Primary Investigation into the performance of Animal Drawn Puddler

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EDITORIAL

A sudden rise in the price gas is hitting the car drivers all over the world. There is a good demand for small, economical cars especially in the countries like the U. S. A. where people depend heavily on cars. Asia is the most populated area on the globe. Especially, China and India have an enormous population that is likely to continue to grow. Both these countries are enjoying continued economic growth toward catching up with developed countries. Many people there buy deluxe cars, the symbol of a wealthy life. Oil consumption is going to increase geometrically in those countries. Growing purchasing power by the large population will have a great impact on world economy.

As in the case of global warming brought about by CO_2 gas emission, increasing pollution of the environment caused by our economic activities has expanded to the point that it can not be readily absorbed in the natural life system. Moreover, there is every indication that natural resources like energy, fresh water and farming land are rapidly running out. With a gradually dropping food supply on a global basis, another serious concern is future food supply to support the expanding population, the key item for our survival. The food situation in developing countries has not been improved for decades and many people are still threatened with starvation. The riches and power are unevenly distributed in the world. Most resources are monopolized and consumed by the people of a small number of rich countries.

Under such world structure, we who are involved in agriculture are striving to achieve sufficient food production. Despite its importance, the social status of the agricultural profession is not very high. It is a world trend that young people drift away from agriculture. The term "agriculture" might somehow have a negative image and does not attract people as long as "agriculture" is used as a key word. Agriculture was originally intended to achieve harmonization between mankind and other life systems. In other words, mankind will be unable to survive on the earth without continual harmonization with the surrounding eco-system, which is also the only workable solution to the problems of natural resources and environment. Wishing lasting continuation of mankind, we should promote mechanization of agriculture to raise land productivity. AMA will continue to support every effort for that objective.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
November 2006

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Potential of Farm Mechanization in Jammu and Kashmir State of India - a Review

by

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Abstract

Jammu and Kashmir, being a hilly state, is blessed with naturally occurring micro agro-climatic regions suitable for cultivation of a wide range of agri-horticultural crops with a great potential for development. But the level of farm mechanization in the state is very poor with respect to mechanical power, efficient implements, water management, land reclamation, renewable energy and post harvest technology sectors. The farm mechanization is badly hampered by stepped, small and irregular fields, undulating topography, lack of skilled manpower, poor facilities of repair, maintenance and manufacture of implements and high cost solar gadgets. Immediate attention of the state government and other funding agencies is required to strengthen the agricultural engineering wing in Jammu and Kashmir. A strong cell of agricultural engineering should be created to handle the farm mechanization problems. Despite various constraints, there is a great scope for increasing productivity of land and farmer's economy through creation of small water resources for irrigation, land development, use of efficient farm power and implements, rain water harvest, disseminating renewable energy gadgets and introducing small scale agro based industries employing post harvest engineering principles.

Introduction

Jammu and Kashmir are situated in the northern region of the Great Himalayan range, spreading over 33-37 ºN latitude and 72-80 º E longitude. The state comprises 6.7 % of the total geographical area of the country, covering over 2.22 lakh square km, of which about 30 % is under cultivation. Despite small geographical area, the state is blessed with diverse agro-climatic conditions, topography and natural resources for cultivation of a wide range of agro-horticultural crops. Agro-climatic conditions vary from subtropical in outer plains and outer hills of Jammu division; subtropical to temperate in mid to high altitude zone including major parts of district Udhampur, Poonch, Rajori and Doda; temperate to cold temperate in Kashmir valley and cold arid in Ladakh-Kargil area. Each agro-climatic zone can be further divided into various micro-agro-climatic zones based on variation in slope, topography and soil and water availability. These numerous micro-agro-climatic zones make feasible the cultivation of almost all types of agricultural as well as horticultural crops in the state, which include cereals, pulses, oilseed, vegetables, fruits, dry fruits, spices and ornamentals.

The weather conditions also vary greatly with the topography and elevation. The mean annual temperature ranges from 24.5 ºC in Jammu, 13.3 ºC in Srinagar to 5.3 ºC in Leh. Similarly, the annual precipitation ranges from a minimum of 92 mm in Leh to 662 mm in Srinagar to a maximum of 1,200 mm in Jammu. The later receives most of the rainfall during monsoon season while Kashmir division receives it in winter. The distribution pattern of rainfall varies greatly with time and space over the year and generally it is erratic in nature, which creates water stress conditions at various stages of crop growth. These climatic and other edaphically conditions have given rise to different agricultural practices and crop sequences in this geographical area.

The state has a total population of 7,718,000, with 1,217,000 land holdings. The area wise classification of available land in the state is given in **Table 1** which also indicates utilization of only 30.34 % area for crop cultivation while the rest of the area lies under forest, permanent pasture, and fallow land. The operational land holding and percent distribution of area operated by major size groups in J & K are presented in **Table 2**. The average size of operated land holding in J & K is 0.83 ha, which is half the average operated holding size in India. The fragmentation of land holding is expected to be greater, especially under small and marginal farmers' categories in the state. The majority of the farmers in the state are marginal having less than 1 ha land holding.

There is an abundance of water in the state received through precipitation (snowfall and rainfall) but the major portion goes to waste and is utilized in the lower states and in Pakistan. Only a small fraction of available water is utilized in the state and farmers are deprived of irrigation as well as domestic use. Only 37.38 % of the total cultivated area is irrigated by different sources (**Table 3**) and the remaining area is rain fed. The major source of irrigation is through canals (90.73 %). Similarly, the natural energy sources like sunshine, wind, vegetation, water flow and other biological wastes which are abundantly available in the state are not being harnessed properly, resulting in very low per capita energy availability, deforestation and poor health.

The post harvest losses, poor marketing and traditional farming systems also restrict farmers from using improved inputs. There has been a general increase in the average yield of important food crops during the preceding years, but it is relatively far less than the requirements of vehemently increasing population. Also the potential yield achieved in experimental fields are not realized in the farmer's field. Thus, a large gap in potential yield and actual yield of most of the crops in the valley is witnessed. Still the main farm power sources for carrying out different farming operations are animal or human power. High waste of perishable food and fruit products occur every year due to limited agro-processing industries and difficult transport and marketing system in the state. It was focused at the national level in 1998-99 that apart from the use of high yielding varieties and chemical fertilizers, farm mechanization plays a vital role in increasing agricultural productivity, which is more relevant in the valley. Timeliness and efficient energy utilization in various farm operations along with other inputs are key factors in improving agricultural productivity. Mechanization enables the farmers to change their cropping pattern and to shift towards more profitable crops as they can efficiently use their inputs and enjoy various advantages of flexibility available with respect to cropping season, resources and marketing. There is a positive relationship between farm power and productivity. A delay of 15 to 20 days can drastically reduce the crop yield, especially in this state, where weather conditions limit the cropping season. Farm mechanization is not a luxury but a necessity. Repeated ploughing over a long period with the traditional plough/tine cultivator have resulted in the formation of hard compact layers beneath the root zone, which restrict the infiltration of water into the soil and its movement. In the long run, this causes soil erosion as the upper layer of the soil is eroded during heavy rainfall. With the use of modern farm equipment, the input use efficiency can be greatly improved and crop cultivation may be converted into more profitable venture. There is a great scope of

Table 1 Land use in Kashmr valley

Classification	Area, 1000 ha	
	J & K	India
Total geographical area	2,220	328,759
Forest	658	-
Net area sown	733	140,149
Uncultivated area	582	-
Permanent pasture and other grazing land	126	-
Land under misc. crops and trees	72	-
Culturable waste land	140	-
Fallow land	105	-

Source: Digest of statics of Jammu and Kashmir (1996-97)

Table 2 Operational holding and percentage distribution

Class	Size of holding, ha	No. of operational holding, lakh		Percent distribution operated		Av. size of operational holding, ha	
		J & K	India	J & K	India	J & K	India
Marginal	< 1	9.01	567.48	74.04	58.07	-	0.38
Small	1 - 2	1.97	178.81	16.19	18.29	-	1.43
Semi-medium	2 - 4	0.98	132.54	8.04	13.56	-	2.76
Medium	4 - 10	0.19	79.20	1.64	8.10	-	5.94
Large	> 10	0.01	19.25	0.08	1.97	-	17.20
Total	-	12.17	977.28	100.00	100.00	0.83	1.68

Source: Digest of statics of Jammu and Kashmir (1996-97) and Statics Abstract India (1990) farm mechanization in the state of Jammu and Kashmir, but small holdings limit the use of large machinery. However, many agro-horticultural and cash crops like saffron, black cumin, dry fruits, apple and vegetables can encourage the development and utilization of small, handy power equipment in the region. Development and adoption of appropriate engineering based technology in farm power implements, land development and irrigation systems, renewable energy and post harvest sectors will certainly benefit the farming community. This paper describes the present status of farm mechanization, its potential and limitations in the state with special emphasis to Kashmir valley.

Present Level of Farm Mechanization

Farm Power, Tools and Implements

The use of improved farm tools and implements is very limited in the state as compared to many other states of India. The traditional tools and implements are still in use with farmers. They carry out preparatory tillage operations, sowing, intercultural and harvesting operations by traditional methods, which are more energy and time consuming. The present status of farm implements/ machines under use in J & K is shown in **Table 5**.

It can be clearly understood from the **Table 5** that the indigenous (wooden) and soil stirring (SS) ploughs are being used in the preparation of fields and sowing. Broadcasting or kera method (dropping seed behind plough) is normally adopted for sowing of various crops, which not only consumes more man-power but also affects the crop stand, resulting in poor yield. The clod breaking is a severe problem in some of the regions particularly in paddy harvested fields, which is usually carried out by women and children with the wooden hammer. This again consumes more energy for non-productive cause. Tangroo (local name of small spade like tool) and rumbas are used by majority of the farmers in the state for executing weeding and intercultural operations. However, knapsack sprayers and wheat threshers are adopted by some of the medium and large farmers. They also use a tractor for different agricultural operations in their fields as well as on custom hiring basis to other farms otherwise, animal and human power are the main source of farm power. Very few farmers of the hilly region utilize power tillers for field preparation. In Jammu region, very limited use of manually operated maize sheller was reported in recent past. Harvesting of crops and fodder is being done by plain sickles because of their lower cost and local availability. However, plucking of fruits and vegetables is still executed manually with great risk of impairing quality of the product.

Table 3 Area irrigated from different sources

Source of irrigation	J & K Area, 1000 ha	% distribution
Canals	284.25	90.73
Tanks	2.57	0.82
Wells	1.42	0.45
Other source	25.02	7.98
Total	313.26	-

Source: Digest of statics of Jammu and Kashmir (1996-97)

Table 5 Agricultural implements and tools in the state

Implements	Number
Plough	1,075,454
Chaff - cutter	83,890
Pruning scissors	-
Orchard ladders	-
Pump - sets	3,678
Tractors	5,765
Paddy thresher	156
Wheat thresher	987
Maize - sheller	35
Sprayer	2,286

Source: Digest of statics of Jammu and Kashmir (1996-97)

Land Use and Water Management Practices

The state has four major rivers and a number of perennial streams. Besides its 1,335.75 mm average rainfall, only 42.74 % cropped area is brought under irrigation, while the state has exorbitant potential water for irrigation. The most common method of irrigation is through open gravity channels. Approximately 3,678 diesel and electric

Table 4 Area and production of various crops in J & K

Crops	Area, 1000 ha	Production, 1000 q
Rice	275.33	4,290
Maize	304.88	4,544
Wheat	246.88	4,125
Horticultural	133.00	10,210
Oil seeds	71.03	449.63
Vegetable	41.4	5,844
Pulses	31.36	170
Millets	24.40	175
Barley	7.77	-
Condiments & Spices	2.06	-

Source: Digest of statics of Jammu and Kashmir (1996-97)

Table 6 Principal livestock population in the state

Livestock	Number, lakh	
	J & K	India
Cattle	30.550	1,924.530
Buffalo	7.325	697.830
Sheep	29.469	487.650
Goats	17.655	952.550
Horses & Ponies	1.215	9.160
Donkey/mules (others)	0.876	99.140
Total	87.066	3,695.260

Source: Digest of statics of Jammu and Kashmir (1996-97) driven pump sets are available with the farmers throughout the state for lifting water from a surface stream. The state receives abundant quantity of water through precipitation in the form of rainfall and snowfall, which is many times greater than the water requirement of the state. But a major portion of water flows down to other states like Punjab and Himachal Pradesh or even to another country (i.e. Pakistan), through the rivers and their tributaries. A lot of fertile soil is also carried away by runoff water flowing through the rivers. Despite plenty of water resources in the state, irrigation and domestic water availability is very meager due to undulating topography, poor management of water resources and un-exploitation of ground water. It is shocking to know that about 2/3rd of the cultivable area is rain fed in the state, whereas, the down streams are being a potential source of irrigation in other states and Pakistan.

The land is quite fragile and dissected into hills and valleys through numerous streams/gullies. The land slopes are quite high and soil depth is very low at some places. Conveyance of irrigation water through undulating topography to patchy agricultural fields is a complex problem in the hilly region. Small sized and scattered fields in small land holding category and absence of path between two fields restrict the use of tractors, power tillers and improved machine operated implements. The whole state is under severe soil erosion due to high slopes, deforestation, road construction and traditional cultivation practices. The terraced lands are not properly developed for safe water disposal and irrigation.

Post Harvest Technology

The farmers have their own traditional ways of storing and processing the farm produce for their daily consumption. Generally, harvested crops are kept in a heap for long duration to facilitate threshing. Food grains are stored in kuch (local name) made of wood and iron bins. Very high post harvest losses occur in terms of quality and quantity of perishable fruits and vegetables due to lack of sole market, efficient transportation and processing and packaging facilities. Hence, many promising high value crops/vegetables/fruits are not being grown on a commercial scale. Small scale industries for value addition and canning are also scanty.

Renewable Energy

The state government has provided electricity to almost all the villages for lighting but due to inadequate supply of electricity and severe cold, particularly in Kashmir and Ladakh region, fuel wood and coal is also being utilized by the villagers, resulting in deforestation and degradation of land. As a result of special emphasis by the government through several schemes, some of the farmers in the state have adopted renewable energy sources for meeting their domestic energy requirements (**Table 7**). About 1,105 family bio-gas plants of different sizes have been installed in the state, particularly in Jammu region up to March, 1995. Existence of biogas plants is negligible in Kashmir and Ladakh region due to very low ambient temperature in winter. The solar water heater, solar lantern, solar photovoltaic pumping system, domestic and streetlight and solar salination system are also in use. More farmers are coming forward for their adoption due to subsidy offered by the government. Few farmers in hilly regions are using water mills for flour and rice milling but, still, those mills are of old traditional types.

Mechanization Potential

Farm Power, Tools and Implements

There is a great need to develop small tools and implements for tillage, sowing, intercultural, harvesting and threshing operations, so that the requirement of about 74 % marginal farmers (**Table 2**) could be met. Some farmers have tractors to execute tillage operations in their own fields as well as on custom hiring basis however the use of tractors is limited to the plains and valleys only. This compels farmers of neighboring fields to adjust their cropping system with those using a tractor, as the land holdings are small and scattered. There is a tremendous scope for light weight power tillers with efficient matching equipment for various agricultural operations like tillage, sowing, intercultural, puddling, harvesting, threshing, water lifting and transportation, which can be carried by the help of 2-3 men from one field to another field. This mechanical power equipment will suit only medium and large category farmers but other farmers may also use this power on co-operative or custom hiring basis. Declining trend has been observed in the use of animal power as their maintenance for taking only 40 to 50 days field work per year is not as beneficial as maintaining a milk cow. However, it is not possible to fully replace animal power with mechanical power. To maintain an eco-friendly system, there is a need to enhance the use of animal power by development of suitable and efficient matching equipment. The present level of land productivity and area under cultivation can only be increased satisfactorily by adopting efficient farm power and acces-

Table 7 Status of renewable energy sources in the state

Sources	Number
Bio-gas plant	1,105
Solar lantern	2,625
Home lighting system	1,051
Street lighting	889
Solar water heating system	115
Solar desalination system	70

Source: Digest of statics of Jammu and Kashmir (1996-97) sories.

Land and Water Management

The state is presently utilizing only 30.3 % of its total geographical area for cultivation of different agri-horticultural crops. Hence, bringing additional area under cultivation is the need of the day to feed an increasing population of the state. This can be achieved through reclamation measures and conversion of fallow land with the help of deep tillage, leveling and bunding. Of course, considering the alarming rate of soil erosion from cultivated fields and, in order to maintain eco-friendship, conversion of forest land or well-vegetated pasture land is not advisable. Conversion of non-agricultural or wasteland also opens scope for increasing cultivable area in the state. These opportunities can only be realized with the help of farm mechanization and efficient land use practices. Besides this, in depth study for water management is an urgent need in the state, because more than 2/3 of the cultivatable area is rain fed, in spite of the fact that plenty of water flows through rivers to neighboring states and Pakistan. Adoption of small irrigation schemes and exploitation of ground water may be possible solution of the problem. There is a serious threat to the surface water, which is depleting at an alarming rate. J & K State is rich in ground water resources of which only 3 % has been utilized so far. Attention should be given to embark upon a massive ground water exploration program under which a network of tube-wells, hand-pumps and shallow wells should be installed. Practically, about 80 % of cropped area may be possibly brought under irrigation by virtue of excess rain harvest and ground water exploitation. In hilly areas, the possible ways to bring more cropped area under irrigation include rain water harvesting in tanks and its recycling, lifting water from perennial streams and conveying it through pipelines to the nearby fields, diverting perennial flow at a higher point of the stream and conveying the water through gravity channels to the fields and collection of small subsurface seepage water in tanks and using it for irrigation. However, lift irrigation system is not economically viable in some of the cases, where more pipe length and lift energy per unit area irrigated is required due to deep and distant water source. Further, it is possible to save water through minimization of water losses during conveyance, which can be utilized to expand near about 10 % of the present irrigated area. Sprinkler and micro-irrigation systems can also be exploited wherever possible, particularly in high value horticultural crops.

Soil and water engineering research is prerequisite for adoption of other improved farm inputs in the development of rain fed watersheds. Inter-disciplinary approaches of agricultural engineers with soil scientist and agronomist in this sector are likely to increase 100 to 150 % biomass production in the rain fed area of the state.

Post Harvest and Agro-Processing

According to an estimate, about 10 % grain losses in the case of cereals, pulses and oilseeds and up to 40 % in case of fruits and vegetables occur at the country level every year due to lack of storage and post harvest processing facilities. Therefore, raising agricultural and horticultural production always necessitates improved post harvest processing facilities to reduce post harvest losses, so that the improvement in production can be realized and in turn increase the net return to the growers. As far as quality is concerned, the state ranks first in case of fruits like apple, pears and dry fruits, but due to lack of nearby markets, storage facilities, very few agro-processing industries and difficult transportation pose constraints to the farmers to get more remunerative prices for their produce. Losses of perishable items are comparatively greater in the state. Plastic storage structures and vacuum storage of foods including controlled atmospheric packaging have vast potential in the state especially for fruit growers. Farmers are deprived of growing various high valued and off-season vegetables due to lack of post harvest technology for value addition and preservation. Similarly, establishing food industries would also be helpful for the state, which could enhance the farmer's income as well as state's revenue.

Renewable Energy

An estimate shows availability of 8,706,600 livestock in the state (**Table 6**), which reflects vast potential for biogas generation. If 60 % of the livestock at 5 kg dung/livestock/day is utilized for this purpose, about 326,000 family size biogas plants of size 2 cu. meters could be run in the state. Consequently, the biogas generated will serve the needs of more than 4,257,000 persons. This energy production will also save more than 1,087.23 m tones of fuel wood/day and also provide a huge amount of biogas from digested manure. Thus, biogas itself will be a milestone in self-reliance on energy and save the forest. Development of appropriate designs of biogas plant to suit the hilly conditions and minimization of low temperature problem are of more concern to the agricultural engineers.

The mean ambient temperature throughout the year ranges from 13 to 28 ºC in the state. Low ambient temperature gives rise to the energy requirement, which is usually met by coal/electricity/firewood or a combination. The state has about 225 days of sunshine. If only 10 % of solar radiation (1 kw/m^2 surface) is harnessed in the state at 10 % conversion efficiency, 0.01 % surface area of total geographical area has the potential to generate 2.22 x

10^9 MW energy, which will be sufficient for domestic energy requirement of the farmers in the state. The vast and endless source of solar energy can be effectively adopted for heating, cooking, lighting, refrigeration, drying of grain and farm produce. The state also has a huge quantity of biomass by-products, which can be utilized for electricity generation by the use of gasifies.

Hydropower has also great potential among the energy resources in the state. The major rivers and their perennial tributaries can effectively be utilized for domestic energy requirements through water mills and small-scale hydroelectric units. At present, the age-old techniques of water mill operating are prevailing in the state. It is urged that cooperative and constructive efforts are required for efficient harnessing of renewable energy. The agricultural engineers/scientists and developmental agencies of government and NGO's should work on this aspect of non traditional energy resources for the development of eco-friendly, farmer friendly and user friendly power generation system.

Skilled Man-Power

At present, the state does not have any agricultural engineering college. Hence, the state has a negligible number of agricultural engineers. To meet the above mentioned challenges and for efficient harnessing of available potential in agriculture, horticulture, power and marketing sectors, the state must produce adequate agricultural engineers, diploma holders and skilled man power. The state agricultural universities need to establish full-fledged agricultural engineering colleges in order to produce specialized trained personnel in different agricultural engineering fields to cater to the future needs of farm mechanization in hill agriculture of the state. In addition, to develop skilled manpower, the college can also impart training in farm power, farm machinery, land use and development, irrigation and drainage, water shed management, renewable energy and post harvest technology sectors to the development/ extension workers and entrepreneurs.

Conclusion and Suggestions

The review of the agricultural mechanization in J & K State revealed poor adaptability by the farmers due to various reasons as well as negligence of the state government. It is seemed to be in the early stage of development. Further, its potential encourages more in depth research and extension activities in this sector for which immediate attention of the government and other funding agencies, NGO's are needed. Some suggestions for enhancing the pace of mechanization in the state are given below:

- There is first and foremost need to produce adequate agricultural engineering graduates, diploma holders and skilled manpower and their placement by the state government.
- Development of an agricultural engineering package for hill agriculture.
- Mechanization study for the entire state to identify mechanization gaps
- Equipment developed elsewhere needs to be tested, evaluated and modified for better use and adoption in lower and upper hills of the state.
- Introduction of women friendly technology for socio-economic development in the state.
- Light-weight power source (power tiller) for hill agriculture.
- Fallow land and unused land should be brought under cultivation.
- Development of water harvesting tanks/small ponds for collecting surface/subsurface runoff should be under taken on community basis for irrigation basis.
- There is need to develop new models of biogas plants, preferably prefabricated and suitable to produce biogas under low temperature conditions also.
- Eco-friendly renewable energy technologies for conservation of energy and time saving.
- Upgrading the present technology of water mills and their use for domestic electricity production with small turbines.
- Availability of spare parts and small-scale machinery manufacturing facilities at local markets.
- There is need to strengthen the research and development activities in post harvest and agro-processing sectors.
- Government should provide necessary facilities and subsidies for establishing small-scale agro-processing industries.
- There is need to encourage farmers to avail farm mechanization aid on co-operative basis.
- There is also need to introduce custom hiring system through state government agency.

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Case Study in the Conversion of Fired-Wood Fuel to other Suitable ones in the Rural Areas of Vietnam

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Abstract

Burning agricultural wastes for energy was considered and encouraged by the government because agricultural wastes would be converted the to useful energy for agricultural product drying. It also helped decrease the contamination caused by these wastes. For these purposes, we have designed and tested a tobacco dryer using rice husk for burning energy. It was very useful for the areas having an available source of rice husk.

Tobacco drying is an important factor in producing a quality product. To pre-process the product of 9,000 ha we need 3,500 dryers that currently use 40-50 % fired-wood fuel for drying. This activity has been causing the exhaustion of forestry resource and affecting the ecology. So, it is urgent to find a completely alternate fuel that increases the drying quality as well as decreases the drying cost. To obtain this goal, it was necessary to redesign the heat-supply system and the drying bin.

The tobacco dryer structure was changed from a single to a double combustion chamber. The results of the research showed that the double combustion chamber dryer was able to use coal and produce high quality post-drying tobacco of the first and second type and, at the same time, reduce the drying cost.

Using coal fuel to process anchovy has created practical profits, increased the living standards of the peasants in the coastal areas and contributed to the development of the agricultural and fishery economy. This was accomplished by using a new type of steam room which maintained a high quality at an acceptable cost. Also, the use of coal for anchovy steaming will preserve our safe and firm environment.

Introduction

Most dryers in Vietnam use wood and coal fuel for tobacco drying. Among them, coal makes up 50-60 %. Thus, it has remarkably contributed to the forestry exploitation that has adversley affected the environment. It would be desirable to redesign the heat-supply and the drying bin so that we could use coal, reduce the drying cost and increase the quality of the dryed tobacco.

For many years, we have researched many tobacco dryer models to acquire the final aim that is to completely substitute coal for wood. This substitution has initialy obtained satisfactory results. After doing research and constructing the tobacco dryer using coal fuel with heat from a double combustion chamber, we have done the experimental research to determine the best operating parameters and the technical and economic norms of this dryer type.

We also made and tested a tobacco dryer using rice husk for burning energy. It was very useful for the areas having available rice husk source.

The annual anchovy yield of Ninh Thuan province is very high. It is necessary to steam and dry them before exporting. To meet this demand, anchovy processing areas in Ninh Thuan province have about 200 steam rooms which mainly use fired wood as fuel. Because of the depleting forests, it is desirable

Table 1 Levels and the variable intervals of the research elements in the experiment design

Element	Levels					Variable interval
	+ 1	0	- 1	+ α	- α	
N	6	5	4	7	3	1
G	4	3	2	5	1	1
T	110	100	90	120	80	10
S	1.8	1.6	1.4	2.0	1.2	0.2

to find another appropriate fuel as compared to wood.

The Purposes of our Research

- Use coal exclusively to decrease the deforestation.
- Find a fuel that is less expensive.
- Produce a higher quality of post-drying tobacco of the first and second type.
- Improve the quality of steaming anchovy so that they will meet the export criteria.

Experimental Method

Experimental Design

We have used the Completely Randomized Design (CRD) Method: All elements of the experiment were randomly selected.

Experimental Plan

Choosing the researched parameters: The choosing of input parameters is based on the transcendental information, the suggestions of experts and the theory researched results of the basic science. Any unreliable parameter must be determined by monoparameter experiment.

Setting up the experimental plan: Experimental plan is built correlatively with the second-degree experimental plan and nonlinear plan.

Experimental data processing, constructing and verifying the experimental regression model: - Applying the variance analysis method (ANOVA). - Applying the rough odd suppression method of Aknazarova (1982). - Using Statgraphics-vers 7.0 software to construct and verify the experimental regression model, based on Fisher criteria.

Seeking the extremum of the objective function in the experimental plan: Multi-object optimized problems are completely solved on the computer. Multi-object Optimized Method is solved by the Great Number Method of Gass.S.I.

Discussion

The Heat Exchanger Using Honeycomb Coal

We calculated and designed the heat exchanger so that the heat that radiates around the burner and the heat exchanging pipe will be greater than the heat quantity lost through the wall, the floor and absorbed by the drying air. It means:

$$Q' \geq Q_1 + Q_2 + Q_3 + Q_4 + Q_5,$$

where Q' is the heat quantity supplied by the heat exchanger, Q_1 is the useful heat quantity of evaporating water, Q_2 is the heat quantity releasing out, Q_3 is the heat quantity lost through the wall, Q_4 is the heat quantity lost through the floor and Q_5 is equipment accumulated heat quantity.

To obtain the desired results for the post-drying tobacco quality and the fuel expenditure, We have researched, manufactured and tested two types of heat exchangers (**Fig. 2** and **4**).

Fig. 2 is the heat exchanger with 2 burners (two-layer type), with 4 sub-heat conducting pipes. The diameter of the main heat conducting pipe is 280 mm. There are seven 900 angles on every heat conducting pipe. This heat exchanger uses 100 % honeycomb coal.

Fig. 4 is the current heat exchanger with 3 heat conducting pipes and 1 combustion chamber. The diameter of the heat conducting pipes is

Fig. 1 Honeycomb coal

Fig. 2 The double combustion chamber heat exchanger (two-layer type)

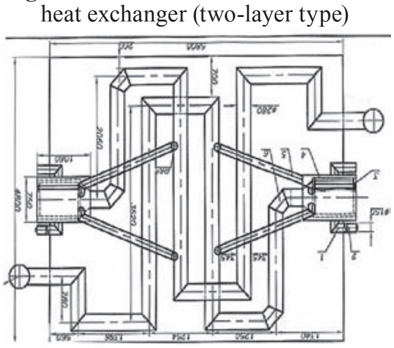


Fig. 3 Transportation of fresh tobacco leaf to dryer group

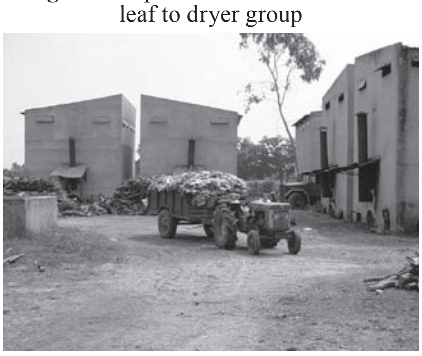


Fig. 4 The 3 heat conducting pipes heat exchanger

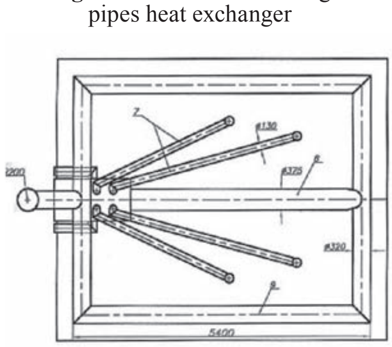
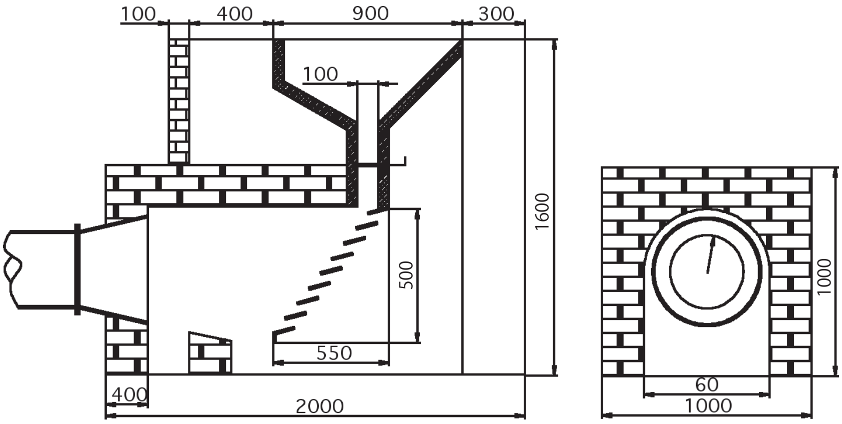


Fig. 5 Rice husk combustion chamber used for tobacco drying



Drying bin

Combustion chamber

320 mm. This heat exchanger uses 60-70 % coal and 30-40 % fired-wood.

The Heat Exchanger Using Rice Husk as Fuel

Dimension: length x width: 1 m x 0.6 m; Combustion chamber's volume: 0.441 m^3; The materials of combustion chamber: Refractory-brick with thickness of 20 cm.; Cylinder-shaped combustion chamber, horizontal (**Fig. 5**); The length of heat exchanger (the pipe): 19.7 m; The height of chimney: 5 m.

Anchovy Steam Room

Combustion Chamber Volume Design; The Basic Parameters of the Anchovy Steam Room

The steam room: (square-shaped room top)

Length = width = 0.9 m and height: 0.62 m

Combustion chamber:

The volume of the combustion chamber: (0.9 x 0.9) x 0.45 = 0.36 m^3

The fired-grate area: 0.8 x 0.75 = 0.6 m^2

The anchovy steam room is designed as the following **Fig. 6**.

Case Study Results

Tobacco Drying Results

Case Study to Determine the Mathematical Equation Model

The Researched Elements: The number of tobacco stories in the dryer: n (stories); The declination of the heat exchanging system: g (degree); Fuel supply cycle: t (minute); Exhausting door area: S (m^2)

The Output Norms: Product quality: L (%); Specific fuel expenditure for 1 kg product: A_r kg (coal)/ kg (dry tobacco)

Experimental Results: After processing the attained data and eliminating the regression coefficients that are not reliable out of the model, we have acquired the results. The regression function was determined as follows:

+ The function of specific fuel

Table 2 Fuel expenditure results and dry tobacco production

Ordinal number	Dryer with 1 burner			Dryer with 2 burners		Dryer with rice husk burner	
	Coal fuel, kg	Wood fuel, m^3	Tobacco production, kg	Coal fuel, kg	Tobacco production, kg	Rice husk fuel, kg	Tobacco production, kg
1	1,220	5.5	566	2,110	546	3,215	530
2	1,110	7.0	580	2,215	577	3,250	540
3	1,350	4.5	571	2,012	529	3,210	534
4	1,315	4.5	528	2,340	641	3,306	562
5	1,260	5.0	543	2,305	629	3,290	535
6	1,410	4.0	555	2,284	616	3,312	558
7	1,387	4.0	510	2,256	585	3,285	516
8	1,256	5.0	531	2,140	555	3,285	520
9	1,365	4.0	522	2,262	601	3,296	527
Average	1,297	4.8	545	2,214	587	3,272	536

consuming level (A_r):

A_r = 32.23334 - 12.07680.n + 3.20386.g - 1.25417(E-3)t + 2.74323.S + 0.0132687.nt - 0.0265063.gt - 0.484062.gS + 0.953537.n^2 + 0.116537.g^2

+ The function of product quality (L):

L = -127.245 + 12.3828.n + 0.153244.g + 1.74362.t + 78.5707.S + 0.103313.nt + 4.30313.gS - 2.40353.n^2 + 0.937277.g^2 - 0.0121613.t^2 - 25.2757.S^2

The Results of the Two-Object Optimal Problem

The function of specific fuel consuming level (A_r) is minimum at the value A_{rmin} = 5.9 kg (coal)/kg (product) and the function of product quality (L) is maximum at the value L_{max} = 56.64 % when the operating parameters of the dryer is satisfied: The number of tobacco stories in the dryer: n = 5 stories; The declination of the heat exchanging system: g = 3º 6'; Fuel supply cycle: t = 97 minutes; Exhausting door area: S = 1.64 m^2

The Experimental Results of Dryer with one Burner, Two Burners Using Coal as Fuel and Dryer Using Rice Husk as Fuel

Comment: The average consumption of the tobacco dryer with 1 burner is 1,297 kg of honey-comb coal and 4.8 ster of wood for every drying batch and the average production is 545 kg dry tobacco. The average consumption of the tobacco dryer with 2 burners is 2,214 kg honey-comb coal for every drying batch and the average production is 587 kg of dry tobacco, (not use fired wood). The average consumption of the rice husk burner tobacco dryer is 3,272 kg rice husk for every drying batch and the average production is 536 kg of dry tobacco (**Table 2**).

The Comparison of Experimental Results among the Dryers with 1 Burner, 2 Burners and Rice Husk Burner

From **Table 2**, we have the fuel expenditure, the dry tobacco production and the price of honeycomb coal fuel is 0.038 USD/kg; rice husk is 0.019 USD/kg and fired-wood is 9.47 USD/ster. We have calculated the fuel expenditure for 1 kg dry tobacco leaf when dried in three heat exchangers mentioned above (**Table 3**).

Comment: We used the statistical analysis method when comparing the above data and the result of the comparison shows the difference of the drying expenditure among the three dryers.

The average drying expenditure of 1 kg dry tobacco leaf when dried by dryer (1 burner) is 0.174 USD/kg, (2 burners) is 0.143 USD/kg and (rice husk burner) is 0.115 USD/kg.

Thus, the drying expenditure of the dryer (2 burner) is 0.031 USD/kg lower than (1 burner) and 0.027 USD/kg higher than the (rice husk burner) dryer.

Practically, we use coal for tobacco drying. The source of supply is very abundant and does not effect on our environment. For rice husk fuel, its source is finite because it is often concentrated in the plains where rice is cultivated plentifully, while in the tobacco cultivated areas, rice husk is very scarce. Therefore, if we transport rice husk to these areas, the transport costs will be very high. As a result, the drying expenditure is higher than coal drying.

The Result of Dry Tobacco Leaf Ratio among the 1 Burner, 2 Burner and Rice Husk Burner Dryers

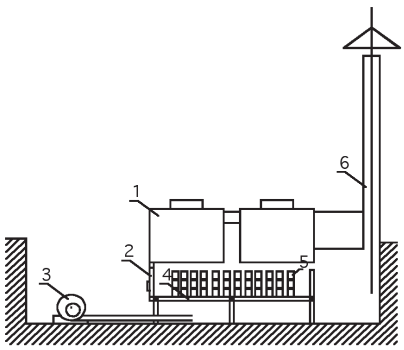
According to the experimental results and the classified results of post-drying tobacco, we have the following ratios:

Comment: The **Table 4** shows that the ratio of the 1^{st} + 2^{nd} type of the 1 burner dryer is 56.7 %, of the 2 burner dryer is 68.2 % and of the rice husk burner dryer is 58.1 %.

Table 3 The comparison of the drying expenditure among the dryers with 1 burner, 2 burner and rice husk burner

Ordinal number	1 burner, drying expenditure USD/kg	2 burner, drying expenditure USD/kg	Rice husk burner, drying expenditure USD/kg
1	0.174	0.146	0.115
2	0.187	0.145	0.114
3	0.164	0.144	0.114
4	0.175	0.138	0.111
5	0.175	0.139	0.116
6	0.164	0.140	0.112
7	0.177	0.146	0.120
8	0.179	0.146	0.119
9	0.172	0.145	0.118
Average	0.174	0.143	0.115

Fig. 6 Anchovy steam room



1: Steam room, 2: Burner door, 3: Centrifugal fan, 4: Burner grate, 5: Coal pieces in the combustion

We have used the statistical analysis method to compare the differences of the tobacco leaf ratio of the 1st + 2nd type among the 1 burner, 2 burner and rice husk burner dryers. The results show that the tobacco dryer with 2 burner heat exchanger operates well with honeycomb coal fuel and the quality of the post-drying production of the 1st + 2nd type is higher than the 1 burner and rice husk burner.

