Symposium

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Economic Cost Outlook for Surfactant Intermediates[1]

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ABSTRACT

Synthetic alcohol, natural alcohol and linear alkylbenzene (LAB) surfactant feedstocks will all be needed to meet market requirements in the coming decade. Of the synthetic alcohol processes, the Alfol® alcohol process, due to its strong byproduct credit, will be the most cost efficient. Moreover, LAB and natural alcohols will have the lowest production costs of all surfactant intermediates throughout the decade.

INTRODUCTION

During the next decade, the ability of a formulator to prosper in the North American and world surfactant markets will be dependent on careful control of formulation costs. Consumers will be more value-conscious and more discriminating. They will buy a product which offers cost/performance advantages. The most cost-efficient formulators will have a future marketplace advantage.

A formulator's cost is heavily dependent upon the price of the formula ingredients of the detergent; and those ingredient prices, in turn, are dependent on their respective costs of production and beginning raw materials.

Conoco Chemicals Company has made an analysis of the outlook for major surfactant detergent intermediate production costs, by year, through 1992. In this analysis, it became apparent that linear alkylbenzene (LAB), natural alcohol and Alfol® Alcohols are, in that order, the lowest cost intermediates and warrant very serious consideration as the detergent intermediates of choice. Ethylene-based processes with no strong byproducts will become increasingly less competitive.

PROCESSES AND BYPRODUCTS

Specific processes examined were the major synthetic alcohol processes, a natural alcohol process and the production of LAB.

[1] Presented by Dennis A. Dixon, Conoco Chemicals.

Ethylene-Based Synthetic Alcohol Processes

The synthetic alcohol processes are based on ethylene as a feedstock. All the major alcohol producers use oligomerization technology. This produces either a Poisson or exponential distribution of even-carbon-numbered alpha-olefins. Versions of this process, such as isomerization/disproportionation and elimination/substitution, are designed to alter or peak distribution in favor of the surfactant-range material. These olefins can then be hydroformulated with synthesis gas in an OXO process to produce alcohols. Alternatively, olefins in the form of aluminum alkyls are oxidized and hydrolized to produce alcohols and either alumina or alum as a coproduct. Other major byproducts are nonsurfactant-range alcohols or olefins.

Natural Alcohol

Natural alcohol is derived from the triglycerides contained in naturally occurring fats and oils. Detergent-range natural alcohols are derived mainly from triglycerides in coconut oils and tallow fat. Chemically splitting these fats and oils yields glycerine and linear even-carbon fatty acids. These fatty acids are hydrogenated to produce surfactant range alcohols. The glycerine is refined and marketed in a variety of food and food-related applications. Glycerine accounts for a small percentage of the triglyceride feedstock.

LAB

Raw materials for the production of linear alkylbenzene are benzene and normal paraffins. The paraffins, derived from kerosene, are converted to olefins via the UOP Pacol process, and then reacted with benzene in the presence of hydrogen fluoride to produce linear alkylbenzene. The hydrogen fluoride catalyzed process is an extremely efficient conversion system for producing LAB and generates little byproduct. The small amount of byproduct generated is used in lube oil applications.

CONOCO CHEMICALS' CREDENTIALS

Conoco Chemicals' credentials for making this type of analysis are among the best in the field. It was the first US producer of detergent-range synthetic alcohol with its Alfol® ethylene oligomerization process. In addition, it has performed extensive research and development in all ethylene-based synthetic alcohol processes used by the major producers. This work was carried through to engineering and design of commercial plants. Its numerous patents are also testimony to its know-how in the field. Its West German affiliate, Condea, has produced detergent range natural (triglyceride-based) alcohol for several years. In addition, the company has completed a Class A engineering study for a natural alcohol plant based on the fatty acid process.

Conoco first produced detergent alkylate in 1947. In 1964 it was the first US producer to manufacture biodegradable LAB. The company recently brought onstream a 150 million pound-per-year LAB plant in Lake Charles, Louisiana. In addition, it is involved in joint ventures in Spain and Japan which, with US production, make Conoco Chemicals the largest single producer of LAB in the world. The company also produces ethylene oxide-derived products, including alcohol ethoxylates and ether sulfates, and produces LAB sulfonic acid and sulfonates at its Hammond, Indiana, facility.

