9. Mechanization and Energy Management

Several need-based and region-specific mechanization and energy management tools, implements, machines and technologies were developed for enhancing productivity and profitability of different farming systems.

Tillage implements

Animal-drawn implements for he-buffaloes: The implements comprise Tendua plough, clod breaker-cum-puddler and *biasi* plough. The average draught requirement for Tendua plough was 683 N for 98-mm width as compared to 556 N for 75-mm width. Field capacity of Tendua plough of 98-mm width was 0.014 ha/h with a field efficiency of 75%. The modified clod breaker of 7 rings performed better as compared to existing one of 5 rings, and field capacity of the modified clod breaker was 0.34 ha/h. The field capacity of 5-tyne *biasi* plough was 0.16 ha/h, and by using this plough, farmer could save ₹ 2,025 per ha and 356 MJ/ha energy in comparison to the indigenous plough. The weeding efficiency with *biasi* plough was 66%.

Biasi operation with 5-tyne *biasi* plough

Tractor-operated check-basin former: The new tractor- operated check- basin former scraps, collects and distributes uniformly collected soil to form side and cross bunds at regular intervals of 6 m in a single pass. It forms a check basin of 2m × 6 m with an effective field capacity of 0.15 ha/h. The cost of operation of the former was ₹ 3,070/ha; resulting in 96% saving over conventional manual method.

Tractor-operated check-basin former

Tractor implements performance with tillage equipment: An instrumentation system for measuring tractor-implement performance in the real field condition has been developed. With the system and set-up, performance of 11 different types of commercially available primary, secondary and conservation tillage implements was evaluated with 60-hp and 35-hp tractors in Vertisols with average cone index varying within 2,000 to 3,000 kPa in working depth and moisture content of 15 to 22% (d.b.). Performance was measured as per the BIS recommended speed with varied number of gear and throttle position combinations. All required data were recorded through universal data acquisition system.

Based on various performance parameters, it could be concluded that operating 2 bottom MB plough, 3 bottom MB plough, 1.8 m rotavator, large rigid shovel cultivator, subsoiler, sweep cultivator and spring shovel cultivator with 60-hp tractor would be economical; and operating small rigid shovel cultivator and zero-till drill would be economical with 35-hp tractor within the tested field and implement conditions.

Evaluation of tillage equipment in field

Planting implements

Evaluation of a multipurpose drill in ratoon sugarcane: *In-situ* retention of sugarcane trash can play an important role in replenishing soil quality and reducing environmental pollution. A prototype of multipurpose machine for operations like stubble shaving, off-barring, root pruning and drilling of basal fertilizers was developed and evaluated through on-farm trials. Cane yields improved by 16 and 11% over trash burning (farmer's practice) and chopping, followed by recommended practices of fertilizer application (0.45,

0.45 and 0.10 N as basal, at earthing-up and on-set of monsoon rains, respectively), and nitrogen-uptake efficiency (NUE) improved by 9.9%. Band placement of double the basal dose of N (0.9 N) further boosted initial growth, and improved cane yields and NUE by 22 and 11% over farmer's practice. Therefore, the fine tuning of this prototype should offer a practical and economic solution for trash-burning problem in sugarcane cultivation.

Ridge fertilizer-cum- seed planter: A tractor- drawn ridge fertilizer-cum- seed planter attached to three-point linkage of the tractor places fertilizers at a desired depth below the seed and mitigates effects of dry spells as well as waterlogging. The machine has provisions to change depth and angles of tynes besides altering row- to- row distance.

Modified furrower-type sugarcane cutter-planter: Tractor-operated sugarcane planter with modified furrow opener has been developed, which opens furrows of 20-25-cm depth and maintains loose soil-bed at the bottom of the furrow. The planter operation in sugarcane planting varies from furrow opening, sett cutting, sett placement in furrows, fertilizer and insecticide application(s) and soil covering over setts and its tamping simultaneously in a single pass.

Tractor-drawn bed former-cum-onion seeder: A tractor-drawn unique bed former-cum-seeder for onion was designed and fabricated. The bed former forms a broad bed of 90-cm wide and 15-22.5 cm high, while seeds are sown by seeder on the bed.

