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REORIENTING EXPORT PRODUCTION TO BENEFIT RURAL PRODUCERS: ANNATTO PROCESSING IN PERU

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and
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ABSTRACT

This paper describes a simple, labor-intensive production process for annatto, a natural food colorant exported from Peru and other countries. The prospects for the financial and economic viability of decentralized annatto processing are good, provided that managerial problems can be overcome. Moreover, the transfer of this technology to rural areas and changes in arrangements for purchasing the raw materials can increase the benefits to farmers.

KEY WORDS
Appropriate technology, small scale industry, rural development, tree products, annatto, food colorings, cooperatives,

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Introduction

This paper describes a simple technology for production of annatto -- a reddish-orange colorant derived from the seeds of the achiote tree (Bixa orellana) and widely used in foods, dyes, and polishes. A case study of a commercial application of the process in Cusco, Peru shows how an appropriate technology can add value to a primary product through processing and sale for export. The project was also designed to reorient marketing arrangements to benefit rural producers. The technology has a substantial replication potential in many areas of Latin America, the Caribbean, East Africa, and South Asia.

The paper describes the project, the raw material and the product, the supply and demand for annatto, the growing and harvesting of achiote trees, the dehusking of achiote seeds, the annatto processing technology, technical and managerial problems at the plant, the effects of government policies, and impacts of the project on small-scale producers. A financial and economic analysis is also included.

The promotion of exports is often seen as a way for less developed countries (LDCs) to stimulate national economic growth and obtain foreign exchange to purchase imports or repay debts. Too often, however, export industries have been located in urban enclaves, which has increased the dualism between the modern and traditional economies, leaving rural households with limited opportunities for advancement.

One reason for the unequal distribution of wealth between rural and urban areas is that common marketing systems for agricultural products do not allow farmers to participate directly in the transport, resale, and processing of their products. In many LDCs, government policy has favored urban interests over rural ones by keeping food prices low for consumers, establishing parastatals as sole buyers or processors of export commodities, and overvaluing domestic currency.

Where income distribution has been a policy objective, governments have often emphasized land reform or large-scale investments in irrigation or transport. Yet, experience has shown that the ownership of productive resources and the availability of infrastructure are not the only factors affecting rural incomes. Too little attention has been paid to commercial relationships in the marketing and purchasing of rural commodities (Shoemaker 1981).

The processing of agricultural products for export can be designed to increase incomes and employment in rural and peri-urban areas, particularly when exchange relations as well as production arrangements are addressed. In fact, this case study shows that there can be inherent efficiency advantages in locating processing industries closer to the raw material sources. Nevertheless, external support may be needed since it is often difficult for rural industries to arrange financing and to find and retain the critical managerial and technical talent.

Description of the Project

The project grew out of a small grant of $4,700 in 1984 from

Appropriate Technology International (ATI) to ITINTEC, a Peruvian government agency charged with technical research and standards setting. The grant allowed ITINTEC to assess simple technologies for annatto processing and to design a manual dehusker for achiote seed pods. Based on the results of this study, ATI decided to finance a demonstration project for commercial use of the technology.

The follow-on project was designed to benefit the small-scale producers who harvest and prepare achiote seeds by giving them a greater role in the marketing of achiote seeds and the processing of annatto. By working through a marketing cooperative, several layers of middlemen can be avoided so that achiote producers retain a greater share of the value added.

Specifically, the project's objectives were to (1) create a commercially viable plant for production of export-quality annatto, (2) introduce an improved system of dehusking the seed pods, (3) organize the purchase and transport of seeds at local collection centers to give the farmers a more direct outlet for their achiote, and (4) promote new techniques for the cultivation and harvesting of wild achiote trees. Later, the fourth objective was expanded to support nursery production of improved varieties of achiote seedlings and silvicultural extension services.

The project provided a grant to a nongovernmental development organization for provision of credit and technical assistance to establish an annatto processing plant in Cusco. The processing plant would be owned and operated by a rural service cooperative -- the Agrarian Cooperative of Lares. The project budgeted $161,700 for a three-and-a-half year period starting July 1, 1985. It included a loan of $111,500 to the cooperative for physical capital and working capital. The loan repayments are intended to establish a fund to promote other appropriate technologies for the rural poor in the Cusco-Puno region. The plant was installed in May of 1986.

Achiote grows in the Selva Alta, the tropical slopes and valleys along the eastern face of the Andes. Although the selva comprises a large part of Peru's territory, its population density is relatively low. Over the past century, the selva has been the location of several major boom industries: rubber, rotenone, coffee, and petroleum. The government of Peru places a high priority on increasing production in the selva and encourages migration of the landless from the uplands to this sparsely populated area.

Despite public investments in financial and technical assistance, the living standards of most inhabitants of the selva have improved little. Farmers in the region depend on the sale of cash crops such as coffee, coca, cacao, and maize. The regular need for cash is one reason why farmers in the area grow coca, which can be profitably harvested three or four times a year. At least 200,000 hectares (ha) of land in Peru are planted to coca ("En El Pais..." 1988). The Tupuc Amaru terrorist group has connections to the coca trade in this region

The project area is in Southeastern Peru, approximately 160 kilometers (km) from Cusco. It consists of the valleys of Lares, Quillabamba, and Ocombamba in the provinces of La Convencion and Calca (Palomino 1988). The two provinces have land areas of 3,147 km^2 and 36,974 km^2, respectively. The total population exceeds 49,000 in

Calca province and 89,000 in La Convencion (Calsino et al. 1985). Much of the area is remote and the population density averages 3.5 per square kilometer. There are about 6,000 small producers of achiote in the valleys (Reed 1985). The Agrarian Cooperative of Lares was established in 1966 and has a membership of 1,800 small-scale farmers. Its 23 base centers were set up to purchase coffee and provide training for coffee producers.

The Raw Material and the Product

Achiote seeds have a waxy powder-like coating. The use of the seeds in cooking dates back to the Incas (Vasquez 1988). Today, the powder is converted into annatto, a semi-processed colorant containing a carotenoid pigment. Most annatto is produced by a simple, wet chemical process. Annatto powder or paste subsequently undergoes further processing in developed countries to extract the pigment. Solvent extraction is much more efficient, but requires expensive, sophisticated equipment and flammable chemicals.

The pigment can be produced in two forms: bixin ($C_{26}H_{30}O_4$) or norbixin ($C_{24}H_{28}O_4$). Bixin is the oil-soluble form while norbixin is water soluble. Norbixin can be converted into bixin, but the reverse process is difficult (Dinesen 1988). Both forms are sold as either a powder or a solution. Depending on the concentration, these pigments can have a color ranging from yellow to orange, red, or violet (Palomino 1988). They are marketed under such names as international colorant (CI) 75120, EEC Colorant E-16016, Natural Orange No. 4, Lebensmittel-Orange No. 3, bixa, orleans, rocou, and terre orellana. Most of the annatto produced in Peru is a powder with a norbixin content ranging from 25 to 32%. One firm in Lima uses a different process to produce crystallized bixin with a 95% purity.

Bixin is a coloring for oil-based foods such as margarine, salad dressings, edible oil, and peanut butter. Norbixin provides the color for Wisconsin cheddar and other cheeses, some breakfast cereals, and snack foods such as corn chips and cheese-flavored wheat products. Nonfood applications are a small proportion of annatto consumption; they include dyes for lipstick, suntan lotion, textiles, leather, floor wax, shoe polish, brass lacquer, furniture polish, wood stains, nail polish, and hair oil (Ingram and Francis 1969). The cosmetics uses are limited because annatto fades on exposure to light.