COMPARISON OF COSTS

The synthetic alcohol, natural alcohol and LAB processes were compared on a manufacturing cash cost basis. Capital charges, depreciation and general administration expenses were not included. In the comparisons, synthetic alcohol processes are grouped together and treated as a single process. Although an accurate prediction of each individual process is impractical, due to the unique feature of each, the limits within which the processes operate can be accurately set.

Manufacturing cash costs are a buildup of the variable and fixed costs associated with each individual process at a theoretical 100% operating rate.

Variable Costs

The most important variable costs include raw materials, energy and process byproduct credits. Figure 1 shows these costs for each surfactant process.

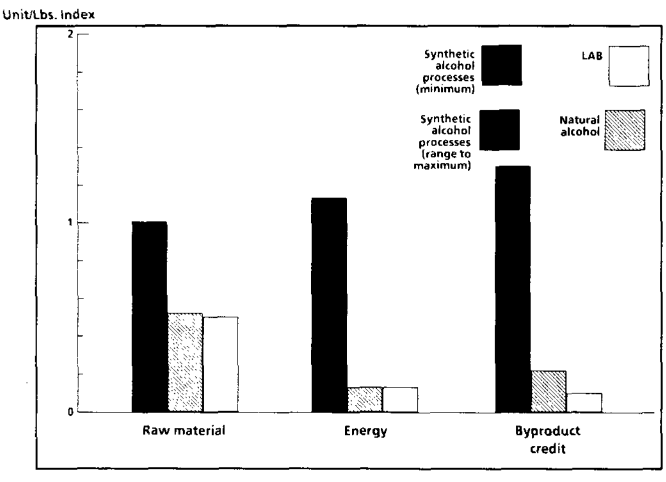

FIG. 1. Major variable cost elements.

The raw materials consumed are assigned a unit/pound value to allow comparison of various processes. For example, to produce a pound of LAB requires approximately one half the quantity of raw materials needed to produce the same amount of synthetic surfactant range alcohols.

Processes that consume larger quantities of raw materials are more sensitive to increases in feedstock prices. For example, if ethylene prices rise rapidly, the synthetic alcohol processes that require larger amounts of ethylene will experience a dramatic increase in raw material costs. Natural alcohol and LAB require smaller quantities of raw materials and are, therefore, less sensitive to changes in feedstock prices.

In energy consumption, the synthetic alcohol processes were found to require as much as eight times more energy to produce a pound of product than is required to produce a pound of natural alcohol or LAB. Synthetic alcohol processes produce a wide range of products and require a large number of processing steps to generate the desired surfactant alcohol. More energy is consumed in separating, recycling and processing the primary surfactant and byproduct materials. In comparison, the natural alcohol and LAB processes maximize production of the desired surfactant products with just small quantities of byproducts, so overall energy consumption per pound of primary product is low. Processes that require larger amounts of energy are more sensitive to increases in petroleum, natural gas and electricity prices.

The ethylene-based synthetic alcohol processes inherently generate large volumes of byproducts per pound of primary surfactant material. If the byproduct materials can be sold into areas with a strong demand, it can be profitable for producers. However, if market demand for the byproducts is weak, prices will be depressed and producer netbacks will be minimal. Most byproducts generated in the ethylene oligomerization alcohol processes are used in extremely competitive applications such as the plastics, lubrication and agricultural markets, and do not offer a major contribution to the financial strength of the synthetic processes. However, a valuable coproduct of Conoco Chemicals' Alfol® alcohol process is Catapal® SB alumina. It is a high purity alumina, derived from aluminum rather than bauxite. The major end use of this alumina is in the manufacture of refinery catalysts used in hydrotreating heavy sour crude fractions.

The LAB and natural alcohol processes are tailored to produce detergent intermediates and are not burdened by complicated processing and large amounts of byproducts to sell.

Fixed Costs

Figure 2 shows the relative sizes of recognized world-scale surfactant plants. Values indicate the capacities required for an economical scale of production of surfactant feedstocks at each individual facility.

