that the sugar first loses water to form methyl glyoxal aldol, or:

$$C_6H_{12}O_6 - 2H_2O \longrightarrow C_6H_8O_4 \qquad (1)$$

The methyl glyoxal aldol then gives methyl glyoxal:

$$C_6H_8O_4 \longrightarrow 2CH_2 : C(OH)CHO \qquad (2)$$

This in turn reacts with water to produce glycerol and pyruvic acid:

$$\begin{array}{l} CH_2 : C(OH)CHO + H_2O + H_2 \longrightarrow CH_2OHCHOHCH_2OH \text{ (glycerol)} \\ CH_2 : C(OH)CHO + \qquad\qquad O \longrightarrow CH_2 : C(OH)COOH \text{ (pyruvic acid)} \end{array} \qquad (3)$$

The pyruvic acid is then acted on by the yeast, and split into carbon dioxide and acetaldehyde:

$$CH_2C(OH)COOH \longrightarrow CO_2 + CH_3CHO \qquad (4)$$

The acetaldehyde and the methyl glyoxal combine with water to form pyruvic acid and ethyl alcohol:

$$\begin{array}{l} CH_3COCHO + O \longrightarrow CH_3COCOOH \text{ (pyruvic acid)} \\ CH_3CHO \quad + H_2 \longrightarrow CH_3CH_2OH \end{array} \qquad (5)$$

Steps (3) and (5) are dismutations, as in the Cannizzaro reaction. The pyruvic acid of (5) can again yield acetaldehyde, which can react with more methyl glyoxal, as the latter is constantly being formed from the sugar. Large amounts of alcohol can thus be formed theoretically without the production of more than one molecule of glycerol.

The theory of Neuberg holds the field at present as best representing the chemical reactions involved in alcoholic fermentation. It is inconclusive because the methyl glyoxal assumed as an intermediate has not been found in actual fermentations of sugar by living yeast.

Distillation

Distillation, the final step in the production of ethyl alcohol, follows well-established procedure. The fermented mash containing 6 to 10 per cent of alcohol is run through continuous stills for the production of crude 50 to 75 per cent alcohol, commonly called "high wines," followed by refining stills, which may be continuous or batch stills. In modern practice the two stages are sometimes combined and carried out in one continuous distilling unit consisting of several columns.

Lactic Acid[1]

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Lactic acid is manufactured in the United States by the comparatively high temperature fermentation of cane or beet sugar, corn starch, or corn sugar by a pure culture of lactic bacteria. The fermentation is completed in from 5 to 6 days and the acid is recovered as a technical or a food product, according to requirements. The uses which lactic acid finds in industry are reviewed.

Lactic acid is essentially an American product. It was first produced commercially by Charles E. Avery at Littleton, Mass., in 1881, when the introduction of calcium lactate as a substitute for cream of tartar in baking powder was attempted. This met with little success, however, and the development of its industrial application, in the leather and textile fields, began about 1894. Since that time the use of lactic acid has increased in these fields and also along other lines—notably foods, beverages, and nitrocellulose solvents.

Lactic or α-hydroxypropionic acid was one of the first of the organic acids to be identified, probably because of its wide distribution in nature. Scheele in 1780 first recognized it as a component of sour milk, from which its name is derived. Pasteur, seventy-seven years later, discovered that the souring of milk was caused by an organized ferment. Pasteur's paper on lactic acid fermentation, presented to the Lille Scientific Society in August, 1857, and his paper on alcoholic fermentation, presented to the Academy of Sciences in December of the same year, were the foundation stones from which was developed the present knowledge of bacteriology and industrial fermentations.

The next important step in the development of lactic acid was the observation by Schultze in 1868 that lactic acid bacteria are present in the yeasts of distilleries. Delbruck made a thorough investigation of the temperatures for lactic formation in distilleries in 1877 to 1879. He found a relatively high temperature to give the optimum results and the lactic fermentations of today are maintained at unusually high temperatures.

Lactic acid is produced by a large variety of bacteria, many yeasts, molds, and some plants. Hence, bacteriological studies of pure cultures were of great importance in the selection of the proper type of fungus and in the determination of its nutritive and temperature requirements, etc., for the commercial production of lactic acid. Lister in 1878 obtained the lactic fungus of sour milk in pure culture and Leichman in 1886 produced a pure culture from soured yeast which was called *B. Delbrucki*. This variety is probably more generally used in lactic acid production than any other of the many types of lactic acid-producing bacteria, because of its ability to acidify rapidly and its high optimum temperature, which retards the growth of other contaminating bacteria and results in a relatively pure grade of lactic acid.

The raw materials which may be used for the production of lactic acid are any substances containing fermentable sugars or carbohydrates which may be converted to fermentable sugars. The materials most commonly used in this country are cane and beet sugar molasses, corn starch, and corn sugar. For many years one lactic plant used the waste obtained in the manufacture of vegetable ivory buttons from tagua nuts, but this operation has been discontinued. In Germany potato starch is commonly used as a source of lactic acid. Wheys from the dairy industry offer possibilities, but so far as the writer knows they are not utilized for lactic manufacture in the United States. The sugar content is rather low and bacteria of the Bulgaricus type must be used as the Delbrucki type will not ferment milk sugars.