Annatto Supply and Demand

Kenya and Peru are the largest producers of achiote, with more than 60% of world supply. Other major producing countries, in decreasing order by volume of production, include Brazil, India, the Dominican Republic, Ecuador, and Costa Rica. In 1987, 3,700 tonnes (t) of achiote seeds were harvested in Peru. Of this amount, 500 t was consumed domestically (either as unprocessed seeds or annatto powder used in soups, rice, and chicken), 700 t was exported in raw form, and 2,500 t was processed into about 200 t of annatto powder. In 1984, 71% of Peru's achiote harvest came from the Cusco area, with most of the rest originating in the Departments of Pasco, Junin, and Ayacucho. Over three-quarters of the Cusco production was from the Quillabamba and Lares valleys (Cader Pachacutek 1988).

Before 1980, Peru only exported the raw seeds. In 1981 and 1982, some exports were in the form of a paste containing 5-10% bixin. Since then, a larger share of the harvest has been processed into annatto powder, as is indicated by growth in the number of privately-owned plants from five in 1986 to twelve in 1988. However, all of these factories were located in the capital city, Lima (Cader Pachacutek 1988). The total installed production capacity exceeds the current achiote harvest in Peru, even though much of the potential raw material is not harvested (Comite de Agroindustria 1988).

Domestic processing allows Peru to gain a larger share of the value added from the product. It also reduces transport costs because the yield of annatto powder is only a small fraction of the weight of the seeds. Furthermore, labor costs for processing achiote are lower in Peru than in the industrialized countries.

Firms in the United States buy 45% of the world production of annatto and another 25% is purchased by companies in Western Europe. Other major importing countries include Japan, Venezuela, and Argentina. A few Japanese firms have entered into joint ventures for annatto processing in Peru and Kenya. Some manufacturers in the United Kingdom use solvent extraction to obtain the pigment for re-export (Comite de Agroindustria 1988). The United States levies no import duty on achiote seeds or annatto, but FDA sanitation requirements must be met (Dull 1988).

The world market for annatto grew slowly but steadily from the end of World War II until the 1980s when it increased sharply. During the 1980s, world consumption required the equivalent of 6,700- 7,800 t of seeds per year (ATMA International 1988). Annual growth in the demand for annatto has been estimated at 7% (Yurica 1986) or 3-10% (ATMA International 1988), but may have slowed to 2-5% more recently (Patterson and Read 1989).

Growth in the demand for annatto has been stimulated by concerns over the safety of some synthetic food colorings, which, unlike annatto, have been found to be carcinogenic. However, annatto is more expensive and less concentrated than coal tar derivatives (Dull 1988). Although synthetic carotenoid substitutes for annatto are available, they are unlikely to make major inroads in the demand at current relative prices (Comite de Agroindustria 1988). Annatto is reasonably heat stable, but requires opaque packaging since the color is affected by light, but this is not a problem in dairy products, which are stored in the dark in refrigerators (Morris 1981). It is also sensitive to food preservatives containing sulfur dioxide.

Between 1975 and 1980, the f.o.b. export price of Peruvian achiote seeds averaged $0.92/kilogram. It declined to $0.68/kg for 1981-85, and increased dramatically to $1.68/kg in 1986 (Ministerio de Industria, Commerce, Turismo e Integracion, MICTI, cited in Cader Pachacutek 1988). In 1-t lots, the delivered price of high-quality achiote seeds in North America was $800-$1,200 in mid-1989, well below the $2,200-$2,600 level of late 1986 and early 1987 (Patterson and Read 1989).

The export price of a kilogram of powdered annatto with a 25% norbixin content has also fluctuated: $1.24 in 1980, $1.82 in 1982, $7.76 in 1984, $18.00 in 1985, $42.50 in 1986 and $59.42 in 1987 (MICTI and ICE, cited in Cader Pachacutek 1988). Annatto prices were unusually high in 1986-87 due to a drought in Kenya and speculation (Comite de Agroindustria 1988). The price fell to $30.00 in 1988 and to $20 in 1989 due to the rapid devaluation of the Peruvian currency. The price paid for a particular shipment of annatto varies in proportion to its actual pigment concentration.

The run-up of annatto prices stimulated entry of many new harvesters and processors into the market, expanding the world supply. At present, the price is depressed as a result of producer and user inventories accumulated after the shortage abated. In addition, government subsidies in some countries have allowed sellers to make low bids and remain in the market.

Despite anticipated demand growth, future price increases may be tempered by increases in production from high-yield plantations recently established in Costa Rica and Brazil. However, political instability in Peru could lead to higher world prices if there are disruptions in the harvesting or transport of achiote, or processing and export of annatto. Another factor that may increase annatto prices would be a ban on some of its substitute food colorings.

The composition of the demand also has shifted. Annatto powder with a 25% norbixin content is currently the form in most oversupply. The demand is greatest for concentrated annatto powder with a pigment content of 32-40%. Some buyers prefer high-quality achiote seeds with a pigment concentration of at least 3%, which they can process themselves.

The Growing of Achiote Trees

Achiote is a small tree that reaches a maximum height of 5-10 m and bears clusters of brown or dark red seed pods with fleshy spines. Although native to the Amazon basin, this species is now found in tropical valleys in many parts of the world. Since it requires little attention, achiote often grows wild along river banks and irrigation ditches.

Achiote does best in a warm, humid climate with temperatures between 24°C and 30°C and rainfall of 1,500-2,000 mm per year, although it will grow with only 1,000 mm of annual precipitation. It prefers deep, well-drained, loamy soils and elevations of less than 1,250 m (Ingram and Francis 1969; Duke n.d.; Vasquez 1988). Most of the achiote in the project area is found at an altitude of 750-2,000 m (Calsino et al. 1985).

Wild achiote has been commercially exploited in the valley of Lares in Peru for a quarter century. Less than 5% of the achiote trees in the project area were planted (Palomino 1988). The few achiote trees planted were mainly established as shade for coffee plantations.

Until the achiote price increases of the mid-1980s, many Peruvian households did not consider it worthwhile to harvest the seeds of the wild trees. Few small farmers were willing to tend the wild trees or establish new stands because other crops were more profitable and little uncultivated arable land was available (Calsino et al. 1985). As the seed prices rose, the interest in harvesting wild achiote and planting improved varieties increased. Throughout Peru, there are now 2,200 ha of achiote plantations (Vasquez 1988).

Neither the wild nor planted trees receive much care. Most farmers do not use fertilizer, pesticides, herbicides, or irrigation in growing achiote, but they do some weeding. Achiote is a fast-growing tree that can flower after 1 year, but takes 3-4 years to reach peak production (Dull 1988). Then, it is pruned near ground level every two years and allowed to coppice to a height of 3-4 meters. Coppicing increases the production of pods and makes them easier to pick. Still, production begins to decline and drops to a low level after 12 years.

At least 16 varieties of the achiote tree occur naturally in the project area. These varieties differ in both the yield of seeds and the quality of the pigment contained in the seeds (Cader Pachacutek 1988). Depending on the variety, an achiote tree bears 1-5 kg of dried seed per year. Average yields in Peru are low, 400-600 kg of seeds per hectare, because the trees are dispersed and are not intensively cultivated (Cader Pachacutek 1988; Vasquez 1988). With irrigation and fertilizer, mature trees can provide two harvests per year. If properly cultivated, better varieties could produce 1,750-3,000 kg of dry seeds per hectare (Yurica 1986). Plantations in Costa Rica are already achieving yields of 1,500-2,000 kg per hectare (Cader Pachacutek 1988). Between 1985 and 1988, over 25,000 achiote trees of improved varieties were planted in Costa Rica using private capital (Dull 1988).

