ENTERPRISE OPPORTUNITIES IN RWANDA

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I. INTRODUCTION

This study was conducted at the request of the USAID Rwanda Mission. Appropriate Technology International conducted this study which identifies technologies that can play a significant role in Rwanda's economic development by serving as the basis for new enterprise development or by improving the performance of existing small enterprises. A central concern of this study was the creation of rural employment and the increase of rural incomes. The study is very broad and identifies potential opportunities in seventeen sectors in which both private and cooperative small and micro enterprises can significantly contribute to Rwanda's economy. By design, the study is a general survey of many sectors rather than an in-depth analysis of any particular sector.

Because of the short duration of this consultancy, attention was centered on those economic activities based on the use of local resources which produce for local consumption. This focus was selected because Rwanda's high rate of growth in salaried employment has resulted in an increased reliance on purchased foods in domestic markets and because of the security considerations and economic benefits that derive from the use of local resources. Given Rwanda's rapidly expanding population and limited foreign exchange earnings, areas involving selection of appropriate technologies to replace imports and to produce goods for export also merit attention.

The study was financed under Project PRIME (Policy Reform Initiatives in Manufacturing and Employment). ATI finds the Mission's PRIME project to be a well planned project with substantial potential for making an impact on Rwanda's economic development.

This report was prepared by Carl Bielenberg with technical input by Glenn Patterson, Carlos Lola, Sabra Breslin, Alphonse Munyabitare and Michael O'Donnell. The Rwanda field work was carried out by Bielenberg and Munyabitare between 14 August and 30 September 1989. Visits were made to several European appropriate technology institutes: SKAT (Switzerland), GRET (France), ATOL (Belgium), KIT (Holland) and GATE (Germany). In Rwanda there were approximately thirty interviews/meetings; a list of people contacted begins on page 74. In addition to trips around Kigali, there were four separate field trips to Gitarama (Central), to Gisenyi and Ruhengeri (Northwest), to Nyabisindu and Butare (South) and to Rwamagana and Kibungo (West).

II. LIST OF TECHNOLOGIES

A. The use of Cultured Milk and/or Ice in Milk Collection and Transport
B. Sunflower Cultivation and Processing
C. Spent Brewery Grains for Animal Feed
D. Agricultural Lime
E. Use of Pozzolanic Materials
F. Metalworking
G. Brewing
H. Cassava Processing
I. Mushroom Cultivation
J. Sorghum Dehulling and Composite Flour
K. Clay Tile and Brick Production
L. Sisal Processing
M. Micro-Hydropower
N. Portable Saw Mills
O. Rhizobium Bacteria
P. Locally Manufactured Packaging
Q. Agglomerated Charcoal Briquettes

Sections A through F discuss in some detail the six technologies that appear to offer the most promise. Pages 4-6 summarize the most important market and technology considerations for each of these technologies and note recommendations for studies and other work necessary to promote their successful application. These points are all elaborated upon in the report itself. Milk preservation, sunflower processing, and agricultural lime appear to be the three most promising opportunities for having a broad impact on rural employment and rural incomes.

Each of the sections for the first five technologies is organized according to the following headings:

i. The Need or Market
ii. The Technology
iii. Existing Activity and Institutional Resources
iv. Uncertainties or Risks
v. Recommendations for Future Action

In recommending future actions, we have tried to identify what kinds of studies and experimental work are needed to promote the successful and timely application of each of the proposed technologies. Each section therefore describes a sub-project or activity that would result in the creation of at least one business based upon each of these technologies. In some cases, the business or business proposal already exists (e.g., using spent brewery grains), and the proposed activity is designed to assist it to become a viable enterprise.

Section F discusses possible ways of improving the metalworking sector in Rwanda. This is not an easy activity, where significant results can be shown in a short period of time, but is important inasmuch as the metalworking sector is the source of

tools used in agriculture and rural industry. Specific interventions, like training in the manufacture of oil presses, are better integrated into activities involving the end user, that is, the sunflower cultivation and processing project, than into an umbrella project involving the metalworking sector. Nonetheless, there are activities involving the metalworking sector, like artisan aluminum foundry, that would not fit into a end-user sub-project, but which could be introduced through a seminar approach conceived by MINIMART.

Sections G through Q discuss very briefly eleven other technologies that were considered but not investigated in detail because of the limited nature of this study, because they have been reported upon elsewhere, or because they do not appear to be as promising as the first group.

Several technologies recently introduced in Rwanda have shown remarkable rates of acceptance by users and are already making an impact on the national economy. These technologies, of which improved charcoal production and beekeeping are examples, were not discussed in this study because their dissemination is already so far advanced. Independent studies of these activities would, however, be very useful for other countries undertaking similar activities.

III. TECHNOLOGY SUMMARY -- SIX BEST OPPORTUNITIES

A. Milk Preservation

1. Market
   - highly dispersed production
   - collection once per day; problems with freshness
   - rapidly growing urban market

2. Technology
   - small scale cultured milk plants
   - utilization of ice during collection

3. Recommendations
   - survey farmers, collection agents and markets
   - establish pilot small scale cultured milk plant, and/or install pilot milk cooling basins at collection points and initiate ice deliveries

B. Sunflower Oil

1. Market
   - little oil produced in country; 7,500 tons imported in 1985
   - lack of foreign exchange

2. Technology
   - manually operated ram press
   - motorized expellers
   - improved sunflower seed; agricultural extension

3. Recommendations
   - commodity sector approach involving all parties (government and private) interested in oil production
   - manually operated ram press has greatest rural employment potential

C. Brewery Grains

1. Market
   - increasing demand for animal feeds
   - brewery grains are high value animal feed supplement
   - brewery produces 240 tons of waste grains per week which currently is being thrown into Lake Kivu

2. Technology
   - fresh wet grains system versus dried

3. Recommendations
   - evaluate the economic and technical feasibility of using waste grains
   - perform feeding trials using wet and dried grains
   - evaluate the feasibility of a wet grain delivery system, providing training to farmers in use of wet grains
   - obtain further information on the economic and technical feasibility of a centralized drying facility

D. Agricultural Lime

1. Market
   - there are likely to be food production short-falls because of a decline in soil fertility
   - extremely acidic soil in uplands areas

2. Technology
   - Rwanda has dolomitic limestone deposits suitable for agricultural purposes
   - liming can be an important input to increasing crop yields
   - fired (mixed feed vertical kiln) versus crushed lime

3. Recommendations
   - assess composition of Rwanda's deposits
   - evaluate the costs and effectiveness of small mixed-charge continuous kilns versus simple low-capacity crushing equipment
   - set up pilot kiln and/or crushing site

E. Pozzolanic Materials

1. Market
   - construction materials are a problem in the populous volcanic regions; fired bricks are carried in over long distances from outside the area
   - the subsoil is composed of pumice

2. Technology
   - pumice building blocks
   - pumice based pozzolanic cement

3. Recommendations
   - evaluate deposits
   - determine optimum mixtures to produce blocks and pozzolanic cement
   - evaluate alternative processing equipment
   - structural testing of blocks

F. Metalworking Sector

1. Market
   - metalworking capacity is central to industrialization
   - the metalworking sector in Rwanda is very weak

2. Technology
   - artisans are extremely underequipped
   - cast aluminum cooking pots

3. Recommendations
   - market assessment of metal products
   - training in the manufacture of specific products

market milk that otherwise might not be marketed, in particular, the surplus milk drawn from cows in the evenings, which is approximately 40% of the total. Conventional large-scale milk processing arrangements are not able to absorb this milk because of the need for transport and cooling.

The process employed in cultured milk plants includes the the following steps.

- Fresh milk for the plant is filtered and tested for impurities, such as added water.

- The milk is then pasteurized by placing the milk can in a water bath which is heated by a wood-fired cooker.

- The milk at pasteurization temperature is transferred in its can to a cold water bath where its temperature is rapidly reduced to about 22 degrees centigrade.

- At this stage the culture is stirred into the milk, and left to stand for 24 hours while fermentation takes place.

- The milk is packaged in half- or quarter-liter plastic bags which are sealed on site; it is then ready for distribution and marketing.

- The starter culture is maintained and multiplied using the same basic process as that used for milk culturing, but on a small scale. Considerably more care is taken with hygiene in order to maintain purity.

An advantage of this processing procedure is that milk introduced into the plant remains in the same can throughout the processing procedure until packaging. This considerably reduces the opportunity for the introduction of undesirable bacteria during processing. Where mains electricity is not available, power for the sealing of the plastic bags is provided by photovoltaic panels, which also provide power for lighting, since much of the processing is done at night if "evening milk" is being processed.

A key to the successful culturing of milk is the raw material. Only fresh, pure and clean milk should be purchased. In the absence of sophisticated testing equipment, this can be achieved mainly through close extension and liaison with farmers. It is of considerable help if farmers have a share and personal interest in the success of the enterprise, and if strong "community pressure" can be applied to farmers delivering poor quality milk.

b. Use of Ice

Prior to rural electrification in the 1930's and 1940's, block ice was widely used in the United States and Western Europe for the collection and distribution of milk. Several

A. THE USE OF CULTURED MILK AND/OR ICE IN MILK COLLECTION AND TRANSPORT

i. The Need or Market

Rwanda is remarkable among sub-Sahelian African nations with respect to its consumption of milk and milk products, and its efforts to develop the dairy industry. Cultured milk has been produced and consumed by farm families throughout the country for many years. Despite the scarcity of farmlands, the family cow remains important because it provides fertilizer for food crops, milk and meat to improve the family's diet, and a small cash income. The cost of keeping a cow is minimal since it eats grasses not usually consumed by other livestock or people.

Because of these factors, and a rapidly growing urban middle class, the government and private entrepreneurs are investing in the collection, processing, and distribution of milk and milk products. The highly dispersed nature of milk production makes collection very difficult, in terms of product quality, and expensive.

Currently milk is only collected once a day (morning milk). To maximize the amount of morning milk collected, farmers often delay milking until late morning. This reduces the overall quantity of milk produced by the cow. A collection system that would allow the farmer to better space the morning and evening milkings would significantly increase milk production. An improved system might involve the use of a small-scale cultured milk technology and/or block ice in the collection and distribution of milk.

ii. The Technology

a. Small-Scale Cultured Milk

Culturing of milk is a widely practiced and understood process in Africa originating from traditional methods of milk preservation. Basic research conducted by Nairobi University has identified culture strains that are suitable for "commercial" cultured milk production.

The properties of cultured milk make it a particularly well adapted product for small-scale milk processing. Cultured milk will keep for two weeks without refrigeration. This eliminates the need for the infrastructure required to maintain a cold chain from producer to consumer. Cultured milk plants can therefore be established in areas where there is no electricity and where communications are poor and uncertain. Without the need for cooling, both capital and operating costs of a cultured milk plant are low. Locating small-scale plants within walking distance of the farmers which they serve eliminates the cost of transporting milk from the farmer to the processor. These factors enable small-scale cultured milk plants to process and

circumstances presently favor the application of this simple technology in Rwanda.

- The electrical distribution network, though well developed by African standards, still serves only the major and secondary towns because of the low level of rural incomes, and because of the virtual absence of population centers in rural areas. Thus ice provides the only effective and affordable means of refrigeration in rural areas.

- The dairies currently collect milk by organizing collection points, where individual farmers bring their milk for pickup and payment. The collection points are operated by collection agents, who earn a commission, or by cooperatives. The collection points could serve as locations for milk cooling, or for ice distribution to individual farmers. Ice could be delivered by the same truck that collects the milk. Each collection point would have a cast cement or steel basin that could hold several milk cans, partially submerged in water, and one or two blocks of ice. The basin could be externally insulated with local materials and enclosed in a house or shed made of local materials. Such a system was tested by the National Dairy in Nyabisindu using brook water for cooling instead of ice. Without ice, the system was ineffective and fell into disuse.

- Consumers report that fresh milk sold in Kigali spoils within twenty-four hours, even if it is refrigerated. Since the Nyabisindu Dairy appears to process its milk systematically, rapid spoilage is probably caused by lack of refrigeration during milk collection and distribution.

- Block ice is produced and sold by the soft drink factory (Limonaderie) in Kigali at a very low price (80 frw for a 25 kg block). The price is currently low because of the low price of electricity (6 frw per kwh) paid by the factory; the efficiency of their ice making equipment (only 2.5 kwh per 25 kg block); a falling level of capacity utilization due to the spread of electricity and refrigerators in Kigali; and the importance of ice as a means of promoting beverage consumption. The plant has a minimum excess capacity of 5 tons of ice per day, which is sufficient to cool about 20,000 liters of milk.

The National Dairy's milk delivery truck collects most of the dairy's milk on its return trip from Kigali to Nyabisindu. None of the collection points are located along the main highway or have access to electricity. The costs and benefits of using ice for milk cooling at the collection points could be tested along this route.

iii. Existing Activity and Institutional Resources

The National Dairy appears to be well run. Although it processes an average of only 3500 liters per day, its products include plain and fruit yogurt, fresh milk, cultured milk and butter. It has already optimized its milk collection routes to minimize delivery times and vehicle mileage. As mentioned above, it has also tried to increase its collection by cooling milk at the collection points. Thus, the proposed technology is consistent with the Dairy's mandate, which is to maximize the amount of marketed milk. It already pays farmers a high price (42 frw per liter) to stimulate the supply of milk, and pays a four franc bonus for milk delivered directly to the Dairy.

The Rwandan Government presently has programs in place to increase milk production, including technical assistance to farmers -- corraling of cattle for improved feeding and manure utilization, genetic improvement using breeding stock and artificial insemination, and disease control.

iv. Uncertainties or Risks

The financial risks involved in testing the effects of ice use in milk collection are small, because the capital investment is small. The National Dairy would have to build basins for its Kigali-Nyabisindu milk collection route, and build and install an ice storage box for its vehicle. At somewhat greater expense, they could build an insulated box body for their truck, with ice lockers accessible from the outside and a fan for circulating air inside the box. This would keep the milk cool during both delivery and collection. Farmers might be encouraged to contribute to the cost of building the milk collection houses.

The major risk involved in this project is that a failure of the experiment to yield the desired result might lead to rejection of the technology by all dairies in Rwanda. In addition, an increase in the collected milk is apt to be gradual. Thus, whatever the initial problems, the experiment should continue for several years. At first, only a few farmers may bring their evening milk for collection, but the opportunity to market this milk may induce them to improve their animals' feeding and obtain more productive stock. A gradual spread of these improvements to other farmers should result in a gradual but significant increase in the quantity of marketed milk and in the incomes of farmers in the project area.

v. Recommendations for Future Action

The proposed project should be implemented in phases. At the end of each phase a decision will be made whether to proceed to the next:

- A survey of farmers and collection agents along the Kigali-Nyabisindu circuit of the National Dairy to assess

their receptivity to the marketing of evening milk, and to anticipate and address problems that may arise during project implementation; reduced consumption of milk by rural producers is one such potential problem (rural nutrition).

a. Cultured Milk

- Test marketing using cultured milk from Kenya.
- Construction of a cultured milk pilot plant.

b. Ice Blocks

- Installation of milk cooling basins at the collection points, and the delivery of ice for 2 to 3 years. This would be followed by an evaluation of the increase in milk collection, and the net savings (or expense) of using ice in milk collection;

- A possible follow-on project, involving either the installation of a small block ice plant at the National Dairy, or the encouragement of ice use by other dairies that deliver to Kigali, or both. The installation of a block ice plant at Nyabisindu would enable the Dairy to use ice on its other collection routes, improve the distribution of dairy products, and also facilitate the marketing of fish, meat, and perishable vegetables from Nyabisindu and Butare.

B. SUNFLOWER CULTIVATION AND PROCESSING

i. The Need or Market

Very little vegetable oil is currently produced in Rwanda. Consumption is satisfied almost entirely through commercial or food-aid imports, which in 1985 totaled nearly 7500 tons. Oil is distributed by OPROVIA; the parastatal food distributor, and prices are fixed by the Government of Rwanda. Canadian rapeseed oil is presently the most widely available vegetable oil, and sells in four-liter jugs for 750 frw, or roughly 170 frw per liter, net of the value of the plastic jug.

The Government of Rwanda is concerned about the cost of vegetable oil imports, as well as the general nutrition of its people, and encourages soybean cultivation. Soybean production has developed apace, but soybeans are not presently processed into vegetable oil. The reason is that all beans (soybeans, kidney beans, etc.), which are the country's greatest staple, are in short supply and are very expensive. Soybeans, though somewhat less appreciated than other dried beans, are seen as a substitute for them and have also increased in price. Both have almost doubled in price since 1985, when most dried beans cost 30 to 35 frw per kilogram, and soya cost 25 to 30 frw. Since soybeans contain only 18% oil, and only 12 to 15% can be extracted mechanically, more than 400 frw worth of soybeans are needed to produce a liter of oil. At these prices, the sale of oil will barely cover the cost of collecting and processing the beans. In addition the cake must be sold as a flour for human consumption at a price that is equal to or higher than the cost of the beans from which it is made. A small oilmill run by the National Dairy of Nyabisindu was marginally viable when beans were available at 30 frw per kilogram, and were processed into oil and flour, but ceased operations when the price increased to 50 frw per kilogram. Unrefined soybean oil has a darker color than imported oils, particularly if the beans are overheated during roasting. Thus, it may also be difficult to market the oil at the same price as imported oil.

Expressing oil from groundnuts is somewhat more promising, but still problematic. Groundnuts are consumed primarily roasted or boiled as a snack food and are very expensive. The current price is 100 frw in Kigali and 80 frw per kilogram of shelled nuts in Kibungo, the center of the principal groundnut producing region. Groundnuts are expensive also because of their high cost of production. The average yield nationally is only 800 kg of shelled nuts per hectare, while 150 kg must be reserved to seed the following crop. Simple motorized or manual presses can extract 30 to 40% of the weight of the seed as oil, so that 200 to 267 frw of nuts would be required to produce a liter of oil. The presscake is highly palatable and nutritious, can be sold as a flour, as seasoned groundnut balls, or for sauces, and can probably bring at least 60 frw per kilogram. At this price, groundnut processing would be very marginal, resulting in an

added value of 13 frw if the yield is 30% and 24 frw if the yield is 40%. An added value of 13 frw would barely cover the processing costs.

Neither groundnuts nor soybeans can be economically used to produce vegetable oil because both are consumed as foods. The prices of both will vary widely, depending upon whether there is surplus or scarcity, and using either as the basis of a local oil industry would therefore be very risky. From a development perspective, it is hard to justify investment in the processing of a food crop that does not materially improve the total nutritional quality or storability of the crop, especially when the crop is already in short supply for direct consumption.

Sunflower, though presently cultivated only on a very small scale, is the only oilseed which appears to have imminent potential in Rwanda. Catholic Relief Services, with three small diesel powered expellers located in Mukarangé, Bugesera, and Rwesero, is currently producing about 25 tons of oil per year from 125 tons of sunflower seed. Sunflower grows well as a companion crop with beans, yields an average of one ton per hectare, and requires only ten kilograms of seed to plant one hectare. Because manual dehulling of sunflower is extremely time consuming, there is apt to be little demand for the seed for direct consumption. The CRS oilmill in Mukarangé presently pays 25 frw per kg for seed, from which it obtains an oil yield of 20 to 25%. One hundred to 125 frw of seed are therefore required to produce one liter of oil. The seed is mechanically shelled and winnowed before pressing, and the presscake is ground into flour, which sells for 40 frw per kg. <u>Surprisingly, the oil is sold for 200 frw per liter, above the price of imported oil.</u> Assuming that 25% of the weight of the seed is removed as husk and lost as evaporated moisture, and that the oil yield from the whole seed is 20%, then the added value per kilogram of seed is:

Revenue from oil		Revenue from cake		Cost of seed		
(0.20x200 frw)	+	(0.55x40 frw)	-	25 frw	=	37 frw per kg raw seed

The cost of mechanically processing a kilogram of seed is roughly 10 to 12 frw (the calculations at the end of this section indicate 11.41-14.55 frw per kg), leaving an impressive profit of about 25 frw per kilogram.

Yields of 20-25%, such as those being obtained by CRS, are not very good. Good quality seed can have as much as 38% oil. The possibility of growing higher oil content seed in Rwanda needs to be explored. A yield of 30% should not be difficult to achieve.

The following table compares an electrically driven oil expeller and manually operated ram press with respect to profitability, level of investment and number of jobs created.

Assumptions

- soft shelled seed with 30% oil content
- sale price of oil = 200 frw
- sale price of cake (human consumption) = 40 frw (expeller)
- sale price of cake (animal feed) = 15 frw (ram press)

	Expeller	Ram Press
Seed processing capacity/8 hr. day	400 kg	80 kg
Cost of expeller or ram press	640,000 frw	60,000 frw
Cost of other equipment	440,000 frw	10,000 frw
Laborers required	2	2
Cost of seed (kg)	30 frw	30 frw
Price/liter of oil	200 frw	200 frw
Price/kg of cake	40 frw	15 frw
Revenue/day	32,800 frw	5,600 frw
Costs/day	16,600 frw	3,200 frw
Profit/day	16,200 frw	2,400 frw

The capital costs of the expeller are somewhat understated because of the need to construct a building to house the expeller, electric motor and inventory of seed and cake. Other considerations are:

- The expeller and electric motor are imported, whereas the ram press can be manufactured locally.

- The expeller requires an investment of 1,100,000 frw (2750 frw/kg capacity) and the ram press 70,000 frw (875 frw/kg capacity).

- The expeller creates 2 jobs for a capacity of 400 kg/day, whereas the ram press would create 10 jobs (5 presses) to provide the same capacity.

- The ram press would present fewer management problems, involves less transport of seed, oil and cake, and would make oil and cake readily available in the rural areas where the seed is grown.

A third sunflower processing option would be simply to shell and winnow the seed to be eaten as a snack food, or for use in the preparation of confectioneries and sauces. For these uses, it is necessary to remove almost all of the shell. This is

neither necessary nor desirable when the seed is to be used for oil expression. Equipment is commercially available that can produce clean dehulled sunflower seed, and simple, locally manufacturable manual and motorized versions could be easily developed.

ii. The Technology

The following forms of technical and management assistance would stimulate the production and processing of sunflower in Rwanda:

- assistance in the selection, procurement, and dissemination of improved seed;

- training farmers and extension agents in sunflower cultivation and harvesting practices that are conducive to higher crop and oil yields;

- demonstration of the manual ATI/Bielenberg ram press, and, if response to this technology is positive, training Rwandan artisans in its manufacture (see attached ATI technical bulletin, this section);

- management assistance to improve the performance of existing motorized oil expeller operations.

The manual ram press and motorized expeller are complimentary technologies; each has advantages for the sunflower grower, processor, and consumer. Ram presses, being simple, rugged, relatively low cost machines, can be installed at a large number of locations close to the growers themselves. Locally made ram presses, costing 40,000 to 50,000 frw, could be owned by individual farmers or small associations of sunflower growers, who produce oil and feed for sale in their own communes. The cost of seed transport, and of down time due to mechanical breakdowns, would be minimized by using this technology. No more than five tons of seed per year are needed for economic use of a ram press, so the press is the technology of choice where sunflower production is a new activity. Control by farmers of the processing technology is often a powerful stimulus to increase sunflower production. Advantages of using the manually operated ram press include improved income distribution, simplified management for the grower and the processor (no need for group ownership of assets or group decision making), and foreign exchange savings (locally manufactured equipment versus imports). If the generation of rural employment is a primary concern, the ram press would be preferred.

Motorized expellers, when combined with dehullers, winnowers, and hammermills, would be desirable to process the larger quantities of oil consumed in the major towns, and enable edible flour to be produced from the cake. Expellers are also important in the near term, since they can process the low oil content seed

that cannot be processed in the ram press, providing the only outlet for the poorer seed that is presently grown. Expellers, like grinding mills, are simpler and less expensive to operate when powered by electricity, than when powered by a diesel or gasoline engine, so the electrified towns and communes are the best locations for these machines. Small expellers need from 20 to 50 tons of seed per year to operate economically, They require much less labor than the manual presses, producing at least 30 liters of oil per man-day, as opposed to five to ten liters per man-day for a ram press.

The manual UNATA equipment, currently being tested in Rwanda, is probably not as useful as either the ram press or motorized expellers for processing sunflower seed in Rwanda. While it is manually operated, simple, and well made, the UNATA press requires that the seed be shelled, winnowed, crushed, and roasted before pressing. A total of four pieces of equipment are required, at a cost of approximately 400,000 frw plus shipping from Belgium. Few if any small businessmen or individual farmers could afford this without financing. A well organized and motivated team of six workers is needed to operate the equipment. Finding and managing such a team requires skills that most small business people lack. The UNATA seed sheller can be set up as a hammermill to grind the cake into edible flour, but this is an extremely fatiguing operation. Although the UNATA technology might be seen as an intermediate technology, between the ram press and motorized expeller with respect to cost, complexity, and productivity, it lacks the major advantages of the other two technologies. Both the ram press and motorized expeller require only two workers, and are thus very simple from the standpoint of labor management. The potentially very high productivity of the expeller (depending upon the model selected) is nicely complemented by the extreme simplicity, low cost, and local manufacturability of the ram press. The UNATA technology falls short of the other two options in these respects.

iii. Existing Activity and Institutional Resources

The potential impact of a small project to promote sunflower in Rwanda is greatly enhanced by the existence of at least three organizations with considerable experience and interest in this crop. Catholic Relief Services has been operating three motorized expellers since 1983, and made the first major effort to encourage sunflower cultivation. The Belgian integrated regional development project "Kibungo II" has been growing sunflower on a cooperative plot, expelling oil for sale, and recently imported expellers to be installed at three communes in eastern Rwanda. Technoserve is encouraging sunflower cultivation and processing in Ntongwe, 40 kms southwest of Kigali, where it has provided improved seed and technical assistance to a farmers' association, and installed the manual UNATA processing equipment. The ISAR (Rwandan Institute for Agronomic Sciences) stations in Rubona and Karama have collaborated with Technoserve to test and evaluate sunflower varieties.

Each of these organizations can make an important contribution to the future promotion of sunflower. CRS is by far the largest processor of sunflower and has the greatest experience in sunflower processing. Kibungo II has good outreach to farmers in southeast Rwanda, is presently marketing improved sunflower seed, and has the authority to work with the communes in this region to organize sunflower production and processing. Technoserve has the management, marketing, and pricing skills needed to help sunflower processors improve their profitability while contributing to the growth of the entire industry. ISAR has the ability to test improved seed and cultivation practices, while the SSS (Selected Seed Service) could be enlisted to multiply and market improved seed.

iv. Uncertainties and Risks

Like most crops, sunflower has its own strengths and weaknesses. Its major strengths are its low seeding requirement (only 10 kg per hectare), its resistance to drought, its compatibility with leguminous companion crops, and, depending upon the variety, temperature, and incident solar radiation, its short vegetative cycle. Its major weaknesses are its extreme susceptibility to bird predation and to seed head fungal attack, necessitating vigilance during seed maturation, harvesting, and drying. High oil yields are obtainable with certain open pollinated varieties, as well as hybrids, but genetic degeneration takes place rapidly, with a consequent loss in crop and oil yields. The ATI-Lutheran World Relief sponsored project in Arusha, Tanzania, has considerable experience in dealing with these problems, and this experience could prove very useful in promoting the development of sunflower in Rwanda. The agronomic conditions are far from identical, but the implications of different approaches, for example, using hybrids vs. using open-pollinated varieties, are well understood.

Several factors will determine whether farmers can be encouraged to grow sunflower on a large scale:

- the price paid for sunflower, which should probably be no less than 30 frw, and which will need to be further increased if the Rwandan franc is devaluated;

- the quality of available seed, which needs to be improved both to make processing profitable at higher producer prices as well as to increase the productivity and durability of the processing machinery;

- the development and dissemination of strategies to improve the yield and reliability of the sunflower crop by collaborating with farmers, and using the experience gained in other African countries; and

- the demonstration of sunflower's other uses, that is, the use of the cake as an excellent poultry and cattle feed supplement and as edible flour.

Failure of the proposed project to address one or more of these issues could result in a general and permanent reluctance by farmers to increase sunflower production.

V. Recommendations for Future Action

The organizations that are currently promoting sunflower in Rwanda are collectively able to implement a sunflower promotion project. Their common deficiency in this respect is that none of them have the sole objective of sunflower promotion. Consequently important problems, like seed degeneration, pricing, and marketing, may not be addressed, or even noticed, until the farmers' interest in sunflower is already shaken. The proposed project coordinators should involve farmers directly, and thereby obtain feedback from them, while working with the organizations that are already promoting sunflower to strengthen the outreach. The project would also provide coordination and technical assistance to these organizations, helping them to work together while solving the agronomic, processing, and management problems mentioned above.

The proposed project needs only four or five staff:

- a coordinator to oversee all project operations and expenditures, prepare reports, and represent the project in its relations with other organizations and with the Rwandan Government ministries. This person should have a background in agricultural economics. He/she may also fulfill one or more of the following functions;

- one or two extension workers to work with farmers and the extension staff of collaborating organizations;

- one skilled mechanic, to oversee the local manufacture of presses and other equipment, and to ensure the proper maintenance and repair of processing equipment in the field; and

- one business management advisor to help improve efficiency of the processing enterprises and assist in the development of pricing and marketing strategies for sunflower seed and oil.

ESTIMATED OPERATING COSTS FOR SUNFLOWER PROCESSING TECHNOLOGIES

Diesel or Electric Expeller, with Equipment for Producing Edible Flour (300 kg/day capacity, operating 200 days/year)

A. Depreciation

Item	Cost (frw)	Life	Capacity (kg/hr)	Hrs/ day	frw/ day
Building with seed store	400,000	20 yrs			100
Oil expeller	640,000	5000 hrs	50	6.0	768
Dehuller	160,000	2000 hrs	200	1.5	120
Winnower, sifter	80,000	2000 hrs	200	1.5	60
Grinder (locally made)	80,000	2000 hrs	100	2.0	80
Diesel engines -for expeller	240,000	5000 hrs		6.0	288
-for dehuller, grinder	240,000	5000 hrs		3.5	168
Electric motors -for expeller	60,000	5000 hrs		6.0	72
-for dehuller, grinder	60,000	5000 hrs		3.5	42

Total Depreciation	Per day (frw)	Per kg seed (frw)
Diesel-Powered Unit	1,584	5.28
Electric-Powered Unit	1,242	4.14

Estimated Operating Costs, Diesel or Electric Expeller, Cont.

B. Repairs, Lubricants, and Wearing Parts

(100% of depreciation for expeller and diesel engines, 50% of depreciation for all other equipment, and 25% of depreciation for buildings)

	Per day (frw)	Per kg seed (frw)
Diesel-Powered Unit	1,379	4.60
Electric-Powered Unit	980	3.27

C. Energy

	Per hr	Per day	Unit Cost	Per kg seed (frw)
Diesel fuel (diesel unit)	1 liter	9.5 liters	62/liter	2.0
Electricity (electric unit)	3 kw hrs	28.5 kw hrs	14/kw hr	1.33

D. Labor -- 1 manager at 350 frw/day, 1 laborer at 150 frw/day 1.67

E. Licenses and Taxes -- 60,000 frw/year 1.0

Total Operating Costs	
Diesel-Powered Unit	14.55
Electric-Powered Unit	11.41

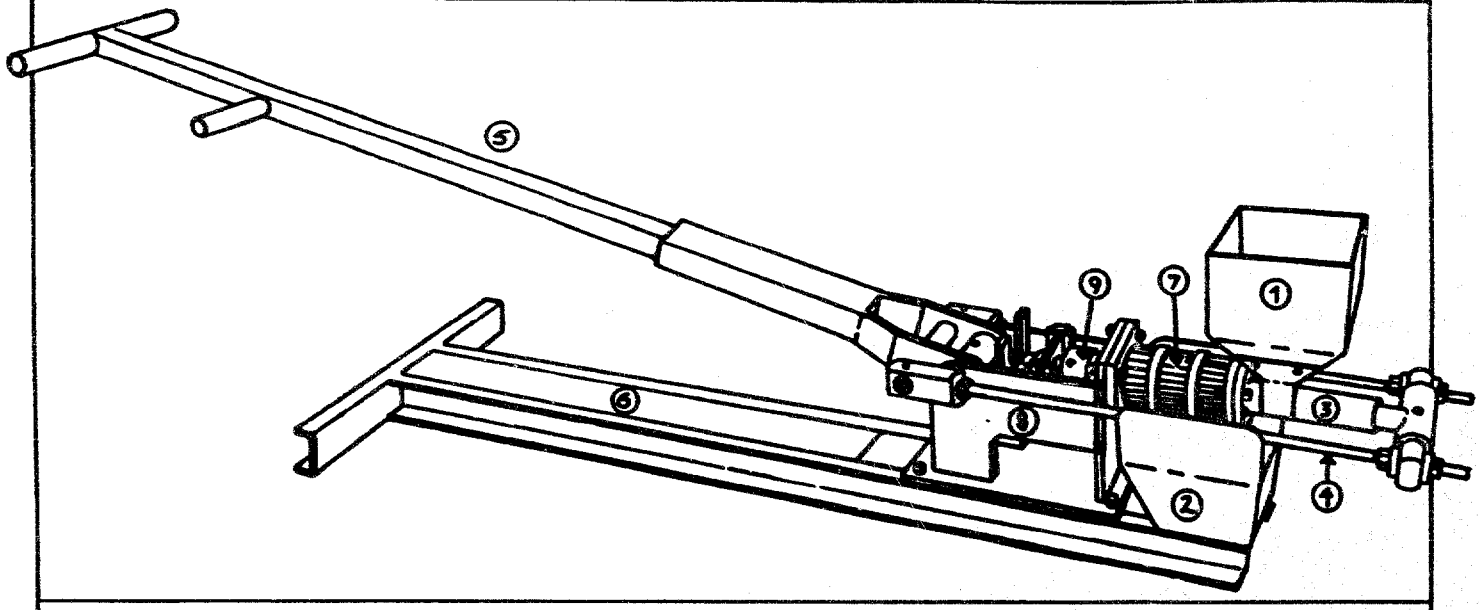
Manual Ram Press, (50 kg/day nominal capacity; several privately owned ram presses in Tanzania are processing over 150 kg per day)

A. Depreciation

Item	Cost (frw)	Life	Capacity (kg/hr)	Hrs/ day	frw/ day
Open-sided shed; 8 m^2 with adobe store for press, seed, oil (4 m^2)	40,000	10 yrs			40
Oil press	60,000	5000 hrs	10	5.0	60
Seed Heater	5,000	2500 hrs	10	5.0	10

	Per day (frw)	Per kg seed (frw)
Total depreciation	110	2.2
B. Repairs, Lubricants, and Wearing Parts (50% of depreciation for equipment, 25% of depreciation for building)	45	0.9
C. Energy -- 1/20 m^3 firewood per day	20	0.4
D. Labor -- 2 laborers at 150 frw/day	300	6.0
Total Operating Costs		9.5

N.B. No taxes or license fees have been ascribed to the ram press, because this would be a rural, informal sector activity.



(1) Seed hopper
(2) Oil collection tank
(3) Cylinder and piston assembly
(4) Draw bar (2)
(5) Removable handle
(6) Base frame
(7) Expelling cage
(8) Main frame
(9) Back-pressure plug

Illustration and photo courtesy of CARE

"CECOCO" OIL EXPELLING EQUIPMENT

FOR SMALL SCALE & RURAL INDUSTRIAL PURPOSES

RECOMMEND TO USE "CECOCO" OIL EXPELLING EQUIPMENTS FOR EXTRACTING OIL FROM SUNFLOWER, PEANUT, COTTON, COCONUT, PALM KERNEL, RAPE-SEED, CASTER, KAPOK AND OTHER SEEDS OR KERNELS.

PROCESSING CAPACITY:

30-50kgs; 50-80kgs; 100-130kgs; 160-200kgs; 200-260kgs per hour in Oil Bearing Materials, capacity varies according to the kind of Raw Material and Dryness Condition of Materials.

EXPELLING EFFICIENCY:

Approximately 90% of OIL CONTENTS in Material dried less than 5-8% Moisture Content in Raw Material.

