REPORT OF THE CHIEF OF THE BUREAU OF AGRICULTURAL CHEMISTRY AND ENGINEERING, 1939

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF AGRICULTURAL CHEMISTRY AND ENGINEERING,
Washington, D. C., October 19, 1939.

Hon. HENRY A. WALLACE,
Secretary of Agriculture.

DEAR MR. SECRETARY: I present herewith the report of the Bureau of Agricultural Chemistry and Engineering for the fiscal year ended June 30, 1939.

Sincerely yours,

HENRY G. KNIGHT, *Chief.*

CONTENTS

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INTRODUCTION

This is the first annual report of the new Bureau of Agricultural Chemistry and Engineering. Previous reports on most of the lines of work mentioned herein were issued by the Bureau of Chemistry and Soils and the Bureau of Agricultural Engineering. In the reorganization of the Department of Agriculture which was effected early in the fiscal year 1939 the agricultural chemical research formerly carried on by the Bureau of Chemistry and Soils was combined with the agricultural engineering research formerly carried on by the Bureau of Agricultural Engineering. These two lines of research were placed under unified administration in the new Bureau of Agricultural Chemistry and Engineering, the purpose being to integrate these closely related activities in agricultural technology.

The consolidation also involved the transfer of work on soils, irrigation, and drainage to other Bureaus. The work relating to soils, formerly carried on in the Bureau of Chemistry and Soils by the Soil Survey Division, the Soil Chemistry and Physics Research Division, and the unit conducting research relative to plant mineral constituents derived from soils, was transferred to the Bureau of Plant Industry. That part of the work of the Divisions of Irrigation and Drainage in the former Bureau of Agricultural Engineering which relates to investigations, experiments, and demonstrations in connection with crop production on irrigable lands, the quality of irrigation water and its use by crops, and methods for improving and maintaining the productivity of irrigated soils, was transferred to the Bureau of Plant Industry. The remaining work of these divisions, which relates to investigations, experiments, and demonstrations in connection with the construction and hydrologic phases of farm irrigation and land drainage, was transferred to the Soil Conservation Service.

At the time the Bureau of Agricultural Chemistry and Engineering was created, it was authorized and directed to administer and operate the four regional research laboratories, established by the Department pursuant to the provisions of subsections (a) to (e), inclusive, of section 202 of the Agricultural Adjustment Act of 1938, for the purpose of developing new uses and wider industrial outlets for farm products and byproducts.

The organization of the Bureau of Agricultural Chemistry and Engineering consists of the offices of Chief, Associate Chief, Assistant Chief in Charge of Agricultural Engineering, Assistant Chief in Charge of Regional Research Laboratories, adviser in chemical research, business administration, information and editorial service, library, and the following research divisions and regional research laboratories: Carbohydrate Research, Fertilizer Research, Food Research, Industrial Farm Products Research, Protein and Nutrition Research, Naval Stores Research, Chemical Investigations of Allergens in Agricultural Products, Chemical Engineering Research, Mechanical Farm Equipment Research, Farm Structures Research, Farm Operating Efficiency Research, Rural Electrification Research, Mechanical Processing of Farm Products, Engineering Plans and Service, Northern Regional Research Laboratory (Peoria, Ill.), Southern Regional Research Laboratory (New Orleans, La.), Eastern Regional Research Laboratory (Wyndmoor, Pa.), and Western Regional Research Laboratory (Albany, Calif.).

The primary function of the Bureau's research is to promote agriculture by the acquisition and dissemination of scientific, technological, and engineering knowledge bearing on the following broad subjects: Production of fertilizer materials and mixtures; the improvement of farmhouses and other structures, farm mechanical equipment, farm operating efficiency, and mechanical processing of farm products; rural electrification; the prevention of farm fires and dust explosions; and the conservation and utilization of agricultural commodities and their products and byproducts.

The more important results of the work of the Bureau during the year are reported in the following pages. Further information concerning many of the subjects discussed may be obtained from the 310 publications issued by the Bureau during the year and listed at the end of this report together with a list of the 13 patents issued to members of the Bureau personnel.

FOOD RESEARCH

VEGETABLES AND VEGETABLE PRODUCTS

Research on vegetables and vegetable processing was continued in the branch laboratories in Florida, Texas, California, Oregon, and Washington, in cooperation with agricultural experiment stations and other State agencies, and with growers and packers. In addition, chemical and technological work on freezing vegetables was started, in collaboration with the Utah Agricultural Experiment Station. These investigations were concerned with the canning and manufacture of derived food products from vegetables that cannot be marketed in fresh form, the preservation of vegetables by quick freezing, the selection of the best varieties and strains of different vegetables for commercial production in particular localities for canning or freezing, methods for determining the proper stage of maturity for harvesting different vegetables, and methods for utilizing the byproducts of vegetable crops.

To insure continued growth of the frozen-foods industry, the products must be highly acceptable to consumers. Disappointment in a first purchase, or even in subsequent purchases, of frozen vegetables is likely to cause a loss of interest on the part of a prospective consumer. Not only must the vegetable be of prime quality to start with, but it must be so processed as to prevent, if possible, deteriorative changes due to enzyme action, oxidation, and drying during storage. Also, in order to prevent deterioration during storage and retard spoilage after thawing, the material must be handled in such a way as to inhibit any increase in the micro-organisms in the product, and preferably to reduce or destroy them. All vegetables are scalded or blanched with hot water or steam for a short time before freezing to inactivate enzymes.

Much experimental work was done to determine the proper temperature and time of blanching for different vegetables in order to inactivate enzymes without causing loss of flavor or other damage to the product. From these investigations it is evident that, if enzyme activity is to be used as a criterion of scalding conditions, the determinations must be placed upon a quantitative basis. Quantitative tests for catalase and phosphatase made on samples of asparagus used

in scalding experiments and the condition of the frozen product after storage indicated that these enzymes need not be completely inactivated before freezing. The action of proteolytic and lipolytic enzymes, as well as that of carboxylase, in asparagus is being investigated in relation to scalding practice and retention of quality. It is possible that the location of enzymes in the plant tissue should be considered in studies to determine what enzyme systems are responsible for deterioration in quality during storage. It was observed that the milk-clotting enzyme found in asparagus is completely inactivated after exposure for 60 seconds at 160° F., whereas catalase is still very active. It was assumed that this is due to the localization of the milk-clotting enzyme near the surface, in contrast to catalase, which is distributed throughout the tissue.

Some evidence was obtained that the off-flavors sometimes encountered in quick-frozen vegetables after storage may be due in part to changes in the proteins. Small quantities of soluble, noncoagulable nitrogenous material were found in frozen peas, decreasing gradually during the first 18 weeks of storage at 0° F. These quantities increased with higher temperatures and longer periods of blanching, indicating that more complete inactivation of proteolytic enzymes or the removal of considerably more soluble noncoagulable protein material resulted from the more drastic blanching treatments. It was observed, however, that high blanching temperatures in themselves have an adverse effect on the flavor of frozen peas.

Studies were carried out on the effect of freezing and subsequent storage on vegetables with known amounts of bacterial infection. The results may indicate desirable changes in the methods of freezing and storage. An investigation was started to determine the causes of darkening of frozen-pack vegetables, reported to take place more rapidly than in canned or fresh vegetables when the cooked products remain on the steam tables of restaurants. Since large quantities of frozen vegetables are sold to restaurants, hotels, and institutions, this darkening is an important economic factor.

Determinations were made of the microbial content of commercially frozen vegetables packed in 1938. Wide variations were found in the numbers of viable micro-organisms, not only in products from different plants, but also in different samples from the same plant. Since the number of surviving micro-organisms in frozen vegetables is affected by the length of the storage period, it would not be logical to establish "tolerances" based on cultural tests. A badly contaminated pack held in storage for a year or more might contain no more viable bacteria than well-handled produce held in freezing storage for only a few weeks. Accordingly, a direct bacteriological test for frozen-pack vegetables, similar to the Breed test for milk, one that will detect all bacteria, whether alive or dead, was investigated, with encouraging results. The chief advantage of such a test is that it would give precise information about the bacteriological content of the vegetables before freezing, thus indicating their sanitary history.

Work in cooperation with the Irrigation Branch Experiment Station at Prosser, Wash., to determine the adaptability for canning of several common vegetables grown under irrigation indicated that climatic and other conditions will probably prevent the development of an extensive vegetable-canning industry in the new irrigated areas. Peas grown

there were not suitable for canning, and green beans and tomatoes did not show satisfactory yields. Sweet corn and lima beans of satisfactory quality were produced, but the yields of the former were reduced by earworm infestation.

In cooperation with the branch of the Texas Agricultural Experiment Station (Substation 15) at Weslaco, Tex., tests were made to determine the relative value for freezing and canning of a number of varieties of different vegetables, particular attention being given to earworm-resistant varieties of sweet corn. Some of the experiments indicated that varieties of tomatoes adapted to the southern part of Texas are suitable for the manufacture of catsup, tomato sauce, and other tomato products, having excellent flavor and color.

Chemical and cooking tests of many varieties of peas and lima beans grown in various parts of California and preserved by freezing indicated that it will be necessary to select particular varieties for production in specified locations in order to obtain a frozen product with the most desirable qualities. As a result of previous work one variety of lima bean is being produced in increasing quantities for freezing preservation in southern California, the expected output for 1939 being a million pounds or more.

As a result of tests in cooperation with Washington State College and the Western Washington Experiment Station on the suitability of different varieties of vegetables for freezing preservation, lists of preferred varieties have been made up and are being distributed to prospective growers by the college and its extension service. Directions based on other experimental work were supplied to prospective growers and processors of asparagus in the Pacific Northwest. It was found that snap beans frozen in salt brine retained their bright-green color after cooking to a much greater degree than did those frozen without brine, and also had a softer texture after cooking than that of dry frozen beans.

Experiments in the utilization of overmature and crushed peas rejected by canneries indicated that such peas can be made into acceptable purees. High-protein feedstuffs were produced by drying several vegetable cannery wastes.

Much study was given to various proposed methods for determining the maturity of peas, including those based on specific gravity, proportions of different sizes, sugar content, and volume of juice that can be expressed. The first two were found to be useless; additional work remains to be done on the other two. In cooperation with the research committee of the Northwest Frozen Foods Association and a commercial canning company, several hundred samples of frozen peas for which tenderometer readings were available and representing six varieties of freezing-type peas were studied to determine the relationship between tenderometer values and the quality of the frozen and cooked products. This study revealed a very close correlation between the tenderometer values and the tenderness of the finished product. When methods of sampling have been standardized, the use of the tenderometer will have a definite and valuable place in the determination of raw grades.

The Seattle Frozen Pack Laboratory collaborated with the Northwest Frozen Food Association and the United States Bureau of Agricultural Economics in working out tentative standards for

grades of frozen peas. These standards were promulgated by the Department on May 25, 1939. Steps are now being taken toward the working out of grades for other frozen products, such as asparagus, through further cooperation with the interested parties. It is generally recognized that standards for frozen commodities are absolutely necessary for commercial success.

