9715

REPORT

of the

Senate Investigating Committee

on

Synthetic Rubber As An Outlet For Minnesota Farm Products

#9715

COMMITTEE

SENATORS

ALEX SEIFERT, Chairman
J. A. SIMONSON
W. L. DIETZ
C. G. BAUGHMAN
ANCHER NELSEN

TO THE SENATE AND HOUSE OF REPRESENTATIVES:

During the Legislative Session of 1943 Senators Weber and Nelsen introduced Senate Resolution No. 8, which appears on the Senate Journal on pages 258 and 259, 24th day of the Senate record. The resolution directed the University of Minnesota to present, at the earliest possible date, all available facts, figures, statistics and advice concerning the development of plants and/or processes for the production of synthetic rubber from agricultural sources. The resolution further provided for the appointment of a committee of five members from the Senate of this State to study the information thus presented, and make recommendations to the proper authorities as to how much synthetic production of rubber may be started at the earliest possible moment, and that such information be forwarded to William Jeffers, Chief of rubber production for the United States of America.

This resolution was passed by the Senate, on February 16, 1943, 28th day, as appears on page 337, Journal of the Senate. Thereafter and on the 80th day of the session, and on April 21, 1943, Senator Richardson, Chairman of the Committee on Committees, recommended the appointment of Senators Seifert, Baughman, Simonson, Dietz and Nelsen, as a committee from the Senate, pursuant to action theretofore taken, to serve on the work outlined by Senate Resolution No. 8 above referred to.

Pursuant to this resolution, your chairman contacted President Coffey of the University of Minnesota and asked for the appointment of a staff of professors who had given study to this subject, and who could assist the committee members with its work, and President Coffey did select Dean Bailey, as Chairman, and Dr. O. B. Jesness, Dr. C. A. Mann, Dr. I. M. Kolthoff, and Dr. L. S. Palmer to present the necessary data, facts and figures for study by the committee.

The committee had its first session on June 29, 1943, at which time Senator Seifert was selected as Chairman, Senator Baughman as Secretary. For the University, Dean C. H. Bailey was

Chairman, and present were Dr. O. B. Jesness, Dr. C. A. Mann, Dr. L. S. Palmer, and Dr. I. M. Kolthoff. The data, facts and figures thus far developed by the University of Minnesota were presented and discussed, and various valuable information on the cost and production of synthetic rubber was gone into. Publications and statistics from the United States Government were also presented and analyzed. The suggestion was made that the study be continued, and all available material be reduced to statement form. This was done by Dean Bailey and his associates and their report delivered to the Committee as of August 12, 1943.

The Committee met again on Monday, October 30, 1944, for the purpose of approving and adopting the former report, and having the same printed. At this time the following Senators were present: Seifert, Dietz and Baughman. For the University, Dean C. H. Bailey, Dr. C. A. Mann, Dr. O. B. Jesness, and Dr. W. F. Geddes, who has been asked to serve in place of Dr. Palmer, who is deceased.

Because of the great progress made in the synthetic rubber program since the first report was prepared, it was deemed advisable to revise and bring up to date any report to be submitted, and for this reason the first report was thoroughly gone over, read section by section, and compared with the latest publications and Government reports on the subject. Dean Bailey suggested that 30 days be given the University in which to revise and compile this amended report, and that the Committee meet again on December 4, 1944, to adopt such report, and order the same printed, and ready for distribution in the next session of the Legislature.

On December 4, 1944, the Senate Committee consisting of Alex Seifert as Chairman, William L. Dietz, Ancher Nelsen, C. G. Baughman, and John Simonson met with the Committee of the University consisting of Dean C. H. Bailey, Dr. O. B. Jesness, Dr. W. F. Geddes, Dr. C. A. Mann, and Dr. I. M. Kolthoff for the purpose of approving the revised report of this Committee. The entire report was read over section by section and after

making some minor changes the report was in all things approved and adopted.

The Committee of the Senate wishes to express its sincere appreciation to Dean Bailey and the various members of his Committee for the many hours spent and deep research made by them in gathering and compiling the data and statistics contained in this report. Many hours of unselfish devotion were given by these experts to the subject at hand and without their advice and assistance this report could not have been completed.

The Committee herewith presents its report of their findings and study made on the subject and asks that the same be accepted and the Committee be discharged.

Committee Expense

From General Contingent Fund (L.A.C.)		$1,500.00
Expenses:		
Committee members' expense	$147.30	
Printing committee report	92.50	
Total expense		239.89
To be cancelled		$1,260.11

Respectfully submitted:

J. A. SIMONSON
W. L. DIETZ
C. G. BAUGHMAN
ANCHER NELSEN
ALEX SEIFERT, Chairman

SYNTHETIC RUBBER AS AN OUTLET FOR MINNESOTA FARM PRODUCTS

The United States is the world's leading user of rubber and the principal source of supply has been the plantations of the South Pacific region. The successes of Japan during the early months of the war gave the enemy control of most of the current production of natural rubber. The importance of rubber in the war effort and in civilian transportation made it essential for this country to develop replacement for the supplies cut off by war. Activities along this line have included both synthetic and natural rubber.

