column. Special molybdenum steel alloys are used to prevent corrosion.

The first column, fed continuously with split soapstock, removes moisture, low-boiling unsaponifiable matter, odorous constituents, low-boiling coloring matter, and some low-boiling fatty acids. The residue from this column is fed into the side of the second column, where the major fractionation by chain length occurs. A palmitic acid fraction is removed from the top of the second column. The main linoleic-oleic fraction may be taken off at a lower point in the second column, or the residue from the second column may be fed to the third column, where the linoleic-oleic fraction is taken off overhead. The final undistilled residue is withdrawn from the bottom of the third column and is further treated in a separate pitch still to produce pitch of required properties.

By thus removing the saturated acids from cottonseed acids by distillation or crystallization, the composition is changed from that of a slow or semi-drying oil (iodine value of 100 with 40-45% linoleic acid) to that of a drying oil (iodine value over 130 with 55 to 60% linoleic acid). Similarly, soy acids with iodine values over 140 with 60-65% linoleic and 5-8% linolenic acid, can be made. Very light-colored acids can be produced by fractional distillation.

These fractionated cottonseed and soy acids are used extensively for making air-drying and baking alkyd resins for use in protective coatings such as paints, enamels, and varnishes. The low linolenic count of soy acids, and its absence in fractionated cottonseed acids results in drying alkyds with a minimum of after-yellowing. This is especially desirable in white and light-colored enamels.

Fractional vacuum distillation is also used in fractionating coconut oil acids, which contain acids ranging from caproic and capric acids up to the 18 carbon acids. The principal acid is the lauric acid, which is readily obtained 90-95% pure.

Refractionation also affords the other component acids, capric, caprylic, and myristic acids, in equal purity.

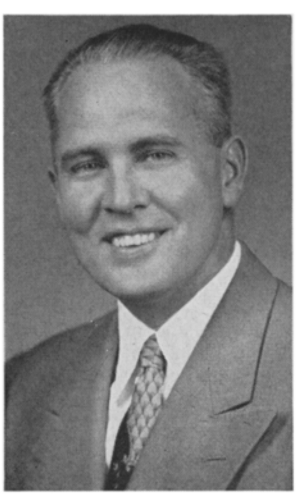
Similarly stearic and palmitic acids over 90% pure are produced by fractional distillation of hydrogenated fractions of cottonseed and soy acids made from soapstocks.

Thus fractional distillation and crystallization of the fatty acids which are produced as by-products of vegetable oil refining now afford a series of fatty acids whose composition can be controlled to a considerable degree, compared to the mixture of acids which occur naturally as glycerides. This control of composition makes them of use as chemical starting materials for many applications where the unfractionated acids would be useless or less desirable. Where the natural composition of fatty acids is acceptable and the natural chemical combination with glycerol is desirable, the oils as such will maintain their useful place as raw materials for industrial uses. In uses where composition is important, and where the free acid affords more latitude or convenience in re-synthesis of new materials, fractionated acids will find an increasing field of use, particularly as new knowledge is gained as to the effect of composition to the properties and usefulness of fatty acids.

Recovery of Animal Fats

CLARK B. ROSE, Darling and Company, Chicago, Illinois

THE general field of fats and oils has developed technologically into a varied and viciously competitive one. It covers all of man's general classifications for matter, animal, vegetable, or mineral. The struggle for progress has been energized by human motivation of pleasure, profit, and more recently the desperate one of survival. The seriousness of the struggle for survival has been aggravated in some instances by the failure to recognize and practice some of the natural fundamentals that control the very existence of the industry.



Clark Rose

Any intelligent approach to the proper evaluation of optimum methods for producing animal fat products implicitly requires that the evaluation include the competitive position of the process not only within the animal fat industry, but also competitively to the corresponding mineral and vegetable products and processes.