Animal-drawn seed- drill for intercrops: The seed drill consists of a rectangular frame mounted with four seed boxes. Two pneumatic wheels one on either side of the main-frame through axles are for transportation. One of these wheels supplies power to the metering mechanism through a chain drive and counter shaft. A clutch is on the counter shaft to engage or disengage

Animal drawn seed-drill for intercrop

power to seed -metering device. Plastic discs with different size grooves are fitted in individual boxes as per the required intercropping pattern. The seed rate is governed by adjusting opening between storage and feed box through rack and pinion arrangement. The draught requirement was observed as 230 N with effective field capacity of 0.17 ha/h at 82% field efficiency.

Bullock-drawn ridge-type drum-seeder: The seeder was developed and evaluated with a pair of bullocks of

Bullock-drawn drum-seeder

smaller size (body weight of 500 kg per pair). The seeder average row- to- row spacing and seed rate was 18.6 cm and 29.6 kg/ha. Its output was 0.2 ha/h with a field efficiency of 68%. The unit cost of the drum seeder and cost of sowing of pre-germinated paddy seeder were ₹ 13,500 and ₹ 118/ha, respectively. Heart rate, respiration rate and body temperature of bullocks were recorded at 90 bpm, 55 bpm and 37.8ºC respectively. The draught requirement was 9.13% of their body weight, which indicates that the drum-seeder can be operated sustainably by a small pair of bullocks.

Planting system for small seeds: Manually operated seed planter-cum-fertilizer applicator consists of a vertical rotor-type metering mechanism for seed and fertilizer (slot size of 10 mm × 10 mm), seed-cum-fertilizer box, chain-and-sprocket type power transmission system, ground wheel, shoe-type furrow opener, seed delivery tube, seed covering and firming-cum-transportation wheel, handle and frame. Metering mechanism is operated by a ground wheel of 400-mm diameter through chain and sprocket. The field capacity and field efficiency of the machine for sowing little millet was 0.04 ha/h and 68%, respectively, at an average operational speed of 2 km/h. The cost of operation for sowing kodo and little millet was ₹ 29/h. This machine costs ₹ 2,500 and is useful for small and marginal farmers of tribal areas of Madhya Pradesh, Chhattisgarh, Andhra Pradesh and Maharashtra to promote production and productivity of millets.

Manually operated multi-millet planter

Tractor-operated garlic planter: Six- row garlic planter is with actuating-spoon (23 mm diameter and 2.5 mm depth)- type metering mechanism for planting at 150- mm row spacing to suit local seed varieties and agronomic practices. It consists of seed-metering plate, seed hopper, agitator and seed-covering device. The power to metering mechanism is provided from ground wheel with the help of chain and sprockets. The field capacity of plants was 0.18-0.21 ha/h at a forward speed of 2.0 to 2.25 km/h. The percentage of missing and multiples was 9.1 and 26.7%, respectively. There was saving of 82% in labour requirement and 57% in operation cost as compared to conventional manual planting. The approximate cost and operation cost of the machine were ₹ 150,000 and ₹ 6,168/ ha, respectively.

Tractor-operated garlic planter

Power-operated sugarcane sett-cutter: The power (0.75 kW, 1440 rpm, single phase electric motor)-operated sett-cutter cuts single eye bud or double eye bud setts. Its capacity is 3,360 setts/h and time required to cut setts in a hectare is 8.24 h. The cost of machine, operation cost and time saving over conventional manual operation were ₹ 75,000, ₹ 98/h and 80%, respectively.

Sugarcane sett-cutter

Tractor-operated small seed planter: The tractor (26.11 kW)-operated six- row planter consists of inclined plate-type metering mechanism, seed-hopper for each

Tractor-operated small seed planter

row, shovel-type furrow openers and three-point hitch system. Its capacity is approximately 1.5 kg. Its metering plate of 130 -mm diameter is made of plastic. Machine's row- to- row spacing is 150 mm, and its plant- to- plant spacing can be changed by changing plate with different number of notches or by changing sprockets. The planter was evaluated for seeding onion (variety: Punjab Naroya) in the field using 24-groove plate at forward speed of 2.0 km/h. The avarage number of plants/m^2 was 88. The avarage percentage of single, multiple and missing was 59.7, 35.0 and 5.3%, respectively. The average yield of onion-crop was 38 tonnes/ha. There was saving of 50.4% in operation cost and 81.1% in labour requirement as compared to conventional method of onion cultivation. The field capacity and cost of operation of the planter were 0.16 ha/h and ₹ 5,090/ha, respectively.

