1979 Arizona Jojoba Conference
University of Arizona
College of Agriculture
Office of Arid Lands Studies
Tucson, Arizona
October 15-16, 1979

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Information Packet

1979 ARIZONA JOJOBA CONFERENCE
UNIVERSITY OF ARIZONA
TUCSON, ARIZONA

PANEL I: SITE SELECTION
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OCTOBER 15-16, 1979

SITE SELECTION FOR JOJOBA

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Introduction

No trained plant scientist will suggest that a plant can be grown economically or competitively under the same conditions where the plant grows wild. The fact that jojoba is a tough plant and grows wild under very harsh conditions (its ability to survive at very low moisture levels, high temperatures, infertile soils and freezing conditions) suggests to many people that it can be grown economically and competitively under these same conditions. This is no more true for jojoba than it is for other cultivated crops such as citrus, apples, or corn.

When you find a stand of wild jojoba exhibiting robust plants with a good seed set, it is easy to make the wrong conclusions. The immediate reaction is to assume that if you could duplicate these conditions you could have a successful commercial planting. Some of the errors of such an assumption are:

1. Lack of proper weather records - without long-term weather records for a particular site, it is very difficult to determine the environmental conditions to which the plants have been subjected. Weather records for specific sites of wild jojoba stands are seldom available; usually the closest weather data is recorded at the nearest town where the weather is usually quite different.

2. Lack of knowledge as to the age of the plants.

3. Lack of knowledge as to the survival rate of young plants.

4. Lack of knowledge as to how consistently the plants produce a crop.

If you were knowledgeable on these four points, you would be in a better position to determine the optimum conditions for commercial jojoba plantings.

Nothing is more critical for the successful cultivation of jojoba than the proper selection of the planting site. You seal your fate when you decide to plant in a particular place; you whole future for good or bad depends on this choice! It is, therefore, critical that you not move too fast in selecting land. Many factors influence the choice of a suitable site, and these factors should be weighted individually and in combination with each other before a final decision is made.

You, as a prospective grower, should become well acquainted with the requirements of jojoba before attempting to establish a jojoba planting. This can be done by studing all the available literature on the known cultural requirements of jojoba. You should take every opportunity to gather reliable information from as many viewpoints as possible. You should travel and see research plots and commercial plantings; in short, you should talk to many people with experience in jojoba cultivation. Then you will be better able to make the site decision based on an analysis of what you have read, seen and heard.

After discussions with other plant scientists and growers and from experimental results and observations, I have concluded that certain factors influence the selection of a suitable site for jojoba plantings. It must be pointed out here that although you can always modify the environment or soil to grow a particular crop at a particular site, such procedures can be costly and may make the investment unprofitable. The additional costs may prohibit jojoba from being grown competitively with other crops or with jojoba grown in more suitable locations. This leads me to conclude that the following factors are most important in the selection of a jojoba planting site.

1. Temperature
2. Moisture
3. Soils
4. Wind

Temperature

Of the above factors, temperature may be the most critical for growing jojoba. All species and varieties of crop plants differ in their physiological responses to ranges in temperature. Each operates best within certain well-defined ranges from low to high. Unfortunately, we do not know the temperature ranges for jojoba. The biggest problem seems to be their response to low temperatures. The effects of low temperature on jojoba have been poorly understood and appreciated by many people interested in growing jojoba. Some of this misunderstanding is a result of misinterpretation of the conditions under which jojoba plants grow. Jojoba, in its wild state, is not found everywhere in its natural range but is only found in very specific locations. When it is found in colder areas, it grows on slopes usually interspersed with heat-absorbing boulders or rocks. Air drainage is often accentuated in mountain areas and temperature inversions are very well developed. A valley adjacent to a mountain range may often be 20°F or more colder than the adjacent mountain slopes. Cold air acts much the same as water and seeks lower elevations, where "it pools up" if there is no outlet and forms cold pockets. Under different topographical conditions these cold pockets may very in size from small areas of less than an acre to several hundred or thousands of acres on the floor of a large valley. It is, therefore, important to select a plantation site with topography which provides adequate air drainage so that cold air can easily move away. Low temperature injuries of jojoba may be dependent on the degree as well as the duration of the minimum temperature reached, the moisture content of the plant tissue, and the general physiological condition of the plant. In our germplasm nurseries we have found that when temperatures reached 29°F we have had terminal growth frozen, and at 20-22°F flower buds were killed. During early seedling development, cold may kill entire plantations. As plants increase in age or size, frost may not kill the plants but it will surely reduce yields by reducing plant size and destroying flower buds.

There is still much to learn about jojoba's response to temperature. Many plant species can be hardened-off by reducing the moisture content of the soil during the fall which, in turn, reduces the plant tissue moisture level. This enables these plants to withstand lower temperatures than those with more succulent tissue. This is not true for all plants, and reducing the soil moisture content can weaken some plant species and cause more damage from freezing than if they were not moisture stressed. We do not know whether or not jojoba will respond to hardening-off.

Further studies of jojoba's response to ranges in temperature are needed to determine the following:

1. The cultural procedures you can economically use to lessen cold damage.

2. The amount of cold tolerance that is present in different jojoba plants of the same age and grown under the same cultural conditions. Differences in cold tolerance may be only a few degrees or it can be enough so that the geographic range of the plant can be extended.

3. Whether or not jojoba will respond positively to hardening-off.

4. If cultivars can be selected of plants that set flowers earlier or later so as to avoid freeze damage to the flowers with a corresponding reduction in yield.

5. If low temperatures are necessary for flowering and fruiting as has been reported recently from research conducted in Australia.

6. If jojoba performs best a maximum temperatures of 95-105^{o}F as most temperate zone plants or at higher temperature levels as often reported by other sources.

There are many other questions need to be answered about the temperature relations of jojoba.

Moisture

Few areas of the world provide optimum temperature for jojoba and at the same time provide sufficient natural rainfall distributed so that irrigation is not necessary. Therefore, information on the amount of rainfall and its seasonal distribution at the potential site is essential. The topography of the land under consideration is important not only from the standpoint of air drainage and frost protection but also from the standpoint of plantation layout, type of irrigation system and erosion and flood control. Water, whether in limited supply or in excess, must be condisered in selecting a planting site. In most cases, some type of irrigation is needed for jojoba production; without irrigation water in sufficient quantity and of an acceptable quality there will be little jojoba production. On the other hand, in more humid regions where jojoba production is being considered, if it can be grown there, excess water must be controlled. Three of the most important factors to be considered are as follows:

1. Quantity of water for irrigation.
2. Quality of water for irrigation.
3. Water costs for irrigation.

Quantity of Water for Irrigation

The quantity of water required for irrigating jojoba and is influenced by the following:

a. The amount and seasonal distribution of rainfall
b. Temperature
c. Wind and humidity
d. The age and size of the plants
e. The type of soil
f. The density of the planting
g. The type of irrigation system used

Before planting, make sure there is an irrigation system capable of applying sufficient water during the time of peak water demand. The supply must also be adequate for the needs of mature plants. If jojoba is to be direct-seeded, the area adjacent to the seed must be kept moist (near field capacity) for at least 30 days to get good germination and stand establishment. Under hot desert conditions in Arizona this amount of water can be considerable, especially if hot, dry winds occur during the germination period. After germination, water applications can be reduced.

Quality of Water for Irrigation

You need to know the chemical quality of the irrigation water of a potential site. We do not yet know the magnitude of the importance of water quality for the irrigation of jojoba but we do know that wells pumping from aquifers replenished by water moving slowly from distant sources through various types of underground mineral material may be high in total dissolved salt or in certain ingredients which may be harmful to growing plants. Evaluation of the chemical quality of water to determine its suitability for use in irrigating any crop depends primarily on the analysis of the total dissolved salts and on the concentration of chloride, sodium, boron, and possibly lithium. We do not have standards established for jojoba. Standards would be based not only on the plant's response to the water but also on the nature of the soils being irrigated, the type of irrigation management, and the climate. There is some evidence to indicate that jojoba is tolerant to fairly high salinity levels provided the soils are porous and free drainage and irrigation management is good. We do not know the long-term effect of growing jojoba under irrigation in saline soils using saline water. Until sufficient information is available on water management specifically for jojoba we can profit from management techniques used on similar crops.

Water Costs

As you know, one of the important advantages of growing jojoba in the place of some other crops is its low water requirement. We must, however, consider the rapidly increasing energy costs. It is important that a plantation be located in an area where pumping and other water costs can be kept as low as possible.

Soils

The most desirable soil type for jojoba seems to be one that is coarse, light or medium textured with good drainage and good water penetration. Jojoba requires good soil aeration and has not done well on heavy soils. The type of soil will have a bearing on the efficiency and type of irrigation that can be used. There may be some danger in planting in fields that were previously planted in cotton if Texas root rot is present; greenhouse and laboratory studies have shown that jojoba is susceptible to Texas root rot.

Wind

Jojoba is wind-pollinated so air movement is necessary. The direction of prevailing wind during pollen release time should be considered in the field layout and the location of the male plants to insure good pollination. Although jojoba is particularly adapted to resistance to water loss, wind does increase the water deficit of leaves especially during the hottest part of Arizona summers. Hot dry winds at seeding time not only increases the quantity of irrigation water required to keep seed moist but can also uncover seed leading to disastrous consequences.

Jojoba has a life expectancy of many years. For this reason it is essential that you choose your site with extreme caution. I believe the establishment of a successful jojoba plantation is possible if you will take the time to study the known facts about jojoba and plan carefully before the first plant is put in the ground. Once plants have been planted, careless decisions as to location and layout cannot be easily corrected!

Suggested reading

Hogan, LeMoyne. 1979. Jojoba - A New Crop for Arid Regions. In: New Agricultural Crops. G. A. Richie (Ed.) AAAAS Selected Symposium. 38.

Yermanos, D. M. 1979. Jojoba - A Crop Whose Time has Come. California Agriculture July-August 1979. pp. 4-11.

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PANEL II: ESTABLISHMENT
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OCTOBER 15-16, 1979

ESTABLISHMENT OF JOJOBA IN FIELD PLANTINGS

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Introduction

After a suitable site has been selected on which to plant jojoba, much planning and effort must go into getting a field of plants established. I will be discussing some of the things which you should consider as you proceed to establish a planting of jojoba.

I will divide my presentation into 3 general time-periods relative to planting:

A. Advance planning of your planting

B. Field preparation and planting

C. Maintainance of the field during the first season after planting

Advance planning of your planting

Since jojoba is a long-lived perennial crop, any of the decisions which you make during this advance planning stage are going to affect your operation for many years in the future, so they should be made very carefully. Also, the amount of capital necessary to establish and maintain your planting will depend on decisions made during this planning stage. I will briefly mention what I think are the most important questions you should be asking yourself at this point.

Should you direct-seed, use seedling transplants or use rooted-cuttings? A decision on the type of planting stock you will use should be made early so you can arrange to obtain the stock and the necessary equipment for planting it. Each of the three types of planting stock has certain advantages and disadvantages associated with it, some of which are listed below:

Direct-seeding

Advantages
- less expensive to purchase the stock and to plant it
- easy to plant
- more flexibility at planting time

Disadvantages - wasteful of seed

- plants are slow getting started

- complete stand uncertain

Seedling transplants

Advantages - conserves seed

- complete initial stand

- may save on early irrigations

Disadvantages - initial cost is high

- more difficult to mechanize planting

Rooted cuttings

Advantages - all plants have genetic potential to be high yielding

- known sex, uniform plants

- complete initial stand with desired distribution of males and females

Disadvantages - initial cost is high

- unavailable commercially

Since rooted cuttings are not yet available on a large scale, you will have to decide between direct seeding and using seedling transplants.

<u>How should you select your planting stock</u>? As with any other crop, the planting stock that you use is of primary inportance. However, unlike the situation with most other crops, we don't have a list of tested varieties to select from when we want to plant a field of jojoba. We must collect seed from wild plants or purchase seed from others who have done so. This seed produces plants which vary in terms of shape, yield potential, etc. It's unfortunate that at this stage of the industry, most of you who are planting will have to use such randomly picked seed. However, if you have the choice, there are a couple of guidelines that you can follow in selecting your seed to improve your chances of having a better than average planting. First of all, if possible, select seed from plants that have desirable attributes. We are not yet completely sure what is desireable in a jojoba plant, however, I have listed below some of the characteristics that we look for when we collect seed from wild plants or from plants in our nurseries.

- upright stature rather than rounded or prostrate. An upright plant may require less pruning and be easier to harvest mechanically

- high seed yield, whether due to size of seed or number of seed

- high wax percentage in the seed

- resistant to diseases and insects (as judged from amount of damage present)

- early producer

- annual bearer

- cold, heat, salt and drought tolerant

- seed abscise easily

A second guideline you should follow, if you have the choice, is to use seed from an area that is close to your farm or from an area that has a similiar climate.

<u>What type and size of irrigation system will you use</u>? For most areas in Arizona that are warm enough for jojoba cultivation, supplemental irrigation will be required. The plants might survive without it; however, for consistent production and to be competitive with other growers you will need to have a reliable irrigation system of adequate capacity. Decisions regarding your method of irrigation and size of system must be made early on in the planning stages of your operation. Your capital outlay and the amount of acreage you will be able to irrigate will depend on the type and size of irrigation system you have. Also, irrespective of the system you decide upon, a considerable amount of lead-time will be necessary to get it into operation.