Fig. 7 The relative graph of A_r with every two-element couple

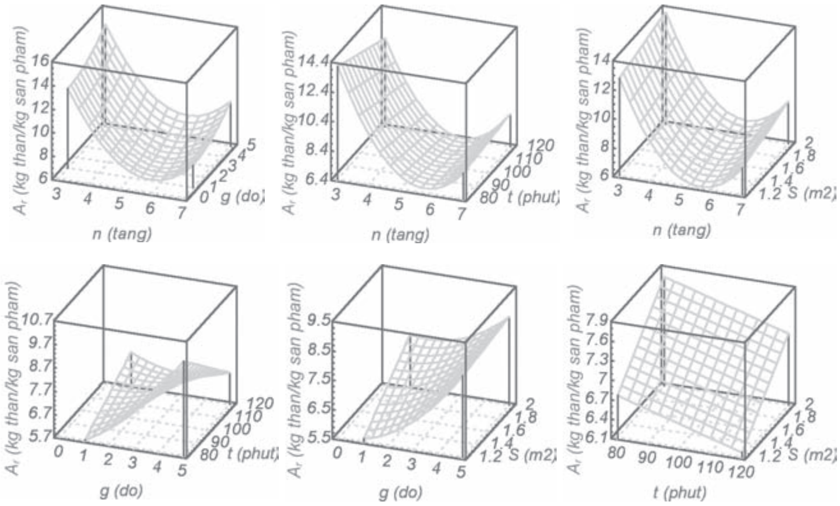
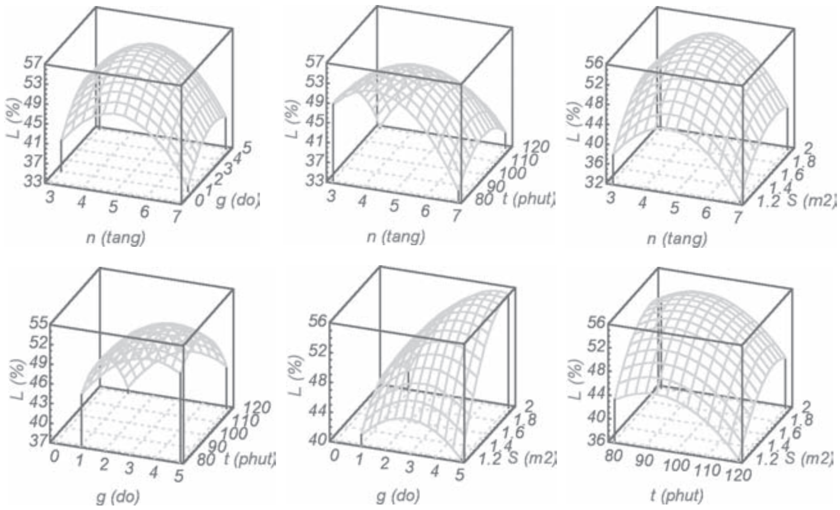


Fig. 8 The relative graph of L with every two-element couple



Anchovy Steaming Experiment

Experimental Results

We have tested the anchovy steaming in three times and realized that the anchovy steam room can absolutely use coal as fuel instead of fired-wood.

Anchovy Steaming with Honeycomb Coal

We have calculated the fuel expenditure for 8-hour steaming per day as follow: The fuel costs for starting up the furnace: 50 pieces of honeycomb coal; The fuel consuming costs for 8 hour operating: 25 pieces x 8 hours = 200 pieces; The total quantity of fuel consumed per day: 250 pieces; In cash: 250 pieces x 0.038 USD/piece = 9.47 USD; The fuel expenditure for 1 kg of product is 9.47 USD/2000 kg = 0.0047 USD/kg.

Anchovy Steaming with Fired-Wood

The expenditure for 1.2 ster of fired-wood is 11.36 USD and the obtained production is 2,000 kg.

The fuel expenditure for 1 kg of product is 11.36 USD/2000 kg = 0.0057 USD/kg

Comment: Anchovy steaming using coal as fuel obtain the economic effect as well as preserve the environment.

Table 4 The ratio of tobacco quality among the 1 burner, 2 burner and rice husk burner dryers

Ordinal number	1 burner dryer, tobacco leaf ratio %				2 burner dryer, tobacco leaf ratio %				Rice husk burner dryer, tobacco leaf ratio %			
	1st type	2nd type	3rd type	4th type	1st type	2nd type	3rd type	4th type	1st type	2nd type	3rd type	4th type
1	28.5	25.4	25.6	20.5	36.5	30.2	18.8	14.5	28.6	25.4	25.6	20.4
2	27.6	28.3	24.4	19.7	38.2	28.3	19.7	13.8	30.6	28.3	21.4	19.7
3	25.7	28.5	25.5	20.3	40.5	29.6	17.5	12.4	32.7	26.5	22.5	18.3
4	30.2	27.6	22.8	19.4	38.6	31.4	17.5	12.5	30.6	27.2	22.5	19.7
5	30.5	28.4	25.2	15.9	36.4	32.8	20.6	10.2	29.5	28.4	25.2	16.9
6	28.4	28.7	25.3	17.6	37.5	30.8	22.2	9.5	33.2	24.7	24.6	17.5
7	31.3	26.6	22.7	19.4	35.8	31.6	21.4	11.2	31.3	27.6	21.4	19.7
8	29.6	26.5	26.4	17.5	38.2	28.6	20.8	12.4	32.6	27.4	23.5	16.5
9	30.7	27.3	26.4	15.6	39.4	29.5	18.6	12.5	31.7	26.4	26.3	15.6
Average	29.2	27.5	24.9	18.4	37.9	30.3	19.7	12.1	31.2	26.9	23.7	18.3

Evaluating the Quality of Post-Steaming Anchovy

According to the experimental results, the anchovy quality in color and hardness steamed by coal is analogous with steamed by wood as well.

The steaming process with coal is completely the same as with wood.

Conclusion

1. With the structure of the dryer changing from 1 to 2 burners, the experimental results show that the tobacco dryer with 2 burner heat exchanger operates well with coal fuel and the quality of the post-drying products of the 1st and 2nd type is higher than the 1 burner.

The experimental results also determined the mathematical equation describing the effects of the dryer operating parameters on the two economic and technical norms. In addition, they have defined the operating zone and the optimal norms for the 2 burner dryer.

From the experimental results of the fuel, the fuel expenditure, the heat efficiency and the quality of tobacco after drying, we have chosen the 2 burner heat exchanger for mass production. This new heat exchanger has the following strong points:

- The heat exchanger has many pipes spreading heat well in the drying bin making heat uniform in the drying bin.
- Transporting coal to the dryer is easier and the labor cost is less than when using wood for drying.
- Safer in fire in comparison with the former.
- Using coal decreasing the deforestation, environmental pollution.
- Heat uniform in the drying bin and the quality of products of the 1st and 2nd type being high.

2. According to the experimental results, using rice husk for tobacco drying is absolutely possible. The quality of post-drying production is maintained. The drying expenditure is lower than that of wood or coal as fuel. However, we also affirm that using rice husk as fuel for the tobacco dryer is profitable when the dryer groups are close to the rice processing plants; Furthermore, we must be careful in preserving rice husk (the rice husk's weight is very little; it is very easy to cause fire).

3. The anchovy steam room has been suitably designed for using coal as fuel, which helps completely replace fired-wood fuel.

The expenditure of coal steaming is 0.09 cents/kg lower than when we use fired-wood as fuel. We are sure that the using of coal for anchovy steaming will attain the desired economic efficiency as well as preserve our firm environment.

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Establishment and Performance of an Indegeneous Small Scale Rice Processing Plant in Nigeria

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Abstract

A small scale Rice Processing Plant with 3 tons per day capacity was established for the Burma Rice farm in Bayelsa State by the National Cereals Research Institute, Badeggi. All the machines were fabricated in the Institute while the Nigerian Agip Oil Company Ltd, Port-Harcourt provided the funds for the whole project including the factory building and other farm structures. The factory was divided into five main sections: threshing and winnowing area, parboiling bay, drying and tempering section, milling section and quality control/bagging unit. The machines installed in the factory were: one rice thresher, one winnower, three rice parboilers, one rotary steam dryer, four milling machines and one pneumatic cleaner. The overall milling recovery of the plant was about 97 %. The performances of the various components were also highlighted.

Introduction

Rice (Oryza sativa L), believed to have originated from ancient China, was one of the most important staple food crops for more than half of the world's population (Bandyopadhay and Roy, 1992). The rice seed contains about 66.4 % starch, 12 % iron and 26.3 % amylose (Ressurrection et al, 1979) while its energy and protein contents are 3.75 % and 7.5 % respectively (IRRI, 1993).

The potential of Nigeria in rice production in terms of availability of land, human resources and weather is so enormous but the actual rice production level of the nation is so low that the country imports rice valued at 600-700 million dollars annually (Guardian, 2002). Also, in spite of the huge rice requirement of the country, the per-capita rice production of 21 kg is very low compared to what is obtained in other West African sub-regions such as Guinea, Gambia and Sierra-Leone which have 135 kg, 110 kg and 108 kg, respectively (NCRI, 1997).

In order for the nation to be self sufficient in local rice production, individuals, corporate organizations and the state and federal government need to utilize the available land potential of 4.6-4.9 million hectares (Kehinde, 1997 and Indachaba, 1985) available in the country. Recently, the federal government of Nigeria inaugurated a committee to come up with a blue print on increase rice production in Nigeria by the year 2004.

However, as part of an effort by the Bayelsa state government of Nigeria to encourage rice production, the Burma Rice Farm was established through a collaborative effort by the Nigeria Agip Oil Company limited, Port Harcourt and the National Cereals Research Institute, Badeggi. The aim of the project was to establish a 3 tons per day rice processing plant to augment the existing rice production capability of the state, provide a source of revenue for local rice farmers to process their crop, provide rural employment for the unemployed youths and generally contribute to rural development in the state.

The Nigerian Agip Oil Company limited, Port Harcourt undertakes oil prospecting activities in Bayelsa state and provided the funds for the whole project while the National Cereals Research Institute, Badeggi provided the processing equipment.

This paper highlights the components of the Burma Rice Processing Factory and gives an overview of the general performance of the factory.

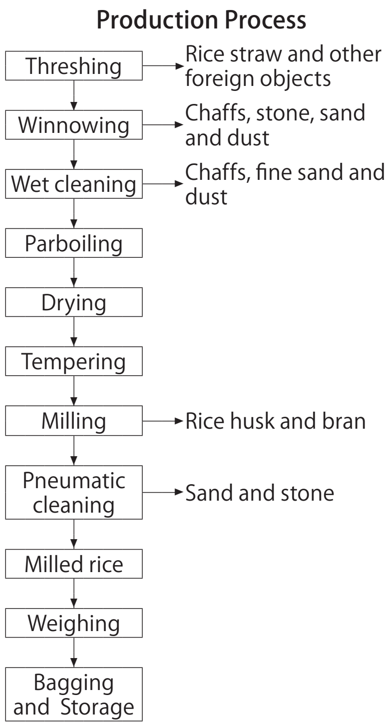
Factory Layout

The rice processing plant layout at the Burma Rice farm has the following five main sections:

i. Threshing and Winnowing Area: This is the area where harvested rice from the field is threshed and cleaned. The harvested rice, tied in bundles, is loaded into trucks on the farm road by labours and transported to the threshing area of the factory. The threshed rice is collected and cleaned with a reciprocating winnower before weighing and bagging. The straw, which is the major by-product of the threshed rice, is spread on the field in order to improve the fertility of the soil.

ii. Parboiling Bay: The cleaned rice is treated hydrothermally in this section. Thus, this area basically houses the parboilers and the wet cleaners. Ample space is provided to accommodate bags of rice and allow movement of people while working.

Fig. 1 Flow chart of the burma rice processing factory



A piping network that conveys water from the over head water storage tank into the boilers, and also serves the wet cleaners, is accommodated in this area.

iii. Drying and Tempering Section: The dryer units are installed in this section. The two units of the dryer, rotary drying chamber and brick wall insulated boiler sections, are conveniently accommodated. A tempering area is also provided in this area to allow for equilibration of moisture between and within rice kernels after parboiling and the first and second pass drying.

iv. Milling Section: Tempered rice is milled in this area before taken for final cleaning. A husk collection point is provided outside the milling area where they are conveyed and deposited with the aid of 3 inch PVC pipes and cyclones.

v. Quality Control and Bagging area: This is the finishing section where milled rice is cleaned by the pneumatic cleaner before weighing and bagging in varying categories of satchets and bags.

Production Process

The production process of the small scale processing plant at Burma is explained in **Fig. 1**.

Bundles of harvested rice from the field are left for about 2-4 days depending on the wetness and maturity of the seeds so that the field moisture content will be adequately reduced. They are then threshed by throwing in a handful (3-5 kg) of the panicles into the machine at intervals of about 30-60 seconds depending on the load. The threshed rice, which is collected with a fabricated rectangular container of 70 cm x 85 cm is poured onto a tarpaulin. They are then introduced into the winnower with the aid of a basin. The chaff, stones, sand and dust are separated by different screens in a reciprocating assembly while the cleaned seeds are collected through a different spout. The winnowed seeds are further cleaned to remove the chaff and minute impurities and dust that adhere firmly to the husks. About 30-40 kg of paddy are cleaned per 10 minute cycle and discharged into the parboiling tanks where they are soaked in water at a temperature of 70 ºC from the boiler for a period of 8-12 hours. The water is then drained through valves and is passed on to the rice in 45-60 minutes intervals. The parboiled rice (which is indicated by cracking of over 95 % of the steamed rice) is discharged at about 45 % moisture content and tempered to 25-30 % moisture content within 1½-2 hours before drying.

The tempered parboiled rice is dried with the rotary steam dryer for 3 hours before discharging at 25-30 % moisture content and tempered for about 3-6 hours. The first pass of tempered rice at a moisture content of 20-22 % is loaded into the dryer for a second pass for about 2 hours. It is discharged at about 16 % moisture content and tempered in

Table 1 Threshing data

S/No.	Quantity of threshed rice per hr.(Tr), kg	Quantity of threshed rice per day (Trd), kg	Quantity of unthreshed rice (Tu), kg	Threshing efficiency (ηcy), %
1	400	3,200	0.1	99.98
2	370	2,960	0.5	99.99
3	405	3,240	0.2	99.95
4	420	3,360	0.08	99.98
5	415	3,320	0.1	99.98

Threshing efficiency ηcy = Tr / (Tr x Tu) x 100 %
Where: Tr = Quantity of threshed rice (kg), Tu = Quantity of unthreshed rice (kg), ηcy = Efficiency of thresher (%)

the tempering area for 18-24 hours before milling.

The milled rice is finally cleaned and graded with the reciprocating pneumatic cleaner before bagging and storage.

Plant's Components and Performance Assessment

The following machines and equipment were installed at the Burma Rice farm:

Rice Thresher

The thresher is made up of a trapezoidal hopper, threshing assembly, straw outlet, frame and power unit. The threshing assembly is comprised of the threshing drum that rotates within a concave made of steel rods. The drum is mainly composed of studs bolted to flat bars that are arranged longitudinally at a distance of 10 cm from one another. The cylindrical threshing drum is powered by a 10 hp air cooled diesel engine.

About 5 kg was fed into the thresher through the hopper. The impact force of the drum (rotating at an average speed of 500 rpm) on the rice panicles dislodged the seed from the straw. The rice straw and chaff were discharged through the straw outlet due to the spiral arrangement of the bars on the rotating drum while the threshed rice seed and some chaff were collected by gravity through the concave into the collector. The few unthreshed rice grains were dislodged from the panicles manually. The total threshed rice after winnowing and the unthreshed rice dislodged manually were weighed and recorded as shown in **Table 1**. The efficiency of the thresher was observed to range from 99.5-99.99 %.

Reciprocating Winnower

One winnower was installed. It was composed of a hopper, reciprocating sieve assembly, chaff outlet, fine impurities, spout and seed outlet. The sieve assembly was essentially made of three metal screens of 15 mm, 5 mm and 2.5 mm diameter hole sizes. They are arranged at an inclination angle of 45 % to the horizontal plane. A reciprocating cam, which was attached to this assembly obtained power from a 5 hp single phase electric motor through pulleys and belts.

Centrifugal blower which obtained power from the pulley of the reciprocating assembly is incorporated at the rear end of the reciprocating system to expel chaff and other lighter impurities.

About 1,000 kg of threshed rice per batch was fed into the machine through the hopper with the aid of a shutter. The reciprocating action of the screens enabled cleaned seed to pass through the upper and middle screens and be discharged through the seed outlet while the straw, chaff and stones were trapped and discharged at the front of the machine due to the combined effect of the screen movement and the centrifugal air blower. The fine impurities (sand) and rice seeds were trapped below the upper and middle screens and discharged through different outlets. The winnowed rice was weighed and further cleaned manually. As shown **Table 2**, the cleaning efficiency of the machine ranged between 87.0-94.0 %.

Wet Cleaners

Three wet cleaners were provided. These were cylindrical vessels having removable stirring assembly and drain valves. Cleaning was done by introducing winnowed rice of different mass into the vessel containing water. The stirrer was then turned vigorously at an average speed of 30 rpm for 2 minutes. The difference in specific gravity of the, chaff and other impurities enabled them to be separated from one another. The lighter impurities that floated on the water were removed with a plastic mesh and the stirrer was turned on again for one more minute for lighter materials to be removed before discharging the filled grains.

The time taken for removal of the impurities was also recorded. This operational procedure was repeated with subsequent batches for about 5 to 7 times before draining the water and washing off the sand that

Table 2 Winnowing data

Rice variety	Initial mass of paddy (Mi), kg	Final mass of paddy after winnowing (Mf), kg	Time spent on winnowing (t), min	Mass of foreign separated materials using machine (Ms), kg	Mass of separated materials using manual machine (Ms), kg	Mass of lost paddy using machine (Mop)	Cleaning efficiency of machine (ηcy), %	Seed retention efficiency (ηry), %	Output capacity of machine (Cmo), kg/day
Faro 52	1,000	992.0	90	7.0	0.5	0.5	93.33	99.95	5,290.6
Faro 35	1,000	991.7	83	7.2	0.7	0.4	91.4	99.97	5,735.13
DA 29	1,000	993.7	75	5.4	0.6	0.3	90.0	99.97	5,746.7
Faro 43	1,000	990.3	92	8.5	0.75	0.45	91.89	99.98	5,166.78
Faro 29	1,000	995.0	80	4.0	0.6	0.4	86.96	99.94	5,970.0
Faro 24	1,000	899.0	76	9.2	0.62	0.38	93.69	99.94	5,677.89

Ms = Mi - Mf, ηcy = Ms / (Ms + Mm) x 100 %, ηry = Mcp / (Mcp + Mlp) x 100 %, Cmo = Mf / t (mins) x 60 mins x 8 hr/day
Where: Mi = Initial mass of paddy (kg), Mf = Final mass of paddy (kg), T = Time spent on machine winnowing (mm), Ms = Mass of foreign separated materials (kg), Mm = Mass of manually separated materials (kg), Mf = Final mass of paddy (kg), Mlp = Mass of lost paddy (kg), ηcy = Cleaning efficiency, ηry = Seed (%) retention efficiency (%), Cmo = Output capacity of machine (kg/day)

deposited on the base of the vessel. The time taken for each operation was recorded as shown in **Table 3**. Although the capacity of the cleaner increased with increasing load per batch, the 45 kg load per batch, which resulted in an average cleaning capacity of 1,167.57 kg per 8 hr working day, was found to be the optimum loading capacity. This was because it yielded the desired capacity of 1,000 kg per day and was also easier to operate compared to the 60 kg and 75 kg load per batch.

Rice Parboilers

Three rice parboilers were fabricated for the farm. The equipment had two main sections: boiler and parboiling units, which were interconnected by a network of 50 mm diameter pipes. The boiler, which was made of 2.5 mm mild steel sheet, had a pressure relief system, drain valve, cold water inlet and hot water and steam outlets. It was placed over a furnace made of bricks. The steaming unit was rectangular in shape and made of 2.5 mm galvanized sheet. A cover was provided to prevent loss of steam while a false bottom was placed 15 cm away from the base of the tank.

One thousand kg of rice from the wet cleaner was introduced into the soaking/steaming tank with water from the boiler at 70 ºC. The water was drained after 8 hours and steam was passed on to the tank from the boiler and left until the husks crack. They were then unloaded and tempered for about 3-12 hours before feeding into the rotary steam dryer. The duration taken for the rice to crack during the steaming operation, quantity of white belly rice and colour difference of the rice were recorded as shown in **Table 4**. The parboiling efficiency of the equipment was approximately 100 % as the percent white belly was either very negligible or totally absent in all the rice varieties. The colour difference for Faro 52 was lower while that of DA 29 was highest.

Rotary Steam dryer

This machine dried about 1.5 tons of parboiled rice per day. Two of these dryers were provided in the factory. It was composed of the boiler placed over a brick furnace and rotary drying unit which were interconnected with a 4 mm diameter pipe. The rotary drying unit was a double wall insulated vessel having a jacket between the two walls for steam circulation. It also had provision for condensation outlet and sets of screens that permitted exit of moist air from the drying rice. Power of rotation of the drum was obtained from a 20 hp electric motor while firewood or gas was used as source of heat.

About 600 kg of parboiled and tempered rice are fed into the rotary drying unit through a detachable hopper. The dryer was turned on while water was heated in the boiler to raise steam. The drum with the content was allowed to rotate at 5 revolutions per minute until the moisture content was reduced from about 30 % to 18 % before it was discharged. The rice was then left to temper for 24 hours and re-introduced for the second pass drying for the moisture to be reduced from about 16.5 % to 13.5 %. The content was finally released and tempered for another 12-24 hours before milling. The drying time for the first and second pass for each variety were noted. As shown in **Table 5**, the average drying time varied from

Table 3 Wet cleaning data

Rice variety	Mass of paddy (Mp), kg	Time spent on first agitation (ta1), mins	Time taken for removal of lighter impurities (tl1), mins	Time spent on second agitation (ta2), mins	Time spent on removal of more lighter impurities (tl2), mins	Cleaned grains discharging time (td), mins	Total time per cycle of cleaning (tT), mins	Average time per cycle of cleaning (ta), mins	Average capacity of cleaner (Ca), kg/day
Faro 52	25	2.0	1.0	2.0	2.0	2.0	9.0	10.33	1,161.67
	25	2.0	3.0	2.0	3.0	2.0	12.0		
	25	2.0	2.0	2.0	2.0	2.0	10.0		
Faro 35	35	2.0	3.0	2.0	3.0	2.0	12.0	11.0	1,527.27
	35	2.0	2.0	2.0	2.0	2.0	10.0		
	35	2.0	3.0	2.0	2.0	2.0	11.0		
Faro 43	45	2.0	2.0	2.0	3.0	3.5	12.5	12.83	1,683.55
	45	2.0	3.0	2.0	3.0	3.0	13.0		
	45	2.0	3.0	2.0	3.0	3.0	13.0		
Faro 29	60	2.0	3.0	2.0	3.0	4.5	14.5	13.83	2,082.43
	60	2.0	2.0	2.0	3.0	4.0	13.0		
	60	2.0	3.0	2.0	3.0	4.0	14.0		
Faro 24	75	2.0	4.0	2.0	4.0	6.0	18.0	17.17	2,096.68
	75	2.0	3.0	2.0	4.0	7.0	18.0		
	75	2.0	2.0	2.0	4.0	5.5	15.5		

Caw = Mp / Ta x 60 mins x 8 hr/day
Where Caw = Average capacity of wet cleaner (kg/day), Ta = Average cleaning time per batch (mins), Mp = Mass of paddy

150-190 minutes during the first pass and 123.33-160 minutes for the second pass.

Rice Mills

Rice mills were installed in the factory. Each pair dehusked and polished the parboiled dried rice. They were made up of a frustrum hopper, milling chamber, husk aspiration unit, milled rice, spout and power unit.

The milling chamber, which rotated at about 650-750 rpm, was comprised of a milling cylinder that was enclosed within a half cylindrical casing and sets of screens at the upper and lower sides. Power to the milling and husk aspiration units were supplied by a 15 hp electric motor through pulleys and belts.

The dried rice was put into the machine through the hopper while the shutter was closed. The machine was then turned on for 2-3 minutes before releasing the shutter slowly for the rice to be dehusked in the first mill of each set. Proper dehusking was ensured by adjusting the pressure device at the spout. The dehusked rice was then polished in the second set of rice mills using the same procedure. The dehusking efficiency of the rice mill was found to be about 100 % while the whole grain efficiency varied between 99.74 and 99.97 % as the percent broken grains were very minimal as shown in **Table 6**.

Pneumatic Cleaner

This machine cleaned milled rice to ensure that fine sand and bran that still accompanied the rice after the initial winnowing and wet cleaning operations were removed. The machine was somehow similar to the winnower except that the reciprocating assembly of the pneumatic cleaner was suspended with four flat spring iron bars while the one in the pneumatic cleaner was suspended with spiral spring iron. Three sets of screens inclined at different angles of 15º, 25º and 45º and different

Table 4 Rice parboiling data

Rice variety	Mass of rice (Mr), kg	Soaking duration (td), mins	Streaming duration (ts), mins	Mass of white belly rice (Mwb), kg	Percent white belly (Wv)	Colour difference (E)	Parboling efficiency (c), %
Faro 52	1,000	480	60	0	0	6.3	100
	1,000	480	60	0	0	6.1	100
	1,000	480	60	0	0	6.5	100
DA 29	1,000	480	75	0	0	9.3	100
	1,000	480	75	0	0	9.7	100
	1,000	480	75	0	0	8.4	100
ROK 5	1,000	480	60	0	0	7.5	100
	1,000	480	60	0	0	7.0	100
	1,000	480	60	0	0	6.8	100
CK 77-3-2-2	1,000	480	90	0	0	8.2	100
	1,000	480	90	0	0	7.9	100
	1,000	480	90	0	0	8.5	100

Wb = Mwb / Mr x 100 %, η pcy = (Mr - Mwb) / Mr x 100 %
Where: Wb = Percent white belly (%), Mwb = Mass white belly rice, Mr = Total mass of parboiled rice, η pcy = Parboiling efficiency of machine (%)

Table 5 Drying data for rotary steam dryer

Rice variety	Mass of parboiled paddy (M), kg	Initial drying time from 30 % m.c. to 18 % m.c. (ti), mins	Final drying time from 16 % m.c. to 13.5 % m.c. (tf), mins	Tempering duration between initial and final drying (tt), mins	Tempering duration after final drying (tta)	Initial average drying time (tia), mins	Final average drying time (tfa), mins
Faro 52	600	150	120	12	24	150	123.33
	600	150	120	12	24		
	600	120	130	12	24		
DA 29	600	180	140	12	24	190	131.67
	600	190	135	12	24		
	600	200	120	12	24		
ROK 5	600	150	140	12	24	160	131.67
	600	150	120	12	24		
	600	180	135	12	24		
CK 77-3-2-2	600	200	150	12	24	176.67	160
	600	150	180	12	24		
	600	210	150	12	24		

directions were incorporated in the reciprocating unit. Also spouts for collection of cleaned rice, fine sand, dust and broken grains were provided within the same assembly. Power to the reciprocating and blower units was proved by a 5 hp single phase electric motor.

Milled rice was introduced into the reciprocating screen assembly through the hopper after switching on the machine. The shutter in the hopper was released to regulate the flow rate of the material into the screen assembly. The reciprocating action of this unit, which moved at 1.2 m/sec, resulted in separation of the fine sand, broken grains and whole grains which were collected through different spouts. The rice bran and other lighter impurities were separated by a forced air stream at a velocity of 7.5 m/sec generated by the blower.

Production Input and Raw Materials

The major raw material in the plant was rice. Other inputs included water, firewood, diesel, engine and gear oils. Water was used in wet cleaning, parboiling of rice and heating medium in the rotary driers. Diesel engine and gear oils were used as fuel for the 150 KVA electricity generating plant. They were also used as the source of fuel for the engine of the rice thresher and lubricant for the gear boxes of the rotary dryers.

Sources of Raw Materials

Rice, the major raw material, is obtained from the Burma Rice farm, which is located around the factory. Currently about 20 hectares of the farm has been cultivated. Since it is to be expanded to 50 hectares within a three year period, enough raw material is expected to be obtained from the farm. An outgrowth scheme proposed by the Bayelsa State government after handing over the project by NAOC is expected to ensure the availability of raw materials in the factory.

Products/by-Products and their Utilization

The main product was milled rice while rice straw, husk and bran were the by-products generated from the factory. The milled rice was packaged in 2 kg polyethylene sachets and 10 kg, 25 kg and 50 kg transparent nylon bags for sale. The rice bran was sold to fish and poultry farmers while the rice straw was spread and worked into the field as organic manure to supplement the soil nutrients.

Conclusion

The Burma Rice Processing Factory is the first complete indigenous rice processing machinery package that has been established in the country by the National Cereals Research Institute after elaborate research work on the development of all components of the plant.

Results on performances of the various machines and equipment in the plant clearly showed high efficiencies. The whole - grain efficiency of over 99 % and over-all milling recovery of about 69.0-71.5 % were very ideal since it compared favourably with the milling recovery of 70-72 % recorded by the modern rice mills in the world.

The equipment was also observed to be sturdy, compact and rugged as breakdown recorded during the test-run period was very negligible. All the equipment was simple to operate and maintain. The federal government of Nigeria is therefore urged to utilize this opportunity by encouraging individuals and co-operative farmers and agricultural business

(continued on page32)

Table 6 Milling data

Rice variety	Mass of dried rice (Md), kg	Mass of milled rice (Mm), kg	Mass of whole grain rice (Mw), kg	Mass of broken grains (Mb), kg	Mass of unmilled rice (Mu), kg	Avegrage mass of milled rice (Ma), kg	Average mass of whole grain (Maw), kg	Whole grain efficiency (Wcy), %	Dehusking efficiency (Dcy), %	Milling recovery (Mr)
Faro 52	1,000.0	696.8	696.4	0.3	-	68.68	99.94	100.0	704.53	70.43
	1,000.0	711.3	711.1	0.2	-	71.13	99.97	100.0		
	1,000.0	705.5	705.2	0.2	-	70.55	99.96	100.0		
DA 29	1,000.0	690.1	689.1	0.9	-	69.01	99.86	100.0	696.30	695.40
	1,000.0	703.1	702.3	0.7	-	70.31	99.89	100.0		
	1,000.0	695.7	694.8	0.8	-	69.57	99.87	100.0		
ROK 5	1,000.0	715.3	714.8	0.4	-	71.53	99.93	100.0	706.37	70.58
	1,000.0	708.6	708.1	0.4	-	70.86	99.93	100.0		
	1,000.0	695.2	694.6	0.5	-	69.50	99.91	100.0		
CK 73-3-2-2	1,000.0	699.9	698.1	0.8	-	69.99	99.74	100.0	69.60	694.87
	1,000.0	685.4	684.6	0.8	-	68.54	99.90	100.0		
	1,000.0	702.6	701.9	0.6	-	70.26	99.90	100.0		

Mr = Mm / Md x 100 %, Dcy = Mu / Mm x 100 %, Wcy = Mw / (Mw + Mb) x 100 %
Where: Mr = Milling recovery of rice (%), Mm = Mass of milled rice (kg), Md = Mass parboiled dried rice (kg), Mw = Mass of whole grain (kg), Mb = Mass of broken grains (kg)

Evaluation of Soil-Water Conservation Tillage Systems for Communal Farmers in the Eastern Cape, South Africa

by

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Abstract

Three tillage systems, viz. tie-ridging, pot-holing and ripping were evaluated to assess their potential as water conservation techniques on four small-scale farms in two districts in the central Eastern Cape Province of South Africa. The conservation treatments were compared to the farmer's normal or conventional practice (as the control) and they were replicated twice on each farm. All tillage systems were based on the use of animal draught power.

Soil moisture content measurements were taken at the 0-10, 15-25 and 30-40 cm depths at the time of planting, at first weeding and at tasseling stage. Moisture content significantly increased with depth for all treatments at all times, but tillage treatments did not have consistent nor significant effect on soil profile moisture contents. Plant height measurements taken at first weeding, at tasseling and at harvest also did not show any tillage treatment effects. However, grain, stover and biomass yields were higher under tie-ridge and pot-hole treatments compared to the rip and conventional treatments, indicating a possible response to better water conservation and use efficiency.

Labour requirements for various field operations increased dramatically under each tillage system whenever there was a reduction in the utilization of animal draught power. Thus, total labour input demand increased in the order: ripping = conventional << tie-ridging << pot-holing. The latter two tillage techniques have a potential for water conservation and increasing yields, but were not readily acceptable to farmers because of their very high labour input requirements. On the other hand, farmers indicated that they would favourably consider adoption of ripping as a labour saving option.

Introduction

Most areas of the Eastern Cape Province (**Fig. 1**), receive low and erratic rainfall. Production of summer crops is usually risky as a result of this low and erratic rainfall com-

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bined with the hot dry spells, which are a normal part of the weather pattern during the most important months of the crop's development. Despite the harsh weather conditions most farmers in the region, especially those in communal areas, still endeavour to produce food crops under dryland conditions. Yields are usually very low and only at subsistence levels.

It is generally acknowledged that one way to improve dryland crop production in the arid and semi-arid regions is retain all rainfall received by techniques that reduce surface runoff, improve infiltration and increase the water storage capacity of the soil (FAO, 1984; FAO, 1994). Such techniques have long been used traditionally in various countries in Africa (Reij et al, 1996), for example, the trus system (U-shaped earth bunds) in the Sudan, the zai system (planting pits dug out with traditional hoes) in Mali and Burkina Faso, and the tassa system (planting pits) in Niger. Other systems of soil and water conservation that have been widely tested and used on the continent include tied ridges (Nyagumbo, 1999; Kayombo et al, 1999), clean ripping and mulch ripping (Chuma and Hagmann, 1997; Nyagumbo, 1999); hillside terraces or stone bunds (Reij et al, 1996; Kayombo et al, 1999), micro-basins (Reij et al, 1996) and trash-lines (Reij et al, 1996; Kayombo et al, 1999).

During the participatory rural appraisal, several soil and water conservation systems were identified as being practised in the province (Simalenga et al, 2000). These include terracing, use of vetiver grass, mulching etc. (**Figs. 2** and **3**). Although these conservation tillage practices have long been practised in arid and semi-arid regions elsewhere with some success, they have not been widely tested and demonstrated to small-scale farmers in the communal areas of South Africa. Their application here has thus been very limited.

The objectives of this work were:

- To test on-farm the effectiveness of the three tillage systems of tie-ridging, pot-holing and ripping as water conservation techniques,
- To demonstrate the conservation tillage systems to small-scale farmers in central Eastern Cape, and
- To assess farmers' response and their evaluation of the systems for possibility of adoption and use.

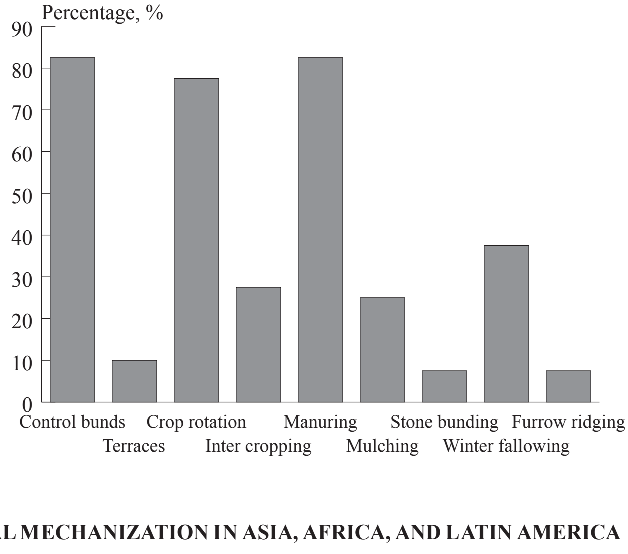
Materials and Methods

The potential of using three tillage systems, viz. tie-ridging, pot-holing and ripping, as water conservation techniques on four small-scale farms in the central Eastern Cape Province were evaluated during the two cropping seasons i.e.1999-2000. Two of the farms were located in a relatively dry district, Peddie, with a long-term rainfall average of 570 mm per annum, whilst the other two farms were locates in a wetter district, Middledrift, with a long-term rainfall average of 703 mm per annum. The conservation tillage treatments were compared with the farmer's normal practice as the control. The normal practice in the area is to plough the fields using mouldboard plough, either by tractor or animal traction, during the autumn or winter months (a practice locally known as winter fallowing) followed by another ploughing at the beginning of the new cropping season. The tillage treatments were therefore applied on "winter fallowed" lands and were replicated twice on each farm. The plot size was 10 m by 25 m, giving a working area of 250 m^2 for each plot.

All treatments, except for pot-holing which was completely done by hand, were based on the use of animal draft power, usually a span of two oxen. Conventional ploughing was by the ox-drawn plough, tied-ridges were constructed by

Fig. 1 Map showing the location of Eastern Cape Province

Fig. 2 Percentage of farmers practising conservation farming in central region, Eastern Cape



ridging with a winged ridger at 1 m intervals then cross-tying the ridges at regular intervals by hand, and ripping was done at 1 m intervals by a ripper made from a modified plough.

Pot-holes were constructed by scooping soil with hand hoes to make shallow circular basins about 1m in diameter at regular intervals. In conventional system, fertilizer and maize seed are placed in the appropriate furrow behind the plough and covered by the next pass of the plough. In the rip system, the fertilizer and maize seed were placed in the ripper line and covered by a light harrowing of each plot after planting all plots. In the tie-ridge and pot-hole systems, planting stations were opened individually by the hand hoe, fertilizer dropped and lightly covered by soil, then maize seed was dropped and covered manually. Planting was done on the side of the ridges or pot-hills. Fertilizer mixture 2:3:2(22) + 5 g/kg Zn (containing 6.5 % N, 9.4 % P, 6.3 % K, 12.5 % Ca, 6.3 % S + 0.5 % Zn) was applied at the rate of 300 kg per ha in each case. No top dressing was applied. The crops were weeded twice, first at about 10 days after germination and second about four weeks later.

A number of measurements were taken during the season as follows. Soil profile moisture content was measured by taking samples with an auger at the 0-10, 15-25 and 30-40 cm depths at two places in each plot prior to planting, at first weeding and at tasseling stage. The samples were kept in air-tight cans, taken to the lab, weighed fresh and again after drying at 101 ºC overnight. Crop heights of six plants in middle rows of plots were measured at three different stages of the crop cycle, viz. at first weeding, at tasseling and finally at harvest.