Continued investigations in cooperation with the North Carolina Agricultural Experiment Station on the manufacture of cucumber pickles under southern climatic conditions resulted in the production of dill pickles of good quality with respect to firmness and keeping quality. Lots of dills put up in 1-gallon cans and pasteurized at the conclusion of their fermentation in barrels were found after 10 months' storage to be firmer than unpasteurized lots. In experiments with various initial salt concentrations and rates of increase for the production of salt stock, the best results were obtained when the brine was initially 30-percent saturated and increased gradually to 70 percent in 6 weeks. With higher initial brine concentrations a larger number of hollow cucumbers or "bloaters" were obtained. Stock of somewhat inferior quality was obtained occasionally when the initial concentration was as low as 20-percent saturated. By whipping the surface of the brine at regular intervals, it was possible to control the mycoderma scum, which forms on the surface of the fermentation vats sheltered from sunlight and causes loss in brine acidity.

The gases evolved during cucumber fermentation were found by analysis to be mixtures of carbon dioxide and hydrogen. It was the first time that hydrogen had been demonstrated to be a product of cucumber fermentation. Twenty-two strains of hydrogen-producing organisms were isolated. Their activity was more pronounced in brines of higher salt content.

Work is in progress on the development of methods for the detection of organisms and products of organisms capable of softening salt stock, particularly the coordination of the plating method with the detection of enzyme activity on cucumber-stem sections, and on the determination and control of the different types of organisms that predominate in the different stages of fermentation.

CITRUS-FRUIT PRODUCTS

A number of citrus-fruit canneries in Florida have installed juice deaerators of an improved type invented by a member of the Bureau's staff. This type is more efficient than other deaerators in use and when properly operated will remove more than 90 percent of the dissolved oxygen in the juice, thus aiding in preserving the flavor and reducing the destruction of vitamins during subsequent processing and storage.

It is believed that some of the off-flavor that develops in canned orange juice during storage may be due to changes in the peel oil in the juice. This possibility is being investigated, and if peel oil in the juice is found to be responsible methods for its elimination will be developed. A method for accurately estimating the peel-oil content of citrus juices was demonstrated, and has been adopted by canners and juice graders.

Bacteriological examinations of canned citrus juices showed that, although flash pasteurization does not always yield a sterile juice,

the organisms that survive it will not multiply and cause spoilage in either orange or grapefruit juice.

Studies on orange oils produced in different localities in Florida showed that the failure of many of such oils to meet U. S. P. specifications is due to a lack of proper technical supervision, rather than to the inherent characteristics of the natural Florida oil.

In cooperation with the Florida Canners' Association and the Florida State Board of Health, studies were continued on the disposal of wastes from citrus-fruit canneries. A trickling filter was developed for promoting biological action on the wastes. This purifies them to the extent that they may be added to large bodies of water without destroying aquatic life. Work on the details of operating the process is nearly completed. Preliminary investigations at Weslaco, Tex., on the disposal of liquid waste from citrus-feed plants indicated that yeast fermentation may be an effective method of treatment. Continued existence of the cattle-feed industry utilizing solid citrus-cannery wastes will only be possible if the liquid waste can be satisfactorily disposed of. It is estimated that the production of citrus feeds, exclusive of their monetary value, results in an annual saving of about $2,000 per cannery, the cost of disposing of the wastes in other ways.

All the results of recent work on byproducts from citrus fruits have been combined in a revision of Department Circular 232, originally published in 1922.

APPLE PRODUCTS

Using methods based on the research of this Bureau, one apple growers' cooperative association in the Northwest started the commercial production of canned apple juice during the year. Blends of apple juice that are better than the juice from individual varieties were made by combining tart, sweet, and aromatic juices in desirable proportions. Modifications were made in the pectinase-enzyme clarification procedure for apple juice that helps to delay or prevent precipitation.

In a study on the availability of apple thinnings as a source of pectin, it was calculated from the weight of thinnings from selected trees that over 100,000 tons of thinnings are available each year in Washington alone. However, thinnings do not appear to be superior to present sources of pectin, such as apple pomace and citrus-fruit peel. Studies were made on the isolation of pectic substances from apples or apple pomace and the preparation of pectin derivatives. From these experiments, new ideas regarding the composition of pectin are being formulated.

Low-ash polygalacturonic acids were prepared by gentle saponification of apple pectin and treatment of the product with hydrochloric acid. A relatively cheap, simple, and practical method of making galacturonic acid by the enzymic hydrolysis of polygalacturonic acid was developed. As high as 85 percent of conversion was obtained. Improvements in the isolation and crystallization of galacturonic acid have resulted in increased yields and lower production costs. Since galacturonic acid has certain valuable therapeutic properties, the reduction in price from $2 or more to less than 10 cents per gram will permit greatly extended investigation of those properties and possibly

ultimate utilization of the acid by the medical profession. Samples have been supplied to research organizations in the hope of developing biological and pharmaceutical uses.

Studies were made on the oxidation of galacturonic acid to mucic acid in an effort to determine the possibility of using pectic substances as a source of mucic acid. Although galacturonic acid was oxidized almost quantitatively by nitric acid, its polymers, as they occur in pectic substances, were not. It appears, however, that acid hydrolysis of pectic substances prior to oxidation might make them available as a source of mucic acid.

MISCELLANEOUS FRUITS AND FRUIT PRODUCTS

As a result of cooperative work on the canning properties of new varieties of peaches and apricots developed by the Bureau of Plant Industry, several selections were recommended for trial in southern California. Commercial canners are adopting methods developed by the Pullman, Wash., laboratory for canning freestone peaches of varieties available in that section. The products have improved appearance and flavor and can be made from varieties of peaches only infrequently canned heretofore.

To provide outlets for surplus prunes in southern Idaho, methods of canning prunes of the available types and of producing prune butter and prune marmalade were developed. The products are highly acceptable and await commercial exploitation.

Continued growth of the fruit-juice industry, production of which increased from about 1 million cases in 1929 to 24 million cases in 1937, is dependent very largely on the quality of the product, which in turn rests largely on the methods employed, particularly those of pasteurization or sterilization. The ideal temperatures and times for flash pasteurization of juices from several fruits were determined at the cooperative laboratory in Geneva, N. Y. Studies were also made of ways for removing oxygen, which in the finished products causes discoloration and precipitation. Blending juices from different varieties of the same fruit and those from different fruits resulted in more palatable flavors. Such blending also makes possible the sale of mixed products from expensive and cheaper fruits at prices that will promote an expansion of sales volume.

Frozen marmalade bases were prepared from sweet and sour cherries. Pectin and part of the necessary sugar were added to some of these at the time of freezing so that by adding sugar in the amount of half the weight of the base and cooking for a short time a satisfactory marmalade may be obtained.

The pack of frozen fruit pulps in 1939 was expected to be three or four times as large as that in 1938. Frozen crushed fruits produced as toppings for sundaes are meeting with hearty approval, and commercial production is rapidly expanding both in quantity and the number of fruits treated. New types of fruit confections, based on products developed in the laboratory, are being produced commercially in California. These consist of frozen fruit pulp in bar form, coated with chocolate, and combined layers of vanilla ice cream and frozen fruit pulp. They are frozen on sticks and sold by vendors at 5 cents each. The products are of real value from a

dietetic standpoint, and in addition furnish an outlet for large quantities of fruit that cannot be sold in fresh form.

Experiments to determine the relative value of different varieties and strains of fruits for quick freezing, in cooperation with the Irrigation Branch Experiment Station of Washington, resulted in the selection of certain varieties for further experimentation, with the view of commercial production. Frozen products were prepared from strawberries, raspberries, blackberries, Logan blackberries, apricots, plums, and peaches for use as desserts, sundae toppings, and fruit-flavor bases. Many of the products were highly satisfactory, although all plums tested showed the characteristic skin toughness and bitterness that is yet an unsolved problem of frozen-pack plums.

An unsuccessful attempt was made to develop a method based on the use of X-rays and a fluorograph for detecting the abnormal tissue in so-called chalky or hard-end Bartlett pears in sorting pears intended for canning.

CEREALS AND SEED PRODUCTS

BAKING INVESTIGATIONS

Appetizing and nutritious cookies were made from mixtures of whole wheat, peanut, and soybean flours in various proportions. Such cookies contain less starch and considerably more good-quality protein, minerals, and vitamins than do ordinary cookies. For this reason they are a better balanced food product and should prove especially desirable to that large portion of the population whose diet is for the most part deficient in protein, minerals, and vitamins.

The best temperature for long-time storage of compressed yeast was found to be 30° F. At lower and higher temperatures the yeast did not keep so well. Packing yeast in solid carbon dioxide previous to storage was found to result in subsequent deterioration.

Irradiation of wheat flour with ultraviolet light for as long as 16 hours had an adverse effect on the quality of gluten and the baking quality of the flour.

It was found that the addition of a water extract (of several hours' standing) of wheat germ to flour resulted in marked improvement in the quality of bread. Such an extract was high in diastatic power. The bread produced with the germ extract was better than that obtained when the wheat germ as such was used.

STALING OF BREAD

Studies on the staling of bakery products indicated that staling of bread is directly connected with the exchange of moisture between crumb and crust. When freshly baked bread is placed in a cabinet maintained at constant temperature and at such degree of humidity that the entire loaf neither gains nor loses in weight, the crumb, with an original moisture content of about 45 percent, loses nearly 10 percent of its moisture in 3 days, while the moisture content of the crust, originally about 20 percent, increases to about 30 percent. Addition of a small quantity of sweetpotato flour (8 to 10 percent) to wheat flour produces bread of better keeping quality than that of bread from wheat flour alone. The use of canned orange juice in bread

making (up to 5 percent of the weight of the flour) also produces bread which stales less quickly than does ordinary bread.

RANCIDITY OF VEGETABLE OILS

Studies on the effects of light transmitted by various light filters on the development of rancidity in oils yielded further evidence that the light energy of the ultraviolet, violet, and blue spectral regions, rather than light intensity alone, promotes rancidity. The speed of the photochemical reaction that induces rancidity increases with the light intensity of this particular region. A sextant red filter, which transmits many times the total energy transmitted by sextant green, inhibits the development of rancidity apparently as well as does the green filter because the sextant red transmits no energy in the ultraviolet, violet, and blue regions.

A physicochemical test has been developed for following the autoxidation of an oil or fat. This eliminates the personal equation characteristic of organoleptic tests. This test indicates the progressive changes that take place from the beginning of oxidation up to and beyond the point where rancidity is recognized by taste or smell. In this test a quantity of the oil under observation is added gradually to a definite amount of magnesium chlorophyll until the mixture when observed under an ultraviolet lamp equipped for fluorescence studies shows that the red fluorescence is quenched. The quantity of oil added is called the chlorophyll value. The greater the quantity of oil required to quench the red flourescence, the higher is the chlorophyll value and the nearer rancidity. Work is being done to establish, if possible, the chlorophyll value that corresponds with organoleptic rancidity.

COMPOSITION OF WILD RICE

In collaboration with the Bureau of Plant Industry, the composition of wild rice was studied. This study was conducted as a project under the Bankhead-Jones Act of June 29, 1935, providing for basic research in agriculture. It is said that many thousands of Indians in the North Central States are dependent in part for a living on gathering and trafficking in wild rice, for which special dietary qualities are claimed. Parched wild rice forms an important part of the diet of these Indians, and this product is becoming popular even in localities far distant from the places of origin. Data regarding the composition and food value of wild rice were needed to determine the merits of a proposed program for improving this commodity through breeding, selection, and cultural methods.