Micro-controller-based variable rate granular fertilizer applicator (VRFA)**:** The prototype of the applicator consists of a differential global positioning system (DGPS), micro-processor, micro-controller, DC motor, 12 V DC power supply, threaded screw arrangement and fluted roller fitted metering mechanism. Digital nutrient availability maps and fertilizer decision GUI have been developed for major crops based on the target yield. For their development, synchronization of DGPS, micro-processor, micro-controller, actuator and metering mechanism was done using visual studio platform. The programme for varying rates of fertilizers was installed in Arduino-Uno micro-controller board. Based on the micro-controller decision four relay switches actuated DC motor clockwise and anticlockwise

GPS-based variable rate fertilizer appllcator

based on its output, which varied fluted roller exposure length according to the fertilizer requirement at the grid point. The VRFA was tested in research field at different speeds (3, 4, 5 km/h), grid sizes (4m×5m, 5m×6 m and 8m×8 m) and fertilizer application rates (10 rates). Forward speed of tractor and fertilizer application rate had no significant effect on the application rate using VRFA. It was observed that the applicator met closely the target fertilizer application rate for grid size of 8m×8m.

Harvesting implements

Crop-yield monitoring using indigenous combine: To create yield variability maps, yield-monitoring system consisting of optical sensor, moisture sensor, GPS, controller unit and display fitted with an indigenous combine (make: Crop Tiger 30, CLAAS) was used. The calibration factors were determined as 6.59 for wheat, 5.62 for soybean and 4.60 for paddy. Yield maps were created for 11 field plots for wheat harvesting during 2013 to 2015. Yield data of all the plots were classified in five yield groups. Yield legend showed that about 63.9% area belonged to 3,910-4,950 kg/ha yield group and 24% to 2,840-3,910 kg/ha. Spatial and temporal variabilities were observed across various field plots. The study also confirmed that yield-monitoring system can be retrofitted with indigenous combine(s) for effective monitoring of spatial and temporal variabilities.

Indigenous combine

Pineapple harvester: Convenient and safe harvesting device of 250-280 fruits/h capacity, and with 70% efficiency has been developed. When the operator pulls the lever of the cranking wheel which is connected to the cutting wheel through a transmission belt, the wheel starts rotating and cuts stalk just beneath the pineapple. The cut pineapples lands on the small collecting tray, which is fixed close to cutting blade and finally shifted to a basket kept on to ground. A single operator is required for cutting and putting pineapples in the basket as well.

Pineapple harvester

The unit reduces drudgery and is cost-effective and energy-efficient.

Potato combine harvester: A 2-row, tractor-operated, trailing-type potato combine harvester with a provision for inspection and simultaneous collection of tubers in bags/crates with the help of 4-6 workers was designed and fabricated. It can be operated with the help of a 45-hp tractor and has a capacity of potato digging @ 0.21 ha/hr.

Improved sugarcane detrashing tool: This tool has a weight of 290 g as against 430 g of the original model to detach yellowish green, dried leaves and sprouted side shoots on the cane-stalk. It has two 'U' shaped stainless-steel knives fitted with a ring of 3-mm thickness of SS rod to adjust diameter of detrashing cane. Its field capacity was 0.1 ha/day.

Tractot-cab and soil-bin

Ergonomically designed tractor-cab: A cabin layout of a tractor was designed based on the anthropometric data of the Indian tractor operators. The cabin was mounted on the tractor (Standard DI 475) with CRC pipes and CRC sheets fitted with silicon rubber fittings. One door on LHS, two windows (one on RHS and one on the rear side) were mounted, and one step at entrance of door was provided. Front headlights, front and rear indicators, rear-side view mirrors were also provided on each side of the cabin. Air-conditioning system was installed inside the cabin. Adjustable rear view camera was provided along with lighting arrangement and monitor inside the cabin.

