Comminuted Collagen: Estimated Costs of Commercial Production

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□ COLLAGEN has been of interest to scientists at the U.S. Department of Agriculture's Eastern Regional Research Center for many years because it is the major protein of cattlehide. In processing, defleshed cattlehide is generally soaked in a lime solution to remove the hair and then is passed through a machine which slices it into two layers or "splits"—an outer or "grain split" and an inner or "flesh split." The grain splits are used to make leather, and the flesh splits are used to make suede leather, as well as collagen for use in the manufacture of sausage casings.

When limed cattlehide flesh splits became underutilized in the 1960s, ERRC scientists recognized that, because of its unique properties, collagen derived from these splits by comminution would be a raw material that offered many uses to the food industry in addition to the manufacture of sausage casings (Fagan, 1968; Kidney, 1970; Talty, 1969a; b). Thus, work was begun to develop a process for preparing a comminuted collagen from cattlehide flesh splits which would retain the unique properties of the protein by causing little or no denaturing of it during manufacture. This work was completed successfully and reported by Komanowsky et al. (1974).

In recent years, various uses for collagen have been reported. Satterlee et al. (1973) showed that a hydrolyzed collagen preparation could replace nonfat dry milk in meat emulsions. Wang and Vieth (1973) prepared enzymatic reactors by immobilizing enzymes on membranes prepared from collagen. A plant producing food-grade collagen for use as an extender, binder, moisturizer, and texturizer in foods and for use in making sausage casings, packaging films, and animal feeds was built in 1976 (Anonymous, 1977). Another plant to produce sausage casings from collagen was scheduled to open last year (Anonymous, 1976). From all this, it appears that interest in collagen, particularly in use of the food-grade product, has increased significantly. As a result of this increased interest, a cost study of the process of Komanowsky et al. (1974) seemed to be in order. The results of this study are the subject of this article. All prices and costs in this publication are as of May 1976.

FIVE PRODUCTS CONSIDERED

Because the optimum physical form of the comminuted collagen may differ somewhat for different end uses, the development work has yielded five separate comminuted products differing in particle size and shape. The specific comminuting steps used determine the physical form of product obtained. Important attributes shared by all of these comminuted collagen products include a very low degree of denaturation and chemical and microbiological acceptability for use in human foods and animal feeds.

The five products also differ in moisture content because, in most of the comminuting steps, water is metered into the comminuting machine along with the hide pieces to serve as a lubricant and coolant. Moisture contents of the five products range from about 78 to 87% (Table 1).

Table 1—**MOISTURE CONTENT AND FLOW RATES** *of raw material and products*

Material	Average moisture convent (%)	Average solids content (%)	Flow rate (lb/hr)	
			As is	Solids basis
Feed (limed splits)	76	24	2,030	487.2
Product 1	78.2	21.8	2,200	479.6
Product 2	85.5	14.5	3,300	478.5
Product 3	83.2	16.8	2,860	480.5
Product 4	82.9	17.1	2,800	478.8
Product 5	86.7	13.3	3,600	478.8

The preparation and properties of these comminuted collagen products have been described in considerable detail by Komanowski et al. (1974) and are reviewed only briefly here. Figure 1, taken from the earlier publication, shows the steps involved in making the various products. The steps through the pH adjustment are common to all five products. The remaining comminuting steps vary with each product. The comminuting procedures shown in Figure 1 were those used in the pilot-plant experiments. The same steps and the same comminuting machines (in some cases, of larger size for greater capacity) are proposed for the commercial-scale plant.

For commerical production of the comminuted collagen, two different types of company operation are envisioned. One involves a "merchant" plant, which manufactures the comminuted collagen and sells it as such on the open market to any and all buyers. The other type involves a "captive" plant, which also produces the comminuted collagen but uses the entire output itself to make other end products for sale, such as sausage casings. Since these two types of plant differ in certain physical features as well as cost aspects, they are discussed separately in this article. The basic process, however, is the same for each.

"MERCHANT" MANUFACTURING PLANT

Figure 2 is a flow sheet of the process as it would be conducted in the visualized commercial-scale merchant plant. While the flow sheet shows that water is

