment are labor use changes in other sectors generated by forward and backward linkages. Direct and indirect effects are measured as equilibrium values comprising all the production and consumption linkages to rice and non-rice sectors, respectively.

The result of the one-percent increase in consumption of rice are presented in **Table 1**. The total employment in the country was estimated at 7,282 million man-days during the 1983-84 fiscal year. Results showed that overall, the maximum increase in employment in absolute terms was in non-mechanized farms or those using bullocks where the increase was 5.43 million man-days as compared to mechanized farm where the increase was only 4.83 million man-days. These results indicate that mechanization displaced labor as observed by other micro-level studies in Pakistan: McInerney and Donaldson[17]; Duff and Kaiser[18]; Ahmed[19] and Lockwood et al.[20]. But when we analyze the indirect (linkages) effect of mechanization, the intensity of the negative effect on employment decreased as we move toward intensive mechanization (**Table 1** and **Fig. 2**).

Table 1 Employment implications of one-percent increase in consumption of rice when increase is met from specified production sector (million mandays)

Farm Operation Land Preparation	Harvesting	Threshing	Total employment* (1)	Absolute increase (2)	Direct increase (3)	Indirect increase (4)	Ratio of indirect/direct employment effect (5)
			7,282.00				
Bullock	Manual	Manual/bullock	7,287.44	5.43	3.98	1.45	0.36
Tractor	Manual	Manual/bullock	7,287.25	5.25	3.33	1.92	0.58
Tractor	Reaper	Manual/bullock	7,287.11	5.11	3.12	1.99	0.64
Tractor	Combine harvester	Combine harvester	7,286.83	4.83	2.11	2.72	1.29

*Actual economy, 1984 (Rs. million).

The indirect increase in employment in intensive mechanized farm was more than three times higher than in the non-mechanized farm (Row 4 column 4 and row 1 colulmn 4 of **Table 1**). The indirect effects are due to the consumption linkages, Mellor[1], Yotopoulus and Nugent[2]; Hazel and Roell[3]; Hazel and Anderson[4] and Mellor and Adam[5]). Due to mechanization there is more income received resulting in more consumption and, thus, the indirect effect of employment.

There is also an increase in employment of the people directly engaged in machine production, distribution and maintenance activities. Of course, these off-farm workers: the mechanics, sales

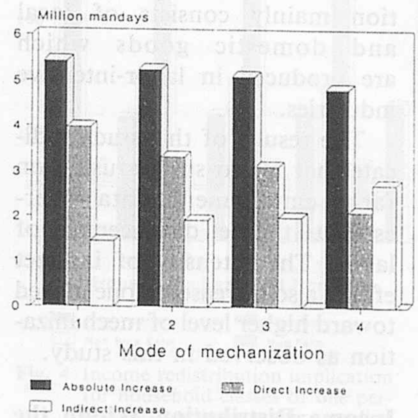

Fig. 2 Direct and indirect employment implication of one percent increase in consumption of rice when increase is met from production sector (million mandays).

agents, etc. belong to moderate or lower income groups. So, an increase in their income also enhances secondary employment effects. There were more consumption linkages with an increase in lower profile income groups as observed by other consumption linkages studies: Desai[21]; Mudahar[22]; King and Byeerlee[23]; Hazel and Roell[3], and Gego Atno[9].

Mechanized farms employed more hired labor and less of family and permanent labor. This situation implies more consumption linkages, because the hired labor comes from landless, poor classes or lower-income profile which has a very high propensity to consume. Their consump-

Table 2 Income redistribution implications for rice farm households of one-percent increase in consumers spending for rice when demand is met from specific rice production sector

Farm Operation Land			Hired labor		Operator		Landowner		Ratio of landowner hired labor and operator incremental income	Total incremental income of rice farm
Preparation	Harvesting	Threshing	Absolute increase	Incremental share	Absolute increase	Incremental share	Absolute increase	Incremental share		
			2,225.22*	—	5,315.81*	—	4,821.33*	—	—	12,362.36*
Bullock	Manual	Manual/ bullock	16.55	(23)	29.28	(42)	24.85	(35)	0.54	70.68
Tractor	Manual	Manual/ bullock	11.19	(16)	30.44	(43)	29.31	(41)	0.70	70.94
Tractor	Reaper	Manual/ bullock	13.59	(19)	32.90	(48)	25.03	(37)	0.59	71.52
Tractor	Combine harvester	Combine harvester	12.95	(18)	30.71	(43)	28.26	(39)	0.65	71.92

*Total economy, 1983-84 (Rs. million).

tion mainly consists of local and domestic goods which are produced in labor-intensive industries.

The results of this study indicate that micro studies using on farm employment data over-estimate the net displacement of labor. The intensity of indirect effects also increases as one moved toward higher level of mechanization as observed in this study.

Income Distribution Within the Rice Economy

Mechanization has a profound impact on income distribution and equity among the rural households. The results on income distribution within the rice economy obtained from the model are presented in **Table 2** and **Fig. 3**.

The result reveals that as intensity of mechanization increases there is a conglomerate increase in the total income of the rice farms. Total incremental income of rice farms under intensive mechanization was Rs. 71.92 million whereas it was Rs. 70.68 million in non-mechanized farm **(Table 2)**. The increase in income of mechanized farms is due not only to mechanization as it is profitable or cheap vs non-mechanization, but also due to the efficient utilization of resources as observed by Ahmad[19] and Salam[24, 25]

In recent years the development of custom market for farm machinery, especially tractor for plowing and reaper for harvesting, was intensified. Consequently, there has been a development of a new class of entrepreneurs who invest heavily in farm machinery and actively sought business.

The total incremental income share was 23 percent for hired labor in non-mechanized farms and a minimum of 16 percent among farms utilizing tractor for land preparation. The rest was for farms where rice production was done manually or by the use of animal power. Landowner share was maximum in the second category of rice production system and lowest in the first category of non-mechanized farm. The operator obtained the highest income share of 48 percent in category number three where land and harvesting were done by mechanization and threshing was done manually, and lowest in non-mechanized farm. These are understandable because the use of reapers require more operator's time compared to non-mechanized farms.

Hired labor share was lower in intensive mechanized farm compared to non-mechanized farms. Landlords were better off with mechanization compared to laborers. The present model, however, does not consider the long-term effect of increase in income of landlords on mech-

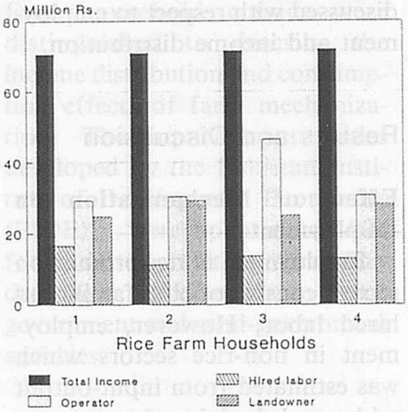

Fig. 3 Income redistribution implication for rice farm household classes of one percent increase in consumer spending for rice when demand is met from specific rice production sector (million Rs.).

anized farms. The investment behavior of landlords were only assumed to be on machinery.

Income Distribution Among Household Classes

The income redistribution implications for household classes of a one-percent increase in consumer spending for rice when demand is met from specific rice production are presented in **Table 3** and **Fig. 4**. The rural-urban income disparity is measured by the ratio of non-farm to farm sector gain in income.

With an increase in demand, national income will increase at a higher rate in mechanized farm than in non-mechanized farm. This is mainly due to the high

Table 3 Income redistribution implication for household classes of one-percent increase in rice production when demand is met from a specific production sector

Farm Operation Land			Rice farm		Non-rice farm		Non-farm		Ratio of non-farm incremental income	Total incremental income
			Absolute increase	Incremental share	Absolute increase	Incremental share	Absolute increase	Incremental share		
Preparation	Harvesting	Threshing	12,362.36*	—	91,161.3*	—	255,186.18*			
Bullock	Manual	Manual/ bullock	70.69	(30)	48.75	(21)	112.97	(49)	0.95	232.68
Tractor	Manual	Manual/ bullock	70.91	(30)	47.27	(20)	116.42	(50)	0.99	234.26
Tractor	Reaper	Manual/ bullock	71.52	(30)	47.30	(20)	118.26	(50)	1.00	236.51
Tractor	Combine harvester	Combine harvester	71.92	(29)	42.52	(18)	126.7	(53)	1.11	241.14

*Total economy, 1983-84 (Rs. million).

efficiency in the use of inputs by farmers in mechanized farms.

The disparities in income in urban over rural households as shown in the ratio of non-farm to farm incremental income increases as we move toward intensive mechanized rice farms. This reveals that there is an increase in urban income as farmers shift to intensive mechanization which is understandable because rice farm income is biased toward mechanized farm. It is also important to realize that rice husking plants or rice mills are mainly situated in urban or near the urban center and belong to the non-farm households. Furthermore, only 41 percent of total rice production is consumed in Pakistan, while the rest is exported. All the export channels and beneficiaries are urban households.

An increase in income of this group resulted in an increase of urban produce commodities. This will further enhance the income of urban households due to forward and backward linkages. Similar results were observed by Ahammed and Herdt[11], and Ahammed and Duff[10] in the Philippines and Indonesia, respectively.

Summary and Conclusion

The objective of the study was to measure the magnitude and incidence of the direct and indirect effects of alternative rice farm mechanization strategies on the economy. Special attention was given to capturing the overall effects of farm mechanization on income and employment. A general equilibrium model developed by Ahammed and Herdt[11], based on the Leontief input-output system was used in order to achieve the objectives.

The input-output table developed by the Pakistan Institute of Development Economics was updated, aggregated and disaggregated accordingly in order to incorporate different rice production systems for 1983-83.

Results reveal that overall, the highest increase in employment in absolute terms were found in bullock or non-mechanized farms. However, there was more indirect increase in employment in intensive mechanized farms due to forward and backward linkages. This shows that micro-level studies using on-farm employment data overestimate the net displacement of labor. The intensity of indirect effects also increased as one moved to a higher level of farm mechanization.

Results also indicate that as intensity of mechanization increases, there is conglomerate increase in total income from rice farms. The percentage share of increase in income due to hired labor decreased in intensive mechanized farms. This was shown by a lower ratio of landlord

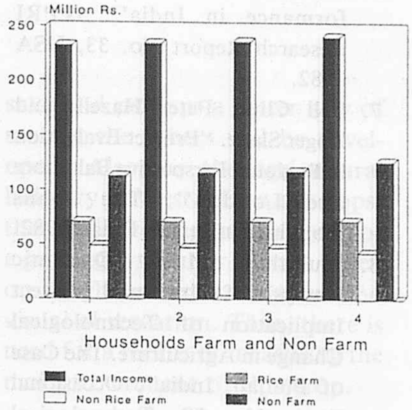

Fig. 4 Income redistribution implication for household classes of one percent increase in consumer spending for rice when demand is met from specific rice production sector (million Rs.).

incremental share over hired labor and operator incremental share.

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■■

Moisture Content Determination for Cassava Development of Direct and Indirect Methods

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Abstract

Moisture loss is one of the principal causes of cassava deterioration. Moisture level determination is, therefore, a potential indicator of cassava spoilage.

This paper reports studies into direct and indirect methods of determining the moisture content of cassava tubers.

In the primary method developed, an oven was used to dry cassava at five temperature levels. Measurements were taken and observations made at intervals of 2 h. It was observed that an oven temperature of 100°C and time of 24 h were best for direct moisture determination of cassava.

The indirect method measured resistance which is a passive property of cassava as an index of moisture content. Results of a 4^3 factorial experiment to determine the pertinent factors are presented. Relationships between length of time (of moisture loss), section of cassava where readings were taken, distance between probes, and resistance are also presented.

It thus appears as if resistance is a reliable method of sensing moisture level in cassava.

Introduction

Cassava, *Manihot esculanta Crantz*, which is said to originate in Brazil, is one of the most valuable staple food sources for tens of millions of people in the West African subregion. Its potential as food source is enhanced by the fact that it is drought resistant, grows all-year round, and is easily multiplied. Unfortunately, however, unprocessed cassava spoils very quickly — in two or three days, and there is yet no scientic method of determining when it is going bad. Deterioration of cassava results from chemical reaction in the tubers as a result of increase in the level of hydrocyanic acid (HNC). The concentration of this acid increases when the tuber loses moisture. This limits the storability and forces the farmer to harvest cassava in small batches. Each batch is processed before he goes for another batch.

Attemps made to store cassava for between three and six months (Adiele et al, 1986; Afolabi and Akano, 1986; Afolabi et al, 1986) were fairly successful but there yet remained a means of correlating the level of deterioration in stored cassava with the moisture content of the tubers.

If there were means of indicating moisture levels inside cassava tubers, there would be more thorough investigation into the very quick deterioration of cassava and perhaps a better way of storing the tubers will be developed. Also, as the agricultural industry in West Africa develops, there will eventually be a need for a grading system for cassava based on weight, moisture content and visual observation. Thus, there is need for a means of measuring the moisture content of this crop.

Literature Review

The effect of hydrogen cyanide content in stored cassava has been investigated by Afolabi et al (1986). They found that hydrogen cyanide concentration changed only slightly when cassava was stored in wetted sawdust or wetted soil. They also found that concentration of this acid actually decreased when the crop was stored in an evaporative cooling system (ECS) although the decrease was insignificant. Cassava left in the soil on the farm maintained a constant level of hydrogen cyanide. There thus seems to be a correlation between moisture and acid levels.

Methods that have been used to determine moisture content can generally be classified into two, namely: (1) direct method and (2) indirect method.

The direct method uses air or water ovens or hot oil to remove moisture from a product and are well described by Hall (1980). Direct methods have been standardized for grains and legumes (ASAE, 1986) and investigated for yams (Ige and Sunmonu, 1981). No work on cassava was, however, found in literature.

Indirect or secondary methods involve the measurement of property of the material, including mechanical, electrical or thermal property which is related to moisture content. A direct method is needed to calibrate the indirect method. Meters have been developed for grains and forage using electrical properties but they are usually designed to sense moisture level not higher than 40% wet basis. The moisture content of cassava was found to be far above this value.

Theoretical Considerations

Preliminary laboratory experiments were carried out to show the variation of moisture content along the longitudinal axis of the tuber at the distal, middle and proximal sections. Also, variation along the transverse section was monitored.

Variation of Resistance with Depth

It was intended to use probes to determine the resistance of cassava at different depths. A model such as the one used by Ige and Sunmonu (1981) was used. As shown in **Fig. 1**, R is the equivalent resistance of the system and R_1 is the resistance of the outer layer.

Unlike yam (Ige and Sunmonu, 1981) cassava was found to have two drying layer zones:

(a) The dry layer zone which is in equilibrum with air; and

(b) The wet layer zone to which the drying front moves.

Figure 1 is a schematic representation of the resistance for the layers.

The equivalent resistance from **Fig. 1** is as follows:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots + \frac{1}{R_n} \quad \ldots\ldots\ldots (1)$$

(a) At the dry layer zone, resistance is homogeneous, i.e., $R_1 = R_2 = R_3 = \ldots = R_n$ therefore, equation (1) becomes:

$$R = \frac{R_1}{n} \quad \ldots\ldots\ldots (2)$$

but n is proportional to depth. Therefore, R is inversely proportional to depth. As physically observed, n is approximately 1 which means that

$$R = R_1 \quad \ldots\ldots\ldots (3)$$

Also, this dry layer zone is very dry making R_1 to be very high which, in turn, makes R to be very high (over 100 kℓ). Even when n is up to three, R is still high from equation (2).

(b) Wet layer zone.

Assuming $n = 1$ at the dry layer zone, and with the knowledge that R_1 is very large relative to other Rs which makes $1/R_1$ tend to zero, it can be easily seen that

$$1/R = (1 + R_1/R_2 + R_1/R_3 + \ldots\ldots R_1/R_n)/R_1 \quad \ldots (4)$$

$$1/R = 1/R_1 + (n-1) R_1 / \prod_{i=1}^{n} R_i \quad \ldots\ldots\ldots (5)$$

where R_1 is very large compared with other resistances

$$1/R \text{ becomes } (n-1) R_1 / \prod_{i=1}^{n} R_i \quad \ldots\ldots\ldots (6)$$

$$R = \prod_{i=1}^{n} R_i / (n-1) R_1 \quad \ldots. (7)$$

This shows that

(i) Resistance is inversely proportional to depth; and

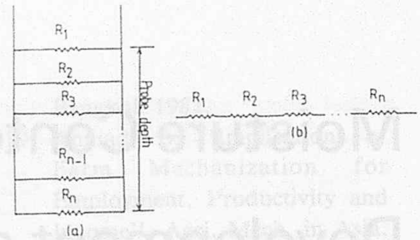

Fig. 1 Schematic representation of resistance: (a) Along the depth of the probe into the cassava piece. (b) Between probe distances.

(ii) Resistance is considerably lower in the wet zone than in the dry layer zone.

Variation of Resistance with Distance between Probes

This is similar to Ige and Sunmonu (1981). This means from **Fig. 1 (b)** that for a given depth:

$$R = R_a, \text{ if } R_a = R_b = R_c = \ldots = R_x \quad \ldots\ldots\ldots (9)$$

where x is positive

This shows that R increases directly as distance.

Variation of Resistance with Drying Time

From equation (9), as material is dried, R_i approaches R_1 gradually from the first layer to the last. The terminal equation becomes:

$$R = R_1^n/(n-1)R_1$$

Resistance will, therefore, increase with drying until it approaches infinity.

Experimental Procedure

Direct Moisture Content Determination

No established standard was found in the literature for determining the moisture content of cassava tubers. Since all indirect methods for moisture determination must be calibrated by a direct method, experiments were carried out to determine the drying profile of cassava at 80, 90, 100, 115 and 135°C.

Samples of about 100 g of

cassava were placed in the oven for each drying temperature. The weights were monitored until constant weights were reached. Visual observations were also made.

It was observed that samples dried at temperatures of 115 and 135°C were caked brown before constant weights were reached. Samples dried at temperatures of between 80 and 100°C did not turn brown nor become caked. Samples dried at temperatures of 115°C and 135°C reached constant weights at 10 and 8 h of drying, respectively, while samples dried at temperatures of 80°C and 90°C reached constant weights at 38 h and 29 h, respectively.

Samples dried at 100°C reached constant weight at about 22 h and did not turn brown nor become caked. Hence, an oven temperature of 100°C was selected for determining the moisture content of cassava by direct method.

Indirect Moisture Content Determination

A digital resistance meter was designed to measure the resistance between two points on a cassava tuber. The range was zero to 99.9 kilo-ohms. Steel probes 20 mm long were used to probe into the tubers.

A 4^3 factorial experiment with 4 replicates was designed to determine the relative effects of depth of probe, distance between probes and hours of drying. The results of these experiments were analyzed statistically using a microcomputer.

Results and Discussion

Direct Method

Figure 2 shows the relationship between the mass of cassava and hours of drying for the different oven temperatures. For all the oven temperatures, there are two regions of drying. The first region (region X) witnessed a sharp rate of decrease in weight while the second period (region Y) is more gradual. The first 4 to 6 h of drying was found to have the most rapid rate of loss in weight. Weight decreases in the early period was almost linear.

As discussed earlier, an oven temperature of 100°C was found to be the most suitable oven temperature for the purpose of moisture content determination. Although the samples at 100°C attained constant weight before 24 h, 24 h was chosen because of convenience.