Synthetic Rubber

Five principal types of synthetic rubber are now being produced on a commercial scale in the United States and Canada. The trade names of these and the dates when they were first introduced commercially in the United States are given below:

Neoprene	1931
Thiokol	1932
Buna-S (now frequently called GR-S)[1]	1940
Buna-N	1940
Butyl	1940

The Buna synthetics were first produced commercially in Germany. Trade names for Buna-S have been adopted by various American concerns such as "Chemigum IV" (Goodrich Tire and Rubber Company) and "Hycar" (Phillips Petroleum Company and F. B. Goodrich Rubber Company). Trade names for Buna-N include "Perbunan" (Standard Oil of New Jersey), "Buna-N Chemigum III" (Goodyear), "Buna-N Hycar" (Goodrich) and "Thiokol R D" (affiliate of Dow Chemical Company). Butyl is called "Flexon" (Standard Oil of New Jersey).

The processes involved and the characteristics of the synthetic rubbers differ for the different kinds and likewise from natural rubber. Some synthetic rubbers are superior to natural rubber in resistances to most influences that cause deterioration, but natural rubber still is better in some important performance characteristics. Thus, while synthetics may have an advantage

[1]GR-S denotes Government Rubber, Type S.

in certain special uses, natural rubber possesses advantages over present synthetics in some of the major uses.

Many technical problems had to be solved before synthetic rubbers could be substituted satisfactorily for natural rubber in tires. The following statements made in Progress Report No. 5 of the Rubber Director (March 17, 1944) are indicative of some of the problems encountered and the progress made in meeting them:

> "An exhaustive testing program conducted both by industry fleets and a special government test fleet, operated under the direction of this office, have shown that all-synthetic passenger tires and small truck tires will give entirely adequate service. Medium size truck tires using 70% Buna S and cotton cord are adequate for short haul and city service. The situation is very different with the larger sizes used on inter-city trucks and busses. Here overheating is so severe — due to heavy loads and relatively high speeds — and the properties of synthetic rubbers are so altered at high temperatures, that only by the use of rayon cord is it possible when using Buna S to avoid wasting rubber, manpower and manufacturing facilities. When rayon is used in these large highway tires with varying percentages of Buna S, depending upon size, performance equal to that of pre-war tires of even these large sizes made with cotton cord and all-crude rubber can be expected."

With respect to inner tubes, Progress Report No. 5 states:

> "**Tubes.** All tubes, civilian and military, sizes 6.00 through 9.00 are made of Buna S, except 6.00-16 and 9.00-16 military types which are used on drop center rims. These two sizes will be converted to Butyl rubber on or before April 1. (Report issued March 17, 1944.) All tubes sizes 10.00 and up are now made of crude rubber, but will be converted to Butyl as rapidly as development work can be finished and Butyl is available. Many tubes now made of Buna S will also be converted to Butyl as soon as enough Butyl is available."

The war emergency rubber program has concentrated attention largely on the production of Buna-S. It was regarded as the best general purpose synthetic rubber and the raw materials for the production of the ingredients used in its manufacture were available.

Buna-S (GR-S) is made by a union of butadiene and styrene through a process called copolymerization. This union is in approximately a three to one ratio followed by a union of a large number of the new molecules. These unions are assisted by an acceler-

ating agent called a catalyst, under heat and pressure. Butadiene at ordinary temperatures is a gas but becomes a liquid under pressure. Styrene is a liquid.

Ethyl alcohol, commonly called alcohol, or grain alcohol, is one of the raw materials from which butadiene may be manufactured. Alcohol in turn may be made from products, including many agricultural products, from which fermentable sugar is obtainable, or it may be made by chemical synthesis from petroleum, natural gas or refinery gas.

Styrene requires for its synthesis two chemical substances, benzene (benzol) and either ethyl alcohol or ethylene. Benzene is now a by-product chiefly of the coal tar and coke industry for which coal is the primary raw material. Ethylene can be obtained from coal gas, or can be produced from grain alcohol or petroleum. The latter is the principal source of ethylene for styrene synthesis at present.

Progress in the Synthetic Rubber Program

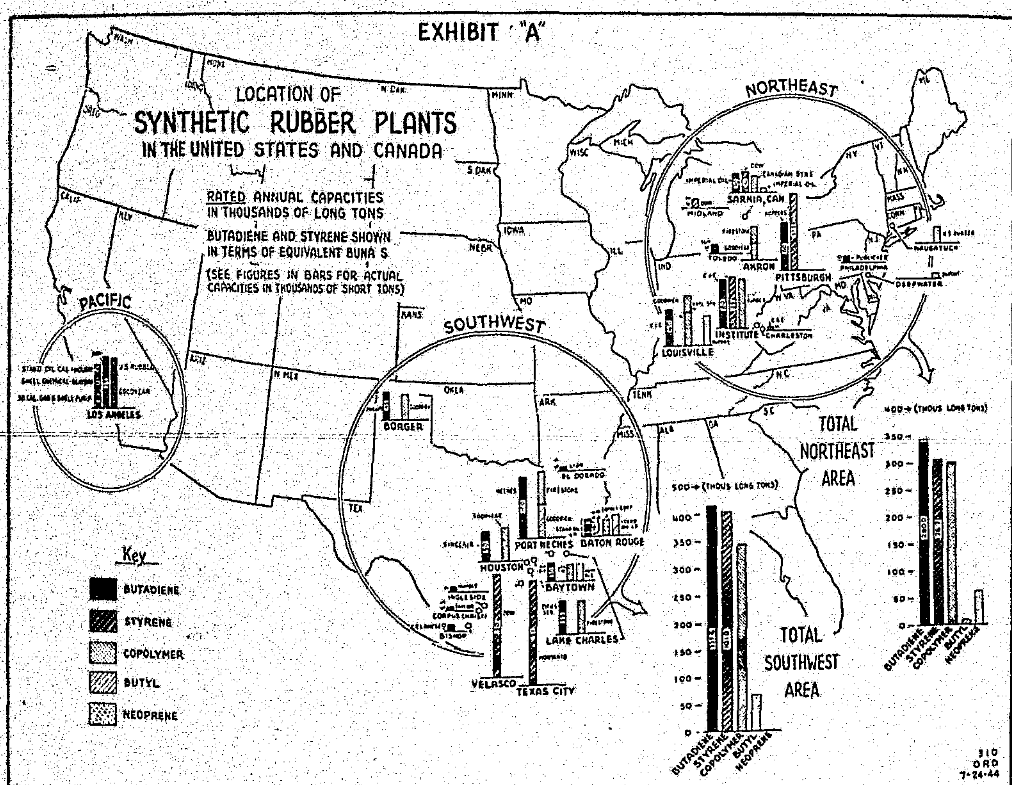
The following table using data from Progress Report No. 6 of the Rubber Director, dated July 25, 1944, indicates the volume of output of synthetic rubbers and the increases which have taken place.