The development of new frontiers in the production and utilization of animal fats must therefore never overlook these fundamental factors:

1. Animals not intended for edible uses cannot economically be produced solely as a source of fats. Therefore the recovery of animal fats is of necessity a by-product process. This is of extreme importance in the "survival" picture since it follows that low net production cost is of paramount importance.
2. As a compensating corollary, it follows that there will always be a "rendering" industry since inedibles must be disposed of. The nature of the disposal will be dictated by the economics of the best plan for such disposal.
3. As a by-product industry, the volume of raw material is relatively inflexible and measured only by the production and consumption of edible products. This seriously limits its end-use competitively with mineral or vegetable sources where supplies can be developed in line with demand.
4. In the animal by-products economy, the revenue from the recovery of fats is not necessarily the principal source of process revenue. At times other products may have the higher market value so that fat or oil may be in reality a by-product of a by-product. Fat may be 20% to 80% of the product revenue, and this fact serves definitely to limit the process selection since the specifications of the other products play a big part in the process economics. Proteins, minerals, biologicals, and other products have to be considered.
5. The various segments of the livestock, packing, canning, and merchandising elements of the meat industries all contribute their particular share of the raw materials supply, varying both in nature and quality. Raw material diversification is quite extensive.

The conclusion that follows these factors requires that animal fat recovery must be inherently low-cost, necessarily efficient, and capable of great versatility as to raw material consumption, producing products of uniformly high quality at maximum yields. This is the pattern for survival.

Raw Materials

Having reached this conclusion, the first consideration in evaluating a rendering process competitively is the question, "what raw materials is it required to handle?" The general sources of raw materials for animal fats in the chronological sequence of their availability are:

1. *Dead stock*—Fallen farm animals because of age, disease, accident, weather, exposure, etc.
2. *Slaughter by-products*—15 to 100 lbs. of raw material per animal slaughtered make up the material in this classification, which includes viscera, trimmings, heads, feet, catch basin skimmings, and condemned carcasses.
3. *Wholesale cutting and boning*—This includes the trim bones, and trimmings from operations producing canned and boneless products and primal cuts, or special products for hotel, restaurant, and retail trade.
4. *Retail markets*—This includes the fat and bone scrap trimmings produced in retail store operations incident to retail merchandising of the meat.
5. *Hotel and restaurant scrap*—Which comprises the scrap, both raw and cooked, from the operation of public restaurants. In this category should be classified the "household grease" which was salvaged during the war with rationing as its motivation but which is not economical, practical, or popular in peace-time.

Consideration of these classifications will lead quickly to the conclusion that the source, quality, condition, and nature of the raw materials for inedible rendering will vary widely, and quality and uniformity hinge on careful control of all operations from the time of initial production of the raw material through processing to the finished product.

Quality will have to be attained by careful selection and prompt and controlled handling throughout processing. Uniformity may be assured either by specializing on one raw material source, such as a single packing house, or by conducting a well-balanced and, in general, a broad operation servicing all sources of material in a heavily populated area.

As in most process industries, it follows that large-scale rendering operations will have inherent advantages over a small one in the elements of product uniformity and of quality control because of the ability to maintain to advantage the balance in raw material supply, material selection and segregation, and proper process handling to meet the demands of the basic fundamental factors described earlier.

TABLE I
Desirable Rendering Product Specifications

	Fats	Proteins	Minerals
Yield	Maximum	Maximum	Maximum
Contamination by other components of the raw material	None	Permissible but desired low as they have no market value	Desired low No market value
Chief chemical component on which value is based	Glycerides	Animal protein	Animal phosphates
Secondary components influencing value	Free fatty acid Non-fats	Minerals Vitamins Biological assay	Biological value over mineral phosphates
Color	Light original and bleachable	Light tan	White
Odor	Good	Good	Neutral or bland
Texture	Uniform	Uniform	Uniform
Composition	Uniform	Uniform	Uniform
Biological value	High	High	High
Palatability	High	High	High
Storage stability	High	High	High

Rendering Product Specifications

Having noted the nature and sources of the available raw materials, the development of the proper processing must also take into account the specifications required in the finished products. As noted earlier, the quality of the protein, mineral, and perhaps biological products which are often primary products must all be given due consideration as well as that of the fat. Where biologicals are not involved, the general classification of qualities desired in the products may be conveniently classified as they appear in Table I.