Tractor-cab

Automation of soil-processing trolley of soil-bin: Soil-processing trolley of the rectangular soil-bin has been automated to prepare uniform test beds at different soil compaction levels in the soil-bin. The trolley comprises rotary tiller, levelling blade and roller for tilling, levelling and compacting soil, respectively. Hydraulic power is used to engage and disengage rotary tiller and leveler, lowering and raising as well as loading roller to achieve desirable compaction level and adjusting depth of operation of the implement. For this, mobile open loop system with tandem circuit has been designed and developed. Individual double acting cylinder is mounted on suitable frame to operate

Mechanization package for value- addition of banana central core stem

About 5 to 7 tonnes of central core stems can be extracted from a hectare of banana- garden. The core has many medicinal values and can be utilized for preparing curries. But the removal of fibres from the central core is cumbersome and time- consuming process. This discourages households and restaurants using curries based on banana pseudostem. A package of equipments for value-addition of banana central core has been developed. These include the following:

Banana central core slicing and dicing unit

This is very unique where banana central core is sliced by a blade and diced by a dicer which has nylon wheels and a punching arrangement. Feeding is automated using a cam arrangement. Its capacity is about 50 kg/h.

Banana central core slicing unit

Banana dicing unit


Banana central core fibre removing unit


Water-removing unit


Juice squeezer

Juicer

Diced banana central core fibre removing equipment

This helps in removing fibres from diced banana central core by rotary action of the attachment.

Central core surface water-removing unit

The surface water is removed by centrifugation technique. Its capacity is 7 kg/batch.

Banana central core juice-extraction unit

A high capacity grinder is used to smash central core into fine pieces, and juice is squeezed out of the smashed banana central core and is collected by a tilting arrangement. Its capacity is about 50 kg of sliced banana central core per hour. The juice extraction efficiency is between 70 and 75% of the weight of the central core.

The whole pacakge of equipment costs about ₹ 1.75 lakh,and is suitable for a cottage-level enterprise.

Automated soil-processing trolley and cone penetrometer

various units of the soil-bin.

A hydraulically operated instrumented cone penetrometer has also been designed and installed in the soil- bin. Double acting cylinder was used as driving unit for cone penetrometer. Accordingly, penetrometer shaft and cone have been fabricated with stainless steel AISI 416 and machined to a smooth finish. The cone has base area of 323 mm^2 and cone angle of 30^o. External threading is done at one end of the probe to have provision for replacing worn out cone as per the requirement. The other end of the probe is also threaded externally for fixing it with the load cell. An 'S' type load cell of 2 -kN capacity mounted between the probe and the piston rod is used to measure cone-index value up to 300 -mm soil depth. For measurement of profile depth, a linear potentiometer is used. Flow rate of the system is adjusted to achieve constant penetration rate of about 30 mm/s.

Implements package for hill mechanization

Single animal-drawn improved wedge-plough: Improved plough is suitable for terrace land of hilly track due to its light weight. Its work rate was 0.02 ha/h at an average draught of 450 N, corresponding to the depth of operation of 100 mm. The cost of operation of the plough was ₹ 2,500/ha; lesser by ₹ 800/ha to traditional plough.

Plough on terraces

Two row zero-till seed-drill: The seed- drill was fitted with inverted (T)- type furrow opener.Its field capacity was 0.027 ha/h at an operating speed of 1.77 km/h. Average draught of the machine was 296 N at a seed

Two row zero-seed drill

sowing depth of 4.4 cm. The machine costs ₹ 8,000, and its cost of sowing was ₹ 2,409/ha. Zero tillage seeding in single pass at residual soil moisture content of 20.4% on the dry basis and 51.8% saving in cost of operation proved advantageous to farmers in terms of timeliness and cost economics compared to traditional practice.

Bullock-operated potato-digger: Light weight potato- digger comprises extension rods, shank, mainframe, harvesting blade, hitch, handle and beam. It was tested with a pair of bullocks on terraces and valleys at an average bullock speed of 1.7 km/h and depth of operation of 120 mm. Size of harvested potato varied from 40 to 60 mm. The digging efficiency and field efficiency of the potato-digger were 93% and 88%,

Field trials of animal-drawn light weight potato digger

respectively. Its draught was 320 N. The effective field capacity and cost of operation were 0.03ha/h and ₹ 1,250/ha, respectively. The labour requirement was 35 h/ha for digging and 150 h/ha for picking of potatoes. It saved