Indirect Method

Tables 1 and **2** give the results of the experiment for undried cassava and also for cassava dried for 4 h. Cassava dried for 1 and 2 h followed the same trend.

The results show that wet cassava has a lower resistance than dry cassava which agrees with the theoretical consideration. For a given tuber, there appears to be more water at the tail section (T) than at any other portion. This is closely followed by the lower middle portions (LM). There is no significant difference between the upper middle (UM) and the stem end.

Figures 3 to **5** show the relationships between moisture content and resistance of cassava for different distances between probes and 1 cm depth of probe. It is observed that the resistance of cassava decreases with an increase in moisture content.

Statistical analysis further

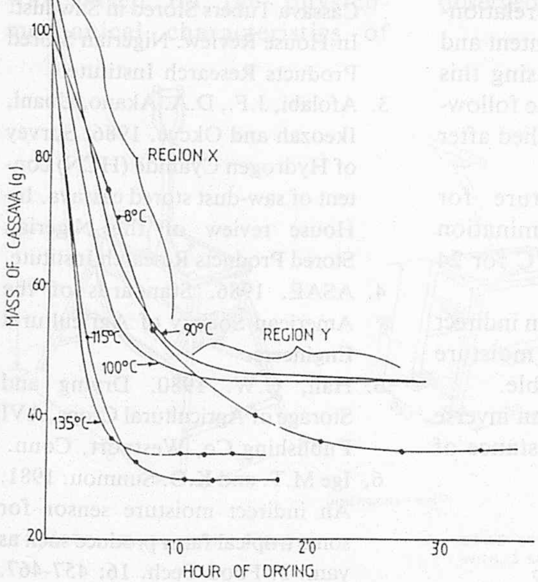

Fig. 2 Mass of cassava and hour of drying for different oven temperatures.

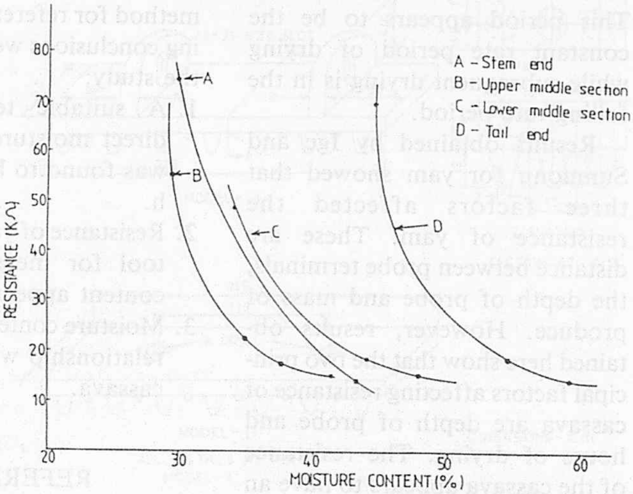

Fig. 3 Moisture content and resistance of cassava for depth of probes 1 cm, distance between probes 2 cm.

Table 1 Variation of Resistance (to Current Flow) of Wet Cassava with Depth, Distance between Probes and Section of Cassava Probed

Depth (cm)	Distance between probes (cm)	Resistance (ohms × 10^3) Stem end	Upper middle	Lower middle	Tail end
1	2	14.650	15.025	14.700	14.275
1	4	14.350	14.700	14.675	14.325
1	6	15.100	14.900	15.075	13.775
2	2	13.450	13.250	13.375	12.225
2	4	13.250	13.100	13.300	11.225
2	6	13.650	13.275	13.500	10.375

Table 2 Variation of Resistance (to Current Flow) of Cassava with Depth, Distance between Probes and Section of Cassava Probed after 4 h of Drying

Depth (cm)	Distance between probes (cm)	Resistance (ohms × 10^3) Stem end	Upper middle	Lower middle	Tail end
1	2	16.450	15.250	13.900	15.650
1	4	16.250	15.850	14.500	14.850
1	6	15.700	15.575	20.050	19.025
2	2	10.300	10.350	10.300	10.200
2	4	10.325	10.250	10.125	10.175
2	6	10.300	10.275	10.450	10.225

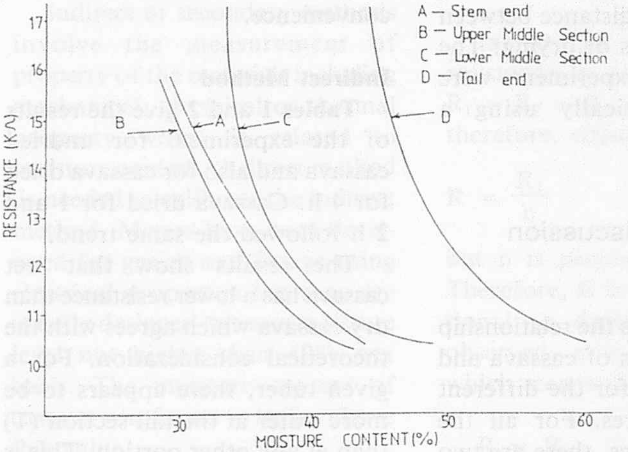

Fig. 4 Moisture content of cassava and resistance for probe depth 1 cm, distance between probes 6 cm.

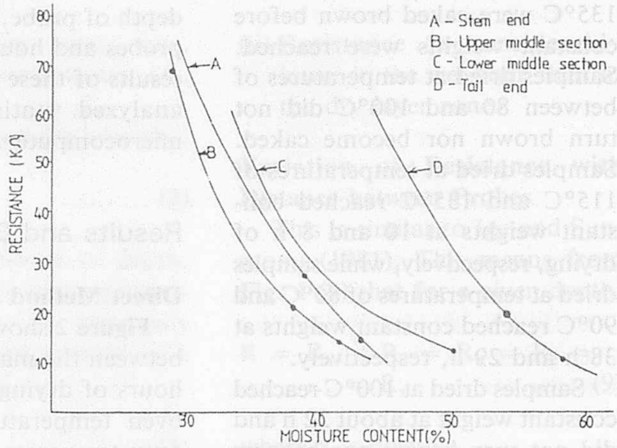

Fig. 5 Moisture content and resistance of cassava for probe depth 1 cm, distance between probes 4 cm.

shows that there is a significant difference between the resistances taken at 0 h and 4 h of drying but no difference between the resistances taken at 1 h and 2 h of drying. The closeness of the results of the first and second hours of drying could be due to the fact that water moved from the inner part of the piece of cassava to the outer part during this period. This was actually physically observed. This period appears to be the constant rate period of drying while subsequent drying is in the falling-rate period.

Results obtained by Ige and Sunmonu for yam showed that three factors affected the resistance of yam. These are distance between probe terminals, the depth of probe and mass of produce. However, results obtained here show that the two principal factors affecting resistance of cassava are depth of probe and hours of drying. The resistance of the cassava appears to have an inverse relationship with the depth of probe. The interaction between depth and hour of drying also show significant differences.

Conclusion

A suitable oven method for moisture content determination in cassava has been developed through experiment. The relationship between moisture content and resistance was studied using this method for reference. The following conclusions were reached after the study:

1. A suitable temperature for direct moisture determination was found to be 100°C for 24 h.
2. Resistance of yam as an indirect tool for measuring moisture content appears reliable.
3. Moisture content has an inverse relationship with resistance of cassava.

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■■

Development of a Unique Groundnut Decorticator

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Abstract

A simple rocking type groundnut decorticator was modified to facilitate fabrication and adjustment of gap between its crushing shoes and concave grate. This was achieved by eliminating the slots provided on each individual crushing shoes and by fixing them directly to the lower segment of the rocking arm. The gap was adjusted by increasing or decreasing the length of the lower segment of the rocking arm through the pivot axle. This enabled the gap adjustment in all the three shoes uniform simultaneously. The modification in the rocking handle also made the packing easier for dispatch. The concave grate design was based on the physico-mechanical characteristics of groundnuts. The capacity of the decorticator was 70-80 kg/h with brekage 3.7%-6.5%. It required 7.05 kg effort to operate.

Introduction

A manual rocking type groundnut decorticator was developed earlier by simplifying the design based on a design by the Tropical Product Institute (T.P.I., United Kingdom). The T.P.I. design comprised of a large hopper-cum-concave grate and 7 units of peg type crushing shoes attached to a rocking handle (**Fig. 1**)[1]. It weighed 40 kg and the cost was about US$ 65 in India. During the evaluation of this machine, it was observed that only the central three shoes were effective in crushing the pods. If, however, the hopper was filled to a level to make the outer shoes effective, it required more effort to operate and the operator got tired easily. The T.P.I. design was thus modified keeping only 3 shoes and hopper size reduced appropriately (**Fig. 1**)[2,3]. The weight of this machine was reduced to 14 kg and the cost was reduced to US$ 17.50. The output varied between 50-60 kg/h (pods) as against 70-80 kg/h (pods) with 7-shoe design.

The technology of the groundnut decorticator with 3 shoes was transferred to local manufacturers. More than 15 000 units were supplied during 1983-88 to farmers and extension agencies. In the course of monitoring of the

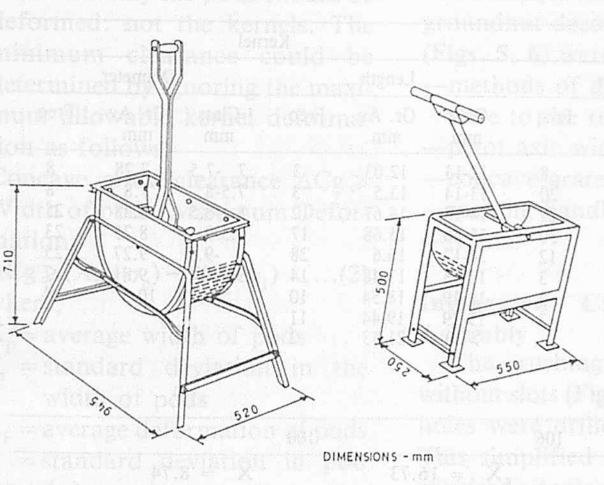

Fig. 1 Manual groundnut decorticator provided with individual adjustable spike tooth crushing shoes.

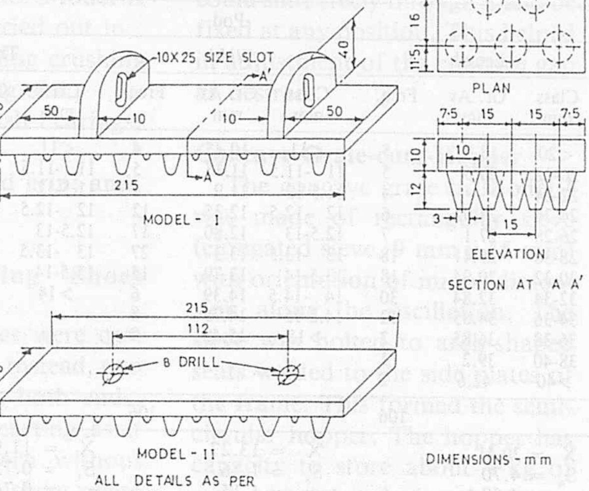

Fig. 2 Details of spike-tooth crushing shoes for Model-I and Model II.

technology, it was found that kernel breakage varied between 2% and 15% at the farmers level. The percentage of high breakage was due to improper concave gap adjustment during the operation of the machine. The concave gap in this design was adjusted through 25 mm slots provided on each crushing shoe (**Fig. 2**). The farmers, however, found it difficult to adjust the gap in all the three shoes uniformly and this adversely affected the performance. This necessitated further improvement in the design. Singh, G. and Pinai, T.[4] modified the design and adjusted the clearance by inserting half-circular washer of 1 mm thickness each under the shelling bar support. The Gujarat State Agro-Industrial Development Corporation adjusted the clearance by splitting the lower portion of the oscillating arm into two. In some designs, the concave gap was adjusted by shifting the perforated screen[5].

Design Consideration

Pod and Kernel Size and Concave Grate

The physical characteristics, namely; the size of the kernels and pods help in the determination of concave grate for minimum breakage. A 50 kg sample of JL-24 variety was sieved through a set of screens having square holes of 12.5 mm and 10 mm (**Table 1**). This gave an approximate size distribution. From **Table 1**, it is observed that 57.18% pods had diameters of more than 12.5 mm, 42.82% between 10-12.5 mm and a small fraction of 1.9% less than 10 mm.

Table 1 Distribution of Groundnut Pod Size (JL-24) as Observed with Sieve Separation

Sieve size mm^2	Pods retained %	Pods passed through %
12.5	57.18	42.82
10.00	40.95	1.97

A more comprehensive size distribution was determined by measuring the length, width and thickness of pods and kernels of a random sample with the help of a dial caliper. The distribution is reported in **Table 2** and **Fig. 3**. During decortication of the pod, it is probable that the kernels would roll along their major dimension (length) before passing through the sieve holes. The length of the grate, therefore, should be more than the largest length of the kernel. From the **Table 2**, it is seen that the longest kernel is 21.53 mm. Thus the minimum length of grate should be over 22 mm.

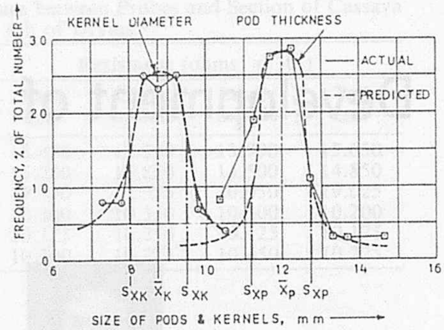

Fig. 3 Size distribution of groundnut pods and kernels (JL-24 Variety).

The width of the grate was decided on the basis of the thickness of pods and kernels. The pod thickness influenced the shelling efficiency while the kernel diameter affected breakage. From **Table 2**, it could also be seen that the kernel diameter varied from 7.28 mm to 10.5 mm. If the width of grate was decided more than 10.5 mm, pods having thickness less than that would pass through the grate unshelled.

The width of the grate (W) could be determined on the basis of average size of the kernels.

$$W = \bar{X}_k \neq S_{xk} \quad \text{.....(1)}$$

where, $\bar{X}_k$ = average diameter of kernels

Table 2 Size Distribution of JL-24 Groundnut Variety

Pod									Kernel					
Length			Width			Thickness			Length			Diameter		
Class mm	Gr. Av mm	Freq.	Class mm	Gr. Av mm	Freq	Class mm	Gr, Av mm	Freq	Class mm	Gr. Av mm	Freq	Class mm	Gr. Av mm	Freq
<20	18.71	5	<11	10.45	4	<11	10.43	8	12-13	12.63	3	7 -7.5	7.28	8
20-22	20.6	5	11 -11.5	11.35	5	11 -11.5	11.33	20	13-14	13.5	3	7.5-8	7.8	8
22-24	—	—	11.5-12	11.9	4	11.5-12	11.79	29	14-15	14.67	12	8 -8.5	8.38	25
24-26	24.92	6	12 -12.5	12.35	12	12 -12.5	12.27	30	15-16	15.68	17	8.5-9	8.75	23
26-28	27.1	7	12.5-13	12.80	17	12.5-13	12.73	12	16-17	16.6	28	9 -9.5	9.27	25
28-30	29.41	18	13 -13.5	13.3	27	13 -13.5	13.3	3	17-18	17.48	14	9.5-10	9.8	7
30-32	30.94	18	13.5-14	13.79	15	13.5-14	13.7	3	18-19	18.54	10	>10	10.5	4
32-34	32.84	30	14 -14.5	14.39	6	>14	14.68	3	19-29	19.44	11			
34-36	34.85	12	14.5-15	14.75	8				>20	21.53	2			
36-38	36.85	2	>15	15.49	9									
38-40	39.2	1												
>40	42.6	2												
		106			106			106			100			
$\bar{X}$ = 30.41 S_x = 4.70 σx = 4.68			$\bar{X}$ = 13.27 S_x = 1.16 σx = 1.15			$\bar{X}$ = 11.97 S_x = 0.75 σx = 0.748			$\bar{X}$ = 16.73 S_x = 1.80 σx = 1.79			$\bar{X}$ = 8.74 S_x = 0.743 σx = 0.739		

$$\bar{X} = \frac{\Sigma x}{n}, \quad Sx = \sqrt{\frac{\Sigma x^2 - n\bar{x}^2}{n-1}}, \quad \sigma_x = \sqrt{\frac{\Sigma x^2 - n\bar{x}^2}{n}}$$

S_{xk} = standard deviation

Substituting the values from **Table 2**

$W = 8.74 + 0.743 = 9.483$ mm

say 9.5 mm

Characteristics of Pods and Kernels and Concave Clearance

The crushing force and deformation of groundnut helped in the selection of concave grate clearance. The force-deformation relationship was measured with the help of an Instron Universal testing machine. A 20-kg local cell was used for measuring the force. The groundnut pods and kernels were deformed at a crosshead speed of 2 mm/min. The pods were loaded along with the section joining the two halves of the hull. This required a lower force. The force-deformations were recorded until the first cracking appeared (**Fig. 4**). The force required for cracking the kernels was also measured (**Table 3**). It is seen that the average crushing force for the pod was 62.4 N with standard deviation of 7.08 N (**Table 3**). Also, the average deformation of pods was recorded at 1.57 mm (S.D., 0.44 mm) before the crushing of pod was initiated. The concave clearance should be selected such that only the pods should be deformed: not the kernels. The minimum clearance could be determined by ignoring the maximum allowable kernel deformation as follows:

Concave grate clearance $\Delta Cg \geqslant$ Width of pod − Maximum Deformation

$$\Delta Cg \geqslant (\bar{X}_p + \sigma_p) - (\Delta_1 - \sigma_1) \quad .....(2)$$

where,

$\bar{X}_p$ = average width of pods

σ_p = standard deviation in the width of pods

Δ_1 = average deformation of pods

σ_1 = standard deviation in pod deformation

substituting the values from the **Tables 2 and 3**

$\Delta Cg \geqslant (13.27 + 1.16) = (1.57 - 0.44)$

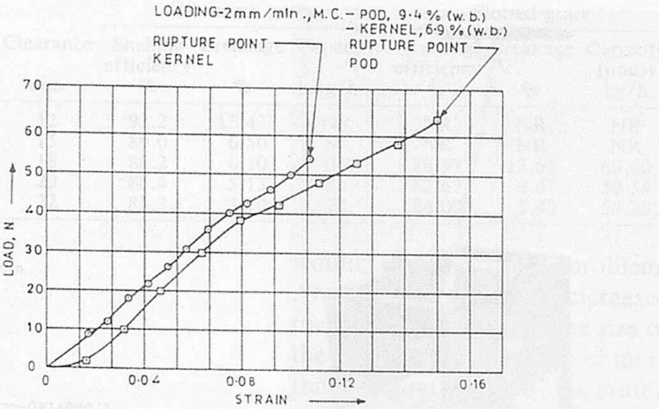

Fig. 4 Force-deformation relationship under compressive loading of groundnut.