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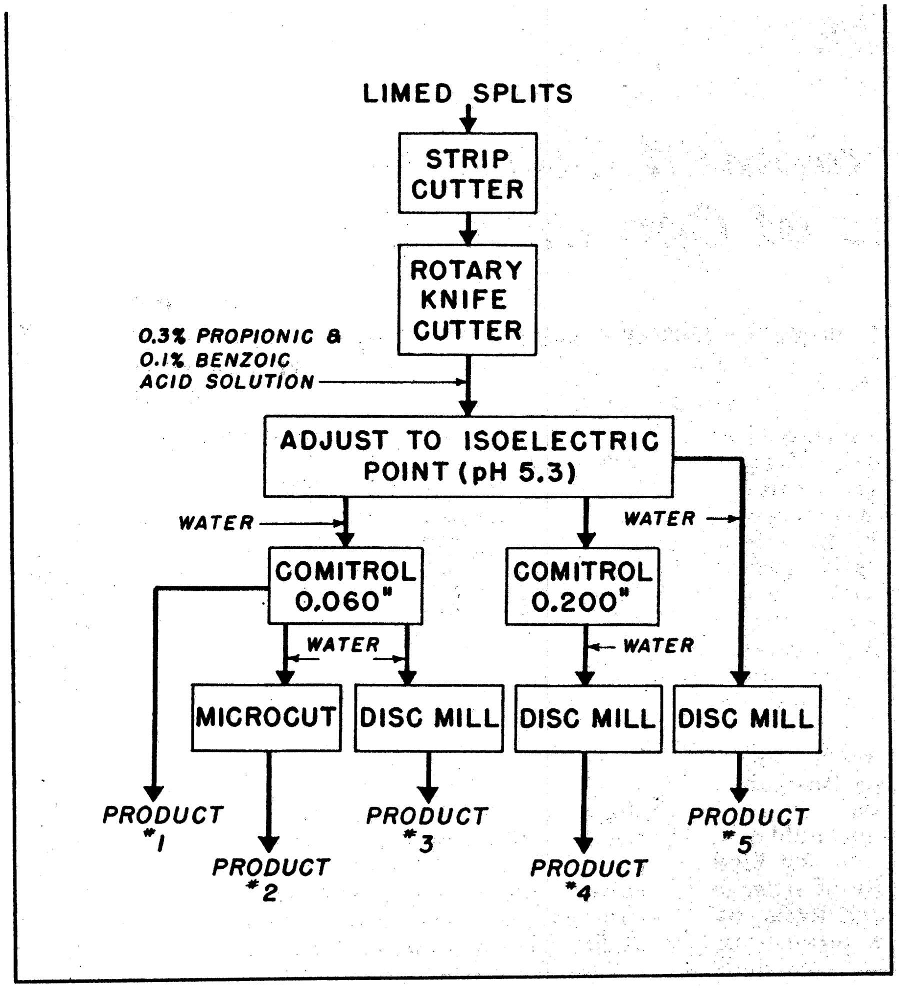
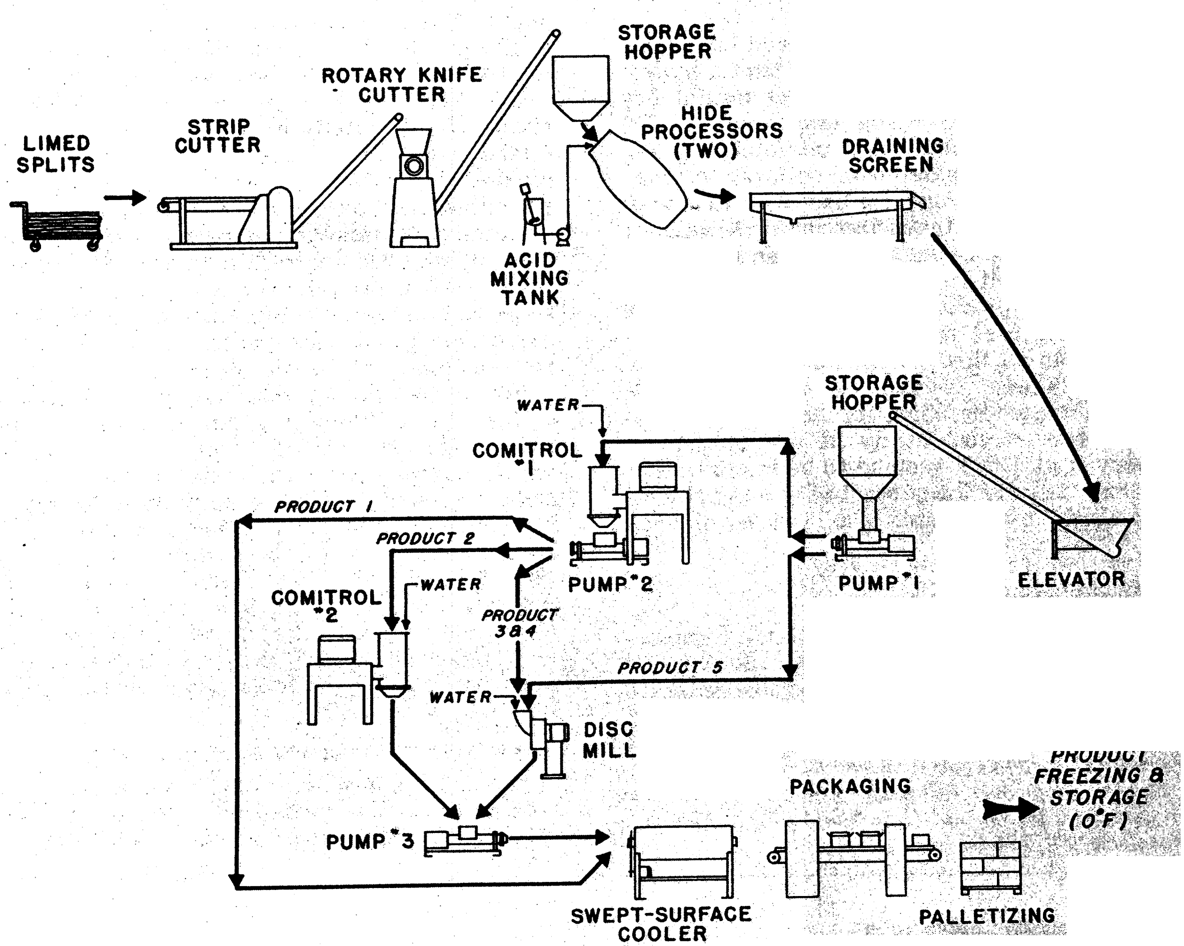


Fig. 1 (at left)—
PILOT-PLANT PRODUCTION *of comminuted collagen products*

Fig. 2 (below)—
COMMERCIAL PRODUCTION *of comminuted collagen products*



added to the comminuting machines (Comitrols, manufactured by Urschel Laboratories, Inc.) and disc mill for all comminuting steps, there is one exception. In making Product 4, for which a 0.200-in cutting head is used in Comitrol No. 1, it is not necessary to add water to the Comitrol.