CALCULATING METHOD FOR OIL TO BE EXPELLED:

Capacity in Weight of Material per hour X Percentage of Oil Content in Material X 90%(Expelling Efficiency) = Approx. Weight of Oil to be expelled per hour

COMBINATION OF EQUIPMENTS FOR VARIETY OF SEEDS OR KERNELS:

Sunflower---------HULLER------WINNOWER------SCORCHER------EXPELLER------FILTER PRESS

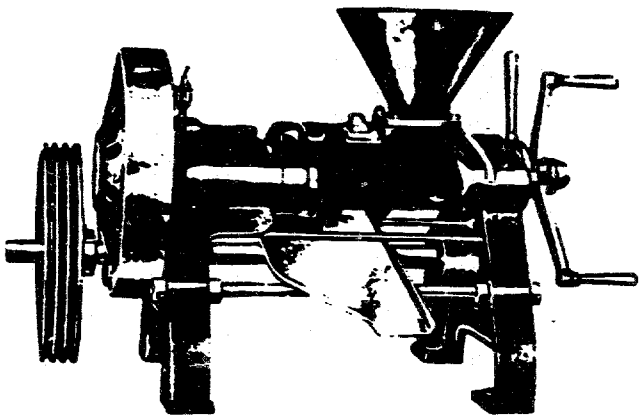
Peanut----------PEANUT SHELLER---CRUSHER---SCORCHER------EXPELLER------FILTER PRESS

Cotton----------DELINTER----------SCORCHER------EXPELLER------FILTER PRESS

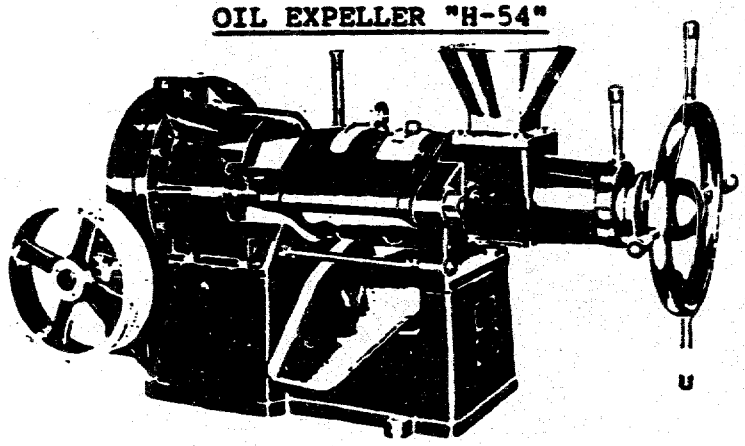
Coconut
Palm-kernel------CRUSHER----------SCORCHER------EXPELLER------FILTER PRESS

Rape-seed
Caster "----------SCORCHER------EXPELLER------FILTER PRESS

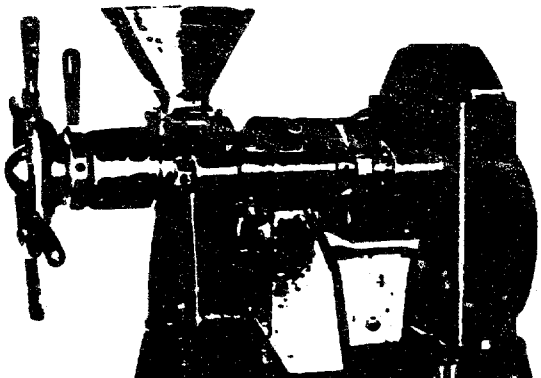
OIL EXPELLER "NEW TYPE 52"



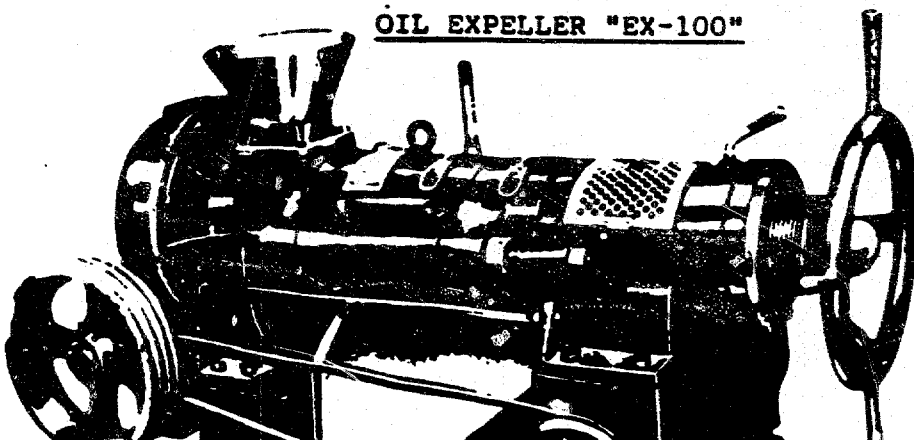
OIL EXPELLER "H-54"



OIL EXPELLER "M"



OIL EXPELLER "EX-100"



C. SPENT BREWERY GRAINS FOR ANIMAL FEED

i. The Need or Market

Rwanda's soils will not be able to support the increased demand for food necessitated by its increasing population. Therefore waste materials having fuel or nutrient value will become increasingly important. Currently, most cattle and small livestock are free ranging and depend on small areas of unimproved pasture, or are fed harvested but unimproved grasses, or crop and domestic wastes. The loss of pasture to farmland has increased awareness by farmers and policy makers that livestock must be stabled and fed cultivated forage, crop wastes, and commercial feeds. The use of animals in the farm economy cannot be seen as a luxury to be inevitably abandoned as the human population continues to increase; rather, animals are an important means of increasing agricultural production by decomposing and recycling organic matter. They also provide the limited income needed by farm families to purchase agricultural inputs as well as to meet their diverse cash requirements. Livestock make up an integral part of Rwanda's strategy of agricultural intensification, and, through their meat and milk production, help improve the quality of life.

The market for commercial feeds is currently limited to a number of small research and demonstration farms and small private farms, which utilize improved breeds of dairy cattle, pigs, or poultry, and which use feeds to improve the cost effectiveness of their herds. Most small farmers do not use feeds, either because they may not be convinced that it is profitable; do not have the disposable income; do not live near a source of commercial feed; or are unable to market their extra production to pay for the feed. All of these factors, and the high cost of commercial feeds, are important impediments to feed utilization by small farmers. Since commercial feeds are, on average, as expensive as the staple cereals and beans that people eat, the small farmer's reluctance to buy feed for his animals is entirely understandable.

The spent grains of the brewery in Gisenyi (BRALIRWA) are one of a number of important wastes that are available inexpensively in Rwanda, and are important sources of animal nutrients. The brewery currently produces 240 tons of spent grains per week, which are discharged directly into Lake Kivu. The grains have a high moisture content (roughly 80%), and are therefore costly to transport and are highly perishable in the form in which they leave the brewery. They are also low in calories, because most of their starch has been converted to sugar and extracted during the brewing process. They are, however, high in protein (25% crude, dry basis), and can be used to balance feedstuffs that are high in calories or vitamins and minerals, but low in protein.

BRALIRWA is the only brewery in Rwanda, and is thus the sole commercial source of spent brewery grains. The general manager

and production manager expressed their willingness to see the brewery grains put to good use, and a silo was erected in 1987 to facilitate loading of the grains into trucks. The brewery has a written protocol for potential buyers, and will sell brewery grains at a cost sufficient to cover the price, maintenance, and operation of the storage silo and unloader, that is, 0.25 frw per kilogram of wet grains. Still, there have been few takers of the brewery grains on a regular and significant basis.

The feasibility of using brewery grains as a cattle feeding supplement depends on a number of factors, primarily involving the costs of processing and distribution. Although cross-country comparisons can be misleading, it is interesting to compare the relative costs of brewery grains in Rwanda and the U.S., and the producer prices of milk. The comparison demonstrates why this area has attracted the interest of Rwandan researchers, policy makers, and potential investors. In the U.S., wet brewery grains cost 1.76 frw/kg (equivalent to $20.00 per ton), trucked a short distance from the brewery. This is roughly seven times the price at the brewery in Gisenyi. By comparison, the average producer price of milk in Rwanda is about 40 frw, while the price in the U.S. is 21 frw per liter (equivalent to $12.00 per hundred pounds). Depending on the genetic makeup of the cow and availability of other nutrients, 10 kgs of wet brewery grains will result in an incremental milk production increase of 4.5 liters. Thus, without counting the losses and costs incurred during processing and distribution, 2.5 frw of grain can produce 180 frw of milk. This is an increase of 72 times, as compared with 5.4 times in the U.S., where wet brewery grains are considered a good buy. If only half of the brewery grains produced in Rwanda were eventually used to feed dairy cows, and only half of the theoretical feed conversion efficiency were obtained, about 4000 liters of additional milk per day could be produced. In this case, the benefit to consumers would be nearly 100 million frw worth of milk per year, while almost two-thirds of this consumer spending would reach the dairy farmers, most of whom only have one or two cows.

The potential importance of using brewery grains for animal feeding goes beyond the increased production that the grains themselves can provide. Positive results from using one cheap commercial feedstuff should demonstrate to farmers, and potential entrepreneurs, the profitability of using other feeds, particularly those derived from local waste products. This could result in more intensive use of other nutritious by-products, like rice and wheat bran and molasses, that currently sell for very low prices, as well as the wastes generated on individual small farms, such as spent sorghum malt and banana pulp.

A final benefit of this project would be to reduce or eliminate the discharge of brewery grains into Lake Kivu. It is unlikely that this discharge has significant feed value for the fish population of the lake, because the lake is so poor in dissolved oxygen, and consequently, fish life. Most of the 4000

Appropriate Technology International

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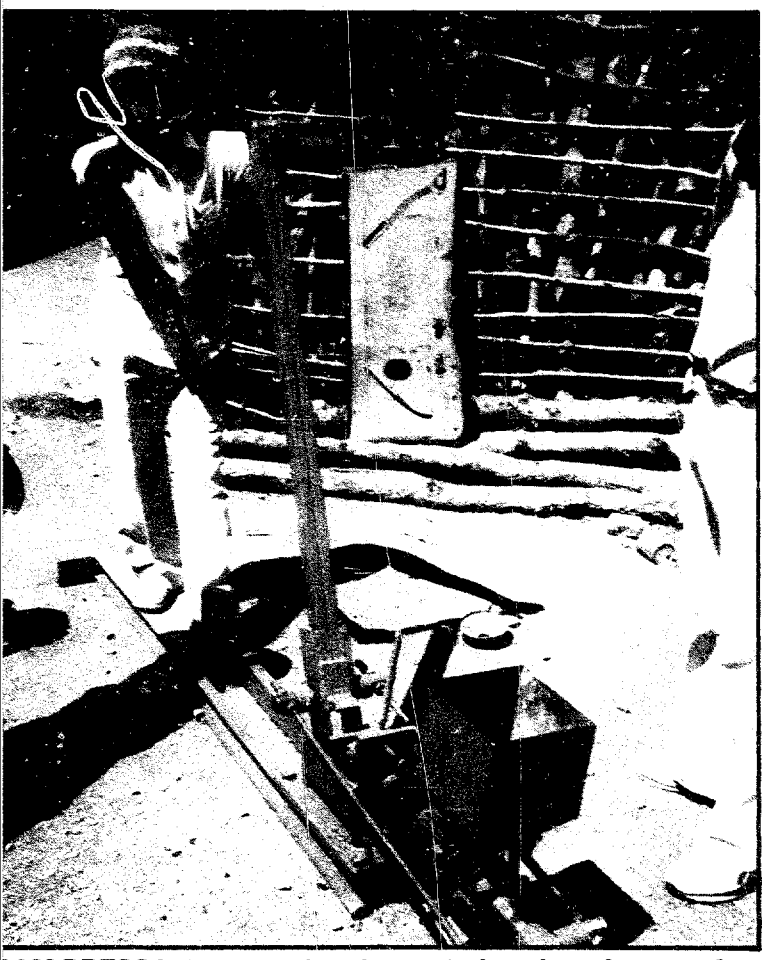
SUNFLOWER SEED OIL PROCESSING IN TANZANIA

Appropriate Technology International seeks to develop cost effective strategies that increase the productivity of poor people in rural areas and market towns in developing countries. ATI's projects focus on appropriate technologies that add value to the resources of the poor. The goal is to establish commercially viable enterprises based on successful appropriate technologies that are easily adapted for widespread dissemination locally as well as for use in other countries and regions.

This Bulletin describes a low cost, hand-operated ram-type sunflower seed oil press which can be manufactured easily in small workshops in developing countries. This ram press was designed to fill a market niche not addressed by two larger I.P.I. scissor jack design presses being manufactured under ATI's Oil Press Production project in Tanzania, which concluded in 1987. Because of its lower cost, and because it proved more practical in rural areas than the large, heavy and costly I.P.I. presses, the ram press is the only press being disseminated by a second Tanzanian project, Village Oil Processing. A third project, the Regional Sunflower Project approved in late 1988, is expected to further disseminate the ram press over a wide area in East and Southern Africa. All three projects are intended to increase the availability of reasonably priced cooking oil, increase the market for sunflower seed and thus increase incomes of sunflower producers, and enable small producers to process cooking oil locally.



RAM PRESS is low cost, hand-operated, and can be manufactured by small workshops in developing countries. This is an early version; later versions feature a different handle and cage.

EXPECTED BENEFITS

(In September, 1988, when these figures were prepared, 96 Tanzanian shillings = US$ 1.00)

Direct Income: Commercial pressing enterprises (individual farm families or cooperatives) either process their own seed, buy seed to produce oil for sale, or process seed as a service to other growers. A small-scale commercial enterprise which processes at least 75 bags of seed (50 kg each) annually can expect to earn a net income of 82,350 TSh (US$ 857) on sales of 900 liters of sunflower oil. Press owners who process seed as a service to growers either charge a small fee (20-30 TSh per liter) or take their payment in kind by retaining a percentage of the oil and seed cake produced (up to 50%). A sunflower grower, who has seed processed locally and splits the oil and seed cake 50/50 with the press owner, earns approximately 70% more per bag than if he sells the raw seed to government purchasing agents.

Employment Created: Two semi-skilled laborers are needed to operate each press during the pressing season—six months per year. Workers have been earning almost 20% more than the official Tanzanian minimum wage for rural labor.

Value Added: The oil and the seed cake (used as a fodder ingredient) derived from the pressed seed are more than twice as valuable as standard black sunflower seed in Tanzania. In September, 1988, sunflower seed sold for 600-800 TSh per 50 kilo bag; the oil and the seed cake were worth approximately 2,420 TSh per bag.

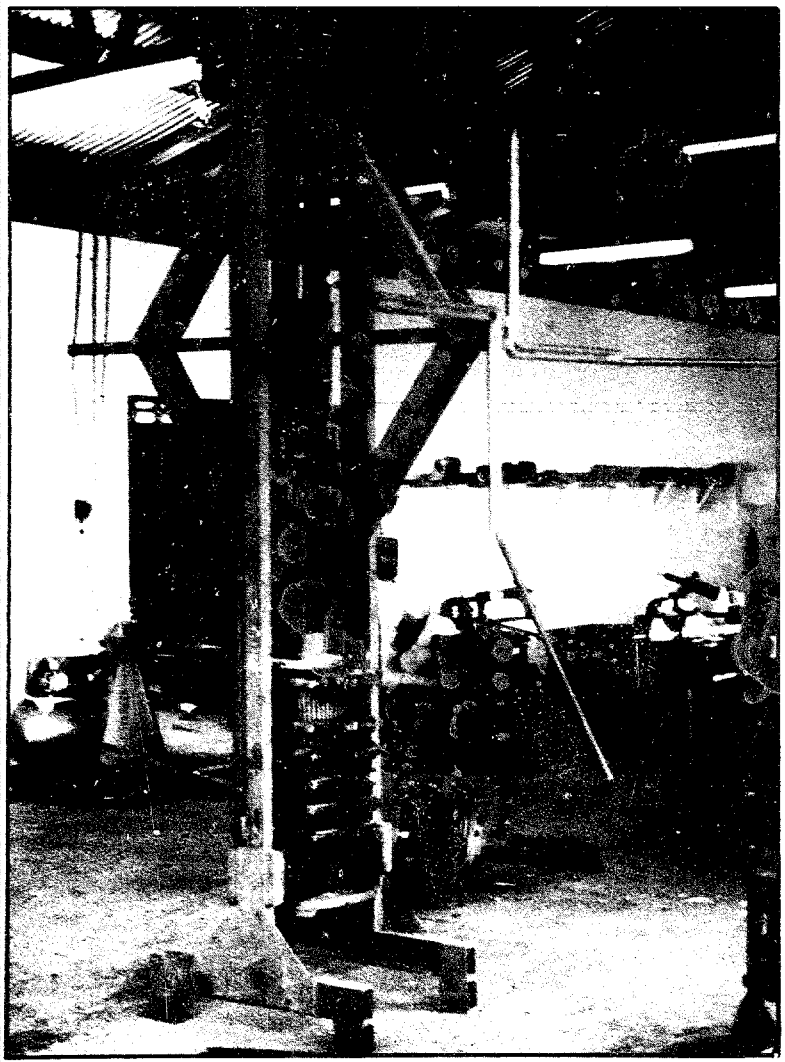
(continued from page one)

A few entrepreneurs have been attracted by the seed cake byproduct. A woman in Arusha who had a small herd of dairy cows purchased the press primarily for the residue cake which would serve as a fodder supplement for her cows; the oil production was secondary. Over time she has developed a thriving secondary business selling sunflower oil to the same customers who purchase her milk.

Other Benefits: Pressing sunflower seed locally increases the availability of low-cost edible oil to the rural poor, especially in the remote areas where animal fats are only available seasonally and industrially produced oils are relatively scarce.

Local pressing businesses usually pay higher prices for seed (as much as 60%) than large government parastatal oilseed factories; thus sunflower becomes a more profitable cash crop. Small-scale farmers who substitute sunflower for less profitable crops will increase the income generating capacity of their lands.

Capital Formation After making a down payment of 10,000 TSh (US$ 104) and repaying the 40,000 TSh (US$ 416) loan over a 3-year period, each oil processing enterprise will own a sunflower seed press and accessories with a book value of 20,000 TSh (US$ 208) (cost of press minus depreciation of 10,000 TSh based on the assumption that the press has a 5 year life). ATI's financial projections show that, in addition to the value of the press, over a 3 year period the typical enterprise would have generated a cumulative net income of approximately 255,575 TSh (US$ 2,662).



In 1984, when ATI introduced its first two sunflower seed processing projects in Tanzania, oil imports were prohibited by the government. Paradoxically, because the Government of Tanzania set artificially low prices for seed, seed production had decreased substantially. As a result, edible oil was available in villages only on a seasonal basis. The bulk of the seed sold to government purchasing agents was processed by medium size factories in centers of oilseed production. There were no traditional or modern small-scale technologies widely available for village use. To alleviate the edible oil shortage, ATI introduced the Oil Press Production Project and the Village Oil Processing Project. Sunflower, which is a cash crop, is the most common oilseed in Tanzania.

The first project supported the Themi Farm Implement Company, which manufactured the 80-ton and 20-ton scissor jack presses. In response to market demand, Themi and ATI developed a smaller, less expensive ram press. Themi has manufactured 20 presses of all three types which are being used to extract oil in rural areas. Themi now is experimenting with an intermediate size I.P.I. press (40 tons) that has been designed to facilitate transport, installation and repair.

By January 1989, the Village Oil Processing project had helped establish 34 privately owned sunflower seed processing enterprises in 23 villages. During the 1986-87 crop year (July 1-June 30), 10 processing enterprises produced 4,933 liters of cooking oil. In 1987-1988, 20 processing enterprises produced 7,250 liters of cooking oil. Thus far, for the 1988-1989 season the 34 processing enterprises have processed over 19,000 liters of oil. Most of this oil is for local consumption.

THE ATI APPROACH

ATI considers four issues in its projects: (i) the institutions involved and the need for institutional development; (ii) the technology involved and the need for adaptation or further refinement of the technology; (iii) the commercial viability and the need for market development, including credit facilities and repayment schedules; and (iv) policy and replication issues. (What factors promote or inhibit the spread or dissemination of the technology to other geographical areas?)

THE OIL PRESS PRODUCTION PROJECT provided funding for Themi Farm Implements and Engineering to manufacture two types of scissor jack oilseed presses (20-ton and 80-ton) designed by the Institute for Production Innovation(I.P.I.), University of Dar-es-Salaam. During the course of the project a smaller, less expensive ram press was designed to fill a market niche not addressed by the larger, more expensive I.P.I. presses. Themi continues to manufacture all three presses and is experimenting with a 40-ton I.P.I. press which is easier to transport, install and repair.

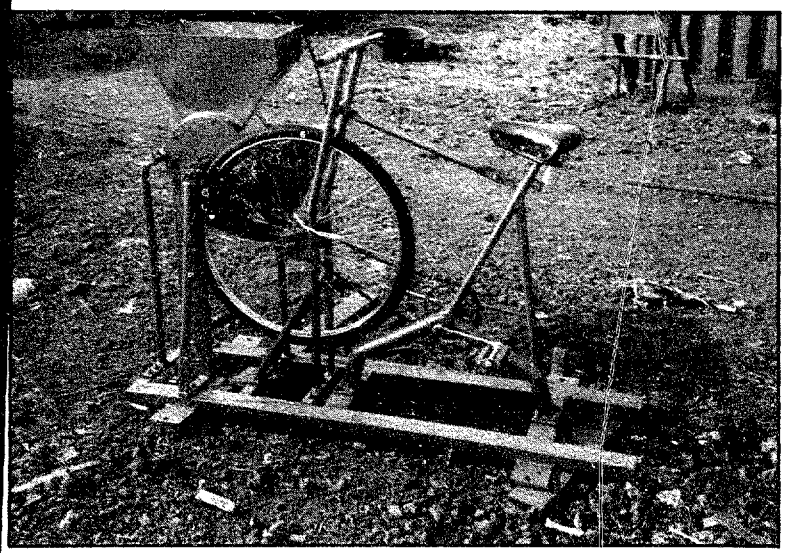
CAMARTEC (Centre for Agricultural Mechanization and Rural Technology)
CAMARTEC is a Tanzanian parastatal which tests technology for use in the rural sector and promotes its production and sale. It also manufactures agricultural equipment such as ox-carts, twin-share plows and planters. Parliamentary mandate empowers CAMARTEC to enter into cooperative agreements with international organizations and to help administer donor funds. CAMARTEC managed the Oil Press Production project.

Themi Farm Implements and Engineering
The Themi Farm Implement Company of Arusha is a private company started in 1981 partially to satisfy the local market for ox-drawn tool-bars and ox-carts. The workshop's equipment is uncomplicated and suited for most general engineering work. Themi produced and installed the initial oil presses and auxiliary equipment for the Oil Press Production and the Village Oil Processing projects.

Institute for Production Innovation (I.P.I.)
The Institute for Production Innovation at the University of Dar-es-Salaam is an autonomous department of the Faculty of Engineering which helps local industry to improve manufacturing practices and to develop products that can be made in Tanzania. It concentrates on technologies that can be used in rural settings. I.P.I. developed the 20 and 80-ton scissor jack sunflower oil presses and provided Themi with initial technical assistance.

Lutheran World Relief (LWR)
Lutheran World Relief is an international development agency based in New York City, with a regional office in Nairobi which coordinates and develops projects in East Africa. LWR has provided both technical and financial support to the Village Oil project.

Evangelical Lutheran Church in Tanzania, Arusha Synod (E.L.C.T.)
The Evangelical Lutheran Church in Tanzania, which is based in Arusha, has a strong development focus. The E.L.C.T. Arusha Synod is the implementing organization for the Village Oil Processing project. The Village Oil Processing project promotes the press, trains manufacturers and press users, organizes village groups, and manages the credit program (6 month loans are given to press purchasers).



BICYCLE-POWERED DEHULLER separates sunflower nut meats from the shells.

RAM PRESS enables sunflower oil to be processed in rural areas.

REPLICATION ISSUES

The ram press has significant replication potential in other sunflower-producing regions of Tanzania as well as in other African countries including Kenya, Zimbabwe, Zambia, Rwanda, and Uganda. A regional project to further expand the impact of this technology, to be co-funded by ATI, Lutheran World Relief, the Government of Tanzania, and other donors will be implemented in East and Southern Africa, beginning in Spring, 1989. During Phase 1 an optimal press design will be chosen from among the several design modifications, a set of jigs and fixtures will be produced to facilitate the production of the press, and parts lists and assembly drawings will be prepared. By late 1989, ATI plans to have a complete replication package including engineering drawings, instructions for jigs and fixtures, a technology manual and commercial assessment of pressing enterprises in several countries. During Phase 2, the press will be disseminated to other areas in Tanzania. The project will also establish a Regional Information Center to keep practitioners informed of developments in sunflower oil processing technologies. Individual country programs supported by this project will provide all or some of the following: technical assistance, training, and financial assistance packages so that low income families can purchase the press and pay for it out of proceeds generated from its use. At least 30 manufacturers in seven African countries will be trained to produce the press. At the end of three years, the replication project should have resulted (through training and information dissemination) in the production of more than 600 ram presses.

Ram Press

The sunflower seed press being disseminated through these projects was designed in 1985 by ATI engineer Carl Bielenberg and subsequently has been modified by other engineers and press manufacturers. It is especially appropriate for rural areas because it is small, manually operated, and has a continuous throughput. The ram press uses a hand-operated lever arm to move a piston back and forth inside a cylinder. The lever arm is connected to the end of the piston by two tie arms, one on each side of the press. As the operator pulls the lever downward, the piston is pulled into the cage by the tie arms. The sunflower seed, fed into the cylinder from a hopper, is pushed into a pressing cage and compressed by the piston against an adjustable restriction cone. Expressed oil squeezes out through the cage and the spent seed cake moves through a choke ring and out the end of the cage.

The press can most efficiently extract oil from soft-hulled, improved varieties of sunflower. The seed should be heated in the sun before processing. Hard-shelled sunflower seed must be dehulled before it can be used in the ram press.

The press is mounted on a steel or wooden base, making it portable. However, mounting it on a cement base makes it more stable and easier to use.

If used properly, the press can extract as much as 60 to 70% of the oil present in sunflower seed. A 50 kilogram bag of fair quality sunflower seed yields from 10 to 12 liters of oil; seed with higher oil content yields as much as 16 liters per 50 kilogram bag of seed.

Manufacturers and engineers have modified the press to: (1) make it easier to use; (2) decrease costs of production; (3) increase efficiency; (4) make it easier to manufacture. For example, the original design included a handle which had to be rotated from a vertical position to a position parallel to the ground. This made it awkward to operate. Now the handle only rotates down to a chest-high position.

Many different versions of the ram press are in use; some these are poorly designed and manufactured. The Region Sunflower Project has begun an engineering assessment all the different versions of the press to document the various capacities, costs, ease of manufacture, reliance c imported parts, etc. The most efficient and cost-effective ve sion of the press will be promoted throughout East an Southern Africa.

Dehuller

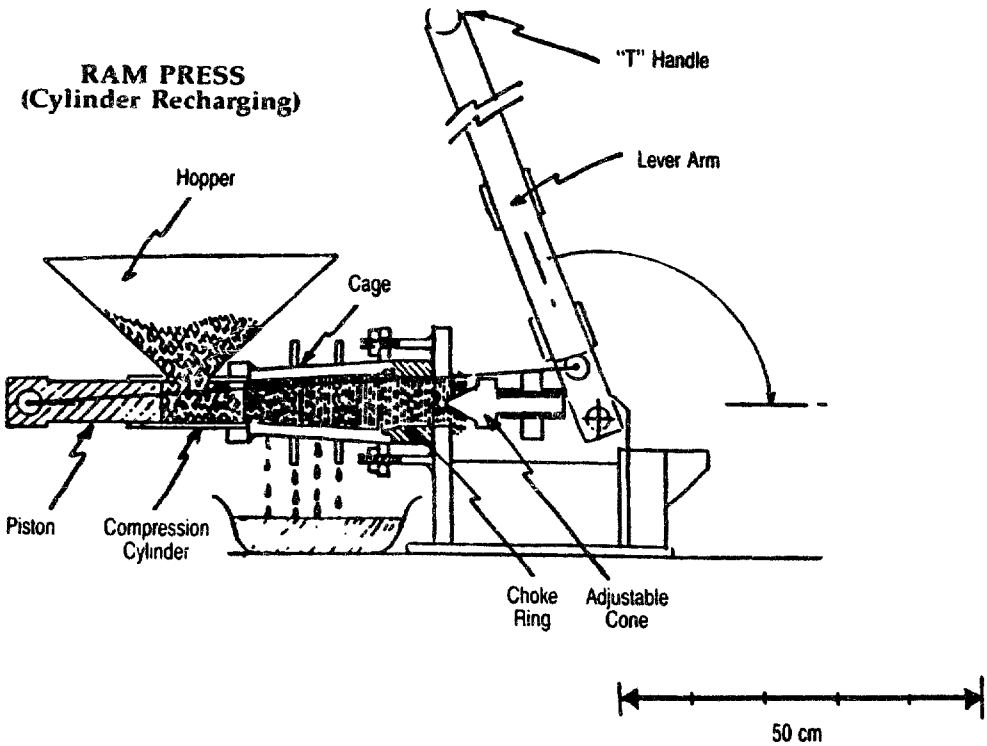
The dehuller uses a rotating disk with three fins to hurl har shelled sunflower seeds against a hard rubber stop. The dis is hand cranked by two people, and pulleys are used to i crease the rotational speed of the disk. Seeds are fed int the center of the disk, accelerated to roughly 100 feet per s cond and ejected onto the stop. The hand crank also powe a small fan which winnows the nut meats from the shells. bicycle-powered dehuller that can be operated by one perso was developed by an ATI engineer.

Clarifier

The dark coating of the sunflower seed husks leaves a fin black sediment in freshly pressed oil, which makes the o appear dirty. A filter screen (using cotton fiber) or a sedimen tation tank can remove these impurities. Any foreign matte that entered during the pressing operations is also screene out at the same time. Alternatively, the oil can be boiled wit water to clarify it. As the oil-water mixture cools, the oil rise to the top and the blackish colored water settles at the bo tom. The oil then can be poured or skimmed off the top.

Seed Residue

Sunflower seed residue (seed cake) is rich in protein and, mi ed with local grasses and feed grains, makes an excellent fee for cattle, pigs and poultry.



The Market

In Tanzania, edible oil availability depends on the season, geographic location and domestic production levels. In most major population centers or along major transport routes, industrially-produced oil is generally available—at least in limited quantities. Besides sunflower oil, other edible fats include "samli" (butter fat produced from cows' milk), vegetable fat imported from Kenya and imported blended vegetable oil. Consumers' order of preference (most to least preferred) is samli, Kenyan vegetable fat, sunflower oil and blended vegetable oil. However, the sunflower oil is cheaper than the vegetable fat and samli is not always available. The marketability of sunflower oil will depend on its price vis-a-vis imported blended oil. In remote areas of Tanzania industrially produced oils are scarce and locally produced fats such as samli or pork fat are only seasonally available. These areas should benefit the most from increased availability of vegetable oil.

Schools and hotels often find it difficult to obtain sufficient supplies of edible fats. This represents a large untapped market for small-scale commercial sunflower seed processing businesses; as yet not many sunflower enterprises are selling oil to these large-scale consumers.

LOCAL COOPERATIVE at Endakiso in Tanzania has purchased one of the Village Oil presses.

Price

Sunflower Oil: In September, 1988 the price for sunflower oil produced by local pressing enterprises was 200 TSh per liter (US$ 2.08). Sunflower oil producers often sell bulk amounts of oil at a lower price.

Sunflower Seed: Since 1984, farmers in the Arusha region have sold their sunflower seed to the Arusha Region Cooperative Union (ARCU) at a government-fixed price. Small-scale sunflower press owners in the Arusha region have been paying 30% higher on average for sunflower seed. Another bonus—farmers are paid on the spot. When they sell seed to the ARCU they must wait two to three months to be paid.

Production of Presses

Thirty-four small-scale sunflower processing enterprises ha been established under the Village Oil Processing projec by the end of 1989, when the project closes, 50 presses w have been manufactured (including an inventory f dissemination after the official close of the project). The ra press can be manufactured from locally available materia such as mild steel. The simplicity of its design has kept bo manufacturing and maintenance costs low. Press manufa turing requires only standard machine tools such as lathe milling machines, welding equipment, and drill presse Therefore, the presses can be made in most rural shops.

Sunflower Oil Production

Twenty sunflower seed processing units produced a total c 7,250 liters during the 1987-1988 production year. Thus far, fo the 1988-1989 season approximately 34 presses produce more than 19,000 liters of oil.

Commercial Viability of Pressing Enterprises

(96 Tanzanian shillings = US$ 1.00, September, 1988)

The commercial viability of the ram press depends on (amon other factors) the amount of seed available, the price of th seed, the oil content of the seed, and the selling price of oi Even with an interest rate of 25%, a ram press costing 50,00 TSh (US$ 520) can pay for itself in 4 months assuming th following: (1) a high grade seed is used—50 kg of seed yield 12 liters of oil; (2) 75 bags (containing 50 kg seed each) ar processed per year (during a six-month pressing season); (3 the price of raw seed is 800 TSh (US$ 8.30) per 50 kg bag; (4 cost of labor is 23 TSh (US$ .24) per liter (a wage rate 60% higher than the minimum wage); and (5) selling price for oi is 200 TSh (US$ 2.08) per liter. If these assumptions hold true the press will generate a net income of 82,350 TSh (US$ 857 in a normal six month pressing season. The press could b even more profitable if oil yields are higher (yields as hig as 16 liters per 50 kg bag have been recorded) or if the pres is operated at full capacity (150 bags of seed can be process ed annually). Full capacity use, of course, depends on th availability of sunflower seed.

The ram press's profitability per unit of oil can be shown b the following breakdown of costs.

Estimated Sales Price	=	200 TSH per liter
Estimated Costs:		
Seed	=	67
Labor	=	23
Repairs	=	5
Interest	=	2
Total Costs	=	97 TSh per liter
Cash Surplus	=	103 TSh per liter

ATI's three year $111,964 grant to CAMARTEC enabled Themi Farm Implement Company to manufacture 20 sunflower seed presses and ancillary equipment such as decorticators. ATI's four year $142,626 grant to Lutheran World Relief is providing technical assistance and loan capital to help Tanzanian village entrepreneurs establish and manage small-scale oil extraction businesses. Funding for the Regional Project breaks down as follows: ATI-$274,000, Lutheran World Relief-$190,000, Government of Tanzania and others-undetermined.

ZIMBABWE SUNFLOWER PROJECT

The Zimbabwe Sunflower Project, scheduled to begin plementation in mid-1989, will provide managem assistance, extension services and loans to groups or s farm families in the communal lands who wish to start pr ing enterprises. Skilled workers in three small machine sh will be taught to manufacture the presses. By the end of three-year Zimbabwe project, it is expected that 180 to jobs will be created in the 180 pressing enterprises to established. In addition, on an annual basis, more than 2 farmers will increase their incomes, enough oil will be duced to meet the requirements of 54,000 people US$ 235,000 of added value will be retained in the rural a by locally processing sunflower seed.

FOR FURTHER INFORMATION

Ram-Type Manual Oil Press, Carl Bielenberg, 1986. Technology Appraisal Report. $5.00

An Engineering Analysis of Three Manually Operated Sunflower Seed Oil Presses Manufactured in Tanzania, Martin J. Fisher, 1988. ATI Working Paper. $5.00

Available from ATI

Independence through Mobility: A Guide to the Manufa ture of the ATI-Hotchkiss Wheelchair. $15.

Manual for Commercial Analysis of Small-Scale Projec 104 pp. $6.

APPROPRIATE TECHNOLOGY INTERNATIONAL

Appropriate Technology International is a private, not-for-profit development assistance organization based in Washingto D.C. and operating in Asia, Africa, Latin America and the Caribbean. ATI's program is concerned with the identification, asses ment and adaptation of technology. In collaboration with local organizations in developing countries, ATI develops and tes commercial applications of appropriate technologies in the fields of minerals utilization, agricultural products processin and small farm equipment.

ATI implements its mission with public funds made available through the Agency for International Development. ATI's pr gram is carried out in cooperation with the Employment and Enterprise Development Division of the Office of Rural a Institutional Development within the Bureau of Science and Technology.

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Bulletin #

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to 7000 tons of fish that inhabit the lake are less than ten centimeters long and live near the surface of the lake, due to high levels of dissolved carbon dioxide and methane in the deeper waters. The discharge of brewery grains probably reduces the level of dissolved oxygen near the discharge point below the already low levels existing elsewhere in the lake, making the waters there less habitable than elsewhere. However, the actual effect of the discharge on Lake Kivu fisheries should be more closely scrutinized by a pisciculture specialist.

ii. The Technology

Several methods may be used to process and distribute the spent brewery grains:

- Fresh grains could be distributed by dump truck to dairymen's cooperatives and feedlots near Gisenyi, mainly along the road from Gisenyi to Ruhengeri. The grains could then be fed directly or, after partial drying, ensilaged near the point of end use.

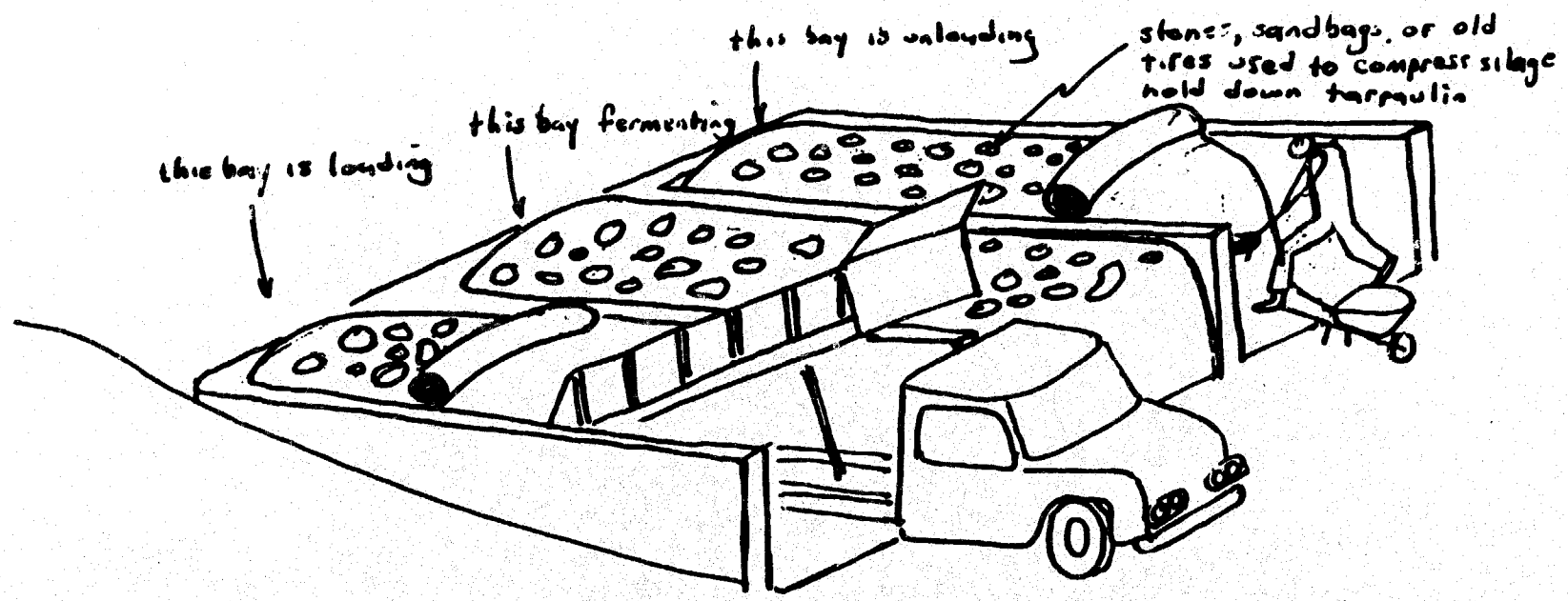
- The grains could be ensilaged in large pit silos near the brewery and then distributed to farmers.

- The grains could be dried, and thereby sold as a dry feed supplement to farmers throughout Rwanda, and to the commercial feedmill in Kigali (SOPAB).

