REPORT 47

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and
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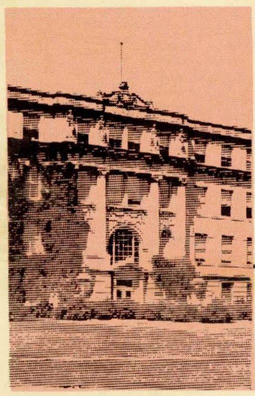

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Introduction

With an annual production in 1965 of over 123 million bushels, Iowa is second only to Illinois in the production of soybeans. Likewise with a production in 1964 of over 838 million pounds of soybean oil it again ranks second only to Illinois (3).

The "crude oil" produced in Iowa plants is all* shipped out of the state where over 90% is used in food products such as margarine, shortening, and salad oil. The amount of soybean oil that comes back into the state is estimated to be at least 75 million pounds annually. This assumes the same per capita consumption as the national rate.

Therefore, why cannot at least part of these food products be produced in Iowa from Iowa soybean oil for Iowa consumers? This report is the result of a study (1) attempting to answer this question. Operations involved in the production of food products are briefly described. A suitable location for an oil refining and processing plant is discussed. The equipment required for plants of various capacities is presented with estimated investment costs, operating costs, and potential profits.

PROCESSING OPERATIONS

General Considerations

Soybean oil, like other fats and oils, is a mixture of the triglycerides of fatty acids with very small amounts of other constituents such as free fatty acids, color bodies, and odiferous materials. These minor constituents are largely removed in the processing of the oil for food purposes to produce a bland, odorfree, and practically colorless oil. The unit processes used in producing a salad or cooking oil are usually *refining, bleaching,* and *deodorization.* Some salad oils are also winterized. If margarine or a solid cooking fat is the product, it must also be *hydrogenated.* In addition, margarine has other constituents as milk solids added to it.

Refining

Purpose. The primary purpose of refining food oils is to remove the *free fatty acids* resulting from a slight amount of glyceride breakdown. These usually average about 0.5% of the oil's weight. While it is possible to remove the free fatty acids by steam distillation or by adsorption, commercial refining in this country is *alkali refining.*

Alkali Refining is the saponification by a suitable alkali solution of the acids, followed by a separation of the resulting soap from the oil. If not removed by previous steaming or water washing, the phosphatides (lecithin) are also removed. Most alkali refining solutions used either experimentally or commercially include caustic soda (sodium hydroxide), but sodium carbonate, and ammonium hydroxide may be used.

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* With the exception of part of the production of the Central Soya Plant at Belmond which is converted to refined industrial (non-food) oil.

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Saponification of the free fatty acids is readily accomplished by mixing the oil with an alkaline solution. However, several practical problems are encountered. To avoid undesirable losses, the operation must be controlled so that all of the free fatty acids, but as few as possible of the triglycerides are saponified. The soap must be completely separated from the oil to minimize loss of any neutral oil with the soap. The refining may be carried out as a *batch* or *continuous* operation.

In *batch refining,* the oil to be refined is mixed with an aqueous solution of caustic soda (sodium hydroxide) until saponification of the free fatty acids is complete. The soap is allowed to settle and the oil drawn off. The refining is carried out in open conical-bottomed tanks, or kettles, equipped with steam heating coils and agitators. The amount and concentration of caustic soda is determined by laboratory tests on the amount of free fatty acids and laboratory refining losses, together with a knowledge of the general characteristics of the specific oil.

In the "dry" method, used most in this country, a higher concentration of caustic solution is used than in the "wet" method.

After the caustic solution is added the mixture of oil and caustic is agitated rapidly (about 40 rpm). Saponification takes about 20 minutes. The agitator is then slowed down to about 8 rpm, and the temperature raised rapidly to 135°-145°F. When the emulsion breaks, the agitation and heat are cut off and the soap is allowed to settle. Settling time varies with oil quality, but 4 hours is usually sufficient for soybean oil. After the oil is drawn off from the soap it is washed with warm water.

In *continuous refining* the oil and the alkaline solution are first brought into intimate contact as they flow through a continuous mixing device. The resulting mixture of oil and soap moves on continuously through a supercentrifuge where the soap is removed. The oil is next mixed with water to remove the remaining soap and is again centrifuged. The washed oil then passes through a vacuum dryer and on to a storage tank.

Comparative Advantages. Continuous refining has advantages in a large scale operation of lower refining loss, smaller space requirement, lower labor requirements, and simpler operation. The smallest practical continuous refining unit has a capacity of about 6 car loads (48,000 gallons or 360,000 pounds) of oil per day.

Batch refining is suitable for a small scale plant. The principal advantage is the use of simple, low cost equipment. Refining losses are relatively high and skilled operators are needed.

Bleaching

While refining removes some color from the crude oil, the refined oil still contains varying amounts of green chlorophyll. While these color bodies are not toxic, the color is esthetically undesirable. Food oils are usually bleached, or decolorized, by adsorbing the color with bleaching earth ("fullers earth"), or clay, and decolorizing carbon. The operation may be either batch or continuous.

Batch Bleaching. About 1.0% by weight of high grade bleaching earth or acid treated clay (bentonite type) with 0.2% decolorizing carbon is added to the oil in an agitated tank under vacuum. The oil is heated to 150°-230°F and pumped to a filter press from which the bleached oil flows to a closed tank. The total time required to process one batch of oil is 4 hours.