Mechanization Index of Madhya Pradesh

Data for mechanization index with respect to seven districts (Raisen, Dewas, Khandwa, Chhindwara, Seoni, Mandla and Ashok Nagar) of Madhya Pradesh were collected from 280 farmers and analyzed. Average power availability was 1.80 kW/ha, which ranged from 1.63 to 2.05 kW/ha across the selected villages. Mechanical power contribution was in the range of 80 to 88%. Input-output data were converted into monetary terms and the cost of cultivation for crops grown in each district was calculated. Mechanization index for seven districts ranged from 52 to 68% (average - 58%) for wheat, 35 to 46% (average - 40%) for soybean, 34 to 41% (average - 37%) for maize and 41 to 46% (average - 44%) for chickpea.

60% in labour and 61% in cost of digging over traditional digging on terraces.

Alternate energy equipment

Solar PV pumping systems for micro-irrigation systems: Two solar PV pumps have experimentally been tested at different solar irradiations with mini-sprinkler, micro-sprinkler and drip systems. Field performance of micro-irrigation systems with 1-hp capacity solar pumps with 3-4 m suction head revealed 2.1 kg/cm^2 operating pressure with 9 mini-sprinklers under the AC pump and 1.1 kg/cm^2 operating pressure with 50 micro-sprinklers under the DC pump. Pressure-discharge relationship of both AC and DC pumps was developed and a discharge of 45-50 litres/min was observed with 9 mini-sprinklers in the solar AC pump.

Solar aerator for fish-pond: In view of solar energy potential (6.4-4.3 kWh/m^2/day with clear sunny days 250-300/year), a spray-type solar aerator was tested for dissolved oxygen in a fish-pond. By operating the aerator for 6 to 7 hr in a day, an increase of 30-35% of dissolved oxygen in the bottom layers was observed.

Performance evaluation of solar PV power plant (25 kW$_p$): A cold-storage facility for fresh horticultural produce (6-8 tonnes), powered by solar photovoltaic (25 KW$_p$ capacity) with battery back-up (240 V, 900AH capacity), has been fabricated and installed. The PUF insulated walk-in -type cold storage chamber (Lenght × Breadth × Height: 5m×4.4m×3 m) was constructed and fitted with a vapour compression refrigeration system (2.5 TR capacity) and a humidifier. Temperature and relative humidity (RH) controllers were fitted in the chamber to maintain temperature at 5-15°C and relative humidity at 65-95%. Energy output from the solar panel ranged from 75 to 115 KWh/day, which was sufficient to operate the storage unit.

Fresh matured unripe mangoes (Dasheri and Bombay Green varieties) were stored in June in the cold storage chamber at 12±1°C temperature and 90-93% relative humidity. Based on the different physico-chemical parameters, it was found that Dasheri mango could be stored safely up to 15 days and Bombay Green up to 8 days as compared to 4 days and 3 days, respectively, at ambient storage.

Low-tunnel solar-dryer: A solar-dryer with 7 m^2 collector area has been developed for non-electrified regions. The PV module produces electricity and also heats ambient air passing beneath it. The PV panel output is used to power brushless DC fans to produce forced convection drying. The system was tested at full load (40 kg tomatoes) at an average solar radiation of 790 W/m^2. The moisture content of the tomatoes was reduced from 95.5 to 5% (wet basis) in 20 solar hours (8 h/d). The total cost of the PV integrated dryer has been estimated at ₹ 95,700.

Solar steam generation system: This system has been developed with three solar collectors each with an aperture area of 1.90 m^2. Each collector has 15 heat- pipe-type evacuated tubes with outer diameter of 59 mm and length of 172 mm. A heat exchanger connected to solar

Solar steam generation system

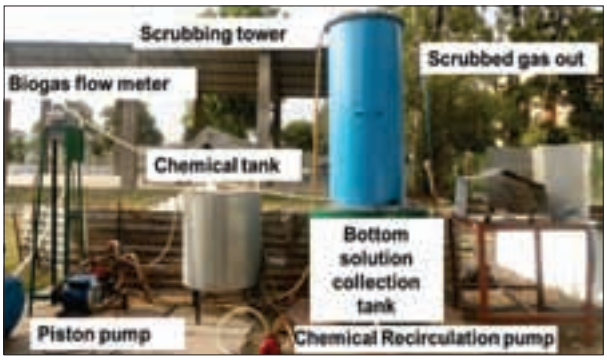
collectors was installed in the storage tank. The heated thermic fluid (Hytherm 600) from solar collectors is circulated through heat exchanger. The steam generation system has thermal efficiency of 15.4%. The approximate cost of the system has been worked out at ₹ 80,000.