Each of these methods has its own advantages and disadvantages, and best use of the grains would probably be made by a combination of at least two. By converting wet brewery grains to silage at the point of use farmers or cooperatives with small herds could buy wet grains in the larger quantities that are economical to transport, and preserve them until they are depleted. In practice, each farm or feed distribution point would have two or three small pit silos, as shown in Figure 1, each with the capacity to hold a dump truck load (or more). One pit would be filled with fresh brewery grains, covered with a tarp, banana leaves, or other impermeable covering. It is important that the grains be compressed sufficiently and covered so that anaerobic fermentation can take place. While this batch ferments, over a five or six week period, one of the others is gradually uncovered and used.

Besides providing a convenient way to store the grains, converting wet brewery grains to silage also increases their palatability. Fresh brewery grains and dry brewery grains are relatively unpalatable, and must be mixed at a low ratio with other feedstuffs to stimulate the cow's appetite. The silaged grains are more appetizing, and will be consumed in larger quantities when unmixed with other feeds. This is important for small farmers, who may have difficulty obtaining other feedstuffs that are highly palatable, and with which grains can be mixed. Feeding wet or silaged brewery grains, as opposed to dry

FIGURE 1: 3-bay pit silos for brewery grains
(size to be based on need; total capacity should = 6 to 8 weeks feed use)



brewery grains, has a further, though less important, advantage. That is the cow needs less water because most of the water she needs to digest the grain is already present in the grain.

Producing silage near the brewery for distribution to farmers between Gisenyi and Ruhengeri is a less promising method of processing. The brewery grains could be stored at low cost at a central location, but distribution to the farmers would be complicated. Unless the silage can be delivered to the farmer without exposing it to air, it must be fed quickly (like the fresh brewery grains), or it will rot. The grains could be compressed and silaged in steel drums, which could be left on a deposit basis at the farms or feed distribution points, but this would render the grains far more expensive and make handling difficult. Conversion of the grains to silage at the point of use appears to be the better of these two methods.

Drying the brewery grains near the brewery is the only economic means of making the grains available to feed users beyond Ruhengeri and the commercial feedmill in Kigali. A number of studies have been performed of drying systems utilizing steam and/or hot air, fueled by methane, fuel oil, coffee husks and peat. The study of the Bureau National d'Etudes de Projets (BUNEP) attempts to minimize the capital and operating costs by using locally made equipment and coffee husks for fuel. However, the steam heated flat plate system, described in their proposal of April, 1987, is probably not the best choice of technology for drying brewery grains.

Drying of brewery grains is, as noted in the BUNEP report, essentially a two-step process, whereby as much water as possible is first pressed out mechanically, and the remaining moisture is removed by evaporation. Solar drying may be used to supplement the drying capacity of an artificial dryer, but cannot be counted on to do the entire job, especially considering the perishability of the grains and thus the need for rapid drying, the magnitude of the supply, and the often foggy or humid atmospheric conditions at Gisenyi. Heated air would appear to be the best medium for rapidly drying the brewery grains. However, the drying equipment must be designed to prevent grains from sticking to the surface of the dryer, and to prevent the grains from clumping.

The first step in the drying process, in which water is extracted mechanically, can be partially carried out at the brewery itself. The silo erected by the brewery has an augur unloading device that looks as if it were designed to expel part of the water in the grains, and thereby standardize their moisture content. The device has a powerful electric motor, a large gear reducer, a long expeller screw, a constriction through which the grains must pass before they are discharged, and a pipe leading from the expelling chamber that drains into Lake Kivu. Brewery technicians explained that the valve on that pipe, which is clearly intended for evacuating water, is never opened except when washing out the silo. We tried to see the manufacturer's

drawings and specifications for the silo unloader, but were unable to obtain permission to do so during this short visit.

If some of the grains are to be distributed wet, either for direct feeding of cattle or for making silage at the point of use, then a certain moisture content is needed to help exclude air from the grains during transport and in the production of silage. Wet brewery grains are distributed in the U.S. at a moisture content of 80 percent. Since transporting this much moisture substantially raises the cost of transport, the high moisture content (m.c.) of the grains presumably plays an important role in their short-term preservation. One of the few small users of brewery grains in Rwanda reported that the grains have a large amount of free water, which runs out of the back of his truck during transport. This would imply a moisture content higher than 80%, and indicates that the unloader is not normalizing the moisture content as it should. The first step in reducing the transport costs of wet brewery grains is to determine the minimum m.c. (over drying causes air spoilage) necessary for safe transport and silage making, and to confirm that the brewery's equipment is delivering grains at this moisture content. Safe transportation will, of course, depend on the depth or compaction of the grains in the vehicle, and whether or not they are covered in an airtight manner. If a dump truck is used to deliver brewery grains, its sides should be raised to enable it to carry its full load capacity, and a tarpaulin strapped down tightly over the load to minimize aeration.

Since the drying plant proposed by BUNEP may be located near the brewery and would use less than the brewery's output of brewery grains, the drying plant does not need to store its raw material. Delivering wet grains from the brewery's silo directly to the drying system will minimize deterioration of the grains before drying. If short term storage were required, one or two small cement-lined pit or bunk silos could be constructed with the floors at the same level as the floor of the drying plant. This would be far cheaper than the 16,000,000 frw spent by BRALIRWA on its own steel silo.

The amount of time and fuel required to dry the brewery grains can be greatly reduced by mechanically pressing out as much of the water as possible. This can be done by centrifugation, with a hydraulic batch press, or with a screw or piston-type expeller. A decision about whether or not to build the pressing equipment in Rwanda should be based on knowledge of the type of equipment used in industrial brewery grain drying plants, and a search for manufacturers of simpler, smaller, less expensive equipment that would be appropriate to the scale of operation proposed by BUNEP (2-3 tons dry product per day). A batch centrifuge or hydraulic press could be built in Rwanda that would do the job. ATI could collaborate with BUNEP to develop a locally manufacturable design, or to identify commercial sources of suitable equipment.

The moisture that remains in the grains after pressing can best be removed by evaporating it and using heated air to remove the evaporated moisture. This is not the type of system proposed by BUNEP in April, 1987. In the BUNEP system the grains are placed on a large area of heated steel sheet, and the moisture is absorbed by essentially stationary ambient air. Using this method, 8 hours are needed to dry a 2.5 cm thick layer of grain to roughly 9% m.c., and 10 kgs of coffee parchment are burned to produce one kilogram of dried brewery grains. Experiments conducted by BUNEP showed that the preferred temperature of the steel sheet is 90 to 100° C, the temperature at which steam at atmospheric pressure can be used to transfer heat to the sheet. The report recommends that fans be used to increase the movement of air across the heated grains to increase the rate of evaporation, and thus increase the depth of grain to four centimeters.

An alternative drying system to that proposed in the BUNEP report is shown in Figure 2. This design, developed by American Drying Systems, can easily be made in developing countries, uses labor and energy efficiently, and is easy to operate and maintain. Drying cars with stacks of independent drying trays are pushed into one end of a drying tunnel and emerge from the opposite end, where the product is exposed to the warmest and driest air. Given the widespread use of brick in Rwanda, the dryer could be cheaply built of masonry; it could be fired with coffee parchment, as proposed in the BUNEP study; and, given the high ambient humidity and temperature at Gisenyi, it probably could <u>not</u> recirculate its exhaust air. The drying tunnel could be increased in length to increase its capacity, or a second tunnel built alongside the first with its blower and furnace on the opposite side. A simple masonry stepgrate furnace could be used to burn coffee parchment, and a sheet steel flue gas heat exchanger and sheet steel plenum built around the furnace used to transfer heat to the drying air. If a dryer of this type evaporates 500 kilograms of water per hour to produce 250 kilograms of dry product, the temperature of the ambient air is 20°C and relative humidity is 73%, as assumed in the BUNEP report, and the drying air is heated to 70°C with coffee parchment having a heating value of 15mJ per kilogram (6460 Btu/lb), the theoretical fuel consumption would be 107 kilograms of parchment per hour. Assuming that under realistic conditions the combustion efficiency is 67%, the heat transfer efficiency 60%, and the efficiency of the dryer, due to losses of unsaturated air, 50%, then the total efficiency would be 20%, and the fuel consumption would be 535 kilograms of parchment for 250 kilograms of product. This is just over one-fifth of the fuel consumption of the prototype flat plate dryer built by BUNEP, and less than half of the projected energy consumption of a full-scale flat plate dryer.

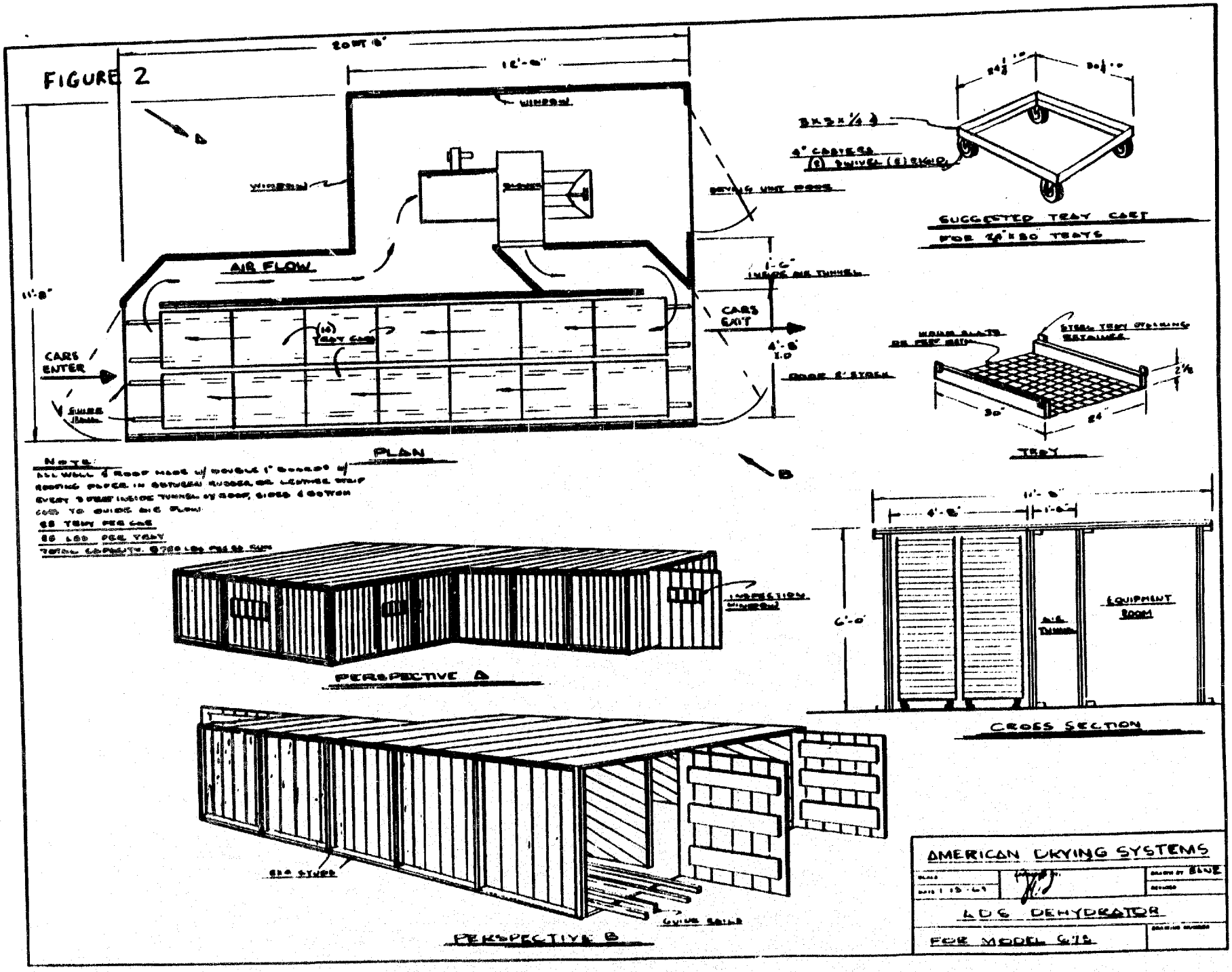


FIGURE 2
20 FT 6"
12'-6"
WINDOW
WINDOW
AIR FLOW
11'-8"
CARS ENTER
(10) TRAY CARS
SLIDE DOOR
PLAN
CARS EXIT
4'-8"
1.0
DOOR 8' STACK
SUGGESTED TRAY CART
FOR 24"x30" TRAYS
TRAY
NOTE:
ALL WALL & ROOF MADE W/ DOUBLE 1" BOARDS W/ ROOFING PAPER IN BETWEEN RUBBER OR LEATHER STRIP EVERY 3 FEET INSIDE THINGS OF ROOF, SIDES & BOTTOM CARS TO GUIDE AIR FLOW
68 TRAY PER CAR
80 LBS PER TRAY
TOTAL CAPACITY 8700 LBS PER 68 TRAY
INSPECTION WINDOW
PERSPECTIVE A
6'-0"
AIR TUNNEL
EQUIPMENT ROOM
CROSS SECTION
PERSPECTIVE B
AMERICAN DRYING SYSTEMS
DRAWN BY BLUE
LOG DEHYDRATOR
FOR MODEL 678

Advantages of the proposed dryer are:

- It heats the brewery grains to a lower temperature, and for a much shorter period of time than the flat plate dryer.

- It subjects both the top and bottom surfaces of the grains to the stream of dry air. The drying surfaces are stacked, thereby reducing dramatically the size of the dryer.

- It does not attempt to blow air through the brewery grains, and therefore requires much less blower horsepower than a throughdraft fixed bed or fluidized bed dryer, and produces less dust (weightloss) from the grains.

- It is reasonably energy efficient, and should therefore be able to operate entirely on the 2500 tons of coffee parchment generated annually at the Rwandex-Gisenyi coffee mill.

Despite the advantages of the stacked tray crossdraft dryer, other types that also use heated air as the drying medium, but which circulate the brewery grains in the air stream, are worth considering. One example is a horizontal drum dryer, where the heated air flows through the interior of the drum, and paddles attached to a central shaft turn the grains so that they fall through the air stream and gradually approach the air entry end of the drum. A great deal can be learned by studying the industrial state-of-the-art, and determining to what extent the more sophisticated larger-scale technologies that are currently in use for drying brewery grains can be simplified and scaled down for use in Rwanda.

iii. Existing Activity and Institutional Resources

Spent brewery grains have long been used to feed cattle in Europe and the U.S., and are a valuable commodity in both the wet and dried forms. Thus much information is available on past and present practices in the use of brewery grains. In Rwanda, brewery grains from the Gisenyi plant are presently ensilaged by the Adventist University in Mudende, and fed to the university's ten brown Swiss dairy cows. Keith Wallace, the university's farm manager, is working with the newly formed Mutura Cattlemen's Cooperative to build a milk collection point on university land to supply milk to the new Gishwati Dairy. The new Gishwati Dairy is a modern facility with a processing capacity of 20,000 liters per day, that will greatly increase the market for milk from farmers living between Gisenyi and Ruhengeri. The milk collection point of the Mutura Cattlemen's Cooperative will have a refrigerated bulk tank, and will also serve as a training center and base for the artificial insemination service for the more than 1000 members of the Cattlemen's Cooperative. The use of brewery grains as a cattlefeed, and particularly the use of

ensilaged grains, can be demonstrated at the collection point, since Mudende is a little more than 15 kilometers from the BRALIRWA brewery.

The BUNEP proposal to the Rwandan Development Bank (BRD) for the recovery and drying of brewery grains is remarkable among investment proposals in that it attempts to minimize the capital and operating costs associated with the drying of brewery grains by the use of appropriate technology. Whether or not funding for this activity has already been approved, ATI would be willing and able to assist the promoter in further refining the technologies involved.

iv. Uncertainties and Risks

The most fundamental uncertainty is whether Rwanda's cattle population can be maintained with the country's high and rapidly increasing human population. Roughly 10,000 cows would be needed to make optimal use of all the brewery grains presently produced by the brewery. Although Rwanda has almost 150,000 milk cows in lactation (FAO report), their milk yield is only 500 liters per year per cow, implying negligible use of feed and poor genetic stock. Because of the increasing shortage of land, even the marginal lands that have been used as pasture in the past are gradually being cultivated. This often occurs when the returns to labor and land derived from cultivation exceed the returns from the pasturage of livestock. The use of brewery grains is one of a number of interventions, including the genetic improvement of Rwanda's livestock, disease control, and permanent confinement for improved manure and feed use, that are already planned or underway in Rwanda to improve the profitability of cattle rearing, and thus encourage the retention of livestock in Rwandan agriculture. However the market for brewery grains, and particularly dried grains marketed to the commercial feed mill, must be able to survive a period of transition, during which the cattle herd will continue to shrink, and milk and meat production remain less profitable than crop production.

The dried brewery grains producer can compete in the uncertain market for high priced conventional mixed feeds by distributing wet brewery grains, and by formulating and producing low cost feed mixtures from waste products and other cheap feed ingredients. Molasses, wheat bran and rice bran are cheap and nutritious feed ingredients (5 frw/kg), but are nonetheless in limited supply in Rwanda. Cassava is a potentially cheap source of starch, to balance the high protein but low energy content of brewery grains, and cassava leaves are high in protein. It may be possible for the producer of dried brewery grains to contract with growers around Gisenyi to supply cassava to be processed and dried in his own drying plant. However, the target price for the feed mixture must be much lower than the 28 frw per kilogram price of conventional feeds. Before undertaking such an activity, it would be wise to evaluate the relative cost and feasibility of producing balanced feeds on the farm using similar materials.

V. Recommendations for Future Action

The purpose of the proposed activity is to assist private entrepreneurs, and the farmers themselves, to produce low cost animal feeds using raw materials that are currently wasted or underutilized in Rwanda. Spent brewery grains from the brewery in Gisenyi are important because they are a nutritionally valuable resource available in large quantity at a centralized location, and because there is at least one private individual promoting the use of this product. The promotion of brewery grains should involve two approaches: distributing wet grains for processing at the farm and cooperative level (ensilaging, possibly in combination with other ingredients); and drying the grains at a centralized location to be sold as a feed component, or, mixed with other ingredients, as a complete feed. The common objective of each approach is to stimulate feed use, in the first case by training farmers to prepare their own feeds, and in the second by producing commercial feeds at substantially lower cost than conventional feeds. The second objective can be achieved by supplying the existing feed industry with a low cost high protein ingredient, and by formulating and producing low cost feeds using other low cost ingredients.

The proposed activity has two prerequisites. First, BRALIRWA's willingness, and long term legal commitment, to supply brewery grains at an attractive price must be confirmed. Second, it must be determined whether the present promoter of the grains drying scheme shares the objectives presented here, and is willing to collaborate in the proposed activity. In addition, several components of the proposed activity (e.g., testing of feeds and farmer training) could not be assured by the private promoter, but could be fulfilled by several local institutions whose interest and ability need to be assessed and whose participation would in some measure need to be financed. ATI's roles in the proposed activity would include: further development of a project plan, assistance in project monitoring and evaluation, and technical assistance. Technical assistance would be provided by ATI engineers or outside consultants and could include assistance in appropriate equipment selection, the design of equipment for local fabrication, plant design and management, and product testing and marketing.

The major components of the proposed project are:

- to research current practices in brewery grains processing and feeding, and to provide technical assistance to the Rwandan promoter of a brewery grain drying plant;

- to assist farmers in the proper feeding of wet brewery grains;

- to perform feeding trials to confirm the economic benefits of feeding brewery grains; and

- to investigate the economic and technical feasibility of using other waste products in the commercial and on-farm preparation of animal feeds.

D. AGRICULTURAL LIME

i. The Need or Market

Rwandan agriculture produces little marketable surplus and uses few purchased inputs. This is primarily a result of the settlement pattern and market circumstances of the country; since there are few urban dwellers (i.e., few people who do not farm) there has been little market for a surplus food crop. Rwanda is geographically isolated, making the importation of fertilizer and the exportation of cash crops very expensive. Despite these obstacles, coffee production grew impressively during the first half of the 1980s, up to more than 40,000 tons. Coffee remains, however, the only major export crop, with tea following a distant second, and then lesser exports like pyrethrum and chinchona. Furthermore, there are indications that the falling real producer price of coffee, and increasing prices of staple food crops, have caused a recent decline in coffee production. Although it is doubtful that farmers are actually replacing their coffee with food crops, it is likely that the necessary maintenance of coffee plantings (pruning, spraying, weeding, mulching) is being neglected as food crops become the more profitable source of cash income.

The context of Rwandan agriculture is changing as the country's population grows, and its soils are unable to support the increased demand for food. The prospect of a food production shortfall is especially ominous because of a decline in soil fertility on the marginal uplands, where a large portion of the population lives. This decline is due to the conversion of pastureland to cultivation and a decrease in the fallow on very steep hillsides that are subjected to high levels of rainfall. The effects of over-cultivation are most seriously manifested on the high-altitude non-volcanic lands along the Zaire-Nile Crest. The obvious effects are poor yields for most crops, except potatoes, and extremely acidic soil. In the highly populous Gikongoro Prefecture, the situation is severe; some soils have a pH of less than 4.0 and high levels of free aluminum ions that are toxic to plants. Farms there yield the lowest family incomes of any part of Rwanda. Soil acidity exists, to a lesser extent, on 200,000 to 300,000 hectares of the country's farmland, or roughly 30% of the total.

The Rwandan government, through the Rwandan Institute for Agronomic Sciences (ISAR) and through a number of regional development institutions, has been conducting research in order to identify a strategy to rehabilitate the nation's upland soils. The results of this research were presented at a conference held in Gikongoro Prefecture in November, 1988, entitled "The Problem of Soil Fertilization and Farmers' Incomes on the Acid Soils of Gikongoro and Other High Altitude Regions of Rwanda." The title implies an important aspect of government's strategy that the inputs required to improve soil fertility must pay for themselves

in increased yields of marketable crops in the near term. Otherwise they will not be used.

The consensus of dozens of researchers working in Gikongoro, Kibuyé, Gisenyi, Kigali, and Byumba is that lime is the most effective input for improving soil fertility. While it is clear that soil fertility depends ultimately on the quantity of organic matter that the soil contains, crop yields on Rwanda's acid soils are too low to provide the quantity and quality of organic matter needed to improve soil structure and nutrient content. Liming the soil to reduce its acidity, followed in most instances by modest doses of chemical fertilizer, can produce the large increases in crop yields needed to pay for these inputs and provide much of the organic matter needed to improve the soil structure and long term fertility.

This strategy is extremely ambitious, but the necessary elements appear to be available to make it work. Rwanda possesses lime deposits of sufficient quality and quantity to meet the need for agricultural lime for the medium term. It is making rapid progress in the improvement of its road system, needed to move lime from the quarries to other parts of the country. Also, the homogeneous social structure, high population density, and strong local government that characterize Rwanda are conducive to the communication and rapid acceptance of new technology. The process of soil restoration will be very labor intensive; tremendous manpower will be required to improve rural roads, to transport and apply the roughly one million tons of lime that are needed in the near term, and to turn under the larger quantities of crop residues that will be produced. Yet, the labor is available in Rwanda's maturing youth and can easily be repaid through increased crop yields. The challenge is a necessary one to provide both employment and food for the country's rapidly increasing population. It is economically sound because the use of local lime will increase crop response to imported fertilizer, as well as to nutrients already present in the soil, but unusable by the crop when the pH is too low.

ii. <u>The Technology</u>

Most of the lime currently produced in Rwanda, except for that used by the cement factory, is processed by artisan enterprises, most of which are located near Ruhengeri. These lime producers employ roughly ten to thirty laborers each, and produce from 200 to 1000 tons of hydrated lime per year, which is sold as binder for construction, for water purification, and for other chemical purposes. Most of the producers use batch kilns of twenty to forty ton capacity that are fired with wood. Two, however, use mixed feed kilns, in which the wood is charged at the top of the kiln in layers with the limestone. All of the kilns are built by the artisans themselves from locally fired clay bricks, and, depending upon whether they are of batch or

mixed feed type and to a lesser degree on their size, they consume from more than 6 to less than 3 cubic meters of wood per ton of product.

The limestone deposits that are quarried by these producers are calcitic limestone of variable quality, and small in size. Total production from all sites is about 4000 tons per year, of which roughly 1000 tons are used for agriculture. Given the small size of the reserves, estimated at 200,000 tons, only a small increase in production capacity at Ruhengeri would be justified. With an approximate 70% $CaCO_3$ content this limestone could be used by the construction or chemical industry.

Kibuyé has large reserves (one to two million tons) of dolomitic limestone that is not as suitable for use in cement production but would be very effective for neutralizing acid soils. Dolomitic limestone is a mixture of calcium carbonate and magnesium carbonate, and is slightly more effective at neutralizing soil than calcitic limestone having the same amount of carbonate. One kilogram of magnesium carbonate ($MgCO_3$) is equivalent to 1.19 kilograms of calcium carbonate ($CaCO_3$). These reserves could be evacuated from Kibuyé by boat to other towns and villages along the shores of Lake Kivu, and will become much more accessible to all of Rwanda once the new road is completed between Kibuyé and Gitarama. These reserves may possess the best potential for agricultural use, and are presently exploited by only two or three artisan producers.

Very large reserves of calcitic limestone exist at Mashyuza near Cyangugu, but are currently designated for exclusive use by Rwanda Cement. The approaching crisis in agriculture and a rapid evolution in the demand for agricultural lime may justify changes in government policy regarding the use of this reserve. Further field testing is required, however, to determine the relative performance of different limestones available in Rwanda, and the cost at which they can be processed into agricultural lime.

The costs of different types of lime for agricultural use should be compared on a common basis. It is customary to compare them by their equivalent calcium oxide (CaO) content, because calcium oxide is the most "concentrated" form of lime that can be used to neutralize acidic soils. Other forms of lime are compared with calcium oxide (which is also called "quicklime") on the basis of their molecular weights, and thus the degree to which the calcium is "diluted" by the rest of the molecule. The active component of natural calcitic limestone is calcium carbonate ($CaCO_3$), one molecule of which weighs 1.78 times as much as a molecule of calcium oxide. If the original limestone is only 75% calcium carbonate, its calcium oxide equivalent is 0.75/1.78 = 0.42, that is one kilogram of this limestone is equivalent to 0.42 kilograms of calcium oxide. This holds true unless the limestone contains some magnesium carbonate ($MgCO_3$), which is actually slightly more concentrated than calcium carbonate, because the magnesium atom is lighter than the calcium atom, but

behaves chemically in exactly the same way. Pure dolomite, which is defined as 54% calcium carbonate and 45% magnesium carbonate, is 1.08 times as effective as pure calcium carbonate for neutralizing soils.

By burning lime in a kiln, a molecule of carbon dioxide is driven off from each molecule of calcium carbonate, and calcium oxide is obtained. The product weighs 56% as much as the calcium carbonate which enters the kiln, not including whatever moisture may be driven off, or mineral impurities that may pass through the kiln essentially unchanged. Calcium oxide is, however, very reactive with water, including moisture in the air, and it is customary to add water or "slake" the calcium oxide to produce a stable dry powder called calcium hydroxide or hydrated lime ($Ca(OH)_2$). A molecule of hydrated lime weighs 1.35 times as much as a molecule of calcium oxide, and its equivalence is thus .74, as compared with .56 for calcium carbonate.

The most modern lime producer in Ruhengeri is the Pozzolana, Lime, and Peat Project (PPCT), set up with Belgian funding in the 1970s. PPCT produces hydrated lime using the method of processing described above, in conjunction with a mixed feed vertical kiln. The hydrated lime powder is separated from impurities with a 450 micron screen and gives a product that is reportedly 81% pure $Ca(OH)_2$, or 60% CaO equivalent, and which sells for 11 frw per kilogram. The impurities, which remain on top of the screen, are mechanically ground in a ball mill to a fine powder and are sold for 9 frw per kilogram. One artisan producer that I visited (COMECARU) used a coarse screen to sift his hydrated lime, which was of visibly poorer quality, and, according to PPCT, contains only 42% $Ca(OH)_2$, The quality of this hydrated lime may have improved since the installation by COMECARU of a continuous kiln. The continuous kiln, in addition to conserving wood, results in a much more uniform firing (calcining) of the limestone, and therefore a product that is higher in calcium oxide and less contaminated by ash from the wood fire.

The multiple advantages of the mixed feed vertical kiln, which also includes less labor and higher productivity than a batch kiln of comparable size, make this an obvious technical improvement that could be introduced to all of the artisan lime producers. It is however necessary to undertake an economic analysis to determine if existing demand levels of hydrated lime justify the additional investment in new kilns. According to PPCT technical manager Jean Baptiste Bizimana, COMECARU voluntarily and spontaneously copied PPCT's mixed feed vertical kiln. The vertical kiln is very simple in design and construction; since the fuel is layered directly with the limestone, there are no external combustion chambers. PPCT's and COMECARU's operating experience provide the means to assess the costs and benefits of the mixed feed vertical kiln compared with the batch kilns that are currently used by most artisan lime producers. A precise evaluation of their experience should be an initial step in the proposed activity for promoting the production of lime for agri-

cultural purposes.

The vast majority of limestone used worldwide for agriculture is not fired, but is simply crushed by mechanical means. In the USA in 1972, 23.6 million tons of crushed limestone were used in agriculture, while only 124,000 tons of hydrated or quicklime were used. The principal reason is that crushed limestone can be produced at a fraction of the cost of fired lime, although crushed limestone has other advantages as well.

There is considerable room for cost savings through the use of crushed limestone. Crushing costs are very dependent on the quality of the limestone, rising sharply if there is even a small percentage of abrasive materials (silica, iron oxide, and alumina). Transport from Kibuyé will be costly until the asphalt road is completed from Kibuyé to Gitarama. The cost of quarrying the raw material also depends, of course, on the depth of the deposit, its thickness and location, but this cost is the same for both methods of processing and does not affect the difference in cost between crushed limestone and hydrated lime. Probably the single most important factor that determines the cost of crushed limestone is the fineness to which it must be ground. A finer product not only requires more mechanical energy to produce, but remains in the crushing machinery longer, thereby reducing its effective capacity and increasing all of the crushing costs.

Dolomitic limestone is considered superior to calcitic limestone for improving crop yields. As mentioned above, dolomitic limestone has a slightly stronger soil neutralizing effect than calcitic limestone having the same carbonate concentration. More important, dolomitic limestone contains magnesium, which, like calcium, is an essential plant nutrient. The relative value of dolomitic and calcitic limestone ultimately depends on the relative amounts of calcium and magnesium that exist naturally in the soil, and on the relative demands that different crops make on these two nutrients. Because these factors are apt to vary greatly from one part of Rwanda to another, one can say that dolomitic limestone is, in general, apt to have a better effect. Dolomitic limestone often contains calcium and magnesium in roughly a two-to-one ratio, which approximates the <u>average</u> requirement of most crops. Potatoes and wheat, which are two of the most important upland crops in Rwanda, are particularly demanding of magnesium, and would likely benefit more from dolomitic than calcitic lime.

iii. <u>Existing Activity and Institutional Resources</u>

The government of Rwanda is convinced of the importance of liming the country's acid soils. Mr. Ndolimana, who heads the National Agricultural Input Programs of the Food Strategy Project of the Ministry of AGriculture, says that it is only the high cost of lime that discourages farmers from using more. He explained that, at 12 frw per kilogram and the recommended application rate of 2.5 tons per hectare, lime costs 30,000 frw per

hectare. This is far higher than the cost of fertilizer: 300 kilograms at 30 frw costs 9000 frw. Evidence of the willingness of farmers to buy fertilizer is seen in the import statistics: five years ago only 2000 tons were used; now nearly 15,000 tons per year are used. The present level of lime use, approximately 1,000 tons per year, would show a similar rate of increase if it were more affordable.

The government intends to address this problem by subsidizing lime through the farm credit programs of the Banque Populaire and the Agricultural Development Bank. The proposed subsidy is 2 frw per kilogram. It is the author's opinion that this money would be better spent in ways that reduce the cost of producing lime: by introducing better lime processing technologies and by encouraging development of the country's major lime deposits. Subsidizing production at Ruhengeri will be money lost, since production costs there can only increase as the deposits are exhausted. The government's willingness to subsidize lime is a positive sign of its commitment to agriculture. The effect of that commitment would be greatly increased, and its cost reduced, if the funds were used to finance investments by private lime producers that actually result in long term reductions in the cost of lime production. The proposed activity would identify, test and demonstrate production technologies in which the private sector can profitably invest.

iv. Risks and Uncertainties

There is little risk that the proposed activity would not contribute to the rational use of Rwanda's lime deposits for agriculture. At worst, the study phase of this activity might identify serious technical or logistical obstacles to the economic production and use of Rwandan limestone for agriculture.

v. Recommendations for Future Action

The cost of quarrying the Kibuyé deposit of dolomitic limestone, and the quality and extent of that deposit, must be known before determining whether and how to process them for agricultural use. Information appears to exist on the proven and potential size of those reserves, so a thorough geological survey may have been done. If not, this should be the first step in the proposed activity. If limestone samples have been analyzed, this analysis should indicate whether or not abrasive minerals may make crushing expensive. If not, new samples should be taken and analyzed for their abrasive content, as well as their calcium and magnesium carbonate content. The survey should also show the structure of the deposit, and indicate how it can best be quarried in a way that minimizes the necessary capital investment.

The next step would be to compare the costs and benefits to the farmer of using burned or crushed lime. This comparison and the transport costs to those parts of the country where the lime is apt to be used, including the cost of human carriage and

spreading on farms. Transport costs are high in Rwanda, despite its small size, because of the difficult topography, the long rainy period, the scarcity of heavy trucks, and the fact that agricultural lime will only be produced on a significant scale at one or two locations. The comparison should also attempt to predict the relative value of the two products in terms of their short, medium and long term effects on crop yields. Rwandan farmers cannot afford a product that will not pay for itself in the short term. Nonetheless, the solubility and granulometry of the lime affect its tendency to be used eventually by the crop, as opposed to being leached from the soil. An accurate comparison is therefore apt to be a complex and interdisciplinary process, probably requiring the services of AID-REDSO, working in collaboration with Rwandan agronomists and soil scientists.

If quarrying of the Kibuyé dolomite on a large scale appears to be feasible, and crushing appears to be the preferred means of processing this limestone, then a strategy to produce, distribute, and market the crushed lime should be developed. If the government is to play an active role in marketing agricultural lime, it might negotiate with a local or regional source of expertise in stone quarrying and crushing to produce a certain quantity and quality of lime at a fixed price. The Chinese road building teams have a large park of used equipment on the Kigali-Ruhengeri road, including equipment for quarrying and primary crushing, and might be interested in such a contract. Since they are or will soon be working on the Kibuyé-Gitarama road, they could easily mobilize some of their equipment and men at Kibuyé. The industrial firm, ETIRU, might also be interested in producing crushed lime. Information obtained through preliminary surveys of the Kibuyé deposits and the market for agricultural lime would help the government to negotiate by helping to determine the quality and quantity of lime that should be purchased and an affordable price.

Another approach would be to identify and test low-capacity, low-cost equipment which would be affordable to local investors. In no event should a large crushing plant be financed by the government. The present demand for agricultural lime is tiny (roughly 1000 tons per year), and can easily be met by a simple low-cost crusher and unmechanized quarry. Although the potential demand may be easily one hundred times larger, more will be accomplished at far less expense by demonstrating the economic viability of a small-scale technology, that can be copied by private investors, than by spending a great deal of money on a large-scale plant that will neither turn a profit nor encourage private investment. The most important objective of this activity is to produce good agricultural lime <u>at minimum cost</u>, and thereby stimulate demand. This can best be done by gauging the production technology to present demand, and by encouraging competition among a number of producers as demand increases.

If burned dolomitic lime appears to be cheaper than crushed

lime, given its stronger initial effect and lower transport cost, then existing lime kiln operators should be encouraged to exploit the Kibuyé deposit. This can best be done by providing limited and conditional access to a number of quarry operators, and training and financing for the construction and operation of continuous kilns. If, at the end of the study phase, neither burned lime nor crushed lime appears to have a clear advantage, then both should be encouraged on a small-scale experimental basis.

The production of agricultural lime in Rwanda can best be promoted by:

- assessing the accessibility, chemical composition, and extent of the larger Rwandan deposits, and particularly the Kibuyé deposit of dolomitic limestone;

- determining the relative cost and quantifying attributes of soil liming with samples from different reserves, obtained by crushing and by calcining and hydration. These costs and values should apply to the kinds of processing (small mixed-charge continuous kilns and simple low-capacity crushing equipment) that are likely to be economical, manageable and affordable to local entrepreneurs;

- pending the results obtained from these studies, promoting the use of small mixed feed vertical kilns and/or limestone crushing at Kibuyé, or suggesting more economical sources, like the cement works at Mashyuza or neighboring countries.

The proposed activity should be implemented in close collaboration with the government's own efforts to promote the use of agricultural lime, so that public funds can be used to promote the most efficient kinds of investment in this new industry.

PREFACE

The preparation of the material for this bulletin was a joint undertaking of the departments of agronomy and soils of the Maryland, New Jersey, New York (Cornell), Ohio, and Pennsylvania Agricultural Experiment Stations. It was made possible through generous aid provided by the National Lime Association, Washington, D. C.

The purpose of the bulletin is to present answers to the many questions that arise in men's minds about liming the soil. The answers were agreed upon in conference after review of the most important evidence available.

In addition to preparing the material for this bulletin, those concerned with this enterprise carried out individual research programs in the above states. The results of these studies were presented in a special issue of *Soil Science* published in January, 1952.

FIRMAN E. BEAR

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100 Questions and Answers on LIMING LAND

1. Where are the acid-soil areas of the United States?

Except for that derived from calcareous parent materials by glacial grinding, the soil east of the 100th meridian, a north-south line running through the centers of Minnesota, Nebraska, Kansas, Oklahoma, and Texas, is acid. That in the western part of Washington, Oregon, and Northern California is also acid.

2. Where are the alkaline-soil areas of the United States?

The alkaline soil areas of the United States are mainly west of the 100th meridian. But there are some areas east of this meridian in which the soil is slightly alkaline, especially in its lower depths. For example, some of the glaciated soil that was formed largely from limestone or calcareous shale produces lime-loving crops without the supplemental use of liming materials.