Labour inputs were measured by recording the number of people and actual time it took them to complete each of the following operations per plot, irrespective of use of animal draft power: land preparation, fertilizer application immediately followed by planting, and for weeding. The labour input timings were converted to man hours per ha for

Table 1 Soil moisture contents (% w/w) at three depths (cm) at three different stages of crop development in middledrift and peddie districts

Treatment	Middledrift district				Peddie district			
	Depth			Treat	Depth			Treat
	0-10	15-25	30-40	Mean	0-10	15-25	30-40	Mean
Profile moisture at planting								
Control	8.11	12.55	15.08	**11.50**^{a}	5.36	8.01	7.43	**6.93**^{a}
Tie ridge	7.45	12.32	14.42	**12.39**^{a}	5.12	7.27	10.82	**7.74**^{a}
Pot hole	9.63	12.90	15.48	**12.67**^{a}	3.80	6.86	8.42	**6.36**^{a}
Rip	8.21	12.96	16.07	**12.41**^{a}	4.66	7.73	9.55	**7.31**^{a}
Mean	**8.35**^{c}	**12.55**^{b}	**15.08**^{a}	11.99	**4.74**^{c}	**7.47**^{b}	**9.05**^{a}	7.08
Profile moisture at weeding								
Control	10.45	13.31	17.06	**13.61**^{b}	11.88	16.68	18.66	**15.74**^{a}
Tie ridge	13.48	15.18	19.09	**15.92**^{a}	10.61	13.84	20.65	**15.03**^{a}
Pot hole	10.36	14.18	15.11	**13.21**^{b}	9.26	15.08	19.65	**14.66**^{a}
Rip	10.06	13.75	15.84	**13.22**^{b}	11.82	21.37	23.89	**19.02**^{a}
Mean	**11.09**^{c}	**14.11**^{b}	**16.77**^{a}	13.99	**10.89**^{c}	**16.74**^{b}	**20.71**^{a}	16.12
Profile moisture at tasseling								
Control	9.09	13.86	16.07	**13.00**^{b}	9.76	14.40	15.33	**13.16**^{ab}
Tie ridge	11.61	15.36	20.43	**15.80**^{a}	9.03	10.39	14.84	**11.42**^{b}
Pot hole	9.72	14.90	21.47	**15.36**^{ab}	9.13	12.27	14.10	**11.83**^{b}
Rip	13.32	14.92	18.54	**15.59**^{a}	11.35	15.46	17.87	**14.89**^{a}
Mean	**10.93**^{c}	**14.76**^{b}	**19.13**^{a}	14.49	**9.82**^{c}	**13.13**^{b}	**15.53**^{a}	12.83

Note: Means with the same letter in a row or column are not significantly different at $P < 0.05$

Fig. 3 Percentage of farmers practising conservation farming in the northern region of Eastern Cape

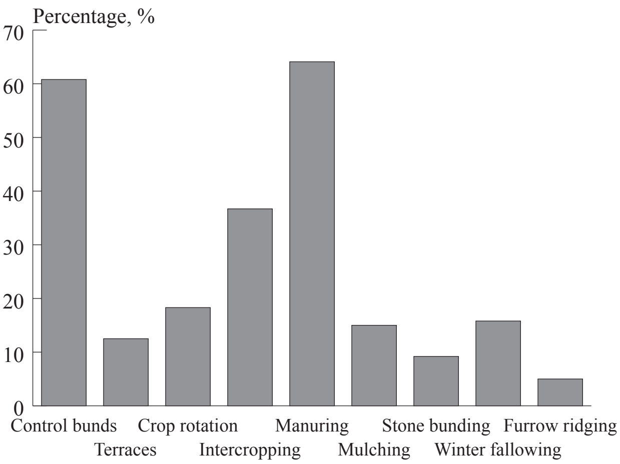
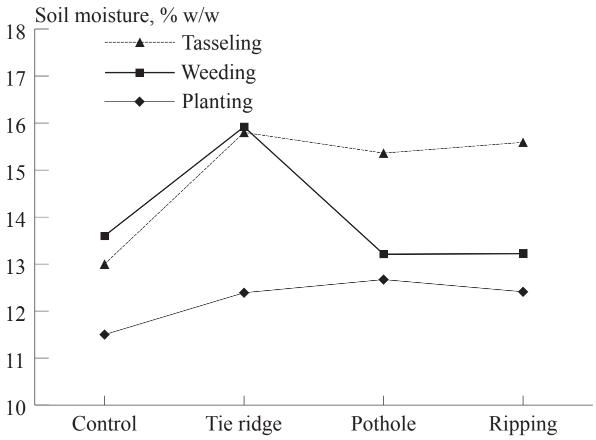


Fig. 4 Comparison of moisture content for different treatments



each operation for the different tillage systems. Grain and stover yields were measured at the end of the season. Rainfall in each district was recorded by a simple rain gauge placed at each farmer's homestead whereby the farmer was responsible for taking the daily readings.

Results and Discussion

The average total rainfall recorded in Middledrift district for the months of September 1999 to April 2000 was 504.5 mm compared to a long-term (66 year) average of 474.8 mm from the nearest station at Blaney (ARDRI, 1989). Rainfall recorded at farms in Peddie district averaged 445.0 mm for the same months compared to a long-term (25 year) average of 341.4 mm at near by Lime Drift station. Overall then, it seems this was an above average rain fall season.

Soil profile moisture contents significantly increased with depth for all treatments at all times of measurement (**Table 1**). This is to be expected as a result of increase in clay with depth. The soils in Peddie were significantly drier than Middledrift soils at time of planting but the different was obliterated by the time of the first weeding. Moisture was also slightly lower in Peddie by tasseling stage as compared to Middledrift sites.

From the data given by Hensely and de Jager (1982), it is estimated that the gravimetric moisture holding capacities of soils in the region lie between 15 to 20 % at field capacity (FC) and 6 to 14 % at permanent wilting point (PWP) for topsoils (0-20 cm depth) and between 15 to 18% at field capacity (FC) and 7 to 11% at permanent wilting point (PWP) for upper subsoils (20-40 cm depth). By this comparison, the soil profiles in Peddie were very dry at planting, and this, in fact, affected crop establishment. The surface 10 cm in Middledrift were also dry at planting but the rest of the profile was well recharged.

Fig. 4 is a summary of typical moisture content during planting, weeding and tasseling for the three treatments. The results have shown that tillage treatments did not have a consistent effect on soil profile moisture contents. Of note, however, is that in Middledrift district the tie-ridging treatment had a significantly higher profile moisture content than the other treatments both at weeding and tasseling stages though the effect was non significant at planting. The inconsistence of the data may be attributed to sampling errors as well as delays between sampling and the laboratory weightings (sometimes samples were only processed the following day). This kind of data is best collected by means of neutron moisture probes in "permanently" installed access tubes.

Measurement of crop heights as an indicator of crop performance showed that, generally, bigger plants were found in control plots and smaller ones in ripped plots throughout the season, though the effect was not always significant (**Table 2**). Plants increased in height considerably from an average of 52 cm at weeding to 130 cm at tasseling with little further increase to about 160 cm at harvest.

Average grain, stover and total biomass yields under the differ-

Table 2 Height of plants (in cm) taken at three different stages of crop development in middledrift and peddie districts

Treatment	Middledrift district			Peddie district		
	Height at weeding	Height at tasseling	Height at harvest	Height at weeding	Height at 2nd weed*	Height at harvest
Control	53[a]	138[a]	160[a]	51[a]	82[a]	177[a]
Tie ridge	53[a]	120[b]	155[a]	55[a]	81[a]	175[ab]
Pot hole	52[a]	124[b]	152[a]	55[a]	80[a]	176[ab]
Rip	48[b]	124[b]	157[a]	47[a]	69[b]	165[b]
Mean	**52**	**126**	**156**	**52**	**79**	**173**

Note: Means with the same letter in a column are not significantly different at P <0.05, *Crops replanted and were not yet at tasseling stage at time of sampling

Fig. 5 Grain yield for different treatments

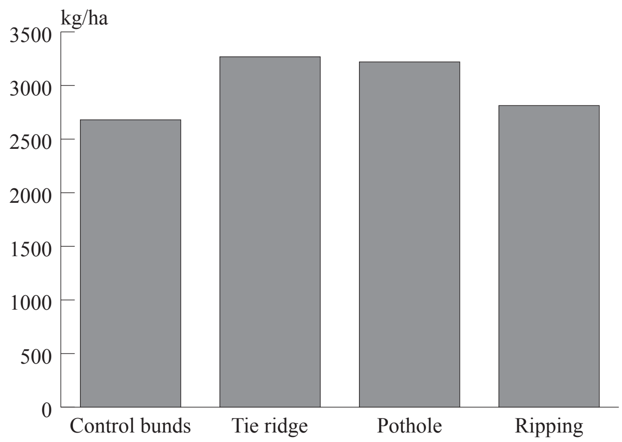
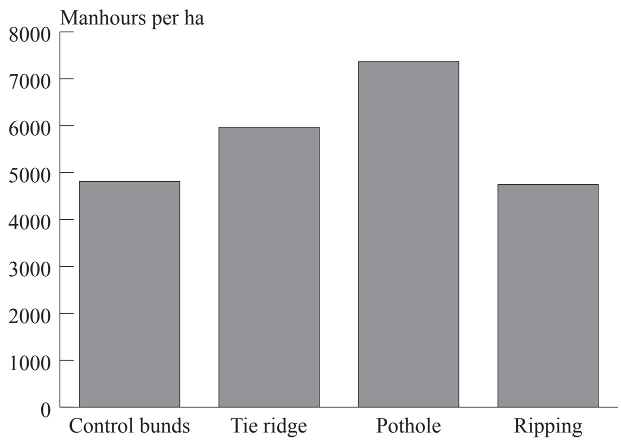


Fig. 6 Labour requirement for different tillage systems



ent tillage treatments in the two districts are shown in **Table 3**. Significantly ($p < 0.05$) higher yields were obtained under the tie-ridge and pot-hole systems than with the rip and farmer's systems, although the effects were non-significant for grain in Peddie district. This result is significant in that it demonstrates the potential of the tie-ridge and pot-hole system to concentrate rain water with better utilization by the crop (**Fig. 5**).

Average labour requirements for the field operations of land preparation, fertilizer application plus planting, and weeding are given in **Table 4**. Labour requirements were virtually identical in both districts for each of the operations, giving some measure of confidence in the accuracy of the data collected. Of the three operations, fertilizer application taken together with planting (seed placement and covering) demands the least labour input under all the tillage systems, except the rip system which has least labour demand at stage of land preparation (**Fig. 6**).

Weeding had the highest labour demand, especially under the two water conservation systems of tie-ridging and pot-poling in which all the work was done manually in order to conserve the structures of each. Pot-holing demanded a lot of labour at the land preparation stage because this was done completely by hand without resort to use of animal draught power. This demand could be considerably reduced by the development and use of appropriate animal-drawn equipment as in case of ridging. Since tying of ridges was done by hand, the labour input went slightly up, but this operation could also easily be mechanised. Labour demand for weeding was significantly reduced in conventional (control) and rip systems by, first, use of the animal-drawn cultivator between crop rows, followed by hand hoeing within the rows.

Conclusion

Tie-ridging and pot-holing systems were effective in water conservation and utilization by plants as reflected in increased yields; however, this former function could not be verified by corresponding increases in soil profile moisture contents, possibly due to sampling errors or a limited depth of sampling. In spite of these advantages, the two tillage systems incurred a very high labour input demand because of the associated reduction in, or complete lack of, use of animal draught power. Small-scale farmers who already face acute labour constraints viewed the high labour requirements of these conservation tillage systems negatively. This poses a considerable hindrance to their adoption and use by the farmers.

Table 3 Average grain, stover and biomass yields under the different tillage treatments in the two districts

Treatment	Middledrift district			Peddie district		
	Grain, kg/ha	Stover, kg/ha	Biomass, kg/ha	Grain, kg/ha	Stover, kg/ha	Biomass, kg/ha
Control	**2,680[b]**	**3,960[ab]**	6,640	**2,467[a]**	**3,520[b]**	5,987
Tie ridge	**3,268[a]**	**4,626[a]**	7,894	**2,621[a]**	**3,991[a]**	6,612
Pot hole	**3,220[a]**	**3,946[ab]**	7,166	**2,563[a]**	**3,954[ab]**	6,517
Rip	**2,813[b]**	**3,446[b]**	6,259	**2,387[a]**	**3,498[b]**	5,885
Mean	2,995	3,995	6,990	2,510	3,741	6,251

Note: Means with the same letter in a column are not significantly different at $P < 0.05$

Table 4 Labour requirements (in manhours per ha) for different operations under different tillage systems measured in the two districts

Treatment	Middledrift district				Peddie district			
	Land preparation	Fertiliser & plant	First weeding	Total labour	Land preparation	Fertiliser & plant	First weeding	Total labour
Control	133[c]	30[c]	4,649[b]	**4,812**	147[c]	33[c]	4,573[d]	**4,752**
Tie ridge	270[b]	126[a]	5,572[a]	**5,967**	229[b]	123[a]	5,306[a]	**5,657**
Pot hole	1,717[a]	137[a]	5,511[a]	**7,365**	1,701[a]	132[a]	5,669[a]	**7,503**
Rip	38[d]	84[b]	4,875[b]	**4,997**	34[d]	83[b]	4,629[b]	**4,746**
Mean	**539**	**94**	**5,152**		**528**	**93**	**5,044**	

Note: Means with the same letter in a column are not significantly different at $P < 0.05$

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(Continued from page26)

Establishment and Performance of an Indegeneous Small Scale Rice processing Plant in Nigeria

oriented entrepreneurs to adopt this technology in order to boost rice production.

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Recent Developments in Sugarcane Mechanisation in India

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Introduction

Sugarcane is the most important agro industrial crop next to cotton which is being cultivated in approximately 4.2 million hectares area in India. The country has produced more than 300 million tonnes of cane at a national average of 70 tonnes per hectare. In the present context of globalisation, ways and means have to be further evolved to produce more sugar per unit area, time and input in order to keep pace with the population growth while preserving the soil and water resources. The challenges in the millennium can be met effectively by way of adopting the appropriate mechanical alternatives not only for increasing the productivity but inculcating cost efficiency in sugarcane production system. The farm mechanisation in the context of sugarcane cultivation should aim at introducing timeliness of operation and reducing human drudgery on one side and improving overall production efficiency on the other.

Present Scenario of Farm Mechanisation

Indian agriculture is characterised by small and scattered holdings and sugarcane cultivation is no exception. Sugarcane crop remains in the field for almost a year and right from land preparation to harvesting of the crop and its timely supply to the mill, there is a heavy demand of labour and machinery throughout its crop cycle. Sugarcane accounts for 60-70 % of the cost of sugar production and thus has a vital role to make sugar industry a commercially viable venture.

In a true sense, if we look at the prevailing degree of mechanisation, it is observed that so called mechanisation is confined to tractorisation, only in general and use of land preparation equipment, mainly cultivator and harrow in particular. As regards planting of sugarcane, inspite of the fact that a number of useful machines have been developed at the Indian Institute of Sugarcane Research, Lucknow, the adoption level has not been encouraging. The mechanisation of cane planting has been, till recently, confined to the use of tractor drawn ridgers for opening the furrows and the remainder of the operations involved in cane planting were done manually. Use of improved equipment in accomplishing other cultural operations required in cane cultivation, is almost non existent.

A brief description of some of the newly developed equipments for sugarcane cultivation has been given and ways and means have been suggested so as to take these useful labour and cost efficient devices to the farmers with a view to sustain sugarcane productivity.

Mechanisation of Sugarcane Planting

After land preparation, sugarcane planting is the major operation to be mechanised first. This is essential to pave the way for mechanising subsequent cultural operations.

Various types of animal drawn and tractor drawn sugarcane planters have been developed and successfully tested and demonstrated at the farmer's fields. These planters are drop type planters where whole cane is cut separately into three bud sets either manually or by a power operated set cutting machine. These sets are fed manually and the rest of the operations, such as opening of furrows, application of fertilizer, insecticide and fungicide, giving a soil cover over the sets and compaction of the soil cover, are carried out automatically with the help of the planter. Various types of set type planters, - semiautomatic and automatic, have been developed. In case of automatic planters, dropping of the set is also automatic besides other operations involved in cane planting.

With the advent of sugarcane cutter planters on the scene, where cutting of whole cane in to sets is also done simultaneously, planting through machine has become a viable proposition. Ridger type/Disc type sugarcane cutter planter have been developed and successfully tested and demonstrated in the farmer's fields. These planters have now become popular among the cane growers and, as a result, a number of commercial manufacturers have come forward and taken up the manufacturing of the IISR design sugarcane planters on a commercial scale. Presently the latest model of sugarcane planter costs Rs.30,000.00. The cost of sugarcane planting with the use of this machine may be reduced by about 50 % as compared to conventional system of cane planting. **Fig. 1** shows the IISR Sugarcane Cutter Planter in operation.

Timeliness of operation and efficient utilization of critical inputs, such as fertilizer, insecticide and fungicide, is also made possible. In order to increase the utilization index, multipurpose equipment taking care of planting, interculture, earthingup, puddling, seeding, etc. can be undertaken by making minor alterations in the machine. Sugarcane planters seem to have a bright future and an important role in managing sustainable sugarcane production.

Mechanisation of Interculture and Earthingup Operation

About 4-5 interculture operations are quite common in sugarcane and each operation, if carried out manually, requires 15-20 man days/hectare. Tractor drawn cultivators can effectively be used by adjusting the spacing between the tynes as per conventional row spacing. Tractor drawn earthingup devices have also been developed and can be used effectively untill the plant growth does not hamper with the operation. Engine operated power weeders have also been developed for interculture purposes and can be used by the small cane growers.

Mechanisation of Sugarcane Harvesting

Gradually, timely harvesting of sugarcane at affordable cost is becoming a problem particularly in the tropical region. Managing a big fleet of labourers to give timely supply of cane to the mill is not easy any more. Under these circumstances, the sugar industry is looking for alternate mechanical means for harvesting the sugarcane crop at a reasonable wage rate.

In subtropical India, normally, sugarcane harvesting is free of cost in exchange for green tops and, as such, in near future the problem does not appear to be of a major concern. Efforts may be made to develop efficient hand tools for harvesting sugarcane crop so as to improve the quality of cutting and output/man/day with reduced energy input. Partial mechanisation seems to be a suitable answer for the time being particularly in the subtropical belt.

The available sugarcane harvesting systems can be grouped into:

1. Whole stalk linear windrowing
2. Whole stalk transverse windrowing
3. Whole stalk bundling machine
4. Hand controlled self propelled harvester
5. Chopper type cane harvesters.

Whole Stalk Harvesting

a. Manual Cutting

Proper manual cutting results in minimum loss of cane and the highest quality of the product. The productivity of manual cutters can be improved by giving them proper training, the use of correct cane knife, balanced diet, etc.

Fig. 2 shows manual harvesting of sugarcane in India.

b. Mechanical Cutting

Cane cutting attachments for agricultural tractors have been developed. This harvesting system still requires an appreciable amount of labour as cane stalks have to be detrashed, detopped and bundled and, subsequently, loaded into the wagons. Heavy recumbent cane is difficult to handle with these aids and dry leaves are removed only partially.

c. Whole Cane Harvester

More advanced machines are now available (CAMECO Harvester),

Fig. 1 IISR sugarcane cutter planter in operation

Fig. 2 Manual harvesting of sugarcane - a common sence on Indian farms

Fig. 3 IISR sugarcane windrower harvester in operation

which cut the cane stalk at the base and detop. The cut canes are placed in a single windrow from 4-6 rows. Subsequently, depending upon the availability of the labour, mechanical loaders/manual loaders can be employed for loading purposes. Eight to ten percent of the trash remains in the harvested cane. At a later stage, use of separate detrashers can be explored for minimizing the level of trash in the cane to be supplied to the mills. **Fig. 3** shows the IISR model of sugarcane windrower harvester in operation.

d. Chopper Type Harvester

With the increasing labour problem, pace of mechanised harvesting may be accelerated and imported models of chopper harvesters may be tried and introduced with the modifications suiting to local needs. Efforts have been initiated in parts of Tamil Nadu and Maharashtra where imported models of chopper harvesters have been tried on a limited scale. There is no doubt that handling of even a heavy tonnage recumbent crop can easily be handled and out put of 25-30 tonnes/field/hour can be achieved but trash percentage in the billets (7-8 %), small size of the fields, high initial cost of the machine, wider row spacing required (1.5 m) and sophisticated systems are the major constraints in successful adoption of these imported machines under Indian conditions. Delays from harvest to crush further aggravate the problem. Efforts are being made to develop an indigenous model of sugarcane harvester suited to Indian conditions. **Fig. 4** shows a modern combine sugarcane Chopper harvester during trials in India.

Fig. 6 Equipment for in-situ incorporation of sugarcane trash in operation

Trash Management

Handling of trash is another area requiring attention of the researchers in the present scenario where manual harvesting is in vogue.

Research conducted at other places, has indicated that application of vinasse and filter cake to the residue, promotes decomposition of the dry matter so that resulting compost can be harrowed into the soil within 30 days. Nutrients derived from the trash may include 32 kg N/ha, 6 kg P_2O_5/ha and 30 kg K_2O/ha. At IISR, an equipment for in-situ incorporation of sugarcane trash has been developed and is under extensive field trials. The equipment is mounted with the tractor and is operated by PTO shaft. The system picks up trash, passes it on to the chopping unit where trash is chopped into small bits which ultimately gets mixed up and buried under the soil with the help of a pair of discs provided at the rear end. Provision has also been made for applying chemical/other substances for quick decomposition of trash.

Burning of trash may be avoided in select areas where insect pests are not a major problem and this precious material can be put to effective use either as a mulch to conserve soil moisture or as organic matter, thereby improving the soil health. **Figs. 5** and **6** show the newly developed equipment.

Machinery for Ratoon Management

Ratoons play an important role in improving overall economics of sugarcane production. A multipurpose machine has been developed which takes care of the important cultural operations required to be performed for raising a good ratoon crop.

The machine takes care of:

1. Stubble shaving
2. Off barring or dismantling of ridges
3. Interculture operation
4. Fertilizer application.

Proper use of this machine will lead to improved ratoon productivity. **Fig. 7** shows the equipment in operation.

Future Strategy for Mechanisation of Sugarcane Cultivation

A number of useful machines for sugarcane culture have been devel-

(continued on page59)

Fig. 4 Modern sugarcane chopper harvester suring trials in India

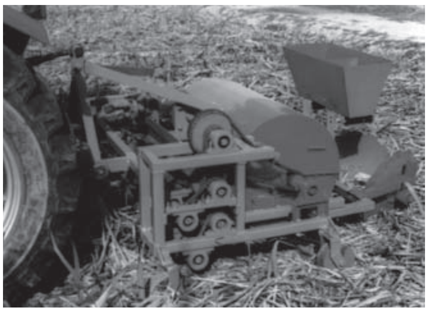

Fig. 5 IISR trash handling equipment

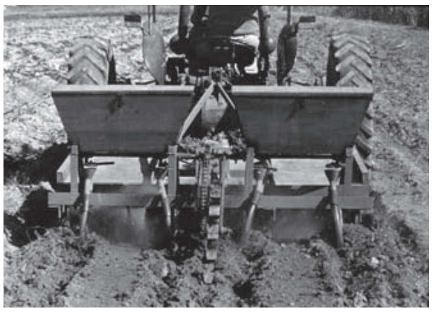

Fig. 7 IISR multipurpose equipment for sugarcane ratoon in operation

Performance Efficiency of an Active Evaporative Cooling System for the Storage of Fruits and Vegetables in a Semi Arid Environment

by

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Abstract

An active evaporative cooler was constructed with a local sponge material as the pad-end and tested under varied parameters of: water flow rate (W_R), 3.5 L/min, 4.5 L/min and 5 L/min); pad thickness (P_T), 30 mm, 60 mm and 90 mm); and air velocity (A_V), 0.8 m/s, 1.3 m/s, 1.8 m/s, 2.3 m/s and 2.8 m/s. Under the settings of W_R (4.5 L/min), P_T (60 mm) and A_V (2.3 m/s), the highest saturation efficiency of 84.6 % was obtained at a temperature of 21.5 º C and 85 % relative humidity at the pad-end, from ambient conditions of 38 ºC and 15 %, temperature and relative humidity, respectively. At this condition, the cooler was evaluated for the storage of Mango (Mangifera indica), banana (Musa sapientum) and tomato (Lycopersicum esculentum). The products were stored in the cooler at a temperature of 22.5 ºC and relative humidity of 80 % and, were found to be in good physical conditions after 18 days for mango and 14 days each for banana and tomato, as compared to only 7 days for those stored under ambient conditions of 38 ºC and 15 %, temperature and relative humidity, respectively.

Introduction

Fresh fruits and vegetables have flavour, aroma, and colour and are essential for normal health (Duckworth, 1979). They are sources of dietary fibre, vitamins and minerals (Pyke, 1986; Fox and Cameron, 1978). For maximum usefulness and optimum nutritive value, fruits and vegetables should therefore, be consumed in a fresh form. However, fresh fruits and vegetables deteriorate easily when stored under ambient condition, mainly due to physiological and microbial activities, which are accelerated at high temperature and low relative humidity of the storage environment (Anon, 1978; Wills et al, 1981).

Post harvest losses of fruits and vegetables can be greatly minimized by storing them at low temperature and high relative humidity (Hall, 1981; Wills et al, 1981; FAO/SIDA, 1986). This storage condition can be achieved through techniques such as refrigeration and ice-bank cooling, which are very expensive to acquire and maintain in developing countries.

FAO (1983) has advocated a storage system based on the principle of evaporative cooling for the storage of fruits and vegetables, which is simple, relatively efficient and of low running cost. Evaporative cooling occurs when air that is not saturated is blown across a wet surface. Heat in the air is utilized to evaporate the water, resulting in a drop in the air temperature and increase in relative humidity (Harper, 1976; Henderson and Perry, 1976; Kays, 1979; FAO/SIDA, 1986; Brooker et al, 1992).

According to Rusten (1985), evaporative cooling is generally more efficient where air temperatures are high, relative humidity very low water is available for the purpose and air movement is conducive. In Northern Nigeria, a semi arid region, these conditions are typical.

An active evaporative cooling system consists of a pad (moist material), fan, storage cabin and water pump. Apart from the general requirements for the efficient operation of an evaporative cooling system, the efficiency of an active evaporative cooler depends on the rate and amount of evaporation of water from the pad. This is dependent upon the air velocity through the pad, pad thickness and the degree of saturation of the pad, which is a function of the water flow rate wetting the pad (Hanan et al, 1978; Wiersma, 1983; Thakur and Dhingra, 1983).

The objective of this study was to evaluate the performance of an active evaporative cooler in a semi arid environment for the storage of fruits and vegetables under the best combination levels of the parameters required for the efficient operation of the cooler.

Materials and Methods

An active evaporative cooler as in Dzivama et al (1999) was constructed and tested under varied levels of water flow rate, pad thickness and air velocity. The cooler consisted of a pad-end 1000 mm x 1500 mm made of local stem sponge, a storage cabin 1000 mm x 1300 mm x 1500 mm made of plywood and internally insulated with 50 mm polystyrene, a 20 watt suction fan and a 150 watt water pump with a discharge capacity of 7.5 L/min. The complete schematic diagram of the cooler is presented in **Fig. 1**.

To determine the best operating

Fig. 1 Schematic diagram of the evaporative cooler

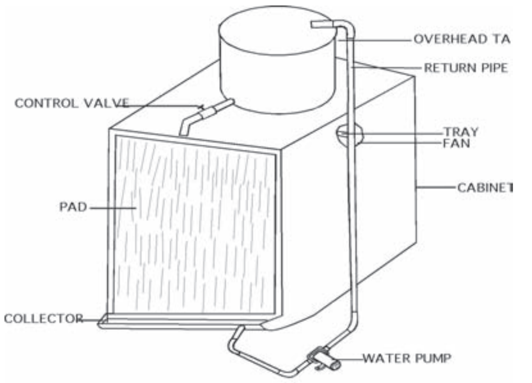


Fig. 2a Saturation efficiency for the various W_R and A_V

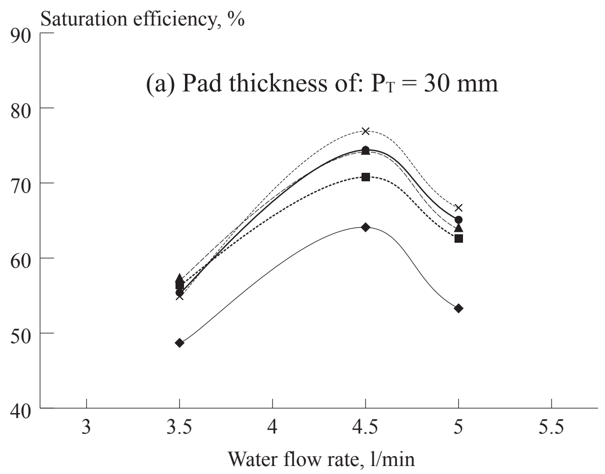
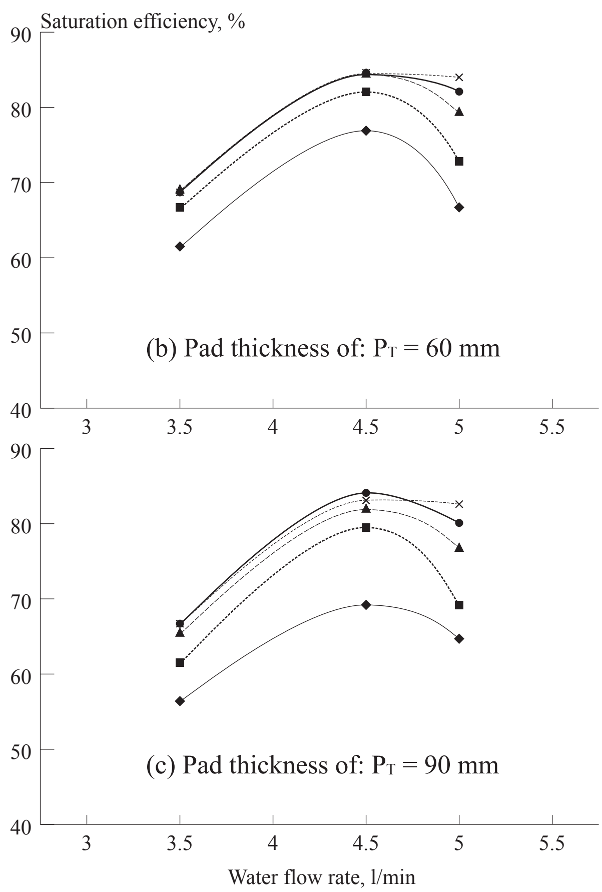


Fig. 2b, c Saturation efficiency for the various W_R and A_V



A_V = 0.8 m/s, A_V = 1.3 m/s, A_V = 1.8 m/s, A_V = 2.3 m/s, A_V = 2.8 m/s combinations of parameters that will give the highest saturation efficiency, the cooler was tested at three levels of water flow rate, W_R (3.5 L/min, 4.5 L/min and 5 L/min), three levels of pad thickness, P_T (30 mm, 60 mm and 90 mm) and five levels of air velocity, A_V (0.8 m/s, 1.3 m/s, 1.8 m/s, 2.3 m/s and 2.8 m/s). The choice of these levels of the parameters was based on available information (Thakur and Dhingra, 1983; FAO/SIDA, 1986; Walker and Hellickson, 1983; Brooker et al, 1992) and factors related to the construction properties of the local sponge into a pad for use in the cooler. The temperature and relative humidity were measured by hygrometer (a Rotroni hygroskop GT-L hygrometer) at 10 min. interval until a steady state condition was reached.

Three replicates of the experiments for each experimental arrangement were carried out and the average temperature and relative humidity were calculated.

The saturation efficiency (S_E) of the cooler was calculated as in (Harris, 1987)

$$S_E = \frac{T_1(db) - T_2(db)}{T_1(db) - T_1(wb)} \times 100$$

Where

T_1 (db) = dry bulb outdoor temperature, ºC

T_2 (db) = dry bulb cooler temperature, ºC

T_1 (wb) = wet bulb outdoor temperature, ºC

The performance efficiency of the cooler for the storage of mango (Mangifera indica), banana (Musa sapientum) and tomato (Lypersicu esculentum) was evaluated at the best operating condition established. One hundred and thirty kilogram (130 kg) each of the products at mature green stage were stored both in the cooler and under ambient condition of 38 ºC temperature and 15 % relative humidity.

Quality assessment of the produce stored inside the cooler compared to those stored at the ambient condition was carried out. This quality assessment of the products included changes in: firmness, physiological weight, titratable acidity/pH and total soluble solute. The assessment for the chemical changes was based on the AOAC (1984) methods.

Fruit Firmness Change

Firmness was determined after every three days from the commencement of the storage to the fully yellow/red rotten stage using a cone penetrometer. The penetrometer has a cone angle of 60º and total weight of 570 g. The penetrometer was placed on the fruit and allowed to penetrate the fruit under its force of gravity for 5 min. The depth of penetration was measured and calculated as the depth of penetration per min.

Physiological Weight Loss

Ten pieces each of fruit and vegetable were chosen and marked for the weight assessment change. The pieces were weighed on the first day of storage and then after every 3 days until the end of the experiment. The average change in weight of the pieces was determined.

Total Titratable Acidity and pH

Three samples each of the fruit and vegetables were randomly chosen for titratable acid and pH determination. The samples were blended in an electric blender. The pH of the blended samples was determined using a pH meter.

To determine the total titratable acid (TA), 5 mL of the solution of each fruit and vegetable was taken and titrated against a standard 0.1 N NaOH solution using 3 drops of phenolphthalein as an indicator.

Fig. 3 Firmness of fruits stored in the cooler at a temperature of 22.5 ºC and a relative humidity of 85 % compared to those stored under ambient conditions of temperature (38 ºC) and relative humidity (15 %)

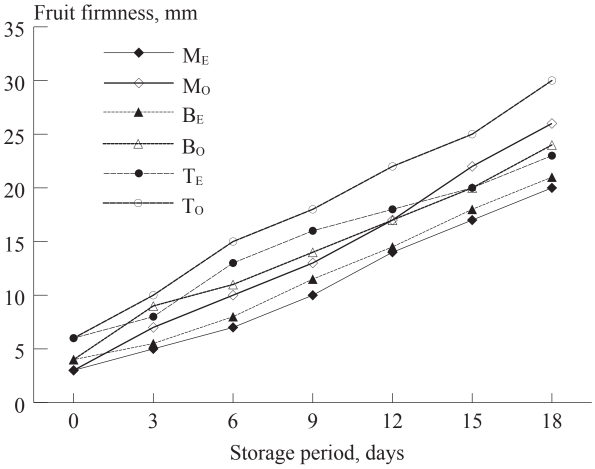
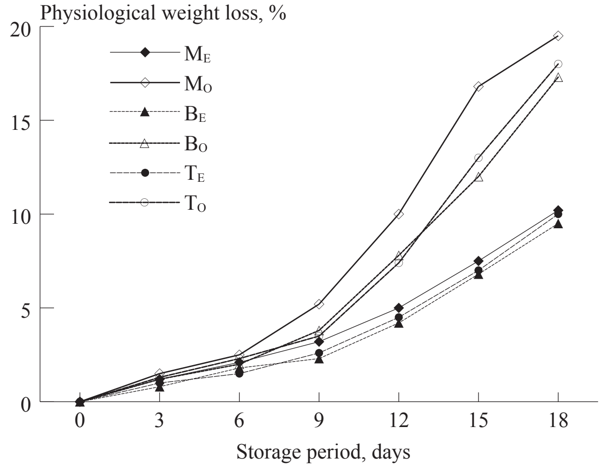


Fig. 4 Physiological weight loss of fruits stored in the cooler at a temperature of 22.5 ºC and a relative humidity of 85 % compared to those stored in the ambient conditions of a temperature (38 ºC) and relative humidity (15 %)



M_E = mango stored in the cooler, M_O = mango stored under ambient condition, B_E = banana stored in the cooler, B_O = banana stored under ambient condition, T_E = tomato stored in the cooler, T_O = tomato stored under ambient condition,

The titration was stopped at a pH of 8.3 when a faint pink colour was noticed. The volume of Na0H used was recorded and the TA was calculated as:

% TA = volume of NaOH x normality of NaOH x 6.706 x 10^{-3} x 100/volume of sample.

Where

6.706 x 10^{-3} = milligram equivalent of malic acid.

Total Soluble Solids (ºBrix)

Total soluble solids were determined using the Bellingham and Starley refractometer No. A85172. From the blended samples, two drops were taken using a glass rod, and placed on the refractometer, and the value of the total soluble solids in ºBrix was read directly from the scale.

On the first day of the experiment, one quality analysis was carried out for each of the products. Three samples of the products were used for each quality assessment, and the experiments were done in three replicates. Subsequent analyses were carried out at three day intervals until visible spoilage of the products was noticed. The maximum shelf life of each of the products stored in the cooler compared to those under the ambient conditions were also recorded.

Results and Discussion

Saturation Efficiency

The result of the saturation efficiency of the cooler is presented in **Fig. 2**. Generally the saturation efficiency increased with increase in the parameters until optimum levels were reached: The optimum levels of W_R, P_T and A_V obtained were: 4.5 L/min, 60mm and 2.3 m/s., respectively, beyond which points the efficiency declined (Graph **a**, **b**, and **c**). The performance efficiency at this optimum condition was 84.6 % at the pad end. This could be explained by the fact that, at P_T of 60 mm and W_R of 4.5 L/min, the pad was sufficiently moist, and at the same time, there was enough pore space within the pad for the air movement. Furthermore, at A_V of 2.3 m/s, the velocity was fairly high, and, because of the fairly large pad thickness of 60 mm, the air-water contact time was increased. This allowed for an increase in heat and mass transfer, thus, an increase in efficiency.

It is possible to obtain saturation efficiency in the cooler approaching 85 % to 100 % for a region with very low outdoor relative humidity and high temperature (Rusten, 1985). Thus, the 84.6 % performance efficiency obtained in the cooler, in Maiduguri with an average ambient condition of 38 ºC and a wet bulb depression of 18.5 ºC compared to 21.5 ºC for the evaporative cooler is considered efficient.

Quality Changes of the Products

Fruit Firmness

The results for the fruit firmness change stored under both the evaporative cooler and ambient conditions are presented in **Fig. 3**. Fruit firmness changes are more under ambient conditions, especially with a storage period in excess of 10 days. Fruit firmness change, which is a biochemical change, occurs during the ripening process. Fruit ripening is accelerated at high temperatures (Wills et al, 1981). This explains the significant change in fruit firmness for the fruits stored under ambient conditions, which is at higher temperatures than that of the evaporative cooler.