• **The Process.** Operations would be carried out as follows: Limed cattlehide flesh splits are received on pallets and stored at 38°F. As needed, pallet loads are moved by fork-lift truck to the cutters. Here the splits are passed through the strip cutter and the rotary knife cutter, yielding pieces roughly ⅜ in on a side. These pieces are then moved by conveyor either directly into one of the two hide processors or into a hopper for temporary storage until a hide processor is ready to receive a fresh charge. Each charge to a hide processor consists of approximately 5,330 lb of chopped hide, 16,000 lb of water, and an aqueous solution of 48 lb of propionic acid and 16 lb of benzoic acid. Inside the slowly rotating hide processor, the hide pieces are gently tumbled for 4 hr in the dilute acid solution, while their pH gradually drops to about 5.3. Next, the hide pieces are discharged from the processor onto a slowly moving screen-conveyor, which retains them for about 15 min while allowing them to drain. The spent dilute acid solution goes to the sewer, and the drained hide pieces are elevated into a storage hopper. Since the hide processors deliver large batches of the acidified hide pieces at intervals spaced several hours apart, the storage hopper enables feeding the acidified pieces continuously and at uniform rate to the subsequent comminuting steps.

A progressing-cavity pump takes hide pieces from the storage hopper and feeds them into the first comminuting machine, either a Comitrol or, in the case of Product 5, a disc mill. A second pump of the same type then takes the discharge from the first comminuting machine and, for Products 2-4, feeds it to the second comminuting machine. The "microcut" designation in Figure 1 refers to a Comitrol machine which is equipped with a fine-cut type of cutting head. After the second comminuting step (after the single comminuting step for Products 1 and 5), the comminuted collagen is again picked up by a progressing-cavity pump and pumped through a swept-surface heat exchanger to lower its temperature to about 35°F. Next, the chilled collagen is packed into a container, consisting of a plastic bag within a corrugated box, that holds 50 lb of product. The boxes are stacked on a pallet in such a way as to leave an air space between adjacent boxes, and conveyed by fork-lift truck to a storage room maintained at 0°F. Here, the collagen freezes and is kept frozen until shipment.

• **Assumptions for Commercial Plant.** To establish a logical basis for the designing, scheduling of operations, and costing of the visualized commercial plant, a number of specific premises or "ground rules" had first to be adopted. The more important of these are discussed below.

The plant was assumed to be established as an adjunct to an existing plant, which was assumed to be either a cattle slaughtering plant or a tannery. The collagen plant and its equipment, however, were assumed to be all new for costing purposes. Plant output was assumed to be a nominal 4 million lb of product per year, based on a moisture level of 76%. Actual product moisture contents will run higher than this, so actual weights would be greater. The plant would be equipped to manufacture all five of the comminuted collagen products. Since it is not known what the market demand for each product would be relative to the other four, the simplifying assumption was made that an equal weight (on the solids basis) of each product would be produced and sold. It is realized, of course, that selling equal amounts of all five products is unlikely in actual practice. However, changing the relative amounts of the five products should have little effect on the manufacturing costs or on plant operating procedures, since the overall processing operations are very similar for each of the five products. It was also assumed, to simplify plant operation, that only one product would be made on a given day.

Daily output of the plant was assumed to consist of 8 hr of production at the rate of 2,000 lb of product (76% moisture basis) per hour, or 16,000 lb a day. Operations would be conducted 5 days a week, 50 weeks a year, to give an annual production of 4 million lb, evenly divided among the five products. On a given workday, plant operations would actually extend over a 14-hr period. This includes start-up operations, 8 hr of operation of the comminuting and packaging lines, and shutdown and cleanup procedures. Workers would arrive at staggered times as needed, and would each work an 8-hr shift. This operating schedule would permit sufficient time to add a second daily work shift if this should become necessary to meet increased sales demand. A second production shift would add only about eight more actual hours of operation a day, namely for running the comminuting and packaging lines, since the startup and shutdown procedures would still require about the same length of time.

Losses during processing were assumed to average approximately 1½% of the weight of limed splits fed to the process. Thus, for a product rate of 2,000 lb/hr, 2,030 lb of limed splits per hour would be fed, both figures based on 76% moisture content. Since all the products have moisture contents higher than 76% because water is added during comminution, actual weight rates would be approximately as shown in Table 1.

• **Sanitary Aspects.** As stated above, the comminuted collagen products produced in pilot-plant operations have been found fully acceptable for food use from the chemical and microbiological standpoints. The limed splits have a high pH (about 12.5) and are bacteriologically clean. While at this high pH, they are cut into approximately ⅜-in × ⅜-in pieces by the strip cutter and rotary knife cutter.

In the next operation, acidification in the hide processor, the pH of the hide pieces is reduced to about 5.3. At this pH level, they are more readily subject to bacterial attack and from this point on must be handled so as to minimize the likelihood of bacterial contamination and/or growth. To minimize the chances of contamination, all processing equipment must be thoroughly cleaned and sanitized at the end of each day's operations. To minimize the growth of any bacteria that may become introduced into the collagen, the latter should be kept moving promptly through all the processing steps. Also, to retard bacterial growth, the material should be kept at fairly low temperature during processing. For this reason, chilled water will be used in the charge to the hide processor. Likewise, the water added to the commin-

Table 2—**EQUIPMENT AND FACILITIES** *required for merchant plant*[a]