More specifically, the market value of the fat products from rendering are determined by well-established trading specifications, which may be summarized at July 1, 1954 markets as shown in Table II. Characteristically, Table II indicates a spread of 25 to 50% in product value between the lowest and highest grades of tallows and greases.

Fortunately, in general, those basic process principles which produce the highest value in fat products also produce the highest value in protein and mineral products as we understand them at this time.

Basic Principles Affecting Rendering Quality

Four basic physico-chemical principles serve to guide any good fat recovery operation and the selection of a process for it. Every renderer pits his effort and ingenuity against these elements in striving to get the best economic return from his operation:

1. *Time* is a factor constantly working against quality from the time the raw material becomes available at its source until the finished products are finally prepared for shipment.
2. *Temperature* is also a relentless enemy unless under strict control. Here, as in most chemical reactions, the old rule of a rise of 10°C. doubling a reaction rate applies viciously, especially on raw material hydrolysis and, in addition, the temperature areas where proteolytic bacteria thrive are particularly destructive to product quality and values.
3. *Bacteria and enzymes* are nature's competitors to the renderers' efforts to delay deterioration. Their effect, if uncontrolled, is tremendous.
4. *Moisture*, nature's relentless solvent and reagent, works to expedite the deterioration of the renderers' raw materials and products. The renderers' principal troubles arise either from not eliminating it soon enough, or completely enough, or under proper conditions.

These are the adversaries in the struggle to produce top quality. They are truly the "Four Horsemen" for they never strike alone. The effect of each is multiplied by its catalytic effect on the other three. A sound recovery method must adequately control all four.

Criteria for Evaluating a Rendering Process

Assuming that the raw material has been delivered to the processing unit with all of the care and dispatch that economics will permit, the rendering operation itself should meet, as economically as possible, the following criteria:

1. The process should deliver the theoretical yield of products as determined in the raw material.
2. The process should produce product quality equivalent to that known to be in the raw material as received.

TABLE II
Standard Tallow and Grease Specifications

		Free Fatty Acid % Max.	H_2O, Unsap. and Insol. % Max.	Maximum Color		Titer °C. Minimum	Approx. Value c/Lb. on 7/1/54
				Raw FAC	Refine-Bleach Lovibond Red		
Tallow	Fancy	4	1	7	2	41.5	6
	Bleachable Fancy	4	1	....	2	41.5	5¾
	Prime	6	1	13	....	40.5	5½
	Special	10	1	19	....	40.5	5¼
	No. 1	15	2	37	....	40.5	5
	No. 3	20	2	39	....	40.5	4⅞
	No. 2	35	2	....	....	40.0	4¾
Grease	Choice White	4	1	11	2	37.5	6
	A-White	8	1	15	....	37.5	5¾
	B-White	10	2	19	....	37.0	5½
	Yellow	15	2	37	....	37.0	5
	House	20	2	39	....	37.0	4⅞
	Brown	35 or over	2	....	....	37.0	4¾

3. The process must be sufficiently flexible to handle economically and efficiently all the classifications of raw material to which it will be applied.
4. The process must adequately maintain its efficiency and quality under variable load conditions from day to day and season to season as the supply of raw material varies.
5. The process must be inherently self-contained and clean, producing no nuisances, and preferably no process discharge that is not a saleable product.
6. The process should require a minimum of labor, and of electrical, chemical, and thermal energy.
7. The process should be as simple as possible mechanically to the end that capital investment, repair, replacement, taxes, and insurance costs are kept to a minimum. In by-product industries this factor is often overlooked. In general, a reduction of $100 per month in expenses is equivalent in profit to adding and supplying a $100,000-per-year customer, and often the cost reduction job is easier to accomplish.

Fat Recovery Processes

All fat recovery processes involve a series of basic operations which may be performed to various degrees of completeness or in variations of order. These basic operations include: preparation of raw material, dehydration, separation of fat from the solid residue, processing of fat to finished product, and processing of residue to a feed product.

Evaluation of the essential processes practiced and proposed will be attempted on the basis of the salient features that distinguish the various methods from each other.