3. Why is some soil acid, some neutral, and some alkaline?

The amount of rainfall largely determines whether the soil will be acid, neutral, or alkaline. In regions of high rainfall, the carbonates are slowly carried away in the drainage water and the alkaline elements in the soil's exchange complex are replaced by hydrogen ions from the water. This leads to soil acidity. In regions of low rainfall, the carbonates remain on or near the surface of the soil. This results in neutral or alkaline soil conditions. In the black-soil areas from the Dakotas southward, calcium carbonate deposits are found in the subsoil. In the prairie states, which lie between the areas of high acidity and high alkalinity, the soil may be virtually neutral.

4. What is the nature of the acids in acid soil?

The acids in acid soil are largely insoluble humic acids and acid clays. Acid soil also contains small amounts of simple soluble acids, such as carbonic, nitric, sulfuric, and phosphoric.

5. What is the nature of the bases in alkaline soil?

Slight alkalinity in soil is usually due to the presence of free calcium and magnesium carbonates. Much higher alkalinities are

found when sodium and potassium carbonates are present. These may develop naturally in the soil or they may accumulate through use of irrigation waters that are high in sodium and potassium salts.

6. In what terms are acidity and alkalinity of soils expressed?

Acidity and alkalinity are usually defined in terms of the concentration of hydrogen ions found in pure water. If the soil solution contains the same concentration of hydrogen ions as pure water, it is neutral. If it contains more hydrogen ions than water, it is acid. If it contains less, it is alkaline. The concentration of the hydrogen ions is expressed in terms of pH values.

7. What is meant by the term "pH"?

The term "pH" is used to express the degree of acidity or alkalinity of solutions. The pH value of pure water is 7. All pH values below 7 are acid and all above 7 are alkaline. Soil pH values range between 3 and 10. A change of 1 unit in pH value represents a tenfold change in hydrogen-ion concentration. Thus a soil at pH 6 contains 10 times as many hydrogen ions as a neutral soil having a pH value of 7. Similarly, a soil at pH 8, which is alkaline, contains only one tenth as many hydrogen ions as one that is neutral. The lower its pH value, the more acid a soil is; and the higher its pH value, the more alkaline it is.

8. How is the pH value of soil measured?

The pH value of a soil can be measured within about 0.2 unit by means of dyes, the colors of which change with changes in pH. If greater accuracy is desired, the pH value is determined in a soil-water mixture by making use of a potentiometer. If this is calibrated to read pH values directly, it is known as a pH meter.

9. What part of the soil acidity does a pH meter measure?

The pH meter measures the concentration of only those hydrogen ions in the soil solution of the soil-water mixture. They constitute the active acidity, which is only a small part of the total. It is this active acidity that determines what the effect will be on the living things that are contained in or grow on the soil.

10. How is the pH value of soil related to its lime requirement?

The pH value of a soil is a measure of the concentration of hydrogen ions that are in the soil-water mixture when the measurement is made. An acid soil also contains "reserve" or "latent" acidity, which is not measured by the pH meter. This reserve acidity

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Reading pH values of soil samples on pH meter

must also be neutralized before the soil's pH value can be raised to the desired level. Soils that are high in clay or organic matter often contain large amounts of reserve acidity, whereas sandy soils do not. This reserve acidity can be determined by treating a series of weighed samples of soil with increasing amounts of lime water and measuring the resulting pH values. After long laboratory experience, a table of factors can be set up for the various soil types by the use of which their lime requirements can be calculated fairly closely from their pH values.

11. What quantities of bases are contained in acid soil?

Most farmed soil contains large amounts of bases, but some does not. The plow depth of an acre of Washington loam soil was found to contain 85,000 pounds potassium, 74,000 pounds calcium, and 17,000 pounds magnesium. The same amount of Lakewood sand contained only 700 pounds potassium, 500 pounds calcium, and 170 pounds magnesium. The values for most other soils would lie between these two extremes. Subsoils usually contain larger amounts of bases than the corresponding topsoils.

12. In what forms do these bases exist in soil?

The bases in soil exist largely in the form of silicate minerals from which they are only very slowly released for plant use. Small portions are held on the surfaces of the soil particles in an exchangeable form. These exchangeable portions and those dissolved in the soil water constitute the immediate source of supply for plants.

13. How can exchangeable bases be extracted from soil?

Exchangeable bases and those dissolved in the soil water can be extracted by leaching the soil with a neutral salt or a dilute acid solution. This results in the replacement of the soil's exchangeable bases by the basic ions of the salt or by the hydrogen ions of the acid.

14. What percentages of the total soil bases are exchangeable?

As much as 25 per cent of the total calcium in acid soil may be exchangeable. Only a very small part of the total magnesium and a still smaller part of the total potassium and sodium can be extracted from such soil.

15. How do laboratory and plant-root extracting procedures differ?

In common laboratory procedures, exchangeable bases are replaced by ammonium or hydrogen ions. Plant roots operate on a similar basis. They excrete carbon dioxide, which, in the presence of water, forms carbonic acid. The hydrogen of this acid replaces the exchangeable bases of the soil complex, which may then enter the plant. Some plants have greater powers of effecting this exchange than do others.

16. What changes take place in soil while becoming acid?

The primary change that takes place when a soil becomes acid is the replacement of exchangeable bases by hydrogen. These replaced bases may then be used by plants or leached from the soil in the form of soluble salts. As a result, soil acidity increases and iron, aluminum, and manganese become more soluble. Available soil phosphorus combines with these elements to form insoluble compounds. The bacteria that decompose soil organic matter, those that produce nitrate, and those that fix atmospheric nitrogen become less active. The ratio of soil fungi to soil bacteria increases. The working qualities of the soil tend to deteriorate, with adverse effects on aeration and drainage.

17. How acid may soil become in its natural state?

Under natural conditions in humid regions, the acidity of the may fall as low as pH 3. In rare instances, it may be even l Most acid soil comes to equilibrium at pH values between 4 a

18. How alkaline may soil become in its natural state?

In arid regions, it is not uncommon for soil to have pH v as high as 10. These very high values, due largely to the pre of sodium carbonate, are found in black-alkali spots. Soil used cropping purposes in irrigated arid regions normally has pH v between 7.5 and 8.

19. At what pH values do crops grow best?

Most crop plants commonly grown in humid regions grow in soil with pH values that are close to the neutral point, but are exceptions. The general relationship between pH values, reaction, base saturation, and crop growth is shown in table

20. Why are soils of limestone origin usually highly producti

Many soils derived from limestone are underlain by lines and many deep-rooted plants are able to reach this underlying su of lime. Since limestones were laid down in sea water and associated with marine life, which absorbed and concentrated

TABLE 1

Relation Between pH Values, Base Saturation, and Crop Grow

pH	Soil Reaction	Base Saturation	Crop Relationships
		%	
3	Extremely acid	Less than 10	Too acid for nearly all cr
4	Strongly acid	10	Too acid for most crops
5	Moderately acid	30	Too acid for some crops
6	Slightly acid	80	All common crops will g
7	Neutral	100	Most crops will grow
8	Slightly alkaline	Free $CaCO_3$	Many crops will grow
9	Moderately alkaline	Some Na_2CO_3	Too alkaline for most c
10	Strongly alkaline	High Na_2CO_3	Too alkaline for all crop

chemical elements required by living things, they contain larger supplies of some of the less abundant mineral nutrients than do many of the other soil-forming materials. Excellent drainage and good subsoil structure, as well as early warming in the spring, are additional explanations of high productivity of many limestone soils.

21. What are the common correctives for acid soil?

The most common corrective for acid soil is limestone in pulverized, burned, or burned and hydrated form. Certain types of blast-furnace slags and other industrial by-products of limestone origin are also suitable for correcting acid-soil conditions. Marl and oyster shells are often used. Wood ashes and some of the common fertilizer materials, such as basic slag, cyanamid, bone meal, and nitrate of soda, have alkaline effects on the soil.

22. What bases do the common liming materials contain?

The common liming materials contain calcium and magnesium, in the carbonate, oxide, or hydrate forms, as their acid-neutralizing elements. Calcitic limestones and their products may contain very little magnesium. A pure dolomite contains calcium and magnesium in the ratio of approximately 20:13.

23. What are the neutralizing values of common liming materials?

Calcite, which is pure calcium carbonate, is commonly assigned a relative neutralizing value of 100. Magnesium carbonate will neutralize 1.19 times as much acid as will the same weight of calcium carbonate. Dolomite, which is made up of 54 per cent calcium carbonate and 46 per cent magnesium carbonate, has a relative neutralizing value of 108. These neutralizing values can be raised by burning the stone and driving off its carbon dioxide. If the oxides then formed are hydrated, the neutralizing values are lowered somewhat, but they are still considerably higher than those of the carbonates. The relative neutralizing values of calcium and magnesium carbonates, of their oxides and hydrates, and of dolomite and its hydrates are shown in table 2.

24. What other neutralizing agents could be used?

Ammonia, which is produced during decomposition of organic matter and may be applied in liquid form as a fertilizer, also is a neutralizing agent, but in a well-limed soil the nitrifying bacteria rapidly oxidize it to nitric acid. Use of liquid ammonia, even though it produces a temporary alkalinity, ultimately results in increased acidity and increased need for lime.

TABLE 2

Relative Neutralizing Values of Pure Liming Materials

Liming Materials	Relative Neutralizing Values	Pounds of Liming Materials Equivalent to 1 Ton	
		Calcium Carbonate	Calcium Oxide
Calcium carbonate	100	2000	3570
Magnesium carbonate	119	1680	3000
Calcium oxide	178	1120	2000
Magnesium oxide	250	800	1430
Calcium hydrate	135	1480	2640
Magnesium hydrate	172	1160	2070
Dolomite	108	1850	3330
Dolomitic hydrate	175	1145	2040

25. What effect would potassium and sodium carbonates have on soil?

Potassium carbonate, in the form of wood ashes, is often used as a source of extra potassium for plants. If either potassium or sodium carbonate were used in a quantity sufficient to neutralize the acidity of a strongly acid soil, it would dissolve the humus and disperse the clay, making the soil unfit for agriculture. Large areas of black-alkali soil in the West are in this condition.

26. What effect does liming have on soil microorganisms?

Under acid-soil conditions, most of the changes in soil organic matter are brought about by fungi and actinomycetes. At higher pH values, bacteria are more active. The nitrate-producing and nitrogen-fixing bacteria require a nearly neutral soil for best development. Unfortunately, white potato scab and sweet potato pox are also favored by high pH values, so the nature of the crop and of the microorganisms associated with it must be taken into consideration in liming recommendations.

27. How does liming affect the physical properties of soils?

Liming an acid soil favors the formation of an improved crumb structure. This is due principally to increase in crop yields, as a result of which larger amounts of roots and other crop residues are added

King Farms, Morrisville, Pa.

Lime made the difference with spinach. Foreground, unlimed soil, pH 5.0; background, soil treated with hydrated lime, pH 6.3.

to the soil. The humus that is formed by decomposition of these residues serves as a binding agent in the granulating process in the soil. The lime has an especially important effect on legumes, notably on alfalfa and sweet clover. The deep-rooting of these legumes and the organic material they contribute aid greatly in the improvement of structural conditions in the soil.

28. Does liming acid soil increase the supply of available nutrients?

Liming an acid soil increases the supply of calcium and magnesium. In addition, microbiological activities are greatly speeded up by liming, with resulting increase in the rate of liberation of nutrient elements from the soil organic matter. Further, nitrogen fixation by the nodule bacteria on the roots of legumes and nitrate production are greatly increased. The availability of soil phosphorus and molybdenum is greatly increased. In general, liming an acid soil to a pH value of about 6.5 is desirable for maintaining a high degree of availability of most of the nutrient elements required by plants. Since the general level of fertility is raised by liming, extra phosphoric acid and potash may be required to meet the needs of the larger crops which liming makes possible. These fertilizers are more effectively utilized as a result of liming.

29. What effect does liming an acid soil have on crop yields?

Most legumes and vegetables grow much better on well-lim soil than on acid soil. This is notably true of alfalfa and such cr as spinach and cabbage. In many cases, liming the soil means t difference between success and failure. Under most conditions, makes it possible to grow a good crop instead of a poor one, w resulting potentialities for greater profits. A few crops are n benefited by liming, and overliming sometimes reduces yields, nota under conditions of limited supplies of one or more of the min elements.

30. Does the value of liming acid soil extend to animals and ma

Liming materials supply readily available calcium and magnesiu By their use, the availability of soil phosphorus and nitrogen increased. As a result, plants on limed soils tend to have high contents of these elements, all of which are essential to animals a man. Liming encourages the growth of legumes, which tend to especially rich in protein, in calcium and phosphorus, and in minor elements that are essential to animals.

31. For what purpose is calcium used by plants?

Calcium occurs as a necessary insoluble calcium pectate in cell walls of plants. This enables erect growth, much as does calcium phosphate in the bones of animals. Together with magnesi and potassium, calcium neutralizes the organic acids that are form in plants. In complete absence of calcium, plants fail to grow beyo the point at which the small supply in the seed or transplant been exhausted.

32. How much calcium is contained in plants?

Plants and plant parts vary greatly in their content of calci depending on the nature of the plants and the conditions under wh they were grown. Some high and low values are shown in table

33. What are the symptoms of calcium deficiency in plants?

Calcium deficiency results in a stunted plant. It becomes evid first in the new roots and leaves. With further development, plant is no longer able to stand erect. In extreme cases, the lea of the terminal bud curl, turn light green, and eventually die, tips and margins being affected first. As growth is retarded, the st

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Calcium deficiency in tomato. Left, no calcium; right, calcium in nutrient solution.

and often the lower leaves thicken and tend to become dark green. The roots are malformed, their tips are blunt and darkened, and they have few lateral branches.

TABLE 3

Examples of Plants with High and Low Percentages Calcium

Dry-matter basis

High Calcium Percentages			Low Calcium Percentages		
Plant	Part	Per Cent	Plant	Part	Per Cent
Sunflower	Leaves	7.64	Oats	Straw	0.15
Pea	Foliage	6.53	Wheat	Straw	0.08
Tobacco	Leaves	6.07	Timothy	Hay	0.04
Alfalfa	Leaves	6.00	Corn	Grain	0.01
Kale	Tops	1.80	Potatoes	Tubers	0.04

Calcium Removed in an Acre of Crop

Crop	Acre Yield	Calcium
		lb.
Alfalfa, hay	4 tons	100
Cabbage, heads	10 tons	10
Corn, grain	100 bu.	1
Corn, stover	2½ tons	30
Oats, grain	50 bu.	2
Onions, bulbs	400 bu.	10
Potato, tubers	400 bu.	2
Soybeans, grain	25 bu.	5
Timothy, hay	.3 tons	15
Wheat, grain	35 bu.	1

34. How much calcium is removed in crops?

The amounts of calcium removed in the produce of an acre of good crops are shown in table 4.

35. Does continued use of high-calcium lime cause trouble?

Continued use of a very pure calcitic limestone or of its burned or hydrated products on soils containing limited supplies of available magnesium may lead to a marked deficiency of this element. The same applies to oyster shells, which are very low in magnesium.

36. What are the functions of magnesium in plants?

Magnesium is an essential constituent of chlorophyll, other cell components and seeds of plants. In addition, it is believed to have value in the synthesis of carbohydrates, fats, and proteins.

37. How much magnesium is contained in plants?

The magnesium contents of plants vary greatly with the species, the variety, and the parts of the plants analyzed. Some extremes in magnesium are shown in table 5.

38. What are the symptoms of magnesium deficiency in plants?

The first symptom of magnesium deficiency is a reduction in the chlorophyll content of the older leaves and a fading from green to yellow. Such a chlorosis develops first in the areas between the veins

TABLE 5

Examples of Plants with High and Low Percentages Magnesium

Dry-matter basis

High Magnesium Percentages			Low Magnesium Percentages		
Plant	Part	Per Cent	Plant	Part	Per Cent
Sunflower	Leaves	3.15	Rye	Straw	0.036
Tobacco	Leaves	2.74	Sugarcane	Stalks	0.020
Spinach	Leaves	1.24	Apples	Fruit	0.018
Buckwheat	Stalks	1.22	Beets	Roots	0.013

of the lower leaves. As the magnesium-deficient plant grows older, the color of the areas between the veins varies from whitish in the bottom leaves through yellow in the middle portion of the plant to a normal green at the top. On cotton, lima beans, blueberries, and certain other crops, the interveinal portions of magnesium-deficient leaves are red, but the veins remain dark green.

39. How much magnesium is removed in crops?

The amounts of magnesium removed in the produce of an acre of good crops are shown in table 6.

TABLE 6

Magnesium Removed in an Acre of Crop

Crop	Acre Yield	Magnesium
		lb.
Alfalfa, hay	4 tons	50
Cabbage, heads	10 tons	4
Corn, grain	100 bu.	10
Corn, stover	2½ tons	7
Oats, grain	50 bu.	2
Onions, bulbs	400 bu.	5
Potatoes, tubers	400 bu.	20
Soybeans, grain	25 bu.	5
Timothy, hay	3 tons	10
Wheat, grain	35 bu.	3

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Magnesium deficiency of leaves. Left, no magnesium; right, 160 pounds MgO on acre

40. Does continued use of high-magnesium lime cause trouble?

Long-time experiments involving repeated applications of high magnesium liming materials have not shown any ill effects from their use. Little tendency toward a relative accumulation of magnesium in the soil has been noted in such tests.

41. What is the ratio of calcium to magnesium in plants?

The relative amounts of calcium and magnesium in plants vary greatly with the species and variety, the parts of the plants analyzed

TABLE 7

Calcium Magnesium Ratios in Some Plants

Plant	Part	Ratio*
Alfalfa	Hay	2.0
Cabbage	Heads	2.5
Corn	Grain	0.1
Corn	Stover	4.3
Oats	Grain	1.0
Onions	Bulbs	2.0
Potatoes	Tubers	0.1
Potatoes	Vines	2.1
Soybeans	Grain	1.0
Timothy	Hay	1.5
Tobacco	Leaves	2.5
Wheat	Grain	0.3
Wheat	Straw	1.4

*Alfalfa hay, for example, contains twice as much calcium as magnesium.

and the supplies of available calcium and magnesium in the soil. Some average ratios are shown in table 7.

42. What is the best ratio of calcium to magnesium in soil?

The ratio of exchangeable calcium to exchangeable magnesium in soil is often as much as 10 or 15 to 1. The ratio of total calcium to total magnesium in plants is seldom more than 2 to 1. Experiments have shown that the calcium-magnesium ratio in soil can be varied considerably with little or no observable effect on the well-being of crops that grow on it. The calcium and magnesium contents of plants vary somewhat with changes in the ratios of these elements in the soil, but not necessarily in direct proportion.

43. How widespread are calcium and magnesium deficiencies?

Calcium deficiency in plants is seldom recognizable in the field. This has led to the conclusion that most soils contain enough of this element to supply the nutritional needs of plants. Some crops, notably peanuts, respond to applications of calcium sulfate and produce better yields on soils that are high in soluble calcium. In

contrast, magnesium deficiencies are fairly widespread, notably on the Atlantic Coastal Plain area. Such deficiencies have been found on potatoes, cotton, tobacco, citrus, corn, blueberries, apples, and a variety of truck crops.

44. How does potassium affect calcium and magnesium uptake?

If large amounts of potassium are available to plants, their uptake of calcium and magnesium may be greatly reduced. Where the levels of calcium and magnesium in the soil are low, heavy applications of potassium may result in deficiencies of these elements, notably of magnesium. In general, the exchangeable calcium and magnesium in soil should be maintained at a high level relative to that of potassium to avoid deficiencies.

45. Does high-magnesium lime induce greater phosphorus uptake?

Both magnesium and phosphorus tend to concentrate in the seeds of plants. Some experiments indicate that phosphorus uptake of plants is increased when extra magnesium is applied to the soil, but there is doubt about the general applicability of this principle. Where lack of magnesium limits plant growth, the uptake of other nutrient elements as well as of magnesium may be increased by use of high-magnesium lime on the soil.

46. Do plants vary in their capacities to grow on acid soil?

Plants vary widely in their capacities to grow on acid soil. Some, like blueberries and azaleas, grow better on acid than on limed soil. Others, like corn, oats, and timothy, are tolerant of a moderate degree of acidity but will also grow satisfactorily on a moderately alkaline soil. Flax, peas, turnips, and red clover are less tolerant of acidity. Such plants as barley, alfalfa, sweet clover, cauliflower, and most vegetables require a soil pH that approaches the neutral point.

47. Why do some plants grow best on acid soil?

The environment in which acid-soil plants evolved was deficient in calcium, hence they developed the capacity to do without it. Such plants frequently contain relatively large amounts of aluminum and manganese in place of part of the calcium. Mycorrhiza often play an important part on the roots of such plants. In some cases, as with potatoes, best results are obtained on acid soil because of lowered susceptibility to scab under such conditions.

TABLE 8

Calcium Content of Some Acid-Tolerant and Acid-Sensitive Plants

Dry-matter basis

Acid-Tolerant Plants		Acid-Sensitive Plants	
Plant	Calcium	Plant	Calcium
	%		%
Corn, grain and stover	0.25	Alfalfa, hay	2.2
Oats, grain and straw	0.35	Clover, hay	1.5
Timothy, hay	0.39	Tobacco, leaves	6.0
Redtop, hay	0.42	Spinach, tops	1.2
Rye, grain and straw	0.22	Celery, tops	2.4
Flax, grain and straw	0.28	Beets, entire plant	1.4
Millet, hay	0.96	Turnips, entire plant	3.1

48. Do plants on acid soil have low calcium contents?

Plants that grow best on acid soil usually have low calcium contents. The large group of plants that can tolerate both acid and neutral soils may contain fairly large amounts of calcium. This is shown in table 8, comparing the calcium content of acid-tolerant and acid-sensitive plants.

49. What are the possibilities of farming without the use of lime?

A considerable number of crops can be grown at fairly low pH values. White potatoes and sweet potatoes grow very well on quite acid soils. Corn, cotton, and rye are tolerant of acid soil conditions. Good crops of peanuts, soybeans, and alsike and crimson clovers can be grown on acid soils. Thus, it is possible to develop complete rotations that can be employed under acid-soil conditions. Except for potatoes, however, most of these crops can be grown more profitably by the use of lime.

50. Can lime be mixed with fertilizer?

Only relatively small amounts of the burned forms of lime can be mixed with fertilizer because they tend to release any ammonia that may be contained in the fertilizer. They also have a tendency to reduce the solubility of the phosphorus. Fertilizer manufacturers often

add 15 to 20 pounds of hydrated lime to each ton of their mixtu as a means of eliminating free acids. Dolomitic limestone, at ra up to 200 pounds a ton, is sometimes used to overcome excess acidity and to supply magnesium. For the most part, liming materi and fertilizers should be applied separately. In general, also, the li should be applied ahead of the fertilizer and worked into the s This tends to keep fertilizer elements in a more readily availa form in the soil.

51. Is manure of any value for correcting soil acidity?

The ammonia that is liberated from manure during its decom sition in the soil may reduce temporarily the acidity of the soil. well-drained soils, this ammonia is soon changed to nitric acid the nitrifying bacteria. Since manure, on decay, also releases bas it has little permanent effect on soil reaction.

52. Can fertilizers be used in place of lime?

For the most part, substitution of fertilizers for lime is an expensi and wasteful practice. Most of the bases that are contained fertilizers are combined with strong acids and have little effect soil reaction. But certain fertilizer materials, notably basic slag a cyanamid, carry free lime and can be used to advantage on acid s Soluble phosphates may be used to inactivate excess iron a aluminum in acid soil and thus reduce the toxicity of these t elements to plants.

53. What effect does organic matter have on soil pH values?

Organic matter, on decay, liberates carbon dioxide. This, in wat forms weak carbonic acid. As water containing carbonic acid mo through the soil it tends to dissolve and carry away soil bases, leavi hydrogen in their place. Organic matter also yields nitric acid decay, but it may release enough bases to neutralize the acid. T humus that is derived from organic matter has a marked bufferi effect in the soil, that is, it helps prevent rapid and extreme fluctuati in soil pH. Clay has a similar effect, but not nearly so great as t of the same quantity of organic matter.

54. Is gypsum of any value as a substitute for lime?

Gypsum is a good source of soluble calcium, but it will not red soil acidity. It is also valuable as a source of sulfur in regions wh the soil is deficient in this element. Large quantities of gypsum used to reclaim alkali soils, for which purpose it is far more effect

than lime. It also has value for improving drainage of wet soils in humid regions under conditions in which the subsoils have good drainage.

55. Does limestone soil ever need liming?

Soil derived from limestone often needs liming in areas receiving 25 or more inches rainfall annually. The need for lime becomes apparent within a relatively short time after the soil is brought under cultivation. The carbonic acid derived from decaying organic matter and plant-root respiration is especially effective in dissolving limestone, which is carried away in the drainage water. Underlying layers of limestone have great value, notably for deep-rooted legumes like alfalfa.

56. What effect does superphosphate have on soil pH values?

Superphosphate has very little permanent effect on soil reaction. By its use on an acid soil, some of the excess iron, aluminum, and manganese may be inactivated, and thus superphosphate may serve as a temporary substitute for lime. But the availability of its phosphorus is greatly reduced under such conditions.

57. Do potash salts have any effect on soil pH values?

Neither the chloride nor the sulfate of potash has any permanent effect on the pH value of a soil. Large applications of potash salts may lower the pH value temporarily, but after they have been leached out, the original pH value will be restored.

58. Why do some nitrogen fertilizers have such acid effects on soils?

Fertilizers containing nitrogen but no metallic base tend to develop an acid condition when applied to the soil. This is especially true of ammonium sulfate. When this material is applied to the soil, the microorganisms oxidize the ammonia to nitric acid and release the sulfuric acid as well. To neutralize the acidity developed by a given weight of ammonium sulfate requires use of an equal weight of limestone or its equivalent in some other form of lime. Somewhat lesser amounts of acid result from use of equivalent amounts of ammonium nitrate or urea. In contrast, calcium and sodium nitrates and cyanamid have alkaline effects on the soil.

59. Do any of the spray materials increase soil acidity?

Sulfur-containing fungicides are strong acidulating agents because their sulfur is oxidized to sulfuric acid in the soil. For every pound of elemental sulfur applied, about 3 pounds limestone, or its equivalent in some other form of lime, is required to neutralize the acid produced.

60. Do industrial dusts and fumes affect soil pH values?

Some industrial plants, such as those producing lime and cement, give off alkaline dusts that usually are of benefit to the surrounding land. Gases and dusts from many other kinds of industrial plants have little effect on the soil reaction. The sulfur dioxide gas that is liberated from old-fashioned coke ovens and from smelters in which sulfide ores are being roasted may markedly increase the acidity of near-by soil.

61. What pH value is preferred for most crops in acid-soil regions?

Many of the common agricultural plants in humid regions grow well on soils at pH values between 5.5 and 6.0, but they often grow much better at somewhat higher pH values. Alfalfa and sweet clover are favored by a soil reaction more nearly approaching the neutral point. When all crops and conditions are taken into consideration, a pH range between 6.0 and 6.5 is probably the most generally favorable one in acid-soil regions.

62. What happens in acid soil as pH values are raised?

As the pH value of a soil approaches neutrality from the acid side, soil fungi tend to give way to bacteria. The rates of nitrate production, nitrogen fixation, and organic matter production and decomposition increase. Certain weeds, notably sorrel *(Rumex acetosella)* and broomsedge *(Andropogon virginicus)* become less abundant. Red and sweet clovers and alfalfa grow much better. Heavy soil generally becomes better aggregated, with resulting improvement in aeration and drainage. Any excess of soluble iron, aluminum, and manganese is inactivated and becomes less troublesome. Availability of phosphorus and molybdenum is increased. Boron, zinc, manganese, and copper become less soluble and less available to plants.

63. On what type of soil does too heavy liming cause most trouble?

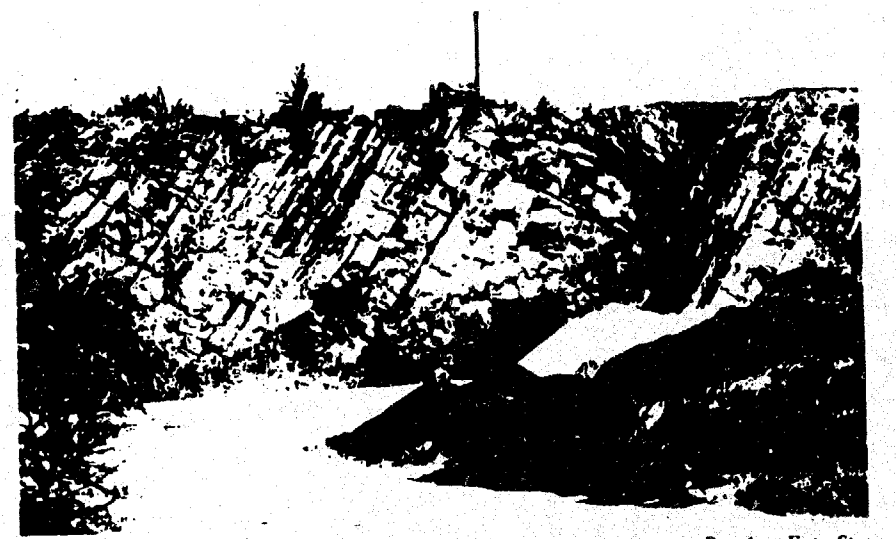
High pH values produced by liming are especially troublesome on sandy soil in humid climates. Such a soil has very little buffering capacity (*see* question 53), and its pH value is quickly raised to a relatively high level with only moderate applications of liming materials. Such a soil is likely to contain only very small amounts of the essential minor elements, and the availability of these small amounts is greatly reduced as the pH value rises. This is notably true of manganese, zinc, and copper.

64. Is it ever advisable to lime to neutrality and add correctives?

For most crops, the most economic procedure is to add enough lime to acid soil to raise its pH value to 6.5. At that value, most of the minor elements that, at higher pH levels, might have to be added as correctives are normally present in available form in sufficient amounts to meet crop requirements. Liming to neutrality or higher means two additional costs, that of the extra liming material and that of the correctives for overliming.

65. How is productivity of high-pH Western soil explained?

The pH value of the soil of the irrigated arid regions is often considerably above neutrality. Good crops are grown on such soil at pH values of 8 or higher. This soil has not been subjected for centuries to the leaching action of heavy rainfall. As a result, it contains much larger amounts of all the necessary mineral nutrients than the acid soil of humid regions. Even so, deficiencies of certain minor elements, notably of iron and zinc, occur over wide areas. In such cases, sulfur can be used as a corrective through its acidulating effect on the soil.



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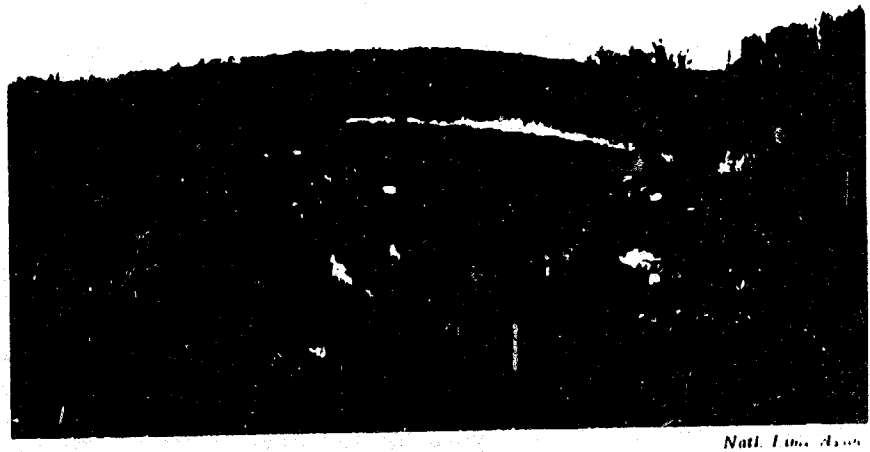
Limestone, in quarry, before it is prepared for use on the soil.



Natl. Lime Assn.

Farm kiln once used for burning lime in alternate layers of coal and limestone.

66. What forms of lime are in most common use?

Pulverized limestone constitutes by far the largest tonnage of any of the liming materials used in the United States. In some areas, the burned or hydrated forms of lime are used. In other areas, marl, ground oyster shells, or blast-furnace slag is employed.

67. How effective is blast-furnace slag as a liming material?

Most of the calcium and magnesium in blast-furnace slag occurs as silicates, which dissolve more slowly than other liming materials. If finely pulverized, they correct soil acidity almost as readily as other forms of lime. Their neutralizing value per unit of weight is normally only about half that of limestone and, accordingly, heavier applications must be made.

68. Can burned lime ever be used to special advantage?

Burned lime has a more rapid effect than pulverized limestone. Many farmers prefer the burned form for quick-growing, high value truck crops. It may be less expensive per unit of lime where liming materials have to be transported considerable distances. Thus, 1,120 pounds of burned lime from calcitic stone or 965 pounds of burned lime from dolomite has the same neutralizing value as 2,000 pounds of pure calcitic limestone. Handling and transportation costs can be cut virtually in half by use of the burned forms of lime.

69. Under what conditions is hydrated lime preferred?

Hydrated lime has the advantage that it is more finely divided than pulverized limestone, it is more readily soluble, and it is faster-acting. It is often used in preference to other forms of lime on high-value, quick-growing truck crops. It is a more concentrated product, 1,480 pounds of hydrated lime derived from pure calcitic limestone or 1,145 pounds of hydrated lime derived from dolomite being equivalent to 2,000 pounds of pure calcitic limestone. A second important feature favoring hydrated lime is that it is always available at the local farm or builders' supply store in one-bag or in ton lots, as the grower may have need for it.

70. What are the advantages of using pulverized limestone?

Pulverized limestone is usually the least expensive liming material in terms of cost by the ton. It is highly popular because of this, the ease with which it can be spread, and its lack of causticity on the skin. For extensive farming it will continue to be the preferred form of liming material. In the more intensive types of farming, notably in vegetable and truck-crop production, it often yields to burned or burned and hydrated lime. The same applies to areas that are far removed from the source of supply, where the cost of these materials for a unit of neutralizing power may be less than that of limestone.

71. To what fineness should limestone be pulverized?

To be of benefit, limestone must react with soil acids. Its rate of reaction is largely dependent on the surface area of the limestone particles. The finer the particles, the greater the amount of surface exposed to solution. For quick effects, it is desirable to use a product most of which passes a 100-mesh screen. Such a product will react with the soil during the first few months after application. Limestone particles passing through a 20-mesh screen and held on a 100-mesh screen will dissolve and become available within a year or so. Particles larger than 20-mesh have very slow effects in the soil.

72. Under what circumstances may coarse limestone be useful?

Limestone particles coarser than 20-mesh may possibly be useful on very sandy soil because of the very low base-exchange capacities of such soils. Such large particles may be useful in maintaining a relatively constant supply of available calcium carbonate. Thus, one might well make a heavy application of limestone screenings for long-time effects and then apply a small dose of quickly available material in preparation for each succeeding crop. The importance of this remains to be demonstrated.

73. Why is fineness of special importance in dolomitic limestone?

Dolomitic limestones are generally much more slowly soluble than the calcitic type. For that reason it is especially important that they be finely pulverized. This fine pulverization greatly increases the surface area that is exposed to the solvent action of the soil acids.

74. Is there any advantage in using limestone screenings?

The coarser the limestone particles applied to the soil, the longer they will last. This means merely that coarse limestone dissolves very slowly and, for that reason, it remains in the soil in an essentially unavailable form. The reason for using limestone is to neutralize soil acids, and this can be done only by applying a product that is fine enough to dissolve quickly. Some of the coarser screenings may remain in the soil 25 or more years. This means that a long time will elapse before the buyer gets a full return on his investment.

75. What factors must be considered in utilizing waste lime?

Waste-lime materials from various industries are available for use on the soil. Among these are wood ashes and lime by-products from sugar factories, gasworks, paper mills, and acetylene plants. Wood ashes may contain as much as 50 per cent calcium carbonate and up to 5 per cent potash in the carbonate or acid-neutralizing form. Many by-product limes from manufacturing enterprises have a high content of water, which makes spreading difficult. They must be used with care, since some of them contain toxic impurities.

76. How rapidly will lime applied at the surface work downward?

The depth and rate of penetration of liming materials from surface applications depend on the kind and amount added, rainfall, soil moisture conditions, and soil type. In Connecticut, on fine sandy loam, 10 years elapsed before a surface application of 2 tons pulverized limestone an acre raised the pH to a uniform value throughout the upper 6 inches of soil. In West Virginia a top-dressing of 1½ tons hydrated lime on a permanent sod raised the pH value of the top 1½ inches of soil from 5.2 to 7.0 after 13 years, while the pH value of the 5- to 7-inch layer was increased only from 5.0 to 5.6. These and other data show that liming materials applied on the surface move very slowly to lower depths.

77. Is plowing-under of liming materials ever desirable?

Yes. If deep-rooting, lime-loving crops are to be grown and the subsoil is acid, plowing under half the lime and harrowing in the

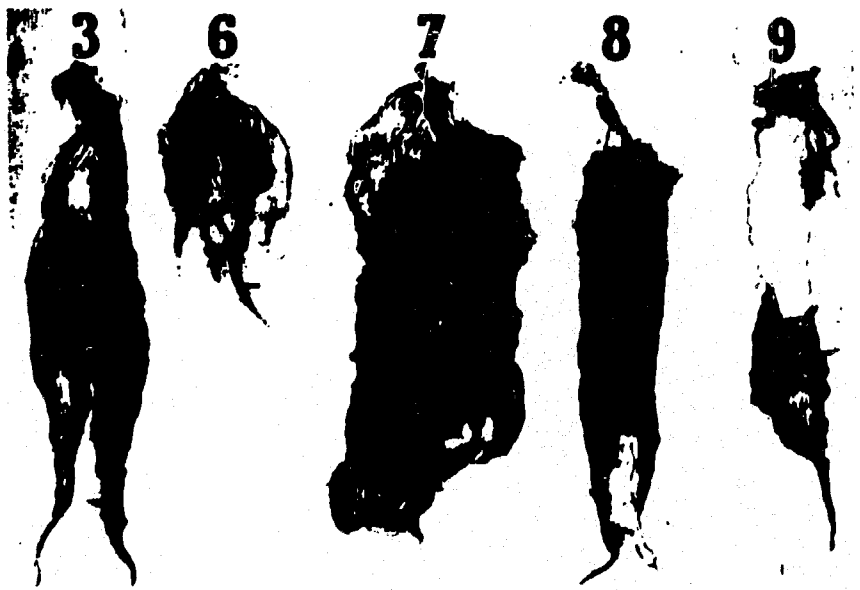
remainder will aid in neutralizing the entire topsoil and upper part of the subsoil, and this may improve yields. For maintenance purposes on soils that are being cropped in rotation and already have a favorable pH value, plowing under lime with a sod or cover crop saves labor and speeds up decomposition of the organic materials.

