difficult to achieve. When an additional molecule enters into the polymerization, such as maleic anhydride, the polyunsaturated acid radicals are combined with maleic anhydride to form di-, tri-, and polyglycerides. In general, the addition of maleic anhydride and cyclopentadiene speeds the reaction so that viscosity changes occur more rapidly.

Another factor, which is of some theoretical importance in the polymerization of drying oils, is the formation of intrapolymers or dimer acids in the same glyceride molecule. The interesterification reactions which occur at high temperatures of bodying apparently reduce substantially any effect which these intrapolymers may have on the properties of the products (5). The interesterification leaves only a very small percentage of intrapolymers in the bodied oil (20).

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Utilization of Inedible Animal Fats

DALE V. STINGLEY, Armour and Company, Chicago, Illinois

IT is a remarkable fact that for centuries only two major uses for animal fats were discovered. Edible fats were used as food, and those deemed inedible were consigned to the soap kettle. It is even more remarkable though, just how vitally important the small percentage of the total production of animal fats that found its way into industrial usage was to the rise of industrial civilization.

Dale V. Stingley

Prior to the development of the petroleum industry, animal fats were almost without exception the sole source of lubricants for motive power and machinery, including metal working oils. Animal fats also, including whale oil, were depended upon as the main source of illumination, and today, as in the past, most of these uses, plus the many additional applications of more recent development, give animal fats a top priority rating as essential raw materials.

Sources and raw materials for inedible animal fats have been discussed in a previous lecture, but, to avoid all possibility of misunderstanding, the term "inedible animal fats" refers to fats and oils that are not suitable for human consumption. They are derived principally from cattle and swine. In this country this is a legal rather than a technical definition since the U. S. Department of Agriculture is the deciding authority and, except for a small production of animal fats produced and consumed locally within the various states, all edible animal fats are processed in government-inspected plants.

In general, inedible animal fats are referred to in the trade as "tallows" (predominately beef fats) or "greases" (predominately hog fat), with recognized grade names based on titer, free fatty acid content, M.I.U., and color standards.

A listing of the accepted grade names and specifications commonly employed is given in Table II of the paper by Kraybill in this supplement.

In our modern industrial system the key to our enormous productivity has been standardization. Natural fats and oils vary somewhat in quality and composition so the above standards were set up many years ago to establish a uniform trading basis. Unfortunately these standards, as originally established, were based on the requirements of the soap industry and are now in many cases too broad and indefinite to meet the needs of the modern industrial user. As a result, individual companies have in many cases set up their own purchase specifications in an attempt to obtain materials suitable for their needs or, in other cases, depend upon standardized products such as fatty acids, hydrogenated oils, lard oils, and other refined materials to guarantee the uniformity they require.

The need for standardized products and for fat products with modified chemical or physical properties is the reason for the existence of a sizeable industry which takes crude inedible animal fats, further processes them, and, in turn, supplies these materials to industrial users. In general, these secondary processors employ commercial grades of tallows and greases, but in many cases their needs are best served by more stringent specifications, with the result that they must be selective in their sources of raw materials.

CURRENTLY our annual production of inedible animal fats is very close to 2,700,000,000 lbs., and it is to be expected that this figure will continue upward since, as our population increases, there will be a greater need for meat with a consequent rise in the production of by-product animal fats. Over the past 15 years, in fact, the production of inedible animal fats has just about tripled, but this rate of increase cannot be expected to continue indefinitely because of natural limiting factors. We shall probably experience a much slower growth rate in the future.

In any case, increased production plus a changing picture of consumption over the past few years have given producers of inedible animal fats a wide variety of headaches. The major factor in this changing picture of the utilization of inedible animal fats has been the marked drop in demand for fats and oils for the production of soap. In this country synthetic detergents now account for over 50% of the total production of detergents, and their growth has been relatively rapid. For example, in 1939 some 20,000,000 lbs. of synthetic detergents were consumed, but this figure has now grown to 2,134,000,000 lbs. in 1953. During the same 15 years the production of soap has declined from 3,700,000,000 lbs. annually to slightly less than 2,000,000,000 lbs., with further declines to be anticipated. If we consider these figures, it is easy to see why the combination of increased production of inedible animal fats plus declining consumption in the major outlet has resulted in headaches.

Industrial consumption excluding soap has shown little increase over the past 15 years and currently is in the neighborhood of 500,000,000 pounds. Therefore, if we sum up the supply and demand picture, we find that at the present time our domestic production of inedible animal fats is 180% of our domestic requirements, and whereas in 1939 supply and demand were almost exactly balanced, we now are faced with a surplus of over 1,000,000,000 lbs. which is currently being disposed of in the export market. These statistics are quoted to give a background picture of our field of discussion and to permit a better understanding of the scope of the inedible animal fat industry.