There are 3 basic types of irrigation systems which you might consider using: furrow irrigation, drip irrigation and overhead sprinkler irrigation. Each has its advantages and disadvantages. If you are planting jojoba in a field that has previously been planted with some other crop, the field is likely already set up for furrow irrigation. If so, it would likely be less expensive initially to retain this system. Other advantages of this system are that by watering only in the furrows adjacent to the rows of jojoba you can avoid wetting the entire soil surface and the associated weed problems. Also, on saline soils, furrow irrigation can be used to move salt away from the germinating seed or young transplants.

Drip irrigation is efficient in water use and it also avoids wetting the entire soil surface so weed problems should be reduced. Disadvantages of this system include a high initial cost and a limited life span.

Overhead sprinkler irrigation is more flexible than furrow irrigation in that it doesn't require a carefully graded field. However, sprinkler irrigation wets the entire soil surface which results in inefficient water use. Wetting the entire soil surface can also result in more severe weed problems.

The above discussion has been a very brief summary of some of the advantages and disadvantages of these 3 types of irrigation systems. The best system for you will depend on your specific circumstances; the type of soil you have, water availability and cost, salinity problems, available capital, etc. For a specific answer for your situation, you should consult with an irrigation engineer who is familiar with your area. Specific questions you will want to have answered include: How much irrigation water will be required by jojoba in the area in which you are planting? What size of pump(s) will be needed to serve your acreage? What type of irrigation system should you use? How much will it cost to get this system operating? How much will it cost to operate and maintain? How long will it take to get it into operation? What is the life-span of the system?

What planting pattern should you use? This is another decision which should be made well in advance of the date of planting. The planting pattern you use will greatly influence the number of seeds or transplants you will need.

Between-row spacing The main thing to keep in mind in choosing a row spacing is to allow enough room for machinery operation. We've had experience with 2 different row spacings, 10 feet and 16 feet. Ten feet between rows does not allow enough room for tractor operation. Already, with plants only 3-1/2 years old, it is difficult to drive a small tractor between the rows without injuring plants on either side. We now use 16 feet between rows which is about the same distance that Dr. Yermanos is recommending in California.

Within-row spacing Depending on the type of harvester which is developed for jojoba, we may eventually want a hedge type of planting in which there is little or no space between plants within a row, or we may want an isolated-plant type of planting in which there is enough room between plants within a row to allow for harvest operations.

If you direct-seed or use seedlings of unknown sex for your planting stock, about 50% of the plants will be male. Some of the excess males as well as undesirable types of females must be removed. In your initial planting, you should plant enough plants to allow for these removals. For direct-seeding, we recommend planting a seed every 6-12 inches. For seedling transplants, we recommend planting a plant every 1-1/2 feet. Both of these patterns will result in an uneven spacing of plants within the final planting following the removal of excess males and unwanted females. To achieve a more even plant spacing within the final planting, you could plant clusters of seeds or seedlings at the desired spacing.

<u>Ratio of males to females</u> Jojoba is dioecious (male and female flowers are on separate plants). In nature, the ratio of male to female plants is about 1:1, which means that only about 1/2 of the plants are producing seed. We are fairly certain that higher yields could be obtained from a given area if relatively fewer males were present, however, what the best ratio would be is not known. Ratios of from 1:4 to 1:8 have been suggested. In our plantings, we try to use a ratio of 1:5 (males:females).

<u>When should you plant</u>? When you should plant is based on how cold the winters are in your area and when the soil temperature reaches a certain level in the spring. For areas in which freezing weather occurs during the winter, early spring plantings have a couple of advantages. The seedlings will have a long growing period before the onset of winter which should increase their chances of surviving the first winter. Also, less irrigation water should be required to keep the seed-bed moist in the spring than in the summer. Planting should not be done in the spring until soil temperature exceeds 70-75°F.

For frost-free areas, planting could likely be done from early spring through early fall with a high degree of success.

<u>Will any special treatments be necessary for your field</u>? You should have your soil analyzed to determine if there will be fertility, pH, salinity or toxicity problems. You should also determine whether or not there is a hard-pan in your soil that will have to be broken.

<u>Field preparation and planting</u>

<u>Preparation</u> Your field should be prepared much as a field would be prepared for cotton or other crops. Several extension bulletins have been published giving details on soil preparation for most of the important crops in Arizona. These bulletins can be obtained by contacting your county extension agent. A few points in regard to soil preparation should be emphasized:

- if there is a hard-pan in your soil, it should be broken below where the rows of jojoba will be planted

- if you plan to use furrow irrigation, the field should be carefully graded to assure efficient use of water and adequate salt control on beds

- beds should be well-formed. For both direct-seeding and transplanting, we prefer to plant on an elevated bed of some type. This raises the plant somewhat which should help at harvest and may provide some protection if flooding occurs.

<u>Planting (direct-seeding)</u> For small acreages, the least expensive way to plant is by hand. Beds can be prepared with a bed-shaper that produces a depression in the center of the bed. Seed can then be hand-dropped into the depression and soil raked over them. This method of planting allows for use of mixed sizes of seed and allows for the use of pre-soaked seeds without the danger of injuring them. One person can plant an acre in 1-1/2 to 2 hours by hand.

If you plan to plant larger acreages (more than 20 acres), it may be worth spending the time and money to obtain and set up a planter for planting jojoba seed. A typical cotton planter can be used. All that is required is that plates with the correct size holes be used and that seed be sorted to uniform size. If you have seed of uniform size you will only need 1 plate, however, if you have seed of mixed sizes you will need to sort it and have a separate plate for each size. You risk damaging the seed if you pre-imbibe it and put it through a planter. Also, planting speed should be slow. Jojoba seed is much softer than cotton seed and is easily damaged in a planter.

Whether planting by hand or by machine, we recommend that seed be planted 6-12 inches apart and about 1 inch deep. Seed planted shallower will germinate, however, you risk having predators finding and eating it or having it dry out. After planting the field should be irrigated as soon as possible, and the seed-bed should be kept moist until germination occurs.

<u>Planting (seedlings)</u> As for direct-seeding, for small acreages you may want to transplant by hand. For larger acreages you will want to look into using a mechanical transplanting system.

If your seedlings were produced in a greenhouse, they should be moved to an exposed position for a week or two to harden them before transplanting them into the field.

At transplanting, you should be very careful not to break the roots of the seedlings. Usually young seedlings have only a few roots and these are very brittle and therefore easily broken.

Seedlings should be irrigated as soon as possible after they are transplanted. This is especially important if they are being transplanted on a hot sunny day.

<u>Maintainance of the field during the first season after planting</u>

Maintainance will be discussed in detail in another session, however, I would like to mention a few things which you should be paying attention to during the first season.

<u>Irrigation</u> This is probably the most critical operation you will perform during the first season after planting. It is especially important during the first few weeks. During this period, if the soil is allowed to dry out, transplants which have not yet established good root contact with the field soil may dry out and die. Seeds won't germinate.

<u>Weed control</u> Jojoba is relatively slow-growing during the first season. Fast-growing weeds, if left uncontrolled, can quickly grown over the jojoba plants. As yet, no herbicides have been registered for use on jojoba so you will have to rely on hand or mechanical means of controlling the weeds.

Fertilization The few studies which have been conducted, indicate that jojoba does not respond much to supplemental fertilizer. You may want to put out small test strips of fertilizer to see if you get a response on your particular field. This could be done by side-dressing with different rates of fertilizer after the seed has germinated or after the transplants have established good root contact with the field soil.

Observation Inspect your field often - on a daily basis if possible. Since most of you have had no experience at growing jojoba, frequent observations of the plant will help you gain an understanding of how the plant grows. You will learn to detect early signs of stress in the plant. Also, you will notice insect, disease or rodent problems at any early stage.

Suggested reading

Hogan, LeMoyne. 1978. Jojoba - New Crop for Arid Regions? Crops and Soils November, 1978, pp. 14-16.

Yermanos, D. M. 1979. Jojoba - a crop whose time has come. California Agriculture July-August, 1979, pp. 4-11.

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PANEL III: MAINTENANCE
GORDON FISHER

OCTOBER 15-16, 1979

MAINTENANCE OF JOJOBA PLANTATIONS

It is a great pleasure to be a participant in this conference where again the enthusiasm for our industry runs at a feverish pitch. The fervor is well justified, as our product is both chemically and botanically unique, thus making it valuable and sought-after.

I am sure we would all admit that the basis of our involvement in this new industry is founded upon profit potential and personal satisfaction. The profit potential must be the most important feature for the entrepreneur and the potential, in simple terms, is a function of gross sales less development, maintenance and processing costs. Those of us in the industry can predict with a great degree of reliability the costs associated with the development and processing phases, while the expenses in maintaining a plantation over time are much more difficult to project with the same degree of reliability.

The state of the art of plantation maintenance is hampered by the fact that we unfortunately have very little history upon which we can draw. These maintenance costs over the long term will have great influence on profitability, therefore each cost category must be analyzed in depth and with keen foresight regarding the economic and political climate during the next decade.

Our company farms 9,000 acres to 21 various crops and maintains precise cost records for each crop on each ranch. We have developed and manage 1,000 acres of Jojoba in both California and Arizona.

Let us now discuss a projection of typical maintenance costs for a Jojoba plantation based upon our experiences to date. Please recognize that these costs will vary significantly between farming areas.

Fertilizing

The Jojoba plant grown as a seedling in a nursery environment has responded well to a nutritional program, while young plants growing in the field which were started from either seed or seedlings have shown no response on our soils to any combination of NP&K. Fertilizer has been broadcast and folded into the bed, applied by shank, plus applied as a foliar spray, none of which produced results. We program an application of fertilizer on desert soils the first year and on stronger loamy ground beginning the second year.

Weed Control

This category has been much more costly than originally contemplated. We have performed extensive work with 15 different herbicides and have found serveral successful combinations for our soil types and methods of irrigation. The best herbicide for your soil condition and spectrum of weeds might best be determined by the trial-and-error method. Because the Jojoba has a limited number of feeder roots, control of weed growth can be very important in the early years of the planting. We visualize this industry's growth on land that has not been intensively farmed, if at all, and we will be subjected to a broad spectrum of weeds. It is vitally important that work commence immediately for the registering of herbicides for use on Jojoba.

Cultivation

Because of the seriousness of competition from weeds for moisture and nutrients, cultivation is necessary. The formation of the planting bed to accommodate precise mechanical cultivation equipment is very important. Cultivation of weeds between the rows, although not as vital as cultivation in the plant line, is required to prevent weeds from going to seed. We estimate four to five cultivations per year will be necessary.

Labor

Labor can be categorized into Irrigation, Cultivation and General. The size of the plantation and the type of irrigation system are significant variables which will influence the total labor budget. One man can normally operate one, 160-acre plantation with some help for specific labor-intensive tasks. With the development of Jojoba plantations in the more arid and undeveloped parts of the world, labor is scarce and more costly than in traditional agricultural regions. Consequently, we have found our labor costs running higher than anticipated and the quality of labor less effective than in established farming areas.

One should also realize that besides the normal increases in wages associated with inflation, the employer is being asked each year to contribute a larger portion of funds in the form of benefits in behalf of the employee. Jojoba is generally classified as a crop that is not labor-intensive, but nevertheless, labor costs will be a significant portion of any budget.

Water and Power

This category may have the largest variation in actual costs, which results strictly from the area selected in which the plantation is to be located. The cost of energy to bring water to the surface and disperse the water into the field can singularly be the greatest cost of the farming budget. A careful analysis of the depth of water, along with the recharge of the underground

Water and Power (Cont.)

basin is recommended. One should closely examine the politics of the water issue. During the next five to ten years we foresee changes in water policy that will dramatically affect agriculture.

The quality of water is also important but our experience has been that Jojoba seems quite tolerant of poor-quality water. The application of sub-standard-quality water over time can have adverse effects on the irrigation system. We do not have sufficient knowledge to date to conclusively analyze the long-term effect of poor-quality water on the growth of the plant.

Pest and Disease Control

This cost category can fluctuate greatly associated with nothing else than the area in which the plantation is established. The actual funds spent in controlling pests and diseases on our desert plantations are more than double those of our plantations in a developed farming area.

The problems encountered to date have been:

1) Phythophora parasitica, both in the nursery and in the field
2) Rabbits
3) Gophers
4) Ants which have fed upon the plant and the plastic irrigation system
5) Ground squirrels
6) Kangaroo rats
7) Lizards
8) Aphid
9) False Chinchbug

We have spent funds to date in combatting all of those mentioned.

Replanting, Pruning, Rouging

Some mortality should be expected during the first several years of the planting, and to maintain an economic stand, some replanting, using either seed or seedlings will be necessary. The importance of shaping the plant to facilitate mechanical harvesting dictates that mechanical pruning commence in the second year of growth. If the plant is allowed to sprawl along the ground, this will materially take away from the ability of the machine to accomplish a successful harvest. With most plantations being established from either seed or seedlings, some rouging of plant material will be required. The roughing operation is required to thin out the stand to a reasonable number of plants per acre, to eliminate excessive males and to eliminate those plants which obviously will not be an economic producer. Both replanting and rouging are labor-intensive and will be a costly operation. Once planting material is available with known production history, plantations can be established in the exact configuration desired which will eliminate the labor-intensive task of rouging. This type of planting material is expected to be available on a limited basis in 1981.

Pollinization

The high percentage of female buds that abort may be lessened to some degree by employing mechanical methods to better distribute pollen. The pollen, being heavy and dependent upon the prevailing winds for dispersion, may not be providing adequate coverage of the female plants. A problem which we must work to overcome is the early release of male pollen, ahead of the female flowers' ability to utilize that pollen. The application of chemicals, mechanical methods, and proper irrigation techniques may go a long way toward solving our pollinization problem.