Fig. 5 pH of fruits stored in the cooler at a temperature of 21.5 ºC and relative humidity of 85 % compared to those stored in the ambient conditions of 38 ºC and 15 ºC temperature and relative humidity respectively

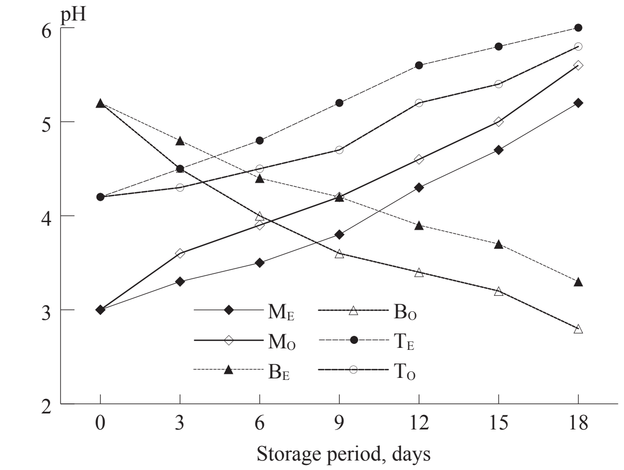
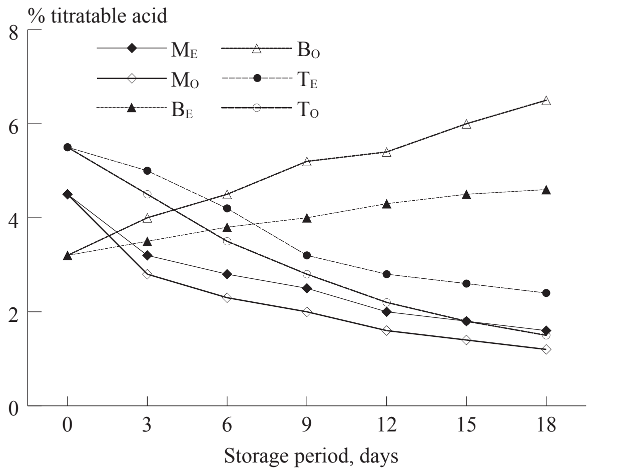


Fig. 6 Percentage titritable acid of fruits stored in the cooler at a temperature of 21.5 ºC and a relative humidity of 85 % compared to those stored in the ambient conditions of 38 º C and 15 % temperature and relative humidity respectively



M_E = mango stored in the cooler, M_O = mango stored under ambient condition, B_E = banana stored in the cooler, B_O = banana stored under ambient condition, T_E = tomato stored in the cooler, T_O = tomato stored under ambient condition,

Physiological Weight Loss

The results of the physiological loss in weight for the produce stored under both, ambient condition and the evaporative cooler are presented in **Fig. 4**. Fruits and vegetables stored in the cooler had lower physiological weight loss compared to those stored in the ambient conditions. The trend in the physiological weight loss in the cooler was similar for all the produce without any sharp increase in weight loss. Under ambient conditions, the produce showed sharp increase in weight loss after 8 days of storage compared to those stored in the evaporative cooler.

Physiological loss in weight of fruit and vegetables is due to both evaporation of water and respiratory losses. Evaporation of water from the produce and the respiratory losses are dependent on the temperature and relative humidity of the air surrounding the produce. Low temperature reduces the respiratory activity and high relative humidity reduces the rate of evaporation from the produce.

The slight losses in weight of the fruit and vegetables recorded in the evaporative cooler with an average storage condition of 21 ºC and 84.6 % temperature and relative humidity, respectively could therefore be attributed to the low temperature and high relative humidity in the evaporative cooler. High loss in weight for the ambient storage could also be attributed to the high temperature (38 ºC) and low relative humidity (15 %).

Titratable Acidity and pH

The results of the change in titratable acid and pH for the fruits and vegetables stored in the cooler compared to the ones stored under ambient condition are presented in **Figs. 5** and **6** respectively. The results show that, there was a general reduction in the acidity and increase in pH of the produce, except in the case of banana. For banana, pH declined with storage. The decline was greater for banana stored under ambient conditions compared to those stored in the evaporative cooler. For mango and tomato, pH increased with storage and the increase was less in the produce stored in the cooler compared to those stored under ambient conditions.

Ripening process brings about change in pH of fruit. During ripening, the acids are converted into sugars; hence increase in pH, except in banana, where the highest level is attained at the fully ripened stage (Wills et al, 1981).

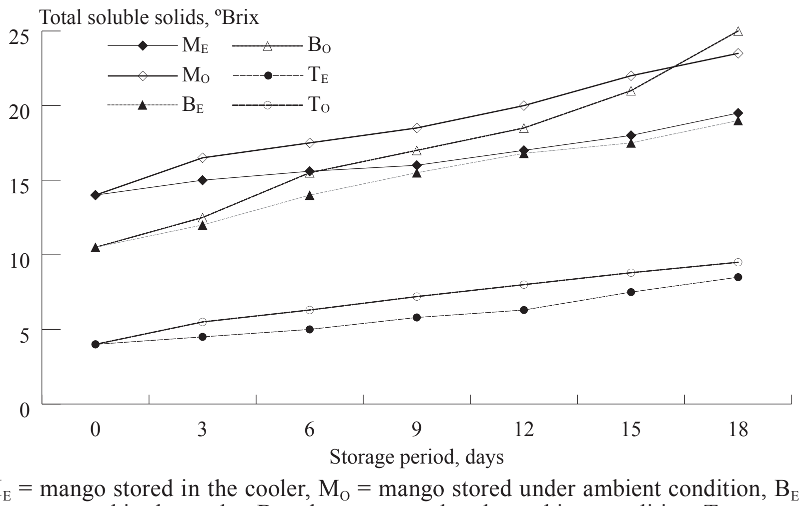
Changes in acidity and pH are generally related, but there is no clear relationship. Acids are considered as reserve source of energy for the fruit. At greater metabolic activity, they are expected to decline, since the fruits use them for metabolic activity (Wills et al, 1981). This explains the slight change in results of the produce stored in the evaporative cooler that were at low temperatures, which slows down the metabolic activity. The greater change in titratable acid obtained for the produce stored under the ambient condition could therefore be attributed to the high temperature of the ambient condition, which accelerated the metabolic activity.

Total Soluble Solids (ºBrix)

The results of the changes in the total soluble solids (ºBrix) of the produce stored in both the evaporative cooler and under ambient conditions are shown in **Fig. 7**. Total soluble solids increased slightly with storage. The produce stored in the evaporative cooler had a lower increases in soluble solids compared to the produce stored under ambient conditions. The slight variation of the total soluble solids for the produce stored in the evaporative cooler could be attributed again to the low temperature and high relative humidity in the evaporative cooler. No significant change in total soluble solids has been reported in all varieties of mango, ripened at 16 to 28 ºC (Vasquez-Salinas and Lakshminarayana, 1985).

The possible explanation in the slight changes in the total soluble solids may be related to the physiological loss in weight of produce. The physiological weight is slightly affected at low temperature and high relative humidity, hence less change in total soluble solids. This explains the relatively significant variation in the total soluble solids

Fig. 7 Total soluble solids (ºBrix) of fruits stored in the cooler at a temperature of 21.5 ºC and relative humidity of 85 % compared to those stored in the ambient conditions of 38 ºC temperature and 15 % relative humidity



M_E = mango stored in the cooler, M_O = mango stored under ambient condition, B_E = banana stored in the cooler, B_O = banana stored under ambient condition, T_E = tomato stored in the cooler, T_O = tomato stored under ambient condition,

for those products stored under the ambient condition, which are at high temperature and low relative humidity of 38 ºC and 15 %, respectively.

Conclusion

From this investigation, the following conclusions could be made:

1. Fruits and vegetables deteriorate easily when stored under ambient conditions, mainly due physiological and microbial activities, which are accelerated at high temperature and low relative humidity and the spoilage can be greatly minimize by lowering temperature and increasing relative humidity of the storage environment.This evaporative cooling system offers an inexpensive approach to achieve this.
2. It is evident that in an evaporative cooler, fruits and vegetables could be stored for a longer period without appreciable damage than those stored under ambient condition.
3. Further investigations are recommended on the construction materials and orientation of the cooling chamber and the water application system to see if there will be an increase in the efficiency of the cooler for the storage of fruits and vegetables.

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Inspection of Watermelon Maturity by Testing Transmitting Velocity of Acoustic Wave

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Abstract

Fourteen "QiLing" watermelons were tested with a system that consisted of an electromagnet, a striking ball, a sensor with two microphones at a distance of 6 cm, a set of signal processing circuits, a computer with a data acquisition board, and a set of software. The test results showed that it is possible to test sugar content of watermelon by testing acoustic wave transmitting velocity. The correlation coefficient of the model was 0.81208 when the test position is at the S position. The model is dependent on testing position, inner defect and growth status of the sample. The coefficients and the correlation coefficient are not sensitive to inner defect for testing at the pedicel. But, for testing at the peduncle, the coefficients are sensitive, while the correlation coefficient is not. The model is very sensitive to the growth status. A good result is expected when the testing is at the S position.

Introduction

Some acoustical properties of fruits can infer the quality of the fruits. Delwiche et al (1989 and 1996) and Jarén et al (1992) evaluated firmness of fruits with impact techniques. McGlone et al (1993), Younce et al (1995) detected firmness by dropping the fruit on a force sensor and measuring the force. Chen et al (1996) developed a low-mass, impact-type firmness sensor for high-speed, on-line sorting of fruits. Pearson (2001) developed an acoustical sorting system to separate pistachio nuts with closed shells from those with open shells. The classification accuracy of this system was approximately 97 %. Terasaki et al (2001) studied the response of apples placed on a vibrating table with sine wave vibrations. Luz et al (2001) studied the acoustical characteristics of four soybean varieties. Mizrach et al (2001) suggested a system based on an ultrasonic energy absorbance method for nondestructive measurements of Cox apples.

Very few studied have been made on the maturity of watermelon in the past. In the maturating of watermelon, the water content and the texture will change. Such change may result in the change of transmission velocity of the acoustic wave, which may be an indication of the quality of the watermelon. Since sugar content is an index of maturity, the relationship between sugar content and velocity of the acoustic wave was setup to evaluate the quality of the watermelon.

Materials and Methods

Materials

Fourteen "QiLing" watermelons, the primary watermelon variety in Zhejiang province, China, were tested. The test positions are shown in **Fig. 1**.

Test System

The testing was conducted with the system shown in **Fig. 2** and was based on acoustic properties. The system consisted of an electromagnet, a striking ball, a sensor with two microphones at a distance of

Acknowlegements: The authors gratefully acknowledge the financial support provided by the Ministry of Education of China and Zhejiang Provincial Natural Science Foundation (No. 301267).

0.06 m, a signal processing circuit, a computer with a data acquisition board, and software. The sound wave was produced by striking with a steel ball wrapped in rubber, was sensed by two microphones, and then transformed into an electric signal. The signal was amplified and filtered by a processing circuit which passes frequencies from 3 to 3000 Hz. The processed signal was sampled at a rate of 10 kHz with a PCL-1800 data acquisition board (Advantech Co., Ltd.).

The sensor was put on the watermelon, and then the power to the electromagnet was turned off by the computer. The striking ball was free to strike the sample, and a sound wave produced. The sound wave was sensed by microphones and translated into an electric signal. The signal was amplified, filtered, and then translated into a digital signal by the data acquisition board. The distance between the two microphones resulted in a time difference of the acoustic wave transmittance that permitted a calculation of the transmitting velocity, which was a function of sugar content of the tested watermelon.

Test Procedure

The test was conducted as follows:

1. A watermelon was placed on the system. An acoustic wave was introduced, and the wave was collected by sensors and processed. The processed signal was sampled and stored in the computer. Five points on the surface of the sample were tested as shown in **Fig. 1**.
2. The sample was cut. A sugar content test was made at the five points with a sugar content meter (WYT-4).
3. The sugar content data were put into the computer.
4. The data were analyzed with a MATLAB program.
5. A model was setup to show the relationship between acoustic character and sugar content.

Data Processing

Data processing was done with a MATLAB program as shown in **Fig. 3**. A digital filter model was designed for noise filtering, and a self-correlation model was programmed to calculate the transmission velocity of the sound wave. At the end, a statistical analysis was made to establish a model between sugar content of the watermelon and transmission velocity with a third degree POLYFIT function.

Results and Analysis

The relationship between acoustic wave transmitting velocity and sugar content at a test point was described by equation 1, which corresponded to the POLYFIT function of MATLAB.

$$V = a_0 s_c^3 + a_1 s_c^2 + a_2 s_c + a_3, \quad ....(1)$$

where

V = transmitting velocity at a test point,

S_c = sugar content at a test point, and a_0, a_1, a_2, a_3 are coefficients

Effect of Test Positions

The relationship between acoustic wave transmitting velocity at position S and sugar content is shown in **Fig. 4**, and the result at position Z is shown in **Fig. 5**. The models of both are shown in equations 2 and 3. The model differed for the two test positions, as well as the correlation coefficient of the model. The R^2 of the model at position S is higher than at position Z. This means that a better result is expect when the test is made at the S position.

The model at the S position was (**Fig. 1**):

$$V = -5.5175 s_c^3 + 133.15 s_c^2 - 1064 s_c + 2833.4 \quad ....(2)$$

$R^2 = 0.81208$

where

R^2 is the correlation coefficient of the model.

The model at the Z position was (**Fig. 1**):

$$V = 1.6073 s_c^3 - 40.4672 s_c^2 + 336.7457 s_c - 904.9022 \quad ....(3)$$

$R^2 = 0.64902$.

Effect of the Inner Defects

The relationship between acoustic

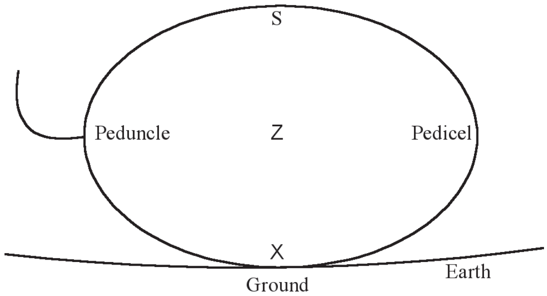


Fig. 1 Test positions and the names

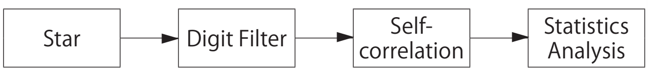


Fig. 3 Data processing

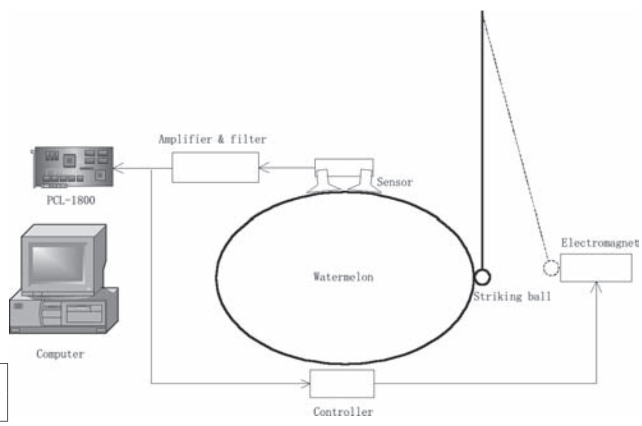


Fig. 2 Schematic diagram of the test-bed

wave transmitting velocity at the pedicel and sugar content is shown in **Fig. 6(a)**. On the left, the data of watermelon without defect are included and, on the right, the data are removed. The models for these are shown in equations 4 and 5. **Fig. 6(b)** and equations 6 and 7 are for the test position at the peduncle. The coefficients and the correlation coefficient are not sensitive to inner defect when the test position is at the pedicel. But, for test position at the peduncle, the coefficients are sensitive to inner defects, while the correlation coefficient is less.

When the test position was at the pedicel position (**Fig. 1**) and the data of the watermelon with inner defects was included, the model was as follows:

$V = -4.7512s_c^3 + 114.63s_c^2 - 900.67s_c + 2340.2$ ....(4)

$R^2 = 0.6052$.

When the test position was at the pedicel position (**Fig. 1**) and the data of the watermelon with inner defects was removed, the model was as follows:

$V = -6.2305s_c^3 + 143.66s_c^2 - 1088.2s_c + 2739$ ....(5)

$R^2 = 0.6327$.

When the test position was at the peduncle position (**Fig.1**) and the data of the watermelon with inner defects was included, the model was as follows:

$V = 0.89043s_c^3 - 19.507s_c^2 + 132.05s_c - 229.46$ ....(6)

$R^2 = 0.7473$.

When the test position was at the peduncle position (**Fig. 1**) and the data of the watermelon with inner defects was removed, the model was as follows:

$V = -8.7162s_c^3 + 208.18s_c^2 - 1663.1s_c + 4478.9$ ....(7)

$R^2 = 0.7605$.

Effect of the Grown Status

When the data of the pedicel sample which was close to ground was included:

$V = -4.7512s_c^3 + 114.63s_c^2 - 900.67s_c + 2340.2$ ....(8)

$R^2 = 0.6052$.

When the data of the pedicel sample which was close to ground was removed:

$V = 4.0547s_c^3 -81.847s_c^2 + 547.34s_c - 1184.4$ ....(9)

$R^2 = 0.9468$.

The effect of growth status is shown in **Fig. 7**. On the right the data of the pedicel sample which was close to ground was removed. The model for each is shown in equations 8 and 9. The correlation coefficient increased from 0.9468 to 0.6052 by removing the data of the pedicel sample which was close to ground during growing, which infered that the model was very sensitive to the growth status.

Conclusions

1. It is possible to test sugar content of watermelon by acoustic wave transmitting velocity for the correlation coefficient of the model which is 0.81208 when the test position was at the S position (**Fig. 1**).
2. The test result is also dependent on test position, inner defect and growth status of the sample. The correlation coefficient of the model at the S testing position was 0.81208. The coefficients and the correlation coefficient were not sensitive to inner defects of the sample when the testing is at the pedicel. But, for testing at peduncle,

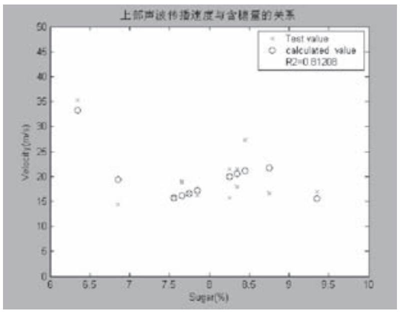


Fig. 4 Relationship between acoustic wave transmitting velocity at S position and sugar content

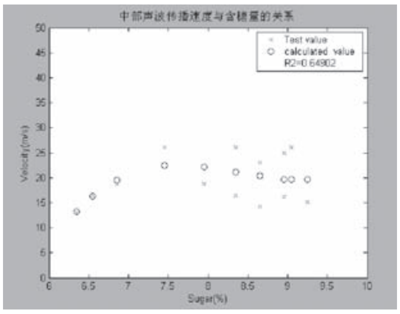
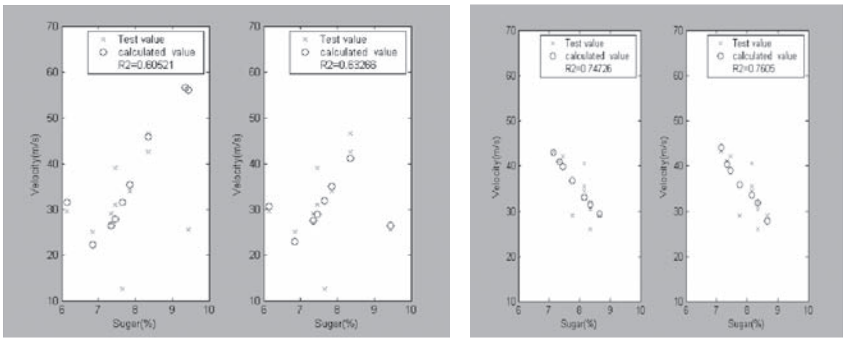


Fig. 5 Relationship between acoustic wave transmitting velocity at Z position and sugar content

Without defect With defects Without defect With defects



(a) Testing position at pedicel (b) Testing position at peduncle

Fig. 6 Effect of defects on the test results

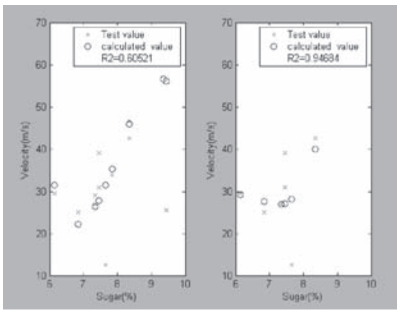


Fig. 7 Effect on the growing status on test result at pedicel

the coefficients were sensitive to inner defects while the correlation coefficient was not. The model was very sensitive to the growth status.

3. Best results were expected when the testing was at the S position.

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Development and Testing of a Chilli Seed Extractor

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Abstract

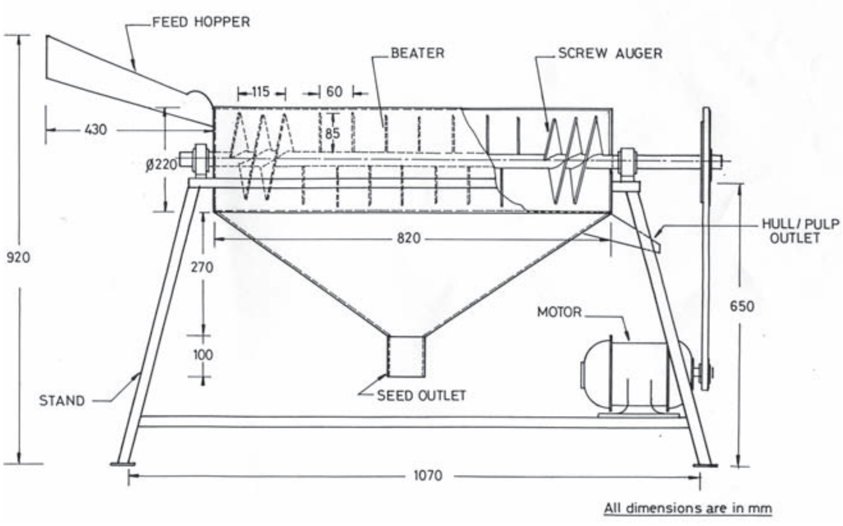
A seed extraction machine for chillies has been developed to overcome human drudgery by manual seed extraction process. The unit consisted of a beater for extraction of seeds and a perforated concave sieve for separation of seeds. It was operated by a one hp single-phase electric motor. Trials were conducted at various peripheral speeds and extraction efficiency and germination were determined. The test results of the machine showed that a maximum seed extraction efficiency of 94 % and the germination of 92 % were attained at 480 m/min peripheral speeds.

Introduction

Chillies are dried ripe fruits of the species of genus capsicum. Chillies are also called red peppers or capsicum and constitute an important well-known commercial crop used as condiment and culinary supplement. India is the largest producer of chillies in the world, accounting for over 45 % of the total area under cultivation (Pruthi, 1993). The seed from dried chillies are extracted and used for crop propagation. The extraction of seed practiced with labour is highly time consuming and costly besides involving drudgery. The chilly seed extraction machine has been developed and evaluated to overcome the drudgery due to the pungent nature of the chillies and to increase the productivity of seed processing industries.

The seed extraction machine, consisting of a fixed cylindrical casing with sieve and rotating shaft that had cutting, crushing and conveying blades, was used for extracting seeds from vegetables (Mohanty, 1997). The capacity of the machine was 210 kg/h for tomatoes at 370

Fig. 1 Chilli Seed Extractor



rpm with an average seed extraction efficiency of 84.7 %. Germination percentage of the seed was 82.8 % without any visible damaged seeds.

The manually operated seed extractor with a rotary hollow metallic cylinder with corrugations and helix fixed on its surface, and with a stationary expanded metal concave and feed hopper was used for tomato seed extraction (Karla, 1983).

A mechanical seed extraction machine, consisting of a rotary shaft with beaters rotating inside a horizontal fixed drum, was used for tomato fruits (Nicholos, 1971).

The machine has a seed-separating screen holding frame, seed and pulp outlet and water pipe attachment. The capacity of the machine was 2,000 kg/h of tomatoes.

Materials and Methods

The Chilli seed extraction machine consisted of a feed hopper, beater with auger assembly, concave with cover, stand and electric motor as shown in the **Fig. 1**.

The concave was made of 3 mm thick mild steel with 230 mm depth and 270 mm width and 850 mm length. A cover having the same dimensions was hinged to one edge of the concave assembly for easy opening and closing. A shaft of 20 mm diameter was housed inside the concave and mounted on bearings at both ends. Beaters of 6 mm thickness with 851 mm length and 25 mm width numbering 45 were fixed on the periphery of the shaft at 90 degrees at a predetermined interval in the helical fashion in order to enable forward movement of the material as the seed were extracted by beating action. A screw auger was fixed on both ends of the shaft for the length of 30 cm for easy conveyance of the material. The equipment was powered by 1 hp single-phase electric motor and the power from the motor was transmitted through a belt to beater.

Design of the Shaft:

$$hp = \frac{2\Pi NT}{4500},$$

where

hp is the horse power of motor (0.5 hp),

T is the Torque in kg-m, $T = (T_1 - T_2) R$, and

$T = 0.511$ kg-m, and

N is the speed, rpm (700 rpm).

$T_1 - T_2 = 10.22$ kg ....(1)

where T_1 and T_2 are tensions on the tight side and slack side respectively, kg, and R is the radius of pulley (0.05 m).

Also, $\frac{T_1}{T_2} = e^{\mu\theta}$,

where

μ = coefficient of friction between belt and pulley (0.3), and

θ = angle of lap of belt, radians (Π radians).

$\frac{T_1}{T_2} = 2.57$ ....(2)

Solving Equations (1) and (2), $T_1 = 16.7$ kg and $T_2 = 6.5$ kg.

M = Bending moment acting on shaft, kg-cm, and

$M = (T_1 + T_2 + W) L = 423$ kg cm, where

W= weight of pulley, kg (5 kg), and

L =distance between pulley and bearing, cm (15 cm).

$T_e = \sqrt{(K_m \times M)^2 + (K_t \times T)^2}$, where

K_m = combined shock and fatigue factor for bending for gradually applied load (1.5), and

K_t = combined shock and fatigue factor for torsion for gradually applied load (1.0).

$T_e = 636.55$ kg-cm.

Also, $T_e = \frac{\Pi}{16} f_s d^3$,

where

f_s is the allowable shear stress for mild steel shaft (350 kg/cm^2),

d is the diameter of shaft, cm, and

d = 2.0 cm.

The dried Chilli fruit fed through the feed hopper was subjected to the beating action of the beaters and macerated into pieces without cell rupture and, there by, the seeds were

Fig. 2 Seed extraction efficiency with different peripheral speeds at indicated feed rate

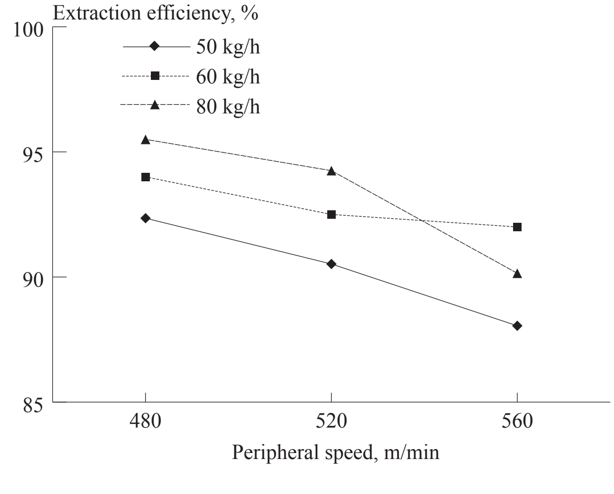
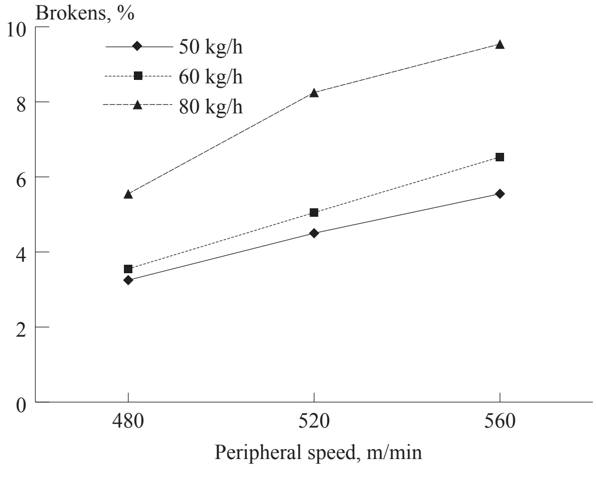


Fig. 3 Percentage of brokens at different peripheral speeds at indicated feed rate



separated from the fruits. The seeds were separated through separate outlet. Seed extraction was carried out for feed rates of 50, 60, and 80 kg/h and peripheral speeds of 480, 520, and 560 m/min of the beater. For calculation of extraction efficiency and percentage of brokens, the following formulae were used:

$$E = \frac{S_1}{S_1 + S_2},$$

where

E = Extraction efficiency (%),

S_1 = Seed coming out of seed outlet, kg,

and

S_2 = Seed coming out of skin outlet, kg.

$$B = \text{Brokens (\%)} = \frac{S_3}{S_1 + S_2},$$

where

S_3 = Broken seeds, kg.

According to the International Standards for seed testing, the top of paper method of germination was adapted for chilli seeds.

Results and Discussion

The results obtained by testing the chill seed extractor for different feed rates and peripheral speeds is illustrated in **Figs. 2** and **3**. The maximum seed extraction efficiency of 95.5 % was obtained at 480 m/min and at a feed rate of 80 kg/h. The minimum brokens of 3.25 % was obtained at 480 m/min and at a feed rate of 50 kg/h. The maximum breakage of 9.54 % was obtained at 560 m/min and at 80 kg/h. This was due to more speed and higher feed rate. Germination of chilli seeds at different feed rates and peripheral speeds are given in **Table 1**.

Table 1 Germination of chilli seeds at different feed rates and peripheral speeds

Feed rate, kg/h	Peripheral speed, m/min	Germination, %
50	480	92.00
	520	91.00
	560	91.00
60	480	91.00
	520	90.00
	560	90.00
80	480	90.00
	520	88.00
	560	85.00

Conclusions

An optimum peripheral speed of 480 m/min and feed rate of 60 kg/h was selected to obtain a maximum extraction efficiency of 94 % with 91 % of germination.

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■■

Design and Fabrication of a Small-Scale Fruit Picker of Adjustable Height

by

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Abstract

A fruit picker with adjustable height for picking tree-top and high-to-reach fruits was designed and fabricated. It can pick high fruits of most common tree varieties and weighs about 5 kg. Limited field trials indicated that the picker satisfactorily controlled the height, yet was made of simple components. Its low cost of about US$ 100 makes it economical for reducing losses due to unpicked fruits and injuries resulting from primitive means of fruit picking. The device is also multi-purpose; it can be used for other small-scale operations including pruning and spraying by fitting the appropriate attachment.

Introduction

Harvesting of fruits is an important operation in agricultural practice. Economics as related to timeliness, competition for labor, and good market prices have pushed for mechanization of almost all agricultural operations. In fruit harvesting, most of the efforts have been devoted to large-scale operations yet with limited success. However, it seems that very little attention has been given to small-scale fruit harvesting including small farms typical of most developing countries, in addition to the all-popular home gardens.

In the developing countries, due to the unavailability of an adequate machine, people have devised and adapted different ways to pick their fruits including hand picking, using a ladder, using a pole to hit the fruits, or using a barrel in an attempt to reach high tree-top fruits. Obviously, these primitive methods are inefficient and, more importantly, inflict substantial loss to fruit quality as well as trees due to inevitable injuries. Moreover, relevant agencies report numerous incidents of injuries to people falling from trees with young children and old people being the most vulnerable. In many cases, the other most common alternative is to leave the unreachable portion of fruits un-picked. Clearly, this latter portion is counted as loss to the farm or garden, which can be substantial to a family's income and when considered at the national level.

The traditional and most popular mechanized means for fruit harvesting is by shaking. This method, in addition to being expensive to most small farmers and home gardeners, has proven to be harmful to trees, especially in regions where trees have shallow root zones as in Jordan. Consequently, this work is an attempt to make available a simple, reasonably priced, flexible and effective piece of equipment that would suit mainly the fruit harvesting of small farms and home gardens.

Materials and Methods

Design Considerations

The basic criteria considered in the design of this device included:

1. Easy to use and handle,
2. Reasonably priced,
3. Convenient in the sense that it is extendable and flexible,
4. Rugged yet light-weight,
5. Operated by DC power (battery) for mobility,
6. Simple modification would be sufficient to convert it into an efficient manual operation,
7. Multi-purpose, and
8. Simple design so that it can be fabricated locally.

The component selection was based on a set of assumptions based on estimation and testing. In selecting the gear-motor assembly, it was assumed that the gear would be subjected to and capable of carrying a load of 50 N, which was estimated from the weight of the moving bar. Thus, the DC motor should provide enough torque to move this load. From the gear specification and desired speed the motor power was calculated.

The pruner (cutter) and cutting cord were chosen based on experimental measurement of the shear force required to cut numerous fruit varieties. A special attachment designed for this purpose (**Fig. 1**) was attached to an Instron Universal Testing Machine (UTM). The stems of several popular fruit varieties were placed in the attachment and the UTM was operated. The results are shown in **Table 1**.

Table 1 Measured values of the maximum shear force required for cutting different fruit stems along with measured stem diameter

Tree type	Max.cutting shear force required, N	Approx. stem diameter, mm
Apples	35.4	4.4
Apricots	36.5	4.9
Citrus	49.2	4.4
Peaches	62.3	4.9
Pears	97.7	5.4

Constructional Details

The major components of the picker include a DC Motor-driven extendable bar enclosed in a main frame bar, an extension mechanism, a cutting mechanism and head with a flexible basket for fruit collection. An overall view and details of the device are shown in **Figs. 2** and **3**. Following is a detailed description of the device parts:

The Main Frame: This is simply a fixed rugged, light-weight U-beam to which other components are attached.

The Extendable Bar: is a bar enclosed within the frame bar with a rack grooved on its upper side. The extendable bar extends inward or outward relative to the frame bar, thus, providing for variable length (height) of the device. It moves over rollers to minimize friction and provide stability.

The Extension Mechanism: consists of a DC motor, which drives a gear that is permanently meshed to the rack of the extendable bar. The motor is hooked to a switch that can reverse the direction of rotation of the motor to allow for the extension or retraction of the extendable bar.

The Cutting Head: includes a spring-loaded cutter (conventional pruner) that is normally open. The rear end of the cutter is connected to the user by a cord that can be pulled against the spring to effect the cutting.

The Collection Basket: the basket is placed under the cutter to receive harvested fruits. It is attached to the frame by a flexible joint so that it receives the harvested fruits. This aspect adds the advantage of minimal or even no fruit damage upon harvesting.

Finally, the picker is equipped with a flexible belt for ease of use and safety. The device was fabricated in the Engineering Workshops at Jordan University of Science and Technology (J.U.S.T.).

Results and Discussion

The picker proved to provide excellent and smooth control over the desirable height to be reached. Assuming an average user height of 1.65 m, the picker can be utilized

Fig. 1 The attachment used with the instron testing machine

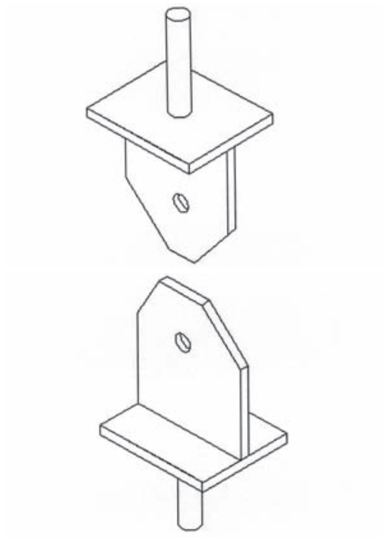
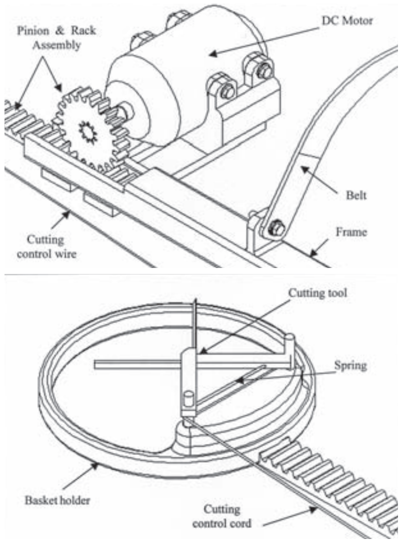


Fig. 2 The detailed view of picker main components



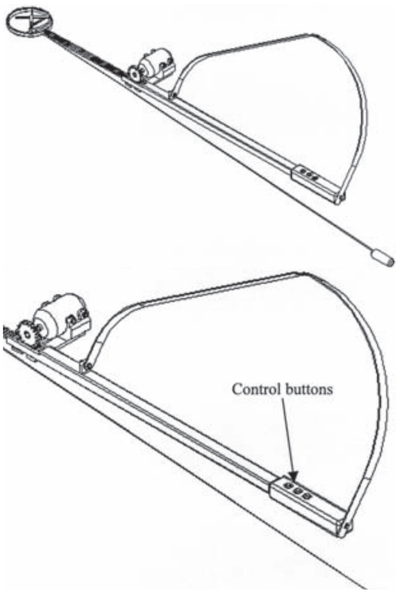
to reach fruits at 4 to 5 meter high. This height includes almost all fruit varieties that are common locally.

According to the experimental tests, the maximum shear force required for cutting the stems of the fruits of most local varieties fell within 100 N. Consequently, the spring of the cutting mechanism was selected with a constant of 4,000 N/m assuming the spring will extend (depress) at least 2.5 cm. Further, the material of the cutting cord was plastic with 5 mm diameter.

Based on the estimated load of 50 N on the gear and a desirable linear speed of 15 cm/sec, the motor should provide 10 watts. Including a safety factor of 2 for stability and to account for friction effects, a motor that secured more than 20 watts was selected. Aluminum with a modulus of elasticity of 71 GPa was selected to make the gear, frame, and rack to satisfy the criteria of rugged and light-weight device. The bending effect of extending the bar was accounted for.

The elementary cost assessment of the technical personnel at the Engineering Workshops at J.U.S.T. indicated that the device costs about US $100, which is within the financial capacity of almost all Jordanian households and farmers.

Fig. 3 Overall view of the picker showing the holding belt and cutting cord



Conclusions and Recommendations

Based on preliminary search and observations, making a fruit picker available with adjustable height fills a gap and fulfills a need. Preliminary tests showed that the device is simple yet effective. Testing also showed that the device performed satisfactorily and will make a suitable tool for cutting almost all losses of tree-top and high-to-reach fruits for the majority of fruit varieties common in Jordan. The cost of the device of about US$ 100 makes it affordable to almost all Jordanian home gardeners and farmers. The device is equipped with a flexible belt for convenience and can also be utilized for pruning and spraying simply by attaching the appropriate tool at the end instead of the cutter. A sound quantitative study of losses suffered by small farmers due to leaving high fruits unpicked in addition to statistics on injuries due to attempts to hand-pick them is needed.