Estimated Synthetic Rubber Production (Long Tons)

	1943	1944	First 6 Months 1945
Buna S	184,781	712,376	390,000
Butyl	1,373	21,159	27,550
Neoprene	33,603	57,453	33,500
Buna N	14,487	20,049	9,700
Total	234,244	811,037	460,750

These figures show the rapid expansion which took place in 1944 as new plants came into operation. They also show the predominant position given to Buna S. The estimates for the first half of 1945 indicate only a moderate additional expansion although the relative increase in Butyl is large. This means that the present development is expected to be adequate to take care of needs.

The locations of the plants which have been established to provide synthetic rubbers or materials needed in their manufacture naturally will have some bearing on the sources of raw materials used in the future. As shown in Exhibit A, these plants are found in eastern, southwestern and Pacific states. Texas, West Virginia, Louisiana, Pennsylvania and Kentucky are in the lead in butadiene plant capacity. Texas and Pennsylvania are first and second in styrene capacity. Texas leads in copolymer plants, with California, Kentucky, Louisiana and West Virginia coming next with the same rated total plant capacities. Kentucky and New Jersey have the neoprene plants and Louisiana and Ontario the butyl plants.



From Progress Report No. 6 (issued July 25, 1944), Office of Rubber Director, War Production Board, Washington, D. C.

Report No. 6 of the Rubber Director states that "The supply of synthetic rubbers is ample to provide for any presently foreseen requirement of essential rubber goods." In fact, the total output is larger than used in this country before the war and is regarded as sufficient to meet war needs with continued care in the use of present tires and equipment. A rather serious shortage in large, heavy-duty tires has resulted from a shortage of manpower in manufacturing plants. The Rubber Director concludes that "the problems envisioned by the Baruch Committee . . . have been solved, but the demands of war are such that it may

be many months before sufficient manufactured rubber goods, more particularly heavy-duty truck and bus tires, are available to supply the needs of the civilian economy. . . ."

Natural Rubber Production in the Western Hemisphere

Before considering farm products as a raw material in the manufacture of alcohol for use in making butadiene, some mention of the production of natural rubber in the Western Hemisphere may be in order.

Several rubber producing plants are found in this hemisphere and considerable effort has been made to expand the output of natural rubber from this source. The more important of these plants are found chiefly in the Central American countries and further south towards the equator, particularly in Brazil. The plants which have the greatest potential yields are the Hevea and Castilla trees of tropical America, and the guayule shrub native to northern Mexico and nearby Texas. Another plant which has attracted considerable attention is the Russian dandelion or Kok-saghyz, but production costs are out of line in comparison with other plant sources.

The third progress report of the Rubber Director says that "The Amazon Basin development is being pushed with vigor and should bear some fruit in the near future." It also sees promise in the Cryptostegia plantations in Haiti, but indicates that there remain some unsolved problems of extraction. By the middle of last March, 53,000 acres were under lease for planting to guayule. Originally, it was the intent to use marginal lands for this shrub, but plans later were shifted to the use of land under irrigation because it was found this would shorten the production cycle from four to two years. The importance of producing food, however, has led to a decision against expanding acreage of guayule on irrigated land. As the Rubber Director says, "Food for 1943 has become more important to the nation than a rubber insurance policy for 1946 and beyond."

Experimental plantings of Russian dandelion (Kok-saghyz), the root of which is relatively rich in rubber latex, have been made in widely scattered parts of the United States, some of these now being in their third year. The plant thrives in many temperate zone settings, including Minnesota, but costs of production have been prohibitive thus far.

Less emphasis is now being placed on the development of natural rubber production in the Western Hemisphere than earlier in the war. The time required and the costs involved in expansion of natural rubber production have played a part in this change. An important reason for the shift in emphasis, however, is the gratifying progress which has been made in the production of synthetic rubbers.

Industrial Alcohol for Butadiene Production

Production and Sources. The raw materials required for the production of butadiene may be obtained from petroleum and natural gas or from farm products. Those derived from petroleum in the government butadiene program include butylene, butane, and naphthas or other petroleum fractions. Ethyl alcohol is the only raw material derived from plant products which has been utilized to date but considerable experimental work has recently been carried out with a fermentation process which produces another chemical from starch, known as butylene glycol, which can be converted into butadiene. This process is still in its experimental stages so that at the present time ethyl comprises the important outlet for farm products in the rubber program.