Represented are a range of existing synthetic alcohol capacities, a natural alcohol plant based on a fatty acid engineering model, and Conoco's new LAB plant at Lake Charles. Fixed costs are generally higher for processes that involve high technology or many processing steps and which generate a large number of byproducts. The synthetic alcohol plants require more operating personnel, and more maintenance and support groups than do natural alcohol or LAB plants.

To further demonstrate the fixed-cost relationship between the processes, Figure 3 shows the relative fixed cost of the processes at various operating rates.

Again, the synthetic alcohol processes operating at 100% are shown to have higher fixed costs than either natural

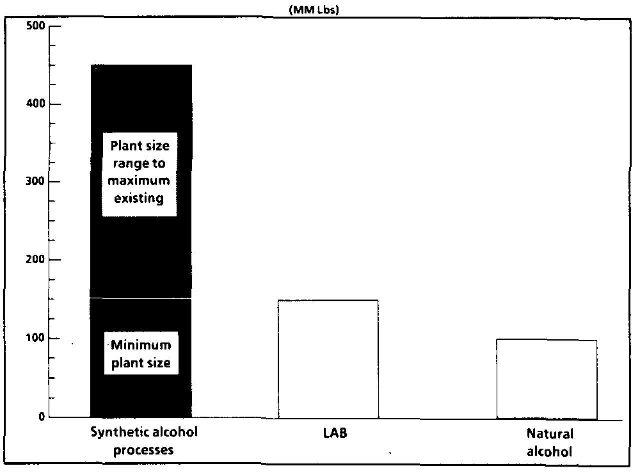

FIG. 2. World-scale surfactant plants.

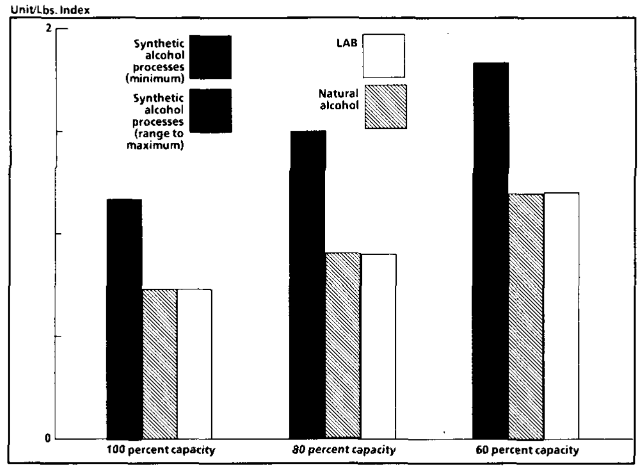

FIG. 3. Fixed costs.

alcohol or LAB. At 80%, a more realistic operating rate, or even 60%, the fixed costs grow significantly higher for the synthetic alcohol processes than with either LAB or natural alcohol. It is obviously easier for a small plant to operate at higher operating rates because a smaller market share is required to sell out the plant's production.

THE ECONOMIC MODEL

Before examining the cost trends for the various surfactant intermediates projected through 1992, the macroeconomic model assumptions on which the projections are based should be examined.

First, general inflation is fixed at 6% per year over the forecasting period.

Next, petroleum prices are set to escalate below inflation from 1982 through 1984; this is because of the current world oil glut and producers' willingness to accept lower prices until the economy improves. From 1985 through 1992, petroleum price escalation is assumed fixed at 9%. Conoco believes that once the economy improves, producers will again escalate the price of oil at a rate higher than inflation, in an effort to recoup lost revenues. The raw materials for LAB are kerosene and benzene. These materials are world commodities and are priced on a world supply/demand balance primarily as a function of crude oil and refinery economics. Therefore, prices for these raw materials are assumed to follow the petroleum escalation rate.

The macroeconomic model also assumes that natural gas price decontrol will be completed by 1986, as provided for by the Natural Gas Policy Act passed by the US Congress. Approximately 70% of the ethylene now produced in the United States is being produced from natural gas liquids. Decontrol of natural gas pricing will further raise the price of natural gas products, including natural gas liquids. Natural gas liquids presently are very low priced relative to the heavy liquids, which are feedstocks for the other 30% of ethylene produced in the USA. As decontrol is fully implemented, the natural gas liquids will gradually begin to lose their price advantage so that ethylene prices will escalate as producers pass through increases in the costs of feedstock.