The average results of analyses on hull-free samples of wild rice gathered from about a dozen localities in Minnesota were as follows, expressed in percent on a water-free basis: Ether extract (fat), 0.93; crude fiber, 1.22; ash, 1.72; protein, 16.30; sugar, 2.14; nitrogen-free extract, 77.69. Thus, wild rice grown in Minnesota is richer in protein than are the common cereals. In mineral and sugar content it resembles wheat. Wild rice has about the same amount of fiber and fat as so-called brown rice. The average results of analyses on corresponding samples after parching showed a decided loss in the sugar content and appreciable losses in ash, crude fiber, fat, and protein contents. Parched rice from which little or no bran was removed in the process

of removing the hulls was higher in protein, minerals, and vitamin B than the samples from which much of the bran was removed. Hence, the former has appreciably greater food value than the latter. This fact may be of significance in cases where wild rice forms a large portion of the diet. Parching, in a sense a roasting process, is a necessary step preliminary to the removal of the hulls, and it adds flavor to the product.

EGGS AND EGG PRODUCTS

The method recently developed by the Bureau for checking the accuracy of egg-grading practices by measuring the surface of broken-out egg white with special apparatus has been applied commercially. It was found that, because of shaking, eggs lose candling grade when subjected to frequent candling, although the true quality remains unchanged. Furthermore, when seller and buyer have eggs candled before and after delivery, the buyer may find his eggs of lower grade than he expected, although the candling was correctly done in both instances. Ignorance of this fact must have led to many disputes. If the eggs are allowed to rest after handling, the effect of the shaking on the position of the yolk gradually disappears, but this may take a week or more.

A quick method was developed for estimating the quantity of oil in the shells of oiled eggs. This is suitable for commercial use in determining whether or not the oiling is being done properly. A study of the protein responsible for the gel structure of egg white brought out interesting facts concerning ovomucin, some of which may be connected with the natural deterioration of shell eggs. This study is not yet completed.

Experiments were started to determine the relative keeping qualities of frozen eggs produced at different seasons. These were suggested by the knowledge that egg whites contain a substance called lysozyme, which is capable of dissolving certain types of bacteria and which, from previous work, appeared to vary in quality or activity at different seasons of the year. Further work is needed to demonstrate the effects of freezing and freezing storage on the activity of lysozyme in eggs, particularly its specificity for the types of organisms that cause food spoilage and food poisoning.

ENZYME INVESTIGATIONS

Further studies were made on the proteinase of wheat. The crude enzyme separated from bran was purified and concentrated about eightfold by a combination of protein precipitations and adsorption on alumina. The reactions of the purified enzyme corresponded to those characteristic of papainases, and thus the enzyme appears to have been definitely identified. However, in view of the objection raised outside the Department that the enzyme from whole wheat might not be responsible for the behavior of white flour and, therefore, that the simple explanation of the action of oxidative bread improvers might not hold, an investigation was made of the enzyme in white flour. By means of salt extractions a surprisingly large quantity of enzyme was separated from patent flour. After the enzyme was slightly purified, it was tested and found to have the same essential character as that separated from bran. No differ-

ences have been noted thus far. Both bran and flour proteinase preparations are stable in salt solutions but not very stable in water.

A study of the proteinase of lima beans was completed, and the results were published.

It was hoped to observe the enzyme activity in flour made from dead wheat, but attempts to kill wheat by exposure to oxygen and carbon dioxide were not successful. The question is important because dead wheat does not make good flour, and if wheat is stored a long time, a certain amount of loss from death must be reckoned with unless the factor connected with the loss of baking quality can be supplied artificially. For similar reasons the enzymic behavior of pulverized patent flour was studied. It was found, however, that powdering the flour does not affect the proteolytic enzyme particularly, so that the loss in baking quality always shown by pulverized flour appears to be due to a change in the proteins rather than to a specific loss of proteolytic enzyme.

In the study of cereals and other seeds, it was noted that only wheat, rye, barley, and soybeans contain appreciable quantities of free amylase (set free in water) and of total amylase (set free in the presence of papain). Oats, rice, corn, sorghum grain, buckwheat, and cowpeas contain relatively small quantities of this enzyme. The amylase of wheat is set free not only by papain but also by lactic acid, sodium chloride, yeast, and bacteria. The liberation of amylase of barley was inhibited by lactic acid and yeast, but was not affected by sodium chloride. Rye amylase was not affected by lactic acid, sodium chloride, yeast, or bacterial activity. Ordinary white flour was found to be about as rich as whole wheat in total amylase, but it was much poorer than whole wheat in free amylase, probably owing to the fact that the papainlike substances naturally present in wheat are more concentrated in the germ and bran. It was found also that in doughs prepared from ordinary white flour by a standard procedure the free amylase content is practically equal to the total amylase content of the flour and that both the yeast and the common salt in the quantities used for baking bread have the power of liberating the amylase present.

While the role of seed amylase in human nutrition is not yet known, it seems significant that since ancient times the human race has selected for bread and breadlike purposes the three seeds—wheat, rye, and barley—that are comparatively rich in amylase.

The work on papain, which enzyme was previously prepared by the Bureau in crystalline form, contributed much toward the solution of other enzyme problems, particularly those relating to proteolytic enzymes in wheat, lima beans, and muscle. As a result of collaborative work with the Hawaiian Agricultural Experiment Station, papain was prepared that is better than any on the market. In ordinary commercial preparations, at least half the enzyme activity is lost. Preparations made experimentally in the laboratory are about one-third stronger, but it is still uncertain how long they will keep.

Studies of enzyme action at low temperatures were continued as a project under the Bankhead-Jones Act. It was found that the protein-splitting enzyme in beef works slowly but quite definitely on the meat proteins in cold storage. When the quantity of this enzyme normally present in meat was increased by introducing some of the

isolated enzyme, marked digestion occurred, but the action was slowed down greatly at low temperatures. The advisability of using colder warehouses for meat storage is thus apparent. The ester-splitting enzyme in muscle, mentioned in last year's report, was studied in more detail in beef tissue. It was finally prepared in solution, free from all organized tissue, by extraction of washed muscle with either alkali or digitonin. It does not attack unsaturated higher fats, but confines its action exclusively to lower fats and esters of lower fat acids. The enzyme is to be regarded as a typical esterase rather than a lipase, as shown by an investigation of lipase from the pancreas. It does not appear to be of very great significance in the deterioration of meat, but may play an important part in the decomposition of butter, the fat of which is very susceptible to attack by this ferment. Its function in muscle is probably metabolic, rather than catabolic. Discovery of the fact that a synthetic ester, benzyl butyrate, is split by this enzyme with greater rapidity than are the natural esters has permitted a more rapid and delicate test to be made. Since the butyric acid may be removed by distillation, the presence of nonvolatile fat acids in the tissue does not complicate the result.

Considerations of the thermodynamics of the action of enzymes at low temperatures led to the conclusion that although the reactions become slower as the temperature is decreased, the relative ease of decomposition by enzymes is greater than that of other chemical reactions and that caused by micro-organisms. Unfortunately, since enzymes are integral parts of the original product, there is no way of removing them without destroying the commodity.

PHYTOCHEMICAL INVESTIGATIONS

Fundamental research was continued on the composition and properties of naturally occurring fat acid glycerides. In this investigation molecular distillation methods and equipment were used for isolating the compounds without alteration or decomposition. Very few oils and fats have been exhaustively examined with respect to their various components as they actually exist in the plant. More definite knowledge as to the identity and composition of the various glycerides of oils and fats in their natural condition should prove useful in solving problems relating to the breeding of oil-producing plants, the deterioration in storage of oils and fats and foods containing them, and the digestion and assimilation of oils and fats by animals.

Equipment for cyclic molecular distillation was installed and used in preliminary purification work. Cottonseed oil of Prime Summer Yellow grade was distilled, with indications of appreciable fractionation. Successive fractions, consisting essentially of the glycerides of the oil, showed a steady increase in iodine number from 96.5 to 120.8 and in refractive index from 1.4632 to 1.4661. The yellow color showed a definite tendency to concentrate in the early fractions, the later ones being almost colorless, while the undistilled residue had considerable color of a dirty-greenish cast.

A study of α and β linoleic acids and of their bromination and alkaline permanganate oxidation products led to the conclusion that α, β, and natural linoleic acids are identical and have but one geometrical configuration.

Work was continued on the preparation and study of pure unsaturated fat acids and their glycerides, especially oleic and β linoleic acids, triolein and trilinolein. These compounds are needed in future work involving more detailed molecular distillation studies. Highly purified methyl oleate was prepared successfully. Syntheses of triolein and trilinolein were carried out by esterifying the corresponding fat acids and glycerine in an atmosphere of nitrogen and using paratoluenesulfonic acid as a catalyst. The products were partly purified by low-temperature crystallization from acetone. Final purification was accomplished in the Hickman cyclic molecular still without any evidence of polymerization or decomposition. Triolein prepared in this manner yielded a theoretical iodine number. Work is in progress on the preparation of pure glycerides in quantities sufficient for further study.

The flavor of Montmorency cherry juice was found to be due mainly to benzaldehyde, with a trace of geraniol. One-third of an ounce of a mixture of about 35 percent of methyl alcohol and 65 percent of ethyl alcohol was separated from 25 gallons of the cherry juice. The nonvolatile acids consist chiefly of malic acid with a very small amount of citric acid. A study of the flavoring constituents of red raspberries is in progress.

At the request of the Hillculture Division of the Soil Conservation Service one gum-bearing and eight saponin-bearing plants were examined with the object of determining their commercial possibilities.

PHARMACOLOGICAL INVESTIGATIONS

The last four of a series of eight papers reporting the results of studies on phenothiazine, the insecticidal material found to have therapeutic value as a urinary antiseptic, were published during the year. The widespread interest in this side-line investigation on phenothiazine was indicated by the large number of requests for information and reprints received from physicians. Experiments were started, in cooperation with Stanford University School of Medicine, to determine the possible value of phenothiazine and its oxidation product, thionol, for the treatment of trichinosis. Upon investigating the cause of dermatitis or sunburn suffered by a number of orchard workers after applying phenothiazine as an insecticidal spray, it was found that although phenothiazine applied to the skin protects the underlying tissues from sunburn, the compound taken internally sensitizes the body to the action of ultraviolet light, so that what would ordinarily be a minor burn becomes one of greater magnitude. The sensitization of the orchard workers probably resulted from inhaling some of the spray.