Continuous Bleaching. Several continuous systems suitable for large scale operation have been developed, where the mixture of oil and adsorbent is sprayed into a vacuum vessel through which it moves continuously. These systems produce very good oil with shorter contact between the oil and adsorbent.

Hydrogenation

Purpose. If soybean oil is to be converted to a solid fat such as shortening or margarine, hydrogen must be added at the double bonds in the chain. The reaction is carried out under pressure using a catalyst; usually finely divided nickel. While some continuous hydrogenating is practiced, hydrogenation of soybean oil is usually a batch operation using either a "recirculation system" or a "dead end system".

Hydrogen Production. Since hydrogen cannot be economically shipped it is usually produced at the hydrogenation plant. Important methods include:

1. Steam-hydrocarbon process.
2. Steam-iron process.
3. Electrolysis of water.
4. Steam-water gas process.
5. Steam-methanol process.
6. Dissociation of ammonia.

The first two processes are considered most suitable for large size units producing 50,000 SCF or more per day. Number 3 is excellent where low cost electricity and a market for oxygen are available. Number 4 is not very practical because of the difficulty in producing pure enough hydrogen. Number 5 is usually too costly. Number 6 is used in some small installations.

Recirculation System. In this system a vertical steel vessel with steam heating coils and a circulating pump is used. After the oil is charged into the closed tank, the air is exhausted by a vacuum pump and hydrogen bubbled in at the bottom. The hydrogen is taken off the top and recirculated continuously. If necessary the gas is purified before being returned to the hydrogenator. The circulation of the hydrogen provides necessary agitation for the reaction. Pressures vary but usually are less than 100 psi. Progress of the reaction is commonly checked by determining the index of refraction or iodine number of samples.

Dead End System. In this system the hydrogen is maintained at the desired pressure above the oil. Contact between the oil, catalyst, and hydrogen is maintained by mechanical agitation. The progress of the reaction can be roughly followed by measuring hydrogen consumption. A total hydrogenation cycle can be completed in an 8-hour shift.

Deodorization

Purpose. Refined and bleached oils and fats still contain very small amounts of volatile products which produce odors and tastes. These are removed either with batch or continuous procedures by steam stripping under vacuum to produce perfectly bland products.

Batch Process deodorizers are vertical steel vessels with provision for heating by either steam or "Dowtherm". Steam is injected into the oil at the bottom and removed at the top carrying along the odorants by a 3-stage or 4-stage steam ejector vacuum system. Typical batch units vary in capacity from 2,000 to 40,000 pounds per batch and operate with heating steam at 250 psig on an 8-hour cycle.

Continuous Process. In one type of continuous deodorizer the hot oil passes down a vertical vessel through holding sections and bubble cap trays with stripping steam travelling upward. All metal in contact with the oil is stainless steel and "Dowtherm" is used for heating. In large units (one or more tank cars per day) the continuous system is more economical to operate and is said to produce a better quality product.

PRODUCTS

Salad and Cooking Oils

Soybean oil may be processed into a salad or cooking oil by refining, bleaching, and deodorizing. The keeping qualities of this oil may be inferior to refined corn or cottonseed oil because of possible flavor reversion and oxidation. An oil with longer shelf life can be produced by hydrogenating selectively to convert as much of the linolenic acid radicals to linoleic as practical with minimum hydrogenation of the less unsaturated radicals. Since in this process part of the oil is hardened sufficiently to separate out at refrigerator temperatures the oil must be winterized, that is, cooled to a low temperature and filtered. Further stability is insured by adding an antioxidant and packing in dark bottles. Salad dressings are made by combining the salad oil with vinegar, suitable spices, and emulsifiers.

Shortenings

All vegetable oil shortenings are of two general types: compound shortenings and all-hydrogenated shortenings.

Compound shortenings are made by blending unhydrogenated oil with solid fat. Those made from soybean oil only are usually considered impractical because of poor preserving properties.

All-hydrogenated shortenings may consist of an oil hydrogenated to the exact degree necessary to give the desired properties or a mixture of two or more batches each hydrogenated somewhat differently. The latter type is the more common.

Shortenings can be "tailor-made" according to desired end use. "High stability" shortenings for deep frying, crackers and biscuits, and packaged prepared dry baking mixes should be selectively hydrogenated to give the minimum poly-unsaturated glycerides for the desired softening point. High emulsion type shortenings for cake use have small amounts of mono- and diglycerides added just before the end of the deodorization. All shortenings are whipped-up with air or nitrogen to give a white color. They are also "tempered" by holding a given temperature for about 24 hours to develop the proper plasticity. Stabilizers such as the antioxidants NDGA (nordihydroguaiaretic acid), BHA (butylated hydroxyanisole), or *n*-propyl gallate either with or without a synergist such as citric acid may be added.

Margarine

Margarine is made by stirring properly hydrogenated oil in the melted form with "cultured" skim milk. Color, salt, vitamins, and frequently emulsifiers and a preservative are added. The resulting emulsion containing 80 percent fat is cooled in a "Votator" type unit and formed into a suitable size and shape for sale to the customer.