Repairs and Maintenance

The repair and maintenace of both equipment and ranch are typically higher in the first few years as a result of the concentration of operations. The repair of irrigation equipment and in particular that equipment associated with the well may become very costly over the years. A careful evaluation of the inputs that affect this cost category is suggested.

Supplies and Miscellaneous

Supplies and Miscellaneous is typically higher in the early years, again as a result of the higher concentration of activity. The supplies and miscellaneous items required to support ongoing operations are invariably purchased in the first several years and can be a significant expense.

Management and Supervision

Perhaps the most important cost category, as 90 percent of the failures in agriculture today can be attributed to either under-financing or poor management. The significance of having a highly skilled and technical team with a broad base of experience cannot be overemphasized. Very little knowledge can be gained from the textbooks regarding the growing of this crop. Thus, we must rely upon management's basic know-how to provide us with successful decisions. Each plantation may have similar general problems, but the micro-variables of soils, climáte and water often compound the difficulty of arriving at workable solutions which can be applied to all plantations. We have found ourselves doing a great deal of trial-and-error type farming. We have had successes, and we have had failures.

Prepare for Harvest

The preparation of the field for harvest entails the pulling in of any irrigation ditches and smoothing the surface over which the harvesting equipment will pass. Because we do not have natural, uniform ripening of the seed, we will be working with certain chemicals to bring about ripening. All costs associated with preparing the field and the crop for an orderly one-time mechanical harvest will fall into this category.

Harvest

The viability of this industry will be to a great degree predicated on our ability to develop and employ mechanical harvesting techniques. Already, work has begun in this area and actual testing performed. Of great value is the proper establishment of the plantation to facilitate mechanical harvesting. It is recommended that the planting be established on a berm no less than 14 inches above ground level to facilitate the mechanical removal of the seed utilizing the type of equipment that we are developing today. The time required to develop a functional harvester for jojoba is estimated at three to five years. I feel confident that we will achieve our objective of conducting a one-time harvest with a high percentage of fruit recovery and minimal damage to the plant within this three to five-year period.

Processing

The processing of the seed after harvest is simply one of proper drying either using the sun or mechanical drying equipment, then removal of the hulls. Hulling equipment which performs satisfactorily is available from several equipment manufacturers. The extraction of the oil from the seed may be done either mechanically or chemically. A combination of the two may be the ideal because of industry's requirements. No new technology is required to properly process the jojoba bean.

In conclusion, the state of the art for maintaining a jojoba plantation is one of reliance upon past practices which have been successful with other crops, one of trial-and-error, and one of developing new technologies.

As we move ahead in this new industry, let us not forget our obligation to document our successes and failures for what we call "the state of the art" today will become in fact the history books of tomorrow.

9-11-79

1979 ARIZONA JOJOBA CONFERENCE
UNIVERSITY OF ARIZONA
TUCSON, ARIZONA

PANEL IV: HARVEST AND PROCESSING
KENNITH FOSTER

OCTOBER 15-16, 1979

A Processing Scenario for Alternative Jojoba Products

INTRODUCTION

The desert shrub jojoba (Simmondsia chinensis) grows naturally over an extensive area in the Sonoran Desert that covers parts of Arizona, California and Mexico (Figure 1). Jojoba nuts contain a yellowish, odorless, oily liquid (about 50 percent by weight) with unusual properties, commonly referred to as "jojoba oil." Chemically, the oil is a liquid wax made up of non-glyceride esters having a narrow range of chemical composition; the esters are almost entirely composed of straight-chain acids and alcohols.

This unique liquid wax (hereafter referred to as oil) has a wide variety of industrial applications in lubricants, paper coatings, polishes, electrical insulation, carbon paper, textiles, leather, precision casting, cosmetics and pharmaceuticals. Jojoba oil can be hydrogenated to a hard, colorless solid (wax) resembling spermaceti, carnauba wax and beeswax in both chemical structure and properties. New industrial uses are being considered for this solid wax, including food coatings, polish and candles.

Jojoba oil production now comes from the harvest of wild stands in Arizona, California and Mexico; however, extensive plantation development is now underway which ultimately will require commercial processing of jojoba seeds by the mid-1980s. Plants varying in size from 500 tons of seed per year to 75,000 tons of seeds per year will be needed to produce two potentially marketable products--jojoba seeds and raw jojoba oil and two potentially marketable by-products--hulls and jojoba meal. In addition to the basic products, the plants may also produce secondary products of greater economic value from the raw oil such as bleached oil, sulfurized oil, hydrogenated wax and bottled oil. The technological processes to yield these products have been developed already.

PROCESS AND PRODUCT DESCRIPTION

The supply of jojoba seed produced on plantations in the U.S. Southwest could increase from 140 tons to 75,000 tons annually during the next 20 years. To process this seed supply, small plants in this decade and larger plants in the second decade would be required.

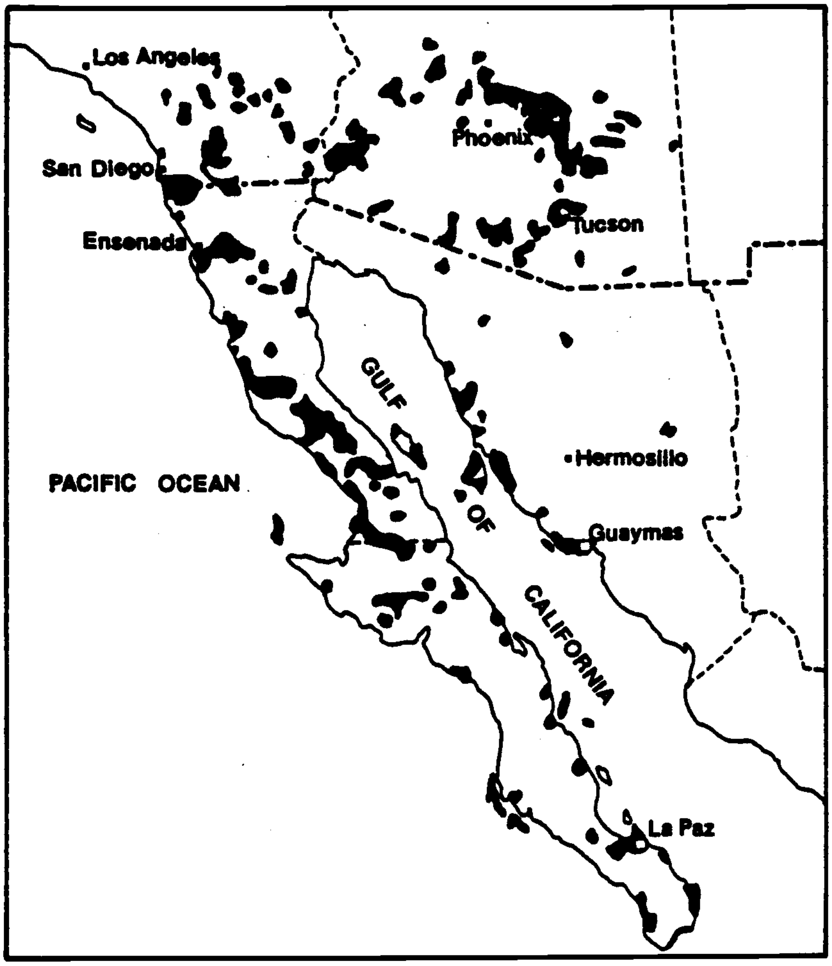

Figure 1. Distribution of Simmondsia chinensis

Processing design has been reviewed under the auspices of a National Science Foundation grant by the Midwest Research Institute in a cooperative research effort with the University of Arizona Office of Arid Lands Studies. The relationships of the possible raw materials, processes and products in the jojoba processing plant are shown in Figure 2. At each stage in the process, the output from a particular process can be considered a marketable product, or as a raw material for further processing.

The first four products shown in Figure 2 can be considered the primary products and by-products of a basic jojoba processing plant, and the others can be considered secondary products obtained from the raw oil. To produce the four basic products requires four separate processes: a) pre-processing; b) mechanical or mechanical/solvent extraction; c) meal grinding and storage; and d) product packaging. Figure 3 shows the process flow diagram for a basic jojoba seed processing plant. To produce the four secondary products requires five separate secondary processes: a) sulfurization; b) bleaching; c) hydrogenation; d) bottling; and e) product packaging.

The basic and secondary processes are described below. The basic processes are briefly discussed and details on the equipment and operations required are described in the next section. The secondary processes are described in more detail.

Basic Processes

Preprocessing: Unhulled jojoba seeds as received from agricultural harvests will contain varying amounts of moisture and trash. Truck-loads of the harvested seeds will be sent to the processing plant, weighed in the truck, and then unloaded either to a bin or onto the ground.

The seeds in the unloading bin will be conveyed to a batch dryer to remove moisture, and then to a cleaner to remove trash. The dry seeds will be stored in a large bin beside the plant building.

The seeds will be conveyed to a bar huller to remove the hulls. Hulls and seeds will be conveyed to a shaker and then separated. The hull will be conveyed to a storage bin beside the plant building; the seeds will be conveyed to a separator. The clean, dry seeds will be conveyed to either a weigh hopper for bagging or to a seed storage bin to be held for mechanical extraction.

Mechanical extraction process: The jojoba oil will be mechanically extracted from the seeds in a mechanical oil expeller commercially available for processing soybeans, cotton seeds, etc. The seeds will first be conveyed from the storage bin to a chopper for flaking and the flaked seeds will be cooked and dried in a cooker-dryer. The

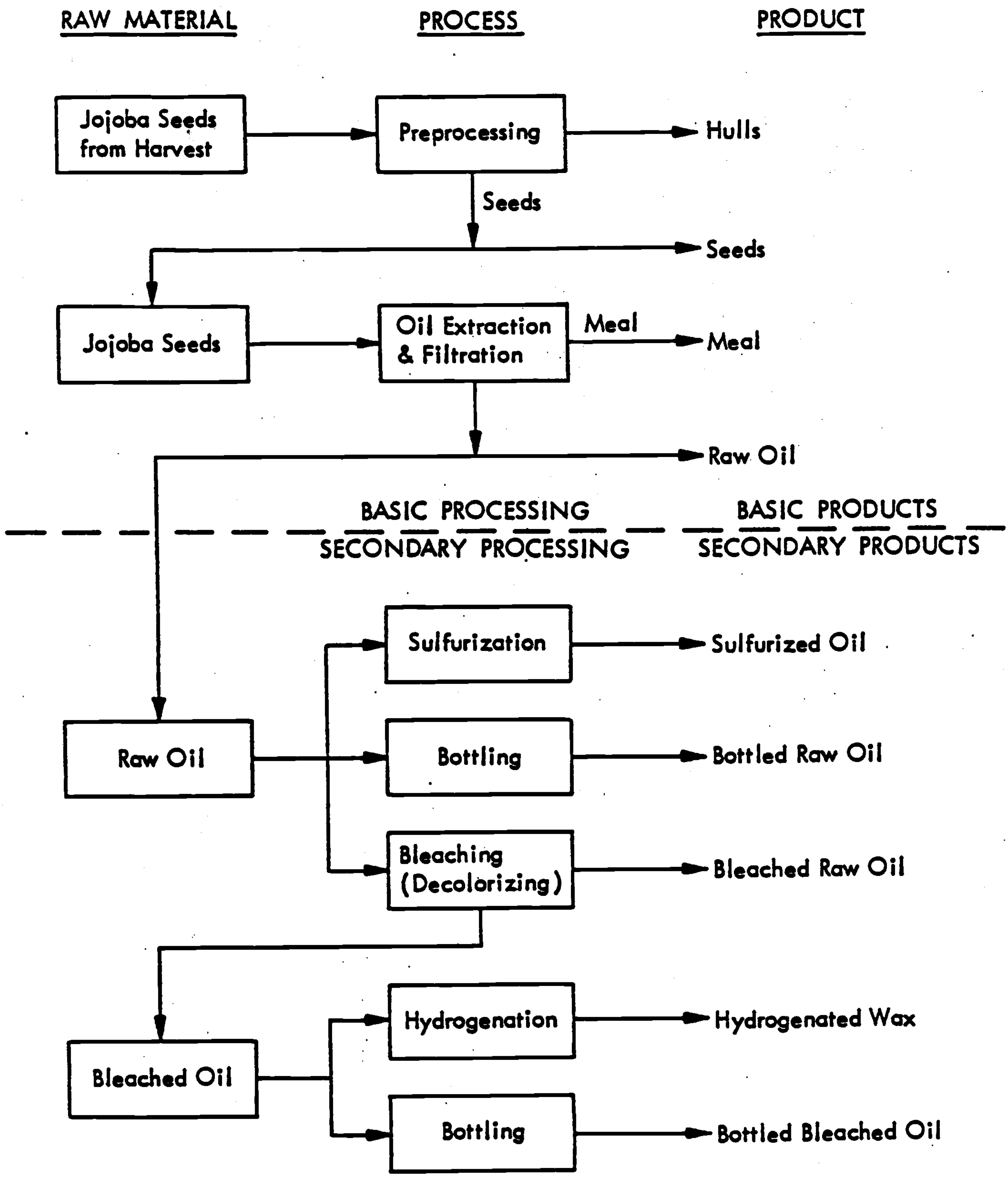

Figure 2. Raw Material, Process, and Product Relationships for Jojoba Seed Processing.