In further studies on the chronic toxicity of cadmium, it was observed that the incisor teeth of rats eating the cadmium-containing diets were white instead of the usual brown. Since fluorine bleaches rat incisors and was present in subminimal amounts in the food given to the rats, the question arose as to whether the cadmium itself produced the bleaching or whether it promoted the action of fluorine. This question has not been answered definitely, but it appears that the cadmium itself causes bleaching and that the actions of cadmium and fluorine are additive. The fact that cadmium acts similarly to fluorine in this respect suggests the possibility that other substances

may do the same. The question is important in studies of fluorine toxicosis by examination of teeth in areas of endemic mottled enamel. During the study on the mechanism of cadmium-bleaching of incisors, it was found that thyroid administration very markedly increased the degree of fluorine bleaching. It is important, therefore, to determine whether in areas of endemic mottled enamel hyperthyroid individuals are the most affected. If so, it has an important bearing on tolerance limits for fluorine insecticides on food products and raises the question of whether the public health should be protected by tolerance limits aimed to protect the hypothyroid, hyperthyroid, or normal individual.

Preparatory to determining the distribution of antimony in the various organs of the rats fed on antimony-containing diets, a colorimetric method suitable for the determination of very small quantities of antimony in the absence of sulfates was developed. This method must still be tested for its applicability to the analysis of tissue digests. A study is in progress on the effect of continued ingestion of antimony-containing diets on fertility and reproduction in rats.

Investigations were started on the pharmacological effects of organic compounds proposed for use as insecticides, including 2-acetaminofluorene, pentaerythrityl bromide, azobenzene, and dimethylacridan. It was found that all these compounds are capable of inhibiting growth and that azobenzene and dimethylacridan produce blood injury, but further work is necessary to establish the critical dosage level for each of these substances.

PLANT VIRUSES

In cooperation with the Bureau of Plant Industry chemical studies were continued on tobacco-mosaic virus as a basic research project under the Bankhead-Jones Act. The problems were approached on the assumption that this virus is a complex dissociable nucleoprotein. By using a method of measuring the quantity of virus protein in the tissues of the plant, based on the previous finding that proteolytic enzymes do not digest this virus, it was possible to correlate the disease with the production of abnormal protein and to observe the variation between ordinary and relatively immune plants. The rate of production of virus protein was found to be more rapid initially than was previously supposed. Virus protein was not produced entirely, if at all, at the expense of previously synthesized normal protein. The quantity was highest in growing tissues, and decreased in amount as the infected plant grew old, with almost complete disappearance in more resistant plants. The results of the experiments provide a foundation for the investigation of any connection that may exist between metabolic processes and the elaboration of abnormal protein in susceptible plants.

The virus protein was found to dissociate under the influence of urea and similar substances, thereby becoming digestible by proteolytic enzymes. Reassociation occurred, however, on removal of the reagent. Ultraviolet light did not affect the digestibility, but destroyed the activity of the protein as a virus. Digestibility and virus activity, therefore, are not related.

The size of the particles of two strains of tobacco-mosaic virus were of the same order of magnitude, as shown by the results of

sedimentation experiments in the ultracentrifuge. Dielectric measurements showed that these particles behave electrically like colloidal aggregates rather than free molecules.

ANIMAL VIRUSES

Chemical studies on animal viruses and the proteins of tumors were started during the year as a basic research project under the Bankhead-Jones Act, the object being to study one or more of the tumor-producing agents on the hypothesis that they are susceptible to straight chemical investigation. Soluble preparations of rabbit myxoma of great potency were made from the tumors, and the investigation of these preparations is now under way. Because of the great complexity of the system and the long time required for each test, the results obtained so far are insufficient for publication.

PRESERVING BIOLOGICAL SPECIMENS

The investigation of processes for preserving botanical and entomological specimens in as nearly natural condition as possible was continued as a basic research project under the Bankhead-Jones Act. Well-preserved biological specimens are needed in scientific research, as permanent records of healthy and abnormal conditions and for exhibition or educational purposes. Improvements were made in both the interrelated processes mentioned in last year's report.

One of these processes consists essentially in chemically treating fresh plant materials to toughen the tissues and set the natural color, after which the specimens are flattened, dried, and mounted on glass or between transparent cellulose films. The technique for the preservation of the natural color of specimens has been simplified and improved so as to extend the scope of the method and increase its practicability. The use of lower temperatures during the first stage of treatment has made possible the application of the preserving process to certain fruits and thick succulent plant tissues. Other improvements have been made in the various steps of the general process, in the treating formulas, and in the types of mounting. Such improvements have permitted the preparation, with sufficient fidelity for record purposes, of many specimens, including leaves, vines, fruits, and flowers. Particular attention was given to the preservation of pathological material, and interesting results were obtained in showing as permanent records the appearance of insect pests and plant parasites and their relationship to the plant hosts.

The other process permits the specimen to be encased intact, or without distortion, in a solid, nearly colorless, and transparent plastic. Its essential features are dehydrating the specimen, mounting in prepolymerized liquid methacrylate plastic, removing the air, completing the polymerization at proper temperatures, and finally heat-treating to prevent or minimize "crazing." After machining, the mounts can be polished to a high luster. The mounted specimens, which are exceptionally pleasing in appearance because of the unusual brilliance and transparency of the plastic, may be viewed from any angle, and are light in weight and unbreakable. This method makes it possible to keep specimens indefinitely, with complete preservation of their shape, size, and natural color. The method of embedding has been improved with respect to elimination of cloudiness, formation of bubbles, and extraction of color from the specimens by the

liquid plastic. A treatment has been devised that should prevent or greatly minimize crazing.

A number of unusually valuable and rare botanical specimens have been preserved by both methods in order to retain them as permanent records in their original color and shape. These and numerous other specimens prepared by both methods have attracted considerable attention and elicited much favorable comment. However, there are a number of difficulties to be overcome before the methods can be released for general use.

WALNUTS

The method devised by the Bureau for facilitating the removal of hulls from sticktight walnuts by treatment with ethylene is in almost universal use in the inland valleys of California, where high temperatures prevail during harvest time. The quality of the walnuts, as determined by the color of the kernels, is improved and therefore the return to the grower is materially increased by the process.

CARBOHYDRATE RESEARCH

SUGARCANE AND CANE SUGAR

Analyses of raw and clarified juices from six varieties of sugarcane, and of the muds removed during clarification with lime and heat at low, medium, and high hydrogen-ion concentration, indicated that the substances principally affecting the rise in purity during clarification are phosphates and proteins, although silica and other substances are also important at times. At a given pH value the increase in purity obtained is governed by the proportions of these precipitable materials in the raw juice and is little affected by differences in the method of clarification. While ash content is generally reduced by clarification, the actual salt content increases, since the removal of silica and bases is usually more than balanced by the increase in lime. Decrease of ash is partly due to the substitution of organic acid radicals for the phosphate ions precipitated. The increase of lime in the ash of the juice after clarification appears to be related to the content of nonprotein nitrogen in the juice. The color of juices and sirups is associated not only with iron content but also with lime and nitrogen.

Low ash content was found to be a consistent characteristic of the juices from varieties C. P. 28–19 and C. P. 29–116, and low nitrogen content was characteristic of juices from varieties Co. 290 and C. P. 29–116. Variety C. P. 28–11 was high in both ash and nitrogen. It seemed probable that the comparatively high nitrogen content of the varieties Co. 281, C. P. 28–11, and C. P. 28–19 limits their production, since generally low tonnages are obtained per acre. When fertilized with nitrogen compounds these varieties increased less in tonnage and more in nitrogen content than did such varieties as Co. 290 and C. P. 29–116, which are low in nitrogen. Differences in ash content seemed to be associated more with potash and sulfate content than with variation in all constituents.

Study of the clarification of juice from cane stored under different conditions indicated an improvement when the cane dries out and a small adverse effect when the cane is kept moist.

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To evaluate a sugarcane for sugar production, the fiber and normal juice content must be considered as well as the analysis of the expressed juice. By direct determination, the fiber content of the most common commercial varieties of Louisiana cane was found to range from 10 to 16 percent. Leaving cut cane on the ground for 9 days before grinding was found to increase the fiber content by about 2 percent, based on the weight of the cane. The advantages of low-fiber cane, when accompanied by low sucrose content and low purity, as in the case of Co. 290 and C. P. 29–116, are offset by the much greater volume of water that must be evaporated for 100 pounds of sugar produced.

In cooperation with the Bureau of Plant Industry, the keeping qualities of additional new seedling varieties of sugarcane were determined. A number of seedling varieties were found to be superior in keeping qualities to some varieties being grown commercially. From the standpoint of keeping quality, Co. 281 is superior to all the other varieties in commercial production, and this is the only variety fully recommended at present for windrowing or storing.

It was found that the degree of damage sustained by cane during a freeze may be estimated by a chemical test on juice from cane that has been stored at 80° F. at high humidity for as little as 24 hours. This test will supplement physical examination of the cane and distinguish between degrees of damage that lead to fermentation and those that do not. Two types of fermentation may occur in frozen cane, depending largely on weather conditions following the freeze. One is a simple alcoholic fermentation that causes considerable loss in sucrose but no operating difficulties in the sugar factory. The other is a dextran-acid type of fermentation that causes a great deal of trouble in the factory because of the high viscosity resulting from the dextran gum. A study of the dextran and the true and apparent sucrose contents of sugar-house products from frozen cane showed the surprisingly low dextran content of 0.4 to 0.5 percent, based on solids. The true sucrose content of these products was found to be lower than the apparent sucrose, indicating that false apparent purity is partly involved in the difficulty in exhausting molasses from deteriorated juices. Results of an investigation on the micro-organisms isolated from frost-damaged sugarcane and their fermentation products when grown in culture media were published.

Sugarcane in Louisiana was subjected to rather severe freezing temperatures during 4 nights between November 25 and December 1 in the past season. From studies made on the cane following these freezes, it was evident that sugarcane chilled below 32° F. but above actual damaging temperatures (about 25° F.) keeps as well or better in the windrow than cane windrowed before the freeze. At least for 2 weeks, in most localities, the alcoholic fermentation predominated over the dextran-acid type of fermentation ordinarily experienced. As a result, at most factories operations continued without difficulties under these conditions. Except to protect the crop from further freezing damage, there is little gained in windrowing cane that has been injured to the point of fermenting. When standing cane is frozen, the top of the stalk is likely to be most seriously injured and to deteriorate most rapidly. Topping back, therefore, is a help but prevents only part of the factory difficulties in working up frozen

cane because excess acidity and gums develop in all sections of the cane.

The external wax of sugarcane was found to vary widely in quantity between different varieties and to some extent between the eastern and western sections of the Louisiana sugarcane belt. It was highest in varieties Co. 290 and C. P. 28–19, averaging about 1.5 pounds per ton of cane, and was very low in C. P. 29–116, which contained only 0.2 pound per ton. This wax has possible commercial value because of its high melting point. The content of internal fats and waxes in sugarcane was found to be relatively uniform in all varieties and locations.

In experiments to determine the possibility of producing a cheap carbon from some of the byproducts of sugar manufacture, it was found that carbon comparing very favorably with the commercial grades of activated carbon when tested on refinery melt solution could be made without the use of impregnating substances.

Hydrogen peroxide was found to be effective for reducing sulfite flavor and odor of oversulfured sirups and molasses.