The concentration of pigment in the seeds of different varieties ranges from 1.5% to 5.0%, but is typically 1.7% to 2.7% in the project area (Begazo 1985; ITINTEC 1985; Montesinos 1986). Often, the shape of the pods and color of the seed can provide an indication of the yield and quality of pigment (Osorio and Perez 1988; Vasquez 1988). Some varieties have pods that tend to open prematurely, allowing moisture to enter and ruin the colorant.

Most people who harvest wild achiote are aware of the differences in pigment quality, but collect whatever seeds are easily available because no price premium is paid for high-quality seeds. A sample of achiote producers in Peru harvested an average of 1.4 ha of wild trees, collecting 480 kg of seed per year (Calsino et al. 1985). Farmers who plant seeds form wild achiote trees try to choose seeds from high-yielding trees, but predicting the yields of trees grown from seed is difficult because achiote cross-pollinates in mixed stands.

Although the project originally concentrated on the harvesting of wild achiote, it did have a small component for demonstration plantings and field trials of improved varieties. Plantations of improved achiote varieties could supplement farmer incomes, especially if coffee prices are low or coca cultivation is limited. Consequently, the project later devoted more attention to providing farmers with better planting stock as well as information on improved cultivation techniques for both wild and planted trees. In the long run, improvements in growing the trees and selecting seeds will be important to insure a sustainable supply of raw materials for production of a high quality that can be readily marketed for export.

Table 1 lists the estimated costs of establishing a 1 ha achiote plantation in the Valley of Lares. It omits harvesting, threshing, and transport costs, as well as the opportunity costs of

TABLE 1. Plantation Establishment and Maintenance Costs for One Hectare of Achiote in the Valley of Lares (U.S. dollars)

Expenditures By Year

Item	**1**	**2**	**3**	**Total**
Seedlings (635)	38			
Fertilizer	15	20		
Herbicides	2	4		
Land clearing and preparation	87	25	26	
Transplanting	10	49	26	
Subtotal	152	98	52	302

Source: Acuna *et al*. 1985

the land. The first full harvest would be in the third or fourth year with an expected yield of 1,500 kg of seeds. Except under special programs, many small-scale farmers find it difficult to qualify for bank loans because they lack formal land titles and obtaining a certificate of land possession can take a farmer over 37 days of lost labor plus direct costs (Palomino 1988).

Thus, an agreement in 1987 with the Banco Agrario del Peru, a government development bank, set up a loan fund of nearly $867,000 for seedling production, trials of different cultivars, and commercialization of achiote in the Cusco area. These loans carried a highly subsidized interest rate given Peru's inflation rate and there was a 2-year grace period. Cader Pachacutek screened applicants, collected loan repayments, and provided technical assistance to farmers in exchange for a promised 5% loan fee from the Bank. The Agrarian Bank's loan fund was supposed to establish 660 ha of new achiote plantings over a 3-year period, primarily targeting farmers with 1-2 ha of available land.

Due to the bank's financial difficulties, it was only able to approve loans for 172 hectares of new plantations in the project area and the borrowers just received half of the agreed loan amounts. The Agrarian Bank had previously financed another 1,733 ha of achiote plantations in La Merced and 800 ha in Cusco (Cader Pachacutek 1988). In October of 1988, the bank stopped making loans for anything other that basic food crops.

With funding from ATI and the Agrarian Bank, an achiote nursery was set up in the Lares Valley and another in the La Convencion

Valley. These two nurseries had produced over 450,000 achiote seedlings by March of 1988. Subsequently, it was decided to decentralize production and distribution of seedlings to reduce transport costs and broaden the demonstration effects for local farmers. In mid-1988, the project received a grant of $2,800 from American Jewish World Services to establish 40 dispersed, rural nurseries of 1 ha each. By the first quarter of 1989, 17 of these small nurseries had been established.

The Harvesting of Achiote

Achiote pods are harvested when they are woody, dry, and about ready to split. Although previously hooks were used to lop off the pods, that can damage the trees. As a result, most producers now cut the pods by hand with shears. Most wild achiote trees are harvested once a year over the course of 1-3 months. Some varieties can yield two harvests under favorable conditions. The time of harvest also depends on the location and altitude, and available labor. It starts in July and declines by November, although some may be available until January (Cader Pachacutek 1988; Vasquez 1988). The achiote season does not conflict with peak harvesting times for coffee (May and June) or fruits (November to January).

Most of the labor for harvesting achiote comes from the household, rather than hired workers. Occasionally, neighbors use traditional labor-sharing arrangements (Calsino et al. 1985). The opportunity cost of achiote harvesting time may be less than the casual agricultural wage rate because it is difficult to obtain paid employment during the season when achiote is harvested and some of the work is done by children. In 1986, the casual agricultural wage in Lares was $2.00 per day plus one meal worth about $0.40.

Typically, it takes less than 1 person-day to harvest 100 kg of achiote seeds, depending on the distance between the trees. Since achiote is a short tree, it can be harvested without much climbing. The pods are left outside to dry on mats until they split open, which usually takes 2-4 days in a sunny period. If the seeds are not dried enough, they may become moldy but over-drying can also spoil the color.

Threshing and winnowing is the next step after drying. This takes an additional 6-7 person-days per 100 kg of seed. Traditionally, most threshing and winnowing of achiote is done by beating the pods with sticks on the open ground or a cement floor. Because the beating can cause a large loss of the pigment, some producers have adopted the more time-consuming method of opening the pods by hand. In either case, the seeds are separated from the hulls by sifting them over homemade screen filters or simply letting the wind blow the light hulls away. Threshing and winnowing are done by adult men and women as well as children. Using the slow traditional process, one worker can only prepare 15 kg of seeds in a day.

Before this project, over 90% of the farmers in the area sold achiote at local markets to merchants/truckers who would resell it to warehouse owners in the regional centers of Cusco and Quillabamba. The merchant/truckers purchase other crops beside achiote and try to fill their limited cargoes with the crops that yield them the most profit per unit space. Until a few years ago, achiote had a limited demand and brought a low price. After going through several layers of buyers, the achiote reached exporters or processing plants in Lima.

There was little price competition among the buyers because they often carved out local territories for exclusive purchasing. The short harvest season, perishability of the crop, and remoteness of the areas forced achiote producers to compete with each other. A producer holding out for a higher price, could end up unable to sell the crop at even the original price offered. As a result, a large share of the total profits went to the middlemen and many farmers expressed frustration with these arrangements.

Previously, merchants would either pay in cash at the time of sale or offer producers a form of credit by paying a fixed price in advance of the harvest (Calsino et al. 1985). Advance purchase agreements also protect the merchants in case prices rise and are usually set low enough to minimize their risks from changes in world market prices and inflation. However, almost all achiote purchases are now made in cash because of Peru's high and unstable inflation. Some merchants also assist their clients by bringing consumer goods across difficult mountain roads to small markets.

In La Quebrada, about fifteen merchants buy produce from the farm population of approximately 3,000 families. In 1986, farmers received $1.23/kg of achiote. The truckers received $1.34/kg, earning a 10% margin for transporting it to merchants at local collection centers. The merchants then sold it in Quillabamba for $ 1.78/kg, a gross margin of over 32%. There was an additional margin of 10% or more on shipments to Lima.

One important goal of this project was to break the monopoly of the local middlemen by organizing the purchase and transport of achiote directly from the cooperative's twenty-three local base centers to the processing plant. Most marketing cooperatives in Peru pay farmers with vouchers that may not be redeemable for months or pay low prices on receipt of produce with an uncertain promise of future dividends. Because of the pressing subsistence needs of the producers, an immediate money payment for the full value of the raw material is important. It was also intended that dividends would be paid later to redistribute some of the profits from processing.