It is also probably appropriate at this time to point out the limitations of this paper since certain phases of the industry will be mentioned only in passing as these are assigned to be covered more completely in other papers. One of the subjects in this category is the use of fats in animal feeds. This is a recent development brought about by the conditions above mentioned in an effort to find new domestic outlets for our surplus production. No accurate figures are available on the quantities now going into this usage, but estimates of some 200,000,000 lbs. in 1954 seem to be well-founded. Another subject to be covered elsewhere is fatty acids and their derivatives with specific references to many fields of application. When we subtract these topics, it appears that the logical subject-matter of this paper should be soap, certain lubricating uses, animal oils, plus sulphonated and hydrogenated fats. Even here the interrelated and interchangeable nature of fats, oils and fatty acids will undoubtedly result in some duplication.

IN the soap industry fats and oils from both animal and vegetable sources are utilized, and these fats are employed either alone or in combinations depending upon the properties desired in the finished product. As a general statement, we might say that soap formulas are in effect determined on the basis of fatty acid composition since low molecular weight fatty acids, such as those found in cocoanut oil, give soaps with good performance characteristics at low temperatures which decrease as the temperature rises. The reverse is true for higher molecular weight acids such as those found in animal fats. Actually soap formulation is not quite that simple since many other factors enter in, including the non-soap additives or builders to be incorporated into the finished product as well as the question whether the soap will be used in soft, hard, or salt water. But it is perfectly proper to say that the task the soap is destined to perform largely dictates the choice of fats used.

Fats destined for the soap kettle usually undergo some type of preparatory treatment, depending upon the grade of fat used and the quality of the finished product desired. Tallows and greases used in high grade toilet soaps are often alkali-refined and bleached before saponification; those used for steam laundry chips or powder may only be bleached while those for the production of soaps used as the emulsifying agent for the co-polymerization of butadiene and styrene in producing GR-S type synthetic rubber are commonly refined and then given a light hydrogenation to reduce polyunsaturates which might interfere with the reaction.

Lower grade tallows and greases for the production of laundry bar soaps and cheaper soap products often are untreated, or simply acid-washed; and even though untreated fats are charged to the soap kettle, it is possible in the saponification or "soap boiling" operation to remove many impurities which may be present. This is accomplished by "salt-washing" in which the soap is "salted out" or precipitated from a water solution by the addition of common salt. The resulting saline solution or "lye" which drops to the bottom of the kettle carries with it color bodies, oxidized materials, etc., in addition to the glycerol resulting from the saponification of the fats. These "lyes" are drawn off, purified, and then vacuum-concentrated to give Soap Lye Crude Glycerine, which in the past has accounted for the greater part of our domestic glycerine production.

IN general, sodium hydroxide is used for saponification, but, in the case of jell and liquid soaps, potassium hydroxide is commonly used and the saponification carried on in a mixing kettle or "crutcher." In this operation no lyes are withdrawn, and all of the products of the reaction remain in the soap. Fatty acids in many cases are substituted for whole fats, which again may introduce variations in standard procedures applicable when fats and oils are used.

Many of the comments about the preparation of fats for the production of soaps for use as detergents also apply in the case of fats used in the manufacture of lubricating greases. However in this case we are dealing with the soaps of calcium, magnesium, barium, and other metals in addition to the sodium and potassium soaps previously considered. Further, saponification is carried on under conditions which result in relatively anhydrous soaps in order to insure products which are oil-soluble or dispersible.

In general, fats used for the production of lubricating greases must be uniform in quality to insure uniformity in the finished grease, and many grease manufacturers have established individual specifications for fats with tolerances considerably closer than the regular commercial grades. Other manufacturers have discarded fats almost entirely in favor of fatty acids, principally for reasons of uniformity.

Most lubricating greases are composed of lube oils (mineral oils) thickened or jelled with oil-soluble or dispersible soaps, and usually all of the products of saponification remain in the finished grease. This includes the glycerol produced when fats are saponified, and many manufacturers prefer fats over fatty acids because they have found that the glycerol imparts desirable properties to the finished grease.

Grease manufacturers depend upon their suppliers to furnish raw materials in accordance with their specifications. The supplier must blend, bleach, refine, or hydrogenate regular commercial grades of inedible animal fats as necessary to produce the uniform products required. Much of this work is done by secondary fat processors, such as those engaged in the production of fatty acids, hydrogenated oils, lard oils, acidless tallow oils, etc., since the original renderer of the fats is rarely equipped to perform this service.