BEET SUGAR

Investigation of the various factors that influence composition of sugar beets and quality of beet sugar was continued. The Bureau's annual report to the industry stressed the influence on quality of certain variations in production processes and suggested certain improvements to increase efficiency. The introduction of a technical grading formula for sugars has permitted correlation of factory data, thereby establishing the fact that optimum purity of white massecuites is probably much lower than that practiced by a number of factories. This has enabled certain factories to lower their purities and save much costly remelting, without detriment to sugar quality. It is hoped that even greater aggregate savings may accrue to a larger number of factories that had previously contemplated equipping for production of high-purity massecuites. A single, high-purity raw-sugar boiling system was designed to replace a high- and low-purity raw-sugar boiling system. Besides making possible fuel economy and improvement in sugar quality, this system lends itself to further improvements in the refining process.

A survey and study of disposal of waste water by beet-sugar plants, in relation to stream pollution, was begun, and a tentative solution to a pressing situation at one particular factory was found. The recent introduction of multiple-effect pressure evaporation into the beet-sugar factory indicates the possible solution of the disposal of Steffen waste water. At a fixed power demand, from eightfold to tenfold evaporation is possible instead of fivefold, as previously obtained, thus permitting low-cost concentration and recovery of materials contained in the waste water for commercial utilization.

FARM-MADE SIRUPS

The small-scale production of sugarcane and sorgo sirups in many sections of the country fits well into the program of diverting land from the production of major crops to prevent surpluses and feeding farm families so far as possible from their own land. Each year more and more farmers are attempting to make a start in sirup pro-

duction. Although much of the farm-made sirups is utilized to good advantage at home, many of the more ambitious sirup producers are endeavoring to make sirup a somewhat larger cash crop. In order to sell readily the products must be of uniformly high quality. Good quality is also important in farm-made sirups used at home.

The presence of sediment in farm-made sirups is a serious defect in quality. Investigation of the factors involved in causing such sediment was transferred to the Auburn, Ala., station, where the laboratory has been equipped for a comprehensive study of this problem. Preliminary work was done on the development of a simple photoelectric method for measuring the color and turbidity of sirups, on the composition of sirup sediments, on the use of protective colloids and salts for preventing the separation of sediment, and on the refining of sirups by clarifying and centrifuging.

Cooperation was continued with a number of agencies active in putting the results of the Bureau's sirup investigations into farm-scale and commercial practice. The Bureau supplied technical assistance in the construction and operation of a farmers' cooperative steam plant for sugarcane sirup at Poplarville, Miss., and likewise assisted in the operation of several other plants of less capacity. Cooperation with the Alabama Extension Service specialist on sirups and sirup crops was continued, special attention being given to a new steam plant at Evergreen, Ala. The Alabama specialist has made rapid progress in the sirup work in his State. Cooperative work on sorgo sirup was begun at the Georgia Experiment Station.

At Meridian, Miss., a comprehensive study was made of the variation in sucrose, dextrose, and levulose contents of numerous varieties of sorgo and sugarcane-sorgo hybrids in relation to various factors such as degree of maturity, varietal characteristics, and location in various parts of the plant. The data, which are the most extensive so far obtained for these plants, have an important bearing on physiological functions and evaluation of these plants for sirups and sugar production. The most promising varieties were selected for further investigation. Nineteen varieties had a sucrose content above that for standard sugarcane now in use by the domestic sugar industry. The investigation indicated that harvesting at the proper degree of maturity for a given variety is often a practical and effective means for preventing crystallization or sugaring of the farm-made sirup.

Maple sirup grading standards were prepared for the Bureau of Agricultural Economics, and additional sets of master standards were supplied to the States that use them in connection with the preparation of larger quantities for State distribution. New turbidity grading standards were also supplied. The use of permanent glass standards was further investigated.

HONEY

Investigations were continued on the chemical and physical properties of honeys of various floral types for the purpose of more definitely evaluating the characteristics of these types and their suitability for various uses. Particular attention was given to granulation (dextrose crystallization), as influenced by the solubility rela-

tionship of dextrose and levulose, and to viscosity in relation to hygroscopicity. Results to date indicate that existing data on the solubility relationship of dextrose-levulose mixtures do not exactly apply to honey and similar sugar products of equally high density. The data throw more light on the crystallization process and will be of value in devising improved methods of processing and handling honey commercially.

Although it was expected that honey of the highest levulose content would be the most hygroscopic, since levulose is known to be more hygroscopic than dextrose, it was found that tupelo honey, which contains more than the average proportion of levulose, was actually less hygroscopic than some other honeys of lower levulose-dextrose ratio but of higher viscosity. It was concluded, tentatively, that a higher degree of hygroscopicity in honey is more closely correlated with composition factors causing high viscosity than with the percentage of levulose in the honey. Hygroscopicity, in the sense of ability to retain moisture, is an important property of honey in relation to commercial uses, and a better understanding of the hygroscopic properties of honeys of different floral types will undoubtedly lead to its more extended use for certain purposes, thus opening up some new markets.

STARCHES

Further technical assistance was given to the farmers' cooperative sweetpotato-starch plant at Laurel, Miss., which during the 1938 season processed about 165,000 bushels of sweetpotatoes to produce 1,700,000 pounds of commercial starch. The rated capacity of the plant (10 tons of starch per day) was nearly doubled, with consequent lowering of manufacturing costs, by the introduction of minor mechanical changes that permitted more rapid drying of the starch. The outlook for the 1939 season was most favorable, and production was expected to reach the maximum season's capacity of the factory operating at its increased rate. Sweetpotato starch was found to offer distinct advantages in the baking and confectionery industries. The textile and laundry industries are continuing to use sweetpotato starch with success.

A new and rapid polariscopic method was developed for the determination of starch in sweetpotatoes and starch-factory products, and was used for control work at the Laurel starch plant with satisfactory results. A study in cooperation with the Food Research Division indicated a means of controlling micro-organisms capable of causing fermentation in starch-bearing factory liquors in warm weather. Investigation indicated that starch finished at pH 6.0 to 8.0 is the most stable during storage.

A process designed to recover sweetpotato solubles and to simplify the starch-extraction process in small commercial plants was developed on a laboratory scale. Pilot-plant dehydration studies were started in connection with the problem of storing sweetpotatoes for continuous operation of a starch plant. The process used consists of a preliminary chemical treatment of the ground sweetpotatoes, removal of a large proportion of the water by pressing or centrifuging, and final drying with heat. Lime was found to be as effec-

tive as sulfur dioxide or carbon tetrachloride for facilitating removal of juice by mechanical means. The use of lime is advantageous because lime is cheap and, being noncorrosive to iron, it makes unnecessary the employment of more expensive metals for equipment. A number of different types of commercial presses and centrifuges were tried out to determine their relative worth for dewatering ground sweetpotatoes. It is believed that there will be a rapid expansion in the sweetpotato-starch industry in the South if successful methods of storing raw material and recovering additional byproducts can be found.

It has long been realized that the success of a sweetpotato-starch industry is largely dependent on growing the crop cheaply. Experiments with small-scale equipment now in use for harvesting sweetpotatoes resulted in mechanical improvements and in great saving of time for picking up sweetpotatoes and transferring them to trucks. Equipment to remove vines from potato rows, to be used in connection with large-scale harvesters, is being developed. Large-scale growing operations were investigated, beginning with the preparation of the seedbed and proper placement of plants to insure favorable conditions for use of a harvesting machine (combination digger and loader, as used for white potatoes). Experiments were also made on reduction in number of plants per acre, different planting patterns, and fertilizer placement. This investigation, which is conducted in cooperation with the Mississippi Agricultural Experiment Station and the Division of Mechanical Equipment of this Bureau, is expected to result in far-reaching changes in the agronomic handling of the sweetpotato crop.

MISCELLANEOUS CARBOHYDRATES

In the study of miscellaneous carbohydrates, particular attention was given to the hemicelluloses. The chemical nature and physiological function of this group of carbohydrates are less understood than those of cellulose, sugars, and starches. Relatively little industrial use has been made of the hemicelluloses, one of the principal applications being the use of pectin in jellies. Hemicelluloses are known to be an important factor in the feeding value of many crops, but the exact function is little understood. Increased knowledge of the character and properties of hemicelluloses is expected to lead to their more effective use and to important developments in plant culture. Preliminary to other studies, satisfactory methods must be developed for the extraction, separation, and identification of the various constituents of hemicelluloses.

Work on the various methods for the extraction of hemicelluloses from plant materials was concluded, and the results were published. Variations in such factors as acidity, alkalinity, and temperature of extracting media were investigated with the object of ascertaining the optimum conditions for extracting hemicelluloses. It was found that the optimum conditions are different for the various materials studied, which included sugar-beet pulp, peanut shells, rice hulls, and sweetpotato pulp, and that the presence of pectin has a decidedly retarding effect on extraction.

In cooperation with the Food Research Division, an attempt was made to separate hemicelluloses from plant materials by selective bacterial action on the cellulose present. So far, the results have not been decisive.

An investigation on the hemicellulosic material of sweetpotato pulp, a byproduct of sweetpotato-starch manufacture, showed that the pulp contains about 15 percent of pectin. Further study is being made of the pectic material of sweetpotatoes.

OIL, FAT, AND WAX INVESTIGATIONS

A study was made of the characteristics and composition of stillingia oil, using authentic samples expressed from seeds produced in the United States and China. This was the first extensive study made of this oil by modern methods. The iodine number of the American oil was 176 and that of the Chinese oil was 169, indicating that the former had somewhat stronger drying properties. The American oil contained 2.5 percent less of saturated fat acids and 5 percent more of linoleic acid than the Chinese oil, which account for the stronger drying power of the American oil. The investigation showed that the composition of stillingia oil is similar to that of linseed oil. On account of its strong drying power, stillingia oil is used, when available, in the manufacture of paints and varnishes, as well as in making linoleum. The mesocarp of the fruit of *Stillingia* (Chinese tallow tree) yields the commercial vegetable tallow used by soap makers. The tree is of interest in connection with soil conservation in the South and also as a possible domestic source of drying oil.

The seed oil commonly known as ben oil and moringa oil was also investigated extensively for the first time. The tree (*Moringa oleifera*) from which this oil is obtained was introduced into the American Tropics and subtropics from Asia many years ago. Since it is a rapid grower, even in poor soil, and is reported to be little affected by drought, it has become of interest in connection with soil conservation in certain semitropical regions of this country. A sample of seed from Haiti consisted of 26.2 percent of shells and 73.8 of kernels. The kernels contained 5.1 percent of moisture and 37.7 of oil. The oil had an iodine number of 68 and a saponification value of 186.4 and contained 22.4 percent of saturated fat acids. The glycerides were analyzed quantitatively for individual fat acids. Ben oil, which belongs to the nondrying class, can be used either for edible purposes or for making soap.

In the investigation of new sources of oils, fats, and waxes, preliminary examinations were made of oil from the kernels of the Uruguayan palm (*Cocos pulposa*), of ouricury wax from the leaves of the Brazilian palm (*Syagrus coronata*), and of the wax which separates on the surface of perilla oil on long standing.

Improved methods were developed for the analysis of tung fruits, nuts and kernels, since the older methods were found to be inadequate for present requirements. Field laboratories were established at Bogalusa, La., and Gainesville, Fla., for a comprehensive investigation on production of tung oil and byproducts in cooperation with the Bu-

reau of Plant Industry. Work was started on the improvement of methods for expelling the oil, on the development of a satisfactory solvent-extraction method, and on the utilization of hulls and press cake. Arrangements were made with the Protein and Nutrition Research Division for feeding experiments with tung meal that has been treated to make it nontoxic. Promising results were obtained in preliminary experiments to determine the value of tung press cake and extracted meal for the production of protein plastics.