The production of butadiene from the various sources employed in the rubber program is shown in Exhibit B. While up to the present time the greatest tonnage of butadiene has been produced from alcohol, production from petroleum is increasing rapidly.

The production of industrial alcohol in the United States in past years is shown in the following table.[2]

Production of Industrial Alcohol in the United States in Past Years[1]

Year	Number of Plants	Proof Gallons[2]
1933	34	115,609,754
1934	34	165,103,582
1935	32	180,645,920
1936	35	196,126,236
1937	38	223,181,228
1938	36	201,033,858
1939	36	201,017,546
1940	37	243,727,756
1941	39	298,845,417
1942 (Estimated)[3]	X[4]	424,000,000

[1]From Department of the Treasury Statistics.
[2]A proof gallon represents one United States wine gallon (231 cu. in.) of 100-proof alcohol, which contains exactly 50 per cent alcohol by volume. 1.9 proof gallons = 1 wine gallon of 190-proof (95 per cent) alcohol; 2.0 proof gallons = 1 wine gallon of 100 per cent alcohol.
[3]Estimated from current non-official information.
[4]Beverage spirits industry also producing industrial alcohol.

[2]Taken from "Industrial Alcohol," by W. W. Skinner (revised by P. B. Jacobs), U. S. D. A. mimeographed publication AIC-3, NM-235, March, 1943.

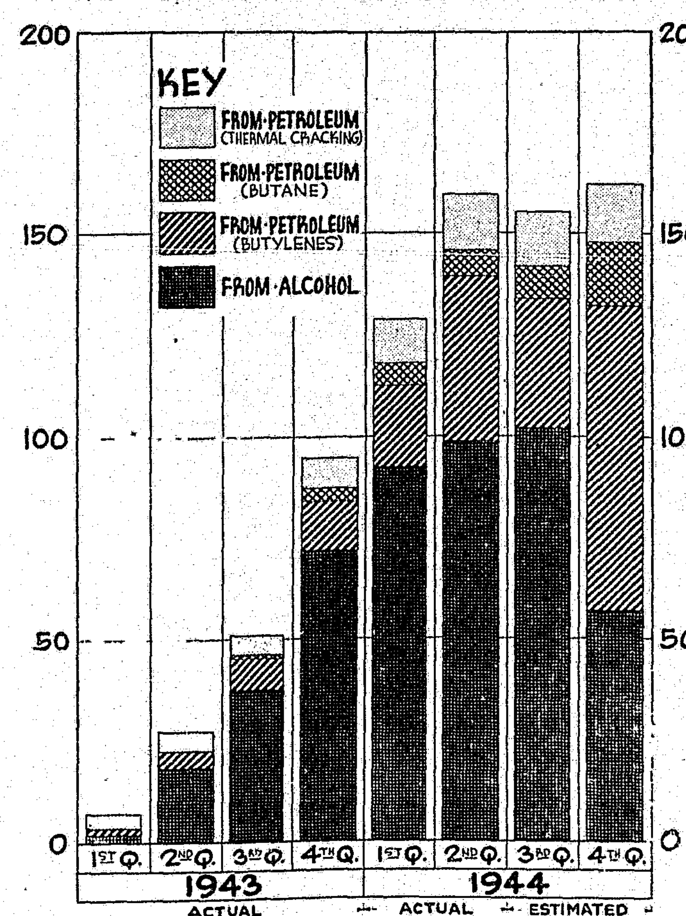
Ethyl alcohol may be prepared from four general classes of raw materials:

1. Saccharine materials, such as molasses, sugar beets, sorgo, sugar cane.

2. Starchy materials, such as cereal grains, potatoes, etc.

3. Cellulosic materials (such as wood and agricultural residues) and the waste sulfite liquor from paper-pulp manufacture (which contains sugars derived from cellulose and hemicellulose).

EXHIBIT "B"
BUTADIENE PRODUCTION BY SOURCES
By Quarters 1943-1944
IN · THOUSANDS · OF · SHORT · TONS



From Progress Report No. 6 (issued July 25, 1944), Office of Rubber Director, War Production Board, Washington, D. C.

4. Hydrocarbon gases, such as ethylene and acetylene from natural gas, coal gas, and waste gases from petroleum refining, or especially prepared for the manufacture of alcohol. These gases are the raw materials for the production of synthetic industrial alcohol.

The trends in alcohol production from various raw materials are shown below.

Trends in Alcohol Production from Various Raw Material Sources[2]

Produced from	YEAR 1933	1934	1935	1936	1937	1938	1939	1940	1941	1942[1]
	Per Cent of Total Production									
Molasses	83.0	83.4	85.5	76.1	75.7	73.1	67.6	68.5	70.4	68.1
Grain	4.1	6.3	2.7	7.0	8.4	9.1	7.7	5.7	5.9	9.1
Synthetic	9.7	7.3	9.7	16.0	15.2	17.6	23.8	25.1	23.4	21.4
Other	3.2	3.0	2.1	.9	.7	.2	.9	.7	.3	1.4
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1]Estimated from current reports.
[2]Taken from "Industrial Alcohol," by W. W. Skinner (revised by P. B. Jacobs), U. S. D. A. mimeographed publication AIC-3, NM-235, March, 1943