78. If applied after plowing, how well should lime be worked in?

Liming materials applied to plowed soil should be mixed with the soil as soon as possible and as thoroughly and deeply as feasible. The better they are mixed with the soil, the more quickly their value is realized and the less likely they are to be lost by erosion. Allowing liming materials to cake or crust on the surface of the ground before incorporation reduces their immediate effectiveness.

79. Is anything gained by liming the subsoil?

Where the value of the crop justifies the added expense, subsoil liming is desirable. Deep-rooted crops can utilize the nutrients and moisture of the subsoil if conditions are favorable for their develop-



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Clover roots grow where the lime has been placed. Tests 3, 6, 7, and 8 fertilizer mixed with 9 inches soil. Test 3, lime mixed with 9 inches soil; test 6, lime mixed with top 3 inches soil; test 7, lime mixed with top 6 inches soil; test 8, lime mixed with bottom 6 inches soil. Test 9, fertilizer and lime mixed with top and bottom 3 inches of soil.

ment. Acid subsoils inhibit branching of the roots of lime loving crops Hence, for alfalfa and asparagus, subsoil liming in addition to surfac liming has been found to be beneficial.

80. Is a localized placement of lime ever of value?

On soils that are only slightly acid, small applications of fin limestone in close contact with the seed of lime-loving crops ma ensure more satisfactory germination. Subsequent growth and per manence of the crop will depend more upon the lime status of th entire body of soil than upon the contact application.

81. How much lime is carried away in drainage waters?

In Illinois and Wisconsin, with lysimeters that allowed natura surface drainage, very little soil water percolated beyond a depth o 4 feet, and very little leaching of lime occurred beyond the roo zone. In Pennsylvania, nearly 4,000 pounds of calcium oxide wa leached out of the plow-depth of Hagerstown loam that had receive 35,200 pounds of calcium oxide during the previous 40-year perio This indicates a leaching loss of about 100 pounds calcium oxid an acre annually. As the pH value of this soil was maintained abov 7, the loss of lime was higher than it would have been under mos farming conditions in a similar climate. The net loss by leaching i the southern states may well be 50 per cent higher than in th northern states.

82. To what extent is erosion a factor in the loss of lime?

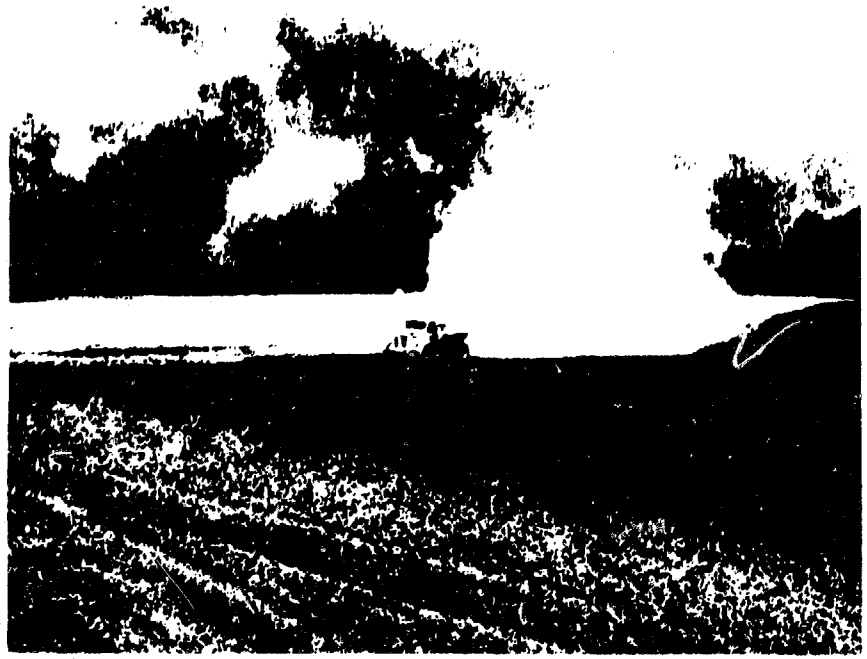
Erosion carries away with the soil all the lime contained in i Even a moderate amount of sheet erosion, following a topdressin of lime, may carry most of the added lime into the nearest creel Where the lime is mixed with the entire plow depth of soil, the los would be proportional to that of the soil itself.

83. Does lime move to the surface from underlying deposits?

Very little lime from lower levels moves to the surface of the soi Deep-rooted plants may bring lime to the surface from lower-lyin deposits. When the soil is put under cultivation, even that which ha been formed from underlying limestone becomes acid. The rate removal in the crop and by way of the drainage water is m rap than its rate of renewal by movement upward from lov level

84. How frequently should maintenance applications of lime be made

The need for renewing the lime supply in the soil depends on th kind of soil, the climate, and the cropping system employed general, maintenance applications are needed every 4 to 6 year



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For maintenance purposes, lime may be applied at any convenient time in the rotation.

On sandy soils, more frequent use of lime and lesser amounts in an application are required than on the heavier types of soil. The greater the rainfall and the larger the amounts of water passing through the soil, the more frequent the need for lime and the larger the amount required. The higher the intensity of the agriculture and the heavier the application of fertilizer, the more necessary it becomes to lime the soil frequently. The best means of dealing with this problem is to have the soil tested regularly for its pH value.

85. What constitutes good liming practice on a permanent pasture?

If both the surface soil and the subsoil are acid and the land is to be plowed in preparation for seeding, half the lime required should be plowed down and the remainder disced into the plowed soil. A surface application of lime, followed by deep discing or other deep tillage, is an effective way to lime pastures that are to be reseeded. In either case, applications of lime should be made at about 5-year intervals to maintain the soil pH value at the proper level. Even if plowing or discing is not feasible, surface applications of lime are still of great value in improving pasture soil.

86. How should an acid soil be prepared for alfalfa?

Acid soil should be limed to a pH value between 6.5 and 7.0 for alfalfa, and a substantial part of the lime should be incorporated into the soil as deeply as possible. If more than 2 tons of lime is to be applied to an acre, best results are likely to be obtained by plowing under half of it. The rest should be applied after plowing and should be thoroughly disced into the soil. Topdressings of lime to established alfalfa sometimes have value in maintaining stands and yields over longer periods than would otherwise be possible in humid regions.

81. When should lime be applied in general farm practice?

Lime should be applied well in advance of planting the crop that has the highest lime requirement, which is usually some legume hay crop. But additional lime should be applied at seeding time if the soil is still very acid. By this procedure, the returns from the use of lime may be greatly increased. For such crops as potatoes and the finer-quality types of tobacco, the soil-borne diseases of which are favored by liming, the lime should be applied after the crops are harvested rather than just before they are planted. Under

Natl. Lime Assoc.

If the soil is strongly acid, lime should be applied and worked into the soil after the land has been plowed.

ordinary farming conditions, lime should be applied whenever a convenient opportunity is presented, if pH tests show that the soil needs it.

88. How frequently should lime be applied to market-garden soils?

For intensive systems of market-gardening, the soil should be adjusted annually to the most effective pH value, which is generally about 6.5. As much as 1,000 pounds of lime may be required annually for maintenance purposes. For cabbage, it may be necessary to raise the pH level higher to control clubroot. Under such conditions, it may be necessary to add manganese sulfate with the fertilizer at a rate of possibly 50 pounds an acre annually.

89. What constitutes good liming practices for lawns?

If the soil test shows that the pH value is below 6.0, enough lime should be added to raise it to that level, but no higher. For bents and fescues, the pH value need not be that high. When new seedings are made, lime should be thoroughly mixed into the seedbed to as great a depth as possible. Subsequent topdressings of lime should be small. Since lime penetrates the soil very slowly, it can be applied to best advantage in early spring, when freezing and thawing are taking place, or in fall, after a long dry period, when water penetrates rapidly. The lime should be allowed to react with moist soil a week or so before any fertilizer is applied.

90. What materials are used to lower the pH values of soil?

To lower the pH values of soil, use can be made of sulfur, sulfuric acid, ammonium sulfate, aluminum sulfate, or acid peats. Of these, sulfur is the most effective for a unit weight of material. About 400 pounds sulfur is required to reduce the pH value of a loam soil one-half unit. In ornamental horticulture, aluminum sulfate is often used for local application to acid-loving shrubs. It has the advantage of high solubility and quick action. Ammonium sulfate is an excellent acidulating agent where nitrogen also is required.

91. Under what conditions is sulfur preferred as an acidulator?

Sulfur is usually the cheapest and most convenient material available for lowering the pH value of soil. To be effective, it must be transformed into sulfuric acid by the sulfur-oxidizing bacteria in the soil. This transformation proceeds fairly rapidly in fertile soils, but is often very slow in those that are low in organic matter. Sulfur must be applied with caution under conditions in which its oxidation is delayed, since it is easily possible to overdo its use.

92. Do sawdust and shavings make the soil acid?

On decomposition in the soil, sawdust and shavings produ carbonic and other weak acids, just as do all other organic materia Any injurious effects that may be noted from the use of su materials, however, are more likely to be due to nitrogen deficien than to acidity. The microorganisms that effect the decay of su materials often need more nitrogen than these materials supply. A a result, the microorganisms compete with crop plants for the nitrog in the soil. The remedy for this lies in the use of extra nitrogen fertilizer form.

93. Do plowed-under legumes cause a lowering in soil pH?

Legumes are high in nitrogen, and when they are worked in the soil, this nitrogen is soon transformed into nitric acid. Thus t pH value of the soil may be lowered by plowing under legume Since most legumes grow best on well-limed soils, the nitric ac produced on their decay is normally combined with the left ov lime in the soil on which they were grown and plowed under.

94. What is a good procedure in preparing acid soil for azaleas

In preparing soil for azaleas, rhododendrons, and other ericaceo plants, it is desirable to dig a trench and fill it with a mixture soil and acid peat or oak-leaf mold. This should meet the requiremen for acidity more or less permanently. If not, acidulating agents shou be applied from time to time. Aluminum sulfate is frequently preferr for this, but elemental sulfur or ammonium sulfate may be us instead. Frequent small applications of these materials to the desir pH levels are better than a large initial dose.

95. Does liming acid soil aid in increasing its organic matter?

If the cropping system includes a sod crop, such as the comm grasses or legumes, or if a considerable part of the crop is return to the soil, as with corn stover and wheat straw, liming the soil ten to increase the organic matter supply. It causes the crops to gr larger, with the result that larger amounts of roots and residu are left on and in the soil. This applies also to systems in whi cover crops are grown and plowed under.

96. Does liming have any effect on the earthworm population?

At low pH values, the earthworm population in soils is great reduced and, in extreme cases, may be almost entirely eliminate When such soils are limed, larger crops are produced, and mo

organic matter is left on and in the soil. This is the food of earthworms. In proportion as soil is maintained at a high level of fertility by liming and by incorporating organic matter, the number of earthworms will be kept at a high level, often at more than a million an acre, mostly in the plow depth during the summer.

97. Does use of lime reduce the need for fertilizer?

At a high lime level, good growth of legumes is promoted, and if such crops are included in the rotation, the need for nitrogen fertilizers may be reduced. Likewise, if soil is well limed, the crops growing on it are likely to contain more calcium and magnesium and less potassium than they would otherwise. Liming of acid soil induces larger yields, which remove more phosphorus and potassium from the soil, and may increase the need for these elements.

98. How much agricultural lime is used yearly in the United States?

On the agricultural land of the United States, 20 to 30 million tons of liming materials, representing a calcium-oxide equivalent of about half these quantities, are used annually. Some additional lime is applied as a constituent of mixed fertilizers and in such materials as cyanamid and basic slag.

99. How is the tonnage distributed among the several forms of lime?

The National Lime Association estimates that of the 22,710,000 tons of agricultural liming materials used in the United States in 1958 there were 21,990,000 tons limestone, 76,000 tons burned lime, 120,000 tons hydrated lime, 246,000 tons marl, and 278,000 tons miscellaneous materials.

100. How much agricultural lime should be used yearly?

In 1946, the U. S. Department of Agriculture, with the help of agronomists from the several states, estimated that more than 50 million tons of liming materials could be used to advantage annually in the United States. If all the farmed land in the acid-soil regions of the country were limed to a pH value between 6.0 and 6.5, the tonnage required would be a great deal larger than that indicated.

(Figures indicate question numbers, not pages)

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E. USE OF POZZOLANIC MATERIALS

i. The Need or Market

The highly populous volcanic region of Rwanda, stretching almost sixty kilometers from Kidaho almost to the shore of Lake Kivu at Gisenyi, has a particular problem in building construction. The subsoil is composed of pumice, which, though excellent for the soil, is not an easy material from which to build housing. Some of the construction in this region is based on the use of quarried and cut pumice blocks, the production of which is meticulous and time consuming. Most, however, is based on the technology that prevails elsewhere in Rwanda: fired clay bricks, made on the periphery of the volcanic zone and trucked to the construction site. The proposed technology, which uses pumice gravel and sand as an aggregate in cast cement blocks, could lower the cost of housing in the volcanic zone by reducing the fuel cost that figures heavily in the cost of fired bricks, and by almost eliminating the transport cost. The cost of pumice blocks that use portland cement as a binder may be further reduced by binding the aggregate with a local pozzolanic cement, rather than portland cement. The production of cement blocks using pumice as an aggregate is currently practiced at the Adventist University in Mudende, where it has been found to be more economical than building with fired bricks. The Pozzolana, Lime, and Peat Project (PPCT) in Ruhengeri has for several years been making pozzolanic binders. The proposed activity is an attempt to demonstrate the use of pozzolanic materials: as aggregate, in the form of pumice blocks; and as binder, in the forms of portland-pozzolanic cement and pozzolanic cement.

ii. The Technology

The technology involved in making cement building blocks using lightweight pumice aggregate is simple. The pumice is dug out of the hillsides as a roughly pea-sized gravel. A portion of this is then crushed to the size of coarse sand to fill the voids between the pea-sized pieces. Crushing the pumice requires very little energy, and may be done with a manually operated machine that can be locally made. The machine would have two steel rollers turned by cranks between which the gravel is crushed. Afterwards, the coarse and fine aggregate are mixed in the proper ratio, dry cement added and thoroughly mixed in, and then just enough water added to moisten the entire mass. Any of a number of commercially available block molds or molding machines can then be used to mold the blocks. A small concrete mixer and vibrating block molding machine are very useful for increasing the productivity of the block production process and the quality of the blocks.

Carey Cascallen, who is in charge of building construction at Adventist University, as well as training in vocational and industrial arts, is responsible for the University's work with pumice-cement blocks. He uses 70% portland cement and 30% pozzo-

lanic binder in the production of blocks used in the construction of University buildings. A total of 30 sacs of portland cement and 13 sacs of pozzolan are mixed with 7.5 m^3 of pumice gravel to produce 1000 twenty centimeter thick blocks. At current prices, portland cement costs 1300 frw per 50 kg bag, pozzolan costs 750 frw per bag, and pumice costs 1000 frw per m^3, delivered to the block making site. Total raw materials therefore cost 56,250 frw per 1000 blocks. Cascallen estimates his labor at only 4 frw per block, and does not include depreciation of his blockmaking machine or block production shed, nor taxes and profit. If these are collectively estimated at 20 frw per block, then the selling price could still be less than 80 frw per 20 cm block.

Three factors contribute to the cost of building with blocks or brick:

- the number of blocks or bricks required per m^2 of wall (15 blocks versus 100 bricks, thus the relative cost is 1200 frw versus 800 frw, where the cost of bricks including transport is 8 frw each);

- the quantity of mortar required (approximately .01 m^3 versus .03 m^3 per square meter of wall, thus 73 frw versus 219 frw);

- the amount of labor required for blocks versus bricks, assumed to be 0.25 man-days per m^2 for blocks, and 1.0 man-days per m^2 for bricks, or 100 frw for blocks versus 400 frw for bricks.

Based upon the above estimates, the cost of building with pumice cement blocks is only marginally cheaper than the cost of building with fired bricks: 1373 versus 1419 frw. However, these blocks were made to the University's very high standards, and substantial reductions in cost could be achieved by optimum aggregate combination, or a greater substitution of pozzolanic for portland cement, and still meet building standards. It is likely that reinforcement requirements (steel bars) would also be reduced as a result of decreased wall weight. GATE has collaborated with the University in the production of houses made from blocks and panels of pumice aggregate, and estimates the total cement requirement at four bags of portland per cubic meter of aggregate. This would reduce the cost per block to roughly 64 frw, or 1133 frw per square meter of laid wall. Further reductions in cost may be achieved by grinding the aggregate to more than two gradations, and by mixing these in the proper proportions to further reduce the void fraction. A greater substitution of pozzolanic binder for portland cement may also be possible. For a more efficient and economical operation the pozzolanic cement and pumice blocks could be manufactured at one site.

If the production of blocks using pumice aggregate and a mostly pozzolanic binder proves feasible, this could support a

large number of small and micro enterprises in the volcanic zone, and would be a profitable sideline activity for the PPCT and other hydrated lime producers. A simple, locally made, hammer or ball mill could be used to produce the fine pumice powder needed to react with the hydrated lime in the pozzolanic binder. It may also be possible to size the screen and adjust the throughput so that the crushed pumice produced has the proper range of particle size to provide a high packing density when mixed with the uncrushed aggregate, and sufficient fines for obtaining high strength from the pozzolanic mixture. This would mean that the lime could be mixed directly with the crushed aggregate leaving the mill, and the uncrushed aggregate and water added to this mixture, to form the blocks.

Mixing the pozzolanic binder at the block production site has a number of advantages that contribute to the low cost of the finished product:

- the pumice need not be dried, as when it is to be mixed with lime and packaged for later use;

- only the lime is bagged and transported from the lime kiln to the block production site;

- the fines that are needed in the pozzolanic binder can perhaps be produced as a by-product of the process of crushing the aggregate, therefore permitting the use of a less sophisticated grinder, which consumes less energy than if the fines were produced separately.

The use of pozzolan improves the workability of harsh concrete mixes, lowers the total heat of hydration, and improves the impermeability and durability of hardened concrete. However, pozzolanic binders are known to have two drawbacks, relative to portland cement. First, they harden very slowly, often requiring two to three months to reach a strength comparable to portland cement. This may require the construction of large curing sheds on the block production site, and the retention of a large inventory of blocks in the curing process, both of which will add to the production cost. Second, pozzolanic binders reportedly exhibit high shrinkage, which is a serious disadvantage when they are used as a substitute for portland cement during the construction of a building. Shrinkage should not, however, be a serious problem in the production of blocks as long as the shrinkage is reasonably uniform from one block to another. Special molds may have to be made if the final dimensions of the blocks must correspond to existing norms. A small quantity of portland cement or some form of accelerator may prove cost effective in reducing shrinkage and/or the curing time of pozzolanic pumice blocks.

iii. <u>Existing Activity and Institutional Resources</u>

The use of pumice aggregate blocks will be widely adopted in Rwanda's volcanic zone only if it proves to be significantly

cheaper than the use of fired bricks. This, in turn, depends on the successful conclusion of some fairly meticulous experimental work. Fortunately, there are a number of organizations, both within and outside Rwanda, that have experience in this area that should be interested in sharing their experience.

The Adventist University, located in the volcanic zone at Mudende (Mutura Commune), is presently building with pumice aggregate cement blocks, and is well suited to implement this project. First, it is in their interest to experiment with ways of reducing the costs of construction, since they have an ambitious building program of their own. They have collaborated with GATE in the construction of prototype houses using pumice-cement panels, and thus have some experience in donor project implementation. They have a vocational and technical education program, of which building construction is an important element, and could integrate this activity into that program, thereby reducing its cost and increasing its educational value. They already possess a block molding machine and a block production shed, and have metalworking facilities where they can build simple equipment for other block producers. They plan to obtain equipment to compression test building materials.

The Pozzolan, Lime, and Peat Project (PPCT) in Ruhengeri was financed in 1979 by the Belgian Agence Generale de Cooperation au Developpement. It has been producing pozzolanic binder and hydrated lime since its inception. Sales of pozzolan have dropped off during the past year due to a drop in the price of portland cement (from a high of 2000 frw/bag to approximately 1300 frw/bag now), and due to the slow curing quality of their pozzolan. The addition of gypsum as an accelerator and some portland cement have increased the cost of their cement, presently at about 750 frw per bag. One purpose of this activity is to test an application of pozzolan where its slow curing may not be a serious disadvantage. PPCT should be interested in participation in a project both because the activity could increase their market for pozzolan, and because they would be well placed to market blocks themselves should experimental work with pozzolanic binders prove successful. PPCT has a materials testing lab and technically qualified people who could be useful in testing blocks and formulating binders.

GATE (the German Appropriate Technology Exchange) has collaborated with the Adventist University in the past, and has considerable experience in low cost building materials, including the use of pumice as an aggregate. ATOL (the Belgian appropriate technology research and documentation service) also has experience in this area. ATI has considerable experience in lime production and pozzolanics in a number of developing countries.

iv. <u>Uncertainties and Risks</u>

The widespread use of pumice-cement and pumice-pozzolanic hollow blocks in the volcanic zone will depend on their cost-

competitiveness with fired brick. Though status perceptions figure heavily in the choice of building materials among those who can afford to choose, there is little risk that hollow blocks will be seen as backward or inferior. Hollow blocks have a number of very desirable properties. They are light-weight (roughly 1/3 to 1/2 the weight of brick per square meter of laid wall), which is desirable both from the standpoint of transport as well as in the construction of multi-story buildings because it requires less reinforcement due to less building mass. They can be laid much faster than brick because of their large size, and require much less mortar. Blocks are, however, compatible with the skills and construction techniques used in building with brick, which is one reason that they, rather than wall panels or other unfamiliar shapes, are the product of choice.

V. Recommendations for Future Action

The next step to take toward implementation of the proposed activity would be to consult sources, such as those mentioned above, which may have detailed documentation on other projects involving the manufacture of pumice-pozzolanic blocks. Adventist University should then be contacted to assess its willingness and ability to undertake the experimental phase, perhaps with technical assistance from one of these sources. The exact nature of the experimental phase will be determined once all relevant sources are consulted, but might include the following steps:

- selection of ideal pozzolanic deposit based on geochemistry data;
- characterization of raw materials: pumice deposits, lime, natural aggregates;
- definition of the optimum mixtures needed to produce required pumice blocks and binder at the lowest cost possible to meet required structural demands in Rwanda;
- choice of adequate processing equipment according to local needs: crusher, mixer, ball mill, block manufacturing equipment;
- structural testing and demonstration of the use of pumice blocks;
- documentation of the experience including recommendations to disseminate the technology.

Assuming that the above experimental phase is conclusive, and shows that hollow blocks can be produced at a highly competitive price, Adventist University will then transfer this technology to one or more private producers. The selection of these producers will depend on the cost of the production technology that is ultimately retained.

F. THE METALWORKING SECTOR

Because of the diverse nature of this sector, and the existence of a variety of activities that could contribute to its development, the format of this section of the report will be different from that of the preceding sections. Following a listing of the different workshops that were visited during this consultancy and a general description of the sector will be a brief description of each of the ideas that were considered for improving the sector.

The short duration of this consultancy did not permit a detailed survey of the metalworking sector in Rwanda. Most of the workshops visited are in Kigali, and are the more remunerative, sophisticated, and heavily capitalized ones.

The Rwandex-Chillington factory in Kigali is an industrial forge which manufactures steel hoes. It is an efficient operation that produces roughly 850,000 hoes per year. It also makes machetes and wheelbarrows. Rwandex is planning to commence production of three-tined hoes this fall, and is installing a small steel and iron foundry, to recast its scrap into raw material for hoe production. Rwandex is interested in large volume production, which rules out involvement in most of the smaller-scale activities proposed here.

The Government Forge in Nyabasindu is a well organized blacksmith shop, employing roughly ten to fifteen professional blacksmiths and an equal number of trainees. Trainees work at the Forge for a fixed period of time in order to improve their skills as private blacksmiths. The Government Forge produces a wide range of products, most of good quality, including three-tined hoes, shovels, axes, machetes, watering cans, rakes, frying pans, ornamental spears, coat hangers, and wood cooking ranges. The forge appears to offer an excellent setting to introduce simple metalworking technologies (i.e., aluminum foundry) to artisans.

L'Etainerie de Huye is a small but well equipped artistic tin casting workshop. The workshop produces beautiful, expensive solid tin ornamental ware for the wealthy Rwandan and expatriate market. Although it was created with a $100,000 (8,000,000 frw) grant, and makes products from expensive imported raw material (Zimbabwe tin at 600 frw/kg), the workshop is a successful and expanding operation. Good management and the skill, diligence, and pride of its workers have helped it succeed.

KORA Workshops in Kigali houses a cooperative of artisans working in wood, metal, clothing, leather, and a number of other areas. Many members who do not have their own workshops rent space in a cooperative workshop building constructed with AID funding. The metalworking artisans are not well equipped, and produce a limited variety of products such as bicycle racks and trunks by welding and coldworking steel.

Mecatel is a small private artisan workshop in Kigali. The owner, a Mr. Severin, appears to obtain most of his income by repairing refrigerators and doing outside industrial repair jobs. The artisans employed at the workshop were making hammermills of fairly good quality and experimenting with a cassava grater at the time of the consultant's visit.

Amergewa is a larger private workshop in Kigali, possessing two metal lathes in addition to the usual cutting and welding equipment. They do diverse fabrication and machining jobs, and have reportedly made brick presses, mills, and rice hullers in the past. Amergewa is owned by Mr. Bertin Makuza, a successful entrepreneur and owner of the Rwanda Foam mattress company.

Catholic Mission Workshop, Rwamagana, has a relatively small metalworking shop and a large woodworking shop that produces excellent quality wooden furniture. The metalworking shop produces hammermills of two different sizes and capacities, and rotary rice weeders for a number of lowland rice projects. Their workmanship is good, they possess a metal lathe, and are well placed geographically to sell manual sunflower oil presses.

Sonatubes is the principal importer of steel to Rwanda. They have a good inventory of steel pipe, tubes, round bar, sheet, and profiles, but do not have many common sizes. Prices are not excessive for the more common products, roughly $1.50 or 120 frw per kilogram.

The Ministry of Mines, Industry, and Artisans (MINIMART) has surveyed the national artisan metalworking sector and found that the vast majority of artisan metalworkers are not based in Kigali, but are dispersed throughout the Country. In an evaluation of artisan-built coffee pulpers concluded in May, 1989, the Ministry identified 148 artisan producers, of whom only four were from Kigali. Their evaluation was motivated by the tendency of artisan-built pulpers to bruise the coffee. It concluded that there is great variability in the quality and performance of the machines, in both those made by different artisans and those made by the same artisan.

Improvements need to be made in the artisan metalworking sector in Rwanda in the quality, affordability, and diversity of the products. This will be difficult to achieve for several reasons:

- Despite the small size of the country, the artisans are geographically dispersed;

- The artisans are probably not very specialized, that is, they will try to make or repair whatever the customer requests, but cannot do it very well;

- Raw material is very difficult to find, there being few vehicles and industries from which to obtain metal scrap, and no commercial distribution of steel, except reinforcing bar for building;

- The artisans are extremely underequipped, and even the most basic metalworking tools are expensive and difficult to find, even in Kigali.

There are, however, at least three factors which would facilitate the promotion of this sector:

- Rwandan metalworking artisans are resourceful, inventive, and often quite sophisticated. Blacksmiths in Ruhengeri, for example, possess almost no purchased tools yet are able to make precision replacement hammers for imported cereal mills. They do this by comparing each hammer with a standard, and by weighing and filing it until it has the standard weight;

- Artisans appear willing to share common workspaces, perhaps in order to legitimize their habitation in Rwanda's major towns, where residence permits that specify one's employment are required;

- MINIMART and the Ministry of Youth and the Associative Movement (MIJEUMA) are actively promoting this and other artisan sectors, and appear to have a good understanding of the potential and limitations of these sectors.

Many artisans probably enter this trade when young, because they are creative people who like to work with their hands, not because they see it as a good way to make a living. This is a strength and a weakness. They may be inventive and resourceful, but not very successful as entrepreneurs. Also, a lack of specialization is possible, and may even be a positive asset, when the tools used by society are simple and undiversified. As the range of tools and their complexity increases, specialization becomes essential to the effective production and/or repair of these tools. Specialization is, in turn, only possible if the artisan is able to market his skill or product effectively, to reach a large enough market to make a living and amortize the tools and skills necessary to compete. Since most artisans are trained by the preceding generation of artisans, there is a powerful inertia in the ways of this sector, as in agriculture. Growth and change have, by contrast, been faster in woodworking (furniture making), where much of the training has taken place in the modern workshops of the Catholic Church. A rapid proliferation of modern private woodworking shops has accompanied and, at the same time stimulated, a growth in the demand for quality furniture.

Ideas for Improving The Metalworking Sector

i. Improving the Design and Production Technology of Existing Products of this Sector

MINIMART has proposed a strategy to improve the quality of artisan-built coffee pulpers. The plan is to host a seminar, which would be attended by a small number of producers from among the most competent in each prefecture. Each producer would bring his best pulper and discuss its merit with the other producers. They would then develop a single "best" design by putting together all of the best features of these various designs. Subsequently each artisan would build a copy of the new design and return to his respective prefecture. Each artisan would, in turn, train other artisans in his own prefecture. Pulpers of acceptable quality, built according to the new design, would be recognized by a stamp or decal to facilitate marketing the machines both to individuals and through the public authorities.

The first part of this concept appears to have real merit: to select and assemble the best producers of a particular product. A technician from OCIR-Café, the coffee processing and marketing parastatal, would guide the artisans in developing the new pulper. In addition, it would be valuable to invite a skilled design engineer, with experience in working with artisans in Africa, to look at the new design from the manufacturing standpoint, and subsequently develop simple methods, jigs and templates to facilitate production of the pulper. This would enable the artisans to produce more pulpers of better quality. Certainly not all of the participating artisans will seize the opportunity to increase their production because of their own financial circumstances and the limited demand for pulpers. The expectation of MINIMART should be, however, that one or more artisans will substantially increase his production of pulpers, and not that the selected design will be necessarily copied by all pulper producers. MINIMART, or some intermediary organization, should be prepared to provide those artisans who are seriously interested in expanding their production with financial and technical assistance.

A few other existing products could be improved through the same approach. A small number of artisans in Kigali and elsewhere are making hammermills for grinding cereal. Some are well made, but most could be improved by improving the design, hardness and balance of their hammers and designing the drive pulleys so that the mill runs at its optimal speed. A seminar involving the best mill producers could convey these and other concepts, and/or transfer a simpler mill design and the technology to produce it.

ii. Introducing New Products to this Sector

There are other new products that could stimulate the growth of the metalworking sector. Some of these, such as oil presses

and cassava graters and presses, depend on the introduction of new crops or processing technologies that are not common in Rwanda at the present time, but could become important in a fairly short period of time if promoted. Other technologies, like brick and tile presses, can be introduced immediately to existing sectors, assuming that the machines are appropriately designed, that is, that they pay for themselves by increasing productivity or product quality.

New products can be introduced through the seminar approach described above, or by working directly with an individual workshop. The seminar approach has an advantage because it provides contact with a number of artisans, of whom only a few may take the initiative to produce the new product. Objective criteria can be used to identify a single trial producer of a new product, but he may turn out to have failings that could not be discovered during the selection process. In the seminar approach all participants understand from the start that a monopoly will not be offered to a single producer. The prospect of having a monopoly is sometimes sufficient to encourage an artisan to produce a new product, even though he would not be interested if he had to compete against other producers. In the seminar approach, further assistance (technical, managerial, financial or marketing) would be provided to artisans who spontaneously attempt to produce the new product in response to what they learned at the seminar.

In order to facilitate the introduction of a new product, and win the confidence of the participating artisans, several conditions must be fulfilled:

- There must be a market for the new product.

- The design must be proven. It should have been successfully introduced under similar conditions in another country.

- The design should be easy to produce with the limited materials and tools available to the target producers.

- The production technology should be fully developed and demonstrated at the seminar -- the artisans should feel confident that they can duplicate the product faithfully and without a great deal of difficulty in their own workshops.

Some new products (i.e., cast or formed cooking pans, pots, etc.) can be produced with very little capital equipment. Others, like oil presses, brick presses and mills require a lathe, drill press, welder, handshear, and small handtools at the very least. Such products can sometimes be made in an informal sector workshop if the machined parts can be contracted out to a nearby machine shop at a reasonable price. In a well-staffed project, where management and marketing assistance are provided, necessary

equipment may be financed on a lease-purchase basis. This, however, could make the artisans dependent on the project for their continued survival. Producers selected should possess the required equipment to produce the product being promoted.

iii. Introducing New Production Technologies

At least one new production technology could have a large positive impact on the Rwandan artisan metalworking sector. Aluminum foundry, which is widely practiced in West Africa, is essentially unknown in Rwanda. The consultant heard reports that there is one artisan aluminum foundry some distance from Gisenyi. The principal activity of aluminum founders in Rwanda would be making cast aluminum cooking pots, the main product of the artisan founders in West Africa.

This activity could be very successful in Rwanda. Most cooking is presently done on industrially manufactured sheet aluminum pans. These pans are available in a range of sizes, but are of identical shape and are rather thin. Eventually, they become perforated by oxidation caused by salt in the food. At this point they are nearly irreparable and are probably discarded. Aluminum casting would enable artisans to melt down these worn out pots, and cast the aluminum into heavier, more attractive and functional cooking utensils.

Aluminum foundry requires almost no capital investment, and typically uses wood charcoal for fuel. A simple clay or brick crucible furnace and a hand-driven blower are used to melt the metal. A graphite or stainless steel crucible should be used to hold the molten metal, because iron impurities tend to embrittle aluminum. The crucible is the only input that might have to be imported. The molds are made from loose damp casting sand, compounded from brook sand and clay, and are formed around patterns that are often made from an original of the object to be cast.

Iron foundry is widely practiced by Indian artisans in East Africa, and could also be transferred to Rwanda. Iron foundry is useful for making machine parts, sewage and water pipe fittings, and iron pots and pans. The market for these products might be more limited, and the metal melting technology, and even the mold making, are somewhat more difficult than in aluminum foundry. The market for iron products would probably best be met by one or more industrial foundries in Kigali. Since Rwandex-Chillington is already planning to install a small induction foundry for iron and steel, artisan involvement in iron casting would be risky at the present time.

Technical Resources for Improving the Metalworking Sector

A.T. International has considerable experience in training artisans in the manufacture of specific products. These products include oil presses, cereal mills and shallow-lift pumps for

irrigation. Training is based on the use of proven designs, simple tooling, detailed instruction manuals and working visits by technical consultants. Our work with artisans is market oriented: a need is identified (e.g., the need to process locally grown sunflower), equipment is then selected and field tested, and, pending user acceptance, local manufacture is initiated. The feasibility of local manufacture is a primary consideration when selecting equipment designs.

Other organizations with experience in transferring manufacturing technology to artisans in francophone Africa are UNATA and ITAC. UNATA (Union pour Assistance en Technologie Appropriée) is a private Belgian organization which designs and manufactures equipment for use in developing countries, and also trains artisans and enterprises in developing countries in the manufacture of this equipment. They have designs for vegetable oil pressing equipment, crop threshers and winnowers, and manual borehole pumps. ITAC (Institut Technologique d'Appui au Codéveloppement) is an association of French artisans and small manufacturers who produce a range of products, from leather shoes to plastic bottles, for which a market exists in most developing countries. They select and order the production equipment and train local artisans or entrepreneurs in its operation. Their experience in metalworking includes blacksmithing and brick press and hydraulic turbine manufacturing.

ADDITIONAL TECHNOLOGIES CONSIDERED UNDER THIS STUDY

The following technologies also hold promise for small enterprise development in Rwanda. Some of these technologies were not investigated in greater detail because they have already been reviewed by other authors (traditional brewing, sisal processing), or are currently under investigation (cassava processing and hydro-powered milling). For others, like mushrooms and clay tile and bricks, there are unanswered questions about the market, or whether practical methods exist to improve those currently in use in Rwanda.

G. BREWING

This concept is based entirely on a working paper of the Ministry of Economy and Finance, prepared under Project PRIME by Steve Haggblade and Nicholas Minot, and entitled "Possibilities of Improving the Performance of the Traditional Brewing Sub-sector in Rwanda." The working paper presents evidence that yields obtained by traditional banana and sorghum brewers could be substantially increased through the use of pectinase enzyme, in the case of banana wine, and improved malt production, in the case of sorghum beer.

For banana wine production, the enzyme would be imported in bulk and distributed in 70 gram packets, sufficient to produce 5 to 6 jerrycans (20 liters each) of banana wine from 200 kilograms of bananas. The yield obtained with enzymes under laboratory conditions, and using mechanical pressure for juice extraction, is about 80% (banana juice/bananas), while 40% is the average yield obtained by traditional brewers. Although a doubling in yield is therefore possible, a 50% increase in extraction is considered more realistic, and could result in a five-fold increase in brewers' net income, from 159 to 915 frw for 200 kilograms of bananas processed. The enzymes reportedly cost 2,761 frw per kilogram, including a 40% import duty, or 196 frw per packet of 70 grams, which would be retailed at 300 frw.

Technoserve's Greg Kruse reported that experiments with enzymes conducted under field conditions in Rwanda showed more modest gains in extraction efficiency. Yields obtained by traditional brewers without enzyme vary greatly from one batch to another because juice extraction is a chemically and biologically sensitive process. Greg feels that the use of enzyme would prove worthwhile to brewers if only to guarantee a more consistent percentage of juice extraction, which typically drops on every fourth or fifth batch.