PRELIMINARY PLANT DESIGN CALCULATIONS

Plant Location

Optimum plant location is an important factor for a successful plant and is dependent upon (2): (1) Raw materials; (2) Markets; (3) Power and fuel; (4) Climate; (5) Transportation facilities; and (6) Water supplies. Each of these factors is considered individually as it relates to the optimum Iowa location.

1. *Raw Materials.* "Crude" soybean oil is produced in 19 plants in Iowa. Six of these plants use mechanical screw presses, or "expellers", and combined produce only about 100,000 pounds of oil per day. The other 13 plants use the solvent process and produce most of the oil in the State. The minimum individual capacity is 40,000 pounds of oil per day with the larger units producing 800,000 or 1,000,000 pounds. The total annual production for 1964 was 838,100,000 pounds (3).

Considerable oil production is concentrated in three areas (see Figure 1): Des Moines, Cedar Rapids, and a group of towns including Mason City, Belmond, Eagle Grove, Fort Dodge, and Iowa Falls. The capacity of the Des Moines plant is believed to be greater than at Cedar Rapids and at least equal to the 5-town group.

2. *Markets.* If Iowa is to be a primary market for the customer products, Des Moines, because of its central location would appear to be a good choice. The 5-town area in northern Iowa would be closer to the markets in the Dakotas, Montana, and Wyoming. The Cedar Rapids area would appear to suffer some from being somewhat closer to Chicago competition. The Corplan report (4) prefers a Davenport location as before Des Moines, largely on the basis of freight costs of the finished products.

3. *Power and Fuel.* Electric power is available on about the same basis in each of the areas considered. Gas is available by pipeline. Steam coal is available close to Des Moines.

4. *Climate.* Climatic variations are minor throughout the State.

5. *Transportation Facilities.* Des Moines has several railroads, two interstate highways, and is a center in Iowa for bus, truck, and airline service. The other areas have railroads and a more limited air service. Bus and truck service is good. The border river towns such as Davenport, Council Bluffs, and Clinton have barge service.

6. *Water Supply.* All of the areas considered except the Mason City complex have river water available. Here water can be secured from wells.

7. *Comment and Conclusions.* Des Moines is attractive on the basis of raw material, Iowa markets, transportation, and water supply. Cedar Rapids appears a second choice with the Mason City area third. Davenport is favored by the Corplan report (4) with Council Bluffs second and Des Moines third.

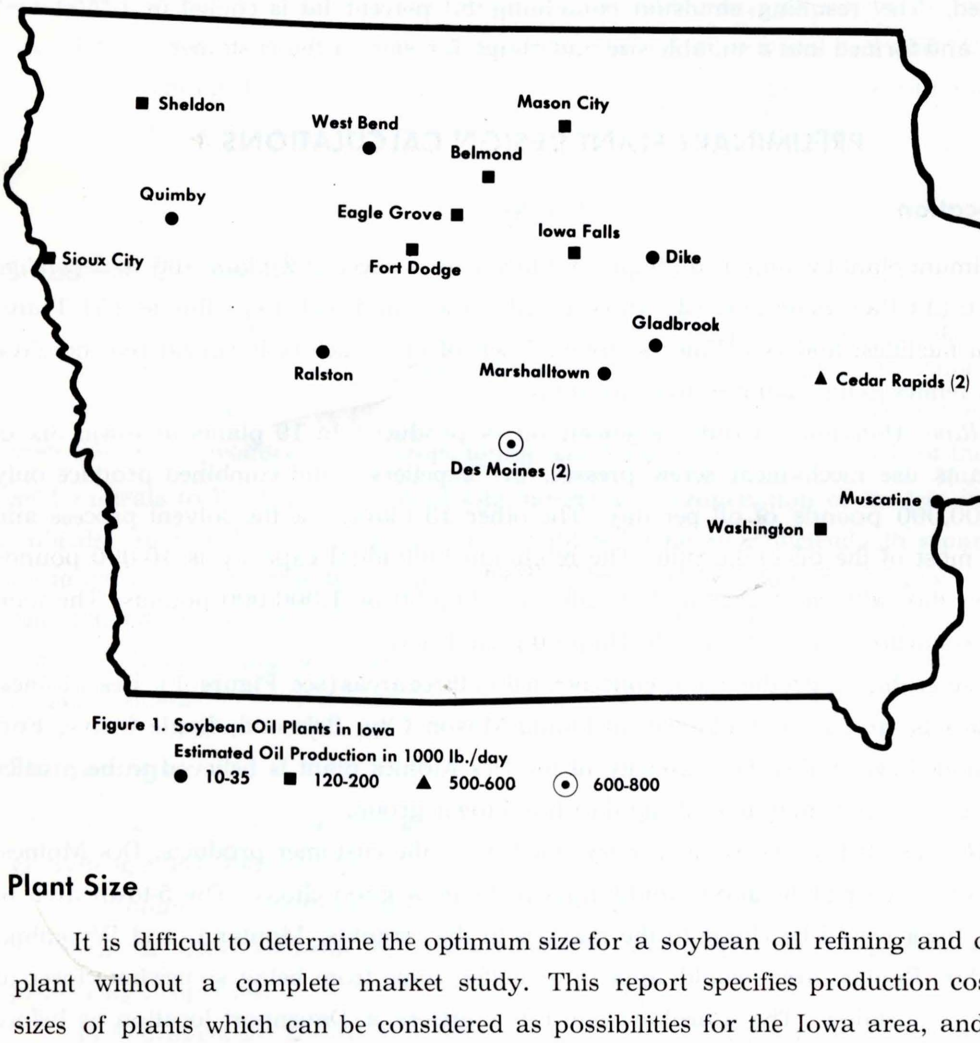

Figure 1. Soybean Oil Plants in Iowa
Estimated Oil Production in 1000 lb./day
● 10-35 ■ 120-200 ▲ 500-600 ⊙ 600-800

Plant Size

It is difficult to determine the optimum size for a soybean oil refining and converting plant without a complete market study. This report specifies production costs for six sizes of plants which can be considered as possibilities for the Iowa area, and does not include a market study.