Open Kettle Rendering

This is the beginning of the industry and is still practiced where farm butchering is done without benefit of custom slaughtering. The inedible waste products from slaughtering are boiled with water, and the fat which floats to the surface is skimmed off and dried. The residue is fed to farm stock.

The tallow product often finds its way into commercial markets through traveling dealers, who also purchase hides and other farm products. The process is the ultimate in simplicity but fails economically in every other respect.

Steam or Wet Rendering

This process, developed initially to produce edible fats when the industry was young and chemical engineering techniques had not been applied to the industry, is still used although, except for edible fats, it is in a distinct state of decline. The flowsheet is described by Figure 1. While producing fat of good quality, the process does not produce a protein product of comparable quality and does so at relatively high cost and low efficiency.

Dry Rendering

This process, Figure 2, named for the basic dehydrating equipment, is operated with several modifications of auxiliary equipment which differ essentially in the method used to remove the fat retained in the dehydrated product after draining the free run tallow.

The hydraulic press modification is directly comparable to the wet rendering process described previously. Basically this process is lower in operating cost and can produce tallow quality from higher

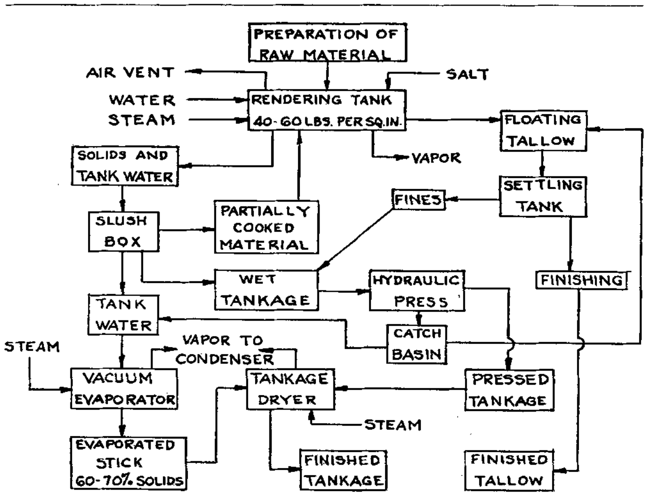


FIG. 1. Steam or wet rendering process.

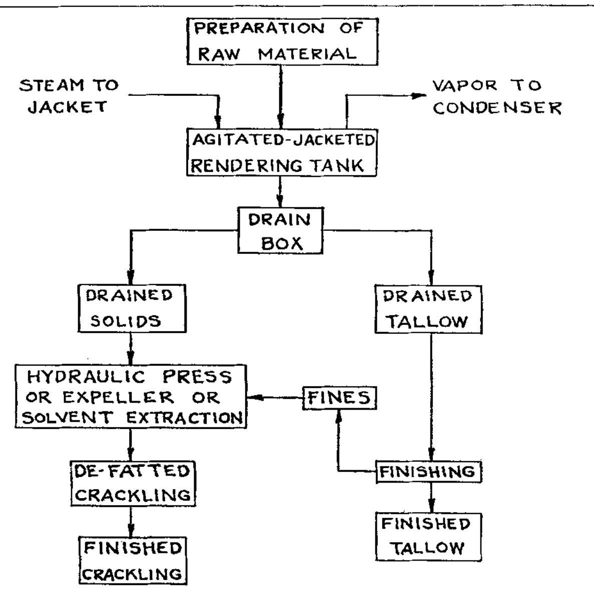


FIG. 2. Dry rendering process.

yielding materials equivalent to wet rendering. Tallow quality on lower yielding material may be inferior to wet rendering but is at a decidedly lower cost. Protein quality by dry rendering is superior in most respects.

There are two other modifications of dry rendering that merit attention. The Expeller process substitutes a continuous worm or screw-press for the batch hydraulic press. By reason of design for conditioning and pressing a small quantity continuously, this unit is capable of lowering the residual tallow left in the residue below that obtained by hydraulic pressing. Offsetting this advantage somewhat are a relatively high power cost and more mechanical maintenance than with hydraulic pressing. If properly operated, there is little difference in quality of tallow product, but the friction produced in the expeller barrel may darken the tallow if excessive. The Expeller protein product is more desirable because of ease in grinding, which tends to offset some of the power used for the expeller operation. The hydraulic and expeller operations are closely comparable, with the individual plant operation largely determining which is best. In strong tallow markets the Expeller should have an economic edge.