Table 3 Force-deformation Values in Quasi-static Crushing of Groundnut, Variety JL-24

Maximum crushing force F_1 N	Maximum deformation at crushing ΔL, mm	Crushing energy $J \times 10^{-3}$	Maximum crushing force, F_2 N	Maximum deformation at crushing ΔL, mm	Crushing energy $J \times 10^{-3}$
58.5	2.2	64.7	56.8	1.2	34.1
68.6	2.2	75.5	60.8	1.12	34.0
66.6	1.4	46.7	66.6	0.92	21.7
62.7	2.0	62.7	52.9	1.04	27.5
58.8	1.68	49.4	63.7	1.28	40.8
52.9	0.96	25.4	46.1	0.96	22.2
49.0	1.06	26.0	49.0	1.04	26.5
66.6	1.32	44.0	44.1	1.12	24.7
71.5	1.58	60.1	59.0	1.52	33.8
68.6	1.16	39.8	48.0	1.44	33.2
$\bar{X}_N = 62.4$ $\Delta N = 7.08$	$\bar{X}_L = 1.57$ $\Delta L = 0.44$	$\bar{X}_E = 49.4$ $\Delta E = 15.7$	$\bar{X}_N = 53.9$ $\Delta N = 6.34$	$\bar{X}_L = 1.16$ $\Delta L = 0.19$	$\bar{X}_E = 30.3$ $\Delta E = 6.5$

Note: Crushing Energy = 1/2 F_{max} ΔL

13.30 mm .....(5)

Modifications Incorporated in Model-II

The major modifications in the groundnut decorticator Model II (**Figs. 5, 6**) were carried out in

—methods of attaching crushing shoe to the rocking arm;

—pivot axle with bush bearings;

—concave grate;

—rocking handle and grip; and

—frame.

Integrated Crushing Shoes Assembly

The crushing shoes were cast without slots (**Fig. 2**). Instead, two holes were drilled at both ends. This simplified the casting as it required single pattern without core. All the three shoes were joined together with nuts and bolts making it an integral unit (**Fig. 6**).

The rocking handle was screwed to the shoes assembly and hand grip. The handle could be detached as and when required, especially during transport. The handle was attached to the pivot axle through a hole drilled at its centre and could slide freely through it and be fixed at any position. This helped in adjustment of the concave gap as desired.

Concave Grate-cum-Hopper

The concave grate in Model I was made of rectangular sieve (elongated sieve, 9 mm × 45 mm) with orientation of minor dimension along the oscillation. The sieve was bolted to arch-shaped seats welded to the side plates of the frame. This formed the semi-circular hopper. The hopper has capacity to store about 4 kg of pods in batches during the decortication. The fabrication of concave grate required punching of

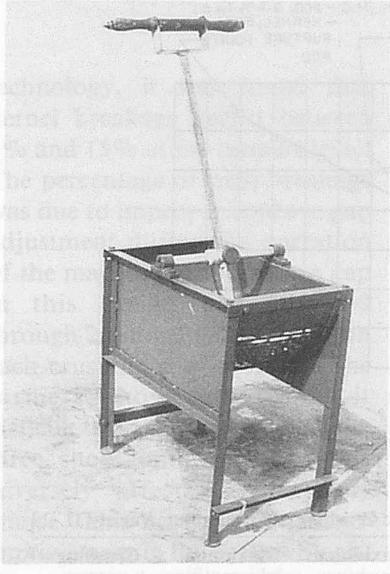

Fig. 5 Modified manual groundnut decorticator Model-II with 9 × 45 mm slotted sieve.

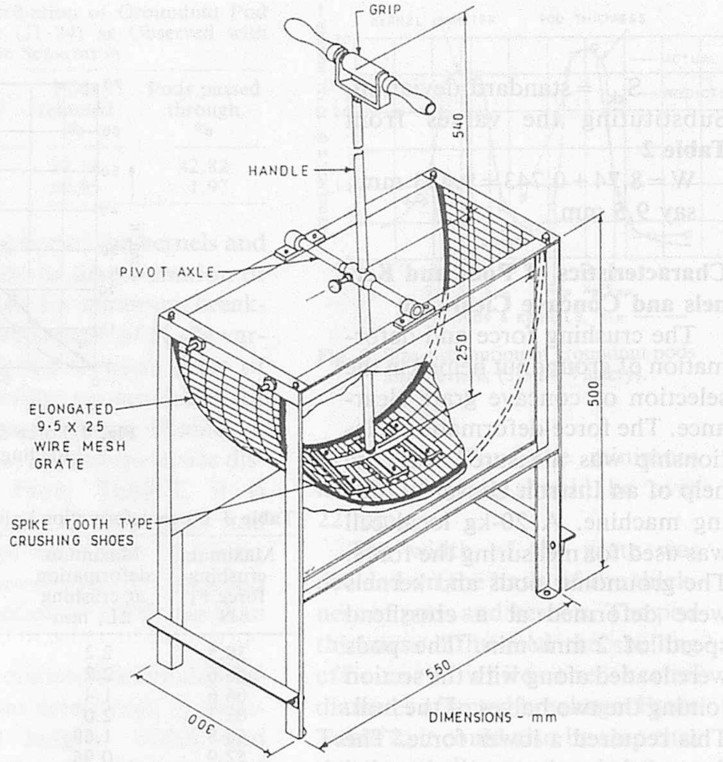

Fig. 6 Modified manual groundnut decorticator Model-II with 9.5 × 25 mm wiremesh sieve.

holes. Of course, punching was possible with the hand fly press, but it required fabrication of dies and punches. The cost of this type of concave was about US$ 4.50. It was, thus, decided to use, instead, wire mesh type concave which cost less than US$ 1.50. The 12 SWG welded wire mesh of 22 × 25 mm size cost Rs.55/m^2 and the concave grate required 240 mm × 785 mm size. A concave grate of 9.5 × 5 mm size hole was wire mesh type elongated sieve increased the effective opening area to 0.096 m^2 as against 0.053 m^2 of the slotted type, or, an increase of 81%. The increased opening area could increase the capacity of the machine.

Frame

The frame was fabricated from angle sections ISA 25 mm × 25 mm × 31 mm. Originally the angle sections were protruding inward supporting the arch-shaped seat. In the Model-II, however, the angle sections were protruding outward. This increased the base-support width by 50 mm resulting in better stability. The farmes were joined together with nuts and bolts enabling it to be dismantled easily for packaging.

Materials and Methods

The performance of the decorticator was evaluated by measuring its capacity of crushing the pod, unshelled pods, kernel breakage, ergonomics of the operator, and effort required during crushing of the pods. The fatigue of the operator was measured by recording the heartbeat by ECG Telemetry (MINI-INSTAMAKE, India) and oxygen consumption by Morgan Oxylog (U.K.). The decorticator was continuously operated by a single person for a duration of 30 minutes. Usually two operators are required; one for operating the machine and the other for filling the hopper. After half an hour of run, the operators swapped position to avoid undue fatigue, if any.

The effort required at the handle grip was measured by fixing a strain gauge dynamometer ring. The effort could also be measured by attaching a 100 N spring dynamometer directly on the grip.

The groundnut veriety JL-24 was shelled at 6.8% (wb) moisture content at 18, 20 and 22 mm clearances with assorted size of pods.

Results and Discussion

Simplification of Construction

One of the major advantages of the modification was to facilitate clearance adjustment. In the original design, this was achieved through 25 mm slots provided on each of the spike-tooth crushing shoes at both ends. In the modified design, this was achieved by adjusting the handle through the hole of pivot axle which was much easier. In addition, the shoe assembly, handle-bar, handle-grip and frame were fabricated as detachable. This facilitated packaging. The packaging size was reduced from 0.184 m^3 to 0.125 m^3. The reduced package lowered the transportation cost by 32% under semi-knocked down condition.

Operator's Fatigue

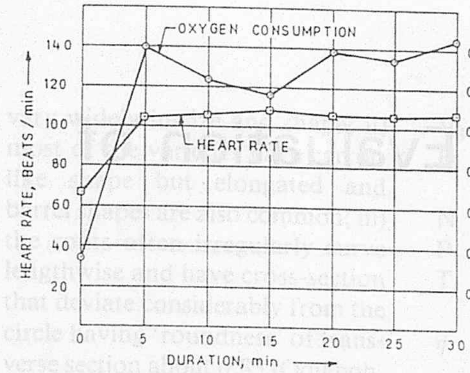

Fig. 7 Operator's fatigue as measured by heart beat and VO2 consumption.

Table 4 Performance Results of Manual Groundnut Decorticator Model II

Clearance	Wiremesh grate			Slotted grate		
	Shelling efficiency	Breakage	Capacity	Shelling efficiency	Breakage	Capacity (pods)
mm	%	%	kg/h	%	%	kg/h
12	93.2	15.43	NR	NR	NR	NR
15	89.0	6.50	86	NR	NR	NR
18	88.2	6.10	85	83.97	12.63	60.60
20	88.4	5.13	80	82.63	8.47	59.54
22	83.3	3.70	70	84.00	8.40	54.30

The average effort required at the handle grip for crushing of pods as measured through the strain gauge dynamometer was 69.0 N (S.D. 21.9 N). The effort measured by the spring dynamometer fluctuated between 60-80 N. This force was well within the normal limit for continuous push-pull action exerted by the operator(6). The ratio between larger sector of the oscillating arm (handle length above pivot) and lower sector (length of crushing shoes below pivot axle) was 2.16 (54/25).

The average heartbeat rate of the operator during crushing for 30-minute duration was 107.2 (S.D. 1.62) with resting heart beat rate of 67 beats/min. It was reported that (6) for continuous 8 hour working duration, the heartbeat rate should not exceed more than 40/min over resting heartbeat rate. The variation of heartbeat rate for 30-minute duration is plotted in **Fig. 6**. It could be seen that there is no appreciable increase in the heartbeat rate which indicates that the operator was not fatigued and could have continued to work.

The fatigue was also observed by measuring the oxygen consumption. The average oxygen (VO_2) consumption for the 30-minute duration was 0.656 ℓ/min (S.D. = 0.062) as against 0.17 ℓ/min at rest.

The maximum uptake of O_2 was reported (6) 2 ℓ/min but for normal working it should not exceed more than 35% of the highest, i.e., 0.7 ℓ/min, for continuous work. The variation of heartbeat rate for the 30-minute duration is plotted in **Fig. 7**. It could be seen that there is no appreciable increase in the rate of O_2 consumption which indicates that the operator was not fatigued during the period.

Shelling Performance

The shelling efficiency, capacity and kernel damage are affected by concave clearance, sieve opening, groundnut characteristics including physical dimension and moisture content, rate of feeding of pods and rate of oscillation. The pods were one year old. The moisture content at the time of crushing was 6.8% (wb). The decorticator was oscillated at uniform speed of 50 cycles/min. The performance data are reported in **Table 4** which shows that the shelling efficiency with the wiremesh type grate was higher (83.3-89%) compared to slotted type (82.5-84%). The wiremesh grate has also lower kernel breakage (3.7-6.5%) as against 8.4-12.65% with the slotted sieves. In general, however, the breakage was high due to low moisture content of pods (6.9%, wb) and large kernel size. It was reported that the minimum kernel breakage (less than 1.5%) was obtained when the pods were shelled within moisture range of 26.65-13.42% (Chinsuwan, 1987). But shelling of groundnut at higher moisture would create storage problem. Another factor which increased the kernel damage was the size of the kernels with diameters of more than 9.5 mm (width of the grate).

The concave clearance influenced the kernel damage, shelling capacity and shelling efficiency significantly. Especially in the case of slotted grate, the clearance which was less than 15 mm resulted in excessive kernel damage and the results were discarded. The acceptable clearance with JL-24 variety was within 15-22 mm. At higher clearance, output and shelling efficiency are both affected adversely.

The shelling capacity with wiremesh concave grate was higher (**Table 4**) as compared to slotted grate due to increased opening area in the case of the former. The wiremesh concave had 0.096 m^2 effective opening area as against 0.053 m^2 in the case of slotted grate.

Conclusion

The constructional feature of the oscillating type manual groundnut decorticator Model-I was improved to facilitate concave gap adjustment for different sizes of pods. The modification also reduced the packaging and transportation costs. The modification did not increase the cost of the decorticator.

The average capacity of the decorticator was 70-80 kg with kernel breakage of 3.7-5.13%. This required 60 N (S.D. 21.9 N) effort at the handle grip to operate the decorticator with 107.2 heartbeat rate and 0.0656 ℓ/min VO_2 consumption.

(Continued on page 64)

Design, Development and Evaluation of A Cassava Chipper

by

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Abstract

A motorized cassava chipper was designed, fabricated and tested at the Department of Agricultural Processing, College of Agricultural Engineering, Tamil Nadu Agricultural University, India. The chipper is simple and inexpensive. It does not require any special skill to operate it. The capacity of the chipper is 270 kg/h. The chip recovery was assessed at 92% for 1 mm chips at 295 rpm. The cost of chipping was estimated at Rs. 18/ton (US$1.38/ton).

Introduction

Cassava (*Manihot esculenta*) is a starchy root crop, (Grace, 1977) grown in most of tropical regions of the world. It is widely used in the production of starch and allied products, animal feed and food. Asia accounts for about 27% of the world's cassava area and produces 37% of the crop. Thailand, Indonesia and India are the major producers of cassava in Asia (Anonymus, 1981).

The tubers, because of high moisture content, (about 65%) cannot be stored for more than 2 or 3 days resulting in accumulation of toxic substances like Scopoletin that make it unfit for consumption. Several researchers have made attempts to solve the above problem. Still no effective or generally applicable storage technology exists to combat the fast post harvest deterioration of cassava tubers. Because of its poor keeping quality, it has to be converted into some other form for low moisture storage. The simplest mode of processing the tuber is therefore, conversion into chips, and process it further for long term storage, by drying the chips. The chips can be used later in non-traditional food industries such as an animal feed, or for export or for manufacturing of cassava flour, and starch during lean period (Hrishi, 1974). The chips have better keeping quality and need less storage space compared to raw tubers.

To facilitate drying, the tubers need to be made into thin chips. Cock (1985) and Rupert Best (1979) reported about the Malaysian and Thai cassava chipping machines which were described as satisfactory. But they are suitable for large industries with high capacity and high initial investment. Moreover, manufacturing of the cutter blades requires highly skilled blacksmiths.

The locally available chippers using the conventional methods are with poor safety measures to the operator's fingers while feeding the tubers, non-uniformity in size of the chips produced resulting in poor quality of chips after drying. With a view to eliminating these difficulties, the present research was undertaken to develop a vertical feed mechanized cassava chipper that is suitable for farm-level and small scale industries for the production of cassava chips for human consumption.

Design

In designing the cassava chipper the following problems were encountered: i) the cassava roots vary widely in size and shape; ii) most of the varieties have carrot-like shape but elongated and barrel shapes are also common; iii) the roots often irregularly curve lengthwise and have cross-section that deviate considerably from the circle having 'roundness' of transverse section about 0.85 (Odigboh, 1976).

The basic parameters of the chipping disc are cutting velocity, shear angle of cut and bevel angle of knife. The cutting energy to cut the tubers into chips by impact force depends on these parameters. The minimum cutting energy per unit area of cross-sectional area of 3.10 kg-cm/cm^2 was 2.68 m/sec, 63° and 37.5° cutting velocity, shear angle and knife bevel angle, respectively, (Visvanathan et al, 1990).

Number of Chipping Blades

A single phase 0.5 hp electric motor was selected as power source on cost considerations. The diameter of the chipping disc on which the blades to be mounted was assumed at 0.30 m. Considering 2.68 m/sec as the optimum cutting velocity (Visvanathan et al, 1990), the torque available on the chipping disc is calculated as follows:

$$V_S = \frac{\pi DN}{60} \qquad (1)$$

$$N = \frac{60 \times 2.68 \times 1.60}{\pi\ (0.30)}$$

$$= 272 \text{ rpm}$$

(a factor of safety of 1.6 was assumed)

$$P = \frac{2\pi NT}{4500\eta} \qquad (2)$$

$$N = \frac{4500\ (0.9)\ (0.5)}{2\pi\ (272)}$$

$$= 118.5 \text{ kg-cm}$$

where,

V_S = cutting velocity, m/sec
D = diameter of chipping disc, m
N = speed of disc, rpm
P = power of power source, hp
T = torque available for chipping, kg-cm
η = mechanical efficiency (assume 90%)

This torque supplies the energy requirement for chipping the tubers. The minimum energy required is 3.10 kg-cm/cm^2 (Visvanathan et al, 1990) and the diameter of the tuber ranges from 30 mm to 50 mm. Hence, the minimum energy required to cut the tuber of average size will be

$$E = E_{ca}\ A \qquad (3)$$

$$E = \frac{3.10\pi\ (4.0)^2}{4} = 39.0 \text{ kg-cm}$$

where,
E_{ca} = cutting energy per unit cross-sectional area, kg-cm/cm^2
A = average cross-sectional area of tuber, cm^2

Hence the number of tubers cut at a time or the number of blades can be calculated as

$$\eta = \frac{T}{E} \qquad (4)$$

$$\eta = \frac{118.5}{39.0} = 3.03$$

The proposed chipping disc will have 3 blades with 37.5° bevel angles.

Chipping Disc

The torque supplied to the chipping disc is stored as it acts as fly wheel. The energy stored in the rotating disc is given by the equation.

$$E_d = I\omega^2 C_S \qquad (5)$$

$$I = \frac{W}{g} R^2 \qquad (6)$$

and $W = \pi R^2\ t\ \rho \qquad (7)$

where,
E_d = energy stored in fly wheel, kg-cm
I = moment of inertia, kg m sec^2
ω = angular velocity
C_S = fluctuation of speed, kg
W = weight of the disc of radius, R/diameter, D, kg
t = thickness of disc, cm
ρ = density of the material by which the disc is made (2300 kg/m^3)

Combining equations (5), (6) and (7) the thickness is calculated as,

$$t = \frac{E_d\ g}{\pi R^4\ \omega^2\ \rho\ C_S} \qquad (8)$$

$$= \frac{(118.5 \times 981)\ 10^6 \times 60^2}{\pi (15)^4\ (2\pi 272)^2 (2300)(0.64)}$$

$$= 6.0 \text{ mm}$$

Hence the thickness of the disc was selected at 6.0 mm.

Disc Mounting Shaft

In the chipper, when the disc and shaft are loaded with the tubers, the shaft is subjected to torque and the bending moment is neglected as the shaft is mounted vertically. The size of the shaft is calculated by the following torsional equation.

$$\frac{T}{J} = \frac{F_S}{r} \qquad (9)$$

where,
T = torque applied, kg-cm
J = polar moment of inertia, cm^4
F_S = torsional shear stress of mild steel, (375) kg/cm^2
r = radius of the shaft, cm
d = diameter of the shaft, cm

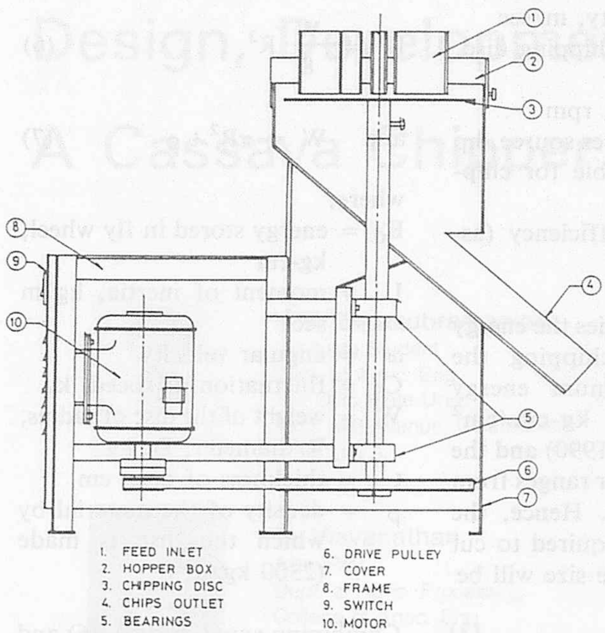

Fig. 1 Cassava chipper, assembled.