In the processing of oil for foods the refining, bleaching, and deodorization operations can be carried out more economically as a continuous rather than a batch operation. If the capacity desired drops below a certain minimum, continuous processing is less practical than batch operation. Hydrogenation is commonly a batch operation.

To establish costs for small scale operations, data for four batch plants having the following capacities were determined: 10,000 gallons; 20,000 gallons; 40,000 gallons; and 80,000 gallons of crude soybean oil per day. Data for two continuous type plants having capacities of 47,000 and 94,000 gallons of crude oil per day are included. These capacities correspond to 6 tank cars (60,000 lbs. per tank car) and 12 tank cars per day, respectively. The six tank car size is considered minimum for economical continuous operation. New refineries with capacities of 12 and 24 cars per day are becoming common.

The estimated total investment for each size plant is given in Table 1. Working capital requirements will vary with the size of inventories of raw material, material in process, and finished product and with accounts receivable.

Calculation Data. For design purposes it is assumed the feed stock is a good quality crude, solvent extracted, nondegummed soybean oil. Also, 35% of the oil will be refined, bleached, and deodorized for sale as cooking or salad oil. The remaining 65% is to be hydrogenated to produce a solid fat. Of the solid fat 44% will be processed into margarine and 56% into shortening. This split into final products is based on current average consumption.

A total of 119 literature references were consulted (1) in compiling data for this report. Information was obtained directly from industrial firms (5, 6). Standard design methods were used to adapt available data. The "six-tenths rule" was applied to determine costs for other sizes than those known. Prices were brought up-to-date by using suitable index values. The selling cost for the products is based on 75% of the retail prices listed in "Fats and Oils Situation". It is assumed that the plants will operate 300 days per year.

No actual design of any of the suggested plants has been made. Conventional equipment used in up-to-date plants has been specified. In the larger units some automation could be incorporated (7). The cost calculations are presented as guides preliminary to actual design.

The detailed tables of cost calculation are given in the thesis by Brekken (1) and in the Appendix of this report.

IS A SOYBEAN PRODUCTS PLANT PRACTICAL IN IOWA?

The preliminary figures indicate that a plant for producing consumer products should be profitable even in the smaller sizes. The raw material is available in adequate quantities within the state. The question of available market for the products must be considered.

The Corplan report (4) indicates little need or incentive to build additional manufacturing capacity for margarine, shortening, or salad and cooking oils at the present based on a reported excess manufacturing capacity of 20 to 30%. Such statistics frequently need careful evaluation. Such excess capacity often is supplied by old inefficient units or plants which are poorly located in relation to raw materials and/or markets. The demand for the products is expected to increase. Even the Corplan report indicates that "additional manufacturing capacity will eventually be needed; probably in about five years". If this is true, it is not too early to start planning for an Iowa plant.

It is difficult to determine how large a market could be developed within Iowa. Thirty percent of the estimated Iowa consumption could be produced in the smallest of the plants considered. Other possibilities should be considered.

Several relatively small meat packing plants are in operation or are in the process of being built in Iowa. To produce a modified lard from the lard from these plants either a partially hydrogenated or a hardened fat such as one from soybean oil must be added. The hardened fat could be sold to these packing plants or the lard could be processed into the modified form in the soybean oil plant. Beef tallow can be blended with soybean oil to produce a compound shortening. The oil would need to be hydrogenated sufficiently to remove the unstable linolenic acid radicals but not enough to destroy the polyunsaturation considered to be desirable in a food product.

A margarine of the popular "polyunsaturated" type could be made using Iowa corn oil and hardened soybean oil or a similar type could be made from properly hydrogenated soybean oil alone. Blends of butter and margarine can be produced. Properly hardened soybean oil could be sold to present creameries where it could be processed with milk and added butter.

A market for various soybean oil products could be developed in existing Iowa food industries. One food plant uses 3 million pounds of hydrogenated soybean oil a year, shipping it in from Kentucky. At least one large bakery advertises "polyunsaturated" fat in its bread.

A plant in Iowa would not be limited to sales in Iowa but should take advantage of the probability of lower transportation on finished product sales in the state. The Corplan report (4) lists the following states in their "proposed marketing area for an Iowa Soybean-oil refining-manufacturing facility": Arkansas, Colorado, Kansas, Minnesota, Missouri, Montana, Nebraska, North Dakota, Oklahoma, South Dakota, and Wyoming.

It is concluded from this study that possibilities of operating a profitable soybean oil food product plant now or in the near future are sufficient to warrant further study. A marketing study should be made to establish the plant size. This should be followed by complete plant design and an economic evaluation for that size plant.

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APPENDIX

Table 1. Total Investment and Return on Investment for Various Sizes of Plants.