Hydro pre-cooler for fruits and vegetables: The pre-cooler (100 kg/batch) has been developed for fruits and vegetables. It consists of an insulated water tank (L×B×H : 0.82m×1.6m×1.0 m), evaporative cooling tower with 0.37- kW motor and 0.45 m diameter axial fan,and an inclined trough for holding products submerged in the tank, belt conveyer and surface moisture drying unit. Cold water is recirculated from the evaporative cooling tower

Hydro pre-cooler

to water tank. Surface moisture drying unit is fitted with an axial fan below the perforated tray. The system cooled 1,060 litres of water in the tank from 38.5°C to 25.1°C in 4 h at the ambient temperature and relative humidity of 37-39°C and 38-51% RH, respectively. A batch of 100 kg fresh mangoes could be cooled from 35°C to 29°C in 20 minutes.

Purified biogas storage system: This has been developed by using a biogas scrubber, moisture-absorption unit (filled with 3A molecular sieves), compressor and purified biogas storage cylinder. Storage tank is provided with a molecular sieve- holder to remove moisture. Gas from the biogas plant was scrubbed inside



Purified biogas storage system

the scrubbing tower by counter-current principle; the gas was supplied from the bottom by using a compressor and the chemical solution was sprayed from the top by using a piston pump. Scrubbing is done using an aqueous solution of NaOH (0.5 M). For every cubic metre of biogas, 14 litres of chemical solution is used. The chemical scrubbing was effective in increasing methane content of biogas up to 92.3%. Prior to biogas storage, moisture of scrubbed biogas was removed by passing purified biogas through adsorption unit. The purified biogas stored in the cylinder is 0.5 m^3 at a pressure of 1.5 bars.

Bioreactor for accelerated biomass composting: A rotating drum-type bioreactor (100-kg biomass/batch) of 1.25m diameter and 1.5 m length has been developed for accelerated composting. The rotating drum is made of double-wall with outer one insulated with 50- mm glass-wool. Heating is provided using four strips of heating element of 1-kW each. The water is filled between double-walls for uniform heating. A temperature indicator -cum -controller is used for controlling temperature of substrate. The bioreactor is mounted on a three-wheeled structure for easy transport. Soybean -straw mixed with

Rotating drum-type bioreactor

biogas slurry @ 1% indicated that micro-organisms were most active during 6-9 days of composting. There was complete decomposition of cellulose, hemicellulose and lignin in 21 days. Significant mineralization of the straw was under thermophillic phase. The temperature of biomass was maintained between 60 and 70°C in the reactor.

Energy auditing of biomass gasification

Energy audit of biomass gasification based power plants in the Punjab State was conducted. Seven plants having total capacity of 67.5 MW were installed at different locations. Malwa Power Plant at Gulabewala village in Muktsar district purchased around 55,000 tonnes of paddy- straw covering nearly 20,000 acres from nearby village at ₹ 1,200/tonne. With an area of nearly 28 lakh hectares under paddy, the state produces and burns nearly 175 lakh tonnes of paddy-straw worth ₹ 2,100 crore every year. If biomass gasification plants are set-up, the straw can generate electricity. Transporting and using paddy- straw is possible in the radius of 20–25 km around the power plants. Beyond this it is uneconomical owing to higher transportation cost. By straw collection, an additional income of around ₹ 3,000 per acre worth ₹ 25,000-30,000 from 10 to 12 acre fields in a day and a net profit of ₹ 3-4 lakh can be earned during paddy season that lasts for six weeks. To promote paddy-straw use, the Government is offering 50% subsidy on baler and reaper. The venture is fairly profitable with a payback period of three to four years for farmers and even others who can invest and earn extra income from collecting and selling paddy-straw.