The success of a marketing cooperative depends on its ability to purchase all of the achiote offered by its members. Unless a cooperative can be depended upon as a regular buyer like a compadre, producers are unlikely to abandon their former marketing channels. Moreover, it is doubtful that farmers would invest land, capital, and labor to establish achiote plantations without some assurance that their increased production could be sold at an adequate price.

The Dehusking of Achiote

The project was also concerned with upgrading the traditional system of threshing and winnowing through the introduction of a simple, labor-intensive dehusking machine. ITINTEC had designed a simple, hand-operated dehusker to open the pods and separate the seeds from the husks and extraneous matter. The ITINTEC dehusker weighed 60 kg and was supposed to have a throughput rate of 100-150 kg of pods per hour (ITINTEC 1985). The traditional manual method of dehusking can result in a 10% loss of the colorant, and this machine was supposed to cut the loss in half (Reed 1985).

Initially, it was expected that twenty-three dehuskers would be built and placed within 1 km of a major road and 3 km from the bulk of the achiote trees in the project area. Due to a 100% cost over-run, only twelve dehuskers were eventually purchased, but it was thought that they could be transported between base centers. Although eleven of these original dehuskers were in use at base centers, they did not work very well. They only opened 25-30% of the pods in a single pass and failed to reach the rated throughput. They also did not keep the husks separate from the seeds and were not sufficiently portable.

Consequently, Cader Pachacutek developed a new dehusker by modifying a design used for dehulling wheat (figure 1). Dried achiote pods fed into the hopper of this dehusker are broken by steel teeth mounted on a rotating drum. The rotating teeth pass close to fixed teeth attached to a semicircular stator. Seeds and small fragments of pods fall through a screen and are collected in a bucket, while the larger material moves off the screening table.

The new dehusker is operated by a hand crank turned at 65 rpm, a rate that can be sustained by one worker for 2 minutes. The maximum dehusking capacity is 45 kg of achiote seed per hour with a team of five workers. A fan has also been added to separate the seeds from the pieces of husk, which are lighter.

Preliminary tests indicate that 94% of the pods are opened in a single pass through this dehusker. Recycling the unopened pods through the dehusker is not recommended since it does not increase the

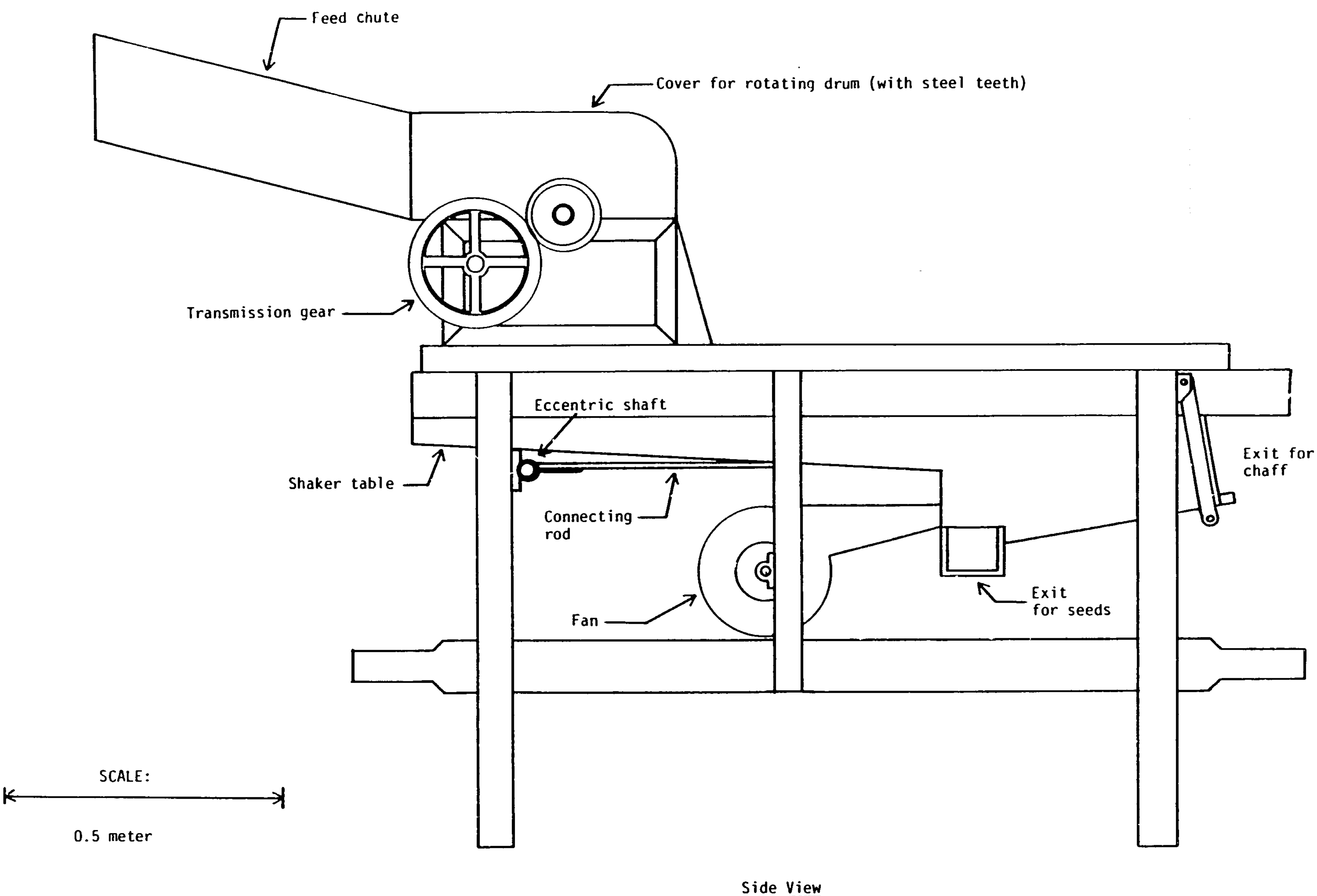

Figure 1. The Improved Version of the Manual Dehusker
SOURCE: CADER Pachacutek 1989

yield significantly. Field testing of the new dehusker should be completed by mid-July of 1989. The estimated production cost of the manual dehusker in Peru is $320, but it could be produced at $200 or less in most other LDCs. A motorized version could be produced at higher cost.

The Annatto Processing Technology

The simple, commercial process for annatto production in Peru relies on the fact that the pigment is not very soluble in water, except in an alkaline solution. Either sodium hydroxide (NaOH) or sodium carbonate ($NaCO_3$) can be used as the alkali. When a strong acid is added to the alkaline solution containing the seeds, a chemical reaction frees the colorant as a coarse precipitate that can be separated by filtration. The process does not require highly skilled labor, but the workers should wear goggles, masks, gloves, and aprons for protection against the chemicals. Potable water and a reliable supply of electricity are also required. The process consists of five steps: (1) extraction through agitation in an alkaline solution and washing, (2) precipitation, (3) filtration, (4) drying, and (5) grinding (figure 2). The Cusco plant uses the same basic technology as most of its competitors in Lima. In fact, nearly all of the equipment for these plants was produced by the same private workshop in Lima.