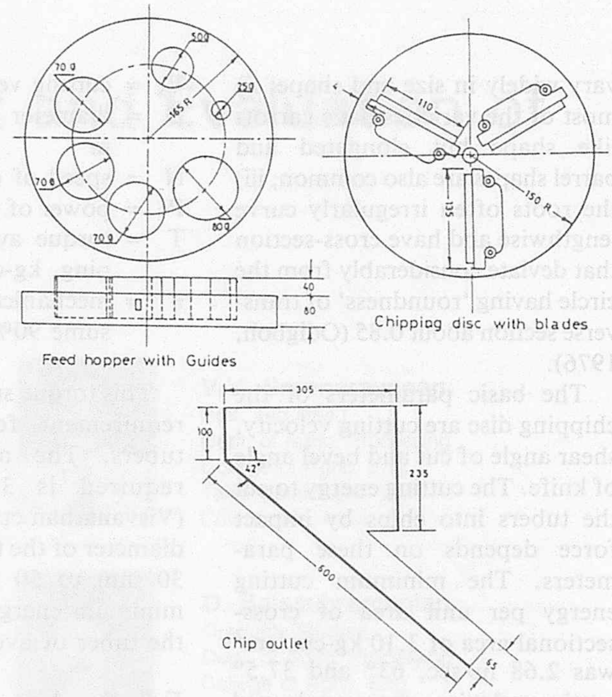

Fig. 2 Feed hopper, chipping disc and chip outlet of cassava chipper.

Hence,

$$d = \left(\frac{16T}{\pi F_S}\right)^{1/3}$$

$$d = \left(\frac{16\,(118.5)}{\pi\,(375)}\right)^{1/3} = 1.17\,\text{cm}$$

Based on the available material, a shaft of 25 mm diameter was selected.

Development

The cassava chipping machine developed is a vertical feed type motorized unit. The various components of the chipper are frame assembly, power source, chipping disc and blades, chipping disc shaft, feed hopper with guides and chips outlet **(Fig. 1)**.

Frame and Power Source

The frame is made of 'L' angles of size 37.5 × 37.5 × 3 mm. The overall dimensions of frame are 385 mm × 360 mm and 400 mm high. In this frame assembly other sub-assemblies like bearing mountings, hopper assembly, prime mover and outlet are mounted. A 0.5 hp single phase electric motor is used as the power source for the chipper. The motor is mounted at the back side of the frame assembly on two rails. The provision of rails facilitate the motor movement in the horizontal direction for adjusting the belt tension.

Chipping Disc and Blades

Chipping disc of diameter 300 mm and thickness 5 mm made from 6 mm thick mild steel was used. Three slots of length 110 mm and width 35 mm are made in the disc at equal angles radially as shown in **Fig. 2**.

Three blades of length 135 mm length and width 35 mm and thickness 3 mm, made of high speed steel are used as cutting blades. The blades are sharpened to 37.5° bevel angle (Visvanathan et al, 1990). The blades are mounted on the disc with screws, and slots provided in the blade facilitate for adjusting the clearance between slot and blade.

Chipping Disc Shaft

A mild steel shaft of 25 mm

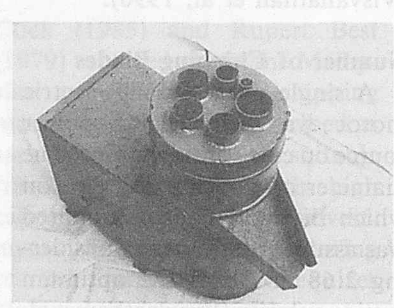

Fig. 3 Cassava chipper.

diameter for a length of 620 mm is mounted on two bearings vertically. At the bottom end, the drive is transmitted through a V-belt pulley of diameter 300 mm. V-belt is used to transmit power from motor to the drive pulley. The chipping disc rotating inside the circular bowl has been mounted at the top end of the shaft.

Feed Hopper with Guides

A feed hopper of diameter 330 mm is used as shown in **Fig. 2**. In the hopper, guide tubes of various diameter are arranged to facilitate safety feeding of tubers and to allow free movement of tubers of different size, vertically downward, under self weight. For this the guides are provided with varying diameters from 80 mm to 25 mm. The hopper has provisions to adjust the distance between feed disc and feed hopper. This is done by adjusting the wing bolts in the slots provided in the feed hopper and circular bowl. This is essential when the thickness of the chips is varied by raising the blades from the disc with the help of spacers.

Chip Outlet

The chipped cassava tubers are collected through the chip outlet. To facilitate the easy discharge of chips the outlet is provided with 42° inclination as shown in **Fig. 2**. The photograph of the complete unit is shown in **Fig. 3**.

Evaluation

The performance of the chipper was evaluated for the chips recovery and capacity, with respect to the speed of the disc. In the unit the chipping disc was provided with 3 cutting blades with 37.5° bevel angle. The unit was run at different speeds by changing the diameter of the drive pulley. Freshly harvested tubers obtained from local market was used. The chip recovery was assessed on the basis of the uniform thickness of the chips without any breakage. The good quality uniform chips without any breakage were collected and weighed. From this chip recovery was determined as a percentage weight basis. The capacity of the chipper for various speed of the disc and chip thickness was also determined.

Effect of Disc Speed on Chip Recovery and Capacity

The effect of the disc speed on the chip recovery of cassava and the capacity of the chipper are given in **Fig. 4**. In the speed range of 225 to 425 rpm of the disc of diameter 30 cm, the chip recovery

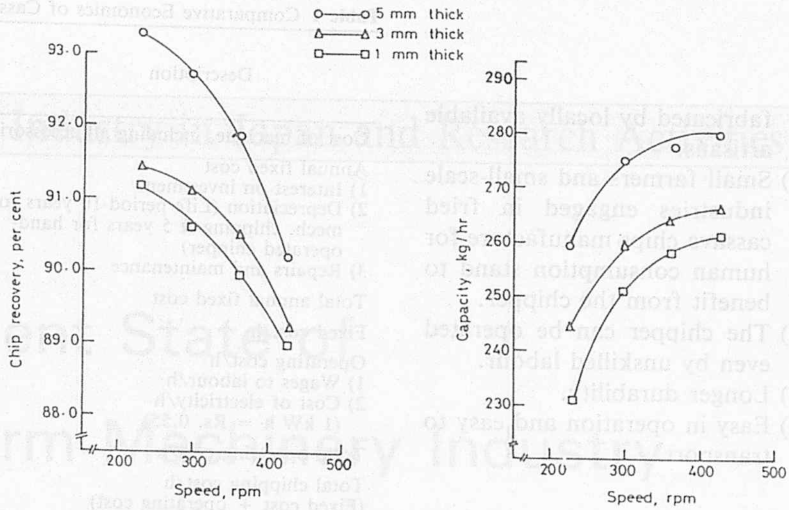

Fig. 4 Effect of speed of the chipping disc on chip recovery and capacity of the chipper.

for the chip thicknesses of 1, 3 and 5 mm decreased with an increase in speed. The percentage chip recovery was greater at higher thickness of the chip at all speeds. This may be due to the fact that more breakage has resulted with thicker chips. In this speed range, the chip recovery ranged from 93.25 to 90.25; 91.5 to 89.25% and 91.2 to 89.0% for the thicknesses of 5 mm, 3 mm and 1 mm, respectively. The reduction in the chip recovery is greater beyond the speed of 300 rpm. Between the speeds of 225 and 300 rpm, the decrease in the chip recovery was in the range of 0.2%.

For the chip thicknesses 1, 3 and 5 mm, at all speeds the capacity increased with increase in speed in the speed range of 225 to 425 rpm. At all the speeds, the capacity was greater for higher chip thickness. The increase in the capacity in the speed range of 225 to 300 rpm is greater compared to the effect shown beyond the speed of 300 rpm. Combining the effect of the disc speed on chip recovery and the capacity of the chipper, the decrease in the chip recovery is greater beyond the speed of 300 rpm and the increase in capacity is not very significant for the same speed range for all the chip thicknesses.

Economics of the Chipper

The economics of the chipper was evaluated comparing it with locally available hand-operated chippers, manual chipping and cost of chipping/ton of the cassava (**Table 1**).

The following assumptions were made while calculating the economics of the chipper.

Interest rate on investment
— 12%

Annual repairs and maintenance
— 10% on the investment cost

No. of working hours/year
— 1 200 h/y for both chippers and 2 400 h/y for manual chipping

Capacity
— 270 kg/h for mech. chipper, 70 kg/h for hand chipper and 25 kg/h for manual chipper

Labour cost
— Rs. 4/h

The cost of chipping is much less for mechanical chipping compared to conventional methods. The cost of chipping is still very much less if the farmer engages his family members for chipping operations.

Advantages

1) The safety of operator is assured.
2) The chipper produces more uniform thickness circular shaped chips.
3) Various size tubers can be accomodated.
4) The chipper and blades can be

fabricated by locally available artisans.

5) Small farmers and small-scale industries engaged in fried cassava chips manufacture for human consumption stand to benefit from the chipper.
6) The chipper can be operated even by unskilled labour.
7) Longer durability.
8) Easy in operation and easy to transport.

Table 1 Comparative Economics of Cassava Chippers*

Description	Mechanical chipper (Rs.)	Hand operated chipper (Rs.)	Manual chipping (Rs.)
Cost of machine, including all accessories	2 500	900	10
Annual fixed cost			
1) Interest on investment	300	108	—
2) Depreciation (Life period-10 years for mech. chipping & 5 years for hand-operated chipper)	225	162	
3) Repairs and maintenance	250	90	—
Total annual fixed cost	775	360	
Fixed cost/h	0.65	0.30	—
Operating cost/h			
1) Wages to labour/h	4.00	4.00	4.00
2) Cost of electricity/h (1 kW h = Rs. 0.55)	0.20	—	—
Total operating cost/h	4.20	4.00	4.00
Total chipping cost/h (Fixed cost + operating cost)	4.85	4.30	4.00
Hence cost of chipping for one ton of Cassava	Rs.18.00	Rs.61.45	Rs.160.00
*Rs. 13 = US$1.	($1.38)	($4.73)	($12.3)

Conclusion

The chipper described above is safe. It produces more uniform circular shaped thin sliced chips, with about 270 kg/h capacity, which facilitates drying. The cost of chipping is less than conventional methods of chipping. It can be used to advantage by small farmers as well as small-scale processing industries.

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The Present State of Farm Machinery Industry

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Outlook of Agriculture

Trend of Agriculture

In 1991 Japanese economy is inclined to be a business recession.

In 1991 food consumption and agricultural production was slightly lower than that of the previous year. The imports of agricultural products is on the increase. In 1990 the imports reached $27.5 billion, which means that Japan is the greatest food importing country. In Japan, feed cereals, soybean, wheat and so on depend on the imports from foreign countries. Food self-supporting rate ended in 47%. This figure is the worst rate of all the advanced countries.

Farming population in 1991 decreased 3.9% over the preceding year to 3,920,000 persons. The aged persons over 65 years old forms 29% of the population.

Farm houses has showed a rapid decrease of late years; 3,790,000 farm houses. Those dealing agricultural products was 78%. Arable land was 5,200,000 ha in 1991, which decreased by 0.7% over the previous year.

Farm income in 1991 increased 4.6%, compared with the previous year. The total income including the income from pension and other than agriculture is taking a favorable turn.

In Japan, food life has become rich since 1970's. While, rice, oranges, milk, eggs and so on has been overproduced. Food industry has developed and the imports of agricultural products showed a sharp increase.

In Japanese agriculture, it is requested to reduce production cost, people destined to bear agricultural production, produce various products satisfying consumers' need, and to realize agriculture keeping the earth favorable.

Trend of Farm Mechanization

Agricultural mechanization in Japan has remarkably progressed in the field of low land rice, chief crop, in a short period since 1955. Thus, continuous system of low land rice has completed. 99% of rice transplanting and 99% of rice harvesting were mechanized. As to rice, working hours per 10 a decreased to 43.8 hours — they were 117.8 hours in 1970.

In recent years farm machinery for rice crop is developed to be larger-sized, higher-efficient and more commonly used. In addition, farm machinery for field crops and livestock farming is being developed and improved, which has been lagged behind so far. Whatever the types it may be, farm machinery is being improved from various points such as performance, safety and cost reduction.

Followings are the number of popularization of farm machinery as of Jan. 1, 1992: riding tractor reached 2,003,000 units; walking tractor 1,786,000; rice transplanter 1,881,000; head feed combine 1,158,000 **(Table 1)**.

Shipments of major farm machinery in the domestic market in 1991 are as follows: riding tractor reached 89,000 units (those under 20PS to 30PS were 40,000; those from 30PS to 50PS were 11,000; those over 50PS were 700); walking tractor 198,000; rice transplanter 83,000; power reaper 30,000; combine 59,000; (standard type were 606); grain dryer 51,000; huller 40,000 **(Table 2)**. This shows a tendency

Table 1 Major Farm Machinery on Farm

Unit: Thousand

Year	Walking type tractor	Riding type tractor	Rice trans-planter	Power sprayer	Power duster	Binder	Combine	Rice dryer
1985	2,579	1,854	1,993	2,151		1,518	1,109	1,473
1986	2,554	1,834	2,098	—	—	—	1,150	—
1987	2,682	1,904	2,179	—	—	1,275	1,201	1,378
1988	2,674	1,985	2,199	1,408	1,674	—	1,244	—
1989	2,654	2,049	2,205	—	—	—	1,258	—
1990	2,185	2,142	1,983	1,871		1,298	1,215	1,282
1991	1,765	1,966	1,904	—	—	—	1,169	—
1992	1,786	2,003	1,881	—	—	—	1,158	—

Source: "Statistical Yearbook of Ministry of Agriculture, Forestry & Fisheries" by the Ministry of Agriculture, Forestry & Fisheries and Other datas.

Table 2 Shipment of Major Farm Machinery

Unit: Number

Year	Walking type tractor	Riding type tractor	Rice trans-planter	Power sprayer	Power duster	Binder	Combine	Rice dryer
1985	195,589	103,859	126,967	128,353	136,970	49,908	95,676	78,304
1986	184,005	109,101	122,441	132,447	133,479	52,234	88,997	74,636
1987	184,885	90,940	101,942	140,635	123,674	44,746	79,278	66,662
1988	213,941	90,261	84,531	144,705	108,958	39,950	66,618	59,666
1989	214,806	89,676	88,444	168,232	110,969	36,789	65,046	58,614
1990	205,944	95,691	89,139	183,820	107,227	37,117	65,247	51,954
1991	197,919	88,860	83,351	173,482	105,549	30,269	59,485	52,347

Source: "Survey of Shipment of Agricultural Machinery" by the Ministry of Agr., Forestry & Fisheries.

that tractor, rice transplanter and combine, chief farm machinery, are decreasing in number and that higher-efficient farm machinery, is increasing in number.

Recently more and more used farm machinery is distributed. In 1990 the demand shows a decreasing tendency. The rate of used farm machinery in the total sales amount is as follows: riding tractor forms 41%; rice transplanter 32%; combine 35%.

Measure of Farm Mechanization

The budget of agricultural, forestry and fishery for 1992 amounted to ¥3,311.8 billion, which shows an increase of 1.4% compared with the preceding year.

The important measures are as follows: In order to promote high-productive and high-quality agriculture for the coming 21st century, we must strive for promoting advanced agricultural management, making animal husbandry active, promoting field agriculture and making paddy field higher productivity.

*To realize that younger generation can enter into agriculture and to improve the living environment in farm and fishing village.

*To consolidate fundamental and leading researchers.

*To consolidate measures for consumers and to secure prices of agricultural products.

*To consolidate measures for preservation of global surroundings and promote international cooperation.

*To consolidate financial system.

*To rear forest resources with various kinds of wood and to maintain domestic forest resources.

Enterprises for agricultural mechanization are incorporated into the above-mentioned measures. The budget is ¥120 billion: this is for subsidiary measure of the introduction of farm machinery. Another budget is ¥1,063.2 billion for financing for the introduction of farm machinery.

Among these subsidiary enterprises, agricultural production, processing and distribution are consolidated to introduce farm machinery. Farm machinery and facilities for personal use and community use are developed and used to consolidate fields. Enterprises are being strived to organize farming workers, to consolidate banks for farm machinery and to reduce production cost.

Movement of Farm Machinery Industry

The output of farm machinery, which increased sharply in 1973 and 1974, amounted to ¥659 billion in 1977. But it decreased sharply to ¥536.7 billion in 1978 because farmers were unwilling to invest money in farm machinery under the popularization of rice crop machinery and under the policy of reducing the acres for rice planting, which aims at adjusting overproduction.

Ever since, except for ¥627.3 billion in 1980, the output remained about ¥500 billion p.a. The output has a gradual increase to ¥638.2 billion in 1984, ¥667.8 billion in 1985 and ¥674.3 billion in 1986. In spite of these increasing tendency, in 1987 the output decreased ¥500 billion again. Since then, it remained about the ¥500 billion again. Since then, it remained about the ¥550-billion level in 1987. It barely hovers round the ¥600-billion level in 1991.

Though other industries are showing signs of prosperity, the farm machinery industry is facing at the decrease in the demand. Each company is striving for developing another demand, extending subcontracted production with other industries, finding fields other than farm machinery and business tie-up to maintain the

Table 3 Yearly Production of Farm Machinery

Unit: Number, Million Yen

Year	Farm machinery total		Riding type tractor		Walking type tractor		Rice transplanter		Power sprayer		Power duster		Blower sprayer	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1985	—	667,895	209,652	247,100	278,581	41,398	132,909	53,835	170,968	10,479	222,877	7,755	7,200	8,361
1986	—	647,265	209,078	254,010	268,307	37,026	134,433	64,541	157,774	9,754	184,132	6,374	7,121	9,535
1987	—	585,810	179,884	215,379	276,286	38,778	92,861	50,181	144,734	8,396	165,241	6,028	6,231	8,296
1988	—	549,854	172,761	209,278	276,684	37,644	81,022	43,554	181,805	9,851	161,763	5,999	8,696	9,958
1989	—	553,368	157,544	197,947	275,629	38,735	87,615	46,337	184,098	10,015	156,802	5,845	9,901	9,400
1990	—	585,561	115,939	198,557	269,027	38,248	91,141	52,462	220,528	12,339	149,789	5,575	9,565	9,514
1991	—	615,131	148,437	203,260	270,714	40,102	87,019	54,265	198,887	10,607	163,306	6,155	9,318	12,766
(1992)		575,700	142,500	187,900	250,000	36,900	79,000	52,700	180,000	8,500	160,000	6,400	9,900	14,300

Year	Grain reaper		Brush cutter		Power thresher		Grain combine		Rice husker		Dryer		Grain polisher	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1985	51,061	12,274	1,350,990	24,573	42,901	15,163	102,593	157,222	80,231	19,661	76,571	42,634	75,314	3,843
1986	55,587	13,777	1,496,433	27,191	41,295	15,246	93,080	150,188	72,000	19,060	73,798	44,590	66,891	3,537
1987	45,867	10,292	1,421,007	24,569	29,126	10,430	78,656	131,265	57,087	16,300	65,378	44,192	61,367	3,083
1988	41,204	9,313	1,546,010	26,160	24,811	8,900	64,412	117,132	49,866	13,137	58,097	37,649	58,982	2,932
1989	37,291	8,841	1,689,181	28,501	23,835	9,005	64,789	127,309	47,478	13,900	55,537	35,244	61,298	3,223
1990	42,502	11,110	1,601,652	25,798	22,634	9,118	68,993	138,396	60,004	18,332	59,269	39,990	58,500	4,871
1991	37,782	9,542	1,657,897	27,117	20,337	7,898	72,913	152,827	60,690	19,124	57,747	43,250	57,625	5,243
(1992)	30,000	7,700	1,900,000	29,700	12,000	4,600	68,500	147,300	50,000	15,800	50,000	36,700	45,000	4,300

Source: ''Survey of Status of Machinery, Production'' by the Ministry of Interntional Trade and Industry. Data by Japan Agr. Machinery Manufacturers' Assn. and Land Internal Combustion Engine Manufacturer's Assen.