Briquetting of jute-sticks: In India, approximately 4 million tonnes of jute-sticks (after removing fibre) are produced annually. These sticks contain higher lignin (18%) and lower ash (1.7%), and thus are suitable for briquetting. They were ground below 2- mm particle size

Briquetting of jute sticks

to produce briquettes using die- and- press- type briquetting machine (500 kg/h) with tapered die of 60-mm diameter. The true density and moisture content of the briquettes are 900-950 kg/m^3 and 6.2% (weight basis), respectively. The calorific value of the briquettes is 18.59 MJ/kg. These briquettes can be used as domestic fuel, at brick kilns and in boilers.

Pilot plant for glycerol refinement: Crude glycerol, a by-product of transesterification process, contains 9.4% soap of *p*H 10.8, 4.3% ash, 4.2% free fatty acids and 21.5% methanol. The pilot plant consists of a neutralization chamber of 25 -l -capacity with a

Plant for glycerol refinement

removable lid and an agitator set -up. Neutralized glycerol is passed by gravity flow into a double-jacketed methanol and moisture distillation reactor of 35-l capacity with an agitator set-up, and heat is supplied through a steam generator. A water-cooled glass condenser is used to condense methanol and moisture. Vacuum distillation is conducted in the same chamber, and the distillate is collected in a chamber of 6-l capacity. Vacuum distilled glycerol is drained into a decolourization chamber of 2-l capacity. Refined glycerol yield from 100g of crude glycerol by this process was 39%.

Biomass gasifier cook-stove: A community-size gasifier cook-stove has been developed. It is made of mild steel cylinder of 540- mm outer and 400- mm inner diameter and a height of 960 mm. Refractory cement and cera-wool are used as insulation material to reduce heat losses and risk of burn injury. The stove consumes 3.0 kg of fuel-wood (100mm×30mm) per hour. Thermal efficiency of the stove is 36.38% with power rating of 5.0 kW.

Biomass gasifier cook-stove

Processing equipments

Power-operated onion detopper-cum-grader: The newly developed power-operated onion detopper-cum-grader consists of feeding, detopping and grading mechanisms. Onions after detopping are graded in five grades of < 35 mm, 35-50 mm, 50-60 mm, 60-85 mm and > 85 mm. Grader's feeding rate, detopping capacity and efficiency were 277 kg/h, 238 kg/h and 86%, respectively. The average power requirement at load was 0.9 kW. The average onion leaf neck length before and after detopping was 314.8 mm and 23.4 mm, respectively. Onions (in percentage)1.88, 44.73, 33.08, 20.29 and 0 were graded in < 35, 35-50, 50-60, 60-85, > 85 mm, respectively. The average output capacity of manual onion detopping and grading was 30 kg/h and 100 kg/h, respectively. The approximate cost of power-operated detopper- cum- grader was ₹ 85,000 and its operation cost was ₹ 256/tonne compared to ₹ 813/tonne of the manual onion detopping and grading.

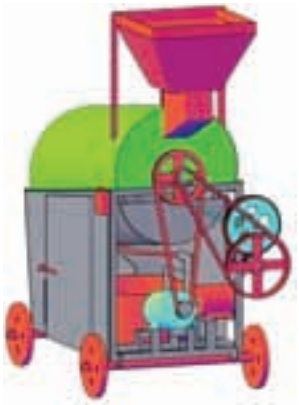
Onion detopper-cum-grader

Pedal-and power- operated arecanut dehusker: Pedal-operated arecanut dehusker was developed using anthropometric data of workers and agronomical principles as well as mechanical design parameters for

Pedal-operated arecanut dehusker

better man- machine system efficiency. Mean value of the heart rate of male workers operating it was 127 beats/min; indicating that the unit can be operated comfortably by workers over a longer time. The dehusking efficiency, kernel breakage and dehusking capacity were 97%, 6.7% and 15kg/h, respectively. The weight of the unit is 110 kg, and is mounted on wheels for mobility. The unit costs ₹ 15,000 with an operating cost of ₹ 3.70 kg/h as compared to ₹ 5.10/kg by manual dehusking in conventional method. The dehusker can also be operated by one hp electric motor with minor modifications.