Storage may have a very detrimental effect on tung nuts. Kernels from tung nuts of the 1935 crop that had been stored in the laboratory for about 3½ years (an extreme condition) were found to contain only 2.6 to 11.7 percent of extractable oil, whereas analyses made early in 1936 showed an oil content of from 54 to 70 percent. The iodine number of the oils extracted after storage ranged from 76 to 144, whereas that of the oils extracted in 1936 was 163 to 166, which are normal values. Deterioration in less degree may occur during normal periods of storage. This subject, which will receive further study, is a matter of importance to both growers and oil millers.

PROTEIN AND NUTRITION RESEARCH

DIGESTIBILITY OF PROTEINS

The nutritive value of a protein depends on its content of certain amino acids and its digestibility. Some protein substances are scarcely acted upon by the enzymes of the digestive tract. Others may be only partly digested, leaving some of the amino acids in chemical combinations that cannot be assimilated and utilized in body building. A protein that cannot be digested to the extent that all its nutritionally essential amino acids are made available for assimilation is of no more value than if it completely lacked those amino acids that cannot be liberated. It is important, therefore, to know how readily certain nutritionally essential amino acids are liberated from different proteins by digestive agents.

Laboratory studies on the rate of liberation of cystine when casein is digested with trypsin showed that this amino acid is liberated very readily. When the digestion was conducted in an alkaline medium, a large part of the casein cystine was destroyed. Taking into consideration the amount destroyed, it is estimated that nearly 80 percent of the cystine was liberated from casein in 24 hours. When the digestion was conducted in a slightly acid medium, the cystine was again liberated very readily, but at a slower rate than when the digests were alkaline. There was no destruction of the cystine in the acid digests. The following observations were made with regard to the instability of cystine under different conditions: (1) Cystine in casein is much less stable toward dilute alkali than is uncombined cystine; (2) destruction of cystine in tryptic-casein digests at pH 8 to 9 is greatly increased when uncombined cystine is added; (3) destruction of cystine in casein at pH 8 to 9 is much greater in the presence of trypsin than when the casein is digested with alkali alone at the same pH value; (4) in tryptic-casein digestions at pH 8 to 9 practically all the cystine of the commercial trypsin used was also destroyed.

PROTEINS OF CORN

Feeding experiments demonstrated that the proteins of corn have a higher food value than is generally recognized. In fact, corn proteins were shown to be more efficient for promoting growth than the best grade of casein when fed at the same protein level in the diet. By feeding freshly ground whole corn, all the proteins of the corn kernel were included. In the past, most of the feeding experiments were not made with the whole corn kernel, but with only one or two of its isolated proteins or with products such as corn gluten, which do not represent the total protein of corn. The nutritive value of corn has often been erroneously appraised in terms of zein, a protein lacking in two nutritionally essential amino acids, without taking into account the other 50 or 60 percent of proteins of corn that have a high food value. In the light of present-day knowledge, it appears very probable that in many of the former feeding experiments with corn the supply of vitamins and mineral elements was inadequate. In the feeding experiments reported herein, the required amount of mineral salts was mixed with the ground corn, together with a small amount of cod-liver oil to supply vitamins A and D. Other vitamins were supplied by daily feeding each animal a definite quantity of solution containing known quantities of the different vitamins in pure, crystalline form. By following this method, instead of using yeast or other vitamin concentrate, the experimental animals received no other protein than that contained in the corn.

Since about 80 percent of the corn produced in the United States is fed to farm animals, and a considerable part of the remainder is converted to meal and breakfast foods for human consumption, it is important to know the amino acid composition of the whole corn kernel. Zein, the chief protein of corn, contains no lysine or tryptophane, both of which are indispensable in animal nutrition. However, feeding experiments demonstrated that this deficiency is supplied by other proteins in the whole corn kernel. Using the method developed in this Bureau and previously used for the determination of amino acids in wheat and its milled products, in soybeans, and in navy beans, quantitative determinations were made of the amino acids in corn. Not much difference was found between yellow corn and white corn with respect to their amino-acid components. Cystine, tryptophane, tyrosine, arginine, histidine, and lysine were all found to be present.

EFFECTS OF STORAGE ON PROTEINS OF GRAINS AND SEEDS

Studies were continued on the effects of storage on the proteins of soybeans, soybean meal, wheat, whole-wheat flour, and white flour, and during the past year corn and corn meal were added to the list of materials under investigation. Knowledge regarding the nature and extent of changes during storage is not only of scientific value but has an important bearing on questions relating to the utilization and nutritive value of agricultural products. The importance of such knowledge has been emphasized by the recent attention given to long-time storage of surplus grain.

Striking changes occurred in the proteins of all the meals and flours during storage. In every case there was a decrease in the solubility of the proteins. There were also decreases in true protein

content, indicating a break-down of the proteins. Most of the samples were found to be less digestible after storage than when fresh. The protein of some seeds seems to be affected more than others. At ordinary room temperature (75° F.) changes take place to a much greater extent than at 30°. The proteins of meals and flours stored in closed containers do not change as much as when stored more exposed to the air, as in bags. The total nitrogen content and the free ammonia in all samples remained constant throughout the storage periods.

In the soybean meal, the rate and extent of the changes were about of the same order in both the fat-free meal and in meal containing 11 percent of fat. The samples stored in bags changed to a greater extent and more rapidly than did those stored in closed glass jars. After storage of the fat-free meal in bags for 24 months at 76° F., the percentage decreases in true protein, solubility, and digestibility were 14.7, 24, and 26.6, respectively. Corresponding values for the whole seeds stored in jars at 76° F. for the same period were 4.6, 12.3, and 17.5, respectively.

In wheat the most striking features, as compared with soybean meal, were the much greater changes that occurred in the true protein and solubility values. The proteins of white flour changed more than did those of whole-wheat flour under the same conditions. Decreases in solubility of the proteins of white flour were much greater than in those of whole-wheat flour. In white flour stored in jars at 76° F. for 1 month and for 12 months, the percentage decreases were 42.8 and 49.3, as compared with 22.4 and 30.8, respectively, for whole-wheat flour stored under the same conditions.

Although corn-storage studies had been in progress for only a little over 6 months, marked changes were observed, particularly in the true protein and solubility values. The rapidity with which the changes occurred is especially noteworthy. The drop in true protein value of corn meal stored in jars at 76° F. for 6 months considerably exceeded that for white flour after storage for 12 months under similar conditions. The change in digestibility was about of the same order as that of the wheat samples.

SELENIUM IN TOXIC PLANTS

Previous chemical studies on seleniferous grains, particularly wheat, developed considerable evidence that selenium is present in the seed in organic combination and that it is closely associated, if not combined, with the protein. Hydrolysis of wheat gluten and fractional crystallization of the resulting mixture of amino acids showed that most of the selenium accompanied the so-called leucine fraction. Because of the difficulties involved in separating the small fractions containing selenium, it was decided to work with a plant material containing much more selenium than ever found in wheat. A variety of *Astragalus* was selected that contained 200 to 300 times as much selenium as occurs in wheat.

A procedure has now been developed whereby an apparently homogenous, crystalline seleniferous compound can be isolated from extracts of *Astragalus* without resorting to precipitation with mercury, as was formerly done. This compound crystallizes from water in the form of prisms which exhibit double refraction and decompose

at 250° to 260° C., leaving a clear reddish oil. It contains about 18 percent of selenium and 10 of nitrogen. It also contains sulfur, and gives a strong positive reaction for amino groups when tested with the ninhydrin reagent. The properties and behavior of this compound indicate that the selenium is tied up with an amino acid or a peptide of low molecular weight. Quantities of this crystalline substance are being prepared for complete analysis and identification. There is evidence that one or more other selenium compounds may be present in the *Astragalus* extracts.

VITAMINS

It has been reported that raw soybeans contain an oxidase that destroys vitamin A under certain conditions. Such an oxidase might be expected to have a destructive effect also on other vitamins and thus account for the fact that animals do not grow satisfactorily when restricted to a diet in which the protein is supplied exclusively by raw soybean meal. Feeding experiments in which a raw-soybean diet containing added vitamin supplements was compared with a raw-soybean diet and daily administration of the vitamin supplements, apart from the diet, indicated that there was no marked destruction of the vitamins as a result of their contact with the raw soybean meal, under the conditions of the experiment. It seems, therefore, that the unsatisfactory rate of growth with raw soybeans alone is attributable to a protein, rather than a vitamin, deficiency.

International standards for vitamins A, C, and D have been supplied during the year in limited quantities to vitamin investigators in the United States who are working in colleges and universities and in agricultural experiment stations.

ALLERGEN INVESTIGATIONS

Investigation of the allergens of agricultural products is a basic research project set up under the Bankhead-Jones Act. While it is primarily exploratory, that is, designed to discover fundamental scientific facts and principles, nevertheless the knowledge gained in this research is of vital concern to agriculture because the use of certain products derived from agricultural materials may be seriously limited by unfounded suspicion that they cause some of the allergic disturbances suffered by at least 10 percent of the people in the United States.

Allergic diseases in the human result from specific and exaggerated sensitiveness to certain foods, plant pollens, and fibers, or to dusts formed by disintegration of these products. In these products and by-products of agriculture are minor components called allergens, which act as incitants of disease. Where the allergens occur, to what they owe their specific toxic action, and under what conditions they are stable or unstable are problems that direct inquiry into their chemical nature.

FRACTIONATION OF ALLERGENIC PROTEINS OF COTTONSEED

Fractional separation of the proteins of the cottonseed kernel led to concentration of the principal allergenic agents in a water-soluble portion containing both protein and carbohydrate. With this fraction,

called CS–1, important differences were established among a group of allergic subjects. All members of the group exhibited some evidence of allergic sensitiveness to cottonseed in clinical examinations. Subsequent comparisons of their reactions to the CS–1 fraction and to the usual diagnostic extracts proved that clinical sensitiveness to cottonseed was invariably accompanied by skin sensitiveness to the CS–1 fraction.

Unexpected complexities have been encountered in the further chemical study of the allergenic fraction CS–1. The carbohydrate portion was removed completely in fraction CS–2 without altering the allergenic properties of the remaining protein. By reaction with picric acid a protein picrate fraction, CS–3, was formed that retained, apparently, all the physiologic properties of the original protein. An intense yellow color contributed by the picric acid permitted development of the new technique in further analytical separations of the allergenic component. A solution of the active protein picrate formed a sharply defined yellow layer when passed through a column of aluminum oxide. In effect, the aluminum oxide was found to adsorb selectively the allergenic protein picrate. Continued passage of large volumes of solvent through the column resolved the original layer of adsorbed protein picrate into supplementary layers, visible bands differing in width and color intensity.