More experiments under field conditions are needed to demonstrate the magnitude of benefits that can be expected from using enzymes in banana brewing in Rwanda. These experiments should also test the benefits, both in terms of yield and labor productivity, of using simple macerators/presses in the juice extraction process. If major benefits are obtained, a project to disseminate the new technology would be extremely worthwhile. Haggblade estimates the annual production of banana wine at 360 million liters, using 900,000 tons of bananas (1987), making banana wine production the single largest economic activity in Rwanda. Using enzymes and/or presses roughly 300,000 tons of bananas could potentially be freed up for direct consumption, or almost 5% of the cultivated land converted to other crops.

Haggblade proposes to improve sorghum brewing yields by producing in Rwanda or importing an improved malt. In other African countries, a commercial malt is marketed and used by home brewers to increase their brewing yields. Haggblade reports that

6.4 liters of beer per kilogram of sorghum are produced by home brewers who use commercial malt, while only 4 liters are produced by home brewers who use their own malt exclusively (germinated sorghum). Rwandan home brewers reportedly average 3 liters of beer per kilogram of sorghum. The malt could be produced and marketed by small, dispersed rural enterprises, which would need to observe better conditions of germination of their malt sorghum than are typically observed by traditional brewers.

Experimentation is needed to determine the effects on brewing yields of imported malt or malt produced under controlled conditions in Rwanda. These experiments would be fairly complex, since they need to determine in what proportion to use the improved malt, as well as in what manner it should be used. If the results are positive, a small-scale malt production facility should be set up to determine the production costs and marketability of improved malt. Introducing improved malt for sorghum brewing appears to be more complex. However, since sorghum beer production is worth about one fourth as much as the production of banana wine, the use of malts for sorghum beer is less compelling than the introduction of enzymes in banana brewing.

H. CASSAVA PROCESSING

Cassava has become one of Rwanda's major staple crops in recent years because large yields can be produced with little labor, even on marginal soils. A World Bank report, published in 1985, rated cassava second only to yams in terms of returns to labor (520 frw per day). In 1985, the national yield on roughly 50,000 hectares of land was estimated at 578,510 tons, or more than 10 tons per hectare. Cassava can be harvested at any time of the year, and, while it remains in the ground, can be stored for long periods of time, making it an important food reserve. While the official price is rather high (12 frw per kilogram of fresh tubers), the actual price in rural areas, which reflects both the demand and cost of production, is said to be closer to 4 frw. At the latter price, it is substantially cheaper than any of the cereals on a dry weight basis, making it a particularly important staple for Rwanda's rural poor.

The peeled cassava tuber is high in calories, but low in vitamins and protein. In order to increase the nutritional benefits of this prolific and easily cultivated crop, and thereby its popularity, the Cooperative Training Center (IWACU) in Kigali is training groups of women to process and cook the tubers and leaves in various ways. The sweet varieties can be cooked and eaten without processing, while the bitter, slower growing varieties that grow well on marginal soils need to be soaked and/or fermented in order to remove the dissolved toxins (cyanogenic glucocides), and reduce their acidity. Such processes, and the resulting food products, are well known in parts of West Africa, but are less well known in Rwanda.

Several cassava products can serve as the bases for small enterprises. Dried cassava chips and cassava flour are already widely marketed, and represent an important source of revenue, especially for rural women. Grinding chips into flour is an important activity of the hammermills that are found in Rwanda's towns and, to a lesser extent, in the countryside. Although the flour can be used, with the proper admixture of a small quantity of egg, salt and sugar, to make cakes, biscuits and cookies, little is currently used in this way. IWACU and the Centre Bon Pasteur have both demonstrated the marketability of such products in Kigali, demonstrating that a market may exist in other towns.

Fermented and roasted cassava or gari is an important West African cassava product that is essentially unknown in Rwanda. It can be produced on a domestic scale, using simple homemade utensils, or on a small commercial scale using locally manufacturable manual and motorized equipment. Gari is slightly more nutritious and much more flavorful than cassava flour, and is easier to produce because it does not require sun drying. Grating the fresh tubers is the most labor intensive step in the gari production process, but this can be done very quickly with an appropriately designed manual or motorized grater. ATI has experience in this technology, and could furnish appropriate

grater designs. Other equipment that is useful to gari production include hand peelers, simple sac presses, and round-bottomed roasting pans. The latter would be an excellent product for a local farm foundry which will soon be established by Rwandex-Chillington.

The private sector is interested in cassava processing in Rwanda. Richard Sangimana, a wealthy Rwandan entrepreneur, consulted technical experts from an Ivoirienne cassava processing plant to determine the feasibility of constructing a plant at Gitarama. Ms. Solange Goma, a Congolese consultant who has been working in Rwanda for several years, is well informed of these plans, and is responsible for IWACU's cassava processing training program.

I. MUSHROOM CULTIVATION

Unlike other technologies discussed in this study, investigation of mushroom cultivation was admittedly not motivated by the existence of an obvious market. Rather, there has been good experimental work done on the cultivation of pleurotus mushrooms by at least two individuals working independently in Rwanda, and this proposal is motivated by the possibility of capitalizing on this work through the promotion of its practical application on a larger scale. While this is a risky approach, there are several indications that the effort might succeed:

- Button mushrooms are currently available in the more expensive restaurants in Kigali. The button mushroom, however, is difficult to grow, is imported, and costs roughly 800 frw per kilogram. By comparison, the pleurotus is easy to grow, and may be produced for less than 200 frw, yet is as flavorful as the button mushroom.

- Villagers are said to harvest and eat, or feed to their children, edible wild mushrooms.

- Mushroom cultivation requires essentially no land, and, apart from the seed (myceliated spores, grown on a damp sorghum substrate) and the plastic culture bags, requires no purchased inputs. The preferred cultivation medium is bean straw, which is readily available to most Rwandan farmers.

- Efforts to market other new foods in Rwanda (dried sardines from Lake Kivu, mixed grain flour for bouille), and new crops (soybeans) have been well received and very effective.

While the pleurotus mushroom is high in protein (30%, when measured on a dry weigh basis), 91% of its fresh weight is water, so that a kilogram actually contains only 27 grams. Probably the strongest argument against promoting mushroom cultivation is that, at 200 frw per kilogram, mushrooms are still an expensive source of nutrients. However, more effort is required to compare the cost and nutritional value of the specific proteins and other nutrients contained in pleurotus mushrooms with the specific nutrients contained in the major staple crops to determine whether the pleurotus would provide nutrients that are otherwise lacking, and to determine to what extent the production cost can be reduced.

If the pleurotus mushroom proves, on further investigation, to be a valuable and affordable foodstuff, it should be promoted through aggressive marketing of the type used by the FAO Lake Kivu Fisheries Project in promoting the consumption of dried sardines. Further effort would be required to train farmers to grow the mushrooms, based on the technology developed by Dr.

Gerard Rusuku of the National University, Keith Wallace of the Adventist University at Mudende, and the Kiaka Project in Kanama (Gisenyi). The mushroom cultivation process itself seems quite simple, and might be effectively taught through the use of video recordings. If the demand for mushroom spores begins to exceed the production capacity of the three laboratories, then the project would transfer the spore multiplication process to small privately owned laboratories. ATI has experience with mushroom cultivation in the Philippines, and could provide technical support to this project through consultants. (See ATI Technical Bulletin #11, "Mushroom Growing in the Philippines.")

Appropriate Technology International

AUGUST 1987
BULLETIN Number 11

MUSHROOM GROWING IN THE PHILIPPINES

Appropriate Technology International seeks to develop cost-effective strategies that increase the productivity of poor people in rural areas in developing countries. ATI's projects focus on productive activities that add value to the resources of the poor. The goal is to establish commercially viable enterprises that are easily adapted for widespread dissemination locally as well as for use in other countries and regions.

The mushroom growing project described in this Bulletin tests the commercial feasibility of two types of small enterprises. The main venture produces mushroom spawns and the substrate on which the spawns are planted. The other venture involves the cultivation of the spawn substrates in growing houses and the subsequent harvest and sale of the fresh mushrooms.

EXPECTED BENEFITS

Direct Income. Each mushroom growing venture will create 14 full-time positions, including three administrative and technical positions, and 11 jobs for unskilled labor. The enterprises also employ homemakers and out-of-school youths on a part-time basis to pack and wrap the mushrooms for delivery to retail sales outlets.

Indirect Income. By the end of 1987, contract growers are expected to be phased into the mushroom enterprise. Six to 20 contract growers (6 in the second year of commercial operation; 20 in the fifth year) are expected to earn additional income of at least $US 377 per year producing oyster mushrooms. Valley High Products,Inc., the name given to the joint venture established to undertake the spawn/mushroom production, will train the contract growers to tend the spawn substrates during the fruiting stage. The growers will purchase the spawns, tend them, and sell the harvest exclusively to Valley High. FFI, ATI's project partner and the major investor (using ATI grant funds) in this venture capital project, is attempting to secure loans for the contract growers. It is expected that the loans will be made directly to the contract growers. The growers will purchase the necessary capital equipment such as growing houses and stands, and repay the loan out of the proceeds of the mushroom sales.

Consumer Savings. Filipinos who buy locally grown mushrooms instead of imported ones will save money. For example, fresh oyster mushrooms are being sold in local supermarkets for the equivalent of $US 50 cents per 250 gram styropor pack. This is 75-90 cents less than the price of an equivalent amount of imported canned mushrooms.

Foreign Exchange Savings. The project is expected to generate foreign exchange savings for the Philippines totaling $US 316,000 annually, corresponding to the projected reduction in mushrooms imported.

Productive Use of Waste Materials. Because mushroom cultivation uses organic waste materials such as cotton waste, rice straw, sawdust and banana leaves, this enterprise helps to add value to these waste materials.

SPAWN SUBSTRATES are cultivated in growing houses; this helps control temperature, humidity, light, weeds and pests.

The ATI Approach

In its projects, ATI considers four issues: (i) the institutions involved and the need for institutional development; (ii) the technology involved and the need for adaptation or further refinement of the technology; (iii) the commercial viability and the need for market development; and (iv) policy and replication issues. (What factors promote or inhibit the speed of dissemination of the technology and the transfer of the technology to other areas?)

THE INSTITUTIONS INVOLVED

Valley High Products, Inc., the mushroom growing enterprise in Antipolo, is a joint venture between the Venture Capital Department (VCD) of the Filipinas Foundation (70% of the investment) and a local investor, Potenciano Roque (30%).

The FFI

The Filipinas Foundation, Inc., a non-profit science and technology foundation in the Philippines, was organized in 1961 by the Zobel de Ayala family. FFI is committed to advancing the Filipino science and technology (S&T) capacity in order to reduce poverty and privation among the Filipino people.

In the early 1980s, FFI intensified its S&T thrust by organiz-

ing two new divisions, the Science and Technology Resea Center (STRC) and the Venture Capital Department (VCD

STRC reduces post-laboratory, locally developed technolog for commercial application in the rural small-industries c text. Toward this end, STRC conducts technology verifi tions, scales up activities prior to pilot testing and establish pilot plants. Agri-related technologies are selected becau they promise a wide impact on rural development and will tract rural entrepreneurs.

VCD, initiated and supported in part by ATI, identifies a finances rural small-scale industry joint ventures with dividual entrepreneurs, cooperatives, private companies a associations.

THE TECHNOLOGY: SPAWN BAG AND MUSHROOM PRODUCTION

The traditional method of mushroom growing uses logs as a substrate or growing medium. To ensure a more predictable and constant yield, FFI adopted a "modern" technology to obtain a substrate. In this technique, sawdust or agro-industrial waste materials (tobacco midrib, rice straw, sugarcane bagasse) are mixed with lime, rice bran and sugar. This "modern" process produces higher, more predictable yields in a shorter time than the traditional method.

Comparison of the New and Traditional Techniques of Culturing Mushrooms

Steps Involved:	DAYS REQUIRED Modern	Traditional
1. Culture Medium Preparation	2	2
2. Pure Culture Isolation and Incubation	7	7
3. Spawn Substrate Preparation, Inoculation, and Incubation	37	37
4. Log preparation, Inoculation and Incubation	0	92
5. Harvesting	60	25
6. Drying	3	3
Total Days	109	166
Biological Efficiency (Yield) Per Kilo of Substrate	40%	15%

Although 40% is the anticipated yield, FFI presently is realizing 26% biological efficiency.

FFI's Mushroom Growing project in Antipolo, Rizal produces mushrooms of the oyster variety, *Pleurotus sajor-caju*. Like other mushrooms, *Pleurotus* can be grown in various ways, using various agricultural waste materials and a variety of containers. FFI uses a spawn bag cultivation process that was laboratory-tested in 1983, underwent pilot plant experimentation from 1984 to 1985, and was ready for commercial production in December, 1985. The process does not require the extra cost of air conditioning and expensive technology.

Although this is an agricultural enterprise, it requires minimal amount of land. One square meter of land can yie 192 kilograms of oyster mushrooms a year.

The ideal temperature in which to grow oyster mushroor is from 25 to 28 degrees Celsius. Humidity should be ma tained at 80 to 85 percent to achieve the maximum biologic efficiency of conversion (40% for a three-month cycle).

To obtain the proper climatic conditions, FFI chose a hillt project site in Antipolo and erected eight growing house

The Growing Houses

Temperature, humidity, air volume, light intensity, weeds, a to some extent rats and insects can be controlled during t cultivation period in growing houses. The growing house built of wood and nipa. The interior walls are lined with plas and jute sack to hold moisture and provide insulation. Insi the growing houses are rows of shelves that hold the spa bags. The growing areas are sprayed with fungicide (such Benlate) and insecticide before the spawn bags are plac on the shelves.

The growing house also helps protect against snails and infestation. Rats can also be controlled by rodenticide a other rat eradication measures.

Spraying a water mist as often as six times a day on the wal floor, ceiling, and shelf spaces helps maintain the desir temperature and humidity (25-28° C; 80-85% humidit Studies have shown that mushrooms can tolerate temperature up to 33° C, as long as the relative humidity maintained around 90%. Sustained low temperature, howev reduces yield.

Culture Preparation

First, the mushroom culture organism must be isolated potato-dextrose-agar or PDA media. In an isolation chamb a small piece of mushroom tissue is inserted in the PD media in a glass bottle. After one week, the bottle should filled with Mycelium, molds of the pure culture. One bott of pure culture can inoculate 20 to 30 bottles of sorghu medium, which serve as the mother spawn. After two week the mother spawn will be filled with molds.

COMMERCIAL APPRAISAL

The Market
Since the mushroom growing industry in the Philippines is relatively young, little information on the mushroom market is available.

FFI conducted a survey of both institutional and consumer markets to estimate the mushroom supply and demand. Target respondents of the survey included a sample of:

- **The Metro Manila Institutional Market** (total universe = 6,800 medium to large restaurants that employ at least 10 workers each and 28 large three-star plus hotels)

- **The Consumer Market** (represented by 130 mushroom dealers who service supermarkets and wet markets)

Comparative studies by the National Institute of Science and Technology have revealed the growing acceptability of mushrooms as a food item among Filipinos. Although only 25 percent of Filipinos were eating mushrooms in 1978, by 1985, mushrooms were included in the diet of 90 percent of Filipinos.

The survey was conducted for a number of mushroom varieties since the technology being adapted by Valley High can be used to cultivate several different varieties of mushrooms.

Of the total population of institutional end-users, nearly 7 percent of the restaurants and 46 percent of the hotels use oyster mushrooms in their menus. Current demand for fresh oyster mushrooms is estimated to exceed 186,000 kilograms per year. At an average selling price of P40.00 ($US 1.95) per kg. of fresh oyster mushrooms, yearly demand should exceed P7,800,000 ($US 380,000).

The growth rate for the mushroom industry as a whole is estimated to be 10 to 20 percent per year. This market growth is expected to continue for the next 5 to 10 years because of population growth and the anticipated increase in purchasing power of Filipino consumers.

No marketing problems are foreseen, since one plant's output would produce less than 15 percent of the market for *Auricularia* and *Pleurotus* mushrooms.

Raw Material Supply
Mushroom growing uses raw agricultural waste materials, a minimum of energy, and a minimum of space. At FFI's Antipolo project, sawdust, rice bran, lime and sugar are used to make up the substrate.

Rice bran comes from nearby rice mills. Sugar, lime and the other small-volume raw materials are locally available. An adequate supply of sawdust, which constitutes 78 percent of the raw material, was assured through the choice of a project site within a 40 to 50 km. radius of 13 sawmills.

Price
Valley High Products, Inc. currently sells a kilo of oyster mushrooms, fresh, ex-plant and unpacked for approximately P40.00 (US $1.95), a price competitive with other producers. Licensed distributors handle distribution and sales of oyster mushrooms to supermarkets and wet market outlets. Spawns will also be sold ex-plant to interested buyers who want to grow and market mushrooms on their own.

HOMEMAKERS WORK part-time packing and wrapping mushrooms. In Antipolo, where jobs are scarce, Valley High Products has created 5 part-time jobs and 14 full-time positions.

PLANT SUPERVISOR Fe Guilatco holds bottles of mother spawn ready to be inoculated into the substrate.

Assembly of Spawn Bags
The spawn bags are assembled in a roofed area outdoors. First, the substrate is prepared by mixing sawdust (78%), rice bran (20%), lime (1%), and sugar (1%). The substrate then is irrigated with water to achieve 70 percent moisture. To attain the quality and hardness of wood, the substrate then is compacted into plastic bags. A plastic ring is inserted to form the neck of the spawn bag. The neck is plugged with cotton and covered with a piece of paper, then sealed tightly with a rubber band.

Next, the spawn bags are sterilized for one and a half hours under a pressure of 20 psi (pounds per square inch). Valley High Products uses a large pressure cooker that is fueled by firewood or spent spawn substrate.

After being sterilized, the spawn bags are removed from the pressure cooker and allowed to cool to room temperature.

Extreme care must always be exercised to avoid contaminating the culture or substrate with fungi other than the desired mushroom. Such contaminating molds will compete with the mushrooms for the nutrients in the substrate, and will reduce the yield or even destroy the entire crop. Fungicide spraying of the growing house helps, but the most effective solution is prevention during the preparation of the substrate.

Inoculation
The next step is inoculating the spawn bags with the young and vigorous mushroom culture of the mother spawn. In an inoculation chamber, the mother spawn (which should be no more than two weeks old) is transferred to 30 or 35 spawn bags. The date of inoculation is recorded on the neck of the spawn bag.

Incubation/Aging
The spawn bags are allowed to incubate for three weeks to a month in the incubation room. Following incubation, the spawn bags are transferred to the growing house where they age for one week.

Harvest
When molds have grown all over the spawn bag, the two opposite ends of the spawn bag are slit open to induce the formation of young fruiting knobs of mycelium called *primordia*.

In three or four days, the open ends of the spawn bag will be flush with full-sized fruiting bodies of mushrooms ready for harvest.

Oyster mushrooms should be picked within four days. After harvesting, any small (non-marketable) mushrooms remaining should also be removed, since the small culls can harbor disease and insects, and seem to delay the next flush.

The key factors for *primordia* formation and development of fruiting bodies are temperature, light, air humidity and oxygen and carbon dioxide content.

If substrate environmental temperature and light requirements are not optimal, *primordia* and fruiting bodies will not be induced. Moreover, the mushroom needs greater moisture at the fruiting stage to support further growth and enlargement prior to maturity.

Large differences in temperature and air humidity between day and night, or high temperature amplitude over a large period of time are unfavorable for the production of oyster mushrooms.

PERISHABLE OYSTER MUSHROOMS should be sold immediately after harvesting.

Post-Harvest

After the mushrooms are harvested, the open ends of the spawn bags are scraped to expose new surfaces for fruiting. Thus, the spawn decreases in size after each harvest. One spawn will produce eight to ten harvests. During the rest period of seven to ten days after harvest, proper moisture and temperature conditions are maintained in the growing house. An insecticide or fungicide is used throughout the growing period to overcome contaminants.

Cleaning and Packing

Meanwhile, the freshly harvested mushrooms are cleaned of sawdust by trimming the stalk. The cleaned mushrooms are packed in styropor trays, covered with stretch film, and labeled.

Oyster mushrooms are perishable, and need to be quickly packed and sold as soon as possible. Four hours after harvest, respiration begins, resulting in a loss in water and weight. If the mushrooms are picked more than a day before they reach biological maturity, they will have a shelf life of approximately one week in a polyethylene bag refrigerated at 40 C.

PRODUCTION WORKERS assemble spawn bags outdoors. Sawdust is the major component of the substrate (78%). Approximately 600 spawn bags are produced daily.

Production

Production of spawn bags for the period February-June averaged 404 bags per day, based on 25 working days per month. In July, 1987, FFI reported production of 592 spawn bags per day (1.25kg/bag) — 98% of the 600 spawn bags/day projected in the business plan.

The spawns are ready for fruiting two months from the date of production. Thus, the spawn produced in the third month would be delivered to the growing house or contract growers in the fifth month. A conservative rejection rate of 10 percent has been assumed. The usual rejection rate for commercial operations is only 3 to 5 percent.

Valley High Products Inc. reported sales of 1800 kgs. of fresh oyster mushrooms in June, 1987 and 1550 kgs. in July, 1987. Total sales revenue for July was P 65,620 ($US 3,200); net income amounted to P 9,560 ($US 465).

Valley High Products, Inc. projects monthly sales of fresh mushrooms will reach 2,260 kgs. ; this would enable the mushroom enterprise to net P 20,000 ($US 980) monthly.

The mushroom harvest is determined by applying the assumed biological efficiency or yield to the number of good spawns. A biological efficiency of 25 percent means that out of one kg. of spawn substrate, 250 grams of mushroom are harvested over the fruiting period. The acceptable yield for commercial production of the oyster mushroom is a minimum of 30 percent. FFI's present biological efficiency is 26% against a target of 40%.

The enterprise can be flexible in its choice of product mix. The technology for spawn production that has been selected is suitable for the cultivation of all mushroom varieties. At the same time, the cultivation technology — the use of a spawn sawdust substrate — can be used for a number of mushroom varieties, for example, shiitake, abalone, oyster and *Auricularia*. A three-month lead time is needed to shift to a different mushroom variety.

POLICY AND REPLICATION ISSUES

Replication Potential: The technology is simple enough to be understood and applied by the contract growers. Because the mushroom growing enterprise uses agro-industrial waste materials and a small area, this project can be replicated anywhere these raw materials abound and the temperature and humidity conditions are suitable. In the Philippines, this includes Baguio, Quezon province, Laguna, parts of Negros and a number of provinces in Mindinao.

The market for spawns appears to be large, judging from FFI's experience during the years of experimentation. FFI has received inquiries about the Mushroom Growing Project from businessmen, traders, the Department of Social Welfare and Development (which is interested in the income-generating benefit of the contract growing option), a religious order of nuns, and a farmers' cooperative in Baguio. Interested groups can begin as contract growers and later shift to commercial-scale production.

FFI plans to establish a shiitake mushroom growing project in Baguio. The farmers' cooperative will be FFI's venture partner.

ATI Sponsored Training: In October, 1987, ATI will sponsor a hands-on training to be attended by representatives of ATI projects in Asia and Latin America. After completing the six day training, participants should have the skills to establish commercially viable mushroom production facilities in their own countries. The course draws upon FFI's business development experience, gained through the Valley High enterprise, and Thai technical expertise in mushroom growing. Subjects to be discussed include theory, taxonomy, morphology, growth and physiology of oyster, shiitake, abalone, and straw mushrooms as well as training in marketing, simple cost accounting, site selection, and preparation of cash flow and break-even estimates.

PROJECT IMPLEMENTATION ISSUES

ATI provided the Filipinas Foundation, Inc. (FFI) a five year grant of $US 367,440 to capitalize the Venture Capital Department's initial investment fund for joint ventures and to pay for information collection and evaluation.

The estimated total budget for one mushroom growing project is Pesos 1.1 million (roughly $US 54,340), which covers capital expenditures, start-up costs, and working capital for four months. FFI supplied 70% of the investment required; this came out of ATI's investment funds. The joint venture partner put up the remaining 30% of the total costs.

Valley High supplies oyster mushrooms to 25 out of 30 supermarkets in Metro Manila. In fact, Valley High Inc. is the only supplier of oyster mushrooms to these outlets.

After only eight months of commercial operation, the Antipolo plant attained cash break-even and no longer needed any capital infusion from FFI or ATI.

FOR FURTHER INFORMATION

A Manual for Mushroom Production by C. Chettanachitara, et al. Published by ATI, available, December, 1987,price to be determined. This manual contains a detailed, illustrated, step by step guide to preparing substrates and spawn, cultivation of several varieties of mushrooms, as well as information on the business aspects of establishing a mushroom enterprise.

Available from ATI

Independence through Mobility: A Guide to the Manufacture of the ATI-Hotchkiss Wheelchair. $15.00

Manual for Commercial Analysis of Small-Scale Projects, 104 pp. $6.50

Macro Policies for Appropriate Technology in Developing Countries, edited by Frances Stewart, 265 pages, Westview Press, 1987. $29.85 plus $2.50 postage and handling. (Make checks payable to ATI).

APPROPRIATE TECHNOLOGY INTERNATIONAL

Appropriate Technology International is a private, non profit development assistance organization based in Washington, D.C. and operating in Asia, Africa, Latin America and the Carribean. ATI's program is concerned with the identification, assessment and adaptation of technology. In collaboration with local organizations in developing countries, ATI develops and tests commercial applications of appropriate technologies in the fields of minerals utilization, agricultural products processing, and small farm equipment.

ATI implements its mission with public funds made available through the Agency for International Development. ATI's program is carried out in cooperation with the Employment and Enterprise Development Division of the Office of Rural and Institutional Development within the Bureau of Science and Technology.

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Bulletin #11

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J. SORGHUM DEHULLING AND COMPOSITE FLOUR

Sorghum is an important staple crop in Rwanda; an estimated 227,549 tons was produced in 1985. Although roughly one-third of this is used to brew traditional beer, the remainder is consumed as food, either in the form of roasted sorghum or as bouille, a smooth porridge made from ground sorghum and consumed as the morning meal. The principal sorghum grown in Rwanda is a red variety.

It is widely believed that the presence of tannins in the seed coat of sorghum reduces its digestibility. The International Development Research Center (IDRC) of Canada has done considerable research on this subject and developed, in collaboration with the Praire Research Laboratory, a simple abrasive dehuller for removing the tannin-containing sorghum bran. ATI has supported the dissemination of this technology in Mali and Cameroon, two countries where sorghum is often dehulled by traditional methods. These methods, which involve using a mortar and pestle, are tiresome and time consuming and result in a low yield, that is, the loss of some of the endosperm with the bran.

Analysis of sorghum samples obtained in Rwanda would help determine the nutritional benefits that could be realized by dehulling. If these analyses show high levels of tannins, it would be worth demonstrating and testing the acceptability of sorghum dehulling in Rwanda. This could be done under controlled conditions by installing dehullers at three project sites that are currently producing composite flour. These projects combine sorghum with maize and soybeans to produce a more nutritious flour for making bouille. By dehulling sorghum, it may be possible to further increase the nutritional value of this product. It may also be possible to produce, as a sideline, a bouille made exclusively from dehulled sorghum.

The first and largest producer of composite flour is Duhamic ADRI, located in Kigali, which produces and sells 300 kilograms per day. They also plan to commence producing baby cereal, an activity which, if it is worthwhile at all, would be improved by dehulling sorghum. Another more recent producer in Butare is selling approximately 50 kilograms of composite flour per day, and there is a third at Cyangugu. Installing a small dehuller at each of these enterprises would enable the project to determine the effect of dehulling on sales of composite flour, and thereby indicate the relative acceptability of dehulled and whole sorghum flour.

K. IMPROVED CLAY TILE AND BRICK PRODUCTION

The dominant building materials in Rwanda are clay bricks and tiles. The majority of rural dwellers build their homes of sun dried adobe bricks with fired hand-formed clay tile roofs, while the relatively affluent urban dwellers use fired bricks for the walls and manufactured clay tiles or corrugated galvanized steel for their roofs. The bulk of the clay tile and brick production is carried out by artisans, using simple though often rather large clamps and kilns, and wooden molds to form the bricks and tiles. These producers sell their bricks and tiles for roughly 4 frw apiece. A few producers using "improved" technologies, including more fuel-efficient kilns and presses, supply the relatively affluent portion of the urban market, charging as much as 30 frw per tile, and 50 frw for large formatted extruded hollow bricks. These modern producers are associated with the Catholic Church (e.g., Muyunzwe), or are financed through donor assistance (CEFMIVA, Ruliba), but have not been copied by the private sector. This can be attributed to the relatively high capital investment involved, and to the limited market that exists for their high priced products.

The question, then, is whether the use of presses and improved kilns can increase the productivity of a clay brick or tile producer sufficiently to offset the better part of his increased capital costs and overhead associated with increasing the scale of his operation. The modern producer can make a better product than the artisan, but his market will still be small unless his price is competitive, at most only slightly higher than that of the artisan producer. The answer appears to depend on the proper choice of technology, and, more importantly, on efficient management of labor and close proximity to the market. Transport costs are very high in Rwanda, often nearly doubling the cost of a fired brick by the time it reaches the construction site.

Appropriate presses and kiln designs exist. The Terstaram or Ceraman, costing roughly 200,000 frw ($2500), is a highly productive manually operated press that can develop ten tons of force, and be equipped with molds for making stabilized earth blocks, clay bricks, perforated bricks, paving tiles, and roofing tiles of various types. Simpler but less productive cinva ram presses can be locally manufactured and, in principle, be outfitted with a similar range of molds. Perhaps the simplest type of press, especially adapted to make flat objects like roofing tiles and paving tiles, is the flyball spindle press. All of these presses enable the moisture content of the clay to be reduced, decreasing the drying time of the pre-fired product, and reducing cracking and warpage. They also produce a more uniform, denser product than can be obtained without compression.

Improved kilns can have a very favorable effect on tile production, but may be less useful for firing bricks. The clamps used in brickmaking in Rwanda are often quite large, and there-

fore fuel efficient, reportedly consuming about one stere (1 m_3) of wood per thousand bricks. A clamp is easy to load and unload, and carries with it no fixed cost, an important issue if the producer does not own the land on which he is working. In firing tiles, and particularly high quality pressmolded tiles, uniform firing is important and can only be obtained in a well designed kiln. Past efforts by Euro-Action Accord and ITARA to introduce improved kilns have not, however, been very successful, and should be better understood before launching another effort in this area.

A retired civil servant, Mr. Sylvère Bishirandora, intends to erect an intermediate technology clayworks on the Rwamagana Road, roughly 19 kilometers from Kigali. He intends to use simple manual and motorized terstaram-type presses made by Appro-tech, and simple earth disintegrators and mixers to make a combination of clay bricks and tiles, and stabilized earth blocks. His interest in utilizing intermediate technologies in this project, in exploring unconventional products like cement-stabilized earth blocks, and his favorable location are good reasons to assist this effort through donor-funded technical assistance. Stabilized blocks could, in particular, provide a low-cost substitute to fired bricks, particularly if produced on the construction site itself. A thorough technical and commercial evaluation of this technology, which can only be obtained by manufacturing, strength testing, and attempting to market soil-cement blocks seems justified, particularly now that the cost of cement has fallen from its previously prohibitive level.

Another area of possible development in the ceramics sector is the production of porcelain for tableware (china), sanitary components, and electrical insulators. Although kaolin is available in Rwanda, a consultant specialized in this field should determine whether the quality of raw material, the skill level among potters who are currently engaged in stoneware production, and the market conditions in Rwanda are conducive to porcelain production. Porcelain production exists in Kenya at a scale and level of sophistication that could easily be duplicated in Rwanda.

Appropriate Technology International

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APPROPRIATE TECHNOLOGY BULLETIN

This Bulletin is part of a regular series designed to inform AID personnel and other interested development practitioners about the activities of Appropriate Technology International (ATI).

UPGRADING SMALL-SCALE BRICKMAKING IN BOTSWANA

Appropriate Technology International seeks to develop cost-effective strategies that increase the productivity of poor people in rural areas in developing countries. ATI's projects focus on appropriate technologies that add value to the resources of the poor. They are designed to be commercially viable and easily adapted for widespread dissemination locally as well as for use in other countries and regions.

The brickmaking project in Botswana described in this bulletin introduces, in a small-scale brickyard, a new technology which produces good quality, low cost, clay bricks that can compete commercially with imported bricks and concrete blocks. This small enterprise is expected to be 100% more profitable than traditional "backyard" operations.

EXPECTED BENEFITS

Micro-Level

By upgrading the SRDA/MHT brickyard at Moshaneng, a rural area located in the Southeastern part of Botswana, and establishing a second brickyard about 50 kilometers away, the project will: (1) increase the availability of locally made, low-cost building materials thus reducing dependency on imports and (2) increase employment and income opportunities for poor people. Based on a projected output of about 2 million clay bricks a year, the project will:

- double the local supply of low-cost building materials for low-income housing;
- provide locally made, industrial quality stock bricks for the domestic market at less than one-quarter of the price of imported bricks—Pula 50 ($25)(MHT) versus Pula 220 ($110)(imported);
- introduce a brickmaking process which will cut fuel consumption by 60 percent and water use by 20 percent over the traditional method and thus save on scarce natural resources; and;
- create employment for 55 people at the two sites.

Macro-Level

Foreign Exchange Savings: Because the bricks substitute for expensive imported bricks and cheap concrete blocks made from low-cost cement imported from the Republic of South Africa, considerable foreign exchange savings should accrue to Botswana.

Market Niche: In order to compete with these imported building materials, the SRDA/MHT bricks must be at least equal in quality to imported bricks or cement blocks, yet be priced low enough to compete with the locally available inexpensive cement block. By producing a low-cost, high-quality stock brick suitable for single or multi-level construction, the SRDA/MHT is filling a specific market niche.

Clay bricks in Botswana usually are produced in small backyard operations which sell a limited number of poor-quality bricks in the immediate vicinity, or are expensive industrial quality stock bricks imported from Zimbabwe and South Africa. Between the two extremes is the SRDA/MHT small-scale brickyard which utilizes the abundance of local clay deposits, charges a low, competitive price and produces a quality product which appeals to a wide market. MHT is demonstrating the commercial potential of a small-scale industry that adds value to local mineral resources. If successful, the small-scale brickmaking industry will be replicated throughout Botswana.

ATI considers four issues in its projects: (i) the institutions involved and the need for institutional development; (ii) the technology involved and the need for adaptation or further refinement of the technology; (iii) the commercial viability and the need for market development, including credit facilities and repayment schedules; and (iv) policy and replication issues. (What factors promote or inhibit the spread or dissemination of the technology and the transfer of the technology to other geographical areas?)

THE INSTITUTIONS INVOLVED

In this project, ATI is working through the Minerals Holding Trust (MHT), a wholly-owned subsidiary of the Southern Rural Development Association (SRDA), a non-governmental organization recognized in Botswana as the model for small-scale mining and minerals processing enterprises.

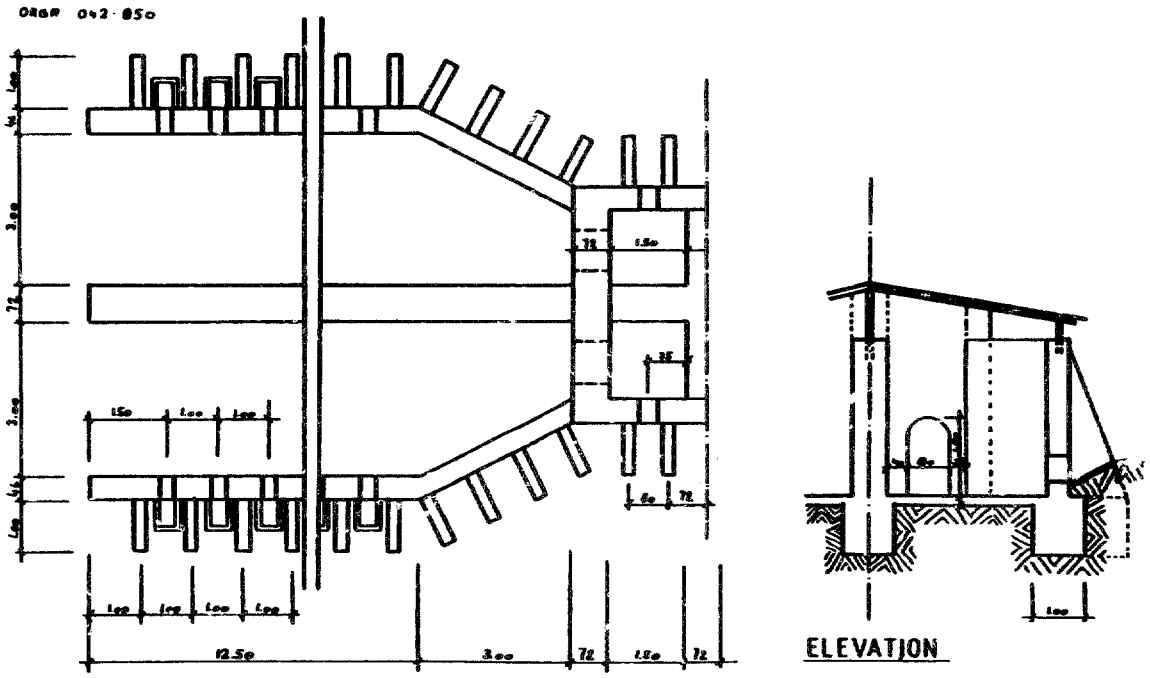
The SRDA/MHT

In 1978 the Southern Rural Development Association (SRDA) was formed to create productive employment in rural areas. A series of projects was developed to respond to the demand for low-cost building materials and industrial minerals. In 1982 these various building materials and mining ventures were grouped together in what is now called the Minerals Holding Trust (MHT). Funding for MHT was provided by the Frederick Ebert Foundation, the US Agency for International Development, the Canadian University Service Overseas (CUSO) and the Organization of Netherlands Volunteers (ONV).

MHT's primary objective is to organize rural people into commercially viable production units which produce building materials and industrial minerals to sell on the local market. In addition to producing clay bricks, MHT mines and processes lime, slate, and pigments (red oxides and yellow ochres). Approximately 300 people, many of them women, are employed by MHT to mine or gather stone or clay, transport the materials to the processing site, and process the minerals. SRDA and MHT staff manage each production unit from initial design and implementation stage through to full-scale production. Marketing is done either directly by MHT or through SRDA retail outlets.