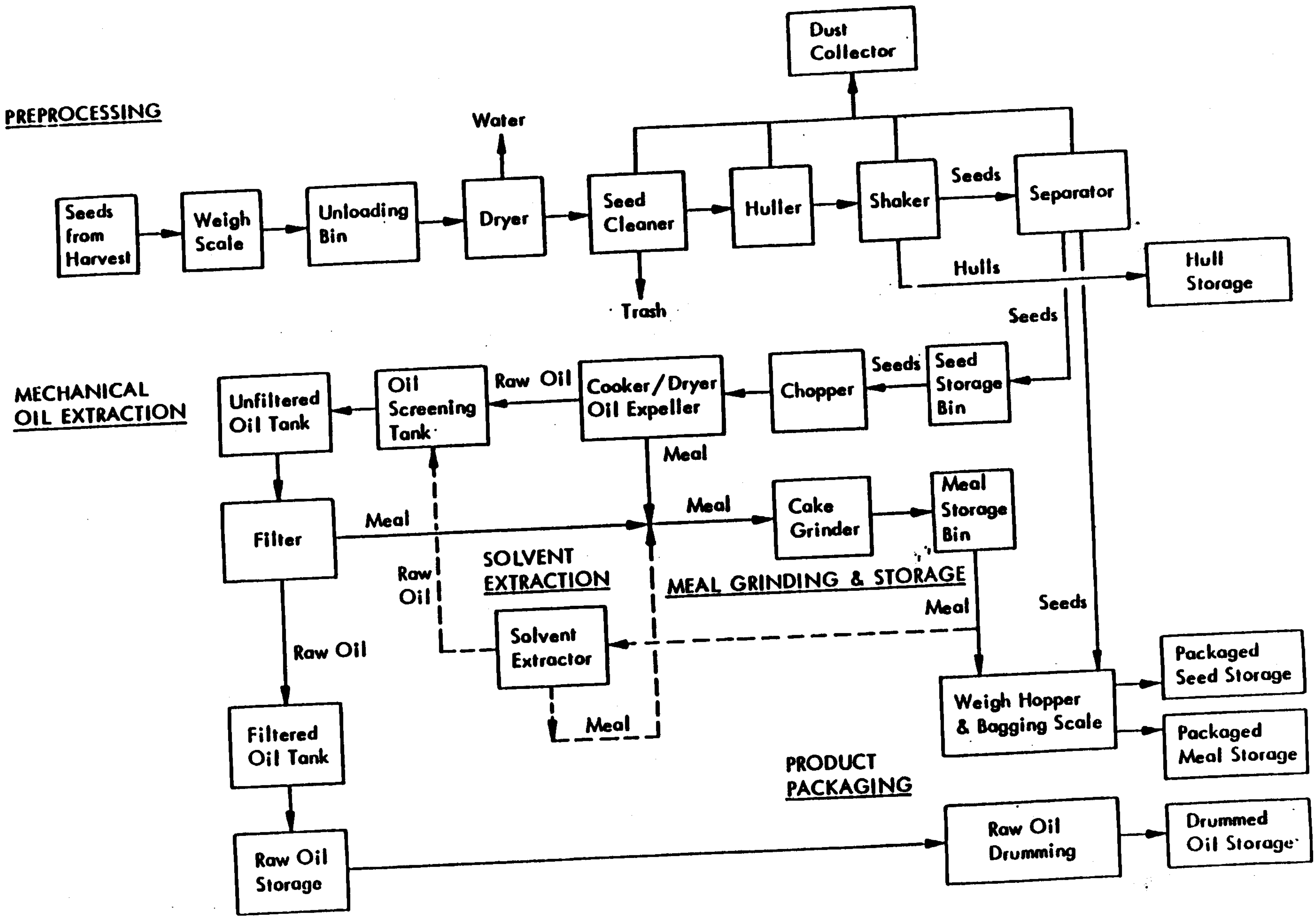

Figure 3. Process flow diagram for a basic jojoba seed processing plant.

hot, dry flaked seeds will be pressed in the oil expeller to yield raw oil and a meal which will be conveyed to a cake grinder for further processing. The raw oil will be piped to a screening tank, filtered to remove any residual meal or other impurities, and then piped to a raw oil storage tank. The meal collected by filter also will be fed to the meal cake grinder.

Mechanical/solvent extraction process: Solvent extraction is used to recover residual oil left in the jojoba meal. Jojoba meal from the oil expeller will be ground and stored in bins prior to solvent extraction. The meal will be passed once through a two-stage Crown Iron Works solvent extractor to extract the oil from the meal with hexane. Desolventized oil from the extractor will be processed in the same manner as oil from the oil expeller, and meal from the extractor will be reground, weighed and packaged.

Meal grinding and storage: Jojoba meal will be conveyed from the oil expeller (or solvent extractor) and filter press to a cake grinder which will size the meal. The sized meal will be conveyed to a storage bin for storage prior to packaging.

Product packaging: The raw oil in the storage tank will be drained into 55-gallon steel drums for shipment. The seeds will be conveyed from the separator to a weigh hopper with bagging scale and will be put into bags. The meal will be conveyed from the meal storage bin to the weigh hopper with bagging scale and will be put into bags. The hulls in the storage bin will be loaded into trucks or placed in bags for shipment.

Secondary Processes

Bleaching process: Mechanical extraction yields raw jojoba oil which is slightly yellow in color. In some products and uses, it may be desirable to have a colorless oil. The color in the natural raw oil can be removed by passing the oil through a filter medium, such as diatomaceous earth or activated carbon, which adsorbs colored impurities. In this analysis, the process that will be used to bleach (decolorize) the oil will be adsorption upon activated carbon in a gravity downflow column. The carbon dosage (i.e., the pounds of carbon per pound of jojoba oil) required to remove the color is assumed to be 3 percent, and the retention time (i.e., the length of time the oil must remain in contact with the activated carbon to remove the color) is assumed to be 30 minutes (usually equilibrium is achieved within 30 minutes).

Figure 4 shows the process flow diagram for bleaching 10,000 pounds of jojoba oil per day. Raw jojoba oil from a storage tank will be piped (at a flow of 3.0 gallons per minute) to the activated

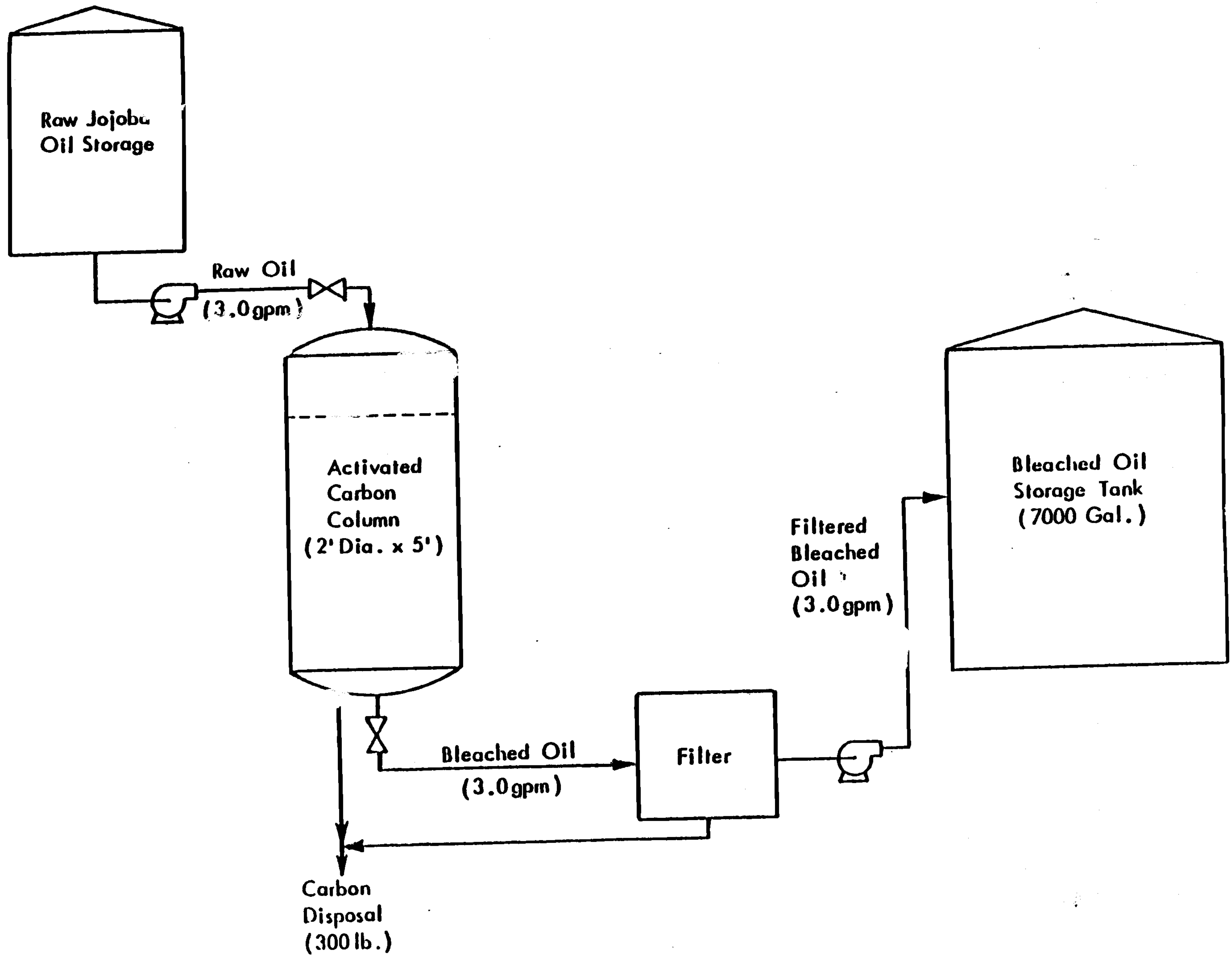

Figure 4. Process flow diagram for bleaching 10,000 pounds of jojoba oil per eight hour day.

carbon column, passed through the column, filtered, and then stored in a tank. The carbon in the column and the filter unit will be sent to a commercial firm for regeneration or disposal.

Given these two assumptions, the column is designed (using current technology) to process 10,000 pounds of jojoba oil and will require 300 pounds of fresh activated carbon per day. The activated carbon has a density of 25 pounds per cubic foot in a packed column. 2/ The volume of carbon required will be about 12.0 cubic feet, and the volume of the column will be about 16.0 cubic feet, assuming the column is 75 percent filled with carbon. A column with a 2-foot diameter and 5-foot height will be used to contain the carbon. The flow rate of the oil (with a 30-minute retention time) will be 3 gallons per minute or 0.95 gallons per minute per square foot in the 2-foot diameter column. (A typical rate of water through activated carbon is 4 gallons per minute per square foot, but can vary widely. 2/ Since the liquid in this process is oil, a low flow rate of 0.95 gallons per minute per square foot is appropriate.) These calculations are shown below.

Carbon Dosage	=	(10,000 lb. oil) (0.03 lb. carbon/lb. oil)
	=	300 lb. carbon
Carbon Volume	=	(300 lb.) ($ft.^3$/25 lb.) = 12.0 $ft.^3$
Column Volume	=	(12.0 $ft.^3$) (1.33) = 16.0 $ft.^3$
Column Diameter	=	2-ft.
Colunm Height	=	(16.0 $ft.^3$) ($1/(1\ ft.)^2\pi$) = 5.0 ft.
Flow Rate of Oil	=	(12.0 $ft.^3$) (7.48 gal./$ft.^3$) (1/30 min.)
	=	3.0 gpm or (3.0 gpm) ($1/\pi(1ft.)^2$)
	=	0.95 gpm/$ft.^2$

In addition to the activated carbon column, two pumps, a filter, and a storage tank are required. The pumps will be capable of transporting oil at 4 gallons per minute at 1 horsepower, the filter will be capable of filtering 4 gallons per minute of oil, and the storage tank will be a closed tank with a capacity of 5 days production run, or 7,000 gallons. (10,000 pounds per day) (5 days) (gallons per 7.19 pounds).

<u>Sulfurization process</u>: Jojoba oil can be sulfurized by using standard commercial techniques for the sulfurization of oils to provide a product which may be useful as a lubricant or lubricant additive. The standard method of sulfurizing such oils as sperm or lard is to add the desired amount of sulfur and heat the mixture

for three or four hours at about 380°F. Flaxman [3], Chasan [4], Kottcamp [5], and Wells [6] sulfurized jojoba oil by adding sulfur in portions while raising the temperature of the oil; they found that jojoba oil can be sulfurized in about one hour.

Figure 5 shows the process flow diagram for producing 10,000 pounds of sulfurized jojoba oil (10 percent sulfur) in a batch reactor. Raw jojoba oil will be piped from a storage tank to a stirred, heated reactor; sulfur will be added with mixing and heating; compressed aire will be blown through the mixture; and the sulfurized oil will be filtered, temporarily stored in a tank, and then packaged in 55-gallon steel drums for shipment.

While jojoba oil can be sulfurized to contain up to 31 percent sulfur, this paper focuses on a process to produce jojoba oil which contains 10 percent sulfur by weight. The basic process has several steps: a) heat the oil to 250°F in an agitated vessel; b) add the desired amount of sulfur to the oil in four to six portions during a one hour period while raising the temperature to 400°F; c) allow the mixture to cool to 350°F, and air-blow with stirring for two to four hours; d) allow to cool to room temperature; and e) filter. Air-blowing is required to prevent the formation of hydrogen sulfide, and filtration is required to remove any sulfur precipitate.