Note: Data for 1992 are forecast by Farm Machinery Industrial Research Corp.

Table 4 Farm Equipment Distributor and Sales Value

Unit: Million yen

Year	No. of retailers (1)	Employes	Annual sales value (2)	Inventory	Square meters of shop m^2	Annual sales value (2)/(1)
1976.5	8,417	43,819	811,535	199,672	740,785	96.4
1979.6	9,257	48,548	1,007,298	159,772	898,854	108.8
1982.6	10,084	49,081	1,018,983	164,269	1,005,546	101.0
1985.6	9,142	43,921	946,507	144,837	985,453	103.5
1988.6	9,444	45,952	1,015,304	159,798	923,726	107.5

Source: Ministry of International Trade and Industry.

Table 5 Handling of Farm Equipment by Agricultural Cooperative Association (1989 Business Year)

Unit: Million yen

Business year	Total number of coops. surveyed	Purchase in this term	Of which purchased through affiliated organs	Amount of supply and handling
1985	4,242	345,606	268,640	378,441
1986	4,194	351,484	275,591	383,023
1987	4,117	333,131	260,530	364,716
1988	3,976	337,970	259,915	379,709
1989	3,717	308,833	237,383	340,989
1990	3,591	349,521	268,763	375,660

Source: ''Statistics on Agricultural Cooperatives—1990 business year—'' by the Ministry of Agriculture, Forestry & Fisheries.

management. The constitution is being consolidated to improve working hours, wages and working surroundings so that more and more young labourers may settle.

Trend of Farm Machinery Production

In 1991 the amount of farm machinery production was ¥615.1 billion, which increased by 5.0% over the previous year. This amount means the recovery to ¥600 billion after five years' absence. While, the amount of shipment was ¥573.9 billion, which decreased by 3.5% over the previous year. In consequence, stocks are on the increase.

Production of the major farm machinery is as follows: riding tractor decreased by 4.8% over the preceding year to 148,000 units. Seeing by h.p., those under 20PS amounts to 60,000 units, those from 20 to 30PS 59,000 units and those more than 30PS 29,000 units. Those of higher horse power shows an increasing tendency, while production is decreasing.

The production of walking tractor amounted to 271,000 units, which showed an increase of 0.6% over the preceding year; those under 5PS amouonted to 169,000 units, those more than 5PS 101,000 units.

The production of combine, which is next to riding tractor is 73,000 units. This is an increase of 5.7% over the preceding year.

Followings are the production of other types of farm machinery: rice transplanter amounted to 87,000 units (a decrease of 4.5% over the preceding year); binder 38,000 units (a decrease of 11.1% over the preceding year); thresher 20,000 units (a decrease of 10.1% over the preceding year); grain dryer 58,000 units (a decrease of 2.6% over the preceding year); huller 61,000 units (an increase of 1.1% over the preceding year); bush cleaner 1,658,000 units (an increase of 3.5% over the preceding year) **(Table 3)**.

Table 6 Export of Farm Equipment 1991

Unit: FOB Million Yen

Year	Unit	Value	Ratio	Major destinations
1985		190,305		
1986		150,792		
1987		135,354		
1988		130,492		
1989		131,042		
1990		132,757		
1991		129,943	100.0	U.S.A., Korea, France
Power tiller	58,176	4,695	3.6	France, Germany, USA
Wheel tractor	58,951	47,265	36.4	U.S.A.
Power sprayer	40,850	1,533	1.2	Iran, Taiwan
Duster	13,657	438	0.3	Taiwan, Thailand, Yemen, France
Lawn mower	90,893	10,168	7.8	U.S.A., France
Brush cutter	1,113,994	26,491	20.4	Italy, U.S.A., France
Mower	56,311	2,766	2.1	U.S.A., Korea
Combine	7,338	11,931	9.2	Korea, Taiwan
Blade, knife	—	2,077	1.6	U.S.A.
Chain saw	205,578	4,607	3.5	U.S.A., France, Italy
Other		17,972	13.9	

Source: Ministry of Finance. Totaled by Japan Farm Machinery Manufactuer's Assn.

Table 7 Import of Farm Equipment 1991

Unit: CIF Million Yen

Year	Unit	Value	Ratio	Exporters
1985		15,303		
1986		17,425		
1987		20,949		
1988		23,095		
1989		27,245		
1990		33,205		
1991		26,598	100.0	Germany, U.S.A., U.K.,
Wheel tractor	3,010	9,916	37.3	U.K., Germany, France
Pest control machine	1,222,634	1,668	6.3	U.S.A.
Lawn mower	87,632	2,548	9.6	U.S.A.
Mower	1,923	1,134	4.3	France, Netherlands, Denmark
Hay making machine	2,256	1,080	4.1	Germany, France, Netherlands
Bayler	1,361	1,909	7.2	France, U.S.A., Germany
Combine	65	949	3.6	Belgium, Germany, U.S.A.
Chain saw	46,140	1,608	6.0	Germany, Sweden, U.S.A.
Other		5,786	21.6	

Source: Ministry of Finance. Totaled by Japan Farm Machinery Manufactuer's Assn.

Trend of Farm Machinery Market

In Japan distribution system for farm machinery is roughly divided into two major channels: the traders concerned and Agricultural Cooperative Association. As of June 1988, the retail shops were recorded to about 9,400, the employees amounted to 45,000 persons, and the annual sales amounted to be ¥1,015 billion (**Table 4**).

According to the governmental survey by Ministry of Agriculture, Forestry and Fishery, the total sales of farm machinery by Agricultural Cooperative Association reached ¥379.7 billion (¥375.6 billion in 1990) (**Table 5**).

Under the declining demand for farm machinery, the farm machinery distribution industry has begun to improve the working environment: aiming at dissolving the shortage of hands and the settlement of the employment. In addition, the industry is striving for expanding facilities and rationalizing the management.

Export and Import of Farm Machinery

Export

In 1991 the exports of farm machinery amounted to ¥129.9 billion, which showed a decrease of 2.1% over the preceding year. The ratio of the exports to the total production amounts ¥615.1 billion ended in 21.1%.

Seeing from the shipments, those for the North America, Oceania and the Middle and Near East have decreased and those for Central and South America and Asia have increased, comparing with those of the preceding year. The exports for the United States, the largest market, reached ¥38.8 billion, which forms 30% of the total exports.

As for the types of farm machinery, tractor was chiefly exported: 59,000 units were exported in 1991 (the total production was 148,000 units), which amounts to ¥47.3 billion.

Seeing by horse power, those under 30PS amounted to 46,000 units, those from 30 to 50PS 11,000 units, those over 50PS 3,000 units.

Majar farm machinery, next to tractor, is bush cleaner. The total exports were 1,114,000 units and reached ¥26.5 billion.

The exports of other farm machinery are as follows: walking tractor 58,000 units; lawn mower 91,000 units; grass mower 56,000 units; chain saw 206,000 units etc. (**Table 6**)

Import

In 1991 the imports of farm machinery amounted to ¥26.6 billion, which means a decrease of 20% over the preceding year.

Followings are the major imported farm machinery: tractors 3,000 unit (those more than 70PS were 2,190 units of all the tractors); chainsaw were 46,000 units. Half the tractors were imported from the U.K. (**Table 7**). ■■

An Introduction to the Department of Biomechanical Systems, Faculty of Agriculture, Ehime University

by
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Introduction

The Ehime University was established in May, 1949 as a national University. It is the largest university on the island of Shikoku. Its current faculty and administrative staff number 1,960 strong. Each year the university accepts 1,878 freshman students, 200 are admitted to the various master's programs and 61 enter the doctor's program. Ehime University offers undergraduate programs in the fields of Law and Literature, Education, Science, Medicine, Engineering and Agriculture. The goal of the university, as a center of academic activities, is to give the student broad knowledge as well as to give him/her the opportunity for indepth study in the arts and sciences. At the same time, the student should be encouraged to apply this knowledge in socially responsible and practical ways.

Ehime University is situated in Matsuyama City in Ehime Prefecture which is located about 950 kilometers southwest of Tokyo. It takes about 7 hours to travel by trains from Tokyo and 80 minutes by plane. The university has three campuses; Johoku, Shigenobu and Tarumi campuses. The main campus, Johoku, is in the center of Matsuyama City. Ehime Prefecture is situated along the beautiful coast of the Seto Inland Sea on the island of Shikoku and is a famous citrus growing area of Japan.

The Faculty of Agriculture

The Faculty of Agriculture is located in the quiet environment of Tarumi, about 4 km southeast of main campus. The faculty has its own independent campus provided with research and administration buildings, lecture buildings, library, experimental facilities, a dormitry and an assembly hall with a cafeteria. Agriculture and forestry in Japan are currently confronted by serious problem in relation to the conservation of natural resources and energy, such as the improvement of self sufficiency in agricultural and forest products, and the ecological balance of the environment.

With the recent growth in overseas technological cooperation and scientific exchange, an increasing importance is given to education and research exchange, in agricultural science with developing and neighboring countries.

To meet the social needs of present times, the college has reorganized to form the Biological Resource Department consisting of eight major cources: Agricultural Biology, Biomechanical System, Bioresource Management, Agricultural Chemistry, Biotechnology, Forest Resources, Rural Engineering, and Environmental Conservation. The educational and research activities are carried out in the department, the University farm and Forest, and the Institute of Agricultural Environment Control as well.

Master's Degree in Agriculture

This course, initiated in June, 1967, grew from the postgraduate course in Agriculture founded in 1958.

The course are offered in 3 fields:

Bioresource Production Science—Agricultural Biology, Biomechanical System, Bioresource Management

Applied Bioresource Science—Agricultural Chemistry, Biotechnology

Life Environment Conservation Science—Forest Resource, Rural Engineering, Environmental Conservation

Doctoral Program in Agricultural Sciences

The United Graduate School of Agricultural Sciences was established in 1985, as a consortium organization of the agricultural faculties of Ehime, Kagawa and Kochi Universities, in Shikoku Region, Southwest Japan. It is a specially arranged university cooperation organization offering a three year doctorate program in agriculture and related sciences.

In order to fill the growing necessity for environmental as well as resource studies, the United Graduate School of Agricultural Sciences offers three Majoring courses

(A) Bioresource Production Sciences Course

The Management and cultivation of plant and animal resources are ultimate goal of the course. The course offers the studies of the plant resource production, hi-technology for plant and animal production, the animal resource production and the agricultural economics. Our staffs related with agricultural machinery all belong to this course.

(B) Bioresource Utilization Sciences Course

The basic as well as applied studies of chemical, physical and biochemical properties of bioresource materials are to be carried out.

(C) Life Environment Conservation Sciences Course

Chemical, physical and biological approaches toward the land development and the ecosystem management are to be pursued.

Monbusho (Ministry of Education, Science and Culture, Government of Japan) offers scholarship to six foreign students who wish to engage in research work of tropical and subtropical agricultural and related science at the United Graduate School of Agriculture Sciences (special course).

Biomechanical Systems

The Department of Biomechanical Systems was composed from branches of agricultural machinery, agricultural ergonomics, and agricultural environmental engineering.

Recent advancement of biotechnology and electronics has been producing notable changes on production, processing and energy in bioproduction system. Although agricultural engineering is an area of study which deals with the development of engineering technology in agricultural production, the field of study of agricultural engineering is no longer concerned only with advanced technology in agriculture, because today's agriculture has incorporated new technologies developed by a wide range of scientific fields and industrial applications into agricultural production system. It aims at furthering automation, mechanization and information technology in agricultural production systems. The labolatories and their major research activities are introduced as follows:

Laboratory of Environmental Engineering

The labolatory is engaged in investigations of method, facilities and analyses of environmental control of plants in order to attain more successful and effective production. Integration of information science such as computers, artifical intelligence, and robots with environmental control systems such as "plant factories", greenhouses and "nursery factories", Expert systems for desease diagnosis is investigated.

Research topics:

1. Computer supporting system for agriculture and horticulture.
2. Acquisition of knowledge for agricultural expert system based on AI.
3. Intelligent plant factory—computer integration of sensor, control system and mechanization.
4. Computer greenhouse automation—introduction of AI to intelligent robot.
5. Efficient greenhouse production—application of new materials and adaptability of controlsystem.
6. Green amenity—comfortability by greening living space.

Laboratory of Measurement Techniques in Plant Science

The laboratory studies stress-physiology in whole plant from a biophysical view point, and contribute to interface between biological and physical sciences in the Department. Application of recent progresses in computer science and biotechnology to agriculture is also important subject.

Research topics:

1. Growth-induced water potential fields in seedlings developed from embryoculture and seeds.
2. Leaf cell water status and relationship between chlorophyl fluorescence and CO_2 assimilation at low water potentials.
3. Relations between plant growth and root-shoot comunication under water and salt stresses.
4. Fruit formation and osmotic adjustment in fruits under environmental stresses.
5. Mineral uptake and ion selectivity in roots when growth and respiration are inhibited under osmotic stress.
6. Cell enlargement in leaves under environmental stresses.

Laboratory of Protected Cultivation

The laboratory covers the field of hydroponic culture.

Research topics:

1. Adaptive control for hydroponics automation.
2. Quality improvement in fruits by applying environmental stress.
3. Improvement of culture media and growth promotion of crops by application of zeolite.

Laboratory of Automated Mechanization

The laboratory deals with automation and robotics of field machinery and devices.

Research topics:

1. Automated air blast sprayer for use in orchards.
2. Automatic transport vehicle for use in greenhouses.
3. Fruit harvesting robot.

Laboratory of Agricultural Postharvest Technology

The laboratory covers both fields of postharvest technology and food process engineering.

Research topics:

1. Drying system—palatability and heat-mass transfer.
2. Storage and quality of rice.
3. Effective utilization of heat pump.

Laboratory of Agricultural Structures

The laboratory is engaged in investigations of plant design and management of agricultural facilities for products.

Research topics:

1. Materials handling system for agriculture and horticulture.
2. Environmental control method in fruit storage house.

Foreign Students

In May 1, 1992 there are 89 foreign students enrolled in the University, and 30 are studying as graduate students in the Faculty of Agriculture and the United Graduate School. Thge 3 foreign graduate students in the field of our Department, and doing their doctoral degrees come from the People's Republic of China, Republic of Korea and Nigeria.

The applicant for the Graduate School is recommended to contact the head of laboratory to ensure about the procedure to be accepted in the graduate course. ■■

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Kyoto University at a Glance

Kyoto Imperial University was founded by Imperial Ordinance on June, 1897 as the second university to be established in Japan. It was renamed Kyoto University in 1947. Within 10 years of the founding of the University, Colleges of Science and Engineering, Law, Medicine and Letters were opened. In accordance with the promulgation of the Imperial University Law, the Colleges were reorganized to comprize 5 Faculties. In 1923 the Faculty of Agriculture was established as the 7th faculty. In April 1953 the Kyoto University Graduate School under new educational system was founded in order to provide a more systematic post-graduate education. At present, Kyoto University is comprized of 11 faculties, 11 graduate schools, 13 research institutes and other attached establishments. The University staff consists of the president, 711 professors, 708 associate professors, 163 lecturers, 1,054 instructors and many administrative and technical officials. The present student body consists of 13,067 undergraduates and 4,441 graduates.

The University has a high value on academic excellence. One of the characteristics of Kyoto University is liberal academic atomosphere. Education and research at the University cover many diciplines. In advancing the frontiers of knowledge, the University is guided by the following objectives i) To develop in men and women the pursuit of excellence in their chosen careers; ii) to encourage researches to perform the highest level of inquiry: and iii) to share with the rest of the world useful research findings. As a matter of fact, numerous excellent studies have been done in the University and five alumni have been recipients of the coveted Novel Prize. More and more, the University policies focus attention on the work of graduate students.

Undergraduate students are required a four-year period of attendance except for the Faculty of Medicine which requires six years. After completing the four years (six years for the Faculty of Medicine) and acquiring the prescrived number of credits, the students are awarded with their diplomas. At the Graduate School (except the Graduate School of Medicine) the doctorial program runs for a period of five years of which the first two years generally entitle the students to pursue a masteral program. The remaining three years of the doctorial program requires the students to specialize in their chosen field and to undertake a creditable research each to entitle them to receive their doctoral certificates.

Faculty of Agriculture

The Faculty of Agriculture was founded with six departments and two affiliated institutions (the Experimental Farm and the University Forests). Department of Agricultural and Forestry

This article is basically drawn from Kyoto University Bulletin 1990/1991.

Engineering and Agricultural Machinery Chair were organized when the Faculty of Agriculture was founded. The latter was the oldest laboratory of agricultural machineries in the Japanese universities. This Chair was reorganized and expanded to three Chairs. Another chair of Agricultural Machinery founded on a national university 18 years later. Since then the number and quality of agricultural machinery laboratories in universities in Japan increased gradually.

Faculty of Agriculture has expanded from time to time and now consists of 10 Departments: Agronomy and Horticultural Science, Forestry, Agricultural Chemistry, Agricultural Biology, Agricultural Engineering, Agricultural Economics, Fisheries, Wood Science and Technology, Food science and Technology and Animal Science. The Faculty is now affiliated 8 institutions.

Graduate School of Agriculture has 11 Divisions and offers both masteral and doctoral degrees. In those Divisions, 10 divisions are identical to each of the 10 departments mentioned above, and another is Tropical Agriculture Division. These Divisions consists of the Faculty, the 8 affiliated institutions and many laboratory included in other Institutes of Kyoto University; Wood Research Institute, Research Institute for Food Science, Research Reactor Institute, the Institute for Chemical Research and the Center for Southeast Asian Studies.

Department of Agricultural Engineering and Division of Agricultural Engineering

The Department of Agricultural Engineering consists of seven laboratories: Agricultural Structure Engineering, Irrigation and Drainage, Rural Planning, Water Use Engineering, Agricultural Prime Movers, Farm Machinery and Farm Processing Machinery.

The Department has comprehensive facilities for studies and research in all engineering aspects of the problems of agricultural production.

The study programs are divided into two courses: the Irrigation, Drainage and Reclamation Engineering course and Agricultural Machinery course. Students should choose one of these courses as a major at the beginning of their third year and may undertake a research project for his/her graduation thesis in one of the seven laboratories in the fourth year.

The first two year students were taught general education courses, foreign language study, physical education and some basic courses in the student's own specialities. Third and fourth year students in the Irrigation and Reclamation Engineering course are taught the principles of development and effective usage of soil and water resources including the design, planning and practice of irrigation, drainage and their structure, water use planning and rural planning.

On the other hand, third and fourth year students in the Agricultural Machinery course are taught the principles and applications of agricultural prime movers, farm machinery and farm processing machinery, which are necessary in designing agricultural machineries and planning farm mechanization.