Normally, most of the industrial alcohol is produced from by-product cane molasses (black strap) in plants located chiefly on the eastern seaboard. Black strap molasses is a cheap raw material and the cost of manufacture is also less than that from grain. The supply of alcohol became a problem when molasses shipments from Cuba and other Caribbean sources were disrupted. Since grain supplies were considered ample, and necessity rather than cost was the governing factor, an increased use of grain was made in alcohol production. Many of the plants formerly using molasses were equipped to use granular wheat flour and the entire beverage-alcohol industry has been temporarily converted to industrial alcohol production for war purposes. In addition, the government facilitated the construction of new plants to produce alcohol from grain at Omaha, Nebraska; Muscatine, Iowa; and Kansas City, Missouri. As the situation improves more black strap molasses may be expected to become available for alcohol production. At present, however, the limited supply of black strap molasses must be supplemented with grain in order to produce the large quantities of alcohol required.

Cost of alcohol production from molasses and starchy materials. The cost of producing industrial alcohol depends upon three main factors: (1) the cost of the raw material at the plant, (2) the value of by-product feeds, and (3) the cost of processing (and of denaturing when this is necessary).

During the decade preceding the present war, the price of industrial alcohol followed the price of black strap molasses. Exhibit C shows the prices of alcohol and of $2\frac{1}{2}$ gallons of

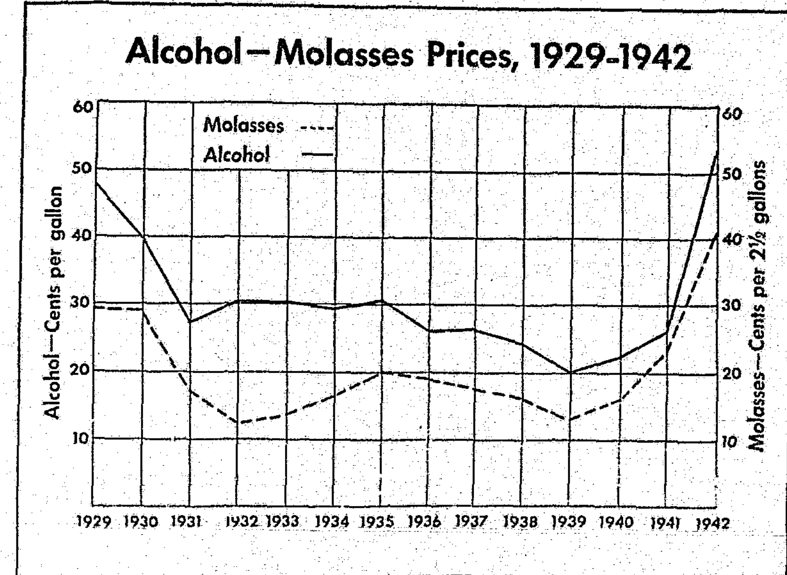


Exhibit C. Prices of alcohol and of $2\frac{1}{2}$ gallons of molasses for the years 1929-1942. The molasses prices are for tank car lots f.o.b. North Atlantic ports; the alcohol prices are for specially denatured alcohol (Formula No. 1) in tank car lots at Eastern ports. (Reproduced from Chemical Industries 54 (3):355, March, 1944, with the kind permission of the publishers.)

molasses, which is the average quantity required to produce a gallon of alcohol. The cost of industrial alcohol prepared from black strap molasses is low. In this connection, a recent federal publication[2] states, "It is estimated that under present conditions (1943) the plant-operating (conversion) cost of producing a gallon of 95 per cent alcohol from **black strap cane molasses** may be as low as 3 to 4 cents per gallon (exclusive of raw material) for a unit operating at the highest efficiency and producing from 20,000 to 30,000 gallons of alcohol a day. Normally, for smaller operations, the cost may exceed 6 cents. With molasses at ordinary, pre-war price of 5 cents a gallon and with a yield of 1 gallon of 99.5 per cent alcohol from $2\frac{1}{2}$ gallons of molasses, the operating and raw material costs would approximate $18\frac{1}{2}$ cents per gallon of alcohol, under good operating conditions."

[2]"Industrial Alcohol," by W. W. Skinner (revised by P. B. Jacobs). U.S.D.A. mimeographed publication AIC-3, NM-235, March, 1943.

In the manufacture of alcohol from farm crops the theoretical yield of alcohol is directly proportional to the fermentable carbohydrate content. The probable average yields of alcohol per bushel of certain crops are as follows:[3]

Raw Material	Fermentable Content Per Cent	Bushel Weight Lbs.	Gallons of 99.5% Alcohol per Bushel
Corn	57.8	56	2.35
Oats	43.6	32	1.02
Barley	54.3	48	1.90
Wheat (all varieties)	58.6	60	2.57
Rye	54.0	56	2.20
Potatoes	15.6	60	0.69

It should be emphasized that the yield of alcohol from hard high protein wheat is less than that from soft, low-protein, high-starch wheat.