To produce 10,000 pounds of 10 percent sulfurized oil in an eight-hour day required piping 9,000 pounds (1,250 gallons) of oil from storage into a 2,000-gallon stirred heated reactor. The reactor will be heated by steam (from a plant boiler) to raise the temperature of the oil to 400°F; sulfur will be added in four 250-pound portions during a one-hour period while raising the temperature of the oil from 250°F to 400°F. The mixture will then cool to 350°F and will be air-blown with stirring for about two hours. The oil will then be allowed to cool, and will be pumped through a filter and stored in a 10,000-gallon (eight days production) tank prior to packaging in 55-gallon drums. The sulfur filtered from the oil mixture will be recycled to the reactor.

<u>Hydrogenation process</u>: Jojoba oil can be hydrogenated to a hard crystalline wax using process conditions and equipment similar to those used to hydrogenate various vegetable oils. Wax produced from jojoba oil has a melting point of about 70°C and can be produced with a hardness approaching that of carnauba wax. Potential uses include floor finishes, carbon paper, polishes, film coatings, and candles.

A process which has been used successfully by Emery Industries, Inc., consists of adding hydrogen under 300 pounds per square inch pressure to the oil in a stirred autoclave at 195°C to 235°C in the

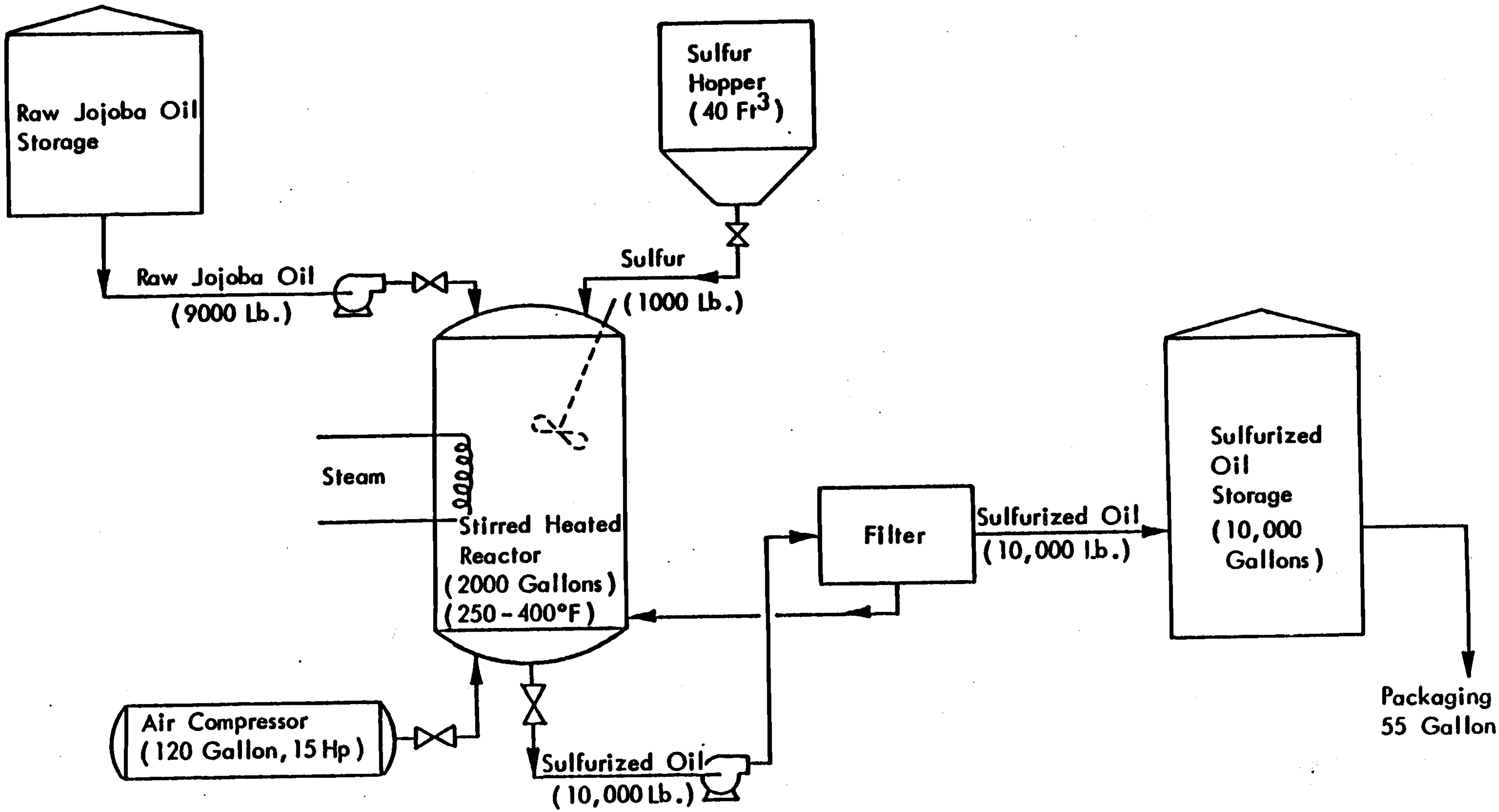

Figure 5. Process flow diagram for producing 10,000 pounds of sulfurized jojoba oil (10 percent sulfur), per eight-hour day.

presence of 0.5 percent nickel catalyst (Girdler G-49B). The batch reaction takes place in one to two hours. The hydrogenated wax is then allowed to cool to about 100°C, filtered to remove the the catalyst, and then passed over a flaker to produce a flaked hard white wax with a melting point of about 70°C and an iodine number of less than 1.0. 7/

Tests conducted by Wisniak and Stein 8/ showed that hydrogen solubility in the oil is 2.2 milliliters (standard temperature and pressure [STP]) per gram at 300 pounds per square inch and 200°C, or about 1 liter (STP) hydrogen per pound of oil. The process used by Emergy Industries required 50 to 100 percent excess hydrogen in the reaction, so that about 1.5 liters (STP) of hydrogen is required for each pound of oil hydrogenated.

Figure 6 shows the process flow diagram for producing 1 ton of hydrogenated jojoba wax in a batch process. Bleached jojoba oil (2,000 pounds) will be piped from a storage tank to a stirred, heated autoclave, to which 3,000 liters of hydrogen gas (STP) and 10 pounds of nickel catalyst, (Girdler G-49B) will be added. The mixture will be heated to 200°C at 300 pounds per square inch pressure with agitation and will be sparged with steam. After one to two hours in the autoclave, the hydrogenated wax will be piped into a holding tank heated at 100°C. When the liquid has cooled to 100°C, it will be filtered and passed over a flaker, where further cooling produces a solid wax which is then flaked. The flaked wax will be conveyed to a hopper, weighed, and packaged in fiber drums. The filtered catalyst will be recycled to the catalyst tank.

The process will produce two batches per eight-hour shift and will require one full-time operator to run the process, clean and maintain the equipment and filter, and fill the fiber drums with flaked wax for storage. The drum-filling operation can be achieved while the mixture is cooling in the reactor and holding tank. Each day's production run will produce 2 tons of wax, which will be packaged in 10 fiber drums (400 pounds per drum) for shipment.

Bottling process: Jojoba oil can be bottled for retail sale and for wholesaling to commercial retail firms. This paper considers a process to fill 1.5 million bottles annually.

Bottles will be filled with raw or bleached jojoba oil using a table-model single-piston filler driven by a 1/3 horsepower motor. The oil will be piped from the storage tank to a 10-gallon hopper mounted on the filling machine and the bottles will be filled automatically on an 8-foot conveyor. The machine will be capable of filling 900 bottles per hour in sizes ranging from 1/2 to 32 fluid ounces. In this analysis, either 1/2 or 1 ounce plastic

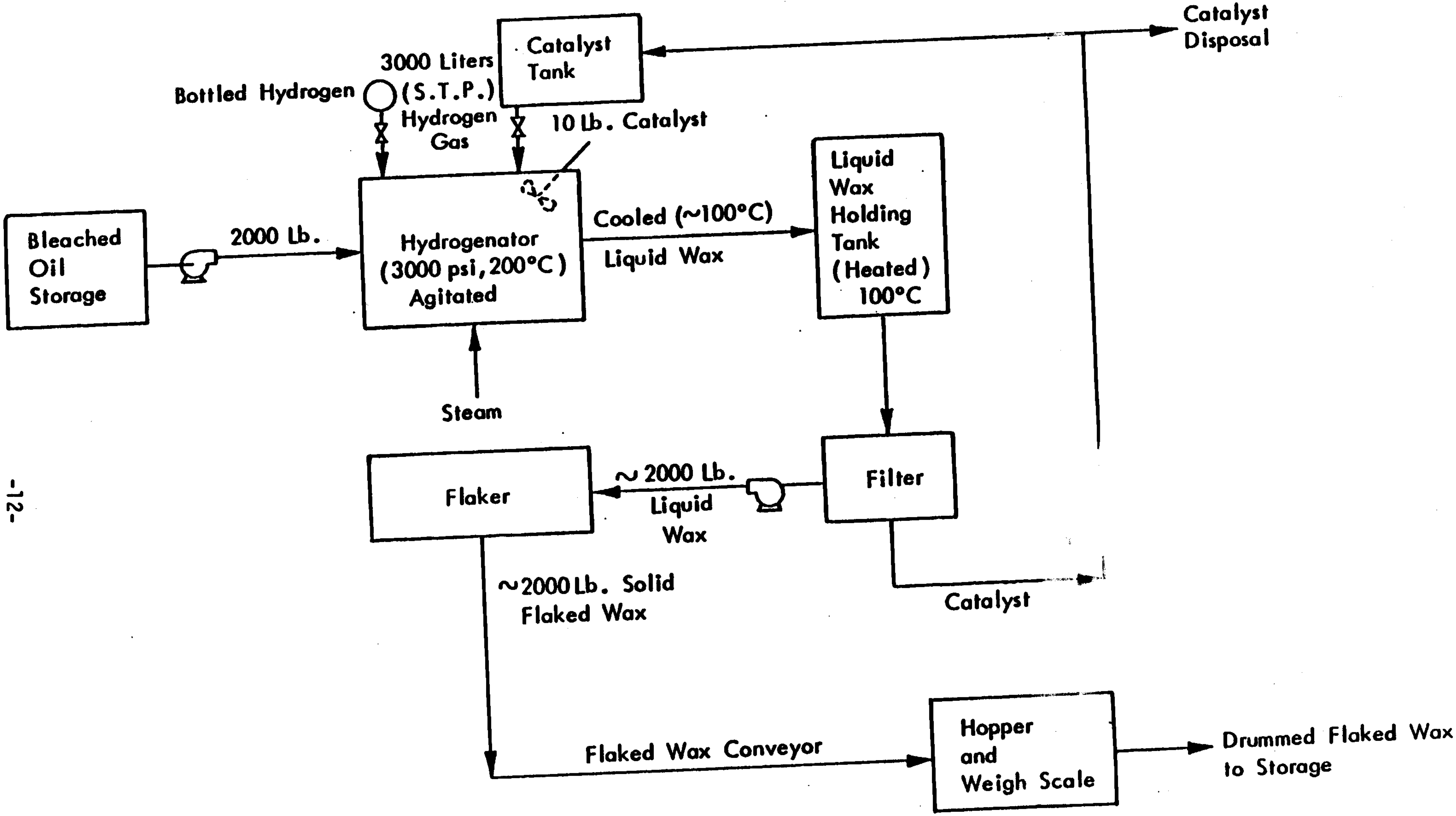

Figure 6. Process flow diagram for producing 1 ton of flaked hydrogenated jojoba wax in four hours.

bottles with a screw cap and printed labels are assumed to be filled in the operation.

DESCRIPTION OF THE BASIC PROCESSING PLANTS AND OPERATIONS

Figure 7 shows a plan view of the small jojoba processing plant adopted from Sverdrup and Parcel and Associates, Inc. [9/]

The process equipment required for the plant is shown in Table 1 as recommended by Anderson IBEC [10/] W. C. Cantrell Company [11/] and Sverdrup and Parcel and Associates, Inc. [9/]

The plant will be supervised by a plant manager. The laboratory will have one full-time chemist and the office will have one full-time clerk. The plant operation will require six full-time workers in the plant: one equipment maintenance worker, one janitor, and four operators. One operator will be responsible for the mechanical extraction process; one operator will be responsible for the filter press, oil drumming and oil storage; and the other two operators will be responsible for operating the preprocessing equipment, packaging seeds and meal, product handling and storage, and general process assistance as needed.

The plant will operate one shift, five days per week, 50 weeks per year, with a throughput of 2 tons of seeds per eight-hour day. Only one shift is necessary since the oil expeller is the smallest commercially available from Anderson IBEC, and a reduction in the size of the capital equipment to expand the operation to three shifts (at the same annual throughput of 500 tons of seeds) would not significantly reduce the capital investment cost, but would triple the labor requirement.

ACKNOWLEDGMENT

This study was funded in part by the National Science Foundation, Division of Intergovernmental Science and Public Technology, Grant No. ISP 77-04295.