Additionally, the US ethylene industry is currently weak with capacity utilization in the 60% range. Margins are low; some ethylene producers even lose money. Conoco foresees that by 1986, the ethylene industry will reach an 80-85% operating rate. By 1986, it is assumed that overall industry profit will return only to modest levels such as experienced during 1980. Decontrol, in conjunction with improved profits for ethylene producers, is expected to force dramatic change and ethylene prices could increase ca. 20% annually through 1986. While that prediction may seem very robust, considering the depressed mid-1982 price of 17 cents/lb, the likelihood of the 20% yearly increase becomes more evident. As mentioned earlier, synthetic alcohol processes require ethylene as their primary feedstock.

Next, triglycerides (naturally derived oils) are expected to escalate in price at two thirds the rate of inflation, and therefore, the price of the feedstock for natural alcohols is expected to increase at an average of 4% per year. The long-term outlook for natural fats and oils is excellent from a supply standpoint, due to dramatic productivity improvements, which are foressen to generate improved yields of natural fats and oils throughout the 1980s. Even a cursory study will show that future supply will come from stable economies and increasingly well managed operations. Therefore, political instability and weather conditions, as historically argued, will have a minimal effect on the availability of oils and fats. Also, future demand for natural fats and oils should remain relatively stable, and this market will, therefore, be softer than the petroleum market.

As mentioned previously, none of the byproducts produced in the synthetic alcohol processes command strong market prices, with the exception of alumina. For this reason, all byproduct values are escalated at the inflation rate (6% per year) throughout the period. Future alumina demand is projected to grow as a function of the petroleum market and alumina is escalated with crude oil.

Figure 4 is a plot of the total manufacturing cash costs (variable cost and fixed cost, excluding depreciation and return on investment) for each surfactant feedstock process, by year, through 1992, using the base case economic assumptions.

All process cost comparisons are done at a 100% operating rate. The manufacturing cash costs of the synthetic alcohol processes are represented by a broad band. The major processes fall within the limits of the band including Conoco Chemicals' Alfol® alcohol process. It is apparent that the cost-index projections for the synthetic alcohol processes will be higher than either LAB or natural alcohol economics throughout the decade, due mainly to high cost ethylene. The bottom line of the band represents our Alfol® process, including the byproduct contribution of alumina. As indicated, the strong contribution of alumina makes the Alfol® process attractive compared to the other synthetic

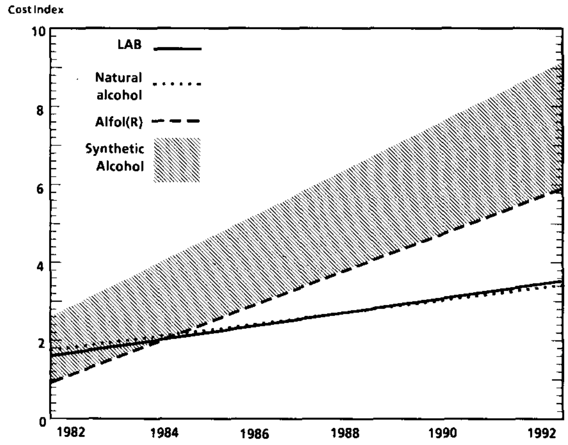

FIG. 4. Base case.

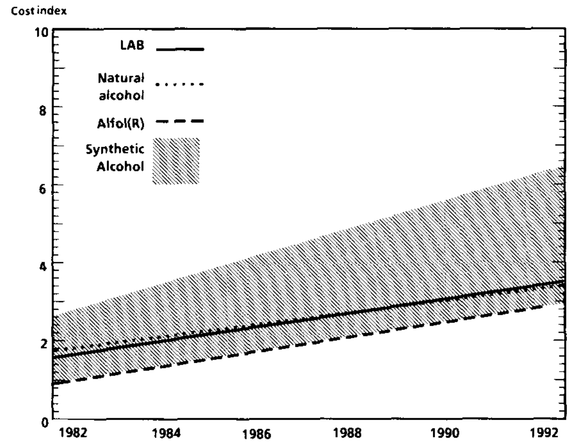

FIG. 5. Ethylene at crude price escalation.

processes, and even more attractive than natural alcohol and LAB in the early years. Currently, the costs of the various detergent intermediates are competitive because of weak ethylene prices.

