Butanol and Acetone from Corn[1]

A Description of the Fermentation Process

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The low price of butanol and the high solvent efficiency of butyl acetate are fundamental to the thriving industry of modern nitrocellulose lacquers. The manufacture of this material by the fermentation of cornstarch is described in this article and the economic effect of the by-products of this process are discussed.

A MUSHROOM as tall and as sturdy as an oak, or an oak as swift to grow as a mushroom, should be classed among the botanists' improbabilities, but nothing short of this could be fairly compared to the rapid growth and sound permanence of chemical industry in America. Unit after unit, based upon some strange habit of matter newly discovered or given new importance by changing circumstances, has developed almost overnight into a profitable part of this young and growing industry. Circumstances have played an important role in this succession of wonders, and persevering research has furnished the *elixir vitae* to keep it going. Few better illustrations of this exist than in the development, by careful research, of the American butanol industry on slender threads of circumstance connecting the British War Office, an odd microörganism, a potential swimming pool filled with an undesired by-product, an early unsuccessful effort at rubber synthesis, the demise of the American whisky industry, the unavoidable limitation of the wood distillation industry, a new type of nitrated cotton, the manufacture of paint and varnish, and the American corn crop.

Early History

To bring these apparently isolated circumstances into their proper mutual relations, it is necessary to go back to 1910, and before, when energetic efforts were being made to synthesize rubber. Polymerizations of butadiene and of isoprene were the bases of hope for the solution of this problem but, unfortunately, neither of these raw materials was to be had easily. At this point a microörganism, *clostridium acetobutylicum* (*Weizmann*) to be accurate, was found to possess a remarkable appetite for starch and a still more remarkable ability to convert it into acetone and butanol. The butanol might well serve as a raw material for the preparation of both butadiene and isoprene. Thus the growth process of the microbe was carefully studied, without, be it noted, any great advantage to the still non-existent industry of rubber synthesis. The second circumstantial thread begins with a peculiar specification of the British War Office that smokeless powder for the British armies be made with acetone as a component of the colloiding solvent, and leads to the beginning of the World War when quantities of powder were required so unimaginably huge that the wood distillers could not be expected to make enough acetone to produce it. In this emergency, the war office dug up the rubber synthesists' microbe and put it to work in England, India, and Canada, changing starch into acetone, to make up the deficit, and butanol. Later, after our entrance into the conflict, an erstwhile whisky distillery in the Indiana corn belt was converted into a plant for the manufacture of acetone under the joint control of the American and British Governments. This story properly begins with this converted distillery, for it has served as the foundation on which a new American industry has been built.

Economic Utilization

The action of the *clostridium* in this old distillery produced great quantities of acetone, which was in urgent demand during the war as a solvent for nitrocellulose, the latter being made into smokeless powder for the British and airplane dope for the Americans. The disguised blessing in this operation was that every pound of acetone produced was accompanied by two of butanol, and although everyone wanted acetone no one was at all interested in butanol. Some of this very plentiful by-product, it is true, was laboriously converted into methylethyl ketone (butanol-1 $\longrightarrow$ butylene $\longrightarrow$ butanol-2 $\longrightarrow$ methylethyl ketone), which was utilized by being added to the acetone output with some of the ethanol simultaneously produced during the fermentation. No one could be persuaded to show interest in the vast amounts of butanol left unused by this operation and immense vats—one now serves very satisfactorily as a swimming pool—were built to conserve it in the hope that it might later find profitable use. It is fortunate that this bit of economy was practiced, despite the expense attached to building the vats, for this surplus butanol now shares equally with "low viscosity cotton" the honors for the founding of our lusty young industry of nitrocellulose lacquers. It is somewhat doubtful if this would have been the case had capital been required to go into its manufacture without the benefit of the compelling proof of its fitness which this surplus furnished.

The swimming pool full of butanol became immediately important upon the discovery of a method of making nitrated cotton of much lower viscosity in solution than the ordinary, for it made readily available an excellent solvent, butyl acetate, at relatively low cost. These two things, cheap butanol and low viscosity cotton, are the foundation of the lacquer industry whose phenomenal growth is among the most amazing of modern industrial wonders. Little more than three years ago nitrocellulose lacquers had been used only in small quantities as a protection for metal surfaces and for airplane wings, whereas today the department stores offer a dozen different varieties in dozens of colors and shades for household use and there are few automobiles made whose finish is not a lacquer. The quantities of lacquer used are increasing at a prodigious rate and, concurrently, the output of butanol has had to grow to supply the necessary solvent. Within the past twelve months the butanol output has been more than doubled, and a still further increase of an approximately equal amount is expected within another year.

The effect of the lacquer made from butanol on the paint and varnish industry has been serious but the wood distillers, already under an accumulation of difficulties, have found it hard to survive the manufacture and sale of the huge quantities of acetone produced as a by-product of this operation. The activities of the microbe result in the production of butanol, acetone, and ethanol in the ratio of 6:3:1, and thus the present unavoidable output of acetone amounts to some 30 tons per day. This must be absorbed by industry, and since no corresponding increase in use has been developed it has operated to control acetone prices. The wood distillers find their domestic market seriously limited by this and their export market, with the exception of Great Britain, practically wiped out. It is interesting to note that this exception comes about because of the British Safeguarding of Industries Act, which provides that acetone made by fermentation shall pay

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