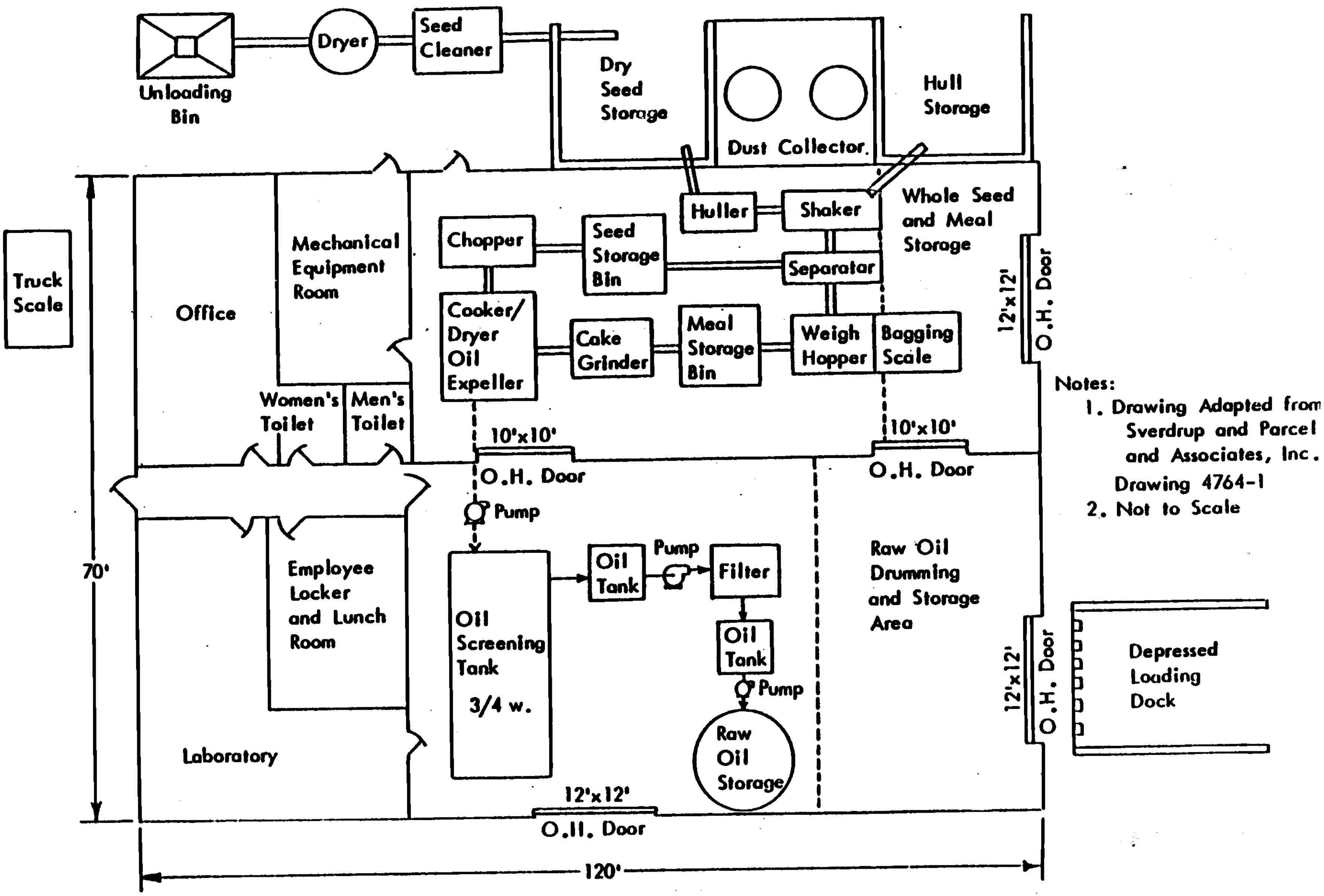

Figure 7. Plan view of a small jojoba processing plant (500 tons of seeds per year).

TABLE 1

DESCRIPTION OF PROCESS EQUIPMENT FOR PLANT I

Equipment Item	Description
Preprocessing System	
Truck Weigh Scale	Pit-type with 9-by-18 foot pad and dial rated at 10 tons.
Unloading Bin	Concrete with screw conveyor and 2-ton capacity.
Batch Dryer	Rotary drum with 1-ton per hour capacity at 10 horsepower.
Seed Cleaner	Eccentric drive with cyclone and hood at 2 horsepower.
Bar Huller	Huller with feeder and magnet with 1/2-ton per hour capacity at 10 horsepower.
Shaker	36-inch shaker with 1.5-tons per hour capacity at 7 horsepower.
Separator	Table-type separator with 1-ton per hour capacity at 3 horsepower.
Dust Collector	Bag-type rated at 8,400 cubic feet per minute, 70^{o}F, 1,496 revolutions per minute and 26 brake horsepower.
Conveyors and Elevators	Seven 6-inch screw-type conveyors with 2-tons per hour maximum capacity at 5 horsepower each.
Mechanical Extraction System	
Seed Storage Bin	Tank-type with 100 cubic foot volume.
Chopper	Seed chopper with 1-ton per hour capacity at 30 horsepower.

TABLE 1 (continued)

Equipment Item	Description
Mechanical Extraction System (con't)	
Oil Expeller	Andersen (AN 30) Duo Expeller equipped with 36-inch by 12 foot dryer (10 horsepower), 14-inch conditioner vessel, three-section drainage barrel, heavy duty water-cooled main worm shaft (40 horsepower), choke unit, thrust unit, assembled vertical shaft (10 horsepower), and across-the-line starters.
Oil Screening Tank	Andersen No. 12 (AN 81) oil screening tank, 5 feet, 11-3/4 inches wide by 7 feet, 5 7/8 inches high by 16 feet, 2 inches long, carbon steel, drive (1 horsepower), oil pump (2 horsepower), and across-the-line starters.
Unfiltered Oil Tank	300-gallon open tank.
Filter Press with Filters	Plate and frame, 30-inches-by-30-inches.
Hopper and Platform for Filter	Concrete platform and 20-gallon hopper.
Filtered Oil Tank	300-gallon open tank.
Raw Oil Storage Tank	5,000-gallon capacity.
Air Compressor	80-gallons at 7.5 horsepower.
Portable Agitator	Agitator at 3.4 horsepower.
Boiler	Fuel oil-fired boiler with 50-gallon receiver rated at 25-boiler horsepower with 1.5 horsepower feed pump.
Steam Pump	Horizontal duplex piston.
Heat Exchanger	Fin tube type.
Rotary Oil Pumps (2)	40 gallons per minute at 5 horsepower.

TABLE 1 (continued)

Equipment Item	Description
Mechanical Extraction System (Concluded)	
Circulating Oil Pump	35 gallons per minute at 5 horsepower.
Vegetable Oil Meter	
Conveyor and Elevators	Four 6-inch screw-type conveyors with 2-tons per hour maximum capacity at 5 horsepower each.
Meal Handling System	
Cake Grinder	Grinder with screens, dust collector, and heavy duty crusher feeder with 1/2-ton per hour capacity at 15 horsepower.
Meal Storage Bin	Open bin with 15-ton capacity.
Conveyors	Three 6-inch screw-type conveyors with 2-tons per hour maximum capacity at 5 horsepower each.
Packaging System	
Weigh Hopper with Bagging Scale	Open hopper with platform bag scale rated at 1,000 pounds.
Sewing Machine	Portable bag closing unit using nylon thread.

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1979 ARIZONA JOJOBA CONFERENCE
UNIVERSITY OF ARIZONA
TUCSON, ARIZONA

PANEL V: MARKETS AND COMMERCIALIZATION

GARY KELSO

OCTOBER 15-16, 1979

MARKETING AND COMMERCIALIZATION OF JOJOBA

Gary Kelso
Midwest Research Institute, Kansas City, Missouri

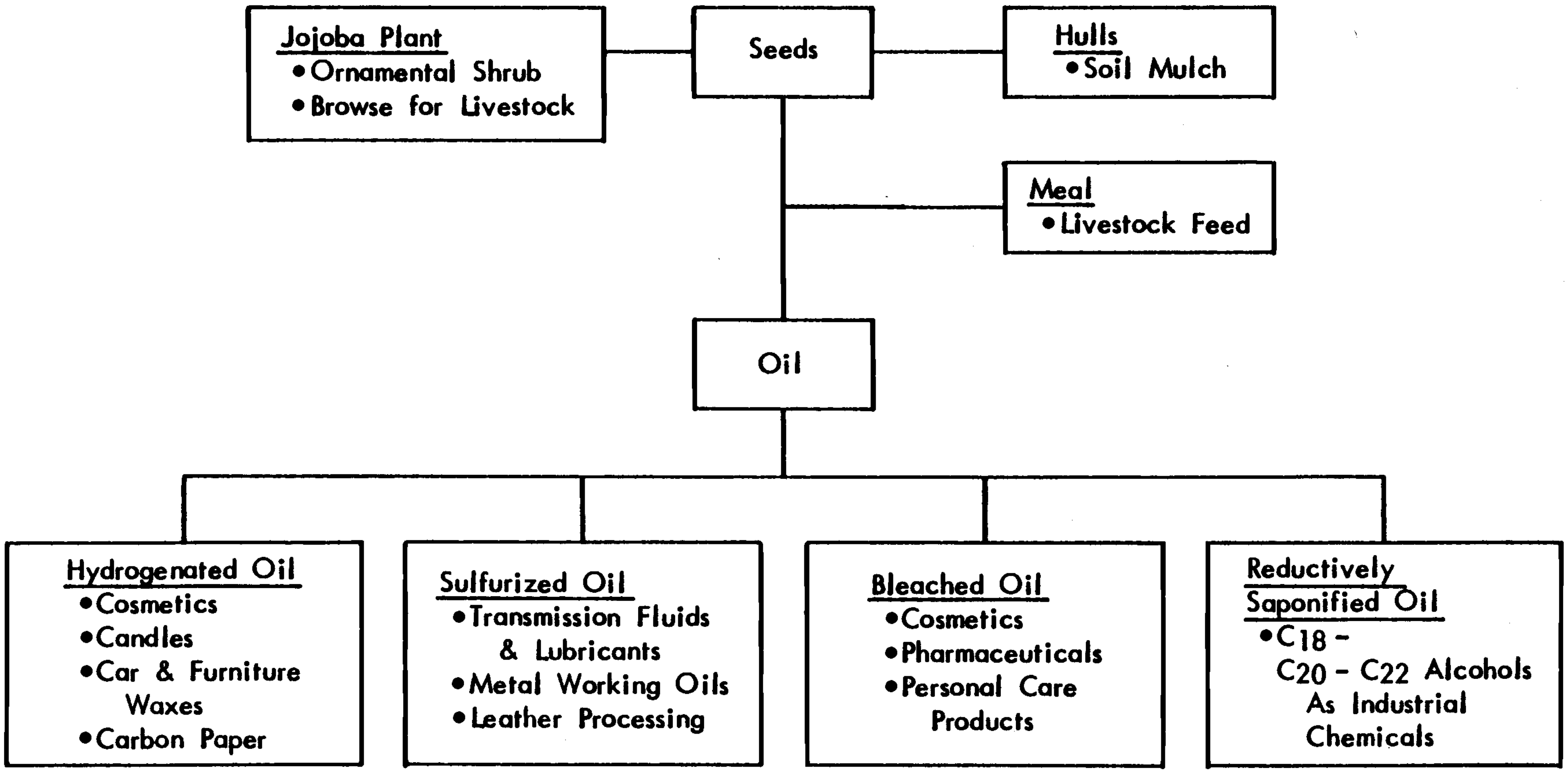
A marketing analysis being performed by Midwest Research Institute for the Office of Arid Lands Studies, University of Arizona, identifies the potential and current uses of jojoba products; the supply, demand, and price of selected jojoba products; and the supply, demand and price of products with which jojoba must compete to enter the commercial marketplace. The feasibility of marketing jojoba products depends on the price structure of the established competitive products in the markets that jojoba has the potential to enter. Other considerations are the supply of jojoba relative to the demand of the various potential markets, and the quality of jojoba products relative to the quality and performance of its competitors.

Although many uses have been suggested for the jojoba plant and its products, the more viable commercial uses are shown in the figure on the following page. The majority of interest has centered around the oil as a potential replacement for sperm whale oil and the wax that can be made from the oil. The oil can be bleached, sulfurized, or hydrogenated to yield a modified oil or wax useful a) in the formulation of gear fluids and lubricants, b) as leather processing oils, c) in pharmaceuticals, cosmetics, and personal care products, and d) in car and furniture polishes. The oil can be reduced with sodium to yield C_{18}, C_{20}, and C_{22} alcohols which may be useful as industrial chemicals.

The products with which jojoba must compete to enter the established markets shown in the figure are other oils and waxes. The oils include mineral oil, castor oil, palm oil, lard oil, cod oil, neat's-foot oil, coconut oil, rice bran oil, soybean oil, peanut oil, linseed oil, safflower oil, and synthetic oil lubricants. The waxes include beeswax, carnauba, candelilla, paraffin, microcrystalline, and cane wax.

The commercialization of jojoba depends upon the ability of the jojoba industry to supply the demands of the consumers in the various markets at a price competitive with the other oils and waxes in current use. At the current prices of jojoba products and competitive products, the only viable markets in the short-term appear to be cosmetics, personal care products, and special candle waxes, such as beeswax and carnauba, may become competitive as the supply of jojoba increases and the price falls.

POTENTIAL JOJOBA USES AND PRODUCTS



The study concludes by estimating potential demand and identifying marketing opportunities and distribution channels for jojoba products in the competitive oil and wax market and in specialty product markets, e.g., candles, cosmetics, pharmaceuticals, and personal care products. Optimal product mix, total revenue, and profitability for the jojoba industry at-large and for the San Carlos Apache Cooperative will be determined.

COMMERCIAL MARKETS FOR THE JOJOBA PLANT

by

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1979 Arizona Jojoba Conference
University of Arizona
Tucson, Arizona
October 15-16, 1979

I. MARKET POTENTIAL FOR THE JOJOBA PLANT

A wide range of potential markets have been suggested for the jojoba plant and the more viable of these are presented in Figure 1. We first briefly consider market potential for jojoba seeds, hulls, and meal, and then discuss jojoba oil.