Secondary processors of inedible animal fats, if we include fatty acids and chemicals produced from fats, process approximately 12% of the total production or, in round figures, about 300,000,000 lbs. annually. It is difficult to determine the exact figure since census reports are not detailed enough to distinguish this type of operation separately.

The production of animal oils, lard oils, acidless tallow oils, and neat's-foot oil is a specialized industry engaged in the separation of liquid oils from inedible animal fats. The raw materials employed are various grades of greases and tallows plus neat's-foot stock, a soft beef fat obtained when the shin bones of cattle are segregated and rendered separately. Basically, animal oils are prepared from their raw materials by a crystallization procedure which separates the fat into a liquid fraction or oil and a solid fraction or stearine. Various methods have been proposed for accomplishing this separation, but so far the procedures involved more than half a century ago are still employed. Solvent crystallization and liquid-liquid extraction, for example, can be considered technical successes, but the cost of installation and operation of such equipment rules them out economically, and insofar as our knowledge goes, there are no commercial installations of this type.

In a typical plant the raw materials, either with or without pre-treatment, such as bleaching or acid-washing, are placed in graining containers, usually some type of open head drum of approximately 50 gal. capacity, and these filled containers are held in a cold room referred to as a "graining room" at around 40° F. until the proper degree of crystallization takes place. The holding time, depending upon the material being grained, may run two days or more. When graining is completed, the cans are removed to the press room where the grained stock is wrapped in press cloth and inserted into a mechanical or hydraulic press in which the liquid fraction is expelled. Pressing is usually carried on in a one-day cycle with the presses being loaded and unloaded during the day shift. Economically this entire operation depends upon the oil produced (approximately 55%) since the stearine fraction is not enhanced in value and often may be worth less than the starting raw material if an unfavorable spread exists between grease and tallow prices. The value of a white grease stearine, for example, is largely determined by the value of prime tallow which it approximates in characteristics.

THE oil resulting from the pressing operation may be further refined, blended, and bleached to produce the various grades of animal oils required, and the finished product is then put into tank cars or drums for shipment to the consumer. Grade specifications and grade names of animal oils may vary, depending upon the manufacturer but a reasonable degree of standardization does exist on those grades which are most in demand.

Grades of animal oils are usually based on color, free fatty acid, and pour-point although for special applications other tests are at times required. Three grades of lard oil account for a considerable portion of the total production. These are Prime Burning Lard Oil, which is low in free fatty acids, less than 1%, light in color and with a pour-point of 45° F. maximum. The name "Prime Burning" is a survival of the days of the railroad switchman's lantern, a usage no longer existent. But today tank-car quantities are consumed in the production of antibiotics, such as penicillin, where the oil acts as a nutrient and anti-foam agent.

Extra Winter Strained Lard Oil used also for antibiotics, as well as textiles, lubricants, and other purposes, is slightly higher in free fatty acids, approximately 2-4%, and also darker in color. No. 1 Lard Oil, one of the lower grades, may run 15% acids and be quite dark in color. It is important to remember that each grade of lard oil is produced to fill a specific need, and while for certain uses it is possible to substitute one grade for another, this will not hold true in many cases. Economics also enters into this picture since a high grade oil produced from choice white grease costs substantially more than a lower grade produced from yellow grease.

Slightly over 50,000,000 lbs. of lard oil are produced annually and find their way into all types of products and uses from caulking compounds, motor oils, and horse liniment to ceramics and antibiotics. These varied and specialized uses have resulted in a great number of small specialty manufacturing concerns catering to the metal-working, textile, leather, lubricating, detergent, and other fields. These concerns vary from one-man operations conducted in a shed in the back yard to firms with 40 to 50 employees. Processes may vary from simple blending or mixing operations to complex chemical reactions, involving sulfurizing, chlorination, ester exchange, etc. Equipment varies accordingly, but, generally speaking, equipment designed for inedible animal fat processing alone can be constructed of carbon steel or black iron unless other reactants result in more stringent requirements.

Before concluding we should discuss briefly the utilization of hydrogenated inedible animal fats. Usually a good grade of tallow, prime or better, is the preferred raw material, and this is completely hydrogenated in conventional equipment, using in most cases reduced nickel formate catalyst. Only a few million pounds of completely hydrogenated animal fats move in regular trade channels, and most of this is consumed by producers of metallic stearates. But a sizeable volume destined for captive use in the manufacture of saturated fatty acids and other fat chemicals is produced annually. Exact figures are not available, but it would appear that about 20% or some 50,000,000 lbs., of an estimated 250,000,000 lbs. of animal fats used in the production of fatty acids and fat chemicals is hydrogenated material.