When starches are used as a raw material, they must be hydrolyzed to sugar either by boiling with dilute acid or by treatment with a malt rich in diastase.

In addition to the sugar, a supply of nitrogen and salts must be present as food for the bacteria in order that they may multiply and acidify at a rapid rate. This food is ordi-

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narily supplied in the forms of gluten from grains or ammonia and phosphates.

The lactic bacteria are susceptible to an excess of acid; hence the acid must be neutralized as it is formed in order for the culture to thrive. This is usually accomplished by the addition, at the beginning of a fermentation, of sufficient calcium carbonate to neutralize the acid as produced. However, a very slight acidity is sometimes maintained during the fermentation to prevent the growth of contaminating organisms. This is done by the gradual addition of lime as required, but very close control is necessary in order to maintain a uniform acidity.

A fermentation usually requires 5 to 6 days for complete conversion of the sugar to lactic acid, although the time may vary widely with conditions. When it is completed, sulfuric acid is added and the calcium lactate converted to lactic acid and calcium sulfate. The latter is filtered off and washed. The resulting weak lactic acid (about 8 per cent) is concentrated in vacuum pans to the desired strength.

Grades

The lactic acids of commerce may be classified as "technical" and "U. S. P." The technical class may be further subdivided into "dark," "light," and "edible," according to the color and to the degree of purification during processing. The dark grade is generally produced from molasses and the light and edible grades from starch or sugar. The preparation of the edible grade is similar to that of the light grade except that more extensive purification treatments are required to remove heavy metals, etc., which would be objectionable in foods and beverages.

The technical grades of acid are usually marketed at strengths of 22 and 44 per cent, although other strengths may be supplied if desired.

The U. S. P. grade of acid is not produced in this country, but is imported from Germany. It is a water-white or very slightly yellow product produced by purification of the technical grade and contains 85 per cent of lactic acid.

The containers in which lactic acid is shipped are wood tank cars, hardwood barrels, glass carboys, and smaller bottles.

Uses

The leather industry is the principal consumer of lactic acid, utilizing probably 80 to 90 per cent of the entire consumption of the country. Its most important function in leather processing is the removal of lime from dehaired hides. The solubility of calcium lactate, together with the mild effect of the lactic acid upon the hide substance, make it an ideal acid for this purpose. The technical lactic acid has to a large extent displaced the old-time bran drench which was formerly used for deliming. The active constituent of the "soured" bran drench was lactic acid produced by natural fermentation; hence the technical lactic acid produces the same effects upon the leather. However, the technical acid has the great advantage of producing a drench of definitely controlled composition which tends to insure uniform and consistent results in this important step of leather production.

Lactic acid is also used for plumping leather, but its advantages over other acids, such as sulfuric, hydrochloric, and oxalic, are not so pronounced as in the deliming operation.

The dyeing and finishing of textiles constitutes an important field for the use of lactic acid, particularly in chrome mordanting and in acid dyeing of wools.

In recent years a large amount of lactic acid has been used in the production of ethyl lactate, a high-boiling solvent for the nitrocellulose used in the production of pyroxylin lacquers.

The edible and U. S. P. grades of lactic acid are gradually finding increased uses in widely diversified lines of food and beverage products, some of which are infant foods, low-alcohol beers, soft drinks, candies, poultry, and stock foods. In infant foods lactic acid appears to have a corrective effect upon the digestive tract; in near-beers its purpose is improvement of flavor and odor; in soft drinks and certain candies it acts as an acidulent replacing citric and tartaric acids. Its advantage over acetic in this respect is that the acidity of the product can be increased by the use of lactic acid without making the taste objectionable. In poultry and stock foods certain advantages are claimed for lactic acid either as the commercial acid or its salts or in the form of buttermilk products.

The wide natural occurrence of lactic acid in food products has accustomed the digestive tract to it. This, together with a mild pleasing taste and marked preservative qualities leads to the belief that the most important development of new uses for lactic acid in the future will be along the lines of food and beverage products.

History and Development of the Modern Yeast Industry[1]

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The history of the yeast industry from the earliest times down to the manufacture of the modern compressed yeast is outlined. The various theories of fermentation which have arisen during the course of the development of the industry are described. A brief survey of the uses and biological properties of yeast is given.

The fermentation industry has had several distinct periods of development. One may be called the period comprising the art of the ancients, including the period antidating the compressed-yeast industry; the second, the compressed-yeast industry before Pasteur; the third, the period of scientific study of yeast which includes the period of Pasteur and the period immediately afterward. This period is chiefly represented by two groups, one group representing the vitalistic and the other the chemical point of view. In addition there was a group who believed in spontaneous generation. The fourth or modern period, following the time of Pasteur and extending to approximately 1914, also covered a further development, the ammonia-molasses phase.

It would be extremely interesting if we could call forth representative men from every one of the great nations which have existed since the dawn of civilization. We would ply them with questions regarding their system of philosophy and their interpretation of the laws of nature. What forces in nature did they recognize and how did they succeed in controlling or combating them? It is impossible for us to conceive, even were di-

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