Sizes Gal./day*	Capital Costs			Percent Return on Investment
	Fixed	Working	Total	
Batch				
10,000	$ 936,000	1,375,000	2,311,000	32.0
20,000	1,365,000	2,724,000	4,089,000	37.3
40,000	1,985,000	5,500,000	7,485,000	41.7
80,000	3,308,000	11,000,000	14,308,000	44.3
Continuous				
47,000	2,385,000	6,447,000	8,832,000	47.2
94,000	3,741,000	12,894,000	16,635,000	50.6

*To convert to pounds, multiply by 7.5.

Table 2. Equipment list for 10,000 gallon/day batch process soybean oil refinery located in Iowa.

Equipment	Installed cost (dollars)
Neutralization	
crude oil storage 50,000 gallon	15,500
crude oil pump - steel, centrifugal, 200 gpm	890
neutralizer - open steel, coiled tank, 5,500 gal. with varispeed agitator and motor	11,100
caustic solution tank - steel, agitated, 250 gal.	2,840
caustic solution pump - steel, centrifugal, 20 gpm	700
foots tank - steel, jacketed, 1,000 gallon	2,500
foots pump - steel, centrifugal, 20 gpm	700
oil separator tank - steel, 1,000 gallon	1,860
wash tank - same as neutralizer except no varispeed	9,940
refined oil pump - steel, centrifugal, 200 gpm	890
Bleaching	
bleacher - cylindrical steel vacuum vessel, closed turbine agitator and coils, 2,000 gallon	11,500
bleaching agent tank - 50 gallon steel tank	100
bleaching steam ejectors - 2 stage with intercondenser	2,200
bleaching filter - aluminum plate and frame, 5 cubic feet	5,000
Hydrogenation	
storage - 7,500 gallons	5,500
convertor - steel, agitated, coiled pressure vessel, 2,400 gallon	14,500
catalyst slurry tank - jacketed, open, agitated steel tank 240 gallon	3,500
steam ejector - one stage	850
catalyst filter - aluminum plate and frame	2,100
exit pump - steel, centrifugal, 36 gpm	1,040
postbleach tank - steel, agitated, coiled tank, 2,300 gallon	7,700
postbleach filter - same as catalyst filter	2,100
postbleach pump - same as exit pump	1,040
Deodorization	
storage - 2-10,000 gallon @ 6,100	12,200
entrance oil pump - steel, centrifugal, 60 gpm	1,100
deodorizor - stainless steel clad coiled vacuum vessel	43,000

(continued)

Table 2. (continued)

Equipment	Installed cost (dollars)
steam ejectors - 3 stage with intercondensers	4,200
exit oil pump - same as entrance pump	1,100
exit heat exchanger - 250 ft^2 steel shell and tube	5,100
polishing filter - 230 ft^2	4,000
Dowtherm boiler - peak rate = 6×10^6 Btu/hr	57,000
storage - 2-10,000 gallon	12,200
End processing	
shortening blending tank - 900 gallon S. S. agitated coiled tank	9,800
margarine water soluble blending tank - S. S. 200 gallon agitated	4,600
margarine oil soluble blending tank - S. S. 750 gallon agitated	9,200
margarine mixing tank - 1,000 gallon S. S. agitated	10,400
votation unit - 3,000 lbs./hr.	9,200

Table 3. Equipment lists for batch process soybean oil refineries located in Iowa

	20,000 gal/day		40,000 gal/day		80,000 gal/day	
Equipment description	size	installed cost ($)	size	installed cost ($)	size	installed cost ($)
crude oil storage	100,000 gal	22,000	200,000 gal	32,000	400,000 gal	45,000
crude oil pump	400 gpm	1,150	400 gpm	1,150	400 gpm	1,150
neutralizer	11,000 gal	19,700	2-11,000 gal	39,400	4-11,000 gal	78,800
caustic tank	450 gal	3,700	450 gal	3,700	450 gal	3,700
caustic pump	30 gpm	700	30 gpm	700	30 gpm	700
foots tank	1,000 gal	2,500	1,000 gal	2,500	1,000 gal	2,500
foots pump	20 gpm	700	20 gpm	700	20 gpm	700
oil separator tank	2,000 gal	2,460	2,000 gal	2,460	2,000 gal	2,460
wash tank	11,000 gal	17,000	11,000 gal	17,000	2-11,000 gal	34,000
refined oil pump	400 gpm	1,150	400 gpm	1,150	400 gpm	1,150
bleacher	4,000 gal	17,000	7,500 gal	22,500	2-7,500 gal	45,000
adsorbent tank	100 gal	150	150 gal	190	2-150 gal	380
ejector	2 stage	2,400	2 stage	3,900	2-2 stage	7,800
bleaching filter	10 ft^3	7,300	16 ft^3	10,000	2-16 ft^3	20,000
storage	15,000 gal	7,400	30,000 gal	11,000	60,000 gal	17,000
hydrogenator	5,000 gal	21,000	2-5,000 gal	42,000	3-5,200 gal	69,000
catalyst slurry tank	500 gal	3,500	500 gal	3,500	500 gal	3,500
jet ejector	1 stage	1,000	2-1 stage	2,000	3-1 stage	3,000
catalyst filter	250 ft^2	6,500	250 ft^2	6,500	280 ft^2	6,900
exit pump	75 gpm	1,160	75 gpm	1,160	75 gpm	1,160
postbleach tank	4,500 gal	10,500	4,500 gal	10,500	5,500 gal	11,200
postbleach pump	75 gpm	1,160	75 gpm	1,160	75 gpm	1,160
postbleach filter	250 ft^2	6,500	250 ft^2	6,500	280 ft^2	6,900
storage	2-20,000 gal	18,600	2-40,000 gal	127,000	2-80,000 gal	39,000
deodorizer	2-7,000 gal	86,000	3-9,000 gal	153,000	6-9,000 gal	306,000
ejectors	2-3 stage	8,400	3-3 stage	13,800	6-3 stage	27,600
exit pump	60 gpm	1,100	60 gpm	1,100	60 gpm	1,100
heat exchanger	250 ft^2	5,100	385 ft^2	6,500	385 ft^2	6,500
polishing filter	230 ft^2	4,000	300 ft^2	4,800	300 ft^2	4,800
boiler (peak Btu/hr)	6×10^6	57,000	7.7×10^6	65,000	7.7×10^6	65,000
storage	2-20,000 gal	18,600	2-40,000 gal	127,000	2-80,000 gal	39,000
shortening blender	1,800 gal	13,500	3,600 gal	18,000	2-3,600 gal	36,000
margarine milk tank	400 gal	7,000	800 gal	9,200	2-800 gal	18,400
margarine oil tank	1,500 gal	11,600	3,000 gal	17,000	2-3,000 gal	34,000
margarine blender	2,000 gal	14,000	4,000 gal	19,000	2-4,000 gal	38,000
votation unit	5,000 lb/hr	12,800	10,000 lb/hr	19,300	2-10,000 lb/hr	38,600
		$414,300		$602,400		$1,007,200