A. Processing Equipment	
1. Strip Cutter To cut limed splits into strips approximately ⅜-in wide. Feed to cutter will be either whole hides folded in half, or sides. Taylor-Stiles Model 236, "Giant" rotary knife cutter, 35½-in-wide throat, with feeder and discharge belt, 15-hp motor; or equal	$39,000
2. Rotary Knife Cutter To cut hide strips from Item 1 into pieces approximately ⅜ in on a side. Taylor-Stiles Model 914, heavy-duty rotary knife-type cutter, stainless steel, 6-in × 14-in throat opening, equipped with screen having 1-in round holes, 15-hp motor; or equal	$ 9,500
3. Portable Elevator, Conveyor Type To elevate cut pieces from Item 2 up into either of the two hide processors, Item 5, or into storage hopper, Item 4. Also to take hide pieces from bottom outlet of storage hopper and elevate them into either one of the hide processors. Stainless-steel, cleated rubber belt, 2-hp motor	$ 10,000
4. Storage Hopper To hold approximately 5,400 lb of ⅜-in hide pieces, or one charge to a hide processor. Vertical, cylindrical stainless-steel open-top tank with Vibra-Screw "live bottom" and 10-in-diameter discharge opening	$ 8,800
5. Hide Processor, Concrete-Mixer Type For neutralization step. To hold total charge of approximately 21,300 lb. Challenge-Cook Model HP-200, with polyester resin lining and pump-out system. Two required at $31,000 each; price for two	$ 62,000
6. Draining Screen To receive wet pieces from hide processor and allow them to drain while on moving belt. Stainless steel, horizontal moving-belt-conveyor type, with stainless-steel mesh belt 30 in wide × 24 ft long, with raised sides along belt, and drip pan under belt	$ 11,000
7. Acid Mixing Tank To dissolve the benzoic acid in the propionic acid before adding the mixed acids to the hide processor for the neutralizing step. Approximately 25-gal plastic tank on legs, with separate cover, bottom outlet, clamp-mounted propellor agitator, delivery pump	$ 1,500
8. Elevating Conveyor To receive drained hide pieces from draining conveyor, Item 6, and elevate them to top of storage hopper, Item 9. Stainless-steel construction, cleated rubber belt	$ 8,000
9. Storage Hopper To store neutralized hide pieces received from Item 8 and feed them as needed to comminuting equipment. Same description as Item 4	$ 8,800
10. Pumps To deliver hide pieces from discharge of storage hopper, Item 9, to inlet of first comminuting machine, Item 11 or 12; also to deliver ground material from first comminuting machine to second one; and from second machine through swept-surface cooler to packaging line. Progressing-cavity type, Moyno Model 1FFJ8 or equivalent; sanitary stainless-steel with Buna-N stator lining; 2-hp motor, 50-550 rpm. Complete with drive and base and with special plunger feeder on pump inlet. Three pumps at $5,200 each	$ 15,600
11. Comminuting Machine For cutting neutralized hide peices into small particles. Urschel Laboratories' Comitrol, stainless steel, with three interchangeable cutting heads: 0.06 in, 0.2 in, and "microcut"; 30-hp motor. Two required; price for two	$ 25,000
12. Disc Mill For comminuting hide pieces, in conjunction with Item 11. Equipped with 36-in discs, stainless-steel contact parts, 75-hp motor. Young-Robinson 36-in mill or equal	$ 28,000
13. Swept-Surface Cooler To cool comminuted collagen product to 35°F before being filled into cartons. Refrigeration load 6-20 tons, depending on product being made. Swept-surface type cooler, 75 sq ft of heat-transfer area, Type 304 stainless steel	$ 25,000
14. Packaging Equipment To fill bag-in-box type cartons, 50 lb net each, at rate varying from 44 cartons/hr for Product 1 to 72 cartons/hr for Product 5	$ 25,000
Total Processing Equipment	**$277,200**
B. Buildings	
1. Main Building Includes processing area, office, maintenance shop, dry storage area, and refrigerated rooms (Items 2 and 3 below). Overall size 50 ft × 110 ft (5,500 sq ft)	$166,000
2. Frozen Storage (0°F) Room For product freezing and storage. Approximately 1,200 sq ft of floor area with 12-ft ceiling. Can store 2 weeks' output of finished products	$ 43,000
3. Refrigerated Storage (38°F) Room To store one week's supply of limed split hides (raw material for the process). Approximately 600 sq ft of floor area, 12-ft ceiling	$ 22,000
Total Buildings	**$231,000**
C. Other Facilities	
1. Fork-Lift Truck For transporting pallet loads of hides, collagen, etc.	$ 10,000
2. Pick-Up Truck For deliveries, pickups, and general use	$ 5,000
3. Refrigeration Unit To furnish refrigeration for 0°F frozen storage room; 18-ton capacity	$ 36,000
4. Refrigeration Unit To provide refrigeration for 38°F room, for swept-surface cooler (processing equipment Item 13), and for air-conditioning of processing area at 60°F; 50-ton capacity	$ 52,000
Total Other Facilities	**$103, 000**

[a]Reference to brand or firm name does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned

uting machines during grinding will be chilled. In addition, the entire processing area will be air-conditioned to a temperature of 60°F or lower. Once the comminuted product has been chilled to 35°F and placed in the 0°F room, where it will freeze and be kept frozen, there should be no further bacterial growth nor opportunity for introduction of microorganisms.

Thus, if the process starts with clean, high-pH limed splits, if proper processing conditions are observed throughout, and if a conscientious program of equipment cleaning and sanitation is maintained, there should be no problem of excessive bacterial count or microbial spoilage in the products. The storage life of the frozen products, from the bacteriological standpoint, should be practically unlimited.

• **Equipment and Facilities Required.** The main processing equipment and facilities required, with a brief description and estimated price of each item, are listed in Table 2.