Interpretation of evidence secured in the resolution of the original adsorbed layer rests on further chemical and clinical study of the separate fractions obtained by this procedure. Multiple layering or banding, as described, signifies discrete differences in chemical composition of the separate layers. Removal of the separate layers, recovering the adsorbed material, and subjecting the separated products to repeated passage through aluminum oxide has provided several subfractions of the original protein picrate. In each instance the adsorbed material has proved active in clinical tests. Slight qualitative differences have been observed, however, in the allergenic activity of two separate layers that contain the major portion of the original protein picrate.

Several lines of investigation have been opened by the fractionation resulting from formation of an active picrate of the allergenic protein and selective adsorption of this protein picrate on aluminum oxide. Further removal of a small portion of inactive material has been attained. Resolution of the adsorbed protein picrate provides a means for separation of subfractions for clinical tests and bioassays and for further chemical characterization of solubility measurements.

Three subfractions obtained from the separate adsorbed layers have been subjected to an extensive series of solubility measurements. Successive fractions obtained in this procedure have shown unexpected irregularities in chemical composition and allergenic activity. These variations may be due to slight differences in closely related chemical entities that are not readily separated into homogenous fractions. However, purification of the allergenic components thus far attained has made feasible a more critical examination of small but important differences in the allergic constitution of the human subject.

CHEMICAL AND CLINICAL EXAMINATION OF REFINED COTTONSEED OIL

Refined cottonseed oil and the plastic or hardened shortening fats made from the refined oil are the most important edible derivatives of the cottonseed. Edible oils and fats from this source alone comprise about one-fourth of all the primary fats consumed as food. Therefore, whether refined edible oils and fats from cottonseed contain the allergens that are present in the seed proteins is significant to the allergic consumer.

For this investigation refined cottonseed oil and hydrogenated cottonseed oil shortening were prepared to represent typical commercial products used by food manufacturers and in the home.

The first attempt to detect cottonseed allergen in the refined oil was by an extraction process designed to separate and concentrate any water-soluble ingredient in suspension or solution in the oil. Exhaustive extraction of 3 liters (3.2 quarts) of cottonseed oil yielded no evidence of protein or other nitrogenous substance. Extractives from the edible oil were also subjected to clinical tests to detect the presence of the seed allergens. Negative results were obtained with a technique capable of demonstrating 1-millionth of 1 percent of allergenic proteins of cottonseed.

Failure to detect any trace of allergen in the refined oil indicates that allergic subjects who are sensitive to cottonseed should experience no distress if the oils or shortenings are included in their diet. Both refined cottonseed oil and cottonseed-oil shortening were fed to cottonseed-sensitive individuals for intervals of 1 to 2 months. No ill effects resulted from continually consuming either the oil or shortening in quantities considerably greater than usual dietary portions.

Oils and fats derived from cottonseed and from other oil-bearing seeds are invariably refined in preparing them for edible uses. Evidently the refining procedures effectively remove the allergenic proteins found in the oil-bearing seeds and in the crude, unfiltered vegetable oils.

ANAPHYLACTIC SENSITIZATION OF GUINEA PIGS TO EXTRACTS FROM AGED COTTON LINTERS

Dusty debris from upholstery is recognized as a specific excitant of asthma. This fact led clinicians to the hypothesis that a gradual disintegration of cotton linters with age resulted in generation of an allergen. However, when linters were aged in hermetically sealed containers there was no evidence of spontaneous generation of an allergen affecting dust-sensitive subjects.

Extracts from the several samples of aged linters did induce, in many instances, positive skin reactions, indicating the presence of either an antigen or a nonspecific irritative agent. Similar reactions were observed in conducting skin tests with heterogeneous mixtures of dust obtained from upholstery containing cotton linters. These observations suggested a further examination of the aged but unused linters to determine whether linters or dust contain an antigenic or a nonspecific physiologically active principle.

In several previous attempts to characterize a specific dust antigen, no investigator had been successful in establishing in animals induced sensitiveness to dust or to the usually suspected parent substance, cotton linters. This observation was confirmed in repeated failures

to sensitize guinea pigs with water extracts of aged linters and linters dust even when the extract was administered in multiple doses totaling 5 to 6 milliliters.

A technique that had been applied previously to the sensitization of guinea pigs to ragweed pollen was found adaptable to sensitization of these animals with water extracts from both linters and dust. Alum added to the extracts caused formation of a precipitate when the solution was made neutral. Subcutaneous injection of this suspension led to the development of a uniform degree of anaphylactic sensitiveness, which could be demonstrated by a subsequent administration of an untreated water extract of the linters. The same technique was applied in sensitization of guinea pigs to house dust.

Successful sensitization of guinea pigs to cotton linters and dust extracts made possible a comparison of the antigenic properties of unused aged cotton linters and heterogeneous mixtures of house dust. One group of animals was sensitized to linters extract and another to dust extract. The animals sensitized to linters extract were injected with dust extract. The animals sensitized with dust extract were injected with linters extract. These crossed reactions resulted in anaphylactic shock in both groups, showing that the same antigenic principle was present in both cotton linters and house dust.

When crossed reactions were conducted with extracts of different mixtures of dust obtained from upholstery, wide variations were noted in antigenic activity. These results indicated the presence of more than one specific sensitizing agent. Important also to the interpretation of these experiments was the detection of a nonspecific toxic agent in a dust obtained from old linters upholstery. Normal animals in which no specific sensitiveness had been established succumbed to injections of an extract of this dust. Symptoms were like those observed in anaphylaxis, resulting in collapse and often death. If the same or a similar nonspecific toxic factor occurs in cotton linters, its concentration is significantly less than in dust obtained from upholstery. Available data show no correlation between the specific sensitizing and the nonspecific toxic principles. The physiologic and chemical properties of both are important to the interpretation of the sensitizing functions of protein and nonprotein nitrogenous components of cellulosic materials.

ANTIGENIC PROPERTIES OF ALLERGENIC COMPONENTS OF COTTONSEED

Hypersensitiveness to foreign proteins can be induced in experimental animals. This induced exaggerated sensitiveness and the collapse or fatal shock resulting from exposure of the animal to the sensitizing protein comprise experimental anaphylaxis. Important differences have been emphasized in comparing induced anaphylactic sensitivity in the animal with the spontaneously occurring hypersensitiveness of allergy in the human. However, similarities between the two reactions suggest that both phenomena may be founded on the same fundamental physiologic alterations. The allergic and anaphylactic responses are being studied with the object of determining the chemical nature of substances capable of producing these reactions.

Concentration and fractionation of the principal allergenic components of the cottonseed kernel have provided protein fractions that

have chemical and physical properties different from the usual anaphylactogens. A fraction that possesses a high degree of specificity and potency as an allergen apparently contains a protein previously unrevealed by chemical fractionation of the nitrogenous components of this seed. By chemical characterization this allergenic fraction resembles a degradation product and would not therefore be expected to induce precipitin formation or anaphylactic sensitiveness. However, when injected into rabbits this fraction induced production of precipitin, a characteristic of the high molecular weight proteins. Sensitivity to the allergenic fraction was induced in guinea pigs by injecting them with the sensitized rabbit-blood serum. Anaphylactic sensitiveness was also induced in guinea pigs by direct injection of a saline solution of the allergenic fraction. These observations demonstrated that the allergenic components of cottonseed function also as a typical antigen. In an extensive series of crossed reactions the crude water extract of whole cottonseed embryo, the allergenic fractions, separated and purified, and other previously known proteins of the cottonseed were employed for sensitizing and testing guinea pigs for anaphylaxis. Results showed that the principal allergenic component of cottonseed is an immunologically distinct entity. It passes readily through semipermeable membranes and may be obtained from the whole cottonseed embryo by dialysis, differing in this respect from the usual type of native antigenic proteins.

Heating the allergenic fraction in water solution for 1 hour 40 minutes at 120° C. did not diminish or alter appreciably the antigenic properties. Formation of a picrate of the allergenic protein in the course of fractionation and subsequent adsorption on aluminum oxide did not affect the capacity to establish anaphylaxis. With respect to these properties the anaphylactogen and the allergen were alike. Whether the component effecting anaphylactic sensitization in animals is identical with that which induces specific cutaneous reactions and other allergic symptoms in the human subject has not been proved. To accomplish this objective requires further development of the purification technique and refinement of available criteria of physiologic activity in the experimental animal and in the human subject.

INDUSTRIAL FARM PRODUCTS RESEARCH

HIDES AND SKINS

Further insight into the physiological processes whereby certain bacteria can live and proliferate in saturated solutions of salt (sodium chloride) is essential to a better understanding of curing processes employing salt. This is applicable not only to the curing of hides and skins but also to the preservation of foods such as vegetables, meats, and fish. Fundamental research was continued, therefore, to ascertain the factors controlling the development of salt-tolerant micro-organisms. Studies were made on the influence of oxygen tension, protein concentration, salt concentration, hydrogen-ion concentration, and oxidation-reduction potential upon the growth of such organisms. The results of some of these studies are being prepared for publication.

That the halophilic bacteria are much more widely distributed in nature than heretofore suspected has been shown in work recently

published by the Bureau, in which such bacteria were isolated from soil, water, dung, and freshly flayed calfskin. Of particular interest is the fact that the sulfur-oxidizing bacteria occurring in sulfur springs were found to be capable of growing in saturated salt media.

The hides and skins and tanning industries have shown marked interest in the Bureau's studies on the possibility of obtaining better curing of hides and skins, with consequent reduction of spoilage losses, by adding antiseptic chemicals to common salt. From laboratory curing experiments during the past year the following observations were made regarding the efficacy of selected chemicals for this purpose. Phenothiazine mixed with salt proved to be ineffective. A preparation comprising about 84 percent of sodium bicarbonate and 16 percent of a dichloroazodicarbonamidine was found to be quite effective in preserving calfskins when mixed with salt to the extent of 0.2 percent of its weight. Anhydrous sodium sulfite, when added at the rate of 1.5 percent of the weight of salt used, was also found to be highly effective. It was far superior in this respect to equivalent concentrations of the acid sulfite, hyposulfite, acid sulfate, and sulfate of sodium, all of which have been suggested for the purpose. The very favorable preliminary showing of the dicarbonamidine compound and of sodium sulfite warrants their further study and large-scale trial.

A semicommercial curing experiment with heavy cattle hides preserved with salt plus sodium silicofluoride and paranitrophenol is still in progress. Observations made thus far indicate that the chemicals added to the salt for curing do not subsequently interfere with the vegetable-tanning process.

Preliminary studies on retarding microbial growth, which causes spoilage of cured hides and skins, showed that, if their moisture content is sufficiently high, resalting with an excess of salt will not stop bacterial degradation. Resalting with small amounts of salt, up to 6 percent of the weight of the cured stock, tended to give better preservation than large excesses.

In experiments on the long-time cold storage of salted calfskins, selection, grading, and physical testing were completed on leather made from the third group of skins taken out of storage after 40 months. The results indicated that the skins had suffered no loss in leather-making qualities. Skins over 4½ years old that have been in cold storage for a little more than 4 years are being tanned commercially into chrome-calf leather.

Through cooperation of the Bureaus of Animal Industry and Dairy Industry, and as a part of the program of research on the influence of animal life history on the quality of hides and skins, hides were obtained from steers that died from lack of vitamin A and from lack of vitamin D for comparison with hides from normally fed animals. These hides are being tanned, one side commercially, and the other side experimentally, for subsequent examination and study.