When it established a brickyard at Moshaneng in 1982, the SRDA/MHT wanted to produce a stock brick suitable for single level construction yet priced low enough to compete with cement blocks. The quality of the stock bricks should appeal to the government and large private building contractors who purchase millions of imported bricks a year, yet be priced within the range of low income consumers.

When ATI staff first visited the operation at Moshaneng, the brickyard had not yet achieved this aim. The bricks had a poor appearance and did not meet the government's building code standard. They were also too expensive, in comparison to cement block, to be used in the low income housing market. Significant improvements had to be made in the production process and management before the SRDA/MHT could challenge its competitors and demonstrate the potential of this innovative small-scale industry.



KILN for Moshaneng Brick Works

THE TECHNOLOGY: LOW MOISTURE BRICK PRODUCTION

'he innovativeness of this project lies in adapting an improved ›roduction technology to a traditional brick production operaion, by addressing two main problem areas: (1) Low com›ressive and tensile strength; and (2) High production costs esulting in inefficient use of labor and resources.

Traditional Slop Molding: In the traditional slop molding proluction process used at the Moshaneng brick manufacturng site, a mixture of two kinds of clay, red and brown, along vith ash was shoveled into unlined pits; water was then addd. The ash reduced the cracking of green (unfired) bricks durng drying. After soaking for 20 hours, the wet mix which conained about 30 percent water was shoveled into an SRDAlesigned pug mill driven by animal or human power, and horoughly mixed. Next, the clay was packed into a four-brick vooden mold and then emptied onto a sanded floor in rows. 'he green bricks were then left to dry in the open for about ive days. Finally, about 30,000 bricks were stacked on top of ›ne another to build a traditional kiln called a field clamp or scotch kiln. In the stacking process, coal was inserted into ertical and horizontal cavities left in the mass of bricks. The ompleted structure was covered with a mud plaster and then ired. It took about 10 days to fire and cool the bricks; then he kiln was dismantled. On average, about 1800 fired bricks vere being produced per day; 26 people were employed at the rickyard. It took roughly one person hour to produce nine inished bricks. Due to uneven heat distribution, the wastage ate was approximately 15-20% of total output.

'he Improved Technology

'he ATI-sponsored project introduced a permanent kiln basd on the Hoffman design principle, low moisture brick pressng technologies, and an improved drying process. The labor orce was reorganized and on-site supervision strengthened. 'he test phase of the project, now being completed, has yieldd excellent results and trial commercial production at Moshaneng will begin shortly. Achievements to date include he following:

- the compressive strength of a SRDA/MHT brick is conistently above the government building code standard of 70 g/cm. Prior to the start-up of the project, a Moshaneng brick veraged 25 kg/cm. Now a Moshaneng brick averages 72 g/cm;
- the wastage rate from deformed, cracked, underfired or verfired bricks has dropped from 15 to 20 percent of producion to 5 percent of production;
- fuel consumption has decreased about 60 percent from 5,000 MJ/1000 bricks to about 5858 MJ/1000 bricks;
- water use has decreased by 20 percent; and
- the firing and cooling time for bricks has been reduced from 0 to 7 days.

'he new production process components at the Moshaneng rickyard are:

:lay Winning and Preparation

The use of ash, the expensive component of the mix, was liminated by improving the drying process. Thus, a small cost avings of about 3 percent was achieved. Green bricks were o longer dried in the open but under roofed sheds which proected them from the sun, wind, and rain.

Research on the mix of local clays which would produce ıe strongest brick at the lowest cost identified three types: rown, red, and kqua kqua. Winning of these clays is done t nearby open pits with simple tools such as picks and hovels. Clay is transported to the brickyard and unloaded. When clay is required for pressing, brown, red and kqua kqua clays in correct proportions are mixed with shovels on the floor in the pressing area. A very small amount of water is added. Although the prepared clay is now ready for pressing, it still looks and feels relatively dry.

Brick Pressing

ATI introduced to Botswana the Terstaram manually operated, low-moisture press manufactured in Belgium. The Ram press is relatively low cost, very strong and easy to assemble and operate. The machine presses two bricks at a time. Workers are part of 5-man teams — two operate the press, two prepare material and one carries completed bricks to the drying site. At present, for each of the two Ram presses, a five-person crew can press 1300-1600 bricks per 8-hour day. At Moshaneng today it takes one person hour to press approximately 32-40 green bricks.

This press has significantly reduced wastage rates from deformed and cracked bricks. Tensile and compressive strength have increased and the bricks exceed building code standards. The press consistently produces a low moisture brick that appears clean and crisp. After coming out of the press, the green bricks can be stacked immediately to dry; this saves floor space. Finally, unlike slop molded bricks which must dry for 5 days before being loaded into a kiln and fired, low moisture pressed bricks need only dry 2-3 days before they can be fired.

Firing

A scaled-down, coal-fired version of a Hoffman-type kiln was developed by SRDA staff, assisted by ATI. As in Hoffman-type kilns, the heat zone progresses forward towards the chimney. Exhaust gases preheat the unfired bricks while fresh air cools bricks already fired. Therefore, less fuel is required to fire bricks and less time is required to cool bricks before unloading. The kiln has two chambers, each about 240 cubic meters (17.5 meters long, 7.65 meters wide and 3.5 meters high). Approximately 60,000 bricks can be loaded into each chamber. Exterior wall thickness is 0.45 meters and the center wall is 0.75 meters. The walls are built from common red clay bricks.

Fire is initially started at the front end of the kiln away from the chimney. A fire is also built to heat the chimney. When the chimney is hot, the entry door is bricked up and hot gases are drawn through the mass of bricks to the exit flue leading to the chimney. The gases provide sufficient heat to continue the process. It takes about 7 days to completely fire a chamber. Based on current experience, SRDA expects to reduce firing time to 3 to 4 days. During firing, as the heat moves toward the back of the chamber and the chimney, bricks near the front are cooling and can be unloaded. Because the kiln has two chambers, while one chamber is being fired and unloaded, the second chamber is being loaded. Consequently, bricks are constantly moving either to or from the kiln.

The new kiln has eliminated wastage caused by unevenly fired bricks. In the old field clamp, bricks which were packed around coal usually were overfired while bricks near the exterior plastered walls of the clamp were underfired. In the new kiln, bricks are loosely packed to allow a free flow of air and the permanent walls provide excellent insulation.

Temperature remains constant throughout the kiln so that all the bricks are evenly fired. At present, the demonstration brickyard is producing approximately 2000 fired bricks per day. If anticipated production efficiencies are realized, and an additional press is operational, the brickyard should produce approximately 6000 fired bricks per day—a 300% increase in productivity.

BRICKYARD WORKERS combine red, yellow and kqua kqua clays in holding pits. In the background is the mixing, pressing and drying shed, with kiln chimney stacks visible in rear.

COMMERCIAL APPRAISAL

The Market

Initial market surveys estimated the total local demand to exceed 10 million bricks. Private building contractors, non-governmental development projects in the Southern District, the government's Self Help Housing Association, and town councils and architects all said that a locally made brick must be of good quality, yet inexpensive, in order to be marketable.

While the expensive, imported brick continues to dominate the high income housing and commercial construction market in Botswana, in the low cost housing sector, the clay brick competes with the cement block. Poor quality bricks suitable for one-story construction made by backyard producers are not widely available. Faced with a choice between clay bricks and cement blocks for the same price, low income consumers will choose bricks. Bricks are considered "modern"; their exterior surface is considered attractive and hence is left unplastered. Block walls, although modern, are not considered attractive and are usually plastered on both interior and exterior surfaces. Building contractors and home owners prefer bricks because the problem of cracking masonry, common when building with cement blocks, can be considerably lowered, if not eliminated.

The upgraded Moshaneng brick is designed to appeal to the widest range of potential consumers and fill a market niche which is at present unoccupied. SRDA/MHT's product will compete in quality and appearance with the imported brick, yet will be priced low enough to compete in price with the cement block.

Raw Material Supply

Various clay deposits are plentiful in Botswana. Although the Geological Survey Department of the Government of Botswana has extensively surveyed most clay deposits in the more populated areas of the country, geological testing should be conducted on a potential site to determine the extent and quality of the deposits. This will determine both the long-term viability of the site and whether an "optimum" clay mixture exists to produce a brick of good quality at a reasonable price.

Water is extremely scarce in Botswana. Water at the Moshaneng brickyard is usually obtained by borehole. Occasionally when the borehole is dry, water must be purchased commercially and carried in by donkey cart. The introduction of low moisture brick pressing technology has reduced water use by approximately 20%.

Although coal is mined in Botswana and is plentiful, it is not inexpensive. Coal must be transported to the brickyard. Workers then must break the chunks into uniform sizes. By introducing the new, very fuel efficient permanent kiln, the brickyard will further lower the fuel energy consumption by 60%.

Writers: Carolyn Hairston, Catherine Fort **Editor: Arleen Richman**

ING CLAY BRICKS on the manually-operated Terstaram press by 5-person teams.

manufactured at the Moshaneng brickyard have cally cost Pula 65 to Pula 75 (US $33 to US $37) per thou- epending on quality. During project appraisal, the target price of the Moshaneng brick was determined as a on of the price of substitutes (concrete blocks and im- bricks) as well as of the projected production cost after roduction of new technologies and a reorganization of ckyard. Thus, a selling price of Pula 50 (US $25) per thou- ricks was established. At this price, the cost of con- ng a double brick wall (including labor) and plastering erior surface is comparable to the cost of a single con- lock wall (including labor) plastered on both sides. The f Pula 50 is considerably lower than the 220 Pula (US er thousand price for imported bricks.

ted Production

tion and sales goals were calculated first by survey- market and second by examining the capability of the MHT staff to effectively implement the new brick pro- n process. This included training workers as well as izing brickyard management and labor to increase pro- ty and output.

project appraisal, static potential demand for bricks lculated to be about 10 million for the three major towns Southern District. The capacity of the plant at neng based solely on projected technical and not considerations (e.g. capacity of machines, kiln, etc.) termined to be about 212,000 bricks a month, or 2.5 bricks a year. The Moshaneng brickyard is not yet com- lly producing bricks using the new technologies. It is ted that beginning with the third year of commercial tion, the brickyard will be able to achieve an annual rate of about 80 percent capacity, or 2.2 million bricks.

Breakeven and Cashflow Analysis

Many of the technologies introduced in this project are being employed in a productive activity in Africa for the first time. By documenting the experiences and lessons learned, ATI will determine if an enterprise of this nature can become an attractive investment opportunity to a small entrepreneur. Prior to start-up, a commercial analysis was performed (based on the target sales price of Pula 50/1000 bricks) from the perspective of the small syndicate or entrepreneur who might want to invest in a brickmaking enterprise. Marketing costs were included along with other fixed and variable costs of production (e.g. raw materials, labor, management, transport). In addition, it was assumed that a five-year loan at 15 percent interest was taken out on 70 percent of the cost of establishing a brickyard. Financing charges more than doubled fixed costs; however, break-even was calculated to be at 40 percent of full capacity. That is, at least one million bricks per year would have to be produced and sold to break even. After the first year of operation, pre-tax profitability was estimated to be about Pula 15,000 (US $7,500) per annum, assuming production at about 60 percent of capacity and Pula 27,000 (US $13,500) per annum assuming 80 percent of capacity. At the former level of profitability, the internal rate of return on capital invested was 14 percent, and at the latter level 34 percent. Hence, a brickyard of this type should be a potentially attractive commercial prospect for the small investor.

FOR FURTHER INFORMATION

Carlos R. Lola, "ATI Brickmaking Projects in Three African Countries," March, 1987, ATI.

Carlos R. Lola, "Fibre Reinforced Concrete Roofing Sheets: A Technology Appraisal," September, 1985, ATI.

Carlos R. Lola, "ADAUA Earthen Construction Techniques," September, 1983, ATI.

Carlos R. Lola, "Research Efforts on Soil Cement Stabilization for Low Cost Housing in Nicaragua," December, 1981, University of Tennessee.

POLICY AND REPLICATION ISSUES

By introducing technologies which improve upon the traditional brick production process, SRDA/MHT is paving the way for other small-scale brick producers. These producers will capitalize on the SRDA/MHT's efforts and tap into the market niche that exists for low-cost, locally-produced brick products for local consumers.

Local dissemination will depend, among other factors, on the Botswana Government's continued policy of not subsidizing the sale of imported building materials. Moreover, the government of Botswana is actively supporting the development of small-scale, labor-intensive, local industries which create employment for the local population. The Government of Botswana now provides market assistance, technical support and concessionary loans to locally-owned businesses.

Based on the demonstrated achievements of the SRDA/MHT project in Botswana, ATI is currently supporting, in Tanzania, a project to determine the most suitable technology for the small-scale village-based manufacture of clay bricks. Performance of three types of manually operated brick presses and three types of clay crushers will be compared.

PROJECT IMPLEMENTATION ISSUES

ATI's support to the Southern Rural Development Association/ Minerals Holding Trust is providing financial, technical, and managerial assistance to upgrade the Moshaneng brickyard and replicate this operation at another site. The activities funded include materials testing, purchase of manually-operated Terstaram presses, construction of the permanent Hoffman-type kiln, construction of drying sheds, logistical support and working capital.

Before the second brickyard is established, SRDA/MHT in collaboration with ATI will conduct an evaluation of the operation at Moshaneng. Special attention will be paid to the brickyard's commercial performance. This includes an analysis of sales and income, worker productivity, overall management and the relative price competitiveness of the SRDA/MHT brick with respect to concrete block and imported brick. The final and perhaps most important issue to be addressed in the evaluation is, who are the main beneficiaries of this project? Are poor people benefiting as consumers as well as employees of a brickmaking enterprise?

Available from ATI

Independence through Mobility: A Guide to the Manufacture of the ATI-Hotchkiss Wheelchair. $15.00

Manual for Commercial Analysis of Small-Scale Projects, 104 pp. $6.50

Macro Policies for Appropriate Technology in Developing Countries, edited by Frances Stewart, 265 pages, Westview Press, 1987. $29.85 plus $2.50 postage and handling. (Make checks payable to ATI).

APPROPRIATE TECHNOLOGY INTERNATIONAL

Appropriate Technology International is a private, non profit development assistance organization based in Washington, D.C. and operating in Asia, Africa, Latin America and the Carribean. ATI's program is concerned with the identification, assessment and adaptation of technology. In collaboration with local organizations in developing countries, ATI develops and tests commercial applications of appropriate technologies in the fields of minerals utilization, agricultural products processing, and small farm equipment.

ATI implements its mission with public funds made available through the Agency for International Development. ATI's program is carried out in cooperation with the Employment and Enterprise Development Division of the Office of Rural and Institutional Development within the Bureau of Science and Technology.

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Bulletin #9

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L. SISAL PROCESSING

Sisal is not an industrial or plantation crop in Rwanda. It is, however, grown in hedges that surround house or garden plots in most parts of the country. Sisal baskets, bags, sacks, rugs, rope, chair seats and similar items are apparently made on an occasional basis by a large number of Rwandans, mostly women. It is, however, a very laborious process, and sisal products are expensive. Consequently, both the domestic and potential export markets for these products are limited.

MINIMART and MIJEUMA have identified sisal processing as an important artisan activity, and have promoted the creation of commune-level cooperative workshops in order to introduce improved processing technology. As part of this effort, Euro-Action Accord hired a Belgian consultant from ATOL, named Lisette Coubergs, to work with several women's groups. She introduced improved looms, spinning wheels, and fiber extraction machines, and made excellent progress in the identification of local plant dyes. In concluding her report, however, she notes that better equipment is still needed to reduce the labor involved in extracting and spinning the sisal fiber. The consultant visited one of these groups in Muhazi, where the spinning wheels introduced by Ms. Coubergs and the fiber extraction machine were not in use; these operations continue to be done by hand. One of the women reported that four days are required to extract and spin the fiber used in making one handbag. The equipment present was locally made and did not appear to be of good quality. It appeared to be based on imported drawings or prototypes, and might have been more useful had it been better made. Poor management by the women's group may also be responsible, however, for the disrepair and disuse of this equipment.

While the communes may effectively encourage sisal processing by setting up small industries to produce sisal fiber, they should encourage individual women to weave the fiber and finish the products themselves. This would tend to keep production costs low by limiting the "factory's" operations to those which can be done more quickly by machine, would result in a greater diversity of finished products, and would facilitate marketing, since the village women would probably market the better part of their production themselves. ATI has worked with a Colombian project partner that developed efficient small-scale sisal extraction and spinning equipment, and such equipment is commercially available from India. With intensive training, local manufacture of sisal processing equipment would certainly be possible. While productive fiber extraction machines are generally motor-driven, a single diesel engine could drive several machines, including other kinds of machinery, like cereal mills or oil expellers, that could be profitably operated by the commune.

Kenya's enormous success in exporting sisal bags undoubtedly contains lessons for countries like Rwanda that contemplate

developing their own sisal manufacture. The export of Kenyan bags on a large scale appeared to take off only once there was substantial artisan production, and therefore the competition among producers needed to keep prices low. Large-scale artisan production and low costs may also depend, however, on the social and technological characteristics of the sisal processing industry in Kenya. These should be better understood before proceeding to promote this sector in Rwanda.

M. MICRO-HYDROPOWER AND SMALL RURAL INDUSTRY

In the United States and much of Europe, rural industry was, until the 20th century, powered by falling water from small rivers and streams. Until the advent of efficient steam engines, followed by gasoline engines and rural electrification, falling water was practically the only source of mechanical energy. A number of developing countries, including Rwanda, are fairly well endowed with water power sites, and may obtain most or all of their electricity from medium and large-scale hydroelectric facilities. Few, however, have explored the decentralized use of water power, that is, the installation of turbines on small rivers and streams to produce mechanical or electrical energy for local use.

Currently GTZ is exploring the potential for small-scale waterpower development in Rwanda. Despite the fact that the entire country has a very broken relief, there appears to be little potential except on the slopes of the Zaire-Nile Crest, that is, in the western third of Rwanda. While the rest of the country is dominated by narrow flat-bottomed valleys, where the watersheds of hillside streams are very small, the crest provides longer slopes along which considerable flows can develop before reaching the valley bottoms or Lake Kivu. Several sites have already been developed with small hydroelectric plants on the Sebeya River at Gisenyi and on the Mukungwa River at Mukungwa.

Very small-scale or "micro" hydropower developments, which are too small to be cost-effectively connected to the national grid, can often be cost-effective when their mechanical power is used directly, or converted to electricity for local consumption. Indeed, such projects can often be built for the cost of a high voltage transformer (10-20,000 dollars or 800,000 to 1,600,000 frw), which would be needed simply to step up the voltage of a small generator to the grid voltage. In 1986, ATI provided financing and technical assistance to a small company in Bukavu, Eastern Zaire, that develops small waterpower sites on the Zaire side of Lake Kivu. This company has developed roughly a dozen sites to date, using turbines and grinding mills built in their own workshop and imported electric generators.

The cost effectiveness of micro-hydropower depends as much upon the existence of a need for the electrical or mechanical power, as upon the availability of suitable sites. In eastern Zaire, dried cassava is the principal foodstuff, and this must be ground into flour before it is eaten. The main application of SODERZA's installations is the grinding of cassava. In Cyanguru Prefecture there is substantial production and consumption of cassava, and hydropower installations located here might prove cost effective from their mill receipts alone. Further north along the Lake Kivu shore, and on the eastern side of the Zaire-Nile Crest, cassava is a less important crop, and it is less clear how the hydropower would be used. Possible applications include sawing wood, crushing lime and hulling coffee. Such

applications need, however, to be carefully evaluated on a case-by-case basis to determine whether the capital cost of the micro-hydro installation can be recovered in a reasonable period of time.

N. PORTABLE SAW MILLS

The woodworking sector in Rwanda is almost equally divided, in terms of its gross income, among a relatively small number of modern mechanized woodworking shops, and a large number of small shops, employing one or more people and using only manual tools. It is difficult to improve this sector, that is, to reduce its production costs, in a way that would not be based on the use of greater mechanization, and thus cause a net reduction in employment. Since many examples of mechanized woodworking shops already exist, including some which produce furniture of excellent quality, there is no compelling need for improved technology in the woodworking sector.

The same is not true for the production of lumber. Almost all lumber presently produced in Rwanda is cut by pit-sawyers (scieurs de long), using long-bladed hand saws. Sawing lumber in this way is extremely slow, hard work, a good sawyer producing roughly two 4-meter planks per day. The availability and high cost of lumber in Rwanda present a significant constraint to the building and woodworking sectors, the latter paying about 60 to 70% of its gross income for purchased lumber (Project PRIME Working Paper No. 2, by Donald Mead and Augustin Ngirabatware, March, 1987). Since almost half of the cost of lumber is the cost of sawing it, the remainder being the cost of stumpage, paid to the owner of the land on which the trees were cut, and the cost of transport and distributor's margin, there is considerable opportunity to reduce the selling price of lumber and lumber products by reducing the sawing costs.

This opportunity is particularly good on forest lands owned and managed by the government. The government has been unsuccessful in negotiating with pit sawyers to harvest and saw trees on the periphery of the Nyungwe Forest, planted as a protective belt. The trees are 75% pines, have a low market value, and do not interest the pit sawyers, according to the Rwandan director of the AEFB Project. Chain saws and portable mills could substantially reduce the cost of harvesting these trees, for lumber or fuel, and sawing the better trees into lumber, possibly permitting these lands to be harvested and replanted at a profit at present lumber and fuel prices.

A similar argument can be applied to the management of the Nyungwe Forest itself. A thorough survey of the plant and animal species in the forest is presently underway, one purpose of which is to recommend strategies for using the forest in a sustainable and economical manner. Portable saw mills, which enable even the largest trees to be sawn in the woods and without moving the tree itself, minimize the impact of tree harvesting on the forest. Most of these machines can be carried into the forest and the lumber carried out by people walking on footpaths. The high productivity of the technology would enable each sawmill to be accompanied by a forestry agent, who would be responsible for seeing that only the harvestable trees are cut.

Portable sawmills are available in a variety of types and sizes; the smallest and least expensive consists of a chain saw with a long cutting bar, special chain and a cutting guide. Chain saws, with or without a sawing guide, are widely used for sawing planks in Cameroon. A number of Band saw mills are also available, the smallest of which can be carried by two men and has a 5-hp gasoline engine. Band saw mills are much faster than chain saws for sawing lumber, cost less to operate, and produce a lot less sawdust, obtaining the maximum amount of lumber from a tree. Circular sawmills are the fastest of the portable mills, often having three blades to saw and edge the board on a single pass. Portable mills range in price from roughly one thousand to ten thousand dollars (80,000-800,000 frw).

The criticism of this concept is that it would increase the rate of deforestation. Despite its successful efforts at reforestation, Rwanda continues to consume more wood than it grows. The vast majority (95%) of this wood is for fuel; less than 1.5% is consumed as sawn lumber. Rwanda presently imports an important part of its lumber, by legal or clandestine means, from Zaire. The rationale behind the use of more productive sawing equipment is to lower the price of domestic lumber, thereby stimulating the woodworking and building sectors of the economy, while increasing the value of the country's forests, thereby helping to defray the costs of proper forest management. The present technology, which consists of pit saws, on the one hand, and a single large stationary mill, on the other, accomplishes neither goal.

A concern with this technology is its tendency to displace the pit sawyers, substituting capital for labor in the production of sawn lumber. The Third Five Year Plan estimated the number of pit sawyers in Rwanda at 750 in 1986, though the actual number may be larger, as many people saw on an occasional basis. The greater the ability of mechanized sawing to reduce the cost of lumber, the greater will be its tendency to put pit sawyers out of work. This tendency can be reduced by introducing the machines to saw lumber of a different grade than that sawn by the pit sawyers. The latter generally negotiate with private land owners to saw a small number of trees, usually eucalyptus or cypress, which are the predominant varieties in Rwanda. If the machines were selectively introduced on the government lands and forest reserves, the principal products would be softwood lumber for packing crates and other low value applications, which, at roughly 3000 m^3 per year, constitutes the largest category of wood imports, and high value hardwoods that are not (legally) available to the pit sawyers, and are currently imported from Zaire.

Another means to reduce the displacement of pit sawyers would be to engage them as owner/operators of the portable mills. The successful use of chain saws and portable mills in Rwanda

will require intensive training by an expatriate technician who has long term experience with, and preferably earned his own living by using such equipment. Pit sawyers could be asked to apply as teams of two or three for training in the new technology, each team including at least one person who is an experienced mechanic, and possibly an experienced charcoal burner. Training would include operation, maintenance and repair of the equipment in the forest, and would be long enough to ensure that the trainees are fully competent. Teams that successfully complete the training would then be allowed to continue using the equipment on a lease-to-purchase or similar agreement, working with forestry agents, and hiring their own laborers, harvesting, processing and marketing forest products on the government-controlled lands.

Whether or not a decision is reached to proceed with the use of this technology in Rwanda, the appropriate government ministries should be made aware of its existence in order to avoid investment in traditional fixed sawmills. Such installations, which are highly capital intensive, requiring massive investments in road construction and transport equipment, can also have a serious detrimental impact on the condition of a natural forest, Fixed sawmills would be particularly inappropriate in Rwanda, in view of the topography and the small size of the forests. Portable sawmills, while a highly appropriate intermediate technology for many countries, including the most developed, are certainly the most efficient modern technology for producing sawn lumber in Rwanda.

O. RHIZOBIUM BACTERIA

Rhizobium is a family of bacteria that live in the roots of leguminous plants, and which fixes atmospheric nitrogen. Rhizobia naturally inhabit agricultural soils, but the artificial inoculation of certain soils with specific bacteria will often increase the yields of leguminous crops. The decomposing roots of these plants free up additional nitrogen that can be assimilated by subsequent crops in the crop rotation. Rhizobia can be multiplied on a substrate of peat or similar material, packaged, and sold to farmers by a simple and inexpensive process. Packaged rhizobia are then mixed with the seed of the legume to be planted, and the soil is thereby inoculated at the same time that the crop is planted. ATI financed a demonstration project of this kind in Thailand. Successful application of this technology can make nitrogen available to plants at a fraction of the cost of importing chemical fertilizer, and without expending foreign exchange.

Research was conducted on rhizobium in Rwanda by the RSEA Project in 1986-1988. The results were not very encouraging: rhizobium inoculation increased soybean yields, but only when phosphorus was added to the soil, and showed no effect on bean yields. Rhizobium inoculation of soybeans without phosphorus increased nodule development but did not increase crop yields.

Much more research is required, in a variety of locations and on the effects of a number of soil parameters, in order to determine whether rhizobium inoculation can be used as an effective substitute for nitrogen fertilizer. Since soil acidity is known to have an adverse effect on rhizobium growth, and since Rwanda's soils tend to be moderately to severely acidic, rhizobium inoculant should, in particular, be tested on soils that have already been improved through lime application. If a comprehensive study defining a research strategy for rhizobium in Rwanda has not already been commissioned, one is needed. It would appear that, given the high transportation costs faced by Rwanda for imported goods, the limited foreign exchange earnings, and the importance of legumes in Rwandan agriculture, rhizobia are one of the few affordable means of improving the country's crop yields.

Appropriate
Technology
International

AUGUST 1988
BULLETIN Number 15

RHIZOBIUM INOCULANT IN THAILAND

Appropriate Technology International seeks to develop cost effective strategies that increase the productivity of poor people in rural areas in developing countries. ATI's projects focus on appropriate technologies that add value to the resources of the poor. The goal is to establish commercially viable enterprises that are easily adapted for widespread dissemination locally as well as for use in other countries and regions.

This Bulletin describes ATI's work with the SVITA Foundation in Thailand to develop an appropriate technology for commercial small-scale production of *Rhizobium* inoculant that will give poor farmers access to an inexpensive substitute for chemical fertilizer. The first project, which concluded in 1987, demonstrated the technical feasibility of small-scale decentralized production of *Rhizobium* inoculant. A second project, which will begin implementation in late 1988, is expected to demonstrate the commercial viability of the small-scale *Rhizobium* inoculant production technology developed in the first project.

EXPECTED BENEFITS

Micro-Level

Direct Income: As a result of these two projects, approximately 10,000 farmers and their families are expected to increase their incomes 17-42% due to increased yields of soybeans and reduced use of nitrogen fertilizers. Statistics from Department of Agricultural Extension Services show that the average farmer near the project area—50 miles from Chiang Mai in the Northern part of Thailand—cultivates 6 rai of soybeans per year (1 rai = .16 hectare = .32 acre). The average yield per rai of soybeans is 200 kilograms. Using *Rhizobium* inoculant increases soybean yields 20 to 50%, resulting in yields of 240 to 300 kgs per rai. At a market price of US$.25 per kg of soybeans, this means income increases of US$60 to US$150.

Employment Created: The *Rhizobium* plant will provide 5 full-time jobs, those of production manager, security guard and mechanic/maintenance man. A consultant will also be employed at the beginning of each production period to oversee the quality control program. In addition, 3 part-time workers will help bag peat, sterilize, label and distribute the *Rhizobium* inoculant during the two peak periods of demand.

Capital Formation: The production facility at Ban Mae will be set up as a joint venture between SVITA and a local businessman and soybean trader.

Macro-Level

Foreign Exchange Savings: In its last four Five-Year Economic Plans, the Government of Thailand placed priority on achieving self-sufficiency in soybean production. Although soybean production has increased approximately 200% over a four year period, demand still exceeds supply. Thus, Thailand continues to import more than 200,000 tons of soybean meal each year at a total cost of approximately US$50 million. Use of *Rhizobium* also will reduce expenditures for costly imported chemical nitrogen fertilizers. It is estimated that, per hectare of soybeans, less than a kilogram of high quality inoculant, which costs 50 Baht, can replace more than 100 kgs of chemical fertilizer nitrogen, which cost 1500 Baht.

Other Benefits: Research indicates that roots of nodulating soybeans leave significant amounts of nitrogen in the soil, increasing the soil fertility.

As small farms become more profitable due to increased agricultural production, fewer small farmers should be forced into debt and subsequently be required to sell their land.

WOMEN FARMERS in Thailand who used* Rhizobium *as an input in soybean production reported 30 to 70% increases in soybean yield.

THE ATI APPROACH

ATI considers four issues in its projects: (i) the institutions involved and the need for institutional development; (ii) the technology involved and the need for adaptation or further refinement of the technology; (iii) the commercial viability and the need for market development, including credit facilities and repayment schedules; and (iv) policy and replication issues. (What factors promote or inhibit the spread or dissemination of the technology to other geographical areas?)

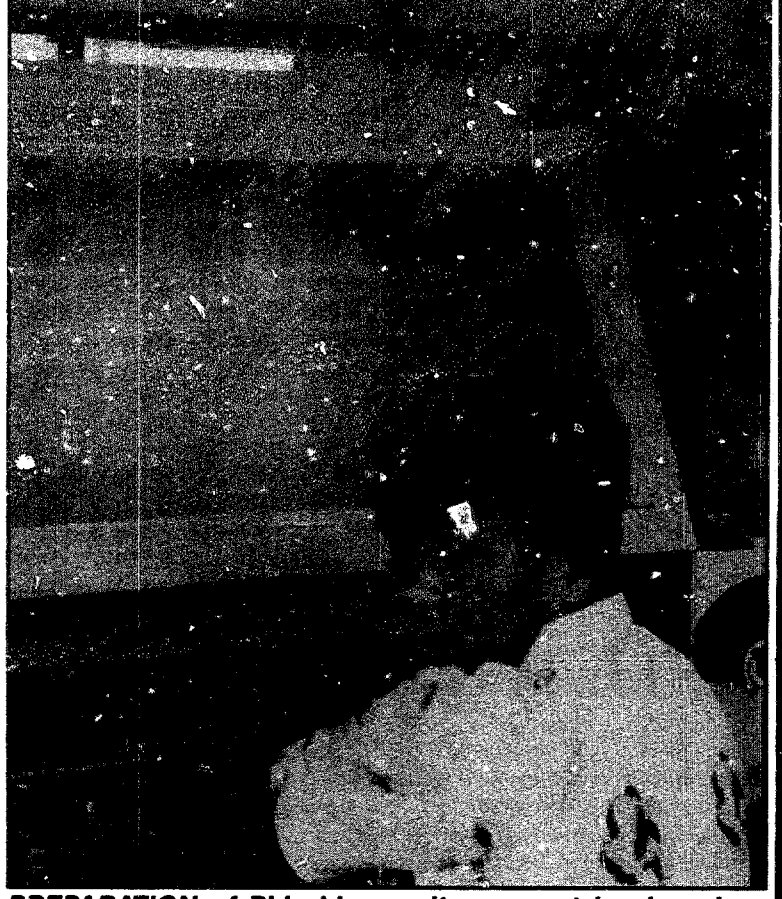
THE INSTITUTIONS INVOLVED

SVITA Foundation

The SVITA Foundation is a private, not-for-profit organization founded in 1978 in Thailand by a group of concerned business, academic, and technical professionals to consolidate the efforts of NGOs to increase incomes of people living in rural areas and urban slum communities. In its role as a facilitating/coordinating organization, SVITA identifies resources and programs within the governmental, NGO and business sectors and matches these with local development needs. Emphasis is placed on enterprise promotion activities, community organization, training and technical support.

BNF Center

The regional Biological Nitrogen Fixation Resource Center (BNF) in Bangkok is an outreach center of NiFTAL. NiFTAL (Nitrogen Fixation by Tropical Agricultural Legumes), University of Hawaii, is the world's leading center on biological nitrogen fixation technology. The BNF provides "mother" *Rhizobium* cultures to the small-scale plant.



PREPARATION of* Rhizobium *cultures must be done in a sterile environment

THE TECHNOLOGY: SMALL-SCALE PRODUCTION OF RHIZOBIUM INOCULANT

Sources of Nitrogen

All plants need soluble nitrogen to synthesize proteins and nucleic acids. Nitrogen is provided either via chemical fertilizers or by decaying plants and animal manure. Although soils in tropical countries are very poor in nitrogen, only one rural farmer in five in developing countries (the majority of which are located in tropical areas) uses nitrogen-rich fertilizer because it is so expensive. *Rhizobium* is an inexpensive source of nitrogen and hence a cost-effective substitute for chemical nitrogen fertilizer. Fertilizers generally available in Thailand are composed of a mixture of nitrogen, phosphate and potassium. It has been estimated that farmers can reduce production costs by as much as 60% by eliminating the chemical nitrogen component.

Rhizobium is a genus of bacteria (one-celled microorganisms) that occur naturally and work in a symbiotic relationship with legumes such as soybeans, ground nuts, and mung beans to enable them to use atmospheric nitrogen. The bacteria cause nodules to form on the roots of plants where they gather nitrogen from the atmosphere and process this inert gas into a form which the plant can use.

Rhizobia are able to live independently of the soybean plant as long as they are provided with nutrients such as carbon and nitrogen compounds and various mineral salts. In the laboratory a liquid bacterial food or broth (culture medium) is prepared where the *Rhizobia* are allowed to multiply to an "optimum" number (one billion cells per milliliter). This liquid culture is mixed with a carrier such as finely ground peat and packaged in polyethylene bags for sale to farmers. Just before sowing, farmers dip the seed in a solution of peat inoculant and water—"inoculating" the soybean seed.

Because the bacteria must be living at the time of inoculation, and because they die at temperatures above 35-40 degrees Centigrade, storage and transport in tropical zones are difficult. In addition, the *Rhizobium* inoculant is needed only at planting time—usually twice a year. The common practice in industrialized countries is to manufacture *Rhizobium* in a large-scale centralized plant; a complex distribution network requires refrigerated storage and refrigerated transport of inoculant. Because transportation problems make it difficult in a developing country to serve a large number of farmers, a large-scale plant would not be cost-effective. In addition, small-scale decentralized production allows a local facility to produce the strain of *Rhizobium* that works most effectively in the soil of a particular region.

The project in Thailand introduced the dilution method of preparing *Rhizobium* inoculant, developed by Dr. Padma Somasegaran of the Nitrogen Fixation by Tropical Agricultural Legumes Project (NiFTAL), which made small-scale decentralized production possible.

hough both large-scale and small-scale production of *zobium* inoculant are based on the same principles, large-le plants mix large batches of *Rhizobium* cultures with terilized peat. In the small-scale method the peat is ster-d in the bags which are inoculated with diluted *Rhizobium* ure. This increases inoculant shelf life to 6 months and inates the need for refrigerated storage. Because locally duced *Rhizobium* inoculant can be sold directly to the ners, refrigerated transport is no longer necessary.

all-scale production of *Rhizobium* inoculant by the "dilu-n method" has several advantages over large-scale duction.

Investment capital for pre-investment costs, technical sup-t and start-up is relatively small—$50,000 versus $2,000,000 large-scale plants.

Most equipment is inexpensive and available locally. menters of 50 to 80 liters are used instead of the 1200 to 0 liter fermenters used in large-scale production.

Using the dilution process increases the production acity of the plant as much as 1,000 times. A broth culture *hizobium* can be diluted as much as 1000 fold to a popula-n of as few as 20 million cells per milliliter and injected sterile peat bags. The cell populations will increase to illion cells per gram of peat during the next 7-14 days.

Because sterilized peat is used as a carrier, the efrigerated shelf life of the *Rhizobium* inoculant increases six months or more. Quality of the inoculant is better ause *Rhizobium* bacteria do not compete with other, er-growing microorganisms contained in unsterilized peat. rage costs are lower because refrigeration is not required.

Small-scale plants can be located in rural farm areas, ucing transportation distances to farmers and eliminating need for a costly cold transportation chain.

Because small-scale plants can be located in the soybean-ducing area, the *Rhizobium* strain most suitable for the al crops and soil conditions can be selected.

Equipment is relatively easy to operate and requires fewer nly skilled technicians.

culant Production

ee major steps are involved in inoculant production: strain ection and preservation of mother cultures, growth of ures in fermenter, and inoculation and mixing of the ure with carrier.

in Selection and Preservation of Mother Cultures: Soil nples from the soybean production sites and seed types opular use must be tested to determine the most effec-strains of *Rhizobia* for the inoculant. Because soil con-ons may vary widely within the project region, several dif-nt strains of *Rhizobia* may be necessary for a generally ctive inoculant. To preserve mother cultures, they must efrigerated; every 6-12 months they must be transferred ubes containing fresh medium.

prepared by transferring bacteria from a mother culture to a flask containing solid culture media. Bacteria from the mother culture are "streaked" onto the solid media and allowed to multiply for 7-10 days at room temperature. Each single bacterium will form a colony. If there are contaminants in the flask, they can be observed within 5 days. If there are no contaminants present sterile water is transferred into the flask and left overnight to dissolve the *Rhizobium* colonies.