Potato peeler-cum-washer: It is a two- in -one machine, suitable for small- scale processors for making potato-chips and other value-added products. The machine works on the principal of abrasive peeling. Its main components are abrasive roller (356-mm diameter), power transmission system, water spray system and water-lifting pump. The peeling drum with protrusions on the inside surface rotates and detaches peel from potatoes. The water spraying unit washes potatoes and simultaneously the peel is removed from the drum through perforations along with water flow.



Potato peeler-cum-washer

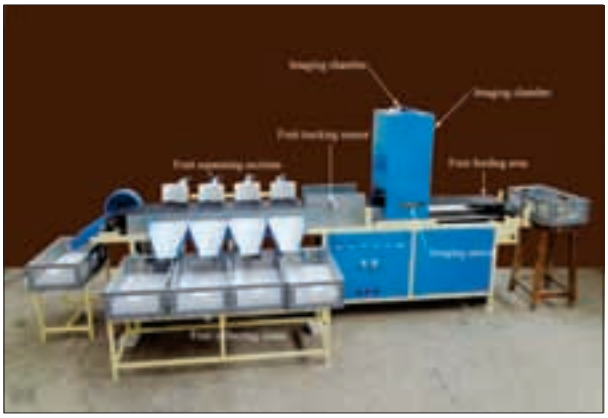
Taro peeler: This machine consists of five brush-rollers mounted over a shaft, a power transmission system and a water spraying system. Overall dimensions of the prototype are 470mm × 750mm × 960 mm. Its capacity is 200-250 kg/h with peeling efficiency of 95-97% with negligible breakage. The machine is easy to use, safe to operate, easy to repair and maintain, of low operating cost, small in size, has low weight, and low noise and vibration.

Taro peeler

Pneumatic-assisted coring device for oblong fruits: The prototype machine consists of a hopper,a moveable wooden roller, a extended fruit dropper, a coring plunger and a stone remover outlet. Wooden roller has a capacity of 6 fruits at a time and it drops fruits through dropper in specific groove on the wooden fruit-holding base for stone removal. All power transmission is controlled by pneumatic air- cylinders. Coring- plunger unit of stainless steel is attached to the main frame. The wooden frames of 470 mm × 50 mm are mounted on an individual mild steel sheet at equidistance on a circular movable unit that rotates only clockwise. The machine is also suitable for coring of fresh date-palms.

Coring device for oblong fruits

Automatic mango grader: The graders of 620 to 650 fruits/h or 200-300 kg/h capacity have been developed with five sections feeding, conveying, imaging, fruit separating and process controlling. Mango fruits are fed manually. The conveying section conveys fruits from feeding section to separating section via imaging section. Imaging section consists of shade- free imaging chamber, imaging device and fruit-detecting sensor. The fruit-detecting sensor is fixed perpendicular to the conveyor axis on the side wall of the imaging chamber at 15mm height from the surface of the conveyor belt. In the fruit separating section, five outlets are given for five grades. Process control section consists of a computer with data I/O card (Arduino Mega 2560, Italy), 5V-four channel



Mango grader

relay, PLC, rotary shaft incremental encoder and a fruit tracking sensor. Camera is connected to the computer with the GIGE Ethernet port. The data I/O card is attached with computer via USB port. The fruit detecting sensor is attached with Arduino board. The machine was evaluated for grading three mango varieties. Higher effectiveness of 98.6% was observed in Alphonso, followed by 96% for Banganapalli and 93.3% for Neelam. This machine would be more suitable for online grading of mangoes based on the external as well as the internal qualities. The operating cost of the machine was ₹ 0.60/kg fruits.

Walnut bleacher-cum-washer: The conventional washing of walnut is done under running water from streams and with tap-water in water drums, troughs or woven vicker-baskets. Nuts are stirred by wooden logs or trampled by feet under running water. Such practices break shell seal resulting in moisture ingress that subsequently leads to microbial growth, darkening of kernel and may cause rancidity, despite the method being laborious and time-consuming.

Walnut bleacher-cum-washer

To overcome these problems, a walnut bleacher-cum-washer (capacity: 150-180 kg/h and efficiency: 95%) has been developed. The unit consists of a rotating drum with meshed surface,and a cylindrical and horizontal and rectangular pyramidal hopper. There is well designed proper output mechanism fitted with lever which lifts drum by 9 degrees. The estimated cost of the machine is ₹ 50,000.