The teaching staff of the department consists of seven professors, seven associate professors, one lecturer and eleven instructors. The Division of Agricultural Engineering consists of the above seven laboratories and the laboratory of Radiation Control in the Research Reactor Institute. Advanced graduate programs are provided. Graduate students study and pursue a specialization in one of the laboratories.

Agricultural Machinery Laboratories

In the Department of Agricultural Engineering there are seven laboratories as mentioned above. Three of these laboratories are briefly described below.

Laboratory of Agricultural Prime Movers—The research activities in this laboratory cover agricultural prime mover, especially internal combustion engines for farm use, agricultural tractors and agricultural system engineering.

The undergraduate course offers lectures, laboratory work and some practice on the principles, mechanics, construction, performance design methods of farm engines, tractor and earth work machinery.

Courses and research worked at the graduate level cover design theories of agricultural prime movers including soil-machine interaction, vihicle dynamics and system engineering in agriculture.

Current researches being conducted include the dynamics of soil compaction, computational mechanics for soil-machine interaction, effect of tire vibraion on tractive efficiency, automatic control system of off-road vehicles, dynamic analysis and automatic control of farm tractors, monitoring system of engine fuel consumption and software of farm mechanization.

This laboratory has two tractor test courses on concrete and soil oval tracks.

Laboratory of Farm Machinery—The major area of research in the Laboratory of Farm Machinery covers fundamental theory, construction of farm machinery, practical programs of design, automatic control of field machinery and farm mechanization problems.

The undergraduate course covers the fundamentals of farm machinery. At the graduate level, analysis of theory, functions of all sorts of farm machinery and their design are taught, and experimental studies are made on the same courses.

Current research effort being undertaken pertain to intelligent robotics for farming such as water melon harvesting hydraulic robot, fundamental studies on the threshing mechanism of the combine harvester, applied studies on saving tilling energy by vibration and electro-osmosis and development of a new concept plow to invert the furrow slice from the same position and fundamental studies on automonous control of farm vehicles and group control system of farm machineries.

Laboratory of Farm Processing Machinery—This laboratory focuses on the concepts and principles associated with processing and handling of agricultural products such as drying, freezing, grading and storage, and the mechanisms and performance of the machineries which realize these processes. Undergraduate students receive extensive instruction on these subjects. Graduate students undertake research on processing and handling of agricultural products.

Current research projects being undertaken include the quality evaluation of agricultural products by their dynamic property, electrical impedance, skin color and ultrasonic wave transmittance properties. Trials are being made on the application of neural networks to pattern recognition and robot control for handling agricultural products.

Foreign Students: Entrance and Graduation Requirements

Foreign students in the University come in several categories: regular students (undergraduate and graduate), research students, research fellow, and auditors. Some students are classified as national government scholars. Although other students are called "private financing students", some of them receive scholarship grant from their governments or aid organizations.

Incoming undergraduate foreign students are expected to have comleted 12 years of formal education or equivalent. For the Faculty of Agriculture, foreign students on private financing are required to pass a general examination for Foreign Students (shihi gaikokujin ryugakusei toitsu siken) given by the Association of International Education, Japan (Nihon Kokusai Kyoiku Kyokai) as well as a Japanese Language Proficiency Test given by the AIEJ. Both tests can be taken in Tokyo, Osaka or Kyushu.

Foreign students who receive satisfactory grades in these tests are allowed to take the Faculty's special entrance examination consisting of written examinations and interview.

A foreign student may enter the masteral program, a two-year course, and then proceed to the doctoral program which is an additional three years of study and research or dissertation. Generally, those who wish to attend graduate study courses must pass the same entrance examination as is given to Japanese students (except Japanese Government Scholarship Students)

Entrance to a masteral program requires foreign students have completed an undergraduate course of study. On the other hand, entrance for a doctoral program, a student must normally have completed a masteral program equivalent to the program offered at the Kyoto University.

Foreign students are made aware that obtaining a doctoral degree in the university is not easy as the degree is awarded only to those who, as independent researchers in their special fields of study, possess the basic erudition and have manifested the required level of research ability.

At the present time four foreign graduate students and a research fellow in the three agricultural laboratories are doing basic research.

Accomplished scholars from overseas with suitable qualifications may be accepted by the University in one of four categories: regular faculty member, guest scholar, guest research associate and research fellow. ■■

Education and Research at the Agricultural Machinery Division Department of Agriculture and Forest Science Faculty of Agriculture, Miyazaki University

by
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Miyazaki 889-21, Japan

Introduction to the University

Miyazaki University was found 1949 by combining the following four special schools: Miyazaki Vocational School of Agriculture and Forestry founded in 1924, Miyazaki Teachers' School founded in 1880, Miyazaki Youthful Teachers' School founded in 1922 and Miyazaki Technical School founded in 1944. Each of these schools had produced a number of men of talent throughout their individual histories. Ever since, the University has grown with the times. In 1966 the Major Courses were begun in Faculty of Education. Graduate Schools of Agriculture and Engineering were opened in 1967 and 1976.

The University is comprised of three Faculties: Faculty of Agriculture, Faculty of Education and Faculty of Engineering. The University is located in the District of Kibana in Miyazaki Urban Educational Area (840,000 m^2) of about 10 kilometers away from the City center of Miyazaki and also Miyazaki Medical College is located near. The airport is also quite close which belongs to the semi-national park of Nichinan Coast. The campus area is full of mythical and legendary sites and is surrounded by the natural beauty of the warm south country. It is perhaps the best in Japan to study and conduct academic research.

The Faculty of Agriculture

The faculty of Agriculture originally consisted of 5 department, but by successively expanding into several specialized courses, eventually had 8 department: Agronomy, Forestry, Animal Science, Veterinary Science, Agricultural Chemistry, Fisheries, Agricultural Engineering and Grassland Science.

Today the Faculty of Agriculture has 4 department: Departments of Agriculture and Forest Science; Biological Resource Science; Animal, Grassland and Fishery Sciences; and Veterinary Science. The Faculty confers undergraduate and graduate degrees, including the master's degree after 2 years post-graduate study.

From April 1988 a doctral course in Agricultural Science started as a joint program with Kagoshima and Saga Universities. From April 1990 another doctoral course in Veterinary Science also commenced as a joint program with Yamaguchi, Kagoshima and Tottori Universities.

Education and Research at the Agricultural Machinery Division

The Agricultural Machinery Division in Miyazaki University is one of the Department of Agriculture and Forest Science.

The subjects of education and research in this division are as follows: the theory of the application of mechanisms, structure and design of agricultural machines, and the establishment of improvements in agricultural productivity through mechanization, automation and systematization.

Present staffs, education and research are as follows:

Staffs:
- Prof. Toshio FURUCHI, Ph.D. (Agr.)
- Prof. Yoshiichi OKADA, Ph.D. (Agr.)
- Prof. Masateru NAGATA, Ph.D. (Agr.)
- Asst. Prof. Masafumi MITARAI, Ph.D. (Agr.)
- Assoc. Prof. vacant (from 1992)
- Asst. Prof. vacant (from 1992)

Courses:
- Utilization of Farm Machinery, Agricultural Processing Machinery, Facilities for Farms, Farm Power and Machinery Design, Agricultural Energy, Agricultural Engineering Design and Drawing by Computers, Experiments in Farm Machinery, etc.

Research Subjects:
- Improvement of system of farm work, Development on weeder, Mechanization of tea-leaf plucking, Precision planters with micro-computer systems for field crops and vegetable seeds, Automatic and robot system for planting and handling, Basic research on soil disinfectors, Work study and labour management in agricultural production, etc.

Agricultural machinery division has modern instrumental facilities for education and research, example, soil bin facilities indoor laboratory, 12 personal computers, video motion analysis system, robot system by computer, farm engines, field equipments, tractor practice field and basic experimental field, etc.

Fig. 1 Tractor operating practice for student.

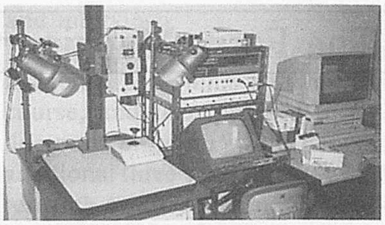

Fig. 2 Video analyzer system for motion analysis.

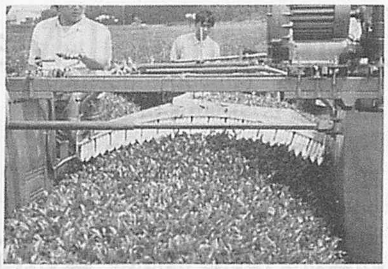

Fig. 3 Field test of tea-leaf plucking machine.

Current Research in Progress in the Agricultural Machinery Division

Working System for Upland Rice Cultured by Small Agricultural Machines

The weed control system in combination of the herbicides and the weeding machines controlled weeds completely. The necessary times for cultivating the paddy rice spent amounts to 38 h/0.1 ha and reduced by 76% of the customary transplanting culture. In the case of upland field composed of Kuroboku soil, the soil moisture did not decrease extremely so that the growth of the paddy rice under the conditions of no-sprinkling was not affected. Its yield was equivalent to that of under sprinkling cultivation and the former showed considerably high yield.

Development of Tea-plucking Machine

The purpose of this study is to develop a harvest machine for improving the quality of tea leaves. The developed selective tea-plucking system is quite similar to the man-plucking method. This system has twin parallel plucking rolls which have a spiral shaped cut in opposite directions each other. The rolls take the plucking motion at a hole which is formed by spiral shaped cuts on the surface of rolls and continually moves from low to high position of rolls.

The relation between the size of the plucking hole and the state of plucked tea leaves was examined.

Precision Planting on Plastic Mulch-film Cultivation System

The plastic mulch-film cultivation system is very popular in Japan. This is because the system for harvesting and delivering becomes quicker or earlier than the normal cultivation in order to catch the early market. Many kinds of vegetables, peanut, sweet-corn, radish, carrot etc, are being produced by this system in Japan.

This cultivation system increases every year and farmers desire earnestly the mechanization of this cultivation system.

The laboratory carries on a development of a precision planter with a sequential control or micro-

Fig. 4 Field test of planter with micro-computer control for mulch-film cultivation system.

computer control for planting seeds into the center of a hole in plastic mulch-film on this system.

Robotics for Minute Farm Operations

Today, Japanese agricultural production is required to become at hight technology for getting at low cost and high productivity. A method for solving this problem is to develop an agricultural robot instead of a farmer. Recently, several papers concerned with robotic studies as a solution to the above problem were presented in Japan.

This research discusses a movement analysis on the robotics operation in minute agricultural works. The tested robot was a multi-joints type. The movement of robot was analyzed by a video camera and an analyzer.

Basic Research on Safe and Efficient Fumigation

The improvement of soil structure to bring out the maximum ability of fumigant and the development of proper application mechanism which is based on the physico-chemical characteristics of soil fumigants are necessary to improve the safety in fumigating operations and the efficacy of pests control in the soil.

The purpose of this work is to consider the effect of clod size on the movement of chloropicrin gas in the soil.

The relationships between clod sizes and permeability coefficient, diffusion coefficient and diffusion patterns of chloropicrin in the soil were measured in the laboratory. It was cleared that the gas diffusion coefficients in the case of clods smaller than 10 mm were 1/7-1/700 times as that in atmosphere and 1/10-1/50 times as that in the clods of 15-20 mm. The clod diameter smaller than 10 mm seemed to be suitable for the soil fumigation.

Graduate Program in the Faculty of Agriculture

Graduate School of Agricultural Sciences for Master's Course

The master's course has 7 division in the Faculty of Agriculture. These are Agricultural Sciences, Forest Science, Animal Science, Agricultural Chemistry, Fishery Science, Agricultural Engineering and Grassland Science.

Postgraduate Course in Agricultural Engineering is as follows: The Master's Course consists of 3 laboratories for irrigation, drainage and reclamation engineering and 2 laboratories for agricultural machinery. The curriculum contains advanced courses and laboratory courses which make use of computers to teach higher levels of techniques and learning. The students, who also include foreigners, receive lecturers and experiments. It is expected that the number of foreign students will increase through internationalization.

United Graduate School of Agricultural Sciences for the Doctoral Course

This graduate program was newly establish as a combination of four Graduate Division in Miyazaki, Kagoshima, Saga and Ryukyu Universities. This is part of a national project to found united graduate schools for the Agricultural sciences leading to the Ph.D. in different parts of Japan. In this course Kagoshima University administers the program as the "primary university", and Miyazaki, Saga and Ryukyu Universities are "participating universities".

The objectives of this program are to train highly specialized technologists for research work in agriculture and fisheries, and also to enhance graduate education through improvements in the graduate schools of four cooperating universities.

Foreign students are cordially invited to apply for admission. They will be thoroughly trained so that they may take an active role in their own countries.

Each student has a major professor and two advising professors. Students conduct research and have additional seminars from faculty in these universities. They are enrolled in the primary university but study at the university in which their major professor teaches. They are also permitted to use the equipment and facilities of the cooperative universities.

Students with degree of shushi (Master) or its equivalent are qualified for admission to the program. Applicants are admitted by examination to the primary university. The degree of Hakushi (Ph.D.) in Agricultural and Fishery Science is awarded by the primary university.

Areas of instruction and research in Miyazaki University are as follows:

1) Course in the Science of Bioresource Production
   Plant Resource Production, Animal Production, Science of Forest and Agricultural Resources
2) Course in the Bioresource Science for Processing
   Applied Biological Chemistry, Applied Resource Chemistry
3) Course in the Science of Life

Environment and Conservation
Agricultural Engineering

4) Course in the Science of Marine Resources
Marine Production and Environment Studies, Applied Science of Marine Resources

The Agricultural Machinery Division of Miyazaki University is included Agricultural Engineering in the Science of Life Environment and Conservation, and it has two major professor who can give doctor's degree. They are Prof. Yoshiichi OKADA and Prof. Masateru NAGATA.

Information for Foreign Student

Scholarship for foreign students or research residents are mainly provided by the Ministry of Education (Monbusho) or the Japan Society for Promotion of Science (JSPS). Applicants should contact the Japanese Embassy in their countries. In addition, the faculty may directly recommend candidates to the Ministry of Education. Applicants should consult members of the faculty in the latter case.

Applicants are required either to have a valid degree comparable to the Bachelor's degree, to have completed a sixteen-year course of school education, or to be recognized by the Graduate School as having an ability equivalent or superior to that of a university graduate. Applicants must be under 35 years of age. The scholarship provides an allowance of 178,500 yen, housing aid of 9,000 yen per month, and round-trip air fare from the student's country. All fees and tuition are waived for successful applicants.

Our laboratory welcomes qualified and ambitious students from foreign countries. Students may be admitted to the Graduate School in one of the following categories: (1) Regular graduate students, (2) Non-degree research students.

If you have a great interest in studying in the Graduate Division, contact: Agricultural Machinery Division, Faculty of Agriculture, Miyazaki University, 1-1, Gakuen Kibanadai-Nishi, Miyazaki 889-21, Japan. ■■

The Updated Version of the AMA Computerized Index Available

A computerized index of technical articles in *Agricultural Mechanization in Asia, Africa and Latin America* has been compiled for the years 1971 through 1990. Each citation includes truncated versions of the title, first and second authors' names and four keywords. Year, issue and page number of each article are given. The citations along with software for searching the database are all included on a single computer diskette for use with IBM-PC, -XT, -AT or compatible type computers.

Anyone wishing to receive this material may send one formatted. 5 1/4-inch, 360 Kbyte, double-sided, double-density diskette to William Chancellor, Agr. Eng. Dept., Univ. of Calif., Davis, CA 95616, USA. The database and searching software will be copied to that diskette, and it will be returned by airmail along with software documentation. There is no charge. Any special customs or postal designation or specifications required should be stated in the letter of request. Annual updates will be available in the future.

Prospect of National Food Research Institute, Ministry of Agriculture, Forestry and Fisheries

by
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National Food Research Institute
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Outline

The National Food Research Institute was formerly established as the Rice Utilization Research Laboratory in 1934 in Tokyo in order to develop technology for coping with problems caused by surplus rice production at that time. The name of the laboratory has been changed 3 times in order to meet social needs related to food circumstance and diversification of food research field. The present framework of the National Food Research Institute was started in 1972. In 1979, the Institute was moved to the cite of Tsukuba Science City for a better facility and communication with other related institutes.

Although the National Food Research Institute is one of 19 institutes which are under the Ministry of Agriculture, Forestry and Fisheries, the Institute differs from other institutes in many ways. The Institute in a word focuses its research field on science and technology relevant to postharvest of agricultural products. The Institute is carrying out R & D on food analyses, resource utilization, material/product development, preservation, processing, biotechnology, as well as nutrition and safety of foods.

The research activity of the Institute is closely linked to our daily diet and focuses the R & D on the improvement of our healthy and plentiful diet, looking hard at present and future demands.

Organization

The Institute is consisted of 8 research divisions in addition to general affairs division and

Table 1 Organization of National Food Research Institute

Director General
General Affairs Division
Research Planning and Coordination Division

- Food Science Division
  - Carbohydrate Science Lab.
  - Protein Science Lab.
  - Lipid Science Lab.
  - Food Rheology Lab.
- Food Analysis and Assessment Division
  - Food Analysis Lab.
  - Speciation Lab.
  - Nondestructive Lab.
  - Food Metric Lab.
- Nutrition and Physiology Division
  - Nutrition Biochemistry Lab.
  - Wholesomeness Evaluation Lab.
  - Food Functionality Lab.
  - Experiment Physiology Lab.
  - Experiment Physiology Lab.
- Postharvest Technology Division
  - Stored-product Entomology Lab.
  - Stored-product Microbiology Lab.
  - Mycotoxins Lab.
  - Food Packaging Lab.
  - Low Temperature Technology Lab.
  - Radiation Utilization Lab.
- Food Material Research Division
  - Cereal Properties Lab.
  - Cereal Products Lab.
  - Protein Materials Lab.
  - High-moistured Materials Lab.
  - Biomaterials Conversion Lab.
- Applied Microbiology Division
  - Applied Mycology Lab.
  - Yeast Lab.
  - Applied Bacteriology Lab.
  - Systematic Microbiology Lab.
  - Enzyme Utilization Lab.
- Biological Function Division
  - Molecular Function Lab.
  - Molecular Engineering Lab.
  - Biomolecular Transfunction Lab.
  - Genetic Engineering Lab.
  - Cell Function Lab.
- Food Technology Division
  - Food Engineering Lab.
  - Process Engineering Lab.
  - Distribution Engineering Lab.
  - Instrumentation Engineering Lab.
  - Biocatalysis Engineering Lab.

research planning and coordination division as shown in **Table 1**. Totally 38 research laboratories are located in the research divisions. Number of personnel is totally 136, and 109 of which are number of researchers in 1992.

R & D Strategy

Food industry has been growing year by year and increasing in its share of annual industry turnover to be more than 10% which is ranked third among all manufacturing industries. The role of food industry including other related industries such as distribution and catering service industries is indispensable for the nation's daily diet and socio-economic activity in Japan.