In the extraction step, a 200-kg batch of cleaned, dehusked achiote seeds is placed in a stainless steel vat containing 400 liters (l) of water and 2.5-3.5 l of a 7% sodium hydroxide (NaOH) solution. An electric-powered agitator is used to stir the contents for 10

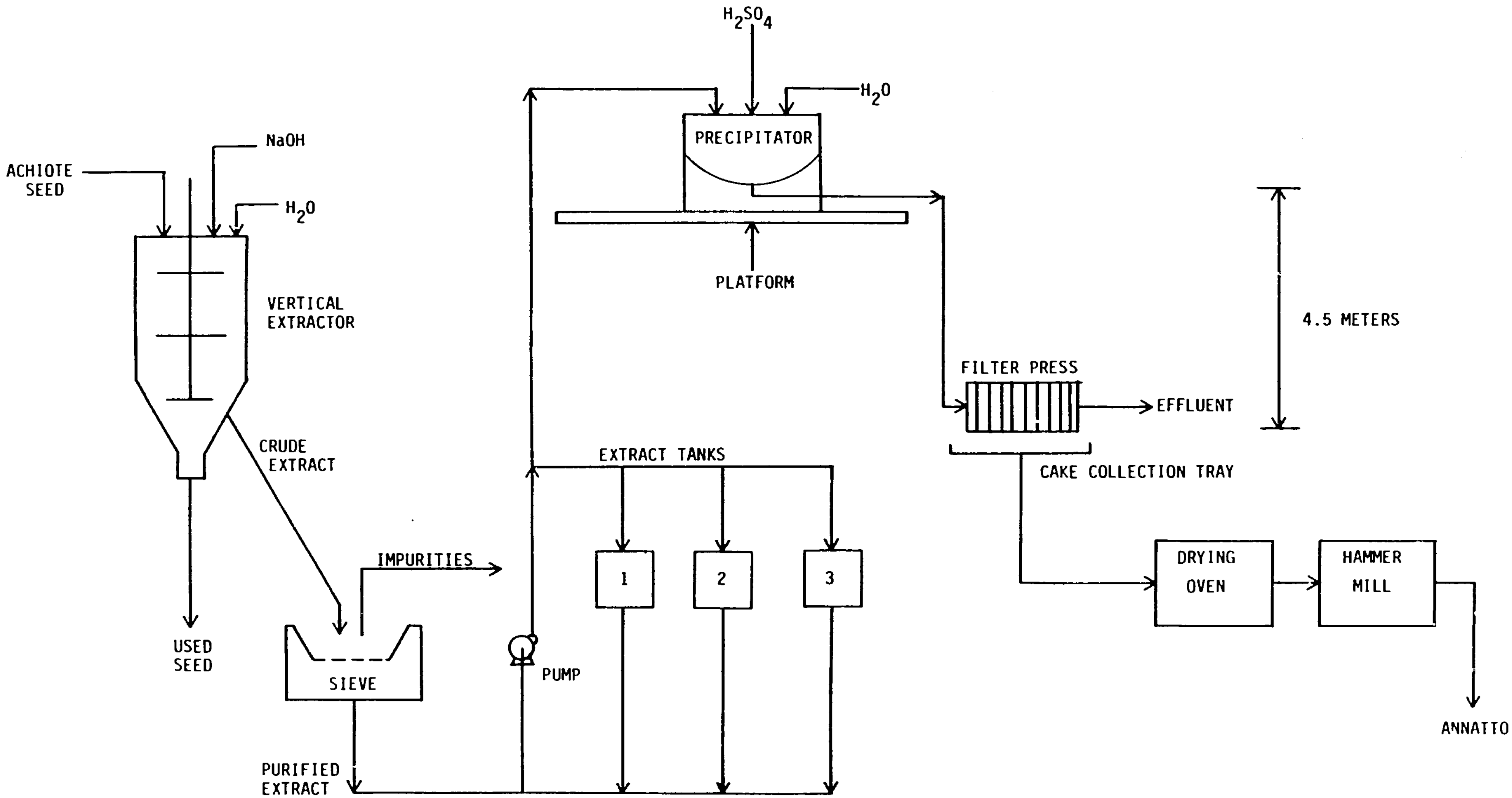

Figure 2. Flowchart for Annatto Extraction

minutes at 130 rpm and then the liquid is drawn through a discharge valve. After that, the liquid is pushed through a 200 mesh screen by hand. Next, another 300 l of water and 1.0 l of the NaOH solution are added. As before, agitation and screening follow.

Then, there are two 10-minute washings in 200-250 l of water. The liquid from the two washings is pumped into the precipitation tank for re-use. A series of hoses and vats allows the washings to proceed without delays in draining and filling. The seeds are allowed to settle to the bottom of the mixing tank and removed through a discharge valve. A spectrophotometer or simply a visual inspection can be used to determine whether the processed seeds still contain extractable pigment.

To separate the colorant from the reddish, alkaline solution, 3.0 l of a 16.3% sulfuric acid (H_2SO_4) solution are added, and the solution is left undisturbed for 4-5 hours until a precipitate forms. The precipitate settles to the bottom of the tank and the liquid is drained off so that the precipitate can be removed. The acid drainage water could be neutralized with sodium bicarbonate before discharge into a sewer.

The two production-limiting steps are filtration and drying. A filter press is used to remove excess water from the precipitate by squeezing the sediment for 8-10 hours. After pressing, a batch is reduced to 16 kg of paste. Between uses, the filters and the whole press are washed with a 1% NaOH solution to recover more of the colorant. The liquid from the washing is used in the next batch.

A warm-air cabinet dryer is used to reduce the moisture content of the paste to 4-8%. The paste from two batches is spread in stainless steel trays. After preheating, the dryer is set at 80°C for the first two hours. The temperature is reduced to 60-70°C for the next 6-8 hours. Higher temperatures damage the colorant.

When the moisture content of the paste falls to 20%, it is removed from the dryer and ground in a hammermill before further drying because large chunks of paste will not dry evenly. It takes 1.75 hours to grind each batch to 1.0-1.5 cm particles. After grinding, the particles are returned to the dryer for another 0.5-1.5 hours until the moisture content is reduced to 4-5%. The total drying time depends on the moisture content of the batches, the thickness of the paste spread on the trays, the relative humidity, the ambient temperature, and the altitude. When dry, the powder is milled again to a finer particle size of 2-5 millimeters. The resulting powder is packaged to prevent absorption of moisture and stored in a cool, dry and dark location.

There are economic advantages to locating annatto processing close to the sources of raw materials. Processing in Cusco instead of Lima saves $0.07/kg of achiote processed in transport costs because the product is less bulky than the achiote seeds. If the plant operates at full capacity, the transport cost savings would amount to nearly $8,000 per year. In addition, location near the producers can avoid the loss of at least 5% of the colorant from friction and exposure to heat and moisture in shipping the seeds to Lima by truck. At the 5% loss rate, with production at full capacity and a sale price of $30 per kg of annatto, the gross value of this savings is $14,000 per year. Furthermore, with a complex distribution chain, the seeds are likely to be stored for a long time. If the seeds are stored for more than three months before processing, another 10% or more of the colorant, worth $28,000, can be lost from heat and moisture. Thus, the total annual savings from processing achiote near the source of the seeds would be $50,000 per plant at full capacity.

Technical Problems at the Cusco Plant

The Cusco plant experienced some technical problems, but most have been resolved. Initially, 2-5% of the recoverable dye was lost due to inadequate washing of the equipment or leakage from improperly attached pipes. Insufficient mixing in the extraction step was a problem until a faster agitator was adopted. Another minor problem was too fine a mesh size in the screen; consequently, a coarser screen has been added before the fine screen.

The pH of the paste produced was too low at first, which damaged the filter press after only a short period of use. Corrosion of the filter press is no longer a problem due to better control of the pH before pressing regular treatment of the filter press with anti-corrosive paint. Proper pH is also important because excessive acidity harms the color of the pigment over time. Since the original filter press was too small, pressing a batch took too long -- 5-7 hours. Recently, the capacity of the filter press has been increased 50% by adding plates to the existing unit.

Initially, the cabinet dryer took as long as 22-30 hours per cycle, resulting in slow production and high fuel costs. This problem with the dryer was resolved through modifications in air circulation that allowed humidity to escape while retaining heat. Also, instrumentation was added for better control of humidity and temperature. At present, the total drying time is 10-14 hours for two batches.