The third modification of the dry rendering process is the solvent-extraction process. After dehydrating and draining free tallow, the greasy residue is washed repeatedly, or continuously, with hydrocarbon or organic solvents to dissolve the fat. The solvent miscella is then distilled and stripped off of the fat and the tallow product recovered. Solvent is removed from the residue by steam-stripping and all solvent condensed and recovered for re-use.

The solvent process is a decided complication, and therefore a higher cost, compared to the hydraulic press or Expeller methods. It also has intrinsic fire hazards attending the operation. It has to justify its use economically by an additional 4 to 6% tallow yield recovery. This set of conditions requires that the process have large tonnage and a good tallow market for economical operation.

Tallow quality from solvent-extraction is equivalent to other methods, and protein quality is superior in some respects. The residue is lighter in color, higher in protein and mineral content, lower in fat, and generally more bland and neutral in odor. The biological values are unimpaired by the extraction process.

Lowry Circulating Rendering

This process, Figure 3, now over 20 years old, was developed by T. K. Lowry of Darling and Company, following a study of the basic principles of cooking, and makes use of three fundamentals of cooking efficiency:

1. Cooking is done under vacuum and at low indirect steam temperatures to conserve tallow quality.
2. Heat transfer is improved by circulating the cooker contents rapidly through a large area heater section by conveyor or pump.
3. Heat transfer is further improved, especially for low fat content raw material, by adding liquid tallow as a primer so that a fluid mass is immediately available when charged to the cooker.

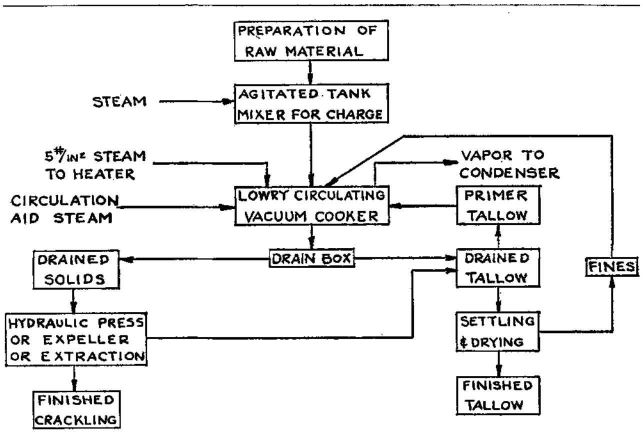


FIG. 3. Circulating rendering process.

Chayen "Impulse" Rendering

This process, Figure 4, developed by British Glues and Chemicals Ltd., is now about five years old. It is an innovation in that pretreatment of the raw material before fat recovery is carried to a more complete state of mechanical disintegration than is common in other processes. Also a large volume of water (seven to nine times the weight of raw material) passes through the mill with the raw material or washes the ground material in a series of first cold and then hot washes. Separation of the resulting slurry of fat, protein, water, and bony material is then carried out in settling units, followed by a series of heaters and centrifuges which render and separate the fat from the water and protein. The products are delivered wet and require subsequent drying, and although something over half the water is recirculated in the system, the balance is separated as waste or goes out in the defatted products to drying.