The research strategy can be summarized as main research subjects such as:

Analysis and Evaluation of Food Composition

1) Evaluation and improvement of wholesomeness of foods
2) Development of techniques for food analysis and quality evaluation

Evaluation and Utilization of Food Materials

1) Evaluation of physico-chemical properties of food materials
2) Development of technology for utilizing food materials

Development of Technology for Processing and Distribution

1) Development of technology for preserving product quality and reducing postharvest losses
2) Development of technology for processing and distribution

Analysis and Utilization of Biological Functions

1) Development of technology for utilizing function of microorganisms and enzymes
2) Utilization of biological function for developing new food materials

All the subjects are focused on the development of future-oriented food system on the standpoint of postharvest science and technology. From this point of view, it is important to carry out R & D in order to convert agricultural products to higher added-value materials by means of chemical and physical technology, as well as biotechnology. Also, the R & D conducted certainly should play an important role in coping with various problems to which the Japanese agriculture itself is currently facing, and finally improving the nation's diet.

Research Subjects Conducted in Each Research Division

Food Science Division

1) Structure of starch and its derivatives
2) Biochemical technology for producing starch derivatives
3) Structure and function of protein and peptides
4) New products from protein and peptides
5) Structure and function of lipid and its derivatives
6) Oxidation mechanism of lipid
7) Physico-chemical properties of hydrocolloids and gels
8) Development of measuring techniques for food texture

Food Analysis and Assessment Division

1) Development and improvement of techniques for food analysis
2) Establishment of criteria for quality evaluation
3) Speciation of components in foods
4) Interaction between minor components and others in foods
5) Near infrared spectroscopy as a means of nondestructive quality evaluation
6) Metrics for quality evaluation
7) Development and improvement of methodology for sensory evaluation
8) Constructing data base on foods

Nutrition and Physiology Division

1) Physiology of nutrients
2) Bio-functionality of nutrients
3) Techniques to evaluate wholesomeness of foods
4) Factors affecting wholesomeness of foods
5) Screening and development of bio-functional components
6) Metabolism of bio-functional components
7) Nutritional experiment with small animals

Postharvest Technology Division

1) Physiology and ecology of insects and microorganisms causing deterioration of stored products
2) Mechanism of mycotoxin production by microorganisms
3) Techniques for identification and controlling mycotoxin
4) Physico-chemical properties of functional packaging materials and development of utilization technology
5) Physiological mechanism of low temperature tolerant property of fruit and vegetables

Food Materials Research Division

1) Physico-chemical properties of cereals
2) Development of utilization technology of cereals
3) Physico-chemical properties of protein materials
4) Development of utilization technology of high moistured foods
5) Development of utilization technology of low- and non-utilized resources

Applied Microbiology Division

1) Mechanism of microbial functions for industrial use
2) Mechanism of maturation in fermentation process
3) Mechanism of interaction of functions among microorganisms
4) Development of new food materials in use of enzymic

reaction
5) Development of screening techniques of microorganisms in use of molecular biology
6) Collection and screening of microorganisms and evaluation of their property

Biological Function Division

1) Structure and function of biopolymers
2) Mechanism of function of biopolymers
3) Development and improvement of functions of biopolymers
4) Controlling mechanism of gene expression
5) Structure and function of bio-cell membrane
6) Mechanism of bio-cell function
7) Modification and improvement of bio-cell function

Food Technology Division

1) Development of new technologies with emphasis on critical conditions
2) Unit operation of food processing
3) System for automation and optimization of food processing
4) Development of sensors and process controlling system
5) Engineering and application of bioreactors
6) Engineering related to physical distribution technologies for foods

Recent Topics of R & D

Utilization of Biomass

Biological products as biomass have benefit of being naturally renewable resource. It is important to note that technological developments for utilizing this resource either directly for foods or indirectly for others necessary in our daily life might contribute to an increase in future demand for agricultural products.

Starch produced through the photo-synthesis system is a basic compound from a viewpoint of biomass utilization. A large number of R & D has been conducted to develop technologies for converting starch into various high added-value products by using biochemical or enzymatic techniques, in cooperation with basic research to clarify the microstructure of starch.

Processing technologies developed in the Institute have been practically applied to industrial productions of high fructose syrup, cyclodextrin, maltoligosaccharide, etc. Erythritol is a recently developed sweetener which has the advantage of being a low-caloric sugar substitute for human consumption.

Ethanol production from biological products as substitution of fossil energy might become a potential outlet of biomass utilization in future. Possible process improvements in order to reduce the cost of ethanol production are being devised on cellulose hydrolysis, fermentation, distrillation, etc.

Application of Biotechnology

A definition of biotechnology is a technology to utilize biological functions. Japanese traditional fermented foods, such as miso, natto, soy sauce, vinegar, sake, etc., have been produced by utilization of various functions of microorganisms. From this point of view, biotechnology always has been important for food processing technology. In addition, new biotechnologies such as DNA recombination, cell fusion, tissue culture, bioreactor, protein engineering, etc. have been developed recently.

The Institute is investing a great deal of effort toward this new field, including searching screening useful microorganisms. A variety of microorganisms which have a potential of producing raw starch degrading enzymes (Charala paradoxa), lytic enzymes (Lactobacillus casei KTB2-6), cellulases (Robillarda sp. Y-20), isomerase (Streptomyces griseofuscus S-41), etc. have been isolated. Enzymes produced by these microorganisms lead to more effective processes for converting biomass resources to foods and other added-value materials.

For example, cloning by using DNA recombinant technology is attracting attention as a method to improve functions of enzymes. At the Institute, studies are being conducted on carbohydrate-related enzymes such as amylase, cellulase, etc.

Studies on cell fusion are also being conducted, which lead to the development of a new mushroom. This technology has also been applied to improve freeze tolerant baking yeast.

Production of useful materials by cultured plant cells will be a promising technology in the future. A study on producing crocin by cultured cells of gardenia fruit is being carried out.

The strategy of R & D in the food industry is to develop a bioreactor which has the advantage for efficiently producing food materials with uniform quality. In the Institute, basic research is being conducted on enzyme immobilization, systematization of the bioreactor, etc.

Food Analysis and Evaluation

It is important to clarify physico-chemical properties of agricultural products as raw food materials for effective utilization to nutritious, safe and high-quality foods. For this purpose, development and improvement of techniques for analyzing and evaluating food quality is one of the major roles of the Institute.

In addition to conventional wet chemical methods, nondestructive techniques are employed, in which analyses can be conducted in a short period of time without any changes in features of object to be measured. Researches on Near Infrared Spectroscopy (NIRS) which is the most practical method for food composition analysis, as well as for overall food quality such as rice taste, processing quality of wheat flour, etc. are strongly conducted. Nuclear Magnetic Resonance Spectroscopy (NMR) is also a nondestructive analysis method. The NMR has potential of giving information of distribution and state of water in foods, for example, showing images on CRT in cooperation with a computer tomographic techniques.

In order to ensure labelling of proper rice variety on the package, a computer-aided image analyzer was developed on the basis of analyzing a contour shape of individual rice kernel which is specific for each variety.

Along with procedures utilizing sophisticated instruments, human senses are also important to evaluate overall acceptance of food. A new technique for sensory evaluation is a target of development.

Food Protection and Preservation

Food deterioration during the marketing and distribution processes are caused by both biological and mechanical factors such as temperature, humidity, gas, light, shock and vibration, etc. At the Institute, studies on development of methods for adequately controlling the conditions in order to prevent deterioration are being conducted together with basic research for clarifying mechanisms of deterioration.

Various novel packaging materials and system have been studied and applied, either independently or in combination with conventional preservation techniques in order to preserve the quality of foods. A computer simulation technique has become a useful tool in the procedure of designing an adequate packaging system. The most effective method for preserving a given food can be determined by modeling the deterioration of packaged foods. A great deal of effort has been put into establishing useful models of food deterioration.

In order to develop a convenient method to design a packaging system for preventing mechanical damage during transportation, a technique using a transport simulator which allows reproduction of actual transporting vibrations is being investigated.

Physical processes such as irradiation to control microorganisms are investigated in order to develop effective techniques for preserving foods and agricultural products.

Research on coping with problems of postharvest losses caused by insects includes physiological and ecological approaches for elucidation of the nature of insect pests. Also, new methods to prevent insect infestation are being developed to provide safer and more effective means of insect control.

Studies involving mycotoxins which are toxic metabolites of fungi have been conducted to clarify their characteristics, as well as development of technologies for identification, controlling and elimination of mycotoxins. A part of these researches is conducted in cooperation with countries which face enormous amount of postharvest losses caused by microorganisms.

Food Processing Technology

Along with recent diversification and upgrading of our daily life, processed foods are becoming more important in our diet. Therefore, it is important to conduct R & D of technologies for improving and developing food processing. Food technology covers various operations such as extraction, separation, concentration, condensation, refining, drying, sterilization, etc. A strategy of R & D in the Institute in this field is to rationalize the operations by using novel ideas based on food science and technology.

Membrane technology is characterized by non-thermal processing. When used for separation or concentration processes, it might have great potential not only as an energy saving technology but also as a promising technique to produce high quality foods. The multi-stage RO (reverse osmosis) system developed in the Institute enables fruit juice concentration to exceed a normal limitation of Brix. A membrane reactor, combined membrane system with bioreactor, is being developed.

Studies are being conducted to develop an application technology using super-critical CO2 gas which has physical properties of high density and high diffusion coefficient like liquid under a relative high pressure condition. When used for extraction process, it might be possible to extract caffeine from coffee beans without any loss of flavour.

The R & D of extrusion cooking with a twin screw extruder plays an important role in the production of new food ingredients and in transformation food resources into acceptable foods. Much know-how obtained from the research has already been tested and accepted for the practical production of textured vegetable proteins and crab meat analog from minced fish meat. This know-how is also applied to a twin screw expeller which provides better process for solid-liquid separation of oil seeds and solves problems caused by high-moistured food wastes.

The idea to replace heat processing with high pressure technology is becoming an attracting technique for food industry. For example, high pressure processing promises sterilization at room temperature so that foods are not received damages of nutritional components.

R & D on developing a control system for manufacturing process by using artificial intelligent control based on Fuzzy reasoning and neural networks in order to meet present consumer's demand to foods is also being conducted.

Wholesomeness

At the present time when our daily diet is becoming satisfactory in terms of quantity, people desire foods to be more wholesome. It is also important to make clear the relationship between food habits and health from a preventological point of view. In order to fulfill these needs, the Institute is conducting research on wholesomeness of diet, as well as on functional food components which have potential to maintain the human body to be in desirable condition.

For the purpose of conducting research on the functional components which are usually minor substances in food materials, it is necessary to develop a sensitive analytical method applying fluorometry, for example. The sensitive fluorometrical technique enabled us to show that buckwheat, green tea, fish and many other foods contain components which have potential to control blood pressure effectively.

The use of cultured cancer cells from animals and humans is becoming a promising technique for screening functional food substances. If the food contains anti-carcinogenic material, the cultured cancer cells will be killed.

The research with small experimental animals is also necessary to confirm that the functionality of food components found with in vitro model could be reproduced in vivo. Recent efforts are mainly focused on subjects concerning amelioration of lipid metabolism by dietary fiber, and improvement of brain function by a polyunsaturated fatty acids (DHA).

These basic studies might contribute not only to improving our eating habits with health benefit, but also to developing specially designed foods, so-called functional foods, in which the functional compositions are added.

International Collaboration

The Institute has been an associate research institute of the United Nations University (UNU) since 1976 so as to collaborate with "Food and Biotechnology Programme" which is one of the activities conducted by the UNU. Main purpose of the UNU is to solve problems in developing country through academic activity.

In case of conducting the programme at the Institute, fellows who work for governmental institutions in each developing country are staying in the Institute for a year mostly after they are selected by the UNU/NFRI committee. They are promised to have an opportunity to work inthe Institute in order to get knowledges or techniques relevant to advanced food science and technology.

More than 40 UNU fellows had already finished their works since the beginning. In 1993, the collaboration with the UNU will be strengthen as a result of reviewing successful experience in the past. Five fellows in maximum are going to be selected in a year. Those who like to apply the UNU fellowship are recommended to contact the UNU committee of the Institute.

In addition, the Institute is continuing to conduct international operations more actively through various channels. For example, the STA (Science and Technology Agency) fellowhsip which is for collaboration with a developed country basically is also an opportunity for a senior researcher in developing country. Those who like to apply the STA fellowship should have a research experience for a specific field which is listed as high priority in the Institute. ■■

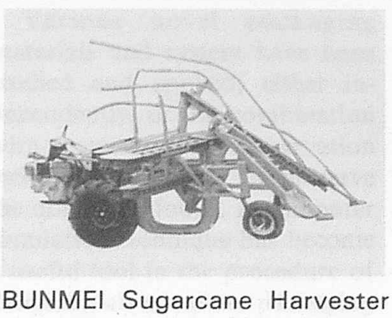
Main Products of Agricultural Machinery Manufacturers in Japan

by
Shin-Norinsha Co., Ltd.
No. 7, 2-chome, Kanda Nishikicho
Chiyoda-ku, Tokyo 101, Japan

Introduced here are the main products of agricultural machinery manufacturers in Japan with a number of photographs.

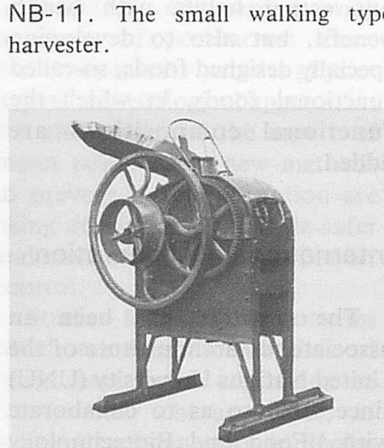
The products are developed and improved for both foreign and domestic markets. For further information please refer to the manufacturers contained in the directory.

The ARIMITSU Greenhouse Sprayer. Operators safety and labour savings are realized because the equipment operates automatically from a remote location, uniformly spraying micron particle size droplets throughout the greenhouse.



BUNMEI Sugarcane Harvester

NB-11. The small walking type harvester.



CHIKUMA Corn Sheller Type 3. Removes kernels from corn-cobs by a short time. Capacity: 750-1, 125kg/h, Power r'd: 1-2 PS, R.P.M.: 300-500, Size in mm: 1,015H x 575W x 1,010L, Weight: Net 90kg Gross 130kg, Shipping meas.: 18 cft.

DAISHIN Portable Generator

SGB4000HX. Brushless generator; Non-fuse breaker; Quiet operation; AC Voltage: (50Hz); (60Hz) Max. Output: (50Hz) 3.6 kVA (60Hz) 4.5 kVA. Engine: Air-cooled, 4-cycle, gasoline 5.2 HP, 6.2 HP; Dry weight 65 kg.

ISEKI Tractor Landmax 1085. Mounted with 108 HP (6,494cc) Diesel engine. The 6-cylinder, well-balanced engine runs without noise and dynamically performs any type of work.

ISEKI Combine Frontier HL500.

Super Rolling mechanism always controls the position of the body at level by the help of sensors. Working width: 1,650mm-1,700mm (5 row). Engine power: 50HP (2,600cc).

KIORITZ Battery-powered U.L.V. Sprayer (Shoulder type) ESD-5. A compact and lightweight battery-powered U.L.V. Sprayer providing easy portability combined with high performance. It is designed for use in environmental hygiene control such as malaria prevention, etc. in addition to general-purpose applications. Operates on six 1.5 V batteries. A rechargeable battery pack can also be used.

KOBASHI Rotor KA Series with 4-point auto-hitch. Working width: 220cm. Required tractor horsepower: 50-65.

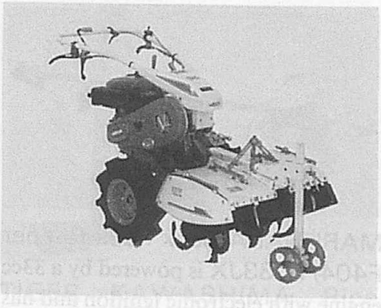
KUBOTA M8580 Tractors. Built to handle a variety of agricultural applications, including field operations, heavy-duty front loader work in barnyards and other farm work. Designed to turn tighter, lift heavier loads, and move more material. Has a powerful liquid-cooled direct injection diesel engine with four cylinders and 80 hp.

KUBOTA Diesel Tractor B20. Provides power and versatility for a variety of heavy-duty jobs, including loader, backhoe, and box scraper work, and still retains all the benefits of a compact tractor. Engine (Model D950-A-T): Water-cooled, 3-cylinder, 20hp. Total weight: 930kg.

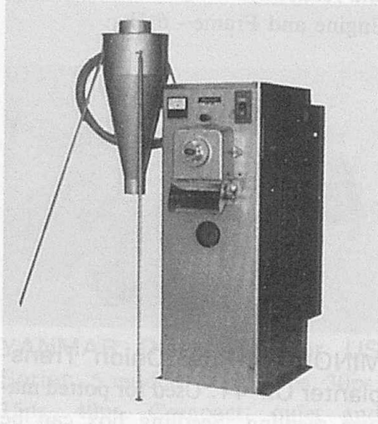
KUBOTA Zero Diameter Turn. Auto Assist Differential, 4WD Front Mower Model FZ2100.
Engine: 4 cycle, liquid-cooled diesel, 20hp. Total weight: 680kg.

MAMETORA Vegetable Transplanter TP-3V. This machine is available in both pot and soil block in seedling transplanting. Application: all vegetable nursery.

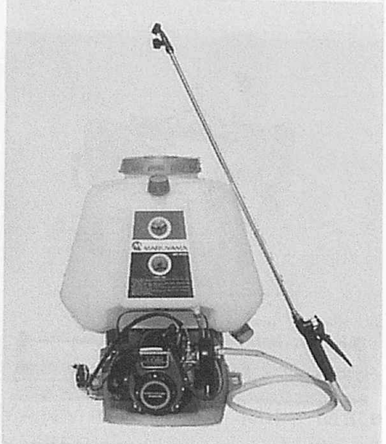
★ ★ ★



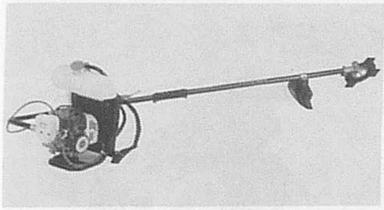
MAMETORA Power Cultivator SRV4V. Wide range use: cultivation to riding, Mounted with 7 PS engine.



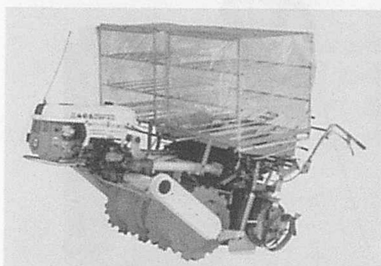
MARUSHICHI Rice Whitening Machine Echo-Star M3. Double jet suction mechanism. Law breakage rate and power. Power: 2.2kW, Capacity: 180-240kg/h.



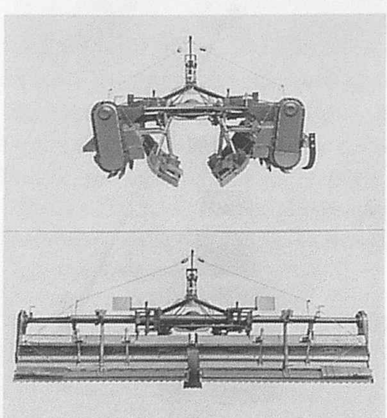
MARUYAMA Portable Power Sprayers MSO55D. Engine: Air-cooled, 2-cycle, output 22.6cc, Pump: Suction capacity 5.1ℓ/mm, max pressure 25kg/cm^2, Weight: 8.5kg.