Culturing in Fermenter: The starter culture is transferred to a larger container called a fermenter which contains sterile liquid culture media. The media in the fermenter must be constantly aerated to provide oxygen for the bacteria. The fermenter can be simply one or more 5 liter flasks. However, a 120 liter stainless steel fermenter was developed for the ATI/SVITA plant.

Media for culturing *Rhizobium* must contain compounds of carbon, nitrogen and other mineral salts. Mannitol, used at present, provides the carbon source and yeast extract provides nitrogen and other nutrients. Since mannitol must be imported, research is being conducted to find substitutes. Sugar cane juice was found acceptable, although *Rhizobium* growth was slower.

Rhizobia multiply in the fermenter for approximately six days, until they reach a population of 500 million to one billion cells per milliliter. At this point the *Rhizobium* broth is diluted with sterile water for injection into peat bags.

Inoculation and Mixing Culture with Carrier: Polyethylene bags containing moist peat are sterilized in an autoclave (steam sterilizer). After cooling down, the bags are sealed. An automatic dispenser or autosyringe is used to inject broth into peat bags. After injection, the injection hole is sealed with tape. The bags are then gently kneaded to evenly distribute the bacteria throughout the peat. Peat bags are stored for 7-14 days during which time the *Rhizobium* population reaches 1 billion cells per gram of peat.

Quality Assurance Procedures: Effectiveness of inoculant depends on its quality. Good quality inoculant contains sufficient living bacteria to cause adequate root nodulation (generally 1 billion cells per gm peat). The *Rhizobia* must also be compatible with soil conditions and seed varieties.

To maintain an effective number of *Rhizobia*, other microorganisms must not be allowed to contaminate the inoculant and *Rhizobia* must not be exposed to life-threatening conditions, such as high temperature or lengthy storage periods.

To prevent contamination by other microorganisms, sterile techniques must be used. Glassware used in culturing *Rhizobium* are sterilized in an autoclave. Water used in culture broths is filtered and deionized. *Rhizobium* cultures are transferred from one container to another and peat bags are inoculated in an enclosed area. The culture medium in the fermenter is checked daily for contamination and changes in pH which sometimes accompany contamination.

The active number of *Rhizobium* bacteria in stored peat bags are determined periodically by laboratory methods until the number of *Rhizobium* decrease to below twenty million cells per gram of inoculant, at which time they should be discarded. The number of *Rhizobium* which are capable of nodulating is determined by the Most Probable Number (MPN) plant infection count which tests the nodulating capacity of *Rhizobium* using another faster-growing legume.

SMALL-SCALE RHIZOBIUM INOCULANT PRODUCTION FLOW CHART

Rhizobium Stock
(Mother Cultures)

↓

Check for Purity

↓

Preparation of Starter
on Solid Culture Media

↓

Multiply for 7-10 days

↓

Dissolve Bacterial Colonies
in Sterile Water

↓

Transfer Starter
Culture to Fermenter

↓

Multiply for 6 Days

↓

Bacterial Culture
10^9 cells per ml

↓

Dilute with Sterile
Deionized Water

↓

Peat Packed in Plastic
Bags (184 g each)

↓

Autoclave at 121°C
For 1 Hour

Inject 16ml Rhizobium Broth Into
Sterile Peat Bags

↓

Store for 7-14 Days

↓

Market

The Market
The Northern provinces produce more than 70% of the total Thai soybean crop. During the 1985/86 rainy season, 896,033 rai were planted and during the dry season 362,115 rai were planted in these provinces. For each rai of soybeans planted, 1.5 bags of *Rhizobium* are recommended. According to studies conducted by the department of agriculture at Chiang Mai University *Rhizobium* use will be adopted by approximately 50% of the farmers where it is introduced. Therefore potential annual demand for *Rhizobium* inoculant in the Northern provinces is approximately 943,612 bags per year. A small-scale *Rhizobium* plant operating at full capacity could produce enough for one-tenth of this market.

Currently the only other producer of *Rhizobium* inoculant in Thailand besides the ATI/SVITA plant is a large-scale Department of Agriculture plant in Bangkok which produces 240,000 bags of soybean inoculant annually.

The Thai government has been actively promoting the use of *Rhizobium* since 1982. The *Rhizobium* inoculant produced by the government plant is sold at a subsidized rate to the government agricultural extension service and mills involved with extension activities. Areas not served by extension services have limited access to inoculant.

Raw Material Supply
Most equipment and chemicals needed can be purchased from local suppliers of scientific equipment. Peat comes from Southern Thailand. The stainless steel 120 liter fermenter is manufactured commercially in Thailand.

Price
The price of a 200 gm bag of inoculant through government-subsidized distribution is 10 Baht. However, this price is not government-regulated and prices of 50-70 Baht per bag have been reported in some rural areas. Cost-benefit analysis and cash flow projections prepared for the commercial project indicate that this technology can produce *Rhizobium* for the unsubsidized price of 10 Baht per bag. Of course, a higher price would make this undertaking even more profitable.

Production
ATI and SVITA commissioned a pilot plant at Ban Mae in Chiang Mai province to test the technical feasibility of small-scale *Rhizobium* inoculant production. Over an eighteen month period 15,000 bags of *Rhizobium* inoculant were produced.

During its first year of commercial operation the Ban Mae plant is expected to produce at least 65,000 bags of inoculant (35,000 for the dry season and 30,000 for the rainy season).

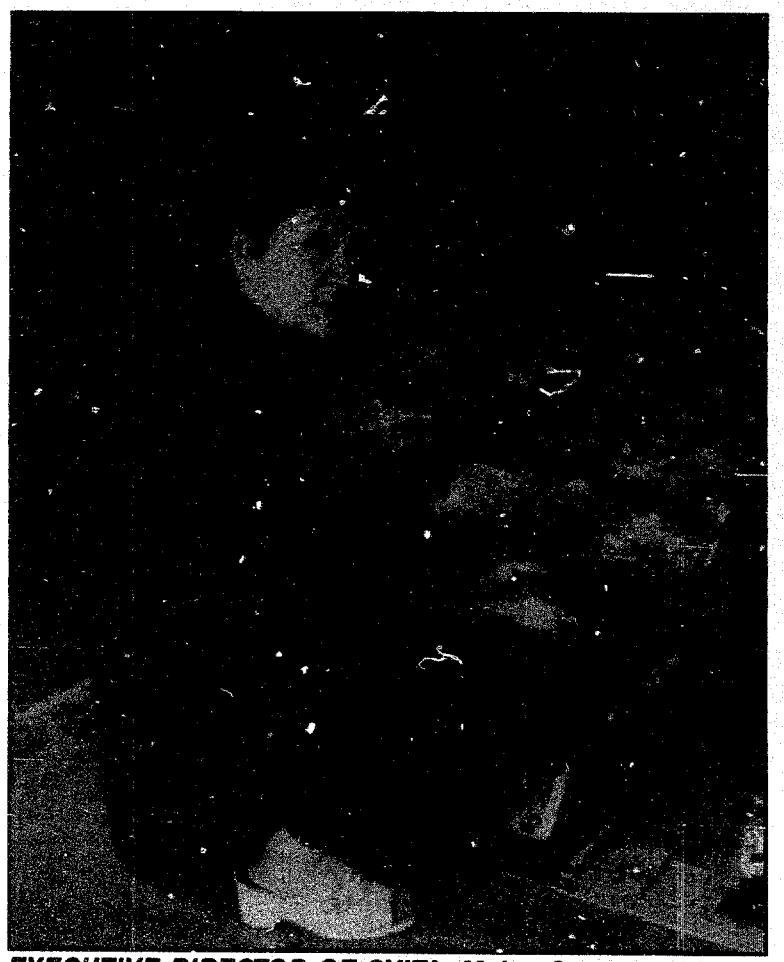
During the second year after start up, the plant is expected to produce at full capacity (120,000 bags of inoculant per year)—this includes down times when no inoculant will be produced due to seasonal demand.

Product Diversification
Although the plant is expected to achieve commercial viability even if it only produces *Rhizobium* inoculant for soybeans, diversification of products would maximize the use of the plant. Diversification could include production of inoculant for other leguminous plants, provision of threshing services or production of high quality seeds. The autoclave/sterilizer could be used during the down season to blanch logan fruit or to can vegetables or fruits.

Marketing Networks
The market for *Rhizobium* is composed of two groups of farmers: the 20% of small farmers who participate in a government-sponsored seed exchange program where native seeds are exchanged for high-yielding varieties, and a larger market segment consisting of farmers without easy access to the government seed stations. This is the segment which the small-scale plant at Ban Mai was designed to serve. During commercial testing of the plant, distributors of agricultural inputs (fertilizers, insecticides, etc.), and soybean brokers (middlemen) and commercial feed mills who purchase grain will deliver the *Rhizobium* inoculant to farmers.

During the final evaluation of the completed *Rhizobium* project, correlations were found between training farmers in *Rhizobium* use and their reported increases in soybean yields. Therefore, the new commercial enterprise will train *Rhizobium* distributors to properly apply the inoculant so that they can provide extension services to customers. They will also be encouraged to distribute inoculant as part of a "package" of inputs including high-quality seed and chemical nitrogen free fertilizer.

To be commercially viable, the small-scale *Rhizobium* plant needs to produce and sell 90,000 bags of *Rhizobium* inoculant per year. To achieve this goal, the use of *Rhizobium* inoculant must be widely adopted by local farmers. This will be achieved through an effective marketing strategy and the guarantee of a consistently high quality product. In other countries where inoculant quality was inferior, farmers failed to achieve significant improvements in crop yields and subsequently discontinued its use.



EXECUTIVE DIRECTOR OF SVITA, Malee Suwana-adth, examines bags of sterile peat inoculated with* Rhizobium *that are ready to be sold to local soybean farmers.

ATI's three year $135,000 grant enabled SVITA to demonstrate the technical viability of small-scale *Rhizobium* inoculant production. Two groups of farmers collaborated in testing the benefits of the inoculant. The first group consisted of approximately 1200 families, members of a regional soybean growers association. The other group, an association of ten women farmers, was provided with *Rhizobium*, good quality seed and training in *Rhizobium* use. These women reported exceptionally high increases—30 to 70%—in soybean yield.

A grant of $36,700 will enable SVITA, over a 33 month period, to demonstrate that commercial production and dissemination of *Rhizobium* inoculant is an effective way to reach and improve soybean yield for the greatest number of rural farmers. During project implementation, data will be gathered on production, marketing strategies, costs and cost effective quality control procedures.

Available from ATI

Manual for Commercial Analysis of Small-Scale Projects, 104 pp. $6.50

Macro-Policies for Appropriate Technology in Developing Countries, edited by Frances Stewart, 265 pages, Westview Press, 1987. $29.85 plus $2.50 postage and handling. (Make checks payable to ATI).

Even if the government *Rhizobium* inoculant plant in Bangkok were to operate at full capacity, it could not meet potential future demand. The ATI/SVITA plant in Ban Mae will only meet 10% of the potential demand for *Rhizobium* in the Northern provinces. Continuing development of the market for *Rhizobium* and increasing acceptance by farmers should increase the need for replication of this technology in other parts of Thailand.

This technology can be replicated in any country wishing to increase yields of leguminous plants. Although the second project has not yet begun implementation, ATI has already received replication inquiries from India, the Philippines, and Sri Lanka.

MACRO-POLICY ISSUES

In most countries, both developed and developing, laws regulate the content of and set quality standards for chemical fertilizer. However, there are very few regulations regarding the content and quality of biofertilizers. This means that an unethical producer could sell *Rhizobium* inoculant containing a very low concentration of bacteria. The unsuspecting farmers who purchase this substandard *Rhizobium* would not realize anticipated increases in crop yield. Government policymakers, therefore, need to be made aware of this problem so that effective legislation can be promulgated.

APPROPRIATE TECHNOLOGY INTERNATIONAL

Appropriate Technology International is a private, not-for-profit development assistance organization based in Washington, D.C. and operating in Asia, Africa, Latin America and the Caribbean. ATI's program is concerned with the identification, assessment and adaptation of technology. In collaboration with local organizations in developing countries, ATI develops and tests commercial applications of appropriate technologies in the fields of minerals utilization, agricultural products processing, and small farm equipment.

ATI implements its mission with public funds made available through the Agency for International Development. ATI's program is carried out in cooperation with the Employment and Enterprise Development Division of the Office of Rural and Institutional Development within the Bureau of Science and Technology.

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P. LOCALLY MANUFACTURED PACKAGING

A recurrent problem noted during the consultant's discussions with small Rwandan entrepreneurs is the shortage and high cost of imported packaging suitable for food products. This problem was noted by the manager of KONFIGI, a cooperative producer of jams, by the manager of the National Dairy in Nyabisindu, by three sunflower oil producers, and by Giselle Duvalle, a Canadian Sister at the Centre Bon Pasteur, which produces peanut butter, relishes and a variety of other food products for the Kigali market. The only producer of plastic containers is MIRONKO Plastics, maker of molded polyethylene products. They produce jerrycan-type containers in various sizes, which are widely used to distribute banana wine and sorghum beer, kerosene, and, to a small extent, locally produced sunflower oil. Producers of high value and semi-solid or viscous food products prefer clear or white polyvinylchloride 1 liter bottles, and 1/2 and 1 liter tubs. These are not produced in Rwanda, and their procurement by small entrepreneurs is complicated, requiring import licenses and scarce foreign exchange allocations. The importation of PVC bottles is practically impossible because they do not stack, and therefore have an extremely low bulk density.

There is interest by local entrepreneurs in the manufacture of food quality containers. Makuza Bertin, owner-manager of a Rwanda foam mattress company, expressed keen interest in this area, and the consultant was informed that the new Gishwati Dairy may produce PVC containers for its ultra-pasteurized milk. ITAC (l'Institut Technologique d'Appui au Codéveloppement) has expertise in PVC packaging, and their bulletin on this subject is enclosed. The scale and capital intensiveness of this technology are high, but might be appropriate if the Gishwati Dairy reaches its anticipated volume of production (20,000 liters per day). If PVC bottles are produced in Rwanda, then the economic feasibility of producing tubs and lids should be investigated.

It would also be desirable to investigate the possibility of using relatively low-tech packaging, made from locally available, reusable and/or biodegradable materials. Examples include earthenware containers for honey and jams that are sealed with wax, and waxed paper tretrapak-type containers for dairy and other liquid products. The identification and evaluation of packaging technologies appropriate to Rwanda would provide an important impetus to the local production of packaging, and thereby the many industries, both extant and potential, that require packaging.

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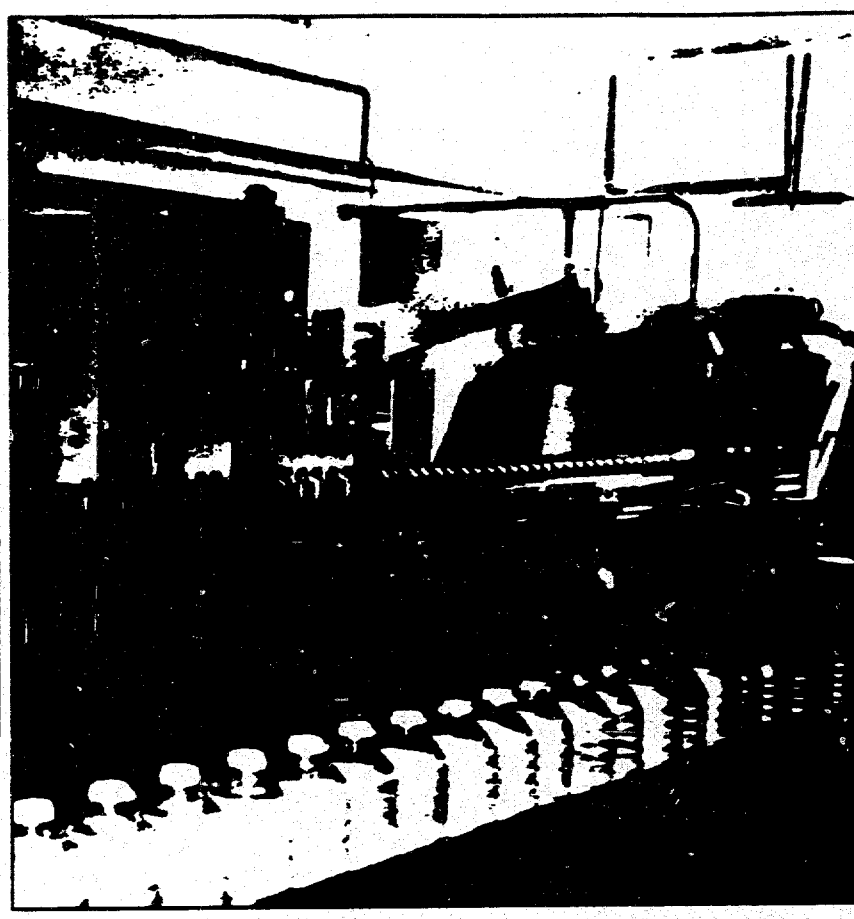
Embouteillage des liquides

Conditionnement d'eau de source en bouteilles plastiques PVC (Poly Chlorure de Vinyle).

Cette activité finale inclut deux activités intermédiaires :
- Production de bouteilles PVC
- Production de compound PVC (matiére premiére nécessaire à la fabrication des bouteilles).



Le conditionnement sous bouteille PVC, permet de conserver et de transporter facilement les boissons liquides.

Légère, pratique esthétique la bouteille PVC remplace avantageusement les bouteilles de verre plus fragiles et plus lourdes .

La matière première se présente sous forme de poudre aisée à transporter .

Le procédé de fabrication proposé fait appel aux technologies les plus modernes et permet d'obtenir des bouteilles présentant des propriétés mécaniques, organoleptiques et d'aspect optimales .

La vente de bouteilles d'eau de source ou minérale est un marché porteur qui permet le démarrage de l'activité avec les plus grandes chances de succès

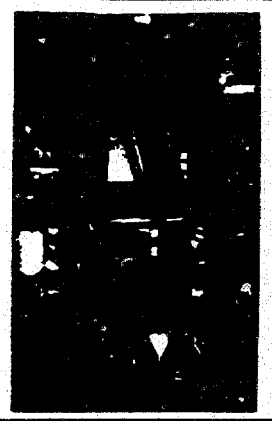
* **Procédé ultra-moderne**
* **Bouteilles de qualité**
* **Marché existant**

DESCRIPTIF DU PROCEDE: le procede comprend 3 etapes

Compoundage : Il s'agit de la préparation de la matière première nécessaire à la fabrication des bouteilles .La technologie utilise un mélangeur rapide double cuve et consiste en la préparation d'un melange intime et homogène sous forme de poudre . d'un certain nombre de composants indispensables à la transformation correcte du PVC .

Production de bouteilles: elle utilise la technique d'extrusion-soufflage et inclut le broyage et le recyclage en continu des déchets.Les bouteilles sont envoyées par transport pneumatique dans un silo de stockage.

Conditionnement : embouteillage automatique



EQUIPEMENT

Compoundage:
mélangeur rapide double cuve

Production bouteilles :
extrudeuse-souffleuse

Conditionnement :
chaine automatisée
d' emboutei lage

UTILITES

Nature	Unité	Nbre	Observations
Energie électrique	KVA	630	Variable selon la production
Air comprimé	m2/h	300 à600	

CAPACITE DE PRODUCTION

Unité	Nbre	Observations
Bouteille	15 à 50	en million par an
Compound	3 à 5000	en tonnes par an
Nbre de postes par journée		3

MATIERES PREMIERES

PVC ou Compound

Produits divers

MATERIEL ROULANT

Nature	Observations
Petit materiel	Chariot élévateur et transpalette

TERRAIN ET BATIMENT

Observations	Surface
Fabrication et aire de stockage	2 à 3000 m2

PERSONNEL

Qualification	Nbre
Cadres	1
Entretien	1
Techniciens	1
Ouvriers	1
Manoeuvres	2 à3

LES SERVICES OFFERTS PAR ITAC

* **Transfert de technologie**
* **Fourniture matériel**
* **Vente savoir faire**
* **Formation**
* **Etude de faisabilité**
* **Montage dossiers d'entreprise**

LES PARTENAIRES D' ITAC

Nom	Compétences
SOURCE DU COL ST JEAN	Compoundage Fabrication de bouteilles Embouteillage

itac

Institut Technologique d'Appui
au Codéveloppement
BP 18
Chateau-Arnoux - 04160F
tel : (33) 92 64 34 42
telex : 420 378 F

Q. AGGLOMERATED CHARCOAL BRIQUETTES

There has been considerable interest in Rwanda in the briquetting of organic materials as a substitute for wood charcoal for the urban fuel market. A large plant has been built for producing papyrus briquettes on the outskirts of Kigali. Some people reported that the briquettes are an excellent fuel that sells well, while others said that the briquettes smoke when first lit, and burn so hot that they make holes in the locally manufactured aluminum casseroles. What is certain is that the production of briquettes by compression is capital intensive, and often does not produce an acceptable charcoal substitute. At the same time, the government is placing strict control on the production of wood charcoal, prohibiting its production altogether in certain parts of the country.

A simpler technology, involving little or no capital investment, is used by women in Nairobi, and a renewable energy project in Sudan, to produce charcoal briquettes. The technology involves the agglomeration of charcoal powder with a binder. Women in Nairobi use a small percentage of clay mixed with water to bind charcoal dust, which accumulates at the charcoal depots, rolling the mixture between the palms of their hands to form charcoal balls. The Sudan project uses revolving drums or pans to form charcoal balls from cottonstalk charcoal, using a small percentage of molasses as a binder. Both methods would be technically feasible in Rwanda. Coffee parchment, papyrus and sorghum stalks are available and easily carbonized fuels, while molasses is sold by the sugar refinery on the edge of Kigali for only 2.8 frw per kilogram.

Pending a review of the cost and user acceptance of compressed papyrus briquettes, I would strongly recommend a demonstration/evaluation of agglomerated charcoal briquettes in Rwanda. This work could be accomplished by sending one or more Rwandan consultants (including at least one woman) to Nairobi and Khartoum to understand and document this technology, producing a small quantity of agglomerated charcoal from different fuels and binders in Rwanda, and obtaining user feedback from these fuels.

Appropriate Technology International

NOVEMBER 198
BULLETIN Number 1

INTEGRATED POTATO PROCESSING TECHNOLOGIES IN INDIA

Appropriate Technology International seeks to develop cost effective strategies that increase the productivity of poor people in rural areas in developing countries. ATI's projects focus on appropriate technologies that add value to the resources of the poor. The goal is to establish commercially viable enterprises that are easily adapted for widespread dissemination locally as well as for use in other countries and regions.

The Integrated Potato Processing Technologies project described in this bulletin will provide subsistence farmers in India with alternatives to the immediate sale of harvested potatoes at depressed market prices. Storing potatoes in rustic stores and/or processing them into potato chips and/or potato powder will add value to the harvested produce. Phase I, financed by ATI, will establish 27 rustic stores, 3 drying units and 1 hammer mill. If Phase I is successful, 54 additional rustic stores will be built and 6 additional drying units and 2 mills established; Phase II is expected to be financed by commercial banks via regular lending channels.

EXPECTED BENEFITS

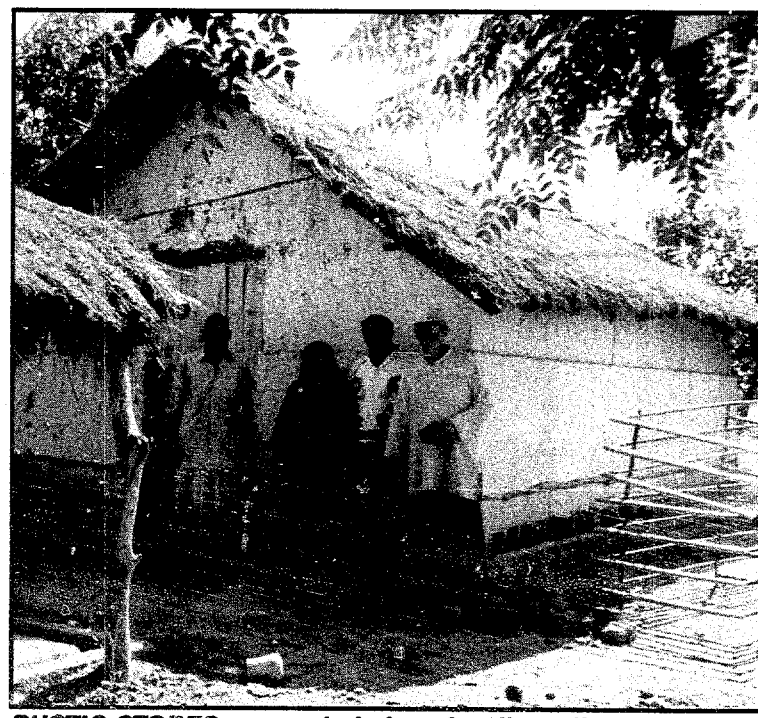
Direct Income: (Farmers' average income in the project area ranges between US$260 and $350.) By the end of Phase II, 75 farmers are expected to increase their incomes by approximately 25%. Storing and/or processing potatoes into chips or powder is expected to add approximately $46 per metric ton to the gross revenues farmers would receive if they sold their potatoes at the farmgate price at harvest.

Employment Creation: One hundred and twenty-six new jobs will be created for unskilled workers from March through June. At this time of year demand for labor is low in the region; wheat threshing (previously done by hand during this period) is now mechanized and school children have summer holidays.

Indirect Income: Marketing potato products and processing and utilizing by-products of potato processing should create additional indirect employment. Starch obtained during potato chip processing can be sold or used to produce starch papads. Discarded potato peels may be processed further into animal feed.

Capital Formation: The sun drying units, valued at $3,213 each, and grinding units, valued at $785 each will be owned by the farmers' society. Individual farm families will own the rustic stores (average 10 ton capacity) valued at $285 each. This combination of joint and group ownership of capital assets is an innovative concept in north India; the project will demonstrate the viability of this model for future replication.

Additional Benefits: Increasing the shelf life of potatoes decreases wastage. At present as much as 25% of the potato harvest (valued at approximately $107 million per year) in India decays because of limited or unreliable cold storage facilities.



RUSTIC STORES are cool, dark and well-ventilated. Potatoes may be stored in these huts for 3-4 months.

THE ATI APPROACH

ATI considers four issues in its projects: (i) the institutions involved and the need for institutional development; (ii) the technology involved and the need for adaptation or further refinement of the technology; (iii) the commercial viability and the need for market development, including credit facilities and repayment schedules; and (iv) policy and replication issues (What factors promote or inhibit the spread or dissemination of the technology to other geographical areas?)

The technologies introduced by this project are called "Integrated Processing Technologies" because each technology is one step in a production process which progressively adds more value to the potatoes. These steps include (1) storage of surplus potatoes, (2) processing and drying of stored potatoes into chips and (3) the milling of chips into powder.

Indian potato "chips" are dehydrated potato slices rather than the potato chips found in Western countries. Potato powder is also known as "potato flour" or "powdered potatoes". Reconstituted with water, potato chips and potato powder can be used in many Indian recipes. The potato chips also can be fried without being rehydrated—these fried chips are traditionally eaten at Hindu festivals.

The rustic storage units are the only element of the technology package new to India. Sun drying and hammer mills are common. However, the project will include research to improve the state of the art of the existing sun drying technology, specifically in the area of quality control and hygiene.

Rustic Stores

The rustic stores are mud huts with thatched roofs, designed to be cool, dark and properly ventilated to ensure adequate humidity during the dry summer months (April through June). The capacity of these huts varies from 5 to 15 tons, depending on the requirements of individual owners. Potatoes may be stored in the huts for at least three months. When not filled with potatoes, they can be used to store ginger, onions, paddy rice and dry fodder.

The floor of the hut is a slotted platform constructed of bricks and strips of bamboo on which potatoes are stacked. A layer of sand underneath the platform is flooded with water. The rustic store operates on the principle of passive evaporative cooling. As water evaporates inside the building, it absorbs heat and lowers the temperature. The hot air rising through a vent in the roof pulls fresh air through vents around the base of the building. This air circulation increases the evaporation rate and continuously cools the inside air.

To decrease radiation from the sun, the store should be constructed in the shade facing south; the outside of the hut also should be white-washed. Chicken wire installed around the outside wall of the hut keeps out rats and other vermin.

Dried Potato Slices

Each drying unit can process a maximum of 1½ tons of potatoes per day. One hundred kg of fresh potatoes yield, on average, 17 kg of potato chips (i.e. 17% yield). Dried p slices will keep for at least a year if sealed in plastic

POTATO SLICES are dried in the sun on stackable, mesh-covered drying racks.

The drying unit occupies a total area of about 3,000 s Equipment used in processing dried potato slices incl a drum washer-cum-peeler, tubs, mechanical slicer, blan draining stands and drying racks. The equipment also c used to dry onions, sweet potatoes and other vegetab

Steps in processing dried potato slices include:

1) Sorting of potatoes. Odd shaped, medium and potatoes, which have low market value, are ideal for proc ing. Decayed, damaged or sprouted potatoes shoul removed.

2) Washing and Peeling. A drum washer-cum-peeler is from a 200 liter drum mounted on an axle made from a Several holes are drilled in the pipe to allow water to flow the drum. The drum is mounted on an angle iron frame rotated by a handle attached to the axle. A grit inside the removes about two-thirds of the skin. A constant flow of in the revolving drum washes out the dirt and skin. After ing, bad spots are removed with a paring knife and potatoes are kept immersed in plain water to pre discoloration.

3) Slicing. Potatoes are sliced to thicknesses of 2-3 m a hand-cranked, pedal-driven or motor-operated slicer. S fall directly into a mesh bag placed in a tub of water. The bath prevents the slices from darkening and mesh reduce handling.

4) Rinsing. Slices are rinsed 2-4 times in fresh water to re free starch. Starch can be saved for further processing

5) Blanching. Slices are blanched by placing 10 kg mesh into boiling water for 3-5 minutes. To ensure even heating bags must be agitated several times. Slices should no overcooked or they will break.

6) Chemical treatment. Immersing potatoes for 7-10 min in a solution of a chemical such as acetic acid keeps slices from turning brown; the slices are agitated 3-4 t during the bath. Hanging the bags on a rack above the drains the water.

7) Drying. Slices are spread in one layer with no overlap in direct sunshine on mesh-covered drying racks. When s curl, (after about 2-3 hours in May-June) they can be stac several inches deep. After stacking, slices should be st every hour until they are completely dry—this takes abou hours. Same size racks can be easily stacked and stor

8) Weighing, Recording, and Packaging. When dry, potat are weighed and production data recorded. Potato slices packaged in 100 kg sugar bags marked with the product date.

Potato Powder

Dehydrated potato slices are inspected to elimin discolored slices and foreign matter before being groun to powder on an electric motor-operated hammer mill. A grinding, the powder is sieved by hand or by a sieving mac to remove large particles which may need to be reground. proximately 200 kg of powder is ground per hour. Powd packaged in 25 kg to 100 kg polypropylene bags enclose outer bags of jute or woven plastic.

The Market
In India, particularly in the northern region of the country, potatoes are a major ingredient of traditional snackfoods. Popular potato-based snackfoods include potato cakes (*tikkis*), potato-filled *samosas* and *pakoras*, shredded potato fries (*sev*), spiced potatoes, and *dosas*.

Decreases in the potato supply in the months following the potato harvest bolster the market for stored potatoes. Cold storage facilities in the project area are always full and in short supply. Potato prices increase dramatically as time elapses after the harvest season. Small to medium bulk amounts of stored potatoes can be expected to be sold in the wholesale and/or retail fresh potato market in local towns and door to door (vendors with carts) to household consumers.

Surveys indicate that the current demand for chips exceeds supply. It was reported that in Delhi in November, 1987, poor quality chips were selling for $1.70 per kg. The chips are sold to intermediate users who will further process or prepare them. This market includes institutions, snackfood vendors in urban areas and restaurants and tea shops along highways and in urban areas.

Because potato powder is a new product in India, the extent of the market is unknown. An extensive market analysis of this product will be undertaken as part of the project. If the results of the analysis are positive, the market will be further developed. Preliminary market research shows that a number of snackfood manufacturers are experimenting with products based on potato powder. Estimated demand for potato powder in 1988 was projected to be approximately 20 tons per month for bulk sales and 10 tons per month for retail sales. However, the viability of the project is not dependent on the production of potato powder; farmers can still earn a fair return on their potatoes by storing potatoes for 3-4 months and/or using the sun to dehydrate them into chips.

Development of a market for a new product such as potato powder may take time. Potato powder initially will be marketed to institutional bulk buyers, e.g. schools, hospitals, prisons, the Armed Services, and manufacturers, i.e. the snackfood industry. Simultaneously, SOTEC through its CIP grant, will be actively developing a household market among the urban middle and upper middle class. SOTEC has developed a set of 30 recipes in addition to a semi-cooked vermicelli-like food (similar to a gram-based traditional snack) which is being test marketed in Bareilly. SOTEC will demonstrate use of potato powder at retail stores, women's clubs, co-operatives, institutions, and religious festivals. Initial marketing efforts may include generous incentives to salesmen and establishing good relations with distributors and retailers.

Price
According to 1987 market surveys in the project area, farmgate prices for potatoes averaged $43-50 per metric ton at harvest time (February-March). By September, the price for potatoes is likely to double. (This cyclical phenomenon which occurs every year reflects seasonal variations in supply.) However, to receive this price, farmers would need to keep the potatoes in cold storage, which is expensive, dependent on an unreliable power supply, and not always available.

The yield of potato chips from fresh, sorted potatoes is 17%; yield of powder is 16.5%. At estimated prices of $0.86 per kg for chips and $1.00 per kg for potato powder, the revenue received from each metric ton of potatoes processed would be $146 from chips and $165 from powder. By storing the potatoes in rustic stores and then processing them into chips and/or powder, farmers expect to realize twice the revenue (after deducting processing costs) they would have earned if they had sold their potatoes at farmgate prices at harvest.

MOTOR-DRIVEN slicer makes 2-3 mm thick potato slices.

Production
During Phase I, the Society will purchase 405 tons of potatoes from its members. Over a 30 day working period, 135 tons of unstored potatoes will be processed. Two hundred and seventy tons will be stored for future sale and/or processing. The product mix between sale of stored potatoes, processing and sale of chips and powder will be determined by market analysis.

Materials and Equipment
Materials for building the rustic storage units are available in the villages, with the exception of a small amount of chicken wire and cement. Equipment for processing and drying potatoes and hammer mills are available locally or manufactured by SOTEC.

REPLICATION ISSUES

One project goal is to demonstrate the ability of the project to secure bank loans for expansion and replication. Once the project's commercial viability has been demonstrated, and commercial loans secured for project expansion, it is anticipated that such financing will be readily available for replication of the technologies in other regions of India and in other countries.

A study is being conducted to assess the feasibility of replicating the project in the Garhwal Hills of Uttar Pradesh in connection with the ATI/IDBI Venture Capital Project for India. In addition, Nepalese development officials have expressed interest in integrated potato processing technologies.

THE INSTITUTIONS INVOLVED

CIP
International Potato Center (CIP), based in Lima, Peru was established by the Consultative Group on International Agricultural Research to bridge the gap in potato research and development capabilities between the tropics and subtropics and the North. Its research emphasizes postharvest storage and processing technologies. The CIP Regional Office will assist in dissemination and replication of the technology and help train farmers to operate the sun drying units and potato powder mills. CIP awarded a grant to SOTEC to develop both potato powder products and the equipment to process these products and to secure markets for these products.

SOTEC
The Society for Development of Appropriate Technology (SOTEC) is a not-for-profit society based in Bareilly, Uttar Pradesh in northern India. Its main objectives are (1) to generate employment opportunities especially for small and marginal farmers and landless people in rural areas and (2) to ensure a fair return for the agricultural produce of small and marginal farmers. SOTEC is responsible for managing the project.

CTI
Compatible Technology Incorporated (CTI), Minneapolis, a private, not-for-profit voluntary group, provides technical assistance to developing countries to combat poverty and hunger primarily through establishing grassroots-level food processing businesses. CTI provided technical assistance to SOTEC in every stage of technology development.

Available from ATI

Manual for Commercial Analysis of Small-Scale Projec
104 pp. $6

Macro-Policies for Appropriate Technolog in Developi
Countries, edited by Frances Stewart, 265 pages, Westvi
Press, 1987. $29.85 plus $2.50 postage and handling. (Ma
checks payable to ATI).

PROJECT IMPLEMENTATION ISSUES

ATI's three year $114,902 grant will enable SOTEC to test
adapt potato processing equipment, conduct market rese
and develop markets for chips and potato powder. Beca
subsistence farmers often need cash immediately after t
sell their crops, a revolving loan fund is an essential elem
of the project. The revolving loan fund in the amount of $21
will provide working capital so the farmers' society can
potatoes from farmers in the group. The farmers' society
use gross revenues to repay the amount borrowed. After
first year, the society will be responsible for obtaining fu
working capital loans from conventional sources. The F
will be used to provide initial working capital for the expan
project, which will likewise repay the loan out of reven
From there it will revolve in similar fashion to finance rep
tion projects. Once the processing system has proven s
cessful, it is expected that the Revolving Loan Fund wil
longer be needed. At that point it will revert to SOTEC.
and SOTEC will jointly determine its further use—most li
to develop new technologies and processes.

APPROPRIATE TECHNOLOGY INTERNATIONAL

Appropriate Technology International is a private, not-for-profit development assistance organization based in Washington,
and operating in Asia, Africa, Latin America and the Caribbean. ATI's program is concerned with the identification, assessm
and adaptation of technology. In collaboration with local organizations in developing countries, ATI develops and tests c
mercial applications of appropriate technologies in the fields of minerals utilization, agricultural products processing, and sn
farm equipment.

ATI implements its mission with public funds made available through the Agency for International Development. ATI's progr
is carried out in cooperation with the Employment and Enterprise Development Division of the Office of Rural and Institutio
Development within the Bureau of Science and Technology.

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Makuza BERTIN, General Manager, Owner, Rwanda Foam

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