Table 4. Fixed capital cost estimates for batch process soybean oil refineries located in Iowa in dollars

Item	10,000 gal/day	20,000 gal/day	40,000 gal/day	80,000 gal/day
Total installed equipment costs (A)	284,200	414,300	602,400	1,007,200
Site, building costs and improvements (60% of A)	170,500	248,600	361,450	604,350
Process piping (25% of A)	71,000	103,600	150,600	251,800
Instrumentation (3% of A)	8,550	12,450	18,100	30,200
Electrical installations (7% of A)	19,900	29,000	42,200	70,500
Service facilities (30% of A)	85,250	124,300	180,750	302,150
Total physical plant costs (B)	639,350	932,250	135,450	2,266,200
Engineering and construction (20% of B)	127,850	186,450	271,100	453,250
Direct plant cost (C)	767,200	1,118,700	1,626,550	2,719,450
Contractors fees (7% of C)	53,700	78,300	113,800	190,350
Contingencies (15% of C)	115,100	167,800	244,000	408,000
Total fixed capital costs	936,000	1,365,000	1,985,000	3,308,000

Table 5. Material balance for a 20,000 gal/day batch process soybean oil refinery for one 24-hour day (all quantities not specified are pounds)

	Raw materials	By-products		Services
Neutralization				
Crude oil	153,300	Soapstock	7,840 (storage)	Steam 5,780
Na OH	655	Water	6,245 (waste)	electricity 465 kwhr
Water	6,245			
Washing				
Oil	145,460			electricity 310 kwhr
Water	14,546	Water	14,546 (waste)	steam 10,270
Bleaching				
Oil	145,460	Carbon	88 (waste)	Steam 17.9×10^3
Carbon	88	Clay	1,820 (waste)	water 6.2×10^5
Clay	1,820	Oil	1,000 (waste)	electricity 465 kwhr
Hydrogenation				
Oil	93,960	Catalyst	76 (recycle)	steam 4×10^4
Catalyst	95	Catalyst	19 (waste)	water 4.7×10^5
Hydrogen	396	Hydrogen	41 (waste)	electricity 620 kwhr
Deodorization				
Oil	144,815	Steam	28,800 (waste)	steam 1.3×10^5
Steam	28,800	Loss	1,085 (waste)	water 12×10^6 fuel oil 400 gallon electricity 310 kwhr
Margarine mixing				
Oil	40,000			electricity 310 kwhr
Skim milk	10,000			

(continued)

Table 5. (continued)

	Raw materials	By-products	Services
Shortening blending			
Oil	53,250		electricity 310 kwhr
Votation			
Margarine and shortening	103,730		refrigeration 25 tons electricity 310 kwhr
Packaging			
Liquid oil	50,480		
Shortening	53,250		
Margarine	50,000		

Table 6. Manufacturing cost estimate for a 20,000 gal/day batch process soybean oil refinery located in Iowa on the basis of one 24-hour day with operation 300 days/year.