• **Fixed Capital Cost.** The next cost item to be computed for the project is the fixed capital cost, or the total dollar investment required to build and equip the plant so that it will be ready to operate. Table 3 lists the individual items entering into the computation of the total fixed capital cost.

• **Selling Price and Operating Costs.** There is a certain minimum price level at which the collagen products must be sold in order to justify the project economically. This price level must cover all costs and expenses of operating the plant and selling the products; it must provide for a payback of the original invested fixed capital (through annual depreciation charges or allowances); and it must also provide, through net profits after taxes, a sufficiently high return on the invested capital to make the project financially attractive to prospective investors of the necessary capital.

The operating cost sheet shown in Table 4 brings together all items of manufacturing cost, expenses, overheads, taxes, and profits. The total of these items indicates the price at which the products must be sold to yield a satisfactory return on the invested capital, and is designated as the "factory selling price" for the products. Of course, if the products find sufficient market demand that they can be sold at a higher price, which will yield a greater return on the investment, the project will be correspondingly more attractive financially. The rate of return on the fixed

Table 3—**MERCHANT PLANT FIXED CAPITAL COSTS**

Item	Estimated cost ($)
1. Land acquisition and site preparation	7,500
2. Driveways and parking areas	6,000
3. Buildings (Table 2)	231,000
4. Boiler (steam–small package unit)	8,000
5. Processing equipment (Table 2)	277,200
6. Erection of processing equipment	40,000
7. Instrumentation (simple)	4,000
8. Piping and ductwork	16 000
9. Installation of electrical power supply (400-kw capacity)	80,000
10. Pickup truck and fork-lift truck	15,000
11. Refrigeration equipment (Table 2)	88,000
12. Freight on purchased equipment	12,000
13. Office furniture and fixtures	3,500
Subtotal	**788,200**
14. Engineering fees, contractor's fee, and contingencies (⅓ of subtotal)	262,800
Total fixed capital cost	**1,051,000**

capital investment selected for the present calculation was 15% per year net profit after all expenses and taxes. Other rates could, of course, be selected if desired, and the resulting adjustment in the factory selling price could easily be calculated.

Table 4 gives itemized costs in dollars per operating day, based on 250 operating days per year. It also gives costs in cents per pound of product, on the 76% moisture basis.

To arrive at a numerical factory selling price in Table 4, it would be necessary to use a specific numerical figure for the cost of limed splits. One objection to using a specific figure is that the cost of limed splits can vary over a rather wide range. Inserting a given specific figure in the table might create a false impression that the figure used is the actual "going price" for edible-grade limed splits. To avoid this impression, the cost of limed splits was carried throughout as a variable item: the total daily cost for limed splits, in dollars, was designated as "CLS"; similarly, the unit cost for limed splits, expressed in cents per pound of product, was designated as "CLS¢." The latter figure was determined from CLS by multiplying by 100 (to convert from dollars to cents), then dividing by 16,000, the number of pounds of product made per day.

There does not appear at present to be any standard "going market price" for edible-grade limed

Table 4—**MERCHANT PLANT OPERATING COSTS**

Basis: Normal plant operation is for 8 hr of production per day, 5 days/wk, 250 days/yr; for total of 2,000 hr of production per year. Production rate is nominally 16,000 lb/day at 76% moisture basis or 3,840 lb/day day on a moisture-free basis (MFB). Annual production is 4 million lb at 76% moisture or 960,000 lb MFB

Item	Cost per day($)	Cost per pound of product, 76% moisture basis[a] (¢)
I. Factory Manufacturing Costs		
A. Direct production costs		
1. Raw materials		
a. Limed splits, delivered, 76% moisture basis; 16,240 lb/day	Cost will vary; = "CLS"	Cost will vary; = "CLS(¢)"
b. Propionic acid, 55-gal drums, 25¢/lb delivered, 144 lb	36.00	0.23
c. Benzoic acid, USP, 55¢/lb, 48 lb	26.40	0.16
Total raw materials	62.40 + 1.0 × CLS	0.39 + 1.0 × CLS¢
2. Packaging materials (assume 1.1¢/lb of as-is product)		
a. Product 1	193.60	1.21
b. Product 2	290.40	1.82
c. Product 3	251.68	1.57
d. Product 4	246.40	1.54
e. Product 5	316.80	1.98
3. Operating labor (7 operators, 8 hr/day each at $4.50/hr)	252.00	1.58
4. Indirect labor (one supervisor @ $5.50/hr)	44.00	0.28
5. Maintenance and repairs (3.5% of fixed capital per year)	147.14	0.92
6. Operating supplies (12% of Item 5)	17.66	0.11
7. Utilities		
a. Steam, 2,000 lb/day @ $3.50/1,000 lb	7.00	0.04
b. Electricity, 2,400 kw-hr/day at 3.0¢/kw-hr	72.00	0.45
c. Fuel for fork-lift truck	2.50	0.02
d. Refrigeration (cost included under water and electricity)	—	—
e. Water, 120,000 gal/day at 30¢/1,000 gal	36.00	0.23
Total utilities	117.50	0.73
Total direct production costs (Items 1-7)	640.70 + packaging material +1.0 × CLS	4.00[b] + packaging material + 1.0 × CLS¢
B. Fixed charges		
8. Insurance (1% of fixed capital per year)	42.04	0.26
9. Taxes—real estate (1.5% of fixed capital per year)	63.06	0.39
10. Depreciation (calculated by straight-line method)	305.61	1.91
Total fixed charges (Items 8-10)	410.71	2.57[b]
C. Plant overhead cost		
11. Non-wage payments (social security, workmen's compensation, vacation, unemployment insurance; basis = 30% of wages)	88.80	0.56
12. Laboratory fees for product testing	15.00	0.09
13. Miscellaneous factory expenses (includes waste disposal)	15.00	0.09
Total plant overhead costs (Items 11-13)	118.80	0.74
Total factory manufacturing cost (sum of A, B, and C)	1,170.21 + packaging material +1.0 × CLS	7.31[b] + packaging material +1.0 × CLS¢