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Non Polluting Pesticide Application Windows for Fruit Orchards in South Central Chile

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Abstract

The objectives of this research work were to establish non polluting pesticide application windows (PAW) for apple, kiwi, red raspberry and blueberry orchards located in the provinces of Linares, Ñuble and BioBio, in south central Chile; and to compare them with the time demands of the annual spraying schedules, with the effective work capacity (EWC) of the foggers available, and with the area of the orchards. In order to achieve these objectives, four long term meteorological data bases including daily rainfall, wind speed, temperature and relative humidity were probabilistically processed. Criteria conforming to an appropriate day for spraying (PAW) each of the orchard species were agreed upon and applied to the daily data bases. The results showed that, in general, there was enough time to carry out these applications, since the annual means go from 15.7 to 19.0 days/month for raspberry and kiwi orchards, respectively. The months with the larger number of appropriate days are March and April, with 22.8 and 22.7 days for kiwi orchards; however, this time is much smaller in January and February (11.5 and 12.9 days for raspberry orchards) due to high temperatures and wind speed and in the months of May (15.0 days for blueberry orchards), June and July (14.5 days and 15.1 days for apple orchards) due to high rainfall and wind speed. The comparison of the application schedules with the magnitude of the PAW shows an adequate relationship. Given the magnitude of the PAW, the EWC (0.36-0.98 ha/h) of the foggers and the area of the majority of the orchards, it can be concluded that the applications can be carried out in a timely way during the existing windows.

Introduction

Fruit production in Chile is a very important agricultural activity giving jobs to thousands of workers and earning millions of dollars in return as export commodities. There are about 235.000 hectares planted with fruit orchards, of which 39,700 hectares are covered by apple trees (Malus domestica)); 7,400 by kiwi

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(Actinidia deliciosa); 5,500 by red raspberry (Rubus idaeus) and 2,000 by blueberry (Vaccinium sp), especially in the south central part of the country (INE, 2002).

To be successfull in fruit exportation it is all important to offer very high quality products, free of any plague or disease. This is achieved through the rational use of pesticides, applying the concepts of Good Agricultural Practices, which are all the actions utilized in the production, processing and transport of foods in order to offer products of high quality, produced with minimum environmental impact, and preventing contamination to workers and consumers (FAO, 1996; ACHS, 1994; SAG, 1996). The spraying of pesticides must be carry out according to the standards set up in the Green Code, which states that the objectives are to protect the consumers of products treated with pesticides, to provide for the safety of all the persons related to the productive process, and to avoid the pollution of the environment, protecting wildlife, soil, water and air (MAFF, 1998).

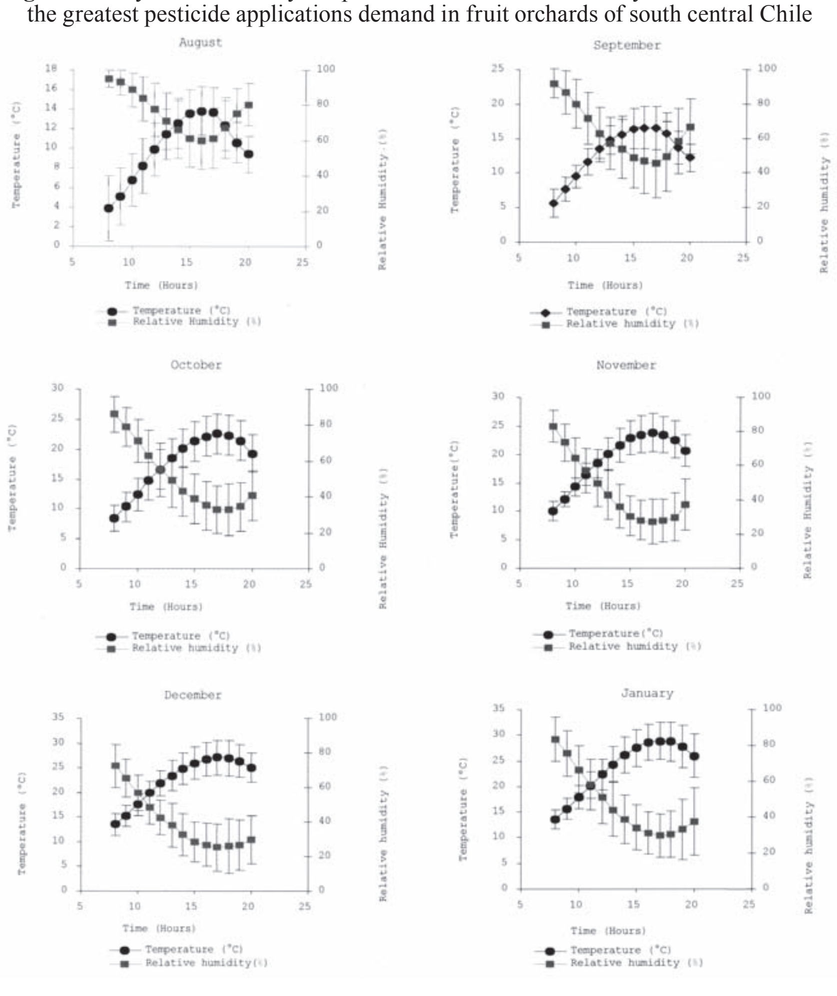
In order to achieve efficacious, non polluting, pesticide applications it is necessary to verify that foggers are in optimum mechanical working conditions, generating droplets with a volume median diameter of 200 to 400 microns to avoid evaporation, drift and runoff from the target. The foggers should be operated at 4 to 8 bar pressure, with nozzles whose number, location and flow, in combination with the calculated travel speed, will assure the recommended litres per hectare. The droplets are to be transported by a wind flow and direction that is appropriate to the size of the sprayed trees, aiming at a 20-30 % target coverage if the pesticide is of the systemic type, or a 40-50 % target coverage if the pesticide is of the contact type (Matthews, 2000; Wilkinson et al, 1999; Baldoin, 2001; Fox et al, 1993).

However, atmospheric conditions are often such that the performance of the sprayers is very negatively affected causing loss of the chemical product, low plague control efficaccy and efficiency, severe pollution, acid rain, phytotoxicity and operator's health hazzard. Among these factors are rainfall, wind, air temperature and relative humidity. It has been pointed out by Matthews (2000), Miller et al (2000), Holtmann and Salyani (1996), Wilkinson et al (1999), Baldoin (2001), Baldoin et al (2001), and FAO (1996) that when certain values are exceeded (rain > 1-3 mm/day; wind speed > 1-4 m/s, temperature > 28-30 º C, and relative humidity < 40 % or > 95 %), the applications become inefficient and/or polluting due to dilution and product wash down, evaporation and drift. It has been estimated by Riquelme (1997) that these losses range from 25 to 50 % in normal conditions and can reach up to 90 % in dormant trees.

The situation just described has led several authors (Matthews, 2000; Miller et al, 2000; Holtmann and Salyani, 1996; Wilkinson et al, 1999; Magdalena et al, 1997; Baldoin et al, 2001; Fox et al, 1993) to develop the concept of “Pesticide Application Window” (PAW), which considers all the factors related to an efficaccious application of the chemical product avoiding environmental pollution. A PAW is the time period when atmospheric conditions are such that pesticide applications can be carried out with minimum risk of environmental pollution.

Given all the previous consid-

Fig. 1 Monthly mean of hourly temperatures and relative humidity fot the months with the greatest pesticide applications demand in fruit orchards of south central Chile



erations, the objectives of this research work were to establish efficaccious and non polluting pesticide application windows for apple, kiwi, red raspberry and blueberry orchards; and to compare them with the time demands of the annual spraying schedules, with the effective work capacity of the foggers available, and with the planted area of the orchards.

Methodology

General Information

The work was carried out between September 2001 and April 2003 in an area located in south-central Chile between the cities of Linares in the north and Los Angeles in the south. The climate is of the Mediterranean humid type with mean temperatures of 22-26 ºC in the summer and 5-10 ºC in winter, mean annual rainfall from 900 mm in Linares to 1,250 mm in Los Angeles, with the months of May, June, July and August having nearly 80 % of the rain (del Pozo and del Canto, 1999).

Four long term daily meteorological data bases were probabilistically processed according to the four species chosen. Each case is described as follows:

Apple Orchards. 32 years (1969-2000) of the University of Concepcion's Agrometeorological Station located in the northeastern outskirts of Chillán city (36º 34' LS; 72º 06' LW; 144 meters above sea level) were processed.

Kiwi Orchards. 25 years (1976-2000) of the Ancoa Meteorological Station (General Division of Waters) located 20 km east of Linares city (35º 53' LS; 71º 19' LW; 410 meters above sea level) were processed.

Red Raspberry Orchards. 15 years (1987-2001) of the Santa Rosa Meteorological Station (Agricultural Research Institute) located 30 km northeast of Chillán city (36º 31' LS; 71º 54' LW; 185 meters above sea

Fig. 2 Mean of the days per month appropriate to apply pesticides in kiwi orchards and days in which the temperature > 28 º C in the Linares area, Chile

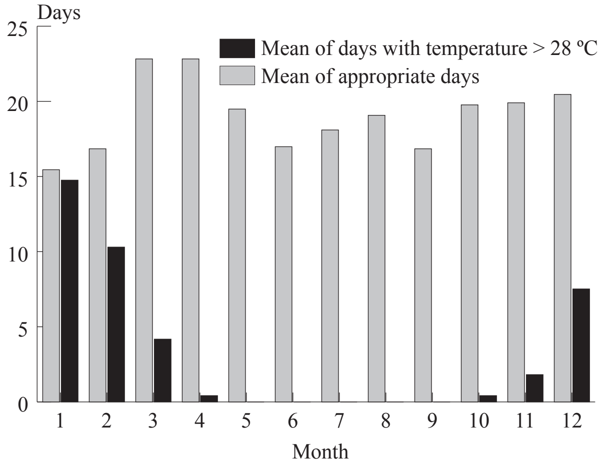


Fig. 3 Mean of the days per month appropriate to apply pesticides in kiwi orchards and days in which the wind speed > 8 km/h in the Linares area, Chile

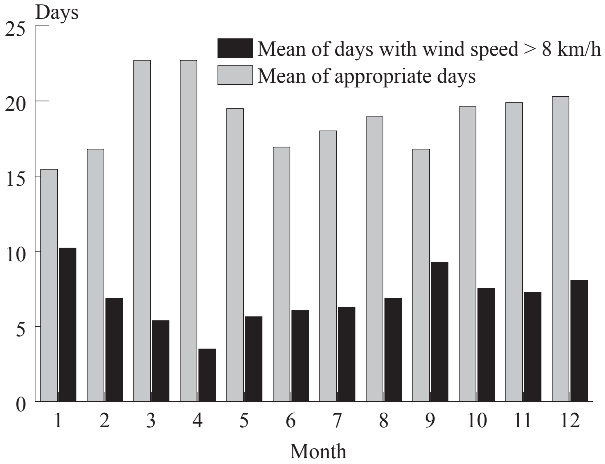


Fig. 4 Mean of the days per month appropriate to apply pesticides in kiwi orchards and days in which the rainfall > 2 mm/day in the Linares area, Chile

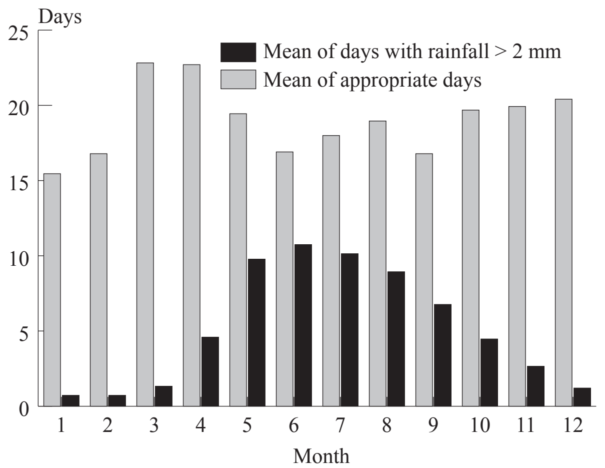


Table 1 Mean and standard deviation of pesticide application windows for apple, kiwi, red raspberry and blueberry orchards in south central Chile, days/month

Month	Apples		Kiwi		Raspberry		Blueberry	
	X	S	X	S	X	S	X	S
January	15.6	2.9	15.5	5.5	11.5	5.6	13.3	2.9
February	15.2	2.4	16.7	4.7	12.9	4.2	14.4	3.7
March	20.1	2.7	22.8	5.6	19.2	6.0	20.5	3.5
April	18.9	2.4	22.7	6.9	17.9	6.1	17.9	4.3
May	16.6	3.8	19.5	6.2	18.3	4.3	15.0	5.1
June	14.5	2.8	16.9	5.3	14.8	6.1	15.6	3.7
July	15.1	2.5	18.0	4.4	17.2	5.2	16.3	5.8
August	16.8	3.1	19.0	4.3	16.9	4.5	17.5	4.0
September	16.9	3.3	16.8	5.9	12.9	6.0	17.4	3.7
October	18.6	2.9	19.7	7.5	16.0	7.2	17.6	6.7
November	18.7	3.6	19.9	7.5	17.0	7.2	16.3	4.0
December	17.0	3.2	20.4	7.7	13.5	6.2	13.4	4.0
Mean	17.0	2.9	19.0	5.9	15.7	5.7	16.3	4.3

level) were processed.

Blueberry Orchards. 21 years (1980- 2000) of the Humán Meteorological Station (Agricultural Research Institute) located 15 km east of Los Angeles city (37º 28' LS; 72º 23' LW; 166 meters above sea level) were processed.

Criteria to Determine a PAW

Based on what was found in the literature (Matthews, 2000; Baldoin, 2001; Wilkinson et al, 1999; Magdalena et al, 1997) and the proposal of a Panel of Experts (2002) of the Faculties of Agronomy and Agricultural Engineering of the University of Concepcion, the following criteria to determine a PAW were established:

- Rainfall: < 1.5 mm/day
- Wind speed: < 2.78 m/s for apple; < 2.22 m/s for kiwi; < 1.94 m/s for red raspberry and blueberry
- Temperature : < 28 ºC
- Relative humidity: 30-95 percent

Analysis Previous to Processing the Meteorological Data

The theory by Campbell and Norman (1998) and del Pozo and del Canto (1999) that relative humidity decreases as the temperature raises in Mediterranean climates, where temperatures > 28 ºC generate relative humidities < 30 %, was validated by Sepúlveda (2002). The graphs in **Fig. 1**, showing the hourly relationship between temperature and relative humidity, indicate that it is allways possible to have, at least, 2 hours in the morning and 2 hours in the evening when the temperature will be < 28 ºC and the relative humidity will be > 30 %, and spraying can be carried out.

This validation makes it possible to have the relative humidity as a function of the temperature, reducing from 4 to 3 the data bases to process. It was then possible to assign ½ day (half day, or 4 work hours) appropriate to apply pesticides to those days when the temperature reached values > 28 ºC.

Processing of the Meteorological Data

To apply the criteria that determine a PAW to the meteorological data the following steps were carried out:

a. Of an EXCEL Microsoft sheet the days with > 1.5 mm of rainfall were eliminated;
b. Of the wind speed sheet the days with winds faster than the criteria set up for each specie were eliminated;
c. Finally, on the sheet with the temperatures a 0 (zero) was assigned to the days when climatic conditions were not appropriated, a 0.5 or 1/2 working day to those when the temperature reached > 28 ºC, and a 1 (one) to those days meeting all the

Table 2 Pesticide application windows for period of half month for apple, kiwi, red raspberry and blueberry orchards in south central Chile, days/period

Period	Apple probability level				Kiwi probability level				Raspberry probability level				Blueberry probability level			
	0.6	0.7	0.8	0.9	0.6	0.7	0.8	0.9	0.6	0.7	0.8	0.9	0.6	0.7	0.8	0.9
Jan 1-15	7.2	6.4	6.0	5.5	6.0	5.2	4.4	4.1	4.0	2.9	2.1	0.8	5.9	5.1	4.4	3.6
Jan 16-31	7.3	7.2	6.2	5.5	6.7	5.6	4.9	4.3	4.5	3.5	3.5	2.0	6.0	5.3	4.5	3.8
Feb 1-14	7.4	6.8	6.4	5.5	8.2	7.9	7.0	4.8	5.2	3.9	2.7	1.5	6.2	5.3	4.3	3.4
Feb 15-29	7.2	6.4	6.0	4.8	8.2	6.4	6.0	4.1	6.2	5.9	5.5	4.6	6.5	5.6	4.8	4.0
Mar 1-15	8.9	8.5	8.1	7.1	11.0	9.4	8.6	6.1	7.5	7.4	6.6	4.1	8.8	8.0	7.1	6.2
Mar 16-31	10.6	10.2	9.2	7.3	13.0	11.9	9.0	5.8	9.0	7.4	6.6	5.4	10.1	9.3	8.6	7.9
Apr 1-15	9.4	8.5	8.1	7.1	11.2	10.9	8.8	5.6	8.0	7.0	6.2	1.8	7.5	6.6	5.6	4.7
Apr 16-30	9.4	8.5	7.7	7.1	10.7	10.0	8.2	6.8	8.4	6.8	5.2	5.0	8.6	7.8	6.9	6.1
May 1-15	7.9	6.8	6.5	5.1	9.6	8.8	6.2	5.0	9.4	8.0	5.6	5.0	6.4	5.2	4.0	2.7
May 16-31	7.0	6.8	5.1	5.0	8.0	7.0	6.0	4.6	9.0	6.0	5.2	3.0	6.4	5.3	4.3	3.2
Jun 1-15	7.3	5.1	4.3	3.4	7.8	6.8	5.0	4.0	7.0	5.6	4.0	3.6	7.4	6.7	5.9	5.2
Jun 16-30	6.8	6.0	5.1	4.3	7.4	7.0	6.2	3.0	5.4	4.8	4.0	2.0	6.4	5.4	4.4	3.4
Jul 1-15	7.7	6.8	6.0	4.5	8.8	7.8	5.4	3.6	7.0	6.0	6.0	5.2	6.6	5.6	4.6	3.7
Jul 16-31	6.8	6.7	5.6	5.1	8.8	8.0	6.2	5.0	6.4	6.0	5.5	4.0	7.4	6.0	4.6	3.2
Aug 1-15	7.0	6.8	6.8	5.4	7.4	7.0	6.2	5.6	6.4	5.8	5.2	3.8	7.3	6.5	5.7	5.0
Aug 16-31	8.5	8.2	7.3	6.0	9.4	8.0	7.0	7.0	7.4	7.0	7.0	6.6	8.5	7.5	6.5	5.5
Sep 1-15	7.7	6.8	6.0	5.1	7.0	6.0	5.2	3.5	4.4	3.8	2.2	1.6	7.2	6.2	5.2	4.1
Sep 16-30	7.9	7.7	6.8	6.2	8.0	6.6	5.0	3.2	5.0	4.8	4.0	2.0	8.4	7.6	6.9	6.2
Oct 1-15	8.5	7.7	6.8	6.2	8.4	7.0	5.2	3.0	5.4	5.0	4.2	2.0	7.3	6.1	5.0	3.9
Oct 16-31	9.4	9.3	8.3	6.0	9.8	8.6	5.2	4.6	8.0	5.9	3.5	2.6	7.9	6.6	5.3	4.0
Nov 1-15	9.6	9.4	8.5	7.7	9.4	7.8	5.2	2.6	7.0	5.8	3.4	3.0	8.1	7.2	6.4	5.6
Nov 16-30	8.2	7.7	6.0	5.1	8.5	7.8	6.1	4.6	8.7	7.9	4.7	1.4	6.3	5.3	4.2	3.1
Dec 1-15	8.2	7.1	5.8	4.5	9.2	8.0	7.5	5.1	5.5	4.0	4.0	2.3	5.9	5.0	4.1	3.2
Dec 16-31	7.7	7.2	6.6	6.1	9.9	9.4	7.4	5.0	4.7	4.5	4.1	3.3	5.9	5.0	4.2	3.3

criteria for a PAW.

Evaluation Periods

The calculation of the different probabilities of occurrence of PAW was carried out for periods of one month and ½ month, given that these are the lengths of the periods most frequently utilized by the producer or the orchard manager to make decisions about spraying. On the other hand, a working day of 8 hours was utilized.

Statistical Analysis

Given that the weather is a stochastic variable changing from one year to the next, a probability study was performed in the following manner. Once the zeros, 0.5 and ones were assigned to each of the days of the years in the data base, the Accumulated Empirical Probabilities Distribution was used to build the corresponding probability distribution. To do this the following steps were carried out (Canavos, 1988):

a. The number of days appropriate to apply pesticides in each period of each year were added up to form observations of the appropriate number of spraying days in each period;
b. The frequencies of spraying days were ordered from largest to smallest;
c. Probabilities were assigned using the rule that the ordered observation k is a measure of the probability (k/(n+1));
d. The number of appropriate days at each probability level was obtained through linear interpolation. In this way, a probability of 0.8 represents the minimum number of appropriate days that can be expected to occur in 80 out of 100 years.

Pesticide Application Schedules

The annual pesticide application schedules for apple, kiwi, red raspberry and blueberry orchards were established for each of their phenological stages according to the information presented by AFIPA (1999); ANASAC (2000); SAG (1996) and the Panel of Experts (2002) previously mentioned.

Foggers Available in the Market

The cadastre created by Sepú lveda (2002) was utilized. This cadastre shows there are 6 registered trade marks with a total of 20 models of foggers, with tanks whose volumes hold from 400 to 2,200 L and pumps with a 75 to 150 L/min flow capacity.

Effective Work Capacity (EWC) of the Foggers

The EWC, in hectares per hour (ha/h), of each model was calculated using the following equation (Ibáñ ez and Abarzúa, 1995):

EWC = W x V x (1 - Lt) / 10

where

W = working width, m
V = working speed, km/h
Lt = lost time, decimal fraction
10 = conversion factor to obtain ha/h

The calculation of the EWC considered the most common plantation distances between the rows for apple, kiwi, red raspberry and blueberry orchards. The working speeds used were 3, 4 and 5 km/h according to the difficulties presented by the terrain and the amount of foliage presented by the trees. The lost time was assigned according to the tank capacity of the foggers considering that the bigger the tank the smaller the lost time, in the following manner: 35 %; 45 %; 50 %; and 60 % of lost time to tank capacities 2,000 L or more; 1,000 L; 700 L; and 400 L, respectively (Ibañez and Abarzúa, 1995; Panel of Experts, 2002).

The size of the orchards, in hectares, that can be sprayed timely with the foggers was calculated with the PAW available at the different

Table 3 Pesticide applications schedule for apple orchards and size of the pestcide application window (PAW) in south central Chile

Plague, disease or application	Application period	PAW size (days) at 0.5 prob. level
Europian canker	July	15.1
Wholly apple aphid, weevils larvae nematodes	August, bud break	16.8
Apple scab	September 1-15, green tips	8.3
Apple scab, powdery mildew	September 16-30, open cluster	8.6
Apple scab	October 1-15, pink blossom to king bloom	8.9
Apple scab, powdery mildew, aphids, tussock moth, weevils, moths, mites	October 16-31, fruit set, 1 cm	9.7
Chemical thinning	November 1-15, fruit 3 cm	10.0
Apple scab, moths, tussock moth	November 16-30, fruit 5 cm	8.7
Apple scab	December	17.0
San Jose scale, moth	January	15.6
Moths	February	15.2
Moths	March	20.1
Europian canker	April, 50 % leaf fall	18.9

probability levels. Only the areas to be worked at 0.8 probability level are presented here, given that this is an appropriate level for agricultural decision-taking of this kind.

Results and Discussion

Pesticide Application Windows (PAW)

Table 1 presents the average size of the PAW (days) during each month of the year. It can be seen there that the annual mean goes from 15.7 to 19.0 days/month for red raspberry and kiwi orchards, respectively, with extremes of 11.5 days for raspberry in January to 22.8 days for kiwi in March. This seems to be a fair amount of time appropriate to carry out the pesticide applications, without causing undue environmental pollution. The smallest PAW occurs during the months of January and February (extremes of 11.5 and 12.9 days for raspberry) due to high temperature and wind speed, as it is shown for kiwi orchards in **Figs. 2** and **3**, and in the months of May, June and July due to high rainfall and some wind, as it is shown, also for kiwi orchards, in **Figs. 3** and **4**. On the other hand, the largest PAW occurs during the months of March (22.8 days) and April (22.7 days) when the air temperatures are lower, the Autumn-Winter rains have not started and the wind speeds are low to moderate (del Pozo and del Canto, 1999). These PAW are especially large for apple orchards with 22.8 days in March and 22.7 days in April.

Table 2 show the sizes of the PAW for periods of half month for the different fruit orchards at four probability levels. It is also seen there that, in general, there are fair amounts of time appropriate to carry out non polluting pesticide applications. It should be emphasized that as the probability level goes up from 0.6 to 0.9 the sizes of the VAP decrease notably, which is due to the concept of probability and how it is calculated (Canavos, 1988). This is especially true for red raspberry orchards during the first halves of January, February, September and November.

Relationship between Effective Work Capacity (EWC) of the Foggers, the PAW and Size of the Orchards

Table 3 presents, as an example, the pesticide application schedule for apple orchards and the sizes of the PAW associated with each control. It should be pointed out that these schedules are subject to changes from one year to the next according to the occurrence of climatic conditions that dominate each growing season. In this schedule it is possible to see that most of the applications are to be carried out from September to January, that is from the beginnig of green tips until the accelerated development of the fruit. Among the plagues and diseases that attack the Royal Gala and Granny Smith apple varieties are apple scab, San Jose scale, moths, and mites. The permanent presence of Apple scab through all the development period of the fruit, from the first half of September to December, is emphasized.

Effective Work Capacity (EWC) of the Foggers, PAW Sizes, and Areas of the Orchards

Table 4 shows that the EWC of the foggers available goes from 0.36 to 0.98 ha/h, according to the model size, row distances for the 4 species, and forward speed. Given these factores, the smallest EWC of 0.36 ha/h is obtained with the smallest model which has the largest lost time due to the small capacity of its tank, only 400 L, at the lowest forward speed of 3 km/h, in raspberry and blueberry which have only 3 m of distance between the rows.

Table 5, on the other hand, shows the areas of the orchards that can be sprayed in the worst situation; that is, with the model with the smallest EWC and at the recomended probability level of 0.8 insuring that the task will be carried out on time. The 0.8 probability level insures that in 8 out of 10 years the task will be performed timely; in the other 2 years it may be necessary to work more than 8 hours daily. **Table 5** shows that, in general, the areas of the apple and kiwi orchards that can be worked in these conditions are larger than 20 hectares; in the case of raspberry and blueberry orchards the areas that can de sprayed timely are, in most cases, larger than 10 hectares. On the other hand, the National Statistics Institute (INE, 2002) has established that there are few red raspberry and blueberry orchards in Chile with areas larger

Table 4 Ranges of effective work capacity (ha/h) of foggers in apple, kiwi, red raspberry and blueberry orchards in south central Chile, according to working speed and distance between the row

Make	Model	Apple	Kiwi	Raspberry	Blueberry
A	Smallest	0.7-1.1	0.9-1.3	0.45-0.75	0.45-0.75
	Largest	1.0-1.6	1.2-1.6	0.59-0.98	0.59-0.98
B	Smallest	0.7-1.2	1.0-1.4	0.50-0.83	0.50-0.83
	Largest	0.9-1.5	1.2-1.6	0.59-0.98	0.59-0.98
C	Smallest	0.7-1.2	1.0-1.4	0.50-0.83	0.50-0.83
	Largest	0.9-1.5	1.2-1.6	0.59-0.98	0.59-0.98
D	Smallest	0.6-1.0	0.7-1.0	0.36-0.60	0.36-0.60
	Largest	0.9-1.5	1.2-1.6	0.59-0.98	0.59-0.98
E	Smallest	0.8-1.4	1.0-1.4	0.50-0.83	0.50-0.83
	Largest	0.9-1.5	1.2-1.6	0.59-0.98	0.59-0.98
F	Smallest	0.7-1.3	0.7-1.0	0.36-0.60	0.36-0.60
	Largest	0.9-1.5	1.2-1.6	0.59-0.98	0.59-0.98

than 10 hectares. Timeliness problems could arise in raspberry orchards larger than 8 hectares during the first half of January, February and September when the pesticide application schedule for this species demands the spraying of products. Producers of red raspberry would be wise to purchase a sprayer model larger than the smallest one available.

Conclusions

There are appropriate size non polluting pesticide application windows for apple, kiwi, red raspberry and blueberry orchards in south central Chile. The largest size windows occur during March and April and the smallest size windows occur during the months of January and February and May, June and July. The probability analysis of number of days appropriate to carry out non polluting spraying in these orchards shows smaller numbers at higher probability levels (0.8; 0.9), especially during the months of June and July.

The individual Effective Work Capacity of sprayers available in Chile is appropriate to timely carry out the annual demands of the spraying schedules, considering the area of the great majority of the orchards and the size of the established windows. The worse situation occurs in red raspberry orchards during the first halves of January, February and September.

Table 5 Ranges of sizes (ha) of the apple, kiwi, red raspberry and blueberry orchards in south central Chile that can be timely sprayed with the smallest fogger, at 0.8 probability level

Period	Apple	Kiwi	Raspberry	Blueberry
Jan 1-15	29-48	26-32	6-10	12-21
Jan 16-31	30-50	29-35	10-17	13-22
Feb 1-14	31-51	42-50	8-13	12-21
Feb 15-29	29-48	36-43	16-26	14-23
Mar 1-15	39-65	52-62	19-32	20-34
Mar 16-31	44-74	54-65	19-32	25-41
Apr 1-15	39-65	60-72	18-30	16-27
Apr 16-30	37-62	49-59	15-25	20-33
May 1-15	31-52	37-45	16-27	11-19
May 16-31	25-41	36-43	15-25	12-20
Jun 1-15	21-34	30-36	11-19	17-28
Jun 16-30	25-41	37-45	11-19	13-21
Jul 1-15	29-48	32-39	17-29	13-22
Jul 16-31	27-45	37-45	17-29	13-22
Aug 1-15	33-54	37-45	15-25	16-28
Aug 16-31	35-59	42-50	20-34	19-31
Sep 1-15	29-48	31-37	6-11	15-25
Sep 16-30	33-54	30-36	11-19	20-33
Oct 1-15	33-54	31-37	12-20	14-24
Oct 16-31	40-66	31-37	10-17	15-25
Nov 1-15	41-68	31-37	10-16	18-31
Nov 16-30	29-48	37-44	13-23	12-20
Dec 1-15	28-46	45-54	12-19	12-20
Dec 16-31	35-58	44-53	12-20	12-20

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(Continued from page35)

Recent Developments in Sugarcane Mechanisation in India

oped and demonstrated on a limited scale at different places. There is no doubt these pieces of equipment are labour and cost saving and will definitely make sugarcane cultivation more profitable in addition to reducing human drudgery. There is a need for concerted efforts by different organisations including sugar industry, State Agricultural Universities, Research Organisations, Cane departments, etc. for popularising these machines. All these useful time, labour and cost saving devices can be taken to the farmer fields with the joint efforts of all those involved in the pursuit of increasing sugarcane productivity. Suitable liaison with the implement manufacturing industries must be developed and prototypes be fabricated and demonstrated on a large scale in order to create awareness among the farmers. Later on, private entrepreneurs could be encouraged to provide these useful machines to the farmers on custom hiring service basis.

The next phase of revolution in Indian agriculture is bound to come through the use of improved agricultural machinery adapted to local conditions. Concerted efforts are required to formulate a strategy for mechanising sugarcane production in India with the sole aim of increasing production and productivity per unit time, area and input at reduced cost of unit operation. This is a must if we survive in the highly competitive international sugar market.

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Performance Evaluation of an Evaporative Cooling System for Fruits and Vesitable Storage in the Tropics

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Abstract

A brick walled evaporative cooler was tested, without loading, to investigate the potential for preserving fruits and vegetables under a semi-arid climate. The cooler is a rectangular double-walled structure enclosing a chamber of 1.38 m^3 capacity. Each double wall of burnt bricks enclosed an interspace filled with water saturated riverbed sand. The test assessed the capacity of the cooler for generating a storage atmosphere of reduced temperature and elevated relative humidity in the enclosed chamber.

Air temperature and relative humidity within the unloaded chamber fluctuated with changes in local climatic conditions. The cooler had an average cooling efficiency of 69 % on a typical cold dry day and effected reductions in temperature to 1.5 and 10.0 ºC when respective temperatures were 14.0 and 26.0 º C. On a hot dry day, the average cooling efficiency was 71 % and reductions in temperature to 8.0 and 12.5 ºC were achieved at ambient temperatures of 26.5 and 35.0 ºC respectively. The cooling chamber's relative humidity was consistently raised to between 82 and 100 %. The cooler extended the shelf life of stored tomatoes by 10 days

Introduction

The enormous post harvest losses of fruits and vegetables which occur in the tropics can be attributed to a general lack of adaptable storage facilities. An effective storage facility should avoid the adverse effects of the hot and dry tropical climate on these commodities.

Storage temperatures and relative humidity requirements of various tropical commodities (IIR, 1967; ASHRAE, 1978; and The Packer, 1988) are given in **Table 1**. Most documented recommendations (**Table 1**) include 0 ºC but some tropical fruits such as bananas, pawpaw and avocado cannot be stored below 12-15 ºC without incurring losses through "chilling injury" (Jamieson, 1981). Relative humidity from 85 % to 95 % is generally recommended. To be acceptable, the storage facility should also be economically feasible and fit the production system of small-scale producers and traders, particularly in the developing countries.

In meeting these basic requirements, the application of a passive cooling system, as an alternative to mechanical refrigeration, is becoming more relevant to the needs of perishable commodity storage. Simple evaporative coolers constructed of cheap and readily available materials have been developed for low-cost preservation of perishable commodities. Gundry's cooling method (Gundry, 1948) consists of wetted charcoal which is cooled without electricity. Those of Hall (1975) and Thompson and Kasmire (1981) employed fans for drawing air through wetted wall surfaces of charcoal and aspen pads respectively. The "zero energy cool chamber" (Roy and Khurdiya, 1985) consists of double walls of bricks interspaced by moist sand. The practical applications of this and other simple low-cost cooling devices have been thoroughly discussed by Sharma and Rathi (1991).

This paper investigates the effectiveness of a brick walled evaporative cooler (Babarinsa and Nwangwa, 1988 and Babarinsa, 1990) for generating a storage atmosphere that will extend the shelf-life of fruits and vegetables in Kano, Nigeria.

Kano is climatically typical of a semi-arid zone and the cooler effectively prolonged shelf life of carrot there (Babarinsa et al, 1997).

Materials and Method

The Cooling System

Description of the Brick Walled Cooler

The evaporative cooler under test (**Fig. 1**) consisted of a double-walled rectangular brick construction with the interspace filled with riverbed sand saturated with water. The clay brick used in the wall construction was factory baked (at 600 ºC) and was of dimensions 25.5 cm x 12.0 cm x 6 cm thick. The sand was pervious to water. The water used was clean and free of foreign matter so as to maintain perviousness and avoid clogging of the sand.

The interior surfaces of the cooling chamber walls were given a smooth finish with 1.2 cm thick cement plaster, while a heat insulating cover of 1.9 cm thick particleboard closed the top. The walls were built on a short plinth of concrete to prevent water seepage into the soil. Two framed doors of sawn wood were fixed one to each of the adjacent walls on a side to provide access to the 1.38 m^3 capacity chamber. These two doors were considered adequate for the needed thermal insulation against heat influx but an additional polystyrene foam board could be installed for more insulation. The permanent structure was erected in an open space exposed to free air but shaded from direct solar radiation with an open sided shed of thatch.

Table 1 Storage and relative humidity requirements for some tropical fruits and vegetables

Commodity	Tempreature, ºC	r.h.,%	Expected shelf life	Information source Ref number***
Avocado	7-13	85-90	2-4 weeks	1
	4-13		2-4 weeks	2
	21.1			3
Banana	21.1	95		2
green*	14.4-17.8			3
coloured**	11.5-14.5	90-95	10-20 days	1
	13-16	85-90	5-10 days	1
Cucumber	7-10	90-95	up to 2 weeks	1
	12	85-95	2 weeks	1
Eggplant	7-10	85-90	10 days	1
Grapefruit	4-16		4 weeks	2
	12.8-14.4			3
	0	85-90		1
	10-15.5	85-90	3-12 weeks	1
Lemon	0-14		1-6 months	2
	12.8-14.4			3
green*	11-14.5	85-90	1-4 months	1
coloured**	4-10	85-90	3-6 months	1
Lime	12.8			3
	9-10	85-90	3 weeks	1
Mango	13		2-3 weeks	2
	8-10	85-90	up to 4 weeks	1
	12.8			3
Orange	0-9		3-12 weeks	2
	0-1	85-90	2-3 months	1
	5.5-7	85-90	up to 18 weeks	1
	0-7.2			3
Pawpaw	4-10	85-90	2-5 weeks	1
	12.8-18.3			3
Pumpkin	10-13	70-75	2-6 months	1
	12.8		1-3 weeks	3
Tomato	13.8-21			3
coloured**	7	85-90	2 weeks	1
green*	11.5-13	85-90	3-5 weeks	1

*Fruits at mature green stage
**Firm fruit with skin colour developed to level acceptable for consumption or use
***1. IIR (1967), 2. ASHRAE (1978), 3. The Packer (1988)

Operation of the System

Indirect evaporative cooling has two stages. The first stage is direct evaporative cooling whereby ambient air passing over the wetted (outer) surface is cooled. This results in continuous evaporation of moisture from the wall surface to the ambient flowing air and the latent heat of vaporization is extracted from the water-saturated sand. This stage thus involves simultaneous heat and mass transfer from the wet sand to the ambient atmosphere through the porous wall.

Cooled wet sand cools the inner chamber air by conduction in the second stage and the internal air temperature is reduced and the air relative humidity is raised simultaneously.

Performance Index

The maximum possible temperature reduction that can be achieved in the chamber is that given by the "wet bulb depression" (defined as the difference between the ambient dry bulb temperature and the ambient wet bulb temperature). With this, the lowest temperature that can be achieved theoretically is the wet bulb temperature, when the cooler operates at 100 percent effectiveness (Hall, 1975 and Landsberg et al, 1979).

The index of performance for an evaporative cooler is termed the cooling efficiency (CE) and is defined as:

$$CE = \frac{Ta - Ts}{Ta - Tw} \times 100\ \%$$

Ta = dry bulb temperature of ambient air, ºC

Ts = dry bulb temperature of the cooled space air, ºC

Tw = wet bulb temperature of ambient air, ºC

The cooling efficiency of the cooler, as given by Eqn (1), indicates that portion of the "wet bulb depression" by which chamber air is cooled. This depends on environmental factors such as the ambient temperature and humidity.

Test Procedure

The experimental procedures focused on the cooler's performance within 24h periods and over 31d period. In each study case the patterns of temperature and relative humidity changes in both the ambient and the cooling chamber of the cooler were investigated. Commodity storage trials were conducted with tomato fruits.

During operation, the cooling chamber was tightly closed and the riverbed sand was kept continuously wet by gently adding water manually three times daily at 09.00h, 12.00h and 15.00h to ensure constant saturation of the sand with water.