Item	units/day	cost/unit ($)	cost/day ($)
Raw materials			
crude soybean oil	153,300 lbs.	.095	14,900.00
average territorial frt. for oil		.0024	
caustic soda (including frt.)	862 lbs.	.055	47.50
process water	20,790 lbs.	.00012	2.50
process steam	28,800 lbs.	.00055	15.90
hydrogen	366 lbs.	.19	69.50
catalyst	19 lbs.	2.25	47.50
carbon (including frt.)	88 lbs.	.13	11.40
clay (including frt.)	1,820 lbs.	.06	109.00
skim milk for margarine	10,000 lbs.	.0125	125.00
total oil loss	2,085 lbs.	.11	230.00
			15,558.30
soapstock credit	7,840 lbs.	.07	-550.00
net raw material cost			15,008.30
Labor			
operating labor, 8 men/shift, 3 shifts/day	192 man-hrs	2.50	480.00
supervisor - 1 man, 8 hr/day	8 man-hrs	3.25	26.00
Services (including contingencies)			
steam	2×10^5 lbs.	.00055	140.00
water	196×10^5 lbs.	.000013	255.00
electric power	3,100 kw. hr.	.02	62.00
fuel	1,000 gal	.15	150.00
refrigeration	25 ton-day	1.20	30.00
Maintenance (6% of fixed capital investment)			274.00
total direct conversion cost			1.417.00
total direct manufacturing cost			16,425.30
Indirect costs			
depreciation (10% of fixed capital investment)			455.00
taxes and insurance (5% of fixed capital investment)			228.00
plant overhead (50% of direct labor costs)			253.00
Packaging			
margarine packaging and handling	50,000 lbs.	.033	1,650.00
shortening and liquid oil packaging and handling	103,730 lbs.	.018	1,870.00
TOTAL MANUFACTURING COST			20,880.00

Table 7. Manufacturing cost estimate for batch process soybean oil refineries located in Iowa on the basis of one 24-hour day with operation 300 days/year in dollars.

Item	10,000 gal/day cost	40,000 gal/day cost	80,000 gal/day cost
Direct costs			
Raw materials	7,500	30,000	60,000
Labor and services	570	2,290	4,580
Maintenance	187	400	660
Packaging and handling	1,760	7,040	14,080
Indirect costs			
Depreciation	310	660	1,100
Taxes and insurance	155	330	550
Plant overhead	127	506	1,010
Total manufacturing cost per day	10,609	41,226	81,980

Table 8. Working capital estimate for a 20,000 gal/day batch process soybean oil refinery located in Iowa in dollars.

Item	Cost
Raw material inventory (1 month supply at cost)	450,000
Materials in-process inventory (1 week supply at manufactured cost)	144,000
Product inventory (1 month supply at manufactured cost)	620,000
Accounts receivable (1 month's production at selling price)	1,000,000
Available cash (cost of labor, raw materials and utilities and supplies for one month)	510,000
Total	2,724,000

Table 9. Working capital estimates for batch process soybean oil refineries located in Iowa in dollars.

Item	10,000 gal/day cost	40,000 gal/day cost	80,000 gal/day cost
Raw material inventory	225,000	900,000	1,800,000
Materials in process inventory	75,000	300,000	600,000
Product inventory	320,000	1,280,000	2,560,000
Accounts receivable	500,000	2,000,000	4,000,000
Available cash	255,000	1,020,000	2,040,000
	1,375,000	5,500,000	11,000,000

Table 10. Percent return on investment for a 20,000 gallon/day batch process soybean oil refinery located in Iowa.

Item	Dollars
Annual margarine sales	
15 million lbs. $0.21/lb.	3,150,000
Annual shortening sales	
16 million lbs. $0.22/lb.	3,500,000
Annual salad and cooking oil sales	
15.2 million lbs. $0.26/lb.	3,940,000
Total annual sales	10,590,000
Annual production cost	6,270,000
Gross profit	4,320,000
Management and marketing expenses (12% of annual sales)	1,270,000
Net profit before income tax	3,050,000
Federal income tax (50%)	1,520,000
Net earnings	1,530,000
Percent return on fixed and working capital	37.3%

Table 11. Percent return on investment for batch process soybean oil refineries located in Iowa.

Item	10,000 gal crude/day (dollars)	40,000 gal crude/day (dollars)	80,000 gal crude/day (dollars)
Total annual sales	5,295,000	21,180,000	42,360,000
Annual production cost	3,180,000	12,400,000	24,600,000
Gross profit	2,115,000	8,780,000	17,760,000
Management and marketing expenses	635,000	2,540,000	5,100,000
Net profit before taxes	1,480,000	6,240,000	12,660,000
Federal income tax	740,000	3,120,000	6,330,000
Net earnings	740,000	3,120,000	6,330,000
Percent return on fixed and working capital	32.0%	41.7%	44.3%

Table 12. Installed process equipment costs for continuous soybean oil refineries located in Iowa in dollars.

Item	47,000 gal/day		94,000 gal/day	
	size	cost	size	cost
crude oil storage, installed	250,000 gal	33,500	2-250,000	67,000
Refining				
crude oil pump				
caustic pump				
caustic preheater				
proportionometer				
crude oil preheater				
mixers				
refining centrifuges, complete				
soap pump				
refined oil pump				
refined oil heater				

(continued)

Table 12. (continued)