As planned, the expected processing capacity of the plant was 2,000 kg of achiote per day. The plant was supposed to operate at an 80% capacity use rate of 20 days per month and 11 months per year, to produce a total of over 352,000 kg annually (Reed 1985). Due to the bottlenecks in filtration and drying, the actual capacity of the plant is currently 480 kg of achiote per day. A maximum operating time of 9 months per year is more realistic. Trial production began in June of 1986.

With more experience in operation, the pigment concentration in the product has improved. Annatto powder with a pigment concentration of less than 25% can be difficult to sell and the market now prefers a product with a minimum concentration of 32%. The pigment concentration was less than 25% in early production due to the use of old seeds and inadequate control of the acidity of the product. In 1988, the plant achieved an average of 25%. It is now currently producing annatto with 29% norbixin. The yield of annatto averaged 8.25% of the weight of the achiote seeds processed in 1988, but has recently been improved to 9.0 percent.

There are still some problems with the quality of raw materials. First, the average pigment concentration of the seeds is 2%, which is only adequate. Second, the moisture content of the dehusked seeds should be around 7%, but has been as high as 15-20%. When the moisture content is too high for very long, the seeds may show signs of fermentation, mold, or peeling of their outer coats. Since the amount of NaOH needed is determined by weighing the seeds, more chemicals are used if the seeds are heavier due to a high moisture content. However, overdrying can cause colorant losses (Dinesen 1988; Patterson 1988). Third, stones and other foreign matter are often mixed in with the seeds. Since achiote is purchased by weight, this increases input costs.

Obtaining the needed food-grade chemicals is a minor problem in Peru as sodium hydroxide and sulfuric acid supplies are tightly controlled because they are also used in cocaine processing. The annatto plant has to send a representative to Lima at high cost and obtain a license each time it purchases these chemicals.

Managerial Problems at the Cusco Plant

The cooperative received what was expected to be an adequate amount of financing for both its physical capital and working capital needs. In addition to the value of the equipment, the cooperative received $12,000 for construction and $53,000 of working capital for purchase of seeds and chemicals. The total financial assistance to the cooperative was $111,500, which has to be repaid as a loan at 12.5% interest per annum. The loan included a grace period of 1.5 years and the repayment period was set at 5 years. The loan was denominated in dollars because of the instability of the Peruvian currency and the ability of the cooperative to generate export earnings.

Changes in world market conditions and mismanagement led to financial problems that seriously affected the ability of the cooperative to operate the plant at an acceptable capacity use rate and establish a reputation as a reliable buyer and seller of achiote. The working capital loan was supposed to cover the cost of purchasing achiote in the first season, but a cash shortage prevented the cooperative from buying the expected amount of seed.

The main reason for the working capital shortfall was alleged financial mismanagement at the cooperative. This problem was aggravated by an unexpected 144% increase in the cost of achiote, from $0.55/kg to $1.34/kg in 1986. The working capital loan was based on a raw material price of $0.61 per kilogram. Although the sale price of annatto also rose, the plant could not afford to buy enough raw material to operate at a sufficient capacity rate.

Consequently, the profits from the first year of operation were insufficient to purchase enough achiote for the second year. The continued working capital shortage kept the plant operating at a low capacity use rate. The plant processed 29,696 kg of achiote in the 1986-87 season, 22,260 kg in 1987-88, and an estimated 30,000 kg in 1988-89.

The cooperative sought an additional working capital loan from the Agrarian Bank of Peru, but this was not forthcoming because of the bank's own financial problems. In late 1987, ATI provided $11,000 in additional working capital from other project money in Peru. The Brooke Amendment blocked A.I.D. and its grantees from providing new funding because Peru was in violation of its debt repayment obligations to the U.S. government.

Due to losses in its coffee operations, the Agrarian Cooperative of Lares verged on bankruptcy. By mid-1988 the cooperative had only paid back $29,000 of its working capital loan and none of its physical capital loan. The structure of the cooperative, with its leadership based in Cusco and the members an 8-10 hour car trip away may have contributed to its managerial problems. Subsequently, the cooperative held an election to change its management. The Cooperative Alto Urubamba has also become involved in collection and transport of achiote for sale to the plant. Several cooperatives have been approached to determine if they are interested in an investment position in the Cusco plant, but have expressed reluctance to share ownership with another cooperative.

In late 1987, as a result of managerial concerns, ATI changed the implementing organization charged with providing assistance and oversight to the cooperative. The new implementing organization, Cader Pachacutek, was given a grant of $30,970 to (1) provide technical and marketing assistance to the cooperative, (2) offer training and extension services to achiote harvesters and farmers, and (3) establish a Joint Management Committee for the processing plant. In late 1988, ATI provided another $23,150 to allow additional cooperatives to participate in the project and make the recommended technical improvements in the processing plant. In mid-1989, an additional $42,000 was provided for further technical modifications and evaluation. The project life was also extended to the end of March, 1990.

Effects of Government Policies

Because of its interest in promoting exports and increasing incomes in rural areas, the government of Peru has created some new institutions and policies in this sector. Unfortunately, some planned activities have not been implemented and, in at least one case, the government has had a negative influence on this annatto processing project. In 1986, the Instituto de Commercio Exterior (ICE) was established to promote open markets, develop quality control programs, and provide assistance in purchasing inputs for nontraditional export products. Decreto Suprema 005-87 created another institution, COREXA, to reduce exportation of unprocessed achiote, protect industrial investments in annatto processing, control raw material prices, and monopolize external commercialization.

To date, COREXA has only implemented a system of providing certificates of possession valid for obtaining loans, licensing product transportation, and negotiating with exporters and buyers. The proposed government program of achiote variety trials, technical assistance to producers, and plant sanitization has not been carried out due to lack of funds.

In 1988, the Cusco plant had a tentative arrangement with a foreign buyer who was willing to pay $1.20 per "point" (each percentage of norbixin in 1 kilogram of annatto). During COREXA's export approval process, one of its staff members leaked this information to another processor in Lima, which was then able to capture the contract at a lower price, $1.10 per point. Strapped for cash, the plant eventually sold some of its annatto inventory to middlemen in Lima in 1989 at $0.70 per point, who then exported it at a much higher price.

Impacts on Small-Scale Producers

Historically, achiote has been less profitable for small-scale producers than other cash crops. Thus, it was viewed as a source of supplementary income that requires little work. Because the producers have immediate needs for cash and the pigment deteriorates in quality over time, achiote cannot be stored to take advantage of possible price increases later in the year.

The prices received by producers have varied considerably from year to year in real local currency terms. Between 1980-82, the farmgate price of air-dried seeds at the Quillabamba and Cusco markets in constant 1980 values averaged 11.9 intis per 45 kg bag. During the period 1983-85, the real price fell to 7.2 intis. It increased to 15 intis in 1986 due to a drought in Kenya, but fell to 11.3 intis in 1987, 10.5 intis in 1988, and 7 intis in 1989.

In terms of U.S. currency, the price fluctuations in Peru were even more dramatic. The farmgate price was $0.48-0.55/kg in 1985. It increased sharply to $2.19/kg in 1986 and remained high in 1987. The price fell to $0.47/kg in mid-1988 and then to $0.31/kg in late 1988 and early 1989. By comparison, Costa Rican farmers received $1.04/kg for higher quality, plantation-grown seed in late 1988.

The distribution margins are large relative to the price producers receive for achiote. In 1988 when local buyers paid farmers $0.35/kg, achiote was resold for $0.44/kg to assemblers with warehouses in Quillabamba or Lares. The assemblers received $0.47/kg from merchant/truckers who in turn sold the achiote to exporters and plants in Lima for $0.61/kg (Palomino 1988).