Effects of Changes in Weather Conditions on Chamber Performance

The effects of changes in local weather conditions on the cooling chamber were investigated to study the effects of diurnal temperature and relative humidity in the course of 24h periods. Another test was conducted in two runs of 31 days in the two months of January and May to investigate the effects of season on the performance of the chamber. The months of January and May were chosen for the second performance study because, very often, they are the coldest and the hottest months, respectively, in Kano.

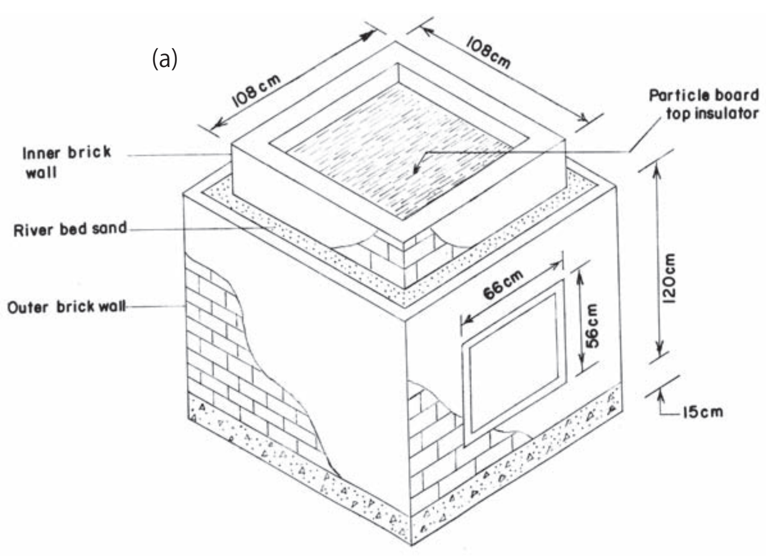
Variations of temperature and relative humidity inside the cooling chamber and in ambient air were continuously monitored with thermohydrographs. One thermohydrograph was mounted inside the chamber and another was outside in close proximity to the cooler. A glass thermometer and a wall hygrometer were positioned near each thermohydrograph for occasional checking of readings. Measurements continued for the 31 days of each test run while numerical data for hourly consideration were extracted from the 7 day recording charts.

Storage of Produce

The cooling system was used to store tomatoes harvested fresh from a market garden in Kano, Nigeria. Tomato fruits were harvested at "breaker point" (at the verge of colour change from green), washed, drip-dried and pre-cooled overnight in an air-conditioned room at 21 ± 1 ºC. In practical use of the cooler, harvested produce would be pre-cooled to within this temperature range under farm shed condition possibly by water-cooling before being taken into the cool chamber.

Before loading, the storage chamber was cleaned and sterilized with fumes generated from a mixture of formaldehyde and potassium permanganate crystals. In the storage trial, the commodity was loaded on a wooden shelf mounted in the closed chamber. The test consisted of the same quantity of commodity placed on a laboratory bench at room temperature.

Storage characteristics of the stored commodity were monitored at specified intervals and practical



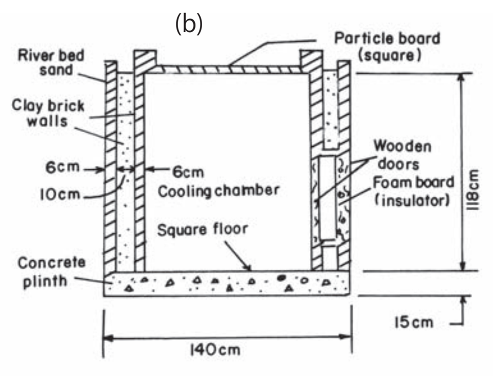


Fig. 1 The brick walled cooler, (a) Isometric view and (b) Sectional view

shelf life was considered terminated at 20 % spoilage level caused by rotting.

Results

Chamber Temperature and Temperature Reduction

Temperatures recorded within each 24h period of the 62 days of test varied with the hour of the day but reduced chamber temperature when compared with ambient for the test period. **Fig. 2** shows the hourly variations in ambient and chamber air temperatures for a typical cold dry, harmattan day (January 4), and a hot dry day (May 19).

On January 4, ambient temperatures ranging from 14.0 to 26.0 ºC were reduced in the cooling chamber to 12.5 and 16.0 ºC, respectively. Similarly, on May 19, ambient temperature of 26.0 to 35.5 ºC dropped in the chamber to 17.5 to 23.0 ºC. Temperature reductions were thus higher on the hot day of May 19 (8.0 to 12.5 ºC) than on the cold day of January 4 (1.5 to 10.0 ºC). On both days as in other days of the test, temperature reductions were higher during hot times of the day.

Chamber Humidity Elevation

The cooling chamber consistently recorded higher relative humidity than ambient on both days (**Fig. 3**). Elevation in relative humidity in the chamber was to the range of 88 to 99 % on January 4 and 82 to 92 % on May 19.

Cooling Efficiency

Hourly temperatures were used to calculate hourly cooling efficiencies for each day (**Table 2** using Eqn 1). In using this equation, the respective wet bulb temperatures of ambient air were derived from a psychrometric chart. An average cooling efficiency for each day was then computed using Eqn (1). Sample values of calculated cooling efficiencies and average cooling efficiency obtained for January 4 and May 19 are as tabulated in **Table 2**. During the cold dry day of January 4 the cooler recorded hourly cooling efficiencies of 60 to 82 % with an average cooling efficiency of 69 %. During the hot dry day of May 19 the cooling efficiencies were 64 to 82 % with an average cooling efficiency of 71 %.

Effects of Season on Performance of Chamber

The daily records of temperatures, relative humidity and cooling efficiencies obtained during the 31-day run of January were analyzed. The

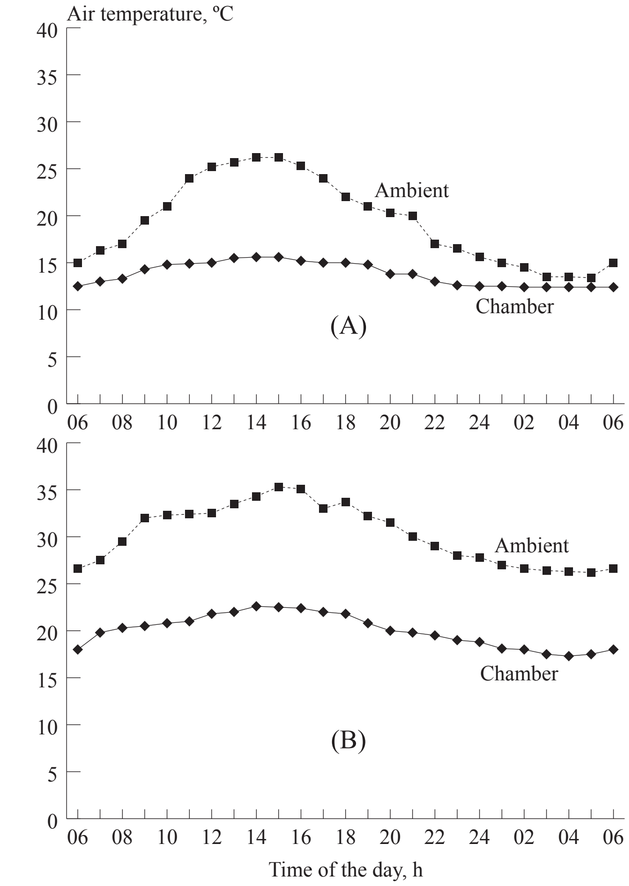


Fig. 2 Hourly variation of temperature for ambient and cooling chamber on (A) January 4, (B) May 19

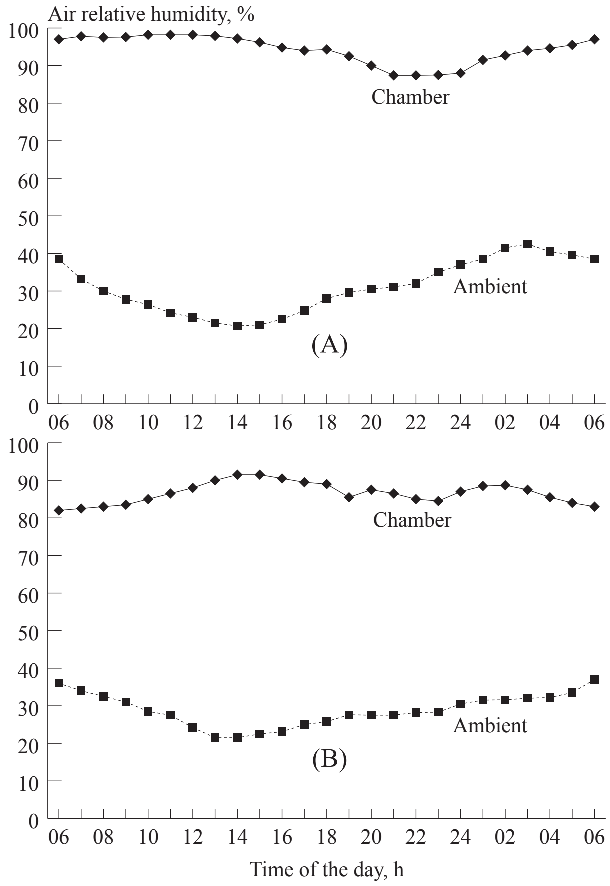


Fig. 3 Hourly variation of relative humidity for ambient and cooling chamber on (A) January 4, (B) May 19

chamber consistently maintained lower air temperature and higher relative humidity than ambient in all daily measurements. Fluctuation in ambient air temperature was reduced in the cooling chamber. In January, daily average temperatures of between 15.5 and 28.0 ºC in ambient were reduced to between 12.3 and 16.7 ºC and in May, from 29.0 to 38.0 ºC to between 18.2 and 24.5 ºC in chamber. Drops in average temperatures in the chamber ranged between 2.1 and 10.3 ºC in January and between 7.2 and 13.2 ºC in May.

Cooler Application for Product Storage

Table 3 shows the response of the fresh tomatoes to storage conditions in the evaporative cooler. Storage of tomatoes in the cooling chamber extended their shelf life. The shelf life of tomatoes, for examples, was 10 days in ambient air but was extended by 11 days in the cooling chamber.

The cooling chamber demonstrated a remarkable potential for reduction of physiological weight loss (PWL) in the stored commodity (**Table 3**). This accounted for the observed extension of shelf life.

Table 2 Hourly cooling efficiencies of evaporative cooler for two days

Time of day, h	Cooling efficiency, %	
	January 4	May 19
06:00	61	67
07:00	63	66
08:00	65	71
09:00	62	73
10:00	66	74
11:00	68	72
12:00	74	75
13:00	74	76
14:00	73	79
15:00	82	82
16:00	77	77
17:00	73	76
18:00	82	74
19:00	70	70
20:00	72	70
21:00	70	69
22:00	72	68
23:00	67	65
24:00	62	66
01:00	71	64
02:00	60	65
03:00	64	67
04:00	65	69
05:00	61	68
Average	69	71
Minimum	60	64
Maximum	82	82

Discussion

Chamber Temperature

Air temperatures attained in the cooling chamber generally exceed those values recommended for optimum shelf life of most tropical fruits and vegetable by refrigeration (**Table 1**). The chamber temperatures are therefore not of optimum benefit if commodities must be stored at established values for refrigeration cooling. However, average chamber temperatures of 12.6 to 16.7 ºC obtained during the test days of January met some requirements of certain commodities such as bananas, pawpaw and tomatoes. Useful application of the evaporative cooler will depend on the daily duration for which the occurrence of such low temperatures prevails.

Relevance of Temperature Reduction

During the hotter times of the day, the attained chamber temperatures rarely meet optimum storage requirements. However, the large drops in ambient temperatures achieved within these hot periods are capable of cutting down commodity losses appreciably in storage.

The considerable air temperature reductions of 9.0 to 11.8 ºC obtained in the chamber on the hot day of May 19 indicate an apparent capability of the chamber to reduce spoilage loss in stored commodities. Considering the relevance of such minor temperature reductions in spoilage control, Jamieson (1981) noted that for most perishable commodities the relationship between temperature and spoilage rate is non-linear so that relative minor reduction in temperature can bring about disproportionately large increase in storage life. In all daily test situations, maximum temperature reductions in the chamber occurred during the daytime at relatively high ambient temperatures. This period of the day therefore has a potential for use of evaporative cooling and the system becomes feasible for preserving perishable commodities. Daytime evaporative cooling is also more promising in hot weather which are usually the most are usually the most liable to spoilage. Such periods of beneficial temperature reduction (of at least 10 ºC) prevailed for a longer duration per day during the hot month of May than during the colder month of January when temperature reductions became lower.

Relative Humidity Elevation

The cooler effectively raised ambient relative humidity to optimum levels (82 to 99 %), which adequately meet the relative humidity requirements (of 85 to 95 %)

Table 3 Storage conditions and characteristics of tomatoes stored in cooling chamber and ambient

	Ambient	Chamber
Test month	March	March
Air temperature, ºC	18 to 35	15 to 24
Relative humidity, %	59 to 79	78 to 100
Stored mass, kg	50	50
Ripening period, day	10	17
Shelf life, day	12	21
Weight loss (after 12 days), %	9.7	2.2

for storing most tropical fruits and vegetables. The chamber relative humidity levels are known to be optimal in retarding water loss and preventing wilting to the benefit of commodities in storage. This useful range of relative humidity remained reliably continuous even during periods of wide variations in ambient temperature and relative humidity.

Cooler Application for Product Storage

From the experimental storage results, the tested cooler demonstrated a remarkable potential for extending the normal shelf life of fresh tomatoes (**Table 3**). Extension of shelf life in the chamber-stored commodity may be attributed to the combined effect of the chamber cooling and humidification.

Conclusion

An evaporative cooler effected considerable temperature reduction and elevation of relative humidity of ambient air under semi-arid conditions. Storage application of the cooler extended the shelf life of stored tomatoes.

As an inexpensive alternative of mechanical refrigeration, the evaporative cooler has potential for application in small-scale preservation of fruits and vegetables and by rural farmers in semi-arid regions.

Effectiveness of the cooler for commodity storage depends on prevailing climatic conditions and the time of the year during which it is to be used.

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Development and Testing of a Tomato Pulper Cum Strainer

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Abstract

A unit for pulping and straining tomato fruits was developed and tested for its performance. Local and hybrid varieties were used for testing. Cold and hot pulping were carried out at different peripheral speeds. The maximum pulp extraction efficiency for the local variety was 91.0 % by hot pulping at a peripheral speed of 47.1 m/s. The maximum pulp extraction efficiency for the hybrid variety was 92.3 % by hot pulping at a peripheral speed of 47.1 m/s. The capacity of the unit is 110 kg/h.

Introduction

Fruits and vegetables are an important supplement to the human diet as they provide the essential minerals, vitamins and fibre required for maintaining health. In India, the production of vegetables is about 68.7 million tonnes annually. However, for various reasons, this abundance of production is not fully utilized and about 30-40 % of it is wasted due to post harvest spoilage (Thangavel et al, 1998). Most of the fruits and vegetables are seasonal and perishable in nature. In a good season, there may be a local glut, particularly of fruit, but because of insufficient transport facilities, lack of good roads and poor availability of packaging materials, the surplus cannot be taken quickly enough to the wholesale markets in urban areas. Moreover, the surplus often cannot be stored for sale in the off-season because of inadequate local cold storage facilities.

Tomato, as a processing crop, ranks first among vegetables grown all over the world (Vijay Sethi, 1994). Tomato is grown in India abundantly both in summer and in winter seasons but those grown in winter are superior in quality because they contain more total solids (Srivastava and Sanjeev kumar, 1994). They are a good source of vitamin A, B1 and ascorbic acid (Pairat and Ranganna, 1976). It contains 15 to 25 mg/100 gm of vitamin C and has four times the vitamin A content of orange juice (Gould, 1974). Fresh tomatoes are very refreshing and appetizing but cannot be stored for a long period. Often they are sold at distress prices

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during the peak harvest season and nearly 25 % of the produce is spoiled due to mishandling. Converting tomatoes into concentrated products such as tomato sauce, ketchup and soup powder can avoid such losses. Though tomatoes are available practically throughout the year, the surplus available during the peak harvest season can be pulped and preserved in the form of concentrate for off-season usage and also the wastage can be avoided to a certain extent. For pulping tomato fruits a unit has been developed and evaluated.

Materials and Methods

Development of a Tomato Pulper Cum Strainer

A tomato pulper cum strainer unit was fabricated for pulping the tomato fruits (110 kg/h) and extraction of juice. The unit was mounted on frame made of mild steel angle iron section 38 x 38 x 6 mm. The unit was kept at an inclination of 25 degrees to facilitate flow of tomato juice after pulping. The pulper cum strainer unit consisted of following components

1. Feed Hopper: The feed hopper was made of stainless steel sheet of 1 mm thickness to induct tomato fruits into inner perforated stainless steel cylinder.

2. Stainless Steel Rotor Shaft: The rotor shaft was the key component of tomato pulper cum strainer unit. Stainless steel blade and nylon brushes were mounted on the shaft.

3. Design of Shaft: The formula and for designing the shaft was,

$$\frac{\pi}{16} f_s d^3 = T \quad ...3.1$$

where

f_s = maximum allowable shear stress, kg/cm^2 [350 kg/cm^2]

d = diameter of the shaft, cm

T = torque, kg cm

Calculation of Torque

Length of flat = 7.62 cm

(c/c distance from shaft and flat)

Width of flat = 2.5 cm

Crushing strength of tomato fruits = 3.1 kg/cm^2

Force required to crush the fruits = 58.86 kg

It is assumed that the force is acting on the middle of the rod.

Torque on the shaft = 58.86 x 7.62/2 = 224.2 kg cm

By using equation (3.1)

d = 1.5 cm

Considering factor of safety 1.5,

d = 1.5 x 1.5

d = 2.25 cm

The rotor shaft of diameter 25 mm and 800 mm length was mounted on pillow block bearing at one end and gunmetal bush at other end.

4. Outer Stainless Steel Cylinder: An outer 1 mm thickness stainless steel cylinder with 250 mm diameter and 500 mm length was coupled with inner stainless steel perforated cylinder by stainless steel plate of 4 mm thickness.

5. Inner Stainless Steel Perforated Cylinder: The inner 1 mm thickness perforated stainless steel cylinder of 150 mm diameter and 480 mm length was welded with outer stainless steel cylinder with stainless steel plate and the bottom portion of the stainless steel plate was fixed on the frame. The perforation size was 2 mm diameter, so that only juice is filtered.

6. Stainless Steel Blade and Nylon Brush: A stainless steel blade of 470 mm length, 25 mm breadth and 6 mm thick was mounted on the rotor shaft by means of stainless steel flat of 76.2 mm length and 25 mm thickness. A nylon brush was provided in the opposite side of stainless steel blade, to avoid clogging of perforated screen.

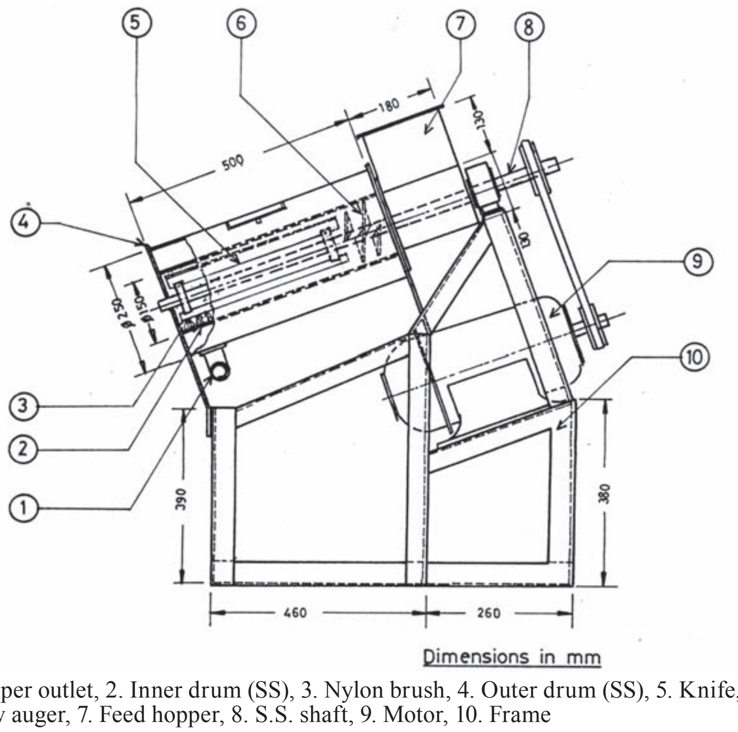
7. Discharge Outlet: Discharge outlet was provided at the bottom and lower end of the stainless steel sheet to collect the tomato juice. The skin and seeds were collected from the stainless steel perforated cylinder separately by opening the door provided at the discharge end of the cylinder.

8. Motor: Calculation of horsepower requirement

$$hp = \frac{2\pi NT}{4500}$$

Where N = speed of rotor shaft,

Fig. 1 Schematic diagram of tomato pulper cum strainer



1. Pulper outlet, 2. Inner drum (SS), 3. Nylon brush, 4. Outer drum (SS), 5. Knife, 6. Screw auger, 7. Feed hopper, 8. S.S. shaft, 9. Motor, 10. Frame

rpm

T = Torque, kg-m

The speed of rotor shaft is selected to be 300 rpm

T = 2.24 kg m

$$hp = \frac{2 \times \pi \times 300 \times 2.24}{4500} = 0.94$$

Hence, an electric motor of 1 hp was selected to drive the rotor shaft. Power was transmitted from the motor to the rotor by means of 'V' belts and pulleys. The schematic diagram of pulper cum strainer is shown in **Fig. 1**. Testing of tomato pulper cum strainer unit was carried out by varying the rpm of the rotor shaft. Extraction efficiency of juice has been computed for hot pulping (boiled in steam jacketed stainless steel pans for 3 min before pulping) and cold pulping of tomato fruits.

Results and Discussion

The tomato pulper was tested for local and hybrid varieties. The results of the experiment are presented in **Table 1**. Juice recovery by hot pulping is higher than cold pulping (Gridhari lal et al, 1998). Hot pulping sterilizes the juice partly, thereby checking to some extent the growth of microorganisms, which cause fermentation in the juice. Capacity of the pulper increases with peripheral speed, however extraction efficiency initially increases with peripheral speed and then decreases. This was due increase in rate of pulping to a certain extent and then fruits were conveyed without pulping as the contact time between blade and the fruits were minimum.

Conclusions

The maximum pulp extraction efficiency for local variety was 91.0 % by hot pulping at a peripheral speed of 47.1 m/s. The maximum pulp extraction efficiency for hybrid variety was 92.3 % by hot pulping at a peripheral speed of 47.1 m/s. The capacity of the unit was 110 kg/h.

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Table 1 Evaluation of tomato pulper cum strainer at different peripheral speeds

Capacity, kg/h	Peripheral speed, m/s	Extraction efficiency, % (local variety)		Extraction efficiency, % (hybrid variety)	
		Cold pulping	Hot pulping	Cold pulping	Hot pulping
85.2	33.3	70.5	70.5	74.7	76.5
91.7	39.0	78.0	78.0	76.3	79.5
110.0	47.1	90.0	91.0	90.4	92.3
120.5	59.9	83.0	83.5	85.2	88.5
135.0	63.2	80.5	81.6	81.8	86.3

Comparative Feasibility Analysis of Alternative Renewable Energy Sources for Small Milk Cooling Plants of Southwestern Uganda

by

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Abstract

The dairy industry in Uganda faces numerous challenges, one of which is the high cost associated with fossil fuel-driven milk cooling processes at locations without grid electricity. In this paper, alternative renewable energy sources, including solar and biogas, are compared to the existing diesel generator power source for a 3,000 L-capacity plant. Based on several economic indicators, the solar (evacuated tube) source coupled to an absorption refrigeration unit was found to be the most economical alternative for southwestern locations.

Introduction

In Uganda, agriculture accounts for over 40 % of GDP and more than 90 % of export earnings. Additionally, agriculture contributes over 60 % of total revenue and employs more than 80 % of the labor force, providing half of the income for the poorest three quarters of the population. The livestock sub-sector contributes approximately 20 % of the agricultural GDP and approximately 50 % of this is attributed to the dairy industry. Cattle dominate the livestock species in terms of numbers and monetary value and account for almost 90 % of the domestic animal biomass. It has been estimated that 90 % of the national cattle herd is in the hands of mixed farm smallholders and pastoralists, who individually can not afford any form of modern processing. Of Uganda's 2001 estimated total milk production of 900 million liters, only 10 % was processed into liquid milk and milk products.

To process the milk, the Uganda Government set up approximately 200 small cooling plant centers scattered around the country, with capacities ranging from 1,800-5,000 liters. In the past, the centers bought the milk from farmers and pastoral-

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ists. More recently, groupings of cooling plants have been combined and leased out to dairy farmers' associations. In return the associations guarantee the supply of a predetermined quantity of cooled milk to the Dairy Corporation, Limited (DCL), the entity that owns and services the plants.

Once it arrives at the centers, milk is immediately cooled in a 3 to 4 hour process, followed by transportation to a larger regional collection center from which insulated tankers transport the cooled product to the only processing plant in the capital of Kampala, owned by DCL. Sixty-two small cooling plants are located in Southwestern Uganda, one of two leading regions in milk production. Approximately 75 % of the small cooling plants are located in areas without grid electricity and are run by diesel generators. Where grid electricity is available, diesel generators are used as back up. Although the annual growth rate of milk production is estimated at 7-10 %, the industry faces numerous challenges, one of which is the energy cost associated with cooling milk or maintaining the "cold chain." The cause of the problem is rooted in escalating unregulated cost of diesel fuel, difficulties in monitoring and controlling intended fuel usage, rising cost of electric power and it's unreliable supply.

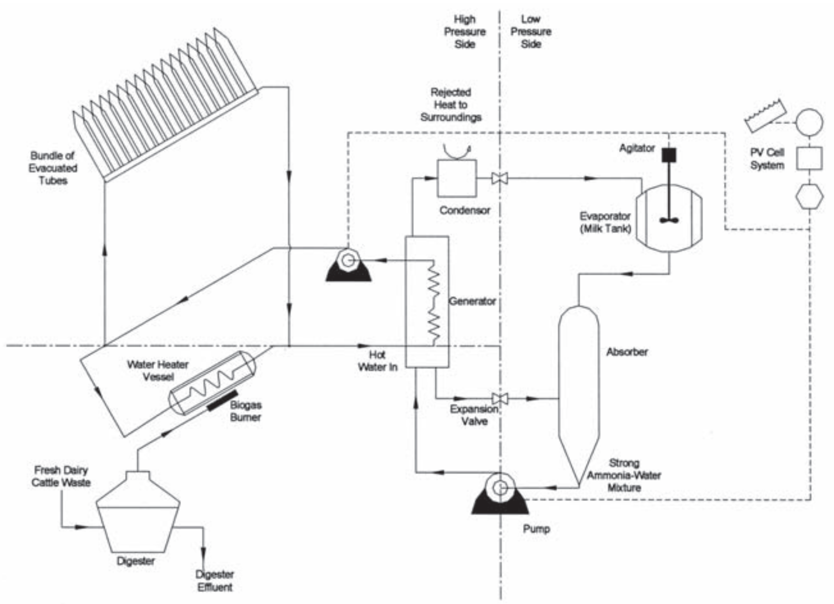
Since only cooled milk is processed, lowering the cooling cost should result in increased farmer earnings and consequently more milk offered through the formal market. This is consistent with the main strategic goals of the dairy industry (Mwesigwa and Mikenga, 2002): 1. increasing milk production, processing and marketing; 2. improving quality of milk and dairy products; and 3. commercializing milk production. The purpose of this paper was to evaluate the competitiveness of alternative renewable energy sources for typical small milk cooling plants of 3,000 liter capacity (predominant plant size) located anywhere in Southwestern Uganda.

Alternative Energy Source Concepts

Alternative energy sources and accompanying refrigeration units are presented in **Table 1**. After a thorough analysis, the list was narrowed down to three candidate concepts for detailed design and economic analysis. The top three concept candidates were biogas, solar/evacuated tubes and solar/photovoltaic (PV) cells. Plant schematics of these processes are presented in **Figs. 1** and **2**.

Animal draft was eliminated because in Southwestern Uganda, use of cattle for work is not consistent with the cultural place of the animal as an admired or valued form of "currency"; somehow, use of cattle for work can be considered disrespectful of the delicate human-animal relationship (Dr. J. Sentongo-Kibalama, Makerere University, personal communication). As such, efforts to deploy animal-powered technologies are likely to meet stiff resistance in Southwestern Uganda. This may not be the case in other parts of Uganda. Although fuel cells are considered more efficient than diesel generators, current costs of $4000-$5000 per kW (www.fctec.com) are prohibitive. Additionally, fuel (e.g., hydrogen and natural gas) is not readily available in Southwestern Uganda. To use geothermal energy, the source must be tapped by drilling deep into the ground to reach the hot water stored within the earth's surface. Production wells and injection wells are then used to pump the hot water to the surface and then returned back to the earth. Direct use can be applied to any situation where heat is needed. For instance, in this project the hot water (75 -150 ºC) can be used to power an absorption refrigeration system. Preliminary investigations into geothermal resources revealed that there are potential sites in the western region of the East African Rift System (Mugadu, 2000). However, no follow-up studies have

Fig. 1 Schematic of biogas- or evacuated tube-power absorption milk cooling plants. To improve system efficiency, practical absorption refrigeration systems usually include a heat exchanger (between the absorber and the generator), a distiller/deflagmator (between the generator and condenser), and a pre-cooler (between the condenser and the evaporator) that are not shown



been reported.

Pico hydro units are small systems (up to 5 kW) that require small water flows. This has made pico hydro units desirable because they can be used at many sites (Maher and Smith, 2001). The maximum refrigeration capacity (RC) for the target system was estimated as follows. RC = V x p x C_p x $\Delta T/t$ = 26.52 x 10^3 W = 7.54 tons, where V = milk volume (3,000 L), p = milk density (1.02 kg/L), C_p = milk specific heat capacity (3.9 x 10^3 J/kg.K), ΔT = difference in milk temperature before and after cooling (28 - 4 = 24 K), t = time required to cool the milk (3 h x 3,600 sec/h = 10,800 sec). As demonstrated above, the required RC far exceeded the maximum capacity of pico hydro systems.

According to Atuheire (2002), the average yearly wind speed (U) in Uganda at a height of 22 m is approximately 5.5 m/s (~12.3 mph). The available yearly wind power per unit area (P/A) can be calculated from: P/A = 0.5 pU^3, where p is the air density (equal to 1.0514 kg/m^3 at the area of interest). Substituting the above values, P/A comes to 87.96 W/m^2. Locations with P/A values less than 100 W/m^2 are unsuitable for continuous sustainable power generation due to the fact that the maximum power producing potential obtainable from the kinetic energy contained in the wind is approximately 60 % of the theoretical maximum power. In reality, this percentage is only about 40 % due to the efficiency of even the best wind turbines available (Manwell et al, 2002).

Fig. 2 Schematic of grid electricity-, photovoltaic cell-, or diesel generator-powered vapor compression milk cooling plant

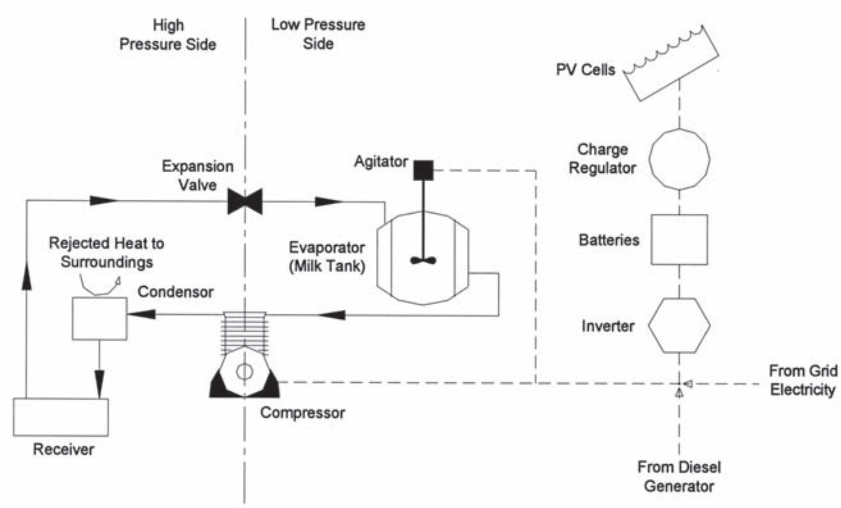
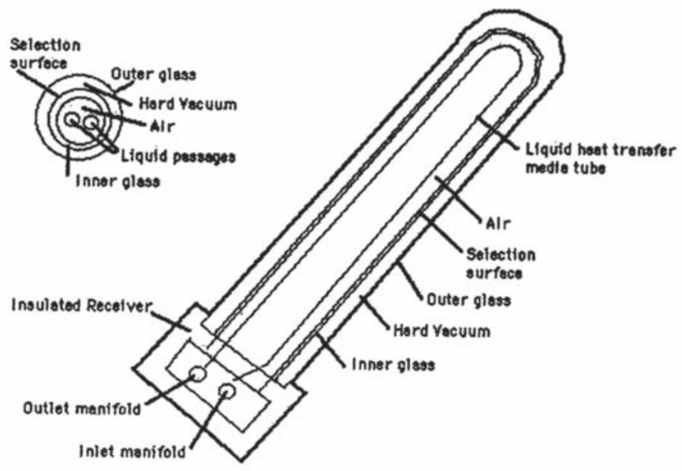


Fig. 3 Schematic of an evacuated-tube collector



Design Details and Cost Estimates

Biogas-Absorption Refrigeration Plant

A design procedure published by Sun (1997) for ammonia-water absorption refrigeration systems was followed with the following assumptions: 1) evaporator temperature, -8 ºC > T_E > -5 ºC; sink temperature, T_S = 30 ºC; concentration of the refrigerant at entrance to the evaporator, x_{15} = 0.99 kg NH_3/kg solution; generator temperature, T_8 = 100 ºC. For a desired final milk temperature of 4 ºC, the energy balance for the ammonia-water absorption refrigeration system is presented in **Table 2**. The cost of the ammonia-water refrigeration unit was estimated to be $8,000 based on the industry experience of $1,000/ton (Mr. Hidekazu “KURI” Kurihara, HIJC USA, personal communication). As shown in **Table 2**, the biogas burner must deliver 43.39 kJ/sec either directly or via a hot water vessel. Assuming a biogas energy content of 11,821 kJ/m^3, an overall biogas burner efficiency of 55 % (Gunnerson and Stuckey, 1986) and two 3-hour cooling cycles per day, the daily biogas demand comes to 144 m^3/day [(6 h/day x 3600 sec/h x 43.39 kJ/sec)/(0.55 x 11,821 kJ/m^3)]. This biogas demand value can be used to either size a digester following well established procedures (e.g., Ward, 1986; Gunnerson and Stuckey, 1986; Marchaim, 1992), or estimate the digester cost using published unit cost, e.g., per cubic meter of biogas produced. The floating-drum biogas plant is the most popular for domestic applications in Uganda. Typical productivity (biogas) and plant construction costs are 0.2 m^3/m^3/day and US$100/$m^3$, respectively (Agricultural Engineering and Appropriate Technology Institute files, Namalere). Assuming linear scaling, the plant size needed came to 720 m^3 [(144 m^3 biogas/day)/(0.2 m^3/m^3/day)]. A simpler digesters made up of a pit in the soil without coating or plastering with a synthetic rubber as a variable gas-holder (Henning, 1986) was considered, but not adopted due to anticipated maintenance problems at the proposed scale. As shown in **Fig. 1**, electricity is needed to run all pumps as well the controller (not shown). The PV cells system selected in the next section should be adequate. The cost breakdown for all units considered is shown in **Table 3**. There may be opportunities to capture some of the lost heat and use it to heat the digester. This would increase the biogas productivity, reducing the digester size and consequently reducing the capital cost.

Solar-Absorption Refrigeration Plant

To deliver 43.39 kW to the generator via conventional flat plate collectors would require an unmanageable surface area. A choice was made to use evacuated tube collectors. Use of vacuum allows this type of solar collector to insulate against heat loss and to prevent the absorber coating from deteriorating. As shown in **Fig. 3**, the basic design of an evacuated tube is an upside-down vacuum bottle that contains a liquid-filled tube that runs through the middle of the tube in a hairpin like fashion. The bottle is a double-glass design that has an absorber coating on its inner glass. To heat the inner liquid, the sun's radiation travels through the outer glass layer and makes contact with the absorber coating. This traps the radiation in the bottle and heats the air inside of the bottle. The air then heats the liquid in the tube. At the end of the tube is a manifold in which the liquid filled tube is connected to. The manifold collects the liquid in the tubes from several bottles. From the manifold, the liquid can then be pumped for a direct heat use application. For this project, the liquid will be pumped into the absorption machine to supply the generator with its required heat input. The required energy of 260.43 kWh/day (43.39 kW x 2 cooling cycles/day x 3 h/cycle) and the minimum average insolation for Uganda of 4.5 kWh/m^2/day (16,200 kJ/m^2/day) were used in the calculator at www.focus-solar.com to estimate the number of tubes required of 1,408.021 (47 bundles of 30). With a specific area of 3.52 m^2/bundle, the resultant total area of 165 m^2 was considered reasonable. At $620/bundle, total

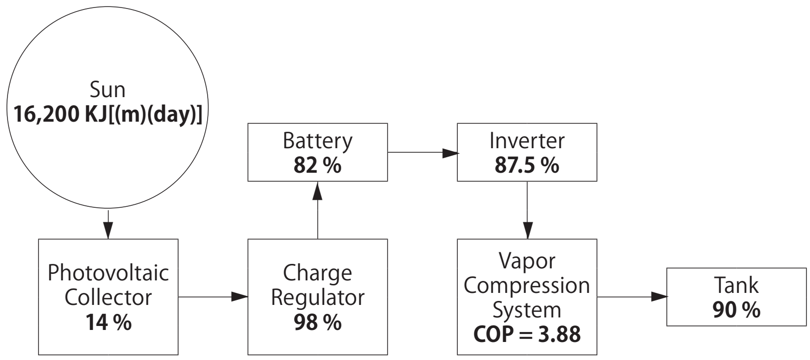
Table 1 Alternative energy sources and accompanying refrigeration modalities

Concept Number	Energy source	Energy conversion/production	Accompanying refrigeration unit type	Sample reference
1	Animal draft	Electric generator coupled to a gear box	Vapor-compression	Dasa and Dasa (1987)
2	Biogas	Animal waste anaerobic digester	Absorption	Sasse (1984)
3	Chemical	Electricity from hydrogen and air reaction in a fuel cell	Vapor-compression	www.fctec.com
4	Geothermal	Direct hot water use	Absorption	Mugadu (2000)
5	Pico hydro	Electricity from pico generator	Vapor-compression	Maher and Smith (2001)
6	Solar	Hot water from evacuated tubes	Absorption	www.focus-solar.com
7	Solar	Electricity from photovoltaic (PV) cells	Vapor-compression	www.mrsolar.com
8	Wind	Electricity generated by a wind mill	Vapor-compression	Manwell et al (2002)

Table 2 Energy balance for the optimal ammonia-water absorption refrigeration system

Item	Quantity	Units
Refrigeration capacity	26.50	kW
Heat input to the generator	43.39	kW
Work done by the pump	0.13	kW
Heat rejected from the condenser	26.45	kW
Heat rejected from the deflegmator	2.23	kW
Heat rejected from the absorber	41.83	kW
Refrigeration effect	1,191.39	KJ/kg
Coefficient of performance	0.61	

Fig. 4 Energy conversion efficiencies for PV vapor compression refrigeration system



cost came to $29,140. To move the liquid through the evacuated tube system (including the tubes, manifold, and piping) and the generator, a small pump with a flow rate of approximately 2 L/min (40 W, $330) was recommended. Other system pumps include the agitator (124 W) and the absorption unit pump (130 W). Total energy came to 6,350,400 J/day ([940 J/sec + 124 J/sec + 40 J/sec] x 6 h/day x 3,600 sec/h). By dividing this energy demand by the isolation and the applicable efficiencies shown in **Fig. 4**, the required PV panel area came to 4.336 m^2 (6,350.4 kJ/day)/(16,200 kJ/m^2/day x 0.9 x 0.875 x 0.82 x 0.14). This area can be accommodated by 32-15" by 14" PV panels at a total cost of $1,920. The associated cost for batteries, regulator and inverter are shown in **Table 3**. Existing solar data indicates that solar energy resource in Uganda is high throughout the year with yearly variation (max month/min month) of only 20 %. This lack of variability has been attributed to location near the equator and eliminates the need for back-up systems.