Item	Cost per day($)	Cost per pound of product, 76% moisture basis[a] (¢)
II. General Expenses		
D. Interest on working capital	45.20 + 0.016484 × CLS	0.2825 + 0.016484 × CLS¢
E. Research and development	80.00	0.50
F. Administration and general (20% of labor, supervision, maintenance and repairs, and operating supplies)	100.00	0.63
Total general expenses (sum of D, E, and F)	225.20 + 0.016484 × CLS	1.41 + 0.016484 × CLS¢
III. Cost to Make (sum of I and II)[c]	1,589.01 + 1.016484 × CLS	9.93 + 1.016484 × CLS¢
IV. Selling Costs (assume 7% of sales)	210.92 + 0.076923 × CLS	1.31825 + 0.076923 × CLS
V. Profits, Taxes, and Discounts		
A. Net profit; 15% of fixed capital per year	630.60	3.94
B. Taxes on income (local, state, and federal); 90% of net profit	567.54	3.55
C. Returns, allowances, and discounts; 0.5% of sales	15.07 + 0.005495 × CLS	0.09 + 0.005495 × CLS¢
VI. Selling Price (sum of III, IV, and V). The daily costs of the five products differ slightly because of differences in packaging material costs. Using packing material costs from Item I. A. 2 gives the following selling prices:		
A. Product 1	3,013.14 + 1.0989 × CLS	18.83 + 1.0989 × CLS¢
B. Product 2	3,119.51 + 1.0989 × CLS	19.50 + 1.0989 × CLS¢
C. Product 3	3,076.96 + 1.0989 × CLS	19.23 + 1.0989 × CLS¢
D. Product 4	3,071.15 + 1.0989 × CLS	19.19 + 1.0989 × CLS¢
E. Product 5	3,148.52 + 1.0989 × CLS	19.68 + 1.0989 × CLS¢

[a]Based on 16,000 lb of product per day

[b]Subtotals may not agree exactly with sum of individual items because of rounding-off to two decimal places

[c]Figures for Items III through VI include the cost of packaging materials for Product 1

splits. Some of these, of course, are being sold and used. The price at which they change hands appears to be arrived at by negotiation between supplier and user, and involves certain considerations—for the seller, an assured outlet for an extended time, and for the buyer, an assured source of supply at a reasonably stable price. Preparing edible-grade splits does involve more care and labor in the slaughterhouse and tannery and also prompt handling of fresh hides, thus incurring higher costs than for the regular or non-edible grade.

The actual manufacturing cost per pound of collagen product will vary slightly among the five products because of the differences in moisture levels. Since the bag-in-box containers are filled to 50 lb net weight, the products with the higher moisture levels (such as Products 2 and 5) require more containers to package the same amount of product corrected to a 76% moisture basis. This results in a slightly higher packaging cost for the high-moisture products for the same amount of collagen solids. However, this difference is small. The difference in packaging cost between the lowest-moisture product (No. 1) and the highest-moisture product (No. 5) is about 0.8¢/lb of 76%-moisture-basis product.

The actual numerical values for factory selling price of the collagen product were calculated from Table 4 by inserting specific numerical values for the cost per pound of edible-grade limed splits. Table 9 gives these values for Product 3, which has a selling price very close to the average factory selling price of the five collagen products. Table 9 also lists the corresponding figures for the captive plant, which is discussed in detail below.

- **Financial Analysis.** Table 5 presents a brief financial statement for the project on an annual basis. The figures here correspond to those in Table 4 (plant operating costs) for Product 3.

- **Effect of Raw Material Cost.** It has been stated that the cost to the collagen plant of edible-grade limed splits could vary over a rather wide range. Their cost, even at the low end of the range, represents a significant proportion of the factory selling price for the collagen products (Table 6). At 21¢/lb for limed splits, their cost represents about 50% of the factory selling price; at 60¢/lb, 71% of factory selling price.

- **Effect of Variation in Fixed Capital Cost.** Another cost item that can vary and affect the factory selling price is the fixed capital investment; that is, the amount of money that must be spent to build and equip the plant so that it is ready to operate. The fixed capital cost has a pervasive effect on selling price because it directly affects the magnitude of a number of operating cost items, including maintenance and repair, operating supplies, real estate taxes, depreciation, insurance, net profits, and taxes on income. It also enters indirectly into a number of other items, especially those based on dollar sales volume, including selling expense, returns, allowances, discounts, and interest on working capital. The charges for those operating cost items that are related to fixed capital investment amount in total each year to nearly 50% of the fixed capital investment. In the present case, where the fixed capital investment is estimated at $1,051,000, the annual total of the operating cost charges that depend on fixed capital investment comes to about $490,000. Dividing this figure by 4 million lb of annual output gives a charge of 12.2¢/lb of product as that portion of the factory selling price that goes to pay for fixed-capital-related items. This figure can help show the "sensitivity" of the factory selling price to fixed capital investment. If the actual fixed capital required should turn out to be 25% higher than that estimated, then the operating cost charges related to fixed capital would increase by 25% or by 3.0¢/lb. This addition would amount to an increase in 4.1% in the factory selling price when limed splits cost 50¢/lb, and a 6.5% increase when

Table 5—**MERCHANT PLANT FINANCIAL ANALYSIS:** *annual basis (250 days/yr); figures are based on "average" factory selling price for Product 3*