The main reasons for the variation in farmgate prices of achiote are changes in world market conditions for annatto and speculation. World price fluctuations tend to be large because a small number of firms in the major importing countries dominate trade in the product. Since the cooperative has only bought a small proportion of the seeds sold in the area directly from producers, competition has not yet forced a decrease in the margins of middlemen.

Also, the plant has only purchased achiote at La Quebrada, rather than at the 23 base centers, as intended. Consequently, achiote producers have had to rely on other producers or a middleman to transport their seeds to La Quebrada at an average cost of $0.08/kilogram. The cooperative then trucked the achiote from La Quebrada to Cusco. Thus, although at least two layers of middlemen were eliminated, one intermediary was still left between the farmers and the processing plant.

The project plan stipulated that 10% of the profits after loan repayment would be reserved for reinvestment. Any profits left over after reinvestment would be distributed to co-op members as end-of-year dividends. The implementing organization anticipates annual dividends of $75-100 per achiote seller from processing by the end of 1989, but so far none have been paid due to the low sales.

Financial and Economic Viability of the Plant

Costs

The financial and economic viability of decentralized processing of annatto have been analyzed using data from the Cusco plant on costs of capital, operation, maintenance and replacement. Table 2 lists the cost and expected lifetimes of the plant and equipment. So that the analysis will be more useful to others interested in setting up a similar plant elsewhere, the operating costs and revenues assume provision of adequate working capital. To better reflect commercial credit terms, an 18% interest rate is included in the financial analysis. The economic analysis examines the viability of the processing plant without financing.

To illustrate the present and potential viability of the plant, four production scenarios were considered. At full capacity use, a plant of this scale and technology could realistically process about 112,800 kg of achiote per year. Due to the working capital shortage and delays in making technical modifications, the Cusco plant only used 24% of its capacity in early 1989. With the necessary financing and upgrading, higher rates of capacity use are feasible. Therefore, an addition to the 24% rate, the profitability has been analyzed at capacity use rates of 37%, 54% and 74%. Other assumptions for the analysis are contained in table 3.

The achiote seed costs in the analysis range from the "very low" current price in Peru to the "high" price prevailing there in 1986-87. The "high" price assumption is similar to the current price farmers in Costa Rica receive for plantation-grown seed of improved varieties.

Revenues

A range of four product prices is taken in the analysis. The "very low" product price reflects what the Cusco plant received from middlemen in 1989, while the "low" and "medium" prices are based on

TABLE 2. Capital Costs and Expected Lifetime of Equipment

Item	Cost	Expected Lifetime	Depreciation	Salvage Value
Land	10,000		0	10,000
Used vehicles	20,000	5	4,000	0
Factory building (200 sq m)	9,000	15	600	3,000
Storage shed (300 sq. m)	3,000	15	200	1,000
Stainless steel tanks				
500 liters	3,900	5	780	0
1200 liters	2,400	5	480	0
300 liters	1,100	5	220	0
Ordinary metal tank	670	5	134	0
Washing vat, 660 liters w/6.6 hp motor	5,000	10	500	0
Screens				
200 mesh	150	10	15	0
74 mesh	150	10	15	0
Centrifugal pump w/2.4 hp motor	1,900	5	380	0
Metal platform	3,000	15	200	1,000
Filter press w/15 pairs of plates	15,000	10	1,500	0
Forced convection dryer w/modifications	7,750	8	969	1,938
Hammermill (300 kg/h w/5 hp motor)	3,500	5	700	0
Wheeled stainless steel bin, 150 liters	100	5	200	0
Weighing scale, 500 kg capacity	800	15	53	267
Balance for chemicals, 5 kg capacity	240	10	24	0
Cistern, 10,000 liters	3,000	15	200	1,000
Hoses and buckets	200	2	100	0
Tools	2,500	5	500	0
Fuel tanks (4)	110	3	37	37
Office furniture	600	10	60	0
Office equipment	1,400	5	280	0
Lab equipment	3,000	5	600	0
TOTALS	98,470	203	12,747	18,242

TABLE 3. Assumptions for the Financial and Economic Analysis

* Time horizon of analysis -- 10 years

* Production

Production Scenarios	Batches/ Year	Batches/ day	Days/ Week	Months/ Year	Days/ Year	Achiote Processed Per Year
Full capacity	563	2.40	6	9	235	112,800
A	418	2.00	6	8	209	83,600
B	304	1.67	6	7	182	60,800
C	208	1.33	6	6	156	41,600
D	135	0.87	6	6	156	27,000

* Batch size = 200 kg of achiote

* Yield = 16.5 kg of annatto (8.25% by weight)

* Bixin content of annatto = 25%

* Product price (per percent of bixin content)

  High $1.40/kg
  Medium $1.20/kg
  Low $1.10/kg
  Very Low $0.70/kg

Variable Costs Per Batch

* Purchase of Achiote Seed

  Very High $1.20/kg = $240/batch
  High $1.00/kg = $200/batch
  Medium $0.80/kg = $160/batch
  Low $0.50/kg = $100/batch
  Very Low $0.31/kg = $62/batch

* Chemicals (including delivery and license fees) = $1.17
  98% Sodium hydroxide -- 0.25 kg at $1.39/kg = $0.35
  98% Sulfuric acid -- 0.5 liters at $1.65/liter = $0.82

* Water -- 1.68 m^3 at $0.95/$m^3$ = $1.60

* Electricity -- 30 kW-h at $0.07/kW-h = $2.10

* Diesel fuel for dryer (14 hours for 2 batches)
  3.9 gal at 1.10/gal = $4.30

* Transport for achiote seeds = $14.00

* Burlap sacks for transporting achiote seeds = $0.40

* Filter cloths -- $7.50

* Packaging of product -- $4.66
  Plastic bags at $1.10/bag = $0.37
  Metal drums at $13.00/drum = $4.29

* Transport of product -- $1.75

* Salaries and fringe benefits of operators at $6.84/day

Production Scenarios	Number of Operators	Days Hired Per Year	Costs Per Year
A	5	209	$7,147
B	5	182	$6,224
C	4	156	$1,067
D	3	182	$3,201

* Safety equipment for operators (gloves, masks, air filters) at $40/month per operator.

Production Scenarios	Cost/Month	Months Hired/Year	Cost/Batch
A	$200	8	$3.83
B	$200	7	$4.61
C	$160	6	$4.62
D	$120	6	$5.33

* Second shift supervisor at $10.19/day required in production scenarios A,B, and C

Fixed Costs Per Year

* Salary and fringe benefits:

  Business manager/accountant -- $4,380
  Night watchman --$1,080
  Buyer/marketer --$2,940
  Secretary --$2,060
  Lab technician --$3,550

* Annual audit --$1,000

* Communications -- $1,000
* Rent at coop (office and storage space) -- $1,200
* Office supplies -- $1,600
* Maintenance -- 5% of buildings, vehicles, and equipment
* Insurance -- 1% of buildings, vehicles, and equipment
* Miscellaneous -- $1,000

Financing

* Long-term loan -- Covers 40% of total physical capital costs. Terms: 1 year grace period, 5 year repayment period, 18% interest rate
* Short-term loan -- Covers 100% of working capital requirements for 1 month of fixed costs plus variable costs for 20 days of operation. Terms: 6 month grace period, 1 year repayment period, 18% interest rate.

Replacement Costs

Year 6: $20,000 + 3,900 + 2,400 + 1,100 + 670 + 1,900 + 3,500 + 100 + 2,500 + 1,400 + 3,000 = $40,470

Year 9: $7,750

Years 3,5,7, and 9: $200

Years 4,7, and 10: $110

Other

* Taxes -- full exemption
* Subsidies -- 0 in economic analysis and financial analysis for countries other than Peru. Assumed to be worth 10% of gross revenues in financial analysis for Peru
* Salvage value in year 11: $18,242

what the plant could have obtained if it had been able to export directly. The "high" product price assumes a 27% increase in world market prices over the "medium" price scenario, but it is still well below the price prevailing in 1986-87.