Table 3 Breakdown of cooling plant equipment costs[1]

Diesel Generator-Powered Vapor Compression Plamt:	
Tank	$18,720.00
Compressor	$5,000.00
Diesel generator (27 kVA)	$8,750.00
Overall process controller	$2,000.00
Total	$34,470.00
Biogas-Powered Absorption Plant:	
Tank	$18,720.00
Ammonia-water absorption unit including the burner	$8,000.00
Cattle waste digester	$72,000.00
PV cells	$1,920.00
Batteries, regulator and inverter	$1,551.00
Extra pump	$330.00
Additional piping	$240.00
Overall process controller	$2,000.00
Total	$104,761.00
Solar (Evacuated Tube)-Powered Absorption Plant:	
Tank	$18,720.00
Ammonia-water absorption unit	$8,000.00
Evacuate tubes	$29,140.00
PV cells	$1,920.00
Batteries, regulator and inverter	$1,551.00
Extra pump	$330.00
Additional piping	$1,114.00
Overall process controller	$2,000.00
Total	$62,775.00
Solar (PV Cell)-Powered Vapor Compression Plant:	
Tank	$18,720.00
Compressor	$5,000.00
PV cells	$46,800.00
Charge regulators	$4,576.00
Batteries	$14,872.00
Inverters	$3,192.00
Overall process controller	$2,000.00
Total	$95,160.00

[1]All costs are in 2003 US$

Solar-Vapor Compression Refrigeration Plant

Based on the amount of energy to be removed from the milk per day (two cooling cycles) of 2 x 286,416 kJ and the efficiencies of the system components shown in **Fig. 3**, the required PV cell area came to 100.8 m^2 (2 x 286,417 kJ)/(3.88 x 0.9 x 0.875 x 0.82 x 0.14 x 16,200 kJ/m^2). This area of collection, which is approximately the size of the rooftops of the facilities, was considered reasonable. The typical total cost for PV cells came to $46,800. The inverter was sized primarily on the demand of the vapor compression subsystem of 3,730 W (5 Hp). For this load, a 4,500 W inverter was selected to account for the agitator motor demand of 124 W and any other lighting or small applications that might be needed. The input for the inverter of 48 V dc is generated by the series connection of four 12 V batteries. In total, the system required 13 of the 48-volt arrays that are connected in parallel for additive current at the same voltage. The inverter was also selected to deliver the specified single phase, 220 V, 50 Hz current needed to power the 3.73 kW (5 Hp) vapor compression unit.

Economic Comparison

The economic information used and the results of the financial comparison are summarized in **Table 4**. Actual interest rate (*i) was calculated from *i = [100 x (100 + market interest rate)/(100 + inflation rate)] - 100. *i of 12.91 was obtained with market interest and inflation rates of 19.57 and 5.90, respectively (The Economist Intelligence Unit Country Report, Uganda, 1st quarter, 1999 - www.eiu.com/schedule). Service life (T) of all the equipment was assumed to be 20 years. The break down of investment expenditures (I_E) for each system is shown in **Table 3**. It was assumed that the residual value (L) after service years was zero, as the equipment should be fully depreciated. Manpower costs were based on two employees (plant manager and operator) for the evacuated tube and PV cell plants. An additional digester attendant was deemed necessary for the biogas plant. Maintenance & repair costs, auxiliary materials, and administrative costs were based on current experience and were assumed to be the independent of plant type.

Energy cost for the diesel plant was based on records from a typical plant. On average 150 L of diesel fuel was consumed per week. The annual cost was computed at a rate of 0.80 US$/liter. The energy cost under the biogas plant is a reflection of the cost of collection from nearby facilities by 4 to 5 laborers on bicycles. The total operating cost (K_o) is the sum of the manpower, energy, maintenance/repair, auxiliary materials, and administrative costs. Operating income (I_O) was based on 50 % capacity (1500 L/cycle/day) and 30 Uganda Shillings (US$ 0.015873) income per liter cooled, which came to $17,143.00 (2 cycles/day x 1500 L/cycle x 360 days/year x $0.015873). Total income (I_T) is the sum of savings on energy (I_E) and operating income (I_O). Return (R) is the difference between total income (I_T) and total operating costs (I_O). Straight-line depreciation was assumed.

The concepts were compared with respect to total cost (K) per kWh, cost-annuity (A_K) per kWh, Return on Investment (ROI), payback period (n) and Net Present Value (NPV). Formulas from Finck and Oelert (1985) were used and are briefly shown in **Table 4**. The total kWh needed to cool 3,000 liters of milk is 57,877.2 kWh/year (26.795 kW x 6 h x 360 days/year). Cost annuity is different from costs per year in that it is a conversion of the investment cost to equal annual payments (annuities). It is done using a recovery factor (RF) that is obtained using the applicable interest rate and serviceable years. In this project RF was 0.134. NPV of an investment is the sum of all cash inflows and outflows discounted to the present. NPV = -Investment costs + (Returns per year x PF) + (Liquidation yield x discounting factor). A higher number is preferred. The Present

Table 4 Economic data and evaluation per annum[1]

	Diesel generator	Evacuated tubes	PV cells	Biogas
Project Data:				
Actual interest rate (*i, %)	12.91	12.91	12.91	12.91
Investment expenditure (C_I, US$)	34,470.00	62,775.00	95,160.00	104,761.00
Residual value (L, US$)	0.00	0.00	0.00	0.00
Serviceable life (T, years)	20	20	20	20
Manpower costs (C_M, US$)	1,579.00	1,579.00	1,579.00	2,211.00
Maintenance and repair (C_{MR}, US$)	500.00	500.00	500.00	500.00
Auxiliary materials cost (C_{AM}, US$)	100.00	100.00	100.00	100.00
Administrative costs, excluding manpower (C_A, US$)	300.00	300.00	300.00	300.00
Energy costs (C_E, US$)	6,000.00	0.00	0.00	650.00
Taxes and levied not dependent on profit (C_T, US$)	0.00	0.00	0.00	0.00
Other expenditures (C_O, US$)	0.00	0.00	0.00	0.00
Total operating costs (K_O, US$); K_O=C_M+C_{MR}+C_{AM}+C_A+C_E+C_O	8,379.00	2,479.00	2,479.00	5,350.00
Savings on energy (I_{SE}, US$); I_{SE}=Diesel Gen. C_E-C_E	0.00	6,000.00	6,000.00	5,350.00
Operating income (I_O, US$)	17,143.00	17,143.00	17,143.00	17,243.00
Other incomes (I_{OT}, US$)	0.00	0.00	0.00	0.00
Subsidies (I_S, US$)	0.00	0.00	0.00	0.00
Total income (I_T, US$); I_T=I_{SE}+I_O+I_{OT}+I_S	17,143.00	23,143.00	23,143.00	22,593.00
Return (R, US$); R=$I_T$-$K_O$	8,764.00	20,664.00	20,664.00	17,243.00
Depreciation (D, US$)	1,724.00	3,139.00	4,758.00	5,238.00
Net profit (P, US$); P=R-D	7,040.00	17,525.00	15,906.00	12,005.00
Economic Evaluation:				
Total cost per year (K, US$), K=$K_O$+($C_I$/T)+($C_I$*i/2)	12,328.00	9,670.00	13,380.00	17,350.00
Cost per kWh (US$/kWh); K/57,877.2	0.21	0.17	0.23	0.30
Cost-Annuity (A_K, US$); A_K=K_O+(C_I-L)RF+L*i; RF=0.134	12,998.00	10,891.00	15,230.00	19,388.00
Cost annuity per kWh (US$/kWh); A_K/57,877.2	0.22	0.19	0.26	0.34
Return on investment (ROI, %); ROI=100(P/0.5C_I)	40.8	55.8	33.3	22.9
Pay-Back period (n, years); n=C_I/R	3.9	3.0	4.6	6.1
Net present value (NPV, US$); NPV=-$C_I$+[R(PF)]+l($q^{-1}$); PF=7.469	30,988	91,564	59,179	24,027

[1]All dollar amounts are in 2003 US$

Factor (PF) is obtained using the applicable serviceable life and the interest rate. The PF in this project was 7.469. Because the liquidation yield is zero, the last term is zero.

Discussion and Concluding Remarks

The biogas and current diesel-driven systems were the most economically unattractive options; they exhibited the lowest NPVs. The cost to implement the Photovoltaic system greatly affects its economic viability. While the NPV and annuity seem competitive, the cost per kWh is greater than even the current system. Evacuated tubes turned out to be the most economical alternative with the shortest pay back period of 3.0 years, and an impressive ROI of 55.8 %. It should be pointed out that this evaluation is considered conservative due to the fact that while operating expenses are based on full plant capacity, income is based of 50 % capacity.

There are two main uncertainties associated with the evacuated tube choice. First, the scale of absorption refrigeration proposed is not widely practiced. Most installed absorption refrigeration plants are in developed countries, with capacities greater than 100 kW (versus the proposed capacity of approximately 30 kW). The changes in scale may affect the assumed scale-capacity relationships used in the economic calculations. Second, there are no known evacuated tube applications in Uganda. Most solar energy applications employ PV cells or flat panel collectors. However, specific industry focus with proven indigenous technical expertise and service network that is in place for the current vapor compression systems are strengths expected to overcome any potential technology adoption bottlenecks.

The current hydroelectric cost in Uganda is approximately 0.10 US$/kWh, well below the cost for the recommended energy source in this study of 0.17 US$/kWh. The recommendation is therefore for locations without hydroelectric grid. There are national plans to extend the grid, however, the targets are high population density locations or high volume industry consumers; the capital cost for remote agricultural locations are considered prohibitive. It would be prudent to study the grid extension plans and timetable for a given location before investing in a solar plant.

The two most important factors in the success of any alternate technology in the Sub-Saharan Africa environment are cost, reliability and appropriateness. While cost can be reliably predicted, the remaining two attributes can only be conclusively established by practice. It is hereby recommended that a full sale evacuated tube plant be pilot tested before wide spread technology deployment is attempted.

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Development of a Simple Pulper for Leaves of Green Plants

by

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Abstract

A simple vegetable pulper was designed and fabricated. The machine consists mainly of a 1,450 rpm rotor and chopper operating in a large hopper. Driven by a one horse power single phase motor the machine has a capacity of about 17 kg per batch. In evaluating the performance of the machine, the leaves of four plant species were used including; cassava (Manihot esculenta), bitter leaf (Vernonia amydalina), and Siam weed (Chromlaena odorata) and glircidia (Gliricidia maculata). The leaves of the plant species were macerated in the machine for six minutes with particle size analysis being done after each minute using the ASAE Standard S424 (1989).

Results indicated that the coarsest material, vernonia, after six minutes of pulping, reduced to a size of 3.5 mm while the finest material after the same period, manihot leaves, attained a size of 2 mm. Compared to the manual method, the machine reduced chopping time per batch of 17 kg by about four hours. Plots of duration of pulping versus feed size indicate a good relationship between the two, the best given by vernonia (R^2 = 0.9892 and the least by chromolaena (R^2 = 0.9598).

Introduction

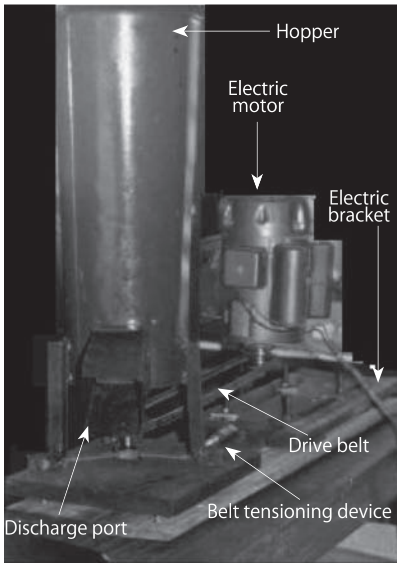
Size reduction of the leaves of green plants is an important step in their processing. Most leaves of vegetable plants and medicinal plants are chopped before cooking, drying or consumption. In the extraction of leaf protein concentrate from the leaves of green plants, the leaves are first macerated to smaller particles.

There are several reasons why the size reduction of the leaves of some green plants prior to their processing into other products is important. The maceration of the leaves of green plants prior to leaf protein concentrate extraction is important because maceration destroys the cell wall material thereby liberating the protein containing cells (Mciejewiez-Rys & Hanczakovwski, 1990; Pirie, 1987; Taylor, 1983; Faskin, 1999; Donnelly & McDonald; 1979). Maceration of the leaves of vegetable plants before drying increases the surface area available for moisture extraction and this makes the drying process faster. Also, chopping of the leaves of green plants results in densification leading to a reduction in bulk volume which facilitates transportation (Aboaba, 1971).

In West and Central Africa, the leaves of so many vegetable species are first chopped before cooking. Some vegetable leaves such as cocoa yam leaves have very large surface areas (up to 1 m^2) and for these leaves to be easily cooked, they have to be chopped into smaller particles. Other vegetables such as Gnetum africanum (eru) must first be intensely chopped before cooking and eating because the high fibre content makes the chewing of un-chopped leaves very difficult.

The importance of chopping the

Fig. 1a Pulper mounted in the laboratory for use



leaves of some green plants cannot therefore be over emphasized. In most of Central and West Africa, the chopping of leaves of green plants for various processes is done manually, despite the tedious and time consuming nature of this activity when using some species. This sometimes accounts for the high cost of processed vegetables in the local markets. In the case of Gnetum africanum, a widely consumed vegetable in the West African subregion, the cost of a kilogram of the chopped leaves is about tens times as much as the cost of a the kilogram of un-chopped leaves. This problem has been aggravated by the lack of appropriate machinery in the local markets. The only piece of equipment used by most people for vegetable chopping in this region is the motorised kitchen blender. This is inappropriate in many ways. First, the capacity is very small and it can only process a few grams of vegetable per batch. Second, when used for vegetable chopping, the end product is always a paste because water has to be added before proper size reduction. The only evidence of large scale mechanised chopping of green leaves is found in tea processing industries. These machines are out of the reach of the common man in the developing nations. Like most machinery designed and developed in the advanced countries, these pulpers are inappropriate for use in the developing countries because of the low level of technical know how. Quite often, when these machines break down, spare parts and, at times, labour have to be imported to maintain them.

Because of all these complications it was necessary to design, develop, fabricate and test a simple vegetable chopper that would meet the needs of the local people.

Materials and Methods

The pulper was designed taking into consideration the socio economic conditions of the rural Central and West African population. The materials selected for the design of various components were those available in the local markets in these regions. Fabrication and purchase of spare parts would therefore be very easy. It was important that the machine be very simple, requiring very little training before use, or else the rural population might not accept it. Also, the cost of the machine had to be within the reach of the target group.

The machine is shown on **Fig. 1(a)**. The detailed engineering design including power estimation and the design of machine elements is available in Tangka (1995). The machine consists of a hopper tapering from a diameter of 230 mm at the

Fig. 1b Diagram of the rotor shaft showing the positioning of the cutter blade. A, C Bearings; T_1T_2 tension on the belt

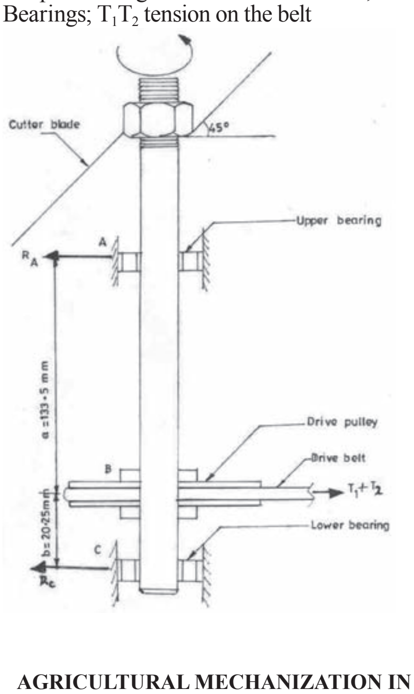
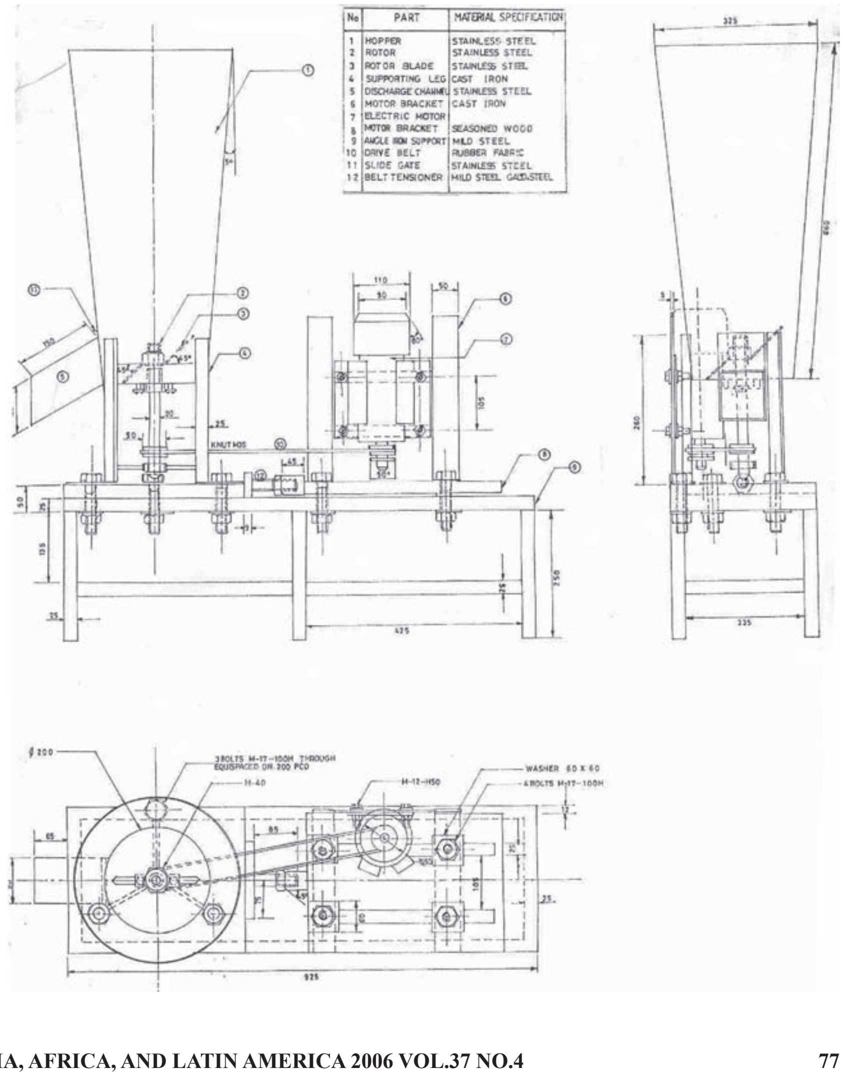


Fig. 1c Orthographic projection of the pulper



top to 200 mm at the bottom over a span of 660 mm. The bottom is sealed with a 3 mm thick stainless steel plate. A 22 mm diameter opening is made at the centre of the base plate through which a rotor shaft is inserted into the hopper. The shaft of diameter 20 mm and length 243 mm is threaded at the top along a length of 30 mm. The threaded section has a slot of thickness 7 mm, enough to receive the connecting rod of a chopper element shown in **Fig. 1(b)**. The cutter element is made of two stainless steel knives each 150 mm long by 40 mm wide by 2 mm thick. In operation, the cutting edges are sharpened down to a thickness of 0.3 mm. The two knives are welded in a slanting position on opposite ends of a connecting rod making an angle of 45º to the vertical when mounted. The connecting rod is 6 mm by 6 mm by 22 mm long. The cutter element is then fitted onto the rotor shaft where it is held firm as shown in **Fig. 1(b)** by a nut (M 23). The shaft is held in position by two bearings of internal diameter 20 mm. The housing of the upper bearing is bolted unto the bottom of plate of the hopper by two bolts and nuts (M 10). The shaft is driven through a pulley of diameter 50 mm by a 1.12 kW (1.5 hp) electric motor. The hopper has a square section discharge channel of length 150 mm. The channel slopes at an angle of 35º to the horizontal to ensure easy discharge of macerated matter when a slide gate located at the entrance is opened.

The above arrangement is suspended on three angle bar supports of height 130 mm. The supports are bolted onto a rectangular wooden bracket 295 mm x 290 mm by 25 mm thick. This wooden bracket is bolted to a supporting wooden member 290 x 947 by 25 mm thick. This basal member contains two slots 360 mm x 17 mm separated by a distance of 150 mm. The slots enable the electric motor bracket to be moved to or from the hopper using four bolts each (M17), thereby tensioning the belt.

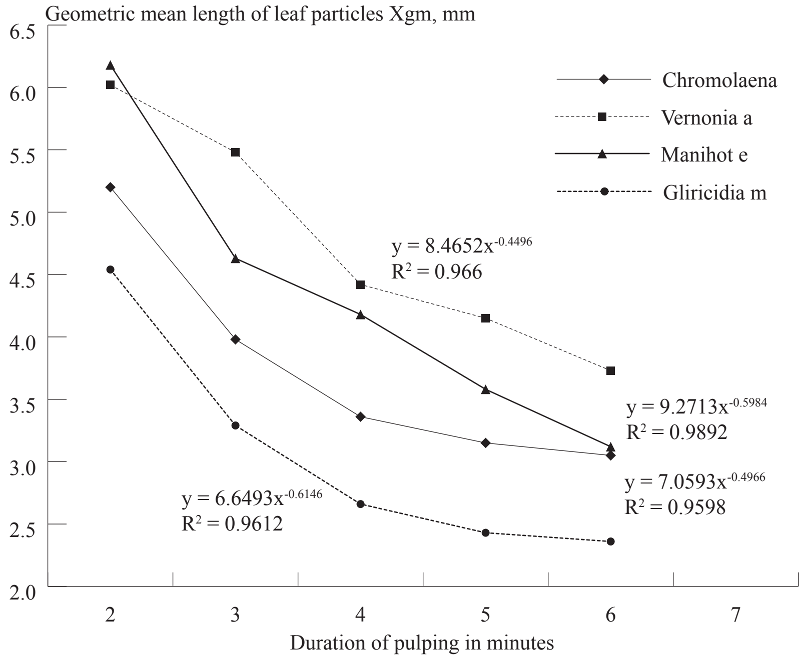
Performance Evaluation of the Pupler

The leaves of some vegetable species consumed widely in West and Central African region were used to test the performance of the pulper. Also, the leaves of other useful plants were used. These were: cassava (Manihot esculenta) leaves, bitter leaf (vernonia amydalina), Siam weed (chromlaena odorata) and Gliricidia (Gliricidia maculata). Each leaf sample was fed into the hopper until full. With compaction, the hopper could contain up to 17 kg of leaves. The discharge port of the machine was blocked with the slide gate. The machine was set into operation and timed with a stop clock. As pulping continued, the particle size of the resulting pulp was analysed periodically through the use of a slight modification of the ASAE Standard S424 (1989). The slight modification included the use of eight sieves instead of the five proposed by the standard. The eight sieves had the following sizes 13.2 mm, 6.7 mm, 4.75 mm, 2.36 mm, 1.7 mm, 1.18 mm, 850 µm, 600 µm, and the pan. The advantage of this modification was that it gave a more detailed representation of the feed size than would have been possible using the ASAE Standard S424 (1989) without modification.

The sieves were fitted together in order of coarseness from the most coarse down to the pan and covered with a lid. The sieve arrangement was then clamped onto a Ro-Tap sieving machine and sieved for five minutes or until there was no noticeable change in weight of the contents of each sieve. The material retained in each of the eight sieves was weighed. It is important to note that with the material being sieved after five minutes of pulping, it became necessary to agitate the material in the sieves after some time, to prevent clogging. After six minutes of pulping, it was not possible to determine the size using this method because of the wetness of the feed and the consequent clogging of the sieves.

Size determination was first done after two minutes of pulping for all

Fig. 2 Variation of the geometric mean length X_{gm} of leaf particles with duration of pulping



the leaves of the plant species. The sample was thoroughly mixed and put back into the machine. The machine was operated for six minutes with particle size analysis being done after each one minute. The particle size was determined using the equation,

$$X_{gm} = \log^{-1}\left[\frac{\sum_{i=1}^{n}(M_1 \log x_1)}{\sum_{i=1}^{n} M_1}\right] \quad \text{.............(1)}$$

$$S_{gm} = \log^{-1}\left[\frac{\sum M_1(\log x_1 - \log X_{gm})^2}{\sum M_1}\right]^{\frac{1}{2}} \quad \text{.....................(2)}$$

$$x_i = (X_i X_{(i-1)})^{\frac{1}{2}} \quad \text{.................................(3)}$$

Where

X_i = the diagonal of the screen opening of the i^{th} screen in mm

X_{gm} = the geometric mean length of the whole sample in mm

X_{gmT} = geometric mean length (in mm) of particles after time T in minutes

χ_i = the geometric mean length of particles on the i^{th} screen in mm

T = time of pulping in minutes

M_i = mass of feed retained on the ith screen (percent total)

$X_{(i-1)}$ = diagonal of screen openings in the next larger than i^{th} screen (starting from the smallest) in mm

S_{gm} = Standard deviation

Φ = the maceration rate of the leaves mm/min

n = the number of sieves

The grindability (defined here as the rate of grinding of material in a particular mill or the rate of decrease of the geometric mean length of the particles with respect to time) was evaluated from the following equation.

$$\Phi = \frac{dX_{gm}}{dt} \quad \text{....................................(4)}$$

The minus sign indicates that the Xgm is decreasing.

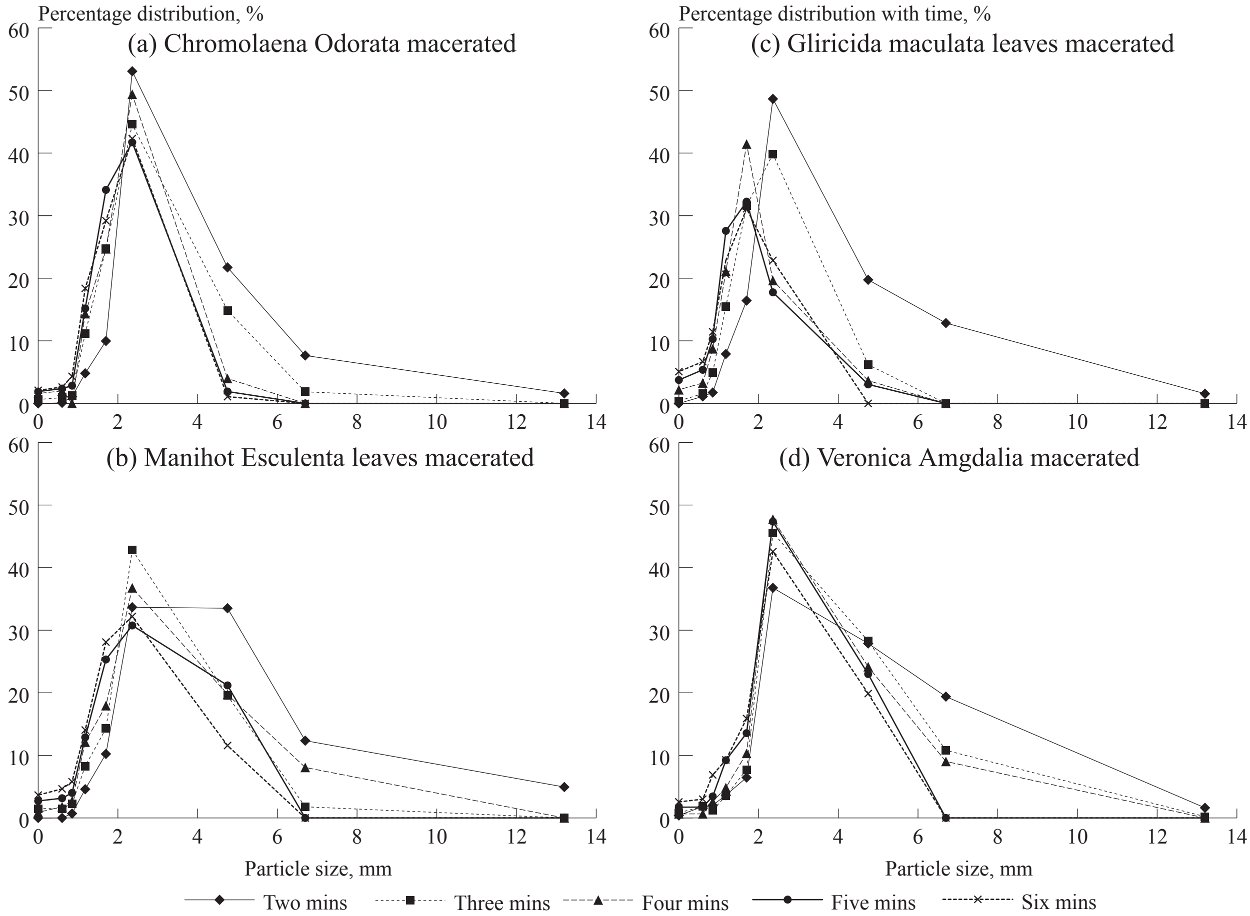
Equation 3 can also be written as mm/min

$$\Phi = \frac{X_{gm0} - X_{gmT}}{T} \quad \text{...........................(5)}$$

Results, Analysis and Discussion

Fig. 2 shows the variation of the geometric mean length of leaf particles with time. It can be seen that the size of the feed decreases rapidly during the first four minutes of pulping after which size reduction continues at a very slow rate. For leaves of Gliricidia maculate, the size of 2.4 mm seems to be the smallest achievable with this

Fig. 3 Particle size distribution for (a) Chromolaena Odorata, (b) Manihot Esculenta leaves, (c) Gliricida maculata leaves, and (d) Veronica Amgdalia macerated through six minutes



machine while the curve for Chomolaena odorata flattens out at 3.1 mm size. For Manihot esculanta and Vernonia amygdalina, size reduction continues after six minutes but, due to juice flow from the pulped matter, it was difficult to accurately determine the size of the feed after this period. The relationship between the time of pulping and the size of the feed shows some good correlation; the best being for Manihot esculenta with an R^2, of 0.99 and the least being Chromolaena with an R^2 of 0.96.

From these plots it can also be seen that it is possible to estimate the size of the feed by just measuring the time of pulping. This can be very useful because the method of sieving, although the most accurate, is very tedious when clogging of the sieves starts. **Figs. 3(a)** to **3(d)** show the behaviour of the different plant samples in the machine. The curves are all skewed to the left showing that as the material gets finer, the rate of grinding reduces.

Results of grindability tests calculated from equation (4) are shown on **Table 1**. The highest rate is given by manihot 0.51 mm/min and the lowest shown by 0.36 mm/min. The higher the grindability, the faster it is for the material to be reduced to a smaller size. Tangka (1995) attributes the differences in grindability of plant leaves to the differences in cell densities of the various plant species. The more cells per unit area on the cross section of a leaf, the more the cell wall material has to be destroyed during grinding and the lower the grindability. Perry and Green (1984), state that the main purpose of the grindability study is to evaluate the size and type of mill needed to produce a specified tonnage and the power requirement for grinding. The results obtained here could not be compared to any other because there is no other machine available in this region for chopping of vegetable matter.

Table 1 Grindability test for different plant species using the pulper

Plant species	Grindability, mm/min
Chromolaena Odorata	0.36
Veronica amygdalina	0.38
Manihot esculenta	0.51
Gliricidia maculata	0.36

The machine was judged very effective in chopping the leaves of green plants when compared to the manual method and traditional method. For some traditional applications, it was just necessary to operate the machine for two minutes to transform 17 kg of the feed to the required size. Tests using the traditional method showed that it took about four hours for a person working at average speed, to chop 17 kg of vernonia to a size of about 6 mm. This was only possible if the manual chopping was accompanied by pounding using a traditional mortar and pestle. Otherwise at the end of the two hours, the product would not be fine enough to pass through the 6 mm sieve.

The total cost of the machine was about $500 but this could be considerably reduced if it was mass produced.

Conclusions

A machine was successfully designed and fabricated. The machine could macerate 17 kg of green leaves to a size of 2.5 mm in two minutes. There was a limit to which the size of each plant leaf could be reduced using this machine. There was a good correlation between the time of pulping and the size of the feed for the materials tested. The cost of the machine was about $500. The price of most small scale food processing machinery in this region was around this amount and as such the price was appropriate.

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Constraints and Prospects of Agricultural Mechanisation in Samoa

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Abstract

This paper discusses the Samoan topography, soil type, climate, farming systems preferred by farmers and crops cultivated. The constraints and potential of mechanization have been pointed out. Some suggestions have been put forward to encourage the farmers to adopt mechanised cultivation in order to increase agricultural production for both subsistence and commercial farmers. Agricultural mechanisation will gain a positive momentum if, at least, some of the suggested policies are adopted.

Introduction

Samoa comprises of a group of islands in the South Pacific Ocean located between 13º and 15º South latitude and 168º and 173º West longitude. It consists of two large islands, Upolu and Savaii along with seven smaller islands. It covers 3,039 square kilometers of land area with a population of about 176,848 people of which 90 % are ethnic Samoans (Government of Samoa, 2001) and a literacy rate of 98 %. The population density is 58.19 per square kilometer. The natural rate of population growth is around 2.4 %. However, emigration has reduced the actual population growth to less than 1 % per annum. Most people live in villages near the coast and normally farm the coastal strips. There is a strong trend among people to move from rural areas to the capital, Apia, seeking better work and more income opportunities. Annual rainfall varies from 2000 to 5000 mm, the lowest rainfall being experienced in the rain shadow areas in the North Western and Western coasts of both islands. Average temperature in the lowland is about 26 ºC and remains fairly constant throughout the year. In the highlands the average temperature varies from 16 ºC to 21 ºC. The mean annual relative humidity is 83.6 % ranging from 80.4 % in August to 84.8 % in February and March.

Traditionally, agriculture has been the backbone of Samoa's economy and remains so today, primarily in terms of subsistence food supply and security (Ullah and Malaki, 2000). Agricultural farming in Samoa ranges from small subsistence farming to large commercial farming the latter comprising of only a handful of commercial entrepreneurs. Majority of farmers in Samoa are small subsistence to semi-subsistence who produce mainly for own consumption (26.35 %). About 66.38 % produce mainly for home consumption and to sell the excess produce for cash.

Agricultural mechanization is an important component for increasing agricultural production. However, farming is not only a question of labour and machinery but also is a system determined by many factors, such as, kind of crops, weather, soil type, capital, technical know-how, etc. To obtain benefits from the utilization of agricultural machinery it is essential to have knowledge about management, operations, maintenance and cost of operation. Mechanization can be used to increase the productivity of existing agricultural holdings and schemes or it can be the means of establishing some new project. Although mechanization is an important component for improvement of agricultural production, it is important to recognize it in perspective as one of several methods and one that requires considerable capital (Rijk, 1989). The adoption of mechanization inputs into farming practices has had minimal success in Samoa's farming history. Currently, various types of farm cultivation methods are practiced in Samoa. Mechanization level varies depending on the methods and cultivation areas. These include land preparation, leveling, planting, plant protection, weed control and harvesting. But not many farmers are adopting mechanization inputs to the extent they need.

It has been of interest to study the reasons why farmers have little interest in adopting agricultural mechanisation facilities for increased production. The specific objectives of this study were:

1. to find the constraints of agricultural mechanization in Samoa.
2. to find the prospect of mechanization under Samoan agriculture, and
3. to suggest strategies that could be adopted to promote mechanization.

Topography

Of the two main islands of Samoa, Upolu is a rugged chain of volcanic cones forming a crested ridge rising to 1,100 m. Savaii consists of broad coalescing domes topped by numerous cones, the highest of which rise to 1,800 m (Kear and Wood, 1959). The landmass of each island rises gently from the mean sea level (with the exception of Eastern Upolu, which rises very steeply). Therefore, in most areas there is a flat to gently undulating coastal plain (1-2 degrees) which passes into gently rolling slopes (2-5 degrees). These in turn merge into steeper foothills (5-15 degrees) which continue sometimes steeply (15-25 degrees) until the upland plateau level is reached at about 600 m in Upolu and Eastern Savaii and at 1,200 m in central Savaii (Wright, 1963). The slopes are often dissected by almost vertical sided valleys. In general, the upland plateau is rolling and surmounted by extinct volcanic cones. The land surface is uneven due to the boundaries between different lava flows which have caused steep pitches in slopes due to large pits and rifts caused by obstructions to lava flows and collapsed steam tunnels (Wright, 1963).

Type of Soil

Hamilton and Grange (1938) conducted the first scientific study on the soils of Samoa. They indicated that the Samoan soil is relatively shallow with plenty of stones, and boulders, and contains oxide-rich minerals derived from olivine basalt. Soils are almost entirely of volcanic origin, except for a few small areas of coastal (coral) sand. Perhaps the most immediate obvious characteristic of Samoan soils is that they are mostly rocky to extremely rocky. There are 55 different types of soil. Soils are predominantly stony latosols of varying fertility (Kear and Wood, 1959). There are a lesser number and smaller areas of tuff derived soil and even fewer alluvial and colluvial soil derived from basalt (Wright, 1963). Samoan soil is generally low in potassium and or phosphate. Equitable rainfall, temperature and good soil properties tend to minimize the impact of relatively low fertility on plant production. Some soils are clay to silty clay loam in the deeper regions to sandy gravel silt loam in the lava field areas. The volcanic soils of Samoa are very young with stones and boulders found just below the surface in agriculture viable land and exposed boulders in the lava fields. These young volcanic soils have made use of machinery cultivation very difficult and expensive to maintain. So, the use of machinery cultivation method is almost non-existent.