Item	47,000 gal/day size	47,000 gal/day cost	94,000 gal/day size	94,000 gal/day cost
mixer				
wash water pump				
wash water heater				
washing centrifuge				
vacuum dryer				
two stage ejectors with condenser				
dry oil pump				
accessories				
F. O. B. point of manufacture		102,700		162,660
Freight (2% of F. O. B. cost)		2,100		3,200
Installation (43% of purchased cost)		44,300		70,000
Bleaching				
storage tank (4 hr. supply)				
oil supply pump				
slurry tank				
automatic adsorbent feeders				
oil heater				
bleaching vessel with ejector				
treated oil pump				
filter feed pump				
oil cooler				
dual automatic filters				
plus accessories				
F. O. B. point of manufacture		71,560		95,305
Freight (2% of F. O. B. cost)		1,400		1,900
Installation (43% of purchased cost)		30,800		41,000
Storage tank installed	1-35,000 gal	12,500	1-70,000 gal	18,500
Hydrogenation (installed)				
hydrogenators				
slurry tanks				
jets				
catalyst filters				
exit pump				
post bleach tank				
post bleach pump				
post bleach filter				
Installed	1-50,000 gal	15,000	1-1,000,000 gal	22,000
Storage (installed)		81,000		114,000
Deodorization				
Basic process equipment		165,000		250,000
Dowtherm heating equipment		56,000		85,000
Installation		49,000		75,000
Storage (installed)	3-50,000 gal	45,000	3-100,000 gal	66,000
End processing				
Shortening blender	1-4,500 gal	20,800	2-4,500 gal	41,600
Margarine milk tank	1-1,000 gal	10,400	2-1,000 gal	20,800
Margarine oil tank	1-3,500 gal	18,500	2-3,500 gal	37,000
Mixing tank	1-4,500 gal	20,800	2-4,500 gal	41,600
Votation unit	1-10,000 lb/hr	19,300	2-10,000 lb/hr	38,600
		800,000		1,250,000

Table 13. **Fixed capital cost estimates for continuous process soybean oil refineries located in Iowa in dollars.**

Item	47,000 gal/day cost	94,000 gal/day cost
Total installed equipment costs (A)	800,000	1,250,000
Site, building costs and improvements (40% of A)	320,000	500,000
Process piping (25% of A)	200,000	312,000
Instrumentation (12% of A)	96,000	150,000
Electrical installations (7% of A)	55,000	87,500
Service facilities (20% of A)	160,000	250,000
Total physical costs (B)	1,631,000	2,549,500
Engineering and construction (20% of B)	326,000	510,000
Direct plant cost (C)	1,957,000	3,059,500
Contractors' fee (7% of C)	136,000	224,000
Contingencies (15% of C)	292,000	458,000
Total fixed capital cost	2,385,000	3,741,000

Table 14. Material balance for a 47,000 gal/day continuous process soybean oil refinery for one 24-hour day (all quantities not specified are pounds)

	Raw materials		By-products	Services
Neutralization				
Crude oil	360,000	soapstock	13,500 (storage)	electricity 1,100 kwhr
Na OH	1,560	water	9,240 (waste)	steam 135×10^2
Water	9,240			
Washing and drying				
Oil	346,500			electricity 730 kwhr
Water	52,000	water	52,000 (waste)	steam 28×10^3
Bleaching				
Oil	346,500	carbon	187 (waste)	electricity 1,100 kwhr
Carbon	187	clay	3,860 (waste)	water 13.9×10^5
Clay	3,860	oil	212 (waste)	steam 42.5×10^3
Hydrogenation				
Oil	224,000	catalyst	179 (recycle)	water 11.2×10^5
Catalyst	224	catalyst	45 (waste)	steam 9.4×10^4
Hydrogen	940	hydrogen	98 (waste)	electricity 1,460 kwhr
Deodorization				
Oil	345,230	steam	24×10^3 (waste)	water 11×10^6
Steam	24×10^3	loss	1,550 (waste)	steam 9.6×10^4 fuel 520 gal electricity 730 kwhr
Margarine mixing				
Oil	99,000			electricity 730 kwhr
Skim milk	24,800			
Shortening blending				
Oil	125,850			electricity 730 kwhr

(continued)

Table 14. (continued)

	Raw materials	By-products	Services
Votation			
Margarine and shortening	249,650		electricity 730 kwhr refrigeration 50 Tons
Packaging			
Liquid oil	118,830		
Shortening	125,850		
Margarine	123,800		

Table 15. Manufacturing cost estimates for continuous process soybean oil refineries located in Iowa on the basis of one 24-hour day with operation 300 days/year in dollars.

Item	47,000 gal/day cost	94,000 gal/day cost
Direct costs		
Raw materials	35,410	70,820
Labor and services	1,088	2,176
Maintenance	470	750
Packaging	8,500	17,000
Indirect costs		
Depreciation	800	1,250
Taxes and insurance	400	625
Plant overhead	140	280
	46,800	92,900

Table 16. Working capital estimates for continuous process soybean oil refineries located in Iowa in dollars.

Item	47,000 gal/day cost	94,000 gal/day cost
Raw material inventory	1,060,000	2,120,000
Materials in-process inventory	337,000	674,000
Product inventory	1,450,000	2,900,000
Accounts receivable	2,500,000	5,000,000
Available cash	1,100,000	2,200,000
	6,447,000	12,894,000

Table 17. Percent return on investment for continuous process soybean oil refineries located in Iowa.

Item	47,000 gal/day cost	94,000 gal/day cost
Total annual sales	25,400,000	50,800,000
Annual production cost	14,040,000	27,870,000
Gross profit	11,360,000	22,930,000
Management and marketing expenses	3,050,000	6,100,000
Net profit before taxes	8,310,000	16,830,000
Federal income tax	4,155,000	8,415,000
Net earnings	4,155,000	8,415,000
Percent return on fixed and working capital	47.2%	50.6%