1. Jojoba seeds: In the Southwest, the jojoba shrub is as an ornamental for landscaping and as a stabilizer of desert soils around private homes and commercial establishments.[1/] There may be a small market for jojoba seed sales to nurseries and individuals for the production of seedlings.

2. Hulls: Jojoba hulls could have market opportunities as a soil mulch or for landscaping. In these markets, jojoba hulls would compete with such products as cypress mulch and redwood bark which sell for about $5.00/16-sq-ft coverage.[2/]

3. Jojoba meal: A by-product of jojoba oil extraction is the oil cake or meal. The meal has a 26 to 32% protein content as well as carbohydrate and fiber.[3/] Although the major cattle feed meal is derived from soybeans which have a protein content of 44 to 50%,[4/] jojoba meal should be of interest to livestock producers located in arid lands where the plant is grown.

The presence of an unusual toxic material, simmondsin, is a major drawback in the introduction of jojoba meal as an animal feed.[5/] The effect of simmondsin on ruminants is unknown at this time.

POTENTIAL JOJOBA USES AND PRODUCTS

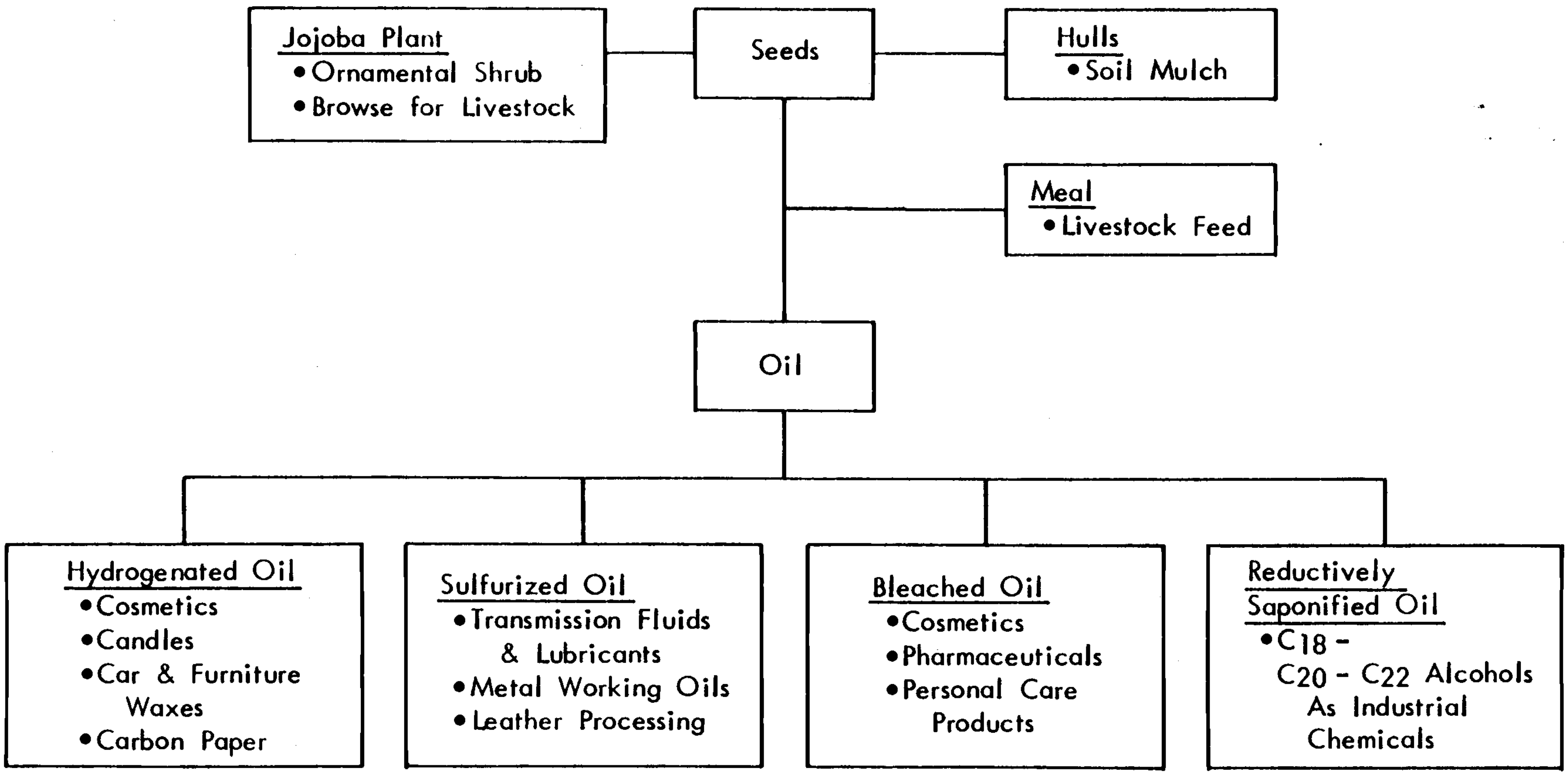

Figure 1

Any analysis comparing the cost of jojoba meal and soybean meal would have to take into account the possibility of the undetermined costs of detoxifying jojoba meal.

4. Jojoba oil: The seeds of the jojoba bush contain an oil that is yellow and odorless, but feels less oily than traditional edible oils.[6/]

Jojoba oil is classified chemically as a liquid wax which is composed almost exclusively of esters formed from acids and alcohols in the C_{18}, C_{20}, and C_{22} range, each containing a double bond.[7/] Table 1 presents the chemical composition of jojoba oil, other liquid waxes, and selected solid waxes. The percentage of acids and alcohol esters derivable from the wax esters is much higher in jojoba oil than in sperm oil. The oil from jojoba is unsaturated while sperm oil is composed of both saturated and unsaturated fatty acids and alcohols with lower molecular weights. In comparison with the solid waxes, spermaceti wax more closely resembles the chemical composition of jojoba oil than other waxes.

The marketing research conducted at Midwest Research Institute (MRI) has concentrated on identifying the markets open to jojoba oil due to its chemical properties and its resemblance to sperm whale oil. The research indicated that jojoba oil has market potential in lubricants, cosmetics, pharmaceuticals, car and furniture polishes, leather processing, candlemaking, and sale of the bottled oil. Other suggested uses of jojoba have included textile processing and use as a fatice; however,

TABLE 1

CHEMICAL COMPOSITION OF VEGETABLE AND ANIMAL WAXES

	JOJOBA OIL	SPERM OIL	SPERMA-CETI	BEESWAX	CANDE-LILLA	CARNAUBA	JAPAN	OURICURY
WAX ACID-ALCOHOL ESTERS (%)	97	75	96	71	28-29	84-85	-	24
HYDROXY ESTERS (%)	-	-	-	-	-	-	-	46
GLYCERIDES (%)	-	25	-	-	-	-	93-97	-
HYDROCARBONS (%)	-	-	-	10-14	50-51	2-3	-	1
ACIDS (%)	-	-	1	14-15	7-9	2-4	4-6	9
ALCOHOLS (%)	-	-	3	2	2-14	2-3	1	15

SOURCE: JOJOBA: AN ASSESSMENT OF PROSPECTS, TROPICAL PRODUCTS INSTITUTE, MINISTRY OF OVERSEAS DEVELOPMENT, LONDON, ENGLAND.

NOTE: - = NIL OR NEGLIGIBLE.

in our contracts with industrial research and development workers, we found no evidence supporting use of jojoba oil in these additional areas.[8/]

Jojoba oil can be sulfurized, hydrogenated or bleached, Sulfurized jojoba oil has potential uses in lubricants and leather processing. Hydrogenated oil can be used in the formulation of cosmetics, car and furniture waxes and polishes, and candles. Jojoba oil, raw or bleached, has potential use in pharmaceuticals, cosmetic preparations, and as a bottled specialty product.

II. SUPPLY, PROCESSING FACILITY SIZE, AND COST OF JOJOBA PRODUCTS

1. Supply of jojoba seeds: Most of the jojoba seed and oil currently available have been hand harvested from wild stands in the United States and Mexico. The natural stands of jojoba found in the American Southwest are often on rocky and steep terrain, and access to these wild stands is limited due to the topography and lack of roads.

In contrast, the majority of the jojoba being harvested from wild stands in Mexico is found in an area which extends from Tijuana along the Pacific Coast and the area amounts to about 1,500 acres of pasture-like land.[9/] This is one of the largest natural stands of jojoba and may be described as semicultivated. It is regularly browsed by cattle which keep the bushes pruned. The area is well kept and easily accessible. In 1975 approximately 16 tons of jojoba seeds were harvested from this stand. It has been estimated that the maximum amount of oil available through harvesting wild jojoba stands both in the United States and Mexico is about 500,000 lb/year.

Dependable supplies of jojoba oil are dependent upon the establishment of jojoba plantations, and cultivation of jojoba is now taking place in the United States and Mexico. There are approximately 5,000 acres under cultivation in the United States and 2,000 in Mexico.[10/] A small plantation has been established in Bakersfield, California, by American Jojoba Industries, and this company plans to add 1,000 acres a year up to a maximum of 10,000 acres under cultivation.[11/]

The U.S. cultivation has taken place in 1978 and 1979, and the plantations should be producing in the 1985/1986 growing season.

2. Processing facility size and cost of jojoba products: Previously MRI has performed an industrial process and product analysis for the jojoba industry.[12/] As a result of this study, the cost of processing jojoba seeds has been segmented into eight potentially marketable products. These are hulls, seeds, meal, raw oil, bleached oil, sulfurized oil, hydrogenated oil, and bottled oil.

Processing costs have been estimated for basic products manufactured in processing facilities with three different capacities (500 tons seeds per year, 5,000 tons seeds per year, and 75,000 tons seeds per year). Costs include capital investment costs, annual operating costs, and unit production costs.

Table 2 summarizes the total unit costs of the eight products which may be produced at the three jojoba seed processing facilities. Raw oil can be processed from seeds at $4.08 to $7.83/lb for Plant I, depending on per utilization of design capacity. Lowest unit costs are obtained for Plant III and are $1.07 to $1.68/lb. Unit costs for bleached, sulfurized, and hydrogenated oil are only "pennies" higher than unit costs of raw oil. Bottling costs are $0.16 to $0.40/1/2-oz bottles and $0.20 to $0.64/1-oz bottles.

TABLE 2

TOTAL UNIT COST SUMMARY OF THE EIGHT PRODUCTS WHICH MAY BE PRODUCED AT THE THREE JOJOBA SEED PROCESSING PLANTS

PRODUCT	UNIT OF COST	PLANT I	PLANT II	PLANT III
HULLS	$/LB	0.00	0.00	0.00
SEEDS	$/LB	1.36-2.66	0.84-1.24	0.52-0.82
MEAL	$/LB	0.06-0.08	0.02	0.01
RAW OIL	$/LB	4.08-7.83	2.32-3.40	1.07-1.68
BLEACHED OIL	$/LB	4.13-7.93	2.35-3.43	1.09-1.70
SULFURIZED OIL	$/LB	4.17-7.92	2.34-3.45	1.08-1.70
HYDROGENATED WAX	$/LB	-	2.37-3.51	1.09-1.73
BOTTLED OIL	$/1/2-OZ BOTTLE	0.25-0.40	0.20-0.27	0.16-0.22
	$/1-OZ BOTTLE	0.38-0.64	0.28-0.37	0.20-0.27

III. COMMERCIAL MARKETS FOR JOJOBA OIL AND WAX

1. Competitive products and prices: A summary of the potential use categories of jojoba oil and wax and the price ranges and market volume of the oil and wax competitors is presented in Table 3. The markets for jojoba oil and wax to be examined include lubricants, cosmetics, car and furniture wax and polish, leather processing, pharmaceuticals, candles, and bottled oil.

The lubricant manufacturing industry consumes over 150 million pounds of oil and wax annually primarily as a base in the formulation of metal cutting and forming oils. The relative quantities of the oils used depends on price. For example, there is a high degree of substitutability between lard oil and synthetic sperm oil. Decreases in the price of lard oil since April 1979 have decreased the demand for synthetic sperm oil.[13]

Lubricant additives for automatic transmission fluids have less substitutability among the oils than do the oil lubricants. This is a very specialized market and a 2- to 3-year testing period generally occurs before new oils or formulations are introduced in the market.[14] A company will not engage in extensive testing unless a new oil has obvious price or performance advantages over other oils. Jojoba oil remains largely an unknown factor to lubrication industry representatives.