The cost of converting cereal grains into alcohol is greater than that for black strap molasses. The carbohydrate of molasses is sugar and can be fermented directly with yeast, whereas starchy materials must first be treated with an enzyme (such as diastase which is present in malt), or with dilute acids to convert the starch into sugar before fermentation with yeast can occur. The federal publication "Industrial Alcohol" states, "The operating (conversion) cost for producing alcohol from corn in manufacturing plants of similar capacity is estimated to be between 7.5 and 13.0 cents per gallon, exclusive of malt cost which runs from 2 and 5 cents per gallon of alcohol produced. With corn at 45 cents per bushel (pre-war price for usual distilling grade) and malt at $1.00 per bushel and allowing 12 cents per bushel for the value of the by-product, and with an estimated yield of 2.50 gallons of 95 per cent alcohol per bushel, and use of 8 per cent malt, the operating and raw material costs of alcohol from corn are estimated at approximately 30 cents per gallon. These costs do not include sales expense or freight, cost of denaturing, or the cost of distribution. Profits to the producer and retailer must be added to these costs to determine the price per gallon to the consumer. These are merely typical figures and will vary with conditions. It should be emphasized that there is no such thing as a fixed "alcohol cost," for it will vary between plants, and even from day to day in the same plant.

[3]From "Motor Fuels from Farm Products," by P. B. Jacobs and H. P. Newton. U. S. D. A. Misc. Pub. No. 327, 1938.

For operation computations based on corn, the Northern Regional Laboratory[4] has suggested the following figures as being probably representative under normal plant construction costs and operating conditions.

Basis 10,000 wine gallons of 95 per cent alcohol per day, from corn, 300-day year, assumed plant cost $750,000, complete recovery of distillers' grain, but no fusel oil, corn oil, or carbon dioxide recovery.

	Cents per Wine Gallon
Interest, depreciation, taxes, surety bonds, insurance, etc.	3.8
Office salaries, supervision, and control	1.0
Labor, maintenance, and by-product recovery	3.1
Water, power, chemicals, supplies, office expense	5.1
	13.0
Malt 8 per cent (at $1 per 34-lb. bushel)	5.6
Total conversion cost	18.6
By-product credit (6.4 lb./gal.)	6.0
Total cost, except corn (Bulk alcohol in tanks at plant, no profit or sales costs included)	12.6

Cost of corn in cents per bushel divided by 2.5, to be added to above conversion figure, to obtain probable entire cost.

The following table[5] shows the approximate price for normal times at which corn, wheat and potatoes and other crops would have to be made available if they are to compete with black strap molasses at 5 cents per gallon for alcohol production.

Estimated Relative Cost of Alcohol from Certain Farm Crops in Comparison with Waste Molasses

(Basis, 100 wine gallons of 95-per cent alcohol produced)

Raw material	Amount required (units)	Price per unit (delivered)	Raw material cost	Assumed processing cost[1]	Total cost	Estimated credit for by-products[2]	Net cost of 100 gals. alcohol[3]
			Dollars				
Molasses (black strap)	250.0 gal.	0.05 gal.	12.50	6.00	18.50	0.50	18.00
Apples	7.0 tons	5.00 ton	35.00	9.50	44.50	5.00	39.50
Corn	40.0 bu.	.40 bu.	16.00	18.00	34.00	6.50	27.50
Grain sorghum	45.0 bu.	.35 bu.	15.75	18.00	33.75	4.50	29.25
Potatoes	145.0 bu.	.10 bu.	14.50	13.00	27.50	1.50	26.00
Sweet potatoes	100.0 bu.	.15 bu.	15.00	12.00	27.00	1.50	25.50
Sugar beets	4.52 tons	5.00 ton	22.60	9.00	31.60	3.60	28.00
Wheat (soft)	40.0 bu.	.70 bu.	28.00	18.00	46.00	6.10	39.90

[1]These costs represent the summation of a great many variables, and will differ for each plant. Malt costs are included for starchy materials, but profit is omitted.
[2]Fusel oil and by-product feed (distillers dried grains) only. The feed values will vary with changes in cost of the original raw materials.
[3]These figures are the net resultant of many variables, and must be considered as being tentative. However, the figures shown probably reflect the relative order of cost for the raw materials and prices used. In order to produce alcohol from farm crops at a cost equal to that of molasses alcohol, the prices paid for the various raw materials must be correspondingly reduced, unless processing costs are cut or by-product values are increased.

[4]Private communication (Nov. 9, 1944) from the Northern Regional Laboratory, Peoria, Illinois.
[5]Privately communicated by P. B. Jacobs at the Northern Regional Research Laboratory on December 19, 1944. This is a revision of a similar table which was included in "Industrial Alcohol," by W. W. Skinner (revised by P. B. Jacobs). U. S. D. A. mimeographed publication AIC-3, NM-235, March, 1943.

The estimates in this table are based on the relative carbohydrate content of the various raw materials plus an estimated conversion cost and an estimated credit allowance for by-products. Despite the low prices at which the farm crops are computed, the respective net alcohol costs are greater than that for alcohol made from molasses. Five cents per gallon of molasses is considered a fair price upon which to compare costs although the pre-war price has been as low as 3 cents and as high as 8 cents a gallon.

The large amount of alcohol produced from grain has stimulated research directed towards the development of more economical methods of processing. The greatest potential saving is in the cost of the saccharification step. The malt required for the conversion of the starch represents a cost of 4 to 5 cents per gallon.[6] Experiments have been conducted with green malt, moldy bran, and with acid saccharification. Another method which has been studied for reducing the saccharification costs is the so-called Balls-Tucker process. In this process part of the protein and the diastase enzymes present in granular wheat flour are removed by agitation with sodium sulfite solution and the diastase used to replace part of the malt required to convert the starch. It is understood that extensive pilot plant and commercial tests which have been conducted with this process have not been encouraging. The employment of a recently introduced continuous process in place of the regular batch process for cooking, saccharification and fermentation represents a possible saving of 1 to 2 cents per gallon.[6] Although technological advances may lower the conversion costs of starchy materials to alcohol, the possible savings are limited.