Another source of revenues comes from the incentives that the government of Peru offers to eligible industries. These incentives include an exemption from all taxes, a 25% subsidy based on the gross value of exports of nontraditional products, and a 10% subsidy for export firms located outside of Lima. Nontraditional exports are defined as products that have an incipient market, unstable product volumes, seasonality of production, and high perishability (Palomino 1988). A condition for receipt of the subsidies is that 70% of the foreign currency proceeds must be exchanged at the government's unfavorable exchange rate rather than a commercial bank rate. Moreover, since it can take 6 months to receive the subsidy after filing for it, the local purchasing power of this payment dwindles rapidly under Peru's high inflation rate.

Due to the foreign exchange restriction and inflation, the real value of the export subsidy in 1986 was about 10%. In 1987, a year of major currency devaluations, the subsidy had a negative value because of a 125% difference between the official and black market exchange rates. In 1988, the difference in exchange rates was sharply reduced. The financial analysis here was done with both with and without a subsidy worth 10% of the gross export revenues. Although Peru also subsidizes diesel fuel industrial users, a market price for diesel was used in the analysis to account for opportunity cost.

Table 4 summarizes the results of the financial and economic analysis for the various production and product price scenarios analyzed, at a discount rate of 15% per year. The three variables with the largest impact on the financial and economic viability of annatto processing are production (the capacity use rate), the product price, and the raw material price. Scenario B represents a feasible production rate that should easily be achieved in a reasonably well-run plant, while Scenario C would be a more conservative production rate. Scenario A is optimistic and Scenario D would hold for a poorly run plant. At present in Peru, the raw material price is at the "very low" level, but the "low" price better reflects a long-term average. A conservative sensitivity analysis could rely on the "medium" raw material.

Since the plant cannot control the product price, which fluctuates with the world market, a break-even product price was calculated for each of the combinations of capacity use and raw material price levels. The break even product price per "point" ranged from $0.68 to $1,90 in the various scenarios. Under the most realistic assumptions, the break-even product prices were $0.83 to $1.17.

To calculate the profitability, assumptions have to be made for product prices. Currently, the "low" and "medium" product prices best reflect the present market. Under the most realistic assumptions, annatto processing shows good profitability. The economic IRR was 47-52% at the 54% capacity use rate and 17-22% at the 37% capacity use rate. The plant would be unprofitable under the very low 24% capacity use rate. At the still low 37% capacity use rate, the plant would be viable under the low, medium and high product price scenarios. When

Table 4. Summary of the Financial and Economic Analysis

Production Scenario	Breakeven Product Price	Raw Material Price Level	Assumed Product Price Level ($)[a]	NPV Financial w/o Subsidy ($)[a]	NPV Financial w/ Subsidy ($)[a]	NPV Economic ($)[a]	IRR Economic (%)
A	0.68	Very low	Very low	46,027	98,701	63,484	33
	0.78	Low	Low	277,659	360,433	295,159	87
	0.92	Medium	Medium	243,388	333,686	260,955	80
	1.02	High	High	320,872	426,220	338,484	97
	1.12	Very High	Medium	97,361	187,659	115,018	45
B	0.83	Very low	Very low	(41,567)	(3,266)	(24,129)	7
	0.93	Low	Low	126,855	187,042	144,329	52
	1.08	Medium	Medium	101,928	167,587	1119,458	47
	1.18	High	High	158,264	234,866	1175,832	60
	1.28	Very High	Medium	(4,262)	61,397	13,343	19
C	1.07	Very low	Very low	(109,172)	(83,026)	(91,758)	-19
	1.17	Low	Low	5,795	46,881	23,237	22
	1.32	Medium	Medium	(11,228)	33,593	6,260	17
	1.42	High	High	27,225	79,516	44,742	28
	1.52	Very High	Medium	(83,725)	(38,904)	(66,178)	-8
D	1.45	Very low	Very low	(155,475)	(138,372)	(138,097)	-40
	1.55	Low	Low	(80,271)	(53,396)	(62,875)	-7
	1.70	Medium	Medium	(115,839)	(88,963)	(98,413)	-23
	1.80	High	High	(66,253)	(32,048)	(48,808)	-1
	1.90	Very High	Medium	(138,830)	(109,511)	(121,365)	-33

the capacity use rate increases to 54%, the plant would also be profitable when the raw material price is very high and the product price is only medium.

In most cases, the net present values were of the same sign for both the financial and economic analyses. However, there were two cases where the economic NPV is low, but positive, while the unsubsidized financial NPV has a small negative value at the 15% discount rate. The 10% government subsidy on gross export revenues did not make a large difference in the financial viability of annatto processing. There were only two cases where an unsubsidized enterprise would show a financial loss (returns less than the 15% discount rate), when a subsidized one would be financially profitable.

Three other factors could further improve the profitability of this plant: (1) consistent production of annatto with a higher pigment concentration; (2) sale of by-products, and (3) diversification of the product line. The analysis conservatively assumes a pigment concentration of 25%, but gross revenues would be higher at a concentration of 28% since a higher price could be obtained.

Sale of the spent seeds by-product as animal feed could increase the plant's revenues substantially, perhaps by more than the annatto itself. Before being mixed with other feed ingredients, the spent seeds would be washed, dried for 6-8 hours in a solar dryer, ground in a hammermill, and then dried in a forced-air dryer. Preliminary indications are that spent seeds are superior to maize as an animal feed. To determine whether a diet containing a large proportion of spent seeds might pose any problems in animal growth, survival or reproduction, ATI is supporting scientific experiments in both ruminants and monogastrics. The tests will examine different proportions of spent seeds in combination with various other feeds.

Another marketable item is sodium sulfate, a by-product of the precipitation step. Sodium sulfate could be sold to the detergent, paper or textile industries, but the Cusco plant has not reclaimed it from the drainage water.

Because of the seasonality of achiote processing, diversification of the product line would increase the efficiency of use of the plant, equipment, and fixed labor costs. Eventually, the cooperative would like to introduce turmeric (Curcurma longa) processing at the plant, but has not yet done a feasibility study for this product. Turmeric may be a good choice for this factory because it can be processed during the off-season for achiote, using much of the same equipment and chemicals. In addition, turmeric is already grown in the project area.

Conclusions

Developing countries can gain substantial economic and social benefits from domestic processing of commodities that were previously exported in raw form. Decentralization of primary processing industries is an effective strategy for rural development where appropriate technologies for small-scale production are available and infrastructure is adequate. In some cases, rural industries have inherent efficiency advantages in primary processing over urban firms. Yet, the ability to obtain financing, especially working capital, and to attract and retain capable managers is often a key constraint for rural industries.

Too often, the macroeconomic and sectoral policies of governments place small or rural enterprises at a disadvantage. In Peru, regulations favor established, large-scale industrialists and traders. Small firms generally pay a higher cost for capital and find it more difficult to obtain the foreign exchange for imported equipment. In addition, legal requirements are more burdensome for small firms (de Soto 1986). Regulations and administrative procedures also limit small firms' access to export markets.

More attention needs to be paid to marketing systems for agricultural, silvicultural, and mineral raw materials to allow primary producers to gain a greater share of the value added in distribution and processing. Cooperatives have successfully undertaken the marketing and processing of agricultural products in the United States and some developing countries to channel more of the benefits to farmers. Yet, cooperatives often require external assistance to ensure that they are well managed. Where effective cooperatives do not exist, private for-profit enterprises may be a better alternative.

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