In review, ethylene is assumed to escalate more rapidly than feedstocks derived from petroleum, and natural fats and oils are expected to escalate below petroleum.

But what if reality varies from these assumptions? Assume that ethylene prices escalate only at a rate equal to crude oil's price escalation, and that other assumptions remain the same as in the base case.

Actually, this is a very conservative and highly unlikely scenario. It assumes that the increasing costs of natural gas feedstocks, resulting from the gradual lifting of natural gas price controls, will not be passed through to the ethylene buyers, and that ethylene profits will drop even lower than they were in 1982. Figure 5 was generated from these assumptions, and the processes hold essentially the same relative position shown in the base case.

Even if ethylene prices escalate as a function of petroleum, the LAB and natural alcohol processes still compete with the most economical of the synthetic alcohol processes. In fact, the synthetic alcohol processes need to charge in ethylene at a 20-40% discount below market price for most of the decade to be able to compete with LAB and natural alcohol. Such a discount could only be rationalized if ethylene producers were subsidized, with feedstocks priced at 25-50% below alternate values.

In a third case, the assumptions are changed to allow for the possibility of strong byproduct values which might increase at the same rate as petroleum, rather than at the lower rate equal to inflation as predicted in the base case, other base case assumptions remaining the same.

Figure 6 shows the resulting cost trends, with natural alcohol and LAB faring better than synthetic alcohol.

Once again, the same economic conclusion is shown with a small differential emerging between LAB and natural alcohol in the latter part of the decade.

The possibility of fat prices escalating at the same rate as petroleum, rather than at the rate lower than inflation, as assumed in the base case, is addressed in the fourth case.

Results of these assumptions are shown in Figure 7, with natural alcohol and LAB showing their strength as the low-cost surfactant intermediates to produce.

Even assuming that natural fats andoils will escalate at the same rate as crude oil, natural alcohol economics remain less costly than the ethylene-based synthetic alcohol processes.

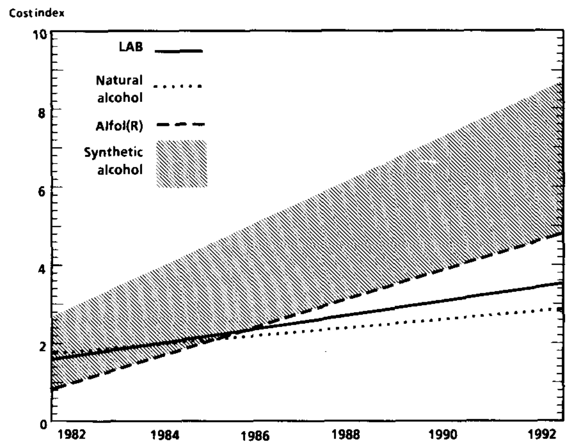

FIG. 6. Strong byproduct prices.

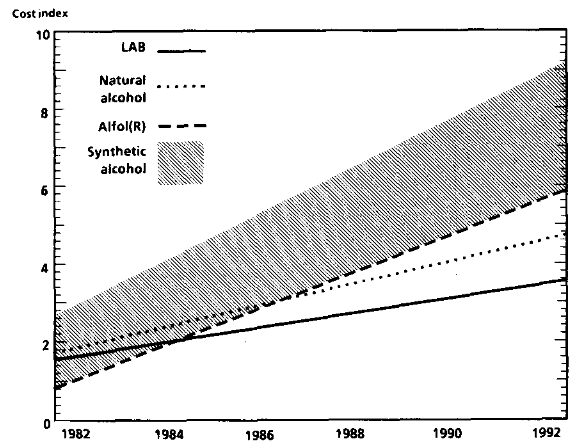

FIG. 7. Fat prices escalate at petroleum rate.