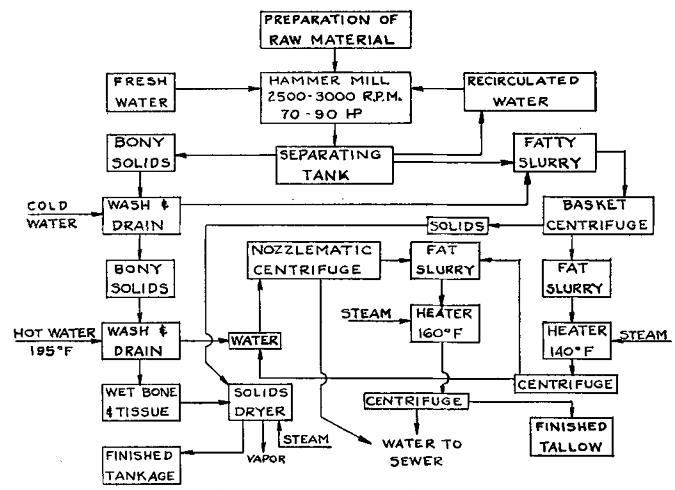


FIG. 4. Impulse rendering.

The use and discharge of large volumes of water, the heavy investment in centrifuge equipment and the emulsions and water-borne losses resulting with some raw materials have discouraged its use except for preparation and defatting of bones for glue.

Kingan Continuous Rendering

This process, Figure 5, is relatively new and, as yet, is limited in the best application to raw fats free of bone or other materials. The raw material is first finely ground, then pumped through a Votator or other heat exchanger, then ground again in a hammer mill. This macerates it sufficiently to permit separation of the rendered fat from the protein and water by a nozzlematic type centrifuge. The wet protein residue then is either discharged to the sewer or dried by conventional dry rendering equipment.

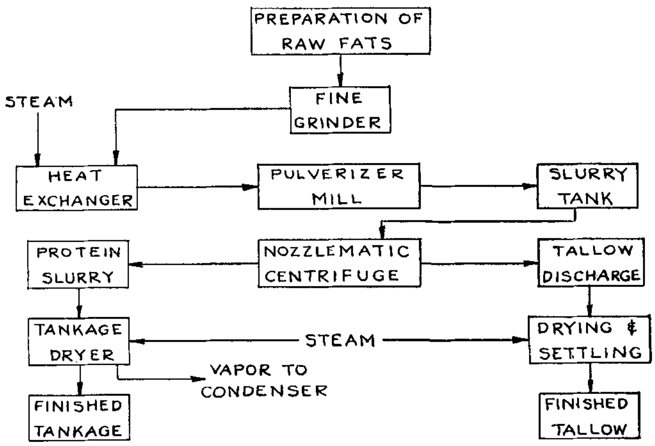


FIG. 5. Kingan continuous fat rendering.

This process appears to be a forward step, because of short process time, in its initially conceived field of oleo oil production. Its application to general rendering appears limited by basic mechanical problems inherent in the selection of its fundamental processing units.

Vio-Bin Azeotropic Rendering

This process, Figure 6, developed by Vio-Bin Corporation of Monticello, Ill., had its inception in low-temperature solvent-extraction of animal and vegetable materials for biological products. It uses the well-known principle of azeotropic distillation of immiscible liquids simultaneously to extract the fat and dehydrate the raw materials at the azeotropic temperature of water and the solvent employed. For example, heptane boiling normally at 192°F., in contact with water, boils at 176°F.

Careful analysis of this process requires attention to three other physico-chemical properties of immiscible liquids:

1. The liquids will boil at the azeotropic temperature until one or the other is totally evaporated and then change to the boiling point of the liquid remaining.
2. The vapor evaporating is of constant composition determined by the relative vapor pressures and molecular weights of water and solvents at the azeotropic temperature. Thus heptane over water at 176°F. produces a vapor 87% heptane and 13% water by weight. It is necessary to evaporate 6½ lbs. of heptane for each pound of water removed from the raw material. This heat input represents lost efficiency compared to dry rendering and is in addition to that required to recover the solvent from the fat after cooking is complete.