The cosmetics industry consumes over 100 million pounds of oils and waxes annually. Prices of the most commonly used oils and waxes

TABLE 3

POTENTIAL USES OF JOJOBA PRODUCTS AND THE PRICES AND MARKET VOLUME OF COMPETITIVE OILS AND WAXES IN 1978 AND 1979

PRODUCT CATEGORY	COMPETITIVE OILS AND WAXES	PRODUCT PRICES ($/LB)	ESTIMATED MARKET VOLUME (LB)
LUBRICANTS	SYNTHETIC SPERM OIL	0.35-1.00	NA
	LARD OIL	0.27-0.39	150 MILLION
	COTTONSEED OIL	0.22-0.34	NA
	SOYBEAN OIL	0.21-0.28	NA
	FISH OIL	0.23-0.27	NA
COSMETICS AND PERSONAL CARE PRODUCTS	SESAME OIL	1.26	NA
	CARNAUBA WAX	0.99-2.01	NA
	ISOPROPYL MYRISTATE	0.89-1.14	NA
	BEESWAX	2.40-2.85	NA
	SPERMACETTI WAX	0.60-1.00	40,000
	LANOLIN	0.65-0.80	16 MILLION
	SAFFLOWER OIL	0.40-0.41	NA
	MICROCRYSTALLINE WAX	0.31-0.36	NA
	MINERAL OIL	1.86-1.48	94 MILLION

TABLE 3 (CONCLUDED)

PRODUCT CATEGORY	COMPETITIVE OILS AND WAXES	PRODUCT PRICES ($/LB)	ESTIMATED MARKET VOLUME (LB)
CANDLES	PARAFFIN	0.15-0.30	100 MILLION
	MICROCRYSTALLINE WAX	0.31-0.36	90,000
	BEESWAX	2.40-2.85	< 10,000
CAR AND FURNITURE WAX AND POLISH	BEESWAX	2.40-2.85	60,000
	CARNAUBA	0.95-2.01	1.5 MILLION
	POLYETHYLENE WAX	0.40-0.73	2.4 MILLION
	MICROCRYSTALLINE WAX	0.31-0.36	3 MILLION
	PARAFFIN	0.15-0.30	6 MILLION
	SYNTHETIC SPERM OIL	0.35-1.00	
LEATHER	NEAT'S-FOOT OIL	0.39-0.51	10-14 MILLION
	CASTOR OIL	0.51-0.61	
	CORN OIL	0.31-0.44	
	PEANUT OIL	0.39-0.51	
PHARMACEUTICALS	LARD OIL	0.27-0.39	3 MILLION
	LINSEED OIL	0.22-0.30	
	SOYBEAN OIL	0.21-0.28	

SOURCE: MRI ESTIMATES BASED ON CONTACT WITH INDUSTRY REPRESENTATIVES.

NA = NOT AVAILABLE.

range from $0.30 to nearly $3.00/lb. Specialty products used in cosmetic formulations may cost from $3.00 to over $10.00/lb. The specialty products are those which have either unusual consumer appeal or impart unique qualities to the final products and will generally comprise less than 10% of the total input of a final product.[15]

The candlemaking industry consumes approximately 100 million pounds of paraffin, while the combined usage of microcrystalline wax and beeswax is under 100,000 lb. At the present time, candles containing jojoba wax must be considered a novelty or specialty item.

Approximately 13 million pounds of wax are used annually in the car and furniture wax and polish market. The amount of each wax consumed is inversely related to its price relative to the price of other waxes. For example, beeswax is selling for $2.40 to $2.85/lb, and its usage level is about 0.5% of the total waxes consumed while paraffin at $0.15 to $0.30/lb represents 46% of the total usage of waxes. Jojoba wax may compete with beeswax and carnauba wax.

Jojoba may have market potential in leather processing and pharmaceutical manufacturing. While the potential market volume for jojoba oil in each of these categories would be relatively small, the supply-demand structure of these markets could support a specialty product at high market prices. Approximately 10 to 14 million pounds of oil are used annually in leather processing and over one half is neat's-foot oil. It is unlikely that jojoba oil would compete with neat's-foot oil on the basis of price alone. However, jojoba oil could be a replacement for decreasing sperm oil reserves and synthetic sperm oils.

According to research conducted by Dr. Pathak of Wyeth Laboratories, jojoba oil increases the yield of penicillin and reduces foam development when used in penicillin production.[16/] Currently, about 3 million pounds of vegetable oils are being used in penicillin production. If further tests confirm jojoba oil has unique characteristics, there would be a range over which the price of jojoba oil would be inelastic in the pharmaceutical industry.

Table 3 suggests an inverse relationship between price and demand for oils and waxes. This relationship is due to the high degree of substitution between these oils and waxes by manufacturers and formulators. When the oils and waxes are technologically interchangeable in the formulation of the final product, price becomes the primary factor determining relative consumption levels.

Figure 2 illustrates this inverse relationship between price and quantity consumed in the United States for selected oils and waxes. There also exists a considerable difference between the price and quantity of the major waxes compared to the oils, i.e., waxes are consumed in much smaller quantities than oils but command much higher prices.

An increase in the supply of one oil, such as soybean oil, will tend to depress the price of that oil and narrow the price spread among the competing products. Decreasing the price of a particular oil will tend to increase substitution and may lower the prices for all oils which compete with soybean oil in terms of price and performance. Of course, prices will not be lowered to the point where profit margins disappear.

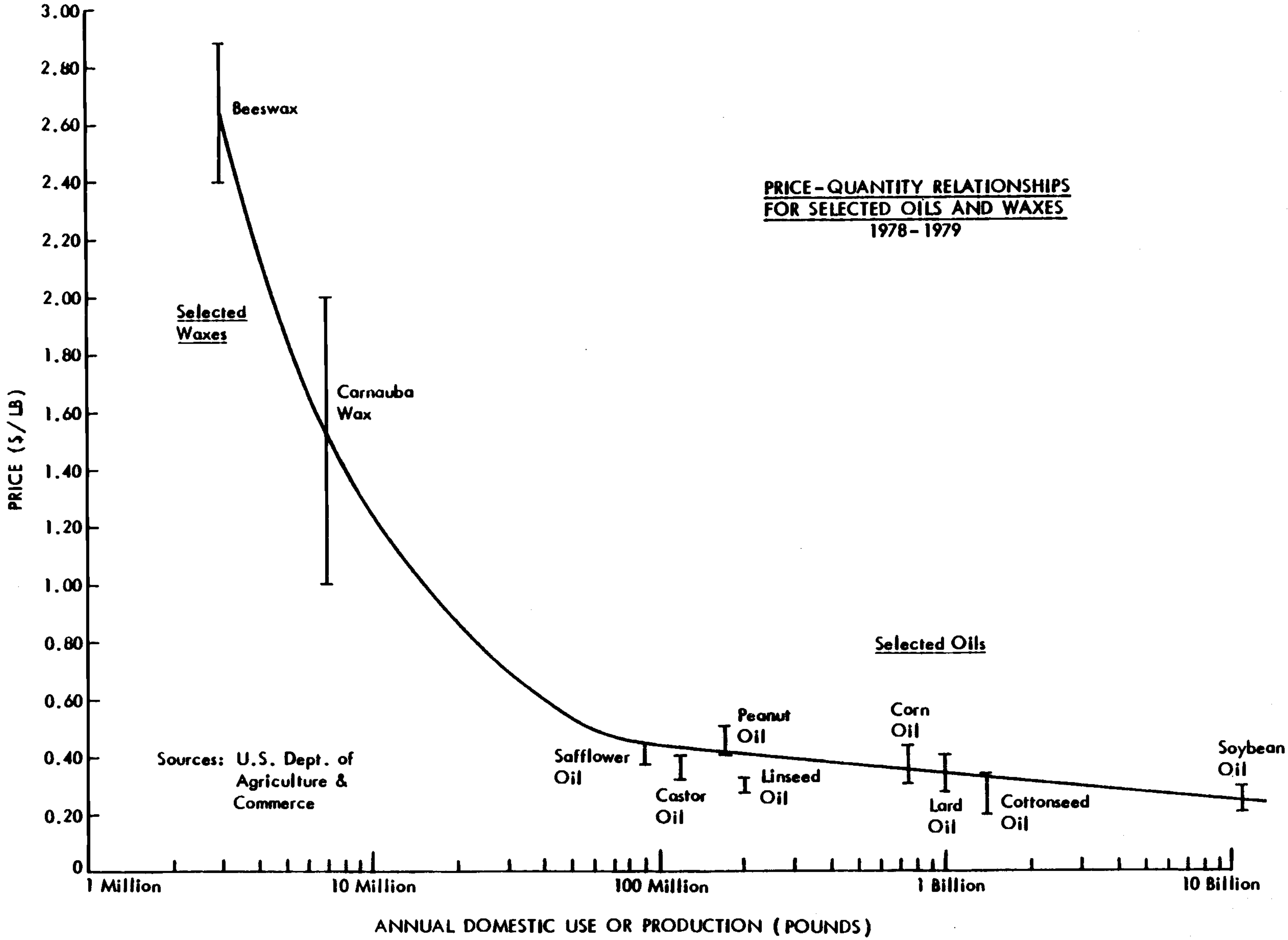
PRICE-QUANTITY RELATIONSHIPS
FOR SELECTED OILS AND WAXES
1978-1979
PRICE ($/LB)
3.00
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0
Beeswax
Selected
Waxes
Carnauba
Wax
Selected Oils
Safflower
Oil
Castor
Oil
Peanut
Oil
Linseed
Oil
Corn
Oil
Lard
Oil
Cottonseed
Oil
Soybean
Oil
Sources: U.S. Dept. of
Agriculture &
Commerce
1 Million
10 Million
100 Million
1 Billion
10 Billion
ANNUAL DOMESTIC USE OR PRODUCTION (POUNDS)

Figure 2

The market for jojoba oil may be similar to other specialty oils. The demand could be quite inelastic when the oil is a required component of a particular product, i.e., jojoba shampoo or other personal care products. However, when that special demand is filled, any additional supply would have to compete with substitutes in a more elastic demand range.

2. Marketing opportunities analysis: For each product category, as shown in Table 4, jojoba price and production requirements as well as competitive oil and wax prices are presented. In analyzing each of these uses independently, cosmetic and personal care products offer the most immediate market opportunity. Virtually 100% of the jojoba oil currently produced is formulated into cosmetics and personal care products, e.g., lipsticks, face and skin creams, and bottled oil. Several cosmetics companies have indicated that they will expand their use of jojoba oil as supplies increase. Jojoba oil is now being used because of its novelty appeal and unique qualities which indicates a strong and relatively inelastic demand even at $7.50/lb. At this price level, jojoba production requirements correspond to the Plant I scenario which assumes that 500 tons of seed are processed annually and yield 0.26 to 0.38 million pounds of oil.

Jojoba oil has commercial market opportunities in the car and furniture wax and polish industry at around $3.00/lb. Jojoba oil can be produced in this price range given the Plant II production scenario. Oil production would require a supply of 5,000 tons of seeds annually and the

TABLE 4

MARKETS, PRICE, AND PRODUCTION LEVEL FOR JOJOBA COMMERCIALIZATION

PRODUCT CATEGORY	COMPETITIVE OIL AND WAX PRICES ($/LB)	ESTIMATED JOJOBA PRICE FOR COMMERCIAL MARKET ENTRY ($/LB)	JOJOBA PRODUCTION REQUIREMENTS
COSMETICS	0.31-2.85	4.08-7.93	PLANT I 500 TONS SEEDS OIL YIELD 263,000 LB TO 375,000 LB
CAR AND FURNITURE WAX AND POLISH	0.15-2.85	2.37-3.51	PLANT II 5,000 TONS SEED OIL YIELD 2,625,000 LB TO 3,750,000 LB
LEATHER PROCESSING	0.35-1.00	1.07-1.68	PLANT III 75,000 TONS SEEDS OIL YIELD 52,200,000 LB TO 74,500,000 LB

TABLE 4 (CONCLUDED)

PRODUCT CATEGORY	COMPETITIVE OIL AND WAX PRICES ($/LB)	ESTIMATED JOJOBA PRICE FOR COMMERCIAL MARKET ENTRY ($/LB)	JOJOBA PRODUCTION REQUIREMENTS
PHARMACEUTICALS	0.21-0.51	1.07-1.68	PLANT III 75,000 TONS SEEDS OIL YIELD 52,200,000 LB TO 74,500,000 LB
LUBRICANTS	0.21-1.00	1.07-1.70	PLANT III
CANDLE MAKING	0.15-0.36	NOVELTY ITEM	NA
BOTTLED OIL	-	NOVELTY ITEM	NA

SOURCE: MRI ESTIMATES.

NA = NOT AVAILABLE.

oil yield would be between 2.6 and 3.8 million pounds. Total wax consumption in this category is estimated at 13 million pounds annually.

Of course, hydrogenated jojoba oil would have to match or exceed the performance characteristics of beeswax and carnauba wax. If hydrogenated jojoba oil totally displaced beeswax and carnauba wax in this product category, it would have a market of slightly over 2 million pounds annually.

Jojoba oil has very limited market potential in pharmaceuticals and leather processing given the present supply-price relationships. At approximately $1.50/lb, jojoba may have limited use as a synthetic sperm oil replacement in leather processing. At some price under $1.50/lb, given demonstrated superior performance characteristics, jojoba oil could replace the vegetable oils used in penicillin manufacture. Jojoba oil's total share for these combined markets would be from 8 to 10 million pounds annually.

The production requirements identified to supply jojoba oil in the $1.50 price range require the Plant III production scenario. This assumes an annual supply of 75,000 tons of jojoba seed with an annual oil output between 52 and 74 million pounds. Oil production under this scenario far exceeds the demands in the pharmaceuticals and leather processing industries.

Jojoba oil used in lubrication and transmission fluids may command prices in the range of $0.75 to $1.00/lb but extensive research, development, and testing would be required before acceptance by the lubrication industry. The testing program would most likely have to be undertaken by the jojoba industry itself rather than the oil companies and formulators. However, it is doubtful that the jojoba industry can support an extensive research program in lubrication at this time.

Jojoba oil is presently utilized to make specialty candles which have a great deal of novelty appeal. However, competitive candle wax is in the price range $0.15 to $0.36/lb which is presently unfavorable for the jojoba industry.

Bottled jojoba oil remains a primary marketing opportunity. It is successfully sold in 1/2- or 1-oz bottles as a novelty item or as a personal care product, e.g., a skin oil. Jojoba oil commands high prices as a cosmetic ingredient and has been relatively successful in this highly competitive and high profit market. Greater penetration by jojoba oil in the cosmetics and novelty market is possible through innovative product development, e.g., scented bath oils, skin cremes, shampoos, liquid candles, specialty soaps, etc.

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