Crops Produced

Samoa's economy is based primarily on agricultural production much of it being at subsistence level. Crops, livestock, fisheries and forestry account for 42 % of GDP. The main cash crops are coconuts (Cocos nucifera), cocoa (Theobroma cacao) and banana (Musa spp.). A major staple as well as export crop was Taro (Colocasia esculenta) which has been virtually wiped out by the taro leaf blight disease (Phytophera colocasia) since December 1993. Banana and breadfruit have become major staples since then. Another destructive cyclone caused food shortage and Samoa had to import rice. Due to the rolling terrain and the loose, rocky and volcanic soil, wetland rice cultivation is not suitable. However, upland or dry land rice could be grown due to favorable soil and climate conditions. Trees like coconuts, bananas and breadfruits are planted by making individual holes similar to taro and are the predominant crops. Other crops like cucumber, gourd, pineapple and lots of vegetables are being planted in small patches of land and, also, by depositing individual seeds or seed pieces, in most cases, rather than cultivating the area to be planted. However, the planted area is first cleared of weeds using the

Table 1 Single crop equivalent area of major crops (Govt. of Samoa, 2000)

Crop	Area in acres household sector	Total area in acres
Coconut	46,300	53,200
Cocoa	9,900	10,400
Taro	10,500	10,500
Taamu	11,900	11,900
Banana	10,700	10,700
Yam	1,300	1,300
Kava	3,000	3,000
Other crops	6,700	6,700
Total	100,300	107,700

hoe or the bushknife (Lantin, 1994). Recently, due to the destructive effects of cyclones and Taro leaf blight, farmers have sought to diversify to taamu (Alocasia microrhiza), kava (Piper methysticum) and cattle production. Other crops grown in Samoa are yams and breadfruits. **Table 1** shows the land area used for individual crops. Area under major crops grown in 1999 and 1989 are presented in **Fig. 1**. A significant variation in the cultivation of different crops in these two years can be seen.

Farming Systems

Farming systems represent an appropriate combination of farm enterprises, cropping systems, livestock, fisheries, forestry, poultry and the resources available to the farmer to raise them for food and/or profitability. Powell (2002) studied the different types of farming systems preferred by Samoan farmers. These may be stated as mixed cropping, mono-cropping, agroforestry, mixed farming and shifting cultivation. A brief description of each follows:

(i) Mixed Cropping

Mixed cropping is described as the growing of two or more crops simultaneously on the same piece of land with or without distinct row arrangement. Studies have shown that planting crops in mixtures have proven to be beneficial to the producer. Mixed cropping is popular among smallholders. In mixed cropping the farmers grow banana, taro, taamu and breadfruit under coconut. Other situations include growing plantains, taro and yams under coconuts. According to the 1999 Census of Agriculture report, crops, such as, banana, taro and taamu were commonly grown with coconut as a mixed crop. Mixed cropping also might constitute mixtures of tree crops, such as, cocoa, coconut, breadfruit, banana, citrus and vegetables, such as, cabbage, lettuce, cucumber, tomatoes, beans, okra, water cress, etc. for home consumption.

(ii) Mono-cropping

Mono-cropping basically refers to the growing of a single crop on the same parcel of land. These include bananas/plantains, vegetables/spices, fruit trees, coconuts, etc. The census of Agriculture (Govt. of Samoa, 1989) stated that nearly four-fifths of 36,500 acre was under taro as a single crop.

(iii) Agroforestry

Agroforestry can be described as any sustainable land use system that maintains or increases total yield by combining food crops and/or pasture with tree crops, with or without livestock, on the same land. Because of the anticipated benefits of agroforestry, namely, windbreaks, recycling of nutrients, erosion control and moisture conservation, some farmers prefer to go for this type of farming system.

(iv) Mixed Farming

Mixed farming describes a cropping system which involves the raising of crops, animals, and/or trees. In other words, it involves the growing of crops as well as the rearing of livestock. Mixed farming is beneficial to many small holders from the viewpoint of diverse nutrition that are available to them. Many farmers, apart from growing crops, rear pigs and chickens that are free ranging.

(v) Shifting Cultivation

Shifting cultivation refers to farming or agricultural systems in which a short but variable cultivation phase of slash-and-burn cleared land alternates with a long, equally variable fallow period. Under this system, forests, secondary bush,

Fig. 1 Comparison of different crops cultivated in 1989 and 1999 (Govt. of Samoa, 2000)

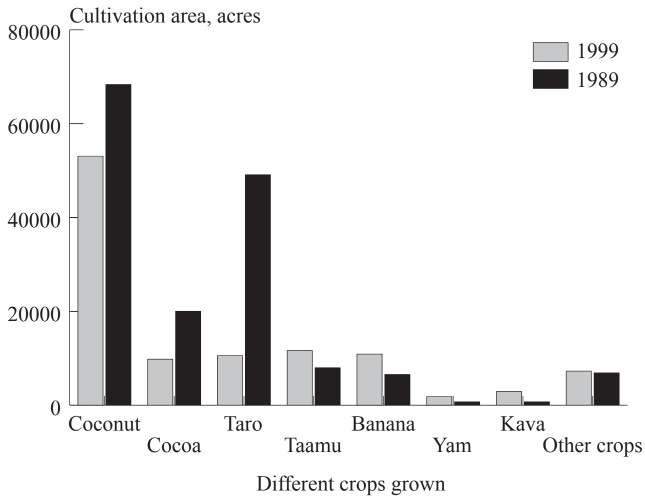
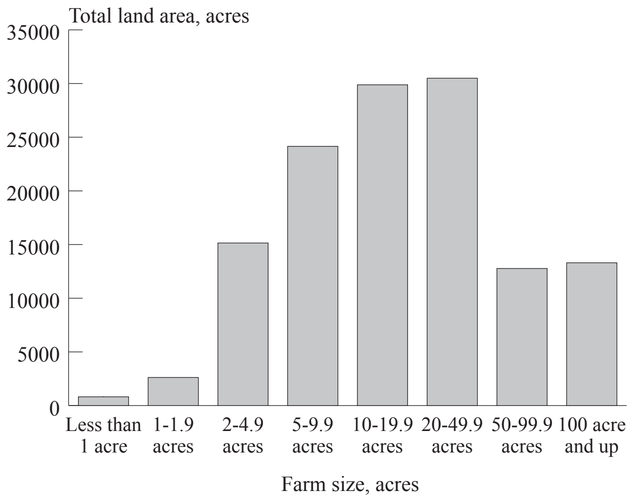


Fig. 2 Size of different farms with the total area shown (Govt. of Samoa, 1991)



woodland or grassland vegetation is cleared with simple hand tools. Shifting cultivation is an extensive system of agriculture evolved and practiced with good results in areas of relatively low population density where the farmer has enough land at his disposal and freedom to cultivate anywhere he chooses in a specified geo-political unit or region.

Farm Size

Farmers cultivate over 75 % of the total land area in many ways. Of the remaining area, 17 % is in non-agriculture use, 2 % is fallow and 3 % is bush. The average agricultural holding size is 15 acres per household with a range from less than 1 acre to about 100 or more acres under agriculture. The majority (72 %) of holdings fall between 2 acres and 20 acres (20 % at 2 to 4.9 acres, 27 % at 5 to 9.9 acres and 25 % at 10 to 19.9 acres) of agricultural activity. Crop farms are located away from the settlements while livestock are kept around the household dwellings except for larger cattle farms. Customary land ownership allows members of extended families access to land for subsistence farming. Most village land is under customary land ownership. With land reforms for access to land under way, access to free hold land has occurred in some rural areas. According to the Agriculture Census (Government of Samoa, 1999) the total area under agricultural activities is estimated at 166,485 acres (67,426.4 ha).

Agricultural Equipment/ Machinery Used

Agricultural mechanization embraces the use of tools, implements and machines for agricultural land development, production, harvesting and on-farm processing. It includes three main power sources: human, animals and mechanical. Natural power (wind and water) has been included under mechanical power, since a mechanical device is required to transfer this power into useful work. As a discipline, agricultural mechanization covers the manufacture, distribution and utilization of tools, implements and machines. Farm mechanization is a sub-category within the agricultural mechanization discipline addressing the power sources, tools, implements and machinery used on farms for crop production and processing (Rijk, 1989).

Samoa depends largely on tools imported from overseas countries like New Zealand, Australia, Germany and the United Kingdom for use in agricultural development. About ten years ago, all the tools needed for farming had to be imported. Now, some of the easier to make tools are being made locally. There is, currently, no policy on agricultural tools and implements. It is not known whose responsibility it is to devise a policy on tools and implements as this is left more or less entirely to the private sector to handle (Imo, 1992).

Each crop production and processing system uses tools and machinery, which may be either common with other crops or specialized for the crop depending upon operation and level of technology used. Samoan farmers use several implements. The traditional tools are bushknife, hoe, rakes, picks, forks, secateurs, spades, planting sticks with steel heads, locally called 'oso', stick crowbars, desuckering tool, shovels, axes, wheelbarrows, coconut de-huskers and bushknives (Atkinson, 1993). The modern implements for land clearing are chainsaws, mist blower, knapsack sprayers and brush cutters. Smaller hand tools like spades, bushknife, hoes, garden rakes, shovels and bush knives are common with farmers who have backyard vegetable crops. Vegetables including peanuts and gingers are cultivated using the pick as the main tool for breaking up the ground. Rakes and shovels or spade are used to complete the cultivation work. Weed control is done by either hand weeding with the bush knife as the main tool for cutting and dislodging the root system before uprooting by hand or by the use of weedicide. Commercial farmers use tractors to power different implements such as disc ploughs, disc harrows, rotavators and chisel ploughs. Information on major items of equipment owned, hired and or borrowed by agricultural holdings was collected in the agricultural census. Detailed information is given in the **Table 2**.

Potentiality of Mechanisation

Mechanisation has the potential

Table 2 Equipment owned, hired/borrowed, by type of equipment (Govt. of Samoa, 1999)

Type of equipment	Number of holdings	Number of items owned	Number of holdings hiring/ borrowing
Tractor	38	42	14
Roto tiller	191	356	27
Copra dryer	1,013	1,037	478
Banana injector	1,378	1,489	342
Knapsack sprayer	5,755	6,501	2,312
Mist blower	468	513	185
Power slasher	3,099	3,514	1,181
Chain saw	1,412	1,578	480
Irrigation water pump	49	55	15
Electric generator	141	145	26

to assist a large number of small farmers in the area of cultivation by designing and developing simple and inexpensive farm machinery and equipment. The soil is full of rocks, boulders and scattered trees. It is possible to take measures to make the soil rock free and clean from unnecessary trees which have no timbre value. Once these jobs are done it will be possible to bring more land under cultivation and use of machinery will be feasible. There is plenty of fallow land which can be brought under cultivation after clearing the land. The Ministry of Agriculture in Samoa already has in place a scheme whereby farmers can hire the tractor and driver plus an implement such as ripper, ridges, harrow or disc plough at a subsidised rate of WST 40.00 per hour (US$13). Farmers' response to this scheme is growing steadily.

Constraints of Mechanisation

At this moment, government has very little to do with respect to the promotion of agricultural tools and implements. This is entirely left to the private sector to handle. Perhaps, later on, the government might decide to involve in devising a policy for the promotion of appropriate tools and implements for use locally. Many Samoan farmers are not aware of the benefits of agricultural mechanization. For them to realize the benefits of mechanization it is very important to know about the available technologies. To lessen the constraints that hinder the development of agricultural mechanization, and develop ways to promote or encourage the farmers to practice agricultural mechanization, it is necessary to take measures for creation of public awareness. The following are some of the major problems and constraints that need to be addressed for rapid development of the agricultural mechanization for subsistence farms and commercial farms in Samoa:

- The presence of rocks and boulders above and just below the soil surface in large parts of the two main islands of Upolu and Savaii limit the use of machinery.
- High cost of farm machinery like tractors and implements.
- The initial cost of removing rocks, stones and boulders by using heavy machinery such as bulldozers or rippers, before using tillage machinery for cultivation, could be possible even though it is an expensive exercise but it is advisable.
- Lack of awareness campaign to apprise farmers about the availability of machinery and equipment, its use and proper maintenance, and the benefits gained from using such machinery.
- The cultural system, such as customary land ownership, inhibits commercial type farming in some ways.
- Cultural barriers in the promotion of cattle rearing which is essential in promoting animal draft power for pulling implements and carts in flat land.
- Industrial skills dwindling due to migration of people who have opportunity to acquire education and develop mechanical skills and knowledge.
- Lack of entrepreneurial skills to start metal working enterprises to produce simple tools and implements, for example, blacksmithing could be initiated at least by those who have been exposed to metal working (Lantin, 1994).
- Less dependence on agricultural land because of low population and assured remittance from family members, relatives working and residing overseas, because of strong family ties.
- Two-wheeled tractors are of limited use under certain soil conditions such as, rocky, and heavy soils etc.

Conclusions

Traditional technology is not sufficient to keep pace with the demands of commercial agriculture. To fulfill this demand agricultural mechanisation should be chosen in selective ways for both commercial and subsistence production. Some strategies or policies to the solution of the aforementioned problems to promote mechanisation both at subsistence and commercial levels are suggested. These are as follow:

- Availability of soft loans.
- Availability of appropriate and reasonably priced machines, preferably of local origin with adequate arrangements for maintenance facilities and spares.
- Train agricultural extension officers about the positive benefits of mechanization.
- Organize training workshop for local farmers whereby the extension officers will train the farmers about machinery operation and maintenance.
- Improved land tenure system will make mechanisation more attractive to farmers.
- Adopt appropriate implements for land preparation, such as a ripper for rocky soil conditions to remove rocks and boulders, and secondary tillage implements when the soil is rock free.
- There is limited information and awareness of farmers on benefits and potential of irrigation application. Creation of public awareness on irrigation methods, opportunities, technologies and benefits through information and training programs should be a part and parcel of mechanization programme.
- There is scope of sprinkler and drip irrigation systems largely due to the scarcity of irrigable water and uneven terrain condi-

tion (Pillay, 2002).

- Government should provide incentive to the interested farmers (exemption of import duty on equipments, power units etc) so that they feel encouraged to import appropriate agricultural machinery for mechanization purpose.
- Proper strategies of land ownership system can be used to an advantage as there is land consolidation in the extended family.

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Design and Development of an Off-Set Rotary Cultivator for Use with a Two-Wheel Tractor for Fruit Tree Cultivation

by

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Abstract

An off-set rotary tiller for use with a basic Thai design two-wheel tractor was designed and developed for cultivating an orchard. Results from the test with 7 kW two-wheel tractor in a mango orchard with 178 rpm rotor speed and 1.8 km/h travelling speed indicated a field capacity of 0.12 ha/h with 92 % weeding efficiency. After the test, soil properties appeared to be 23.49 mm in clod diameter with 0.96 g/cc in bulk density and 371.41 kPa cone index on the average.

Introduction

In Thailand, from 1991 to 2002, the agricultural land use for orchards was increasing by 34.2 % while the land use for paddy field was decreasing by 5.4 % (OAE, 2002). Since the land used for orchards was increasing rapidly, along with the government policy to strengthen the organic agriculture, there was a need to develop suitable machines for these orchards especially for mechanical weed control. Kwangwaropas (1999) reported that weeds eliminated by mechanical cultivation recovered slower than by herbicides. Even though the local made 3-4 kW wheel-less cultivator has been widely used for this purpose, its application is only suitable for light soil such as in vegetable cultivation. It is not suitable for hard soil such as in the orchard because of its light weight and high vibration at the handle.

The import 8-9 kW power tiller could not easily work near the trees because of lower branches. To overcome these problems, an off-set rotary cultivator was designed and developed at the Agricultural Engineering Research Institute.

Design and Development

The off-set rotary cultivator used with a two-wheel tractor was a new design concept. It was different from the conventional rotary cultivator. There are two types of conventional rotary cultivators; one is a center-drive type and the other one is a side-drive type (Sakai, 1999). The off-set type was a new design which could achieve acultivation area further from the outer rim of the wheel, so it could cultivate closer to the tree without the operator or two-wheel tractor being blocked by the lower branches. From **Fig. 1**, the center-drive type leaves a ridge at the center of the width of cut, while the side-drive type can not be attached to the typical Thai two-wheel tractor.

This off-set rotary cultivator was attached to a Siam Kubota NC-Short handle two-wheel tractor with a 7 kW diesel engine. The PTO shaft was at the right hand side of the operator. **Fig. 2** shows a schematic view of the off-set rotary cultivator attached to a two-wheel tractor. The important design details are as follows:

- The rotary cultivator was off-set 30 cm from the outer rim of the left wheel. The cutting width of the rotary was 80 cm while the wheel track of the two-wheel tractor was 115 cm.
- Power from PTO shaft was transmitted to rotary gearbox by mean of chain and sprocket.
- According to the results of the test, the optimum speed of the rotor was 178 rpm with engine speed of 1,800 rpm. The travelling speed was 1.78 km/h at first forward gear and the pitch of the blade was 5.5 cm.
- There were four disk holder flanges on the tiller shaft. Each flange was fitted with six C-L type blades. The flanges were located to attain a 15 degree spiral form of the blade.

Result and Discussion

A field test was conducted in a mango orchard in Nakornrachsima Province. For preliminary tests to observe ease of control, it was found that the travelling direction of the two-wheel tractor was easily controlled. The clockwise moment produced by greater traction of the left cage wheel and pushing force from the rotary could be absorbed by soil side force reacting to the cage wheels of the two-wheel tractor. A performance test was conducted under RNAM Test Code for rotary tillers with an engine speed of 1,800 rpm.

Field Performance of the Off-Set Rotary Cultivator

Weeding Efficiency:

The weeding efficiency was 92.09 % with an initial weed population of 609.7 g/m^2. The actual field capacity was found to be 0.12 ha/h with 88.3 % field efficiency. This capacity was about six times faster than one man with a hoe. The actual field capacity of manual weeding was 30 trees/day by one man (Kwangwaropas, 1999) or 53.3 h/ha for the same plant density of 200 trees/ha. The fuel consumption of the two-wheel tractor was 0.8 L/h or 6.7 L/ha. **Fig. 3** shows the operation of the off-set rotary cultivator.

Soil Properties:

Soil moisture content: Soil moisture content of the test field was 23.38 % (db).

Soil bulk density: Before testing, the average soil bulk density was 1.115 g/cc. After testing, the average bulk density was 0.963 g/cc.

Soil pulverization: After the test

Fig. 2 A schematic view of the off-set rotary cultivator implementing with a two-wheel tractor

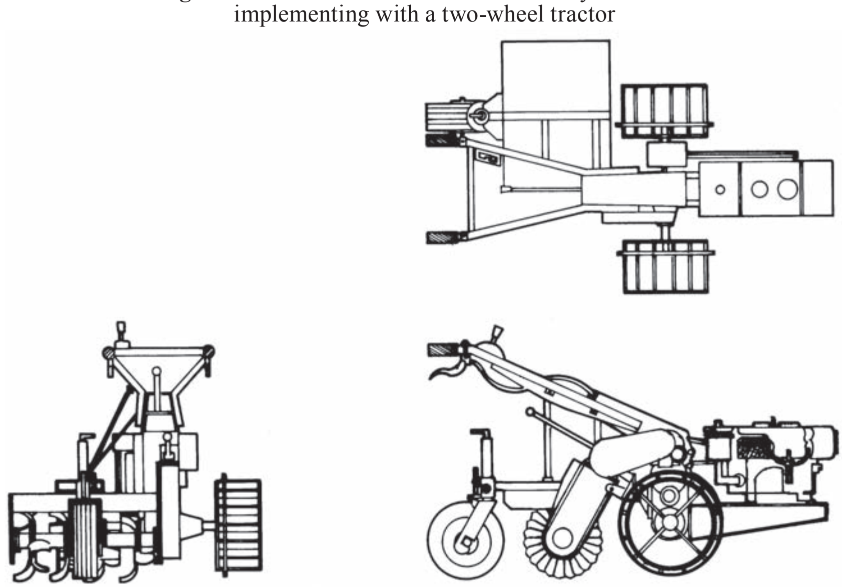
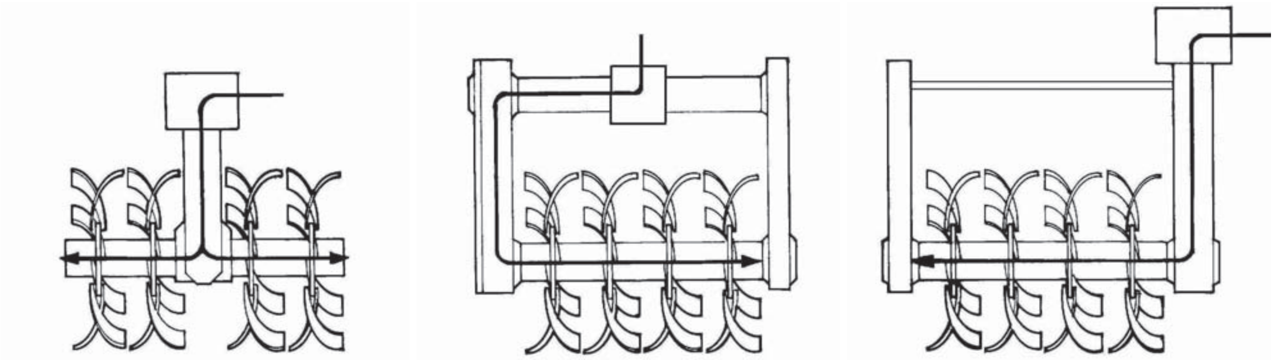


Fig. 1 The power transmission line of the rotary cultivator



A. Center-drive type B. Side-drive type C. Off-set type soil clod size was 23.49 mm by average.

Soil cone index: Cone index of the soil up to 10.5 cm depth was observed before and after test. It was found to be 1134.86 kPa before the test, after the test it was 371.41 kPa. **Fig. 4** shows the average cone index value at different depths before and after the test.

Conclusion

The off-set rotary cultivator used with a two-wheel tractor has many distinct advantages over the wheelless cultivators and the ordinary power tiller for cultivating fruit trees. It is more comfortable and can access around the base of tree effectively. Results of the test satisfied the farmer. For further study, the off-set rotary cultivator should be developed for cultivation as well as weeding in the field crop such as sugar cane.

Fig. 3 Operation of the off-set rotary cultivator

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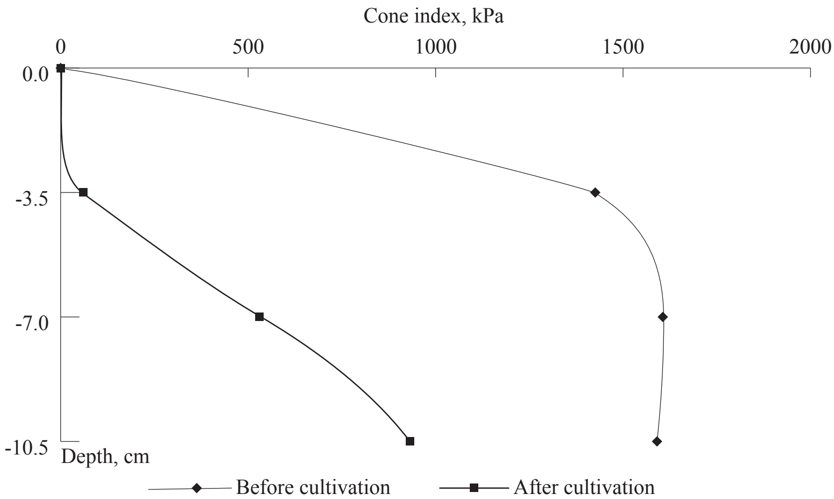
Fig. 4 Average cone index values at different depths before and after cultivation



agriChina in Beijing from 26 to 28 April 2007

Agricultural Exhibition - New: 'Potato Special' - Technical Forum and Excursion Programme - Deadline for Stand Bookings is 15 December 2006

(DLG). The agricultural exhibition agriChina will be held in Beijing for the third time from 26 to 28 April 2007. agriChina is the only international platform for the entire agribusiness segment in China. After being held only twice before, it has established itself as an indispensable meeting place for China' s professional farmers and agricultural specialists. The agriChina concept of international agricultural exhibition, top-flight technical programme and agricultural excursion caters equally to the needs of investors from China and of exhibitors from all over the world. The venue in Beijing has proved successful thanks to its nearness to policy-makers and the large-scale farms in the North and Northeast of China. The organisers are DLG-Agriservice GmbH, a subsidiary of the German Agricultural Society (DLG), and Deutsche Messe AG (Hanover) with its subsidiary firm Hannover Fairs China Ltd. (Shanghai). Their local partner is the China Association of Machinery Manufacturers (CAAMM). agriChina is further supported by the Chinese Ministry of Agriculture, the manufacturers' federation VDMA Agricultural Machinery Association, and the American Equipment Manufacturers (AEM). The deadline for stand bookings for exhibitors is 15 December 2006.

agriChina 2007 will be divided into the following sectors:

- Agricultural machinery and plant production with machinery for sowing and drilling, fertilising, plant protection, irrigation, harvesting, harvest processing and conditioning, harvest storage, tractors, special tractors and transport technology
- Livestock production and management for poultry, pigs, cattle and dairy cattle with livestock breeding, animal husbandry, animal nutrition and animal health, as well as processing and marketing
- Fruit and vegetable cropping with cultivation machinery, greenhouse equipment, harvesting machinery, processing, packing and preservation

New:" Potato Special" with Congress

China is the world's second largest potato producer. In order to cater to the technical requirements of the strongly growing Chinese potato market, the organisers of agriChina 2007 are organising a "Potato Special". This special show will address the entire potato chain with seed material, planting, lifting, transport, storage and processing. An advisory centre will supplement the exhibition segment. This will be backed up additionally by an international potato congress.

National Community Stands

The Federal Ministry for Economics and Technology (BMWi) has promised to promote a German community stand at agriChina 2007. This will provide German firms with the possibility of taking part in the exhibition on favourable terms, as well as allowing them a prestigious exhibition stand with a jointly usable service area and services. Companies interested in participating in the community stand can obtain further information from the organisers. National community stands from France and the USA have already been announced.

The core target group on the visitor side at agriChina 2007 consists of the managers of large-scale farm units and of vegetable, fruit and horticultural centres, agricultural machinery dealers, and specialists from the Chinese ministries as well as government and administrative bodies. These include in particular the areas of mechanisation and technical progress, livestock production, service centres for advisory services and agriculture, as well as the department of state-run enterprises.

Further information on agriChina 2007 and registration forms are available from DLG-Agriservice GmbH, B üro Frankfurt am Main, Eschborner Landstr. 122, D-60489 Frankfurt am Main, Fax: +49/69/24788-113. The contact persons are Karl-Martin Lüth Tel: +49/69/24788-257, E-mail: k-m.lueth @DLG.org, and Ulrike Schmidt-Machinek. Tel: +49/69/24788-268, E-mail: u.schmidt-machinek@dlg.org. Information on agriChina 2006 is also available from Deutsche Messe AG, Messegelä nde, D-30521 Hanover, contact person Anja Marhauer, Tel: +49/511-8932132, Fax: +49/511-8932109, E-mail: anja. marhauer@messe.de.

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Book Review

Modeling Software with Finite State Machines: A Practical Approach

Author(s):
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Ruedi Schmuki - Unaxis, Balzers, Switzerland
Thomas Wagner - Nortel Networks, Friedrichshafen, Germny
Peter Wolstenholme - Six-Fours les Plages, France
Detailed Description:
Modeling Software with Finite State Machines: A Practical Approach explains how to apply finite state machines to software development. It provides a critical analysis of using finite state machines as a foundation for executable specifications to reduce software development effort and improve quality. This book discusses the design of a state machine and of a system of state machines. It also presents a detailed analysis of development issues relating to behavior modeling with design examples and design rules for using finite state machines.

This volume describes a coherent and well-tested framework for generating reliable software for even the most complex tasks. The authors demonstrate that the established practice of using a specification as a basis for coding is wrong. Divided into three parts, this book opens by delivering the authors' expert opinions on software, covering the evolution of development as well as costs, methods, programmers, and the development cycle. The remaining two parts encourage the use of state machines: promoting the virtual finite state machine (Vfsm) method and StateWORKS development tools.

List Price: $89.95, **Number of Pages:** 392
Published by: Auerbach Publications / Taylor & Francis Group, 6000 Broken Sound Parkway, NW, Suite 300, Boca Raton, FL33487, USA

Control and Automation of Electrical Power Distribution Systems

Author(s):
James Northcote - Green - ABB Power technologies AB Vasteras, Swaden
Robert Wilson - Abasis Consulting Limited Whitchurch, Shropshire, UK
Detailed Description:
Implementing the automation of electric distribution networks, from simple remote control to the application of software-based decision tools, requires many considerations, such as assessing costs, selecting the control infrastructure type and automation level, deciding on the ambition level, and justifying the solution through a business case. Control and Automation of Electric Power Distribution Systems addresses all of these issues to aid you in resolving automation problems and improving the management of your distribution network.

Bringing together automation concepts as they apply to utility distribution systems, this volume presents the theoretical and practical details of a control and automation solution for distribution substations and feeders. By discussing distribution planning, performance calculations, and protection, the authors show how to meet specific performance goals. The book also provides two case studies that illustrate the business case for distribution automation (DA) and methods for calculating benefits, including the assessment of clew time saving.

Using Control and Automation of Electric Power Distribution Systems, you can embark on the automation best suited for your needs.

List Price: $139.95
Number of Pages: 464
Published by: CRC Press / Taylor & Francis Group, 6000 Broken Sound Parkway, NW, Suite 300, Boca Raton, FL33487, USA

Food Processing: Principles and Applications

Author(s):
Hosahalli S. Ramaswamy - McGill University, Ste-Anne-de-Bellevue, Quebec, Canada
Michele Marcotte - Agriculture & Agri-Food Canada, Saint-Hyacinthe, Quebec, Canada
Detailed Description:
Food Processing: Principles and Applications is a comprehensive resource that explores the basic and applied aspects of food processing. It describes the physical, chemical, and microbiological basis for each method of preservation. Particular emphasis is placed on the application of three of the most universally used commercial processes: thermal processing, freezing, and dehydration.

Thermal processing - perhaps the most widely used technology in the world - is examined in thorough discussions of the microbial basis of the process and on microbial destruction kinetics. Also described is the characterization of the heating behavior of foods and the equipment used for thermal processing.

Low temperature preservation is also demonstrated with a focus on freezing. The fundamentals of the freezing process, and the techniques and equipment used in commercial freezing operations are also explained. The thermophysical properties and the modeling of freeze times are meticulously addressed in sequence.

Aspects of dehydration are detailed from drying fundamentals to drying equipment, modeling, and storage stability. In the final section, separation processes are highlighted: evaporation, membrane processing, freeze concentration, extraction, and osmotic dehydration.

This book is ideal for undergraduate students in food science who are taking courses in food processing. It is also a must have resource for food process engineers and researchers to forecast results of food processing methods.

List Price: $99.95
Number of Pages: 440
Published by: CRC Press / Taylor & Francis Group, 6000 Broken Sound Parkway, NW, Suite 300, Boca Raton, FL33487, USA

Damage Mechanics

Author(s):
George Z. Voyiadjis - Louisiana State University, Baton Rouge, USA
Peter I. Kattan - Louisiana State University, Baton Rouge, USA
Detailed Description:
Before a structure or component can be completed, before any analytical

model can be constructed, and even before the design can be formulated, you must have a fundamental understanding of damage behavior in order to produce a safe and effective design. Damage Mechanics presents the underlying principles of continuum damage mechanics along with the latest research. The authors consider both isotropic and anisotropic theories as well as elastic and elasto-plastic damage analyses using a self-contained, easily understood approach.

Beginning with the requisite mathematics, Damage Mechanics guides you from the very basic concepts to advanced mathematical and mechanical models. The first chapter offers a brief MAPLE® tutorial and supplies all of the MAPLE commands needed to solve the various problems throughout the chapter. The authors then discuss the basics of elasticity theory within the continuum mechanics framework, the simple case of isotropic damage, effective stress, damage evolution, kinematic description of damage, and the general case of anisotropic damage. The remainder of the book includes a review of plasticity theory, formulation of a coupled elasto-plastic damage theory developed by the authors, and the kinematics of damage for finite-strain elasto-plastic solids.

From fundamental concepts to the latest advances, this book contains everything that you need to study the damage mechanics of metals and homogeneous materials.

List Price: $119.95

Number of Pages: 280

Published by: CRC Press / Taylor & Francis Group, 6000 Broken Sound Parkway, NW, Suite 300, Boca Raton, FL33487, USA

Environmentally Friendly Technologies for Agricultural Produce Quality

Author(s):

Shimshon Ben Yeoshua - The Volcani Center, ARO, Bet Dagan, Israel

Detailed Description:

While ecology as a whole continues to receive considerable attention, postharvest food handling, until recently, had not been examined from a green perspective. This has changed as health-conscious consumers look to improve both their diets and their environment. Environmentally Friendly Technologies for Agricultural Produce Quality is the first book to take a focused look from an ecological point of view at the way produce is preserved, packaged, and shipped. The book's editor, Shimshon Ben-Yehoshua, a leader in the international scientific community, presents a framework he refers to as the triple bottom line, which takes into consideration economic and societal issues and an environmental perspective.

Experts and eminent researchers discuss recent developments, such as the use of genetic engineering, modified atmosphere packaging, pest control for durable and perishable produce, all designed to reduce spoilage without compromising quality or negatively impacting the environment. Keeping faith with the triple bottom line, the book explores related topics such as innovations in transportation and the value of produce to human health. This book makes an excellent handbook for postharvest professionals and others handlers of produce as well as a textbook for students preparing to meet the needs of a health and ecology conscious society.

List Price: $169.95

Number of Pages: 552

Published by: CRC Press / Taylor & Francis Group, 6000 Broken Sound Parkway, NW, Suite 300, Boca Raton, FL33487, USA

Novel Food Processing Technologies

Author(s):

Gustavo V. Barbosa - Canovas - Washington State University, Pullman, USA

Maria Soledad Tapia - Central University of Venezuela, Caracas Apartado, Venezuela

Maria Pilar Cano - Instituto del Frio-CSIC, Madrid, Spain

Detailed Description:

Reflecting current trends in alternative food processing and preservation, this reference explores the most recent applications in pulsed electric field (PEF) and high-pressure technologies, food microbiology, and modern thermal and nonthermal operations to prevent the occurrence of food-borne pathogens, extend the shelf-life of foods, and improve the safety, quality, and nutritional value of various food products.

Documents the results of the Emerging Technologies for the Food Industry symposium held in Madrid, Spain.

Spanning the most influential breakthroughs in food engineering, this guide demonstrates the successful application of PEF technology to products such as fruit juices, eggs, and milk. It also studies factors affecting the PEF resistance of microorganisms, analyzes methods in predictive microbiology and its impact on food safety systems, and examines advances in the use of freezing technologies, ultraviolet light, supercritical fluid extraction, and commercial high-pressure equipment.

List Price: $179.95

Number of Pages: 720

Published by: CRC Press / Taylor & Francis Group, 6000 Broken Sound Parkway, NW, Suite 300, Boca Raton, FL33487, USA

Trace Elements in the Environment: Biogeochemistry, Biotechnology, and Bioremediation

Author(s):

M.N.V. Prasad - University of Hyderabad, India

Kenneth S. Sajwan - Savanah State University, Georgia, USA

Ravi Naidu - University of South Australia, Mawson Lakes, Australia

Detailed Description:

New analytical techniques have enhanced current understanding of the behavior of trace and ultratrace elements in the biogeochemical cycling, chemical speciation, bioavailability, bioaccumulation, and as applied to the phytoremediation of contaminated soils. Addressing worldwide regulatory, scientific, and environmental issues, Trace Elements in the Environment explores these frontiers, including biotechnological aspects of metal-binding proteins and peptides and phytoremediation strategies using trees, grasses, crop plants, aquatics, and risks to ecological and human health. Discussing trace elements in the holistic environment, this book covers advances in state-of-the-art analytical techniques, molecular biotechology, and contemporary biotechnology that enhances knowledge of the behavior of trace elements in the biogeosphere and at the cellular and molecular level.

The editors and their hand-picked panel of contributors provide authoritative coverage of trace elements in the environment. They highlight cutting-edge applications of emerging strategies and technologies to the problems of trace elements in the environment. The editors discuss emerging areas such as bacterial biosorption of trace elements, processes, and applications of electroremediation of heavy metals-contaminated soils, application of novel nanoporous sorbents for the removal of heavy metals, metalloids, and radionuclides. The book focuses on the effects of increasing levels of trace elements on ecological and human health, evaluates the effectiveness of methods of phytoremediation, and covers risk assessment, pathways, and trace element toxicity.

Containing more than 150 illustrations, tables, photographs, and equations, the book's coverage spans the entire body of knowledge available about how and why plants interact with metals and other trace elements.

List Price: $159.95
Number of Pages: 744
Published by: CRC Press / Taylor & Francis Group, 6000 Broken Sound Parkway, NW, Suite 300, Boca Raton, FL33487, USA

Natural Products from Plants, Second Edition

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Detailed Description:

From medicinal, industrial, and culinary uses to cutting-edge laboratory techniques in modern research and plant conservation strategies, Natural Products from Plants, Second Edition reveals a vastly expanded understanding of the natural products that plants produce. In a single volume, this book offers a thorough inventory of the various types of plant-derived compounds. It covers their chemical composition, structure, and properties alongside the most effective ways to identify, extract, analyze, and characterize new plant-derived compounds.

The authors examine new information on the chemical mechanisms plants use to deter predators and pathogens, attract symbiotic organisms, and defend themselves against environmental stress-insights which are key for adapting such mechanisms to human health. Along with updated and revised information from the highly acclaimed first edition, the second edition presents seven new chapters and features more than 50% new material relating to plant constituents, natural product biochemistry, and molecular biology. The book incorporates in-depth treatment of natural product biosynthesis with new collection and extraction protocols, advanced separation and analytical techniques, up-to-date bioassays, as well as modern molecular biology and plant biotechnology for the production of natural products.

Unique in its breadth and coverage, Natural Products from Plants, Second Edition belongs on the shelf of interested researchers, policymakers, and consumers- particularly those involved in disease prevention, treatment, and pharmaceutical applications-who need a complete guide to the properties, uses, and study of plant natural products.

List Price: $149.95
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A I Khatibu


E A Baryeh


S Tembo


H A Cetrangolo


I de A Nääs


A E Ghaly


E J Hetz


A A Valenzuela


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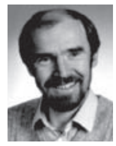
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