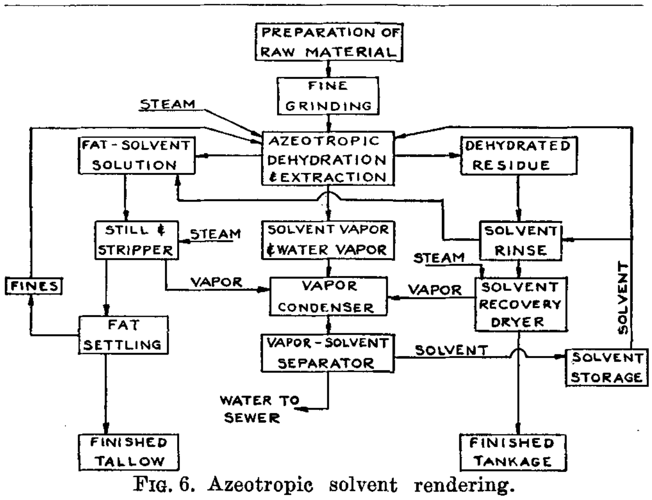


FIG. 6. Azeotropic solvent rendering.

3. The latent heats of vaporization of water and heptane are 990 and 137 B.T.U. per lb., respectively, and the specific heats are 1.0 and 0.36 B.T.U. per lb. per °F. The steam rendering efficiency of the Vio-Bin cooking process is thus theoretically 51% of that of the dry rendering process.

After dehydration the solvent-fat solution is percolated off of the protein-mineral residue, and the residue is rinsed with sufficient fresh solvent to complete removal of the tallow yield. The solvent-wet residue and the fat-solvent solution are then recovered in conventional solvent-recovery equipment, using steam for stripping out residual solvent.

Solvent losses would be a very positive problem and cost factor because of the big volume of solvent distilled, condensed, and separated from water. The process may be applicable to some materials, such as catch basin skimmings, which are hard to handle in other processes.

Dry Melter—Steam Tube Dryer Process

This technique, Figure 7, has been proposed to increase dry rendering unit capacity. It consists of a steam tube dryer following the usual dry melter. The variation arises in the use of the dry melter only

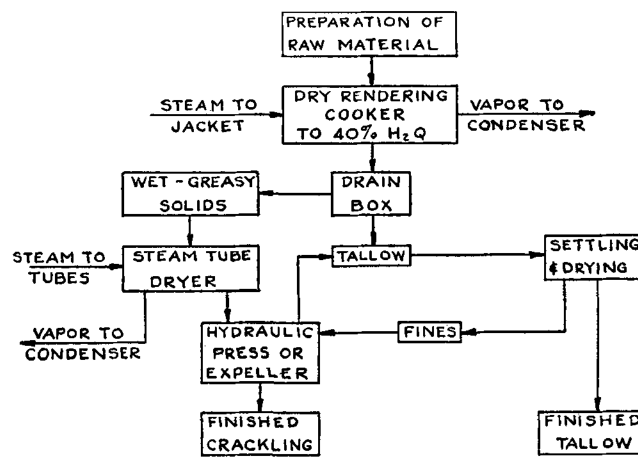


FIG. 7. Dry melter—steam tube dryer process.

for the purpose of heating the fat sufficiently to free the tallow. Free run tallow is then drained, and the wet greasy residue at about 40% moisture is dried in the steam tube dryer at 125-lb. steam pressure. Dryer processing time is about 40 minutes. The dehydrated dryer product is then processed for fat recovery by conventional means, such as hydraulic pressing.

The method offers some advantages as a semi-continuous unit. It has a very serious disadvantage in that a steam tube dryer is poorly contained and may be a nuisance problem from odors which escape. On this point it needs further development.

Enzyme Rendering

The use of enzymes such as Protease for cold rendering of fats was proposed about five years ago. The raw material is hashed to a very fine state in a meat grinder while the enzyme is added to the material at the same time. The material is then incubated in a vat while the enzymes break down the tissues. The hydrolyzed product is then dehydrated and the fat separated by conventional means, which at the same time destroy the enzyme.