Alcohol from wood and waste sulfite liquor. Because of the large supply of wood available in some parts of the state, attention might be called to the fact that this is another possible raw material in the manufacture of alcohol. The process (modified Scholler process of German origin) involves chemical treatment of wood waste to convert cellulosic materials into fermentable sugar out of which alcohol may be made. Soft woods (i.e., conifers and particularly Douglas fir) are said to yield about 52 gallons of 95% alcohol per ton of dry wood. Saw dust and other soft wood wastes apparently are the most likely form of wood

[6]Private communication (Nov. 18, 1944) from Northern Regional Laboratory, Peoria, Illinois.

raw material. The War Production Board has allowed only one plant to be built. In June, 1944, permission was granted the Willamette Valley Wood Chemical Company at Eugene, Oregon, to construct a plant costing $2,247,000 with a rated capacity of 4.1 million gallons of alcohol per year. Employing Douglas fir wood at $2.00 per ton, it is estimated that the alcohol (95%) will cost 30 cents per gallon. This estimate is undoubtedly low. The cost of any alcohol produced in Minnesota would be much higher because the yield from local soft woods is lower, the supply of waste inadequate and the disposition of waste products more difficult. The sale of the latter keeps the manufacturing costs down. The Pacific Northwest appears to be the logical location for production of alcohol from wood wastes.

Alcohol may also be produced from the waste liquor which results from the pulping of wood by the sulfite process. The liquor contains from 2 to 3.5 per cent of sugars which are produced from the cellulose and hemicellulose of the wood by the sulfite treatment. About 65 per cent of the sugar content is fermentable to alcohol so that the alcohol yield is approximately 1 per cent of the volume of liquor fermented. Special technological problems are encountered in the production of alcohol from sulfite liquor and up to the present this vast potential source has not been utilized in the United States.

Butylene Glycol from Grain in Comparison with Alcohol as a Source of Butadiene[7]

Butadiene may also be derived from butylene glycol which can be made by the fermentation of starchy materials such as corn and wheat by certain bacteria. Intensive research is being conducted on problems involved in the production of butadiene from butylene glycol because of the likelihood that the yield of butadiene per bushel of corn or wheat would be higher if manufactured by way of butylene glycol than by way of alcohol. Pilot plant experiments at the Northern Regional Laboratory have yielded 14.5 pounds of butylene glycol per bushel of corn or wheat. The method developed for recovering the butylene glycol from the fermented liquors and its conversion to butadiene gave an over-all yield of 7.05 pounds of butadiene per bushel of grain.

[7]The information given in this section was taken from a private communication (November 18, 1944) from the Northern Regional Laboratory, Peoria, Illinois.

In the production of butadiene from alcohol by the process of the Carbide and Carbon Chemicals Corporation employed in the government-owned plants the reported yield is 2.25 pounds of butadiene per gallon of alcohol, which is equivalent to 5.75 pounds of butadiene per bushel of corn (assuming the usual yield of 2.5 gallons of alcohol per bushel).

Another process for making butadiene from alcohol, known as the aldol process has been developed through the pilot plant stage by the Celanese Corporation of America. Yields as high as 3.0 pounds of butadiene per gallon of alcohol (equivalent to 7.5 pounds of butadiene per bushel of corn) have been reported.

Estimates of the cost of producing butadiene by these three processes with corn at 85 cents per bushel are as follows:

	Cost per Pound Cents
From butylene glycol	18.5
From alcohol by Carbide and Chemicals Corporation process	21.0
From alcohol by the aldol process	17.0

Comparative Costs of Butadiene from Alcohol and from Petroleum Products[8]

The present cost of 95% alcohol is approximately 90 cents per gallon which yields 2.25 pounds of butadiene with a conversion cost of 2 cents per pound. The present cost of butadiene from alcohol is therefore about 40 cents per pound. As the conversion charge is low, the cost of butadiene from alcohol is very closely related to the cost of the alcohol. Estimates of the postwar cost of industrial alcohol vary from as low as 12 cents to as high as 20 cents per gallon but assuming the somewhat optimistic price of 15 cents per gallon the direct cost of the butadiene would be about 8¾ cents per pound.

Butylene is the principal petroleum product which is used for the production of butadiene. Currently, butylenes range in price from about 8 to 12 cents per gallon with a yield of 60 to 75% of butadiene. The approximate cost of butadiene is 7.6 cents per pound with a yield of 65% and an average price of 9.5 cents per gallon for butylene. It is estimated that in the postwar era it should be possible to produce butadiene from butylene for as low as 6.4 cents per pound.

[8]The material in this section has been prepared from information given in the Special Report of Office of Rubber Director on the Synthetic Rubber Program, dated August 31, 1944.