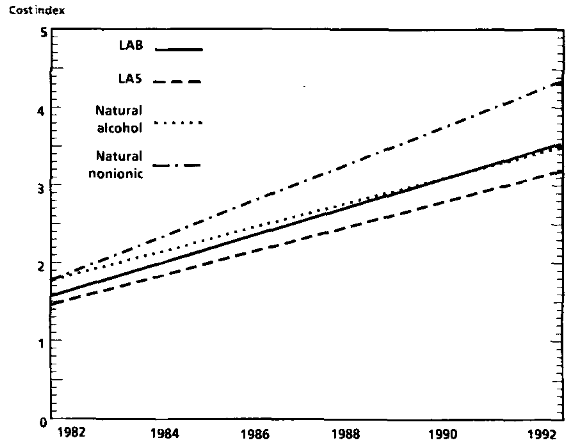

FIG. 8. Comparative analysis of US manufacturing costs of surfactant chemicals.

Most Relevant to Formulators

Carrying the base-case economic model a step further, the outlook for the surfactant products derived from LAB (like LAS) and natural alcohol (like nonionic ethoxylate) were projected.

Figure 8 shows comparative manufacturing costs of LAB and natural alcohol with LAS (linear alkylbenezene sulfonate) and natural alcohol nonionic ethoxylate, the actual ingredients used by detergent formulators.

Comparison is on a 100% active basis. Natural nonionic ethoxylates' cost trend is above that of natural alcohol because it is made by exchanging relatively expensive ethylene oxide for relatively inexpensive natural alcohol. On the other hand, to produce linear alkylbenezene sulfonate, LAB is reacted with sulfuric acid or SO_3, which is relatively inexpensive. As a result, the overall cost of LAS (100% active basis) actually drops because the added molecule is less costly than even LAB and is considerably less costly than ethylene oxide.

Whitener Selection for Today's Detergents

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ABSTRACT

The ultimate choice of a whitener or whitener system for a specific formulation often represents a compromise between the optimum technical performance desired and economic considerations. This overview provides an introduction to fluorescent whitening agents to those new to the field of laundry product formulations and, perhaps, serves as a refresher course for the more experienced formulator. In actual practice, the selection of an optimum whitener system is based on extensive laboratory trials and evaluations.

INTRODUCTION

Fluorescent whitening agents (FWA), formerly designated "optical brighteners," were introduced into the detergent industry during the early 1950s. By the end of the decade, their penetration of the detergent market was universal, but at generally low usage levels. The 1960s witnessed an explosive growth in whitener consumption as suppliers introduced improved products and detergent manufacturers vied for greater market shares with "whiter than white" advertising campaigns. During this period, the detergent manufacturers could select whiteners from among ca. 20 discrete chemical structures offered by six major suppliers. In the 1970s, however, the whitener level trend reversed, resulting in a gradual decrease in consumption. The primary factors involved in this trend were: changing promotional strategies; raw material economics; changing wash load composition; builders (nonphosphate) reformulation; and toxicological/ecological factors.

As a result, the number of suppliers and chemical entities offered have been essentially cut in half. In spite of the reduced consumption, however, fluorescent whitening agents, like the "active" surfactants, remain as a universal ingredient in heavy duty home laundry detergents.

FACTORS INFLUENCING WHITENER SELECTION

Before discussing whitener selection for specific applications, it is beneficial to review several general factors involved in the selection process. It is the variability in these properties which differentiates one whitener from another.

Total Solubility

In general, effective FWA exhibit relatively low total solubility. Since fabric whitening by exhaust procedures is an equilibrium process, a limited solubility enhances fabric deposition. On the other hand, a low solubility limit of some whiteners may preclude their usage in liquid formulations.

Rate-of-Solution

This factor is operative only in powdered laundry products and is reflected primarily in low-temperature performance characteristics. Although a specific whitener may be totally soluble at wash liquor concentrations, the time required to achieve total solubilization, especially at low temperatures, may well exceed the normal wash cycle limit of 10 min. Therefore, the total potential whitening effect expected for a given FWA concentration may not be achieved.

Detergent Whitening

The primary function of a laundry product whitener is to enhance the appearance of white fabrics. A secondary factor that must be considered, however, is the effect of the FWA on the appearance of the laundry product itself. Product appearance is dependent on whitener selection, the type of formulation, and the method of incorporation.

Bleach Stability

In a classical sense, the chemist may consider the term "bleach stability" as a measure of a compound's inherent resistance to oxidation. In relation to FWA, the term has a much narrower definition, specifically the resistance of a whitener to destruction in solution by hypochlorite. All