While the freeing of the fats is accomplished at lower temperature with possible quality improvement,

TABLE III
Characteristic Rendering Processes

Process	Product Yield 1. Tallow 2. Protein	Quality 1. Tallow 2. Protein	Process Flexibility Raw Material	Process Flexibility Variable Load	Waste Volume Cleanliness Nuisances	Process Costs 1. Labor 2. Energy	Process Costs 3. Maintenance 4. Investment	Simplicity and Special Features
Wet rendering	1. Poor 2. Poor	1. Good 2. Fair	Flexible	Versatile	Waste high not contained	1. Fair Steam high	3. High 4. High	Complex Low efficiency
Dry Rendering: Hydraulic press	1. Poor 2. Good	Good	Flexible	Versatile	Waste low not contained	1. Fair 2. Low	3. Fair 4. Low	Simple
Dry Rendering: Expeller	1. Fair 2. Good	Good	Fairly Flexible	Versatile	Waste low not contained	1. Good Power high	3. Fair 4. Low	Simple
Dry Rendering: Solvent extraction	Good	Good	Flexible	Needs high capacity Versatile	Well contained and clean waste low	1. Good Steam high Solvent loss	3. High 4. High	Complex Solvent hazard
Circulating rendering	Same as dry rendering	Good	Not equal dry rendering	Versatile	Clean but not contained	1. Good 2. Fair	3. Fair to good 4. High	Complex
Impulse rendering	Lower than dry rendering	1. Very good Bone very good	Best suited to bone	Lacks some versatility	Waste high not contained	1. Good 2. High	3. High 4. High	Very complex Large water usage
Kingan continuous process	1. Fair 2. Protein not recovered	1. Very good 2. Poor if recovered	Fats only; not bone or meat	Versatile	Waste high well contained	1. Good 2. High for protein recovery	High if protein is recovered	Complex Intended for edibles
Azeotropic rendering	Good	Good	Limited to fine grinding	Versatile	Waste low well contained and clean	1. Good Steam high Solvent loss	3. High 4. High	Complex Solvent hazard
Melter—Steam tube dryer	Same as dry rendering	1. Fair to good 2. Good	Flexible	Needs high capacity Versatile	Waste low very poorly contained	1. Good 2. Fair	3. Fair 4. Fair	Complex Semi-continuous
Enzyme rendering	Inherently lower than dehydration	Determined by process control	Limited to fine grinding	Versatile	Can be clean and contained	1. Good 2. High enzyme cost	High-added step retains drying to get products	Complex

the greater care and control required, and the added processing step with its attendant cost have apparently stopped any further work in this direction. The method shows a process energy loss rather than gain because of the fine grinding required and the fact that the products still have to be dehydrated and the fat and protein separated.

The foregoing descriptions do not conclude the list of rendering processes available for the processor of animal fat raw materials, but they cover the basic types. Some of the others are the Laab Pressure System, the Titan Expulsion System developed in Denmark, and the Pavia Heated Roller process, which was patented in March of this year. These others are substantially modifications of the unit operations involved in the processes described or are based on similar principles.

Table III is an attempt to present in abbreviated form the principal features of the processes discussed as they relate to the seven factors described earlier as criteria for rendering process evaluation. Their very briefness makes difference of opinion about their relative evaluation probable. No attempt to determine the best or better of the processes is intended. Such an evaluation must be left up to each individual processor to determine for his own needs. This follows because such a selection must weigh the factors of raw material to be handled, utilities available, specific or special purpose intended, and local economic factors and personal opinion factors on items subject to such judgment. Table III merely is a summation of such information as was available or seemed inherent or apparent to the processes.

Application of the fundamental and natural principles of animal fat recovery which have been outlined should serve to guide the processor in the process selection best suited for his particular conditions. The observance of physico-chemical factors occurring during the operation and intelligent care in the control and use of these variables will chart the way to maximum product value at lowest unit cost. This is the pattern not only for survival but for success.

Marine Oils. Production, General Chemistry, and Utilization[1]

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THE fish oils of industrial importance in the United States come from three different varieties of fish, pilchard, herring, and menhaden. All are frequently called sardines.

Pilchard were formerly found in the Pacific Ocean all along the American coast, but in recent years the catch has been decreasing drastically, first in the northern waters, and now in the southern waters as well. The reasons for this are not known, but obviously the effect on the marine oil industry is very serious. The annual catch has dropped from a maximum of 1,500,000,000 lbs. to about 7,770,000 lbs. in 1952.

Pilchard spawn in the open sea as far as 300 miles

[1] Technical Paper No. 131 from the Archer-Daniels-Midland Company.