The economics of butadiene production are summarized in the Special Report of the Office of the Rubber Director dated August 31, 1944, as follows:

> "To summarize, at the present time butadiene from alcohol costs approximately five times as much as butadiene from the low cost butylene dehydrogenation. The cost of butadiene from alcohol will continue to be high as long as the price of alcohol is based largely on the cost of grain. If, in the postwar period, sufficient alcohol can be obtained synthetically from petroleum or from molasses or other low cost agricultural products, this cost differential will close rapidly and the two processes would be competitive, if the prices of alcohol and butylene were approximately 9½c and 6c per gallon, respectively, or 15c and 13½c, respectively. These prices of alcohol are somewhat less than are generally estimated for the postwar market and on the basis of the present calculations it appears that the butylene and butane dehydrogenation plants will be the low cost butadiene producers. However, an improvement in the Carbide and Carbon process resulting in a higher yield of butadiene from a given quantity of alcohol or recovery of certain by-products which at the present time are credited at fuel value would make the picture for alcohol butadiene more favorable. In addition, there may be a certain geographical advantage to the alcohol butadiene plants relative to the location of the petroleum butadiene plants in that they are more closely situated to the rubber consuming centers of the country."

Minnesota Farm Products Suitable for Alcohol Production

Considerable controversy developed earlier in the program over the relative reliance which should be placed upon farm products versus petroleum products in the manufacture of butadiene. The surplus situation which has troubled farm markets until relatively recently led some to see in the synthetic rubber program opportunities for expanding agricultural markets and to demand that farm products be used for this purpose. Growing food shortage, however, has changed the picture very decidedly in recent months.

The farm products, important in Minnesota, from which alcohol can be made are listed below with the average annual production and estimated sales for 1931-42.

Products	Production Bushels	Estimated Sales Bushels
Corn	109,665,000	24,333,000
Oats	136,924,000	22,667,000
Barley	44,825,000	17,736,000
Wheat	23,522,000	16,458,000
Rye	5,958,000	3,941,000
Potatoes	22,154,000	11,899,000

It is to be noted that Minnesota's crop production is primarily for use on the farm rather than for sale as grain. The major source of cash farm income in this state is livestock. In view of this, the gains to the state as a whole from expanding markets for cash grain may tend to be exaggerated.

The average farm price of corn in Minnesota for the years 1931-42 was about 51.4 cents. (Figures for 1943 and 1944 are not included because they are affected by war conditions and, therefore, less representative of the usual situation.) For the years 1938-42, it averaged 55 cents. The average farm price of hogs for 1931-42 was $7.04 and for 1938-42 it was $8.22. Using a ratio of 13 bushels of corn for 100 pounds of hogs gives figures of 54 and 63 cents as the approximate return for corn fed to hogs for these periods. These prices are at the farm. Were a farmer to sell corn for alcohol purposes, allowance would have to be made for costs of handling and delivery. The comparison in a previous section of this report indicates that black strap molasses has considerable advantage over corn in the manufacture of alcohol.

Postwar Prospects and Considerations

When war broke out there was a surplus of various farm products in this country. Stocks of some commodities had been built up as part of a program of maintaining prices. War demands changed the situation from one of surplus in feed grains permitting expansion in livestock to one of limited supply calling for downward revision in hog numbers and less feeding of beef cattle. Stocks of wheat were drawn upon to supply feed for livestock and for industrial uses. Unusually large wheat and corn crops in 1944 are again easing the supply situation.

Whether or not farmers will be confronted with surpluses after the war depends upon how well markets hold up. This, in turn, will depend in the case of exports upon the trade policies of this and other countries. The condition of the domestic market will depend mainly upon the condition of nonagricultural employment and activity. Policies favorable to international trade and reasonably full employment at productive work will be the best assurance to farmers of satisfactory outlets for farm products and employment opportunities for farm people.

Victory over Japan will again make available to this country the areas on which we formerly relied for natural rubber. Some forecasts have suggested that the enemy will practice a "scorched earth" policy which will result in wholesale destruction of rubber plantations. While this should not be ruled out as being impossible, it is doubtful whether an enemy in flight will have available the time or facilities to carry out such a program effectively in the case of rubber plantations. The prospects are that considerable supplies of natural rubber may be available soon after the Japanese are driven from rubber-producing areas. If these should not materialize we will have the synthetic rubbers to fall back on until the natural product is restored.

Strong arguments for protection of synthetic rubber no doubt will be advanced when imports of natural rubber again will be available in sizeable amounts. Decision on this matter needs to rest on more than the consideration of the special interests of the synthetic rubber industry. Due weight should be given to the consumers of rubber goods, among which farmers are important. Moreover, this country cannot overlook the dependence of natural rubber producing areas upon the United States as a market and its responsibilities for the establishment and maintenance of peace.

This is mentioned here to suggest that the problem of deciding the relative roles of natural and synthetic rubber after the war is over is many-sided. The assumption that synthetic will replace natural rubber in the future is not a proper basis for postwar planning at this time. Synthetics may be better for some uses and find a place for themselves to that extent. Improvements in technology might be such that synthetic eventually can compete on equal terms with natural rubber, both as to characteristics and costs. If so, their position will be assured. Otherwise, we are likely to look to natural rubber to meet most of our needs.

The raw materials used in synthetic rubbers of the future, to the extent continued production is found advantageous, should be determined by long-run cost considerations and availability rather than on the basis of temporary surpluses of farm or other commodities. Other uses for Minnesota farm products normally are likely to provide better returns than appear probable at present in any extensive production of industrial alcohol unless such use were heavily subsidized. These conclusions are supported by the Special Report of August 31, 1944, issued by the Rubber Director, to which extended reference has been made. It thus appears that synthetic rubber manufacture is apt to offer very limited outlets for surplus products from Minnesota farms.

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