1. Gross sales	= 250 × ($3,076.96 + 1.0989 × CLS)	$769,240 + 274.7253 × CLS
2. Returns, allowances, and discounts	= ½% of Item 1	3,846 + 1.3736 × CLS
3. Net annual sales	= Item 1 − Item 2	765,394 + 273.3517 × CLS
4. Factory manufacturing cost	= 250 × (1,421.89 + CLS)	355,473 + 250.00 × CLS
5. Gross annual profit	= item 3 − Item 4	409,921 + 23.3517 × CLS
6. Other expenses:		
a. Administrative and general	= 25,000	
b. Research and development	= 20,000	
c. Interest on working capital	= 11,539 + 4.1209 × CLS	
d. Selling expenses	= 53,847 + 19.2308 × CLS	
Total other expenses		110,386 + 23.3517 × CLS
7. Profit before taxes	= Item 5 − Item 6	299,535 + 0.00 × CLS
8. Taxes on income: federal, state, and local		141,885
9. Net profit after taxes (net annual earnings)		157,650
10. Percent earned on total fixed capital of $1,051,000		15%
11. Cash flow		
a. Depreciation	= 76,403	
b. Net earnings	= 157,650	
		234,053
12. Payout time in years = fixed capital divided by cash flow	= $1,051,000 ÷ $234,053	4.49

Table 6—**EFFECT OF RAW MATERIAL COST** *on selling price of collagen produced in merchant plant*

Price paid for limed splits at 76% moisture (¢/lb)	65	60	55	50	45	40	35	30	25	20	15	10
Factory selling price of collagen Product 3, 76% moisture basis (¢/lb)	91.7	86.2	80.6	75.0	69.4	63.9	58.3	52.7	47.1	41.5	36.0	30.4
Breakdown of factory selling price (¢/lb of product) attributable to:												
Cost of limed splits	66.0	60.9	55.8	50.8	45.7	40.6	35.5	30.5	25.4	20.3	15.2	10.2
All other expenses	25.7	25.3	24.8	24.2	23.7	23.2	22.8	22.2	21.7	21.2	20.8	20.2
Percentage of factory selling price attributable to:												
Cost of limed splits	72	71	69	68	66	64	61	58	54	49	42	34
All other expenses	28	29	31	32	34	36	39	42	46	51	58	66

limed splits cost 25¢/lb. Thus, the effect of changes in fixed capital cost on factory selling price is relatively small, especially when compared to the effect of changes in the cost of limed splits.

"CAPTIVE" MANUFACTURING PLANT

The collagen plant could also be set up as a "captive" plant, where essentially the entire plant output is used by the manufacturer himself in the production of another product or products which will be sold on the open market. With a captive plant, fewer types of product would be made, probably only one or two. Also, the comminuted products need not be packaged, since they would shortly undergo further processing. Most likely they would go into temporary bulk storage in a refrigerated holding tank. Also, the need for product freezing would be eliminated, at least at the product stage arrived at by the operations included in this article. Thus the costs involved in packaging and freezing would be eliminated. For a captive plant, therefore, both fixed capital cost and plant operating costs would be somewhat lower than for a merchant plant of the same capacity.

Table 7—**CAPTIVE PLANT FIXED CAPITAL COSTS**

Item	Estimated cost ($)
1. Land acquisition and site preparation	7,500
2. Driveways and parking areas	6,000
3. Buildings (See text)	158,000
4. Boiler (steam—small package unit)	8,000
5. Processing equipment	252,200
6. Erection of processing equipment	38,000
7. Instrumentation (simple)	4,000
8. Piping and ductwork	16,000
9. Installation of electrical power supply (375-kw capacity)	75,000
10. Pickup truck and fork-lift truck	15,000
11. Refrigeration equipment	54,000
12. Freight on purchased equipment	11,000
13. Office furniture and fixtures	3,500
Subtotal	**648,200**
14. Engineering fees, contractor's fee, and contingencies (⅓ of subtotal)	216,100
Total fixed capital cost	**864,300**

Table 8—**SUMMARY OF PLANT OPERATING COSTS** *for captive plant (same basis as for merchant plant; see Table 4)*

Item	Cost per day ($)	Cost per pound of product, 76% moisture basis[a] (¢)
I. **Factory Manufacturing Costs** (see text)	1,010.20 + 1.0 × CLS[b]	6.31 + 1.0 × CLS¢[c]
II. **General Expenses**		
D. Interest on working capital (4 wk of sales; 9%/yr)	15.21 + 0.0070066 × CLS	0.10 + 0.0070066 × CLS¢
E. Research and development	75.00	0.47
F. Administration and general	100.00	0.63
Total General Expenses (sum of D, E, and F)	190.21 + 0.0070066 × CLS	1.19 + 0.0070066 × CLS¢[d]
III. **Cost to Make** (sum of I and II)	1,200.41 + 1.0070066 × CLS	7.50 + 1.0070066 × CLS¢
IV. **Selling Costs** (no outside sales)	—	—
V. **Profits, Taxes, and Discounts**		
a. Net profit after taxes (15% of fixed capital)	518.58	3.24
b. Taxes on income (90% of net profit after taxes)	466.72	2.92
c. Product "off-specs," 0.5% of total production	10.98 + 0.0050603 × CLS	0.07 + 0.0050603 × CLS¢
VI. **"Fully Costed Price"** for Product (sum of III, IV, and V)	2,196.69 + 1.012067 × CLS	13.73 + 1.012067 × CLS¢

[a]Based on 16,000 lb of product per day
[b]CLS = cost of limed splits in $/day; equals price per pound × 16,240 lb/day
[c]CLS¢ = cost of limed splits per pound of product; equals CLS × 100 ÷ 16,000
[d]Subtotals may not agree exactly with the sum of individual items because of rounding-off to two decimal places

• **Basic Assumptions.** Except as noted in the preceding paragraph, the "ground rules" or basic assumptions for the captive plant would be essentially the same as for a merchant plant. The operating schedules and procedures (except for packaging and freezing) would likewise be about the same.