MARUNAKA Back Pack Reaper F404/TD33JX is powered by a 33cc engine with electronic ignition and has unique unti-vibration damping. One touch joint between cluch housing and flexible shaft guarantees both safety and reliability. Weight: Body - 2.0kg, Engine and Frame - 6.5kg.

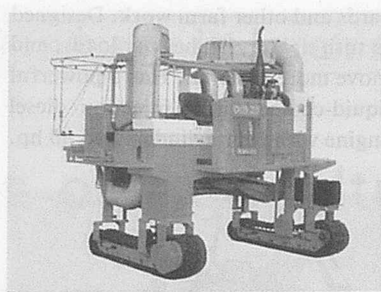


MINORU 4-Row Onion Transplanter OP-41. Used for potted mature seedling. Seedling box can be directly put on the transplanter. Saving the labor and total cost. Measurement (mm): L-2720, W-1095, H-1150. Weight: 355 kg (body only). Engine output (PS/rpm): 2.7/3,600; max. 3.5/4,000. Wheels: drum type × 2.



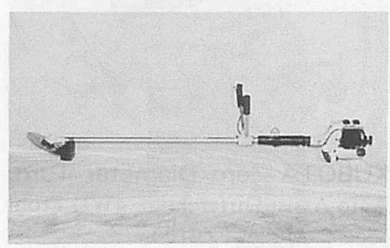
NIPLO Wing Harrow HW-4101B folded by hydraulic power for transport. Working width: 417cm; Required tractor horsepower: over 50.

☆ ☆ ☆



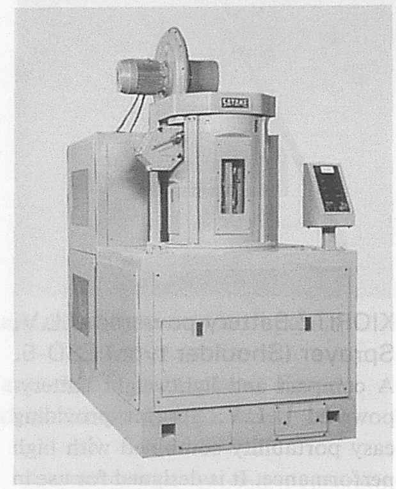
OCHIAI Riding Type Tea Picking Machine OM-25. Full working width cutter bar. Stepless speed control. Water-cooled Diesel engine 28.5PS.

OREC Power Cultivator AR700. Wide range use: Cultivation to riding. Mounted with 7 PS ~ 7.5 PS engine.



ROBIN Brush Cutter Model NBT415. 2 cylinder engine makes the operation easy and comfortable (low noise and vibration). Rotational speed of blade 4000-6000rpm.

SASAKI Fertilizer Spreader BF-300. The lever type action controls the amount of application with high accuracy. Application width: 10-12m. Hopper capacity: 300ℓ. Required tractor horsepower: 20-50PS.

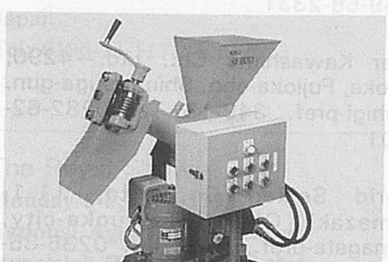


SATAKE New Rice Whiteness, Abrasive and Friction types, have high recovery, uniform & gentle milling, less installation space and high capacity. Model: VRM8A (Abrasive type) & VMA8A (Friction type) Capacity: 8 to 10 mt/h brown rice.

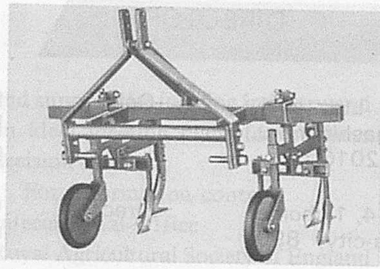
SATAKE Color Sorters with their quality optics and high-grade electronics allow the operator to make efficient separator on the basis of color. Model: GS40AG/AK/AP, GS60AG/AK/AP, GS80AG/AK/AP and CS500B. Major Application: Rice, wheat, coffee, corn, sunflower, beans, spices, etc.

SHIZUOKA's Single Kernel Moisture Tester CTR-800E for rough rice, brown rice, wheat and barley.

STAR Mini-Roll Baler MRB 0810. Automatic pick-up, rolling and ejection. One bale every 30 seconds. Handy bale size (50cm in diameter and 70cm long). Required tractor horsepower: 18-30 HP.



WORLD Squeezer LP-5. The world's first continuous rice-bran vegetable seeds oil extraction equipment (SQUEEZERS). Type: LP-5 (ring system), Capacity: 8kg/h (Rice bran 5), Residual oil: 15% (Rice bran 10%), Power required: 0.4kW, Net weight: 90kg, Cylinder pressure: 5ton, Size in m: 1W x 0.5L x 1.2H.



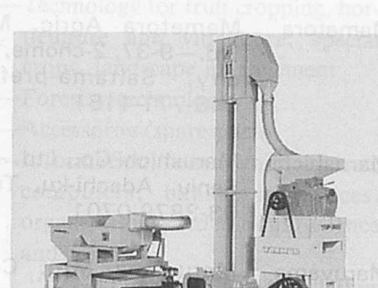
SUKIGARA Double Row Cultivator Model TBC. The row width can be controlled easily and quickly by adjusting each bolt at the left and right of tool bar. Row width: 600-900mm. Suitable working speed: 3-5km/h. Power required: 11-20HP.

TACHIYAMA ROLL BALER RB904. Working width: 900mm, picking up and baling long straw, cut straw, grass and etc. working efficiency: 20-40 a/hour. Required tractor horsepower: 30PS or over.

YAMAMOTO Rice Whitening Machine VP-2201F. Keeps original shape and flavor of rice by high performance of moving screen mechanism and natural flow-down system. Capacity: 1.0-1.8t/hour. Power required: 22kW and 0.23 kW.

TIGER KAWASHIMA Rice Combi and Grader. Rice grading machine and automatic weighting and packaging.

YANMAR Diesel Tractor US Series. 5 models: 20ps, 25ps, 30ps, 35ps, 40ps. Compact, quiet and vibration-reduced diesel engines are mounted at the heart of these US series tractors. Engine: vertical, 4-cycle, water-cooled. Transmission: gear shifting. F8 × R2 or F9 × R3 Drive system. 4-wheel drive.



YANMAR New Mill Mate YM650U. Cleaner + Huller & Polisher + Engine. Input cap: 800kg/h, Engine 23ps. This machine is a complete direct-through rice mill consisting of a hulling section, winnower and polishing section.

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NEWS

1993 JSAM International Workshop on Agricultural Mechanization

09:30-16:00, April 7, 1993
Hirosaki University
Hirosaki, Aomori-ken, Japan

Every year many trainees come to Japan from various parts of the world to learn designing and manufacturing of agricultural machinery at JICA Tsukuba International Agricultural Training Center and other places.

This workshop is to provide the opportunity to know more about the present status and needs of developing countries and to explore the new possibility of appropriate technology for more effective cooperation.

This workshop is organized by Japanese Society of Agricultural Machinery and supported by JICA Tsukuba International Agricultural Training Center and Farm Machinery Industrial Research Corp.

For information contact:
Dr. Toshinori Kimura
Dept. of Agriculture, Iwate University
3-18-8, Ueda, Morioka, Iwate-ken, Japan
Tel: 0196-23-5171 Ex. 2613

The Royal Show

Monday 5-8, July 1993
National Agricultural Centre
Stoneleigh Park, Warwickshire
CV8 2LZ, England

The Royal Agricultural Society of England, organizer of the world's premier international agricultural exhibition, welcomes to the Royal Show.

With a reputation for excellence and a commitment to agricultural progress stretching back more than 150 years, the Royal Show provides opportunities for all those who suply and support the farming industry and an ideal meeting place for business decision makers.

For information contact:
International Office
Royal Agricultural Society of England
National Agricultural Centre
Stoneleigh Park, Warwickshire
CV8 2LZ, England

AGRITECHNICA '93

Nov. 30 to Dec. 4, 1993
Frankfurt am Main
Germany

Since its premiere in 1985, "AGRITECHNICA" has undergone a consistent development to become the key European exhibition for plant production technology. All the leading European manufacturers of agricultural machinery and technology use "AGRITECHNICA" as a platform for optimising company objectives such as cultivating existing customers, communications, gaining new customers, not to forget sales as well. The fact that "AGRITECHNICA" is an excellent venue for realizing these objectives is shown by the high degree of satisfaction of exhibitors at "AGRITECHNICA". "96 percent of all "AGRITECHNICA" exhibitors are satisfied with their participation in the exhibition" stated Dieter Haupt with regard to the 1991 results.

Extremely knowledgeable trade visitors from all over the world visit "AGRITECHNICA", the international innovations exchange, in order to gather information about the latest technical developments and to prepare their investments selectively. Furthermore, the continuously rising number of international agricultural machinery and agricultural technology dealers who consider "AGRITECHNICA" to be the showcase for modern plant production technology is particularly important. The trade days before the official opening of the exhibition introduced specifically for this target group have proved to be highly successful. They cater to the dealers' desire for a calm exhibition atmosphere—an important prerequisite for intensive talks with appropriate partners. "AGRITECHNICA" has thus also evolved as an international exchange for dealers.

Following on from the extremely positive experience gained at the last exhibition in 1991, the exhibition programme of "AGRITECHNICA '93" will again be presented in the familiar Halls 5, 6, 8 and 9 at the Frankfurt Exhibition Grounds. It is divided up into the following sectoral groups:

—Tractors
—Transport vehicles
—Technology for tillage, fertilizing, plant protection, overhead irrigation
—Technology for forage harvesting, cereal harvesting, root crop harvesting
—Technology for harvest processing and conditioning
—Technology for fruit cropping, horticulture and viticulture, special crops, landscape management
—Forestry technology
—Accessories/spare parts
—Information, consultancy services, computers, banks, insurances, organizations, federations, science and research.

"AGRITECHNICA '93" will thus once again be the centre of attraction for enterpreneurial plant producers from all over the world and for all international dealers.

For further information contact:
German Agricultural Society (DLG)
Eschborner Landstrasse 122
D-6000 Frankfurt am Main 90
Germany

A Handbook for Weed Control in Rice

(Philippines)

By Kwesi Among-Nyarko and S.K. De Datta

Weeds are an important constraint to increasing yields wherever rice is grown, and rice researchers have created a great amount of useful scientific information on weed control. That information, however, is scattered among many journals, books, and reports that are not always accessible in tropical countries. The result is no readily-available source of practical information on weed control for many national agricultural development program workers.

This handbook summarizes important information on weed control in rice. Our intent was to provide essential, practical up-to-date information for use by rice researchers, extension workers, farmers, teachers, and students.

Publication of this handbook would have been impossible without the assistance and sustaining interest of so many people, it is impossible to mention them all here. It is with profound gratitude that we acknowledge those who helped us compile the material and those who contributed to improving the presentation.

Size: 28 cm × 22 cm, Pp. 113, Softcover. Published by International Rice Research Institute, P.O. Box 933, 1099 Manila, Philippines

Agricultural Machinery Design and Data Handbook (Seeders and Planters)

(Thailand)

By R.S. Devnani

This book, published by RNAM, has been written with an aim to compile the information related to the design data for the agricultural engineers who are working on the development of seeding and planting machines in developing countries.

There is a dearth of information related to the design and development of agricultural machines, especially when these machines have to be operated under different agro-climatic conditions by the farmers and with different socio techno economic backgrounds. The book contains different chapters where the design aspects for various components such as seed and fertilizer boxes, seed delivery tubes, furrow openers, covering and compacting devices have been discussed in detail. The details of the drive for transmitting power to metering devices have also been described.

In the last two chapters the design considerations for the sugarcane planters, including the type of sugarcane planters used in India and Pakistan are described. The chapter on potato planters covers the design of animal and power operated machines.

The basic design information covered in the book has been carefully selected so that it can be applied to machines which would be useful for the developing countries. In these countries, there is greater emphasis on the reduction of cost of equipment to make it viable for the small farm holders.

The design details are shown with suitable diagrams and tables are included to select the components suitably for machine. The present book is published by RNAM-ESCAP with the following address, and copies can be had on request from:

The Project Manager, Regional Network for Agricultural Machinery, C/o ESCAP, United Nations Building, Rajadamnern Ave, Bangkok 10200, THAILAND

Tools for Agriculture, 4th Edition. A guide to appropriate equipment for smalholder farmers

(U.K.)

The fourth edition of Tools for Agriculture has just been published by IT Publications. This unique guide to small-scale farming equipment offers invaluable information to smalholder farmers, development workers, and manufacturers all over the world. The book will be launched at the Royal Show, Stoneleigh, UK on 8 July.

The comprehensively revised and updated fourth edition, appearing 25 years after ITDG's original published guide to appropriate equipment, Tools for Progress, is the first to be produced from a new computer database, compiled jointly with GRET to enable systematic and continuous updating. Information has been selected from more than 1200 manufacturers in over 90 countries, and is presented here in ten sections for ease of reference, fully illustrated with line drawings and photographs.

Each subject area is introduced by a specialist who sets the range of available tools, implements and machines against a background of good farming practice, and the factors to weigh up when making a choice. The theme of effective choice is also considered in the introductions along with an analysis of why some mechanization projects are more successful than others and how they could be improved.

Price £30.00. Paperback. 256 pp. 30 × 21 cm. Published by Intermediate Technology Publications, 103-105 Southampton Row, London WC1B 4HH, U.K.

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INSTRUCTIONS TO AMA CONTRIBUTORS

The Editorial Staff of the AMA requests contributors of articles for publication to observe the following editorial policy and guidelines in order to improve communication and to facilitate the editorial process :

Criteria for Article Selection

Priority in the selection of articles for publication is given to those that —

a. are written in the English language ;
b. are relevant to the promotion of agricultural mechanization, particularly for the developing countries ;
c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission ;
d. deal with practical and adoptable innovations by small farmers with a minimum of complicated formulas, theories and schematic diagrams ;
e. have a 50 to 100-word abstract, preferably preceding the main body of the article ;
f. are typewritten, double-spaced, under 4,000 words (approximately equivalent to 8 pages of AMA-size paper) ; and those that
g. are supported by authentic sources, reference or bibliography.

Rejected/Accepted Articles

a. As a rule, articles that are not chosen for AMA publication are not returned unless the writer(s) asks for their return and are covered with adequate postage stamps. At the earliest time possible, the writer(s) is advised whether the article is rejected or accepted.
b. When an article is accepted but requires revision/modification, the details will be indicated in the return reply from the AMA Chief Editor in which case such revision/modification must be completed and returned to AMA within three months from the date of receipt from the Editorial Staff.
c. "The AMA does not pay for articles published. However, the writers are given collectively 5 free copies (one copy air-mailed and 4 copies sent by surface/sea mail) of the AMA issue wherein their articles are published. In addition, a single writer is given 25 off-prints of the article and plural writers are given 35 off-prints (also sent by surface/sea mail)"
d. Complimentary copies: Following the publishing, three successive issues are sent to the author(s).

Procedure

a. Articles for publication (original and one-copy) must be sent to AMA through the Co-operating Editor in the country where the article originates. (Please refer to the names and addresses of Co-operating Editors in any issue of the AMA). However, in the absence of any Co-operating Editor, the article may be sent directly to the AMA Chief Editor in Tokyo.
b. Contributors of articles for the AMA for the first time are required to attach a passport-size ID photograph (black and white print preferred) to the article. The same applies to those who have contributed articles three years earlier. In either case, ID photographs taken within the last 6 months are preferred.
c. The article must bear the writer(s) name, title/designation, office/organization, nationality and complete mailing address.

Format/Style Guidance

a. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features :
   i) a brief and appropriate title ;
   ii) the writer(s) name, designation/title, office/organization ; and mailing address ;
   iii) an abstract following ii) above ;
   iv) body proper (text/discussion) ;
   v) conclusion/recommendation ; and a
   vi) bibliography
b. The pages must be numbered (Arabic numeral) successively at the top center. Tables, graphs and diagrams must likewise be numbered. Table numbers must precede table titles, e.g., "Table 1. Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Figure 1. View of the Farm Buildings".
c. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
d. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
e. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
f. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
g. Convert national currencies in US dollars and use the later consistently.
h. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
i. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..." instead of 45 workers..., or, 5 tractors.

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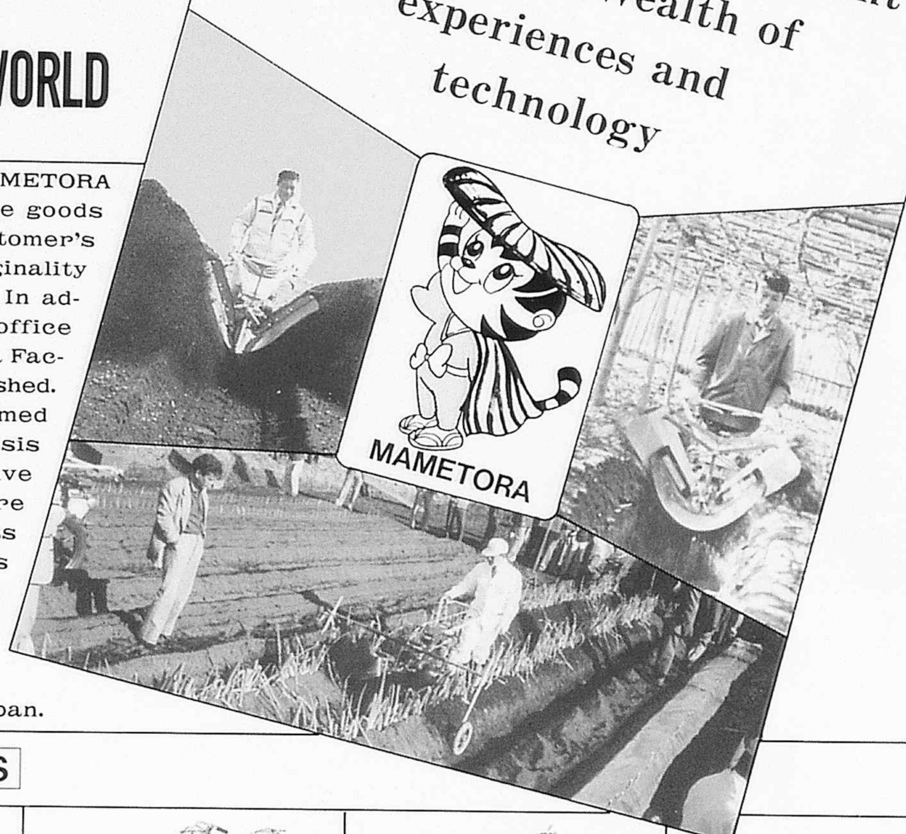

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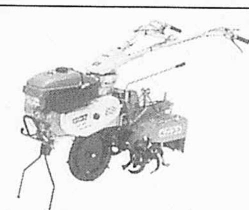

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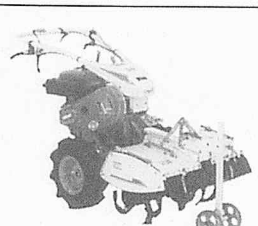

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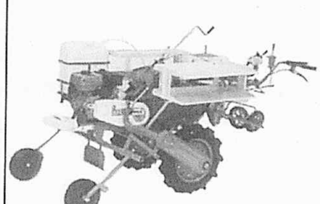

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