• **Fixed Capital Costs.** Comparing capital costs for the captive plant (Table 7) with those for the merchant plant (Table 3) yields the following figures: By eliminating packaging, the cost of processing equipment decreases from $277,200 to $252,200. The reduction in processing equipment results in a decrease of $2,000 in erection costs, $5,000 in electrical installation costs, and $1,000 in freight costs. By eliminating the 1,200-sq-ft 0°F storage room in the main building, the cost of buildings decreases from $231,000 to $158,000. By eliminating the 0°F refrigeration unit and slightly increasing the capacity of the 38°F refrigeration unit to provide for refrigerating a bulk product storage tank, the cost for refrigeration equipment decreases from $88,000 to $54,000. In addition, the engineering fees, contractor's fee, and contingencies expense decreases from $262,800 to $216,100. Thus, the total fixed capital cost estimated for the captive plant becomes lower than that for the merchant plant by $186,700 or 17.8%

• **Plant Operating Costs.** Operating costs are also lower for the captive plant (Table 8). For conciseness in Table 8, the individual items included under "I, Factory Manufacturing Costs" (Nos. 1-13 as in Table 4) are not shown. However, the reductions in cost for these items in Table 8, as compared to the same items in Table 4, are as follows: Item 2, eliminated; Item 3, one less operator =0.23¢/lb; Items 5 and 6 together =0.18¢; Item 7 =0.07¢; A, direct production cost =0.48¢ reduction and elimination of packaging material cost; B, fixed charges =0.45¢; C, plant overhead costs =0.06¢; I, factory manufacturing cost =1.0¢ reduction and elimination of packaging material cost. Items II through VI on the operating costs sheets for the two plants (Tables 4 and 8) can be compared directly. Interest on working capital (Table 8) is lower because there is neither inventory of finished product nor accounts receivable to be carried as working capital. Also, no expense is charged for selling the captive product. An annual profit of 15% of the fixed capital is charged as before, although fixed capital itself is now lower. Taxes on income are also charged. Thus, the selling price (Item VI) represents a "fully costed" price at which the comminuted collagen could be transferred as "raw material" to another portion of the plant for processing into final product for outside sale. This fully costed price is approximately 9¢/lb lower than the average factory selling price of the five merchant plant products, when limed splits cost 35-40¢/lb. The cost for the captive plant collagen is compared in Table 9 to the factory selling prices for Product 3 of the merchant plant, for various limed-split costs.

Table 9—**COMPARISON OF COLLAGEN COSTS** *for merchant plant and for captive plant as a function of raw material cost (all figures based on 76% moisture content)*

Cost of limed splits (¢/lb)	Factory selling price of merchant plant product 3 (¢/lb)	Cost (i.e., "fully costed price") of captive plant collagen (¢/lb)
65	91.7	80.5
60	86.2	75.4
55	80.6	70.2
50	75.0	65.1
45	69.4	60.0
40	63.9	54.8
35	58.3	49.7
30	52.7	44.5
25	47.1	39.4
20	41.5	34.3
15	36.0	29.1
10	30.4	24.0

TO MAKE OR BUY COLLAGEN?

Table 9 compares costs for a merchant plant and a captive plant which have equal capacity, namely 4 million lb/yr. From this table, one might conclude that it is cheaper for a user of comminuted collagen to make the product himself than to buy it. However, the per-pound cost of manufacturing the collagen goes up significantly as the size of plant is reduced, so that a small captive plant may have higher costs than a large merchant plant. For example, for a captive plant having a capacity of 1 million lb/yr, a cost estimate shows a collagen cost of about 26¢/lb over the cost of limed splits, i.e., 66¢/lb when limed splits cost 40¢/lb. This compares with the factory selling price of 63.9¢/lb for a merchant plant making 4 million lb/yr, as shown in Table 9.

In this particular example, since the per-pound costs are not far apart, the decision to make or buy the collagen could turn on other factors, such as the availability and cost of capital to build a captive plant, the anticipated reliability of supply from a captive plant as compared to that from purchasing, and the potential for better control of quality in a captive plant.

To generalize, if a manufacturer plans to use very large quantities of collagen for an extended period of years, a captive plant would be cheaper; for relatively small users, buying the comminuted collagen would save money.

CHANCES FOR COMMERCIAL SUCCESS

The chances for commercial success of a merchant plant to manufacture the comminuted collagen appear to depend chiefly on the development of a market of sufficient size for the product; this, in turn, depends on finding suitable applications and an acceptable price level for the collagen. The factory selling price of the collagen depends in large part on the cost of edible-grade limed splits, which sell at a premium over the price of the regular or non-edible grade. However, with increasing usage and production of edible-grade splits, this premium could narrow, thus enabling a lower factory selling price for the collagen. Factory selling prices average about 24¢/lb over raw material cost.

The chances for commercial success of a captive collagen plant depend, of course, on the market situation for the final product or products into which the collagen is being processed by the parent company. In this case, the price that must be charged to the parent company for comminuted collagen will average about 15¢/lb over raw material cost. Obviously then, a company that utilizes a significant quantity of collagen should provide its own comminuting facility and start with edible-grade limed splits.

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Further details on the process and small samples of the products are available from the authors.