TANNING MATERIALS

In the program of research, in collaboration with the Bureau of Plant Industry, on the development of new domestic tanning mater-

ials that preferably would serve also as new crops for agriculture, special attention was given to canaigre (*Rumex hymenosepalus*). The roots from experimental plantings made in New Mexico and Texas in the fall of 1937 were harvested during August and September 1938.

Observations on the plantings in New Mexico indicated that in regions having extremely low rainfall during the growing season irrigation may be essential to the production of acceptable yields of canaigre roots.

The Texas canaigre plantings were of particular interest because roots from the same 50 parent hills were planted at 12 places to determine the relative adaptability of the different locations for growing canaigre. Plant growth and yields of roots varied widely. Only 2 locations, Winter Haven and Lubbock, showed particularly good yields of roots. An effort will be made to determine the factors responsible for the superior production at these places. The wide range in yields at these 12 locations emphasized the need for more comprehensive information on areas best adapted to the large-scale production of canaigre roots before commercial growing is undertaken. In order to obtain such information plantings were made by the Bureau of Plant Industry at new locations, including 4 places east of the Mississippi River.

Over 200 samples of canaigre roots collected from the experimental plantings were analyzed for tannin content, and analyses of 50 samples representing new progeny plantings are under way. Roots from 123 hills at the 3 locations in Texas showing the best yields were analyzed separately to acquire data on the range in tannin content that may be expected. The range was so wide that progeny studies for the selection and development of individuals or strains of high tannin content will be necessary for adequate crop production. The tannin content of the moisture-free roots from the 12 Texas plantings ranged in average per location from 14.8 to 27.6 percent.

Laboratory studies on the utilization of the nontannin constituents of canaigre roots for industrial products are in progress. In preliminary experiments with six samples, the residues left after removal of tannin yielded upon acid hydrolysis from 25.5 to 36.6 percent of reducing sugars. These results indicate a favorably high content of carbohydrate material for producing alcohol or organic acids by fermentation.

Work was started in collaboration with the Bureau of Plant Industry on the further development of domestic sumacs as tanning materials. Samples of leaves and stems from 3 species grown at the Arlington Experiment Farm of the Department in Virginia from seeds and root cuttings were analyzed, and the data are being held for comparison with results from similar collections in subsequent seasons. Two sumacs native to Texas (*Rhus copallina* and *R. trilobata*) are of special interest because of the high tannin content of their leaves, which, based on the limited results so far obtained, ranges from 30 to 38 percent. Additional specimens from Texas will be collected and analyzed to augment the data now on hand from the analysis of 6 species. Sumacs native to Iowa are being studied in collaboration with the Soil Conservation Service for the selection and propagation

188632—40——3

of plants that might best serve in the dual capacity of supplying tannin and preventing soil erosion. Thus far, 29 samples representing 4 species have been analyzed.

A study of the tannin content of the perennial legume *Lespedeza sericea* was continued in cooperation with the Bureau of Plant Industry. This plant, which was introduced into this country as a hay and grazing crop, especially for the Southeastern States, is valuable as a soil-improvement and soil-holding crop, but is not entirely satisfactory for hay or forage because of its comparatively high tannin content. Efforts are being made to overcome this difficulty by selective breeding and by harvesting the plant when its tannin content is at a minimum.

A special collection of leaves of *Lespedeza sericea*, grown at the Arlington Experiment Farm, was examined to determine the relationship between tannin content and maturity of the plant as indicated by height. The samples represented cuttings made throughout the summer on five plots, each plot being cut when the plants reached a definite height. Seven cuttings were made of plants 6 inches high, four of plants 12 inches high, four of plants 15 inches high, three of plants 18 inches high, and two of plants 24 inches high. The tannin content of the leaves ranged from 4.4 percent for the first cutting at 6 inches to 14 percent for the second cutting at 24 inches. Frequent cutting did not keep down the tannin content. In every plot tannin in the leaves reached a maximum in July. From the examination of one set of samples it appears that ensiling *L. sericea* may be an effective way to reduce the tannin content and make the plant more palatable to cattle. Detailed data from a previously reported study on seasonal variation in the tannin content of *L. sericea* were published.

For comparison with *Lespedeza sericea*, authentic specimens of *L. juncea* from Virginia, North Carolina, Georgia, and Alabama were analyzed for tannin content. The leaves contained, on the moisture-free basis, from 8 to 11.2 percent of tannin, a range slightly lower than for *L. sericea*.

A new glass extractor with automatic and accurate control of temperature was developed and used satisfactorily for the extraction of canaigre for tannin analysis.

LEATHER

Why some chrome-retanned leathers show poor resistance to acid rotting, whereas others show superior resistance, is still an unanswered question. In an effort to throw light on it, an elaborate set of experimentally tanned leathers was prepared. These leathers have been submitted to accelerated aging and are now being tested and analyzed. This set comprises leathers of several vegetable tannages alone and the same leathers retanned with the following types of chrome liquors: (1) Sulfur dioxide-reduced; (2) basic chrome alum; (3) glucose-reduced. The purpose is to determine the influence of the kind of chrome-retanning liquor on the permanence of leather.

Two commercially tanned goatskin leathers, made by the two-bath chrome process, were acquired for experimental binding tests in the Government Printing Office. One of these leathers gave promising results on accelerated aging, showing a loss in strength, after 12 and

18 weeks' exposure in the gas chamber, of only 21 and 34 percent, respectively. The Government Printing Office reported that this leather was entirely satisfactory for binding purposes but showed a tendency to rapidly tarnish imitation gold lettering. The other leather showed moderate resistance to acid rot. On accelerated aging, it lost 38 percent of its strength in 12 weeks and 58 percent in 18 weeks.

A new type of gas chamber, not dependent on illuminating gas, was developed for testing and research work on the accelerated aging of leathers. The exposure chamber is made entirely of glass and is maintained at a constant temperature. Acidic pollution of the atmosphere within the chamber is provided and controlled by means of a constant-level lamp burning, as a fuel, methyl alcohol containing a known concentration of normal amyl sulfite. In this manner a very low but constant output of sulfur dioxide is obtained. The operation of the apparatus can be regulated to provide certain definitely specified conditions. It therefore offers a means that could be adopted generally for the comparable testing of leather and the study of the effects of various materials and processes.

In collaboration with the British section committee on the determination of the acidity of vegetable-tanned leather, of the International Society of Leather Trades' Chemists, a set of 13 specially selected and prepared leathers was subjected to accelerated aging in the gas chamber, tested, and analyzed. Others collaborating in this work submitted these same leathers to the hydrogen peroxide and the oxygen-bomb tests. The purpose was to compare 3 recently proposed methods for the accelerated aging of leather. The results and conclusions from these studies are not yet available.

Through committee memberships the Bureau cooperated with the American Leather Chemists' Association, the Federal Specifications Executive Committee, and the committee on shoes of the American Standards Association.

FARM WASTES

Experiments on the production of moldable plastics from sugarcane bagasse were continued, and results showing the effects of varying conditions of hydrolysis upon the strength and flow properties of the molding powders were published. Particular attention was given to the method of producing molding powders by aniline hydrolysis. Powders made by this method were far superior to those obtained by acid hydrolysis both as to moldability and strength of product. Several manufacturers have shown an interest in the commercial possibilities of molding powders made from bagasse. From cooperative experiments carried out by an automobile-manufacturing firm it appears that these products are at or near the point where they can be utilized in the production of various automobile parts. Bagasse molding powders are now being tried out as material for floor and ceiling moldings for use in the building industry. Advice and assistance were given to a sugar-producing firm in the design, erection, and operation of a pilot plant for experiments in the commercial production of molding powders from bagasse. Actual plant operation and production are expected to be under way soon. Additional laboratory equipment for molding and testing plastics was procured.

Experimental work was begun with a modification of the kraft pulping process in efforts to produce strong paper pulps from cereal straws and sugarcane bagasse. Several cooks were made of wheat and oat straws and bagasse. For the study and evaluation of the resulting pulps a beating schedule was developed, using a standard laboratory beater and sheet-forming equipment. Data on bursting and textile strengths, folding endurance, and tear resistance of the plups in sheet form are being acquired. From results obtained thus far, it appears that more chemicals, or a longer digestion period, will be required for bagasse than for straw, but that fairly strong pulps can be produced from both bagasse and straw.

The results of preliminary investigations on the use of alcoholic nitric acid as a pulping agent were published. Relatively high yields of easily bleached pulp were obtained by this method, and analysis of the pulps showed that only small amounts of α cellulose and hemicelluloses were destroyed by the reagent.

Work was completed on the application of the new conductometric method of analysis to the examination of kraft pulping liquors, and a study of the modification of this method for the examination of sulfite pulping liquors is in progress. These improved analytical methods will be valuable in conducting pulping research as well as in pulp-mill control work.

Preliminary experiments on the use of monoethanolamine as an analytical reagent for the determination of cellulose in crop residues indicated that a single treatment with this reagent removes so much lignin that only a single after-bleach treatment is required. The residue is comparable in composition with the usual analytical Cross and Bevan fraction. This new procedure results in a saving in time over that required by the Cross and Bevan method.

The results of an extensive study on the chemical and physical characteristics of representative commercial paper pulps prepared from wood, bagasse, and cotton were prepared for publication. The study was undertaken in the hope that some correlation between the cuprammonium viscosity of a pulp and its other characteristics might be discovered, but the results indicated that among the 10 characteristics determined no one can be evaluated in terms of any other.

Following the publication of the results of preliminary experiments on the removal of iron from water with lignin complexes, numerous requests were received for samples of the preparations for trial in the treatment of domestic and industrial water supplies. Preliminary tests with lignin complexes prepared from corncobs indicated that they may be suitable for the removal of fluorine from water.

The results of the studies on the utilization of various agricultural wastes by destructive distillation, which extended over several years, were prepared for publication. They indicate that the continuous type of retort is suitable for the destructive distillation of some agricultural waste materials on a commercial scale.

LIGNIN

The results of an investigation on the biogenesis of lignin indicated that lignin is not synthesized in the plant from cellulose, pentosans, or pectin, but most probably directly from sucrose.

Among the first steps in the synthesis of lignin is the production of a substance or substances having firmly bound methoxyl groups in etherlike combination. Such substance or substances may be formed in the course of splitting up of carbohydrates by a process of hydrolysis, oxidation, reduction, and dehydration, and not necessarily directly from formaldehyde by a process of methylation. Data on the percentage of methoxyl at various stages of development of the plant tended to support this hypothesis. Evidence was obtained that coniferyl alcohol or aldehyde is not, as has been claimed, an intermediate substance in the synthesis of lignin by the plant.

Experiments were conducted on the nitration of lignin under various conditions. In one series of experiments lignin was first acetylated, and the nitration of the acetylated lignin was then carried out in a mixture of glacial acetic acid and acetic anhydride. The acetyl group in the nitrated lignin was removed by hydrolysis. The nitrolignin thus obtained is being studied.

When lignin is fused with alkali, protocatechuic acid, catechol, and oxalic acid are the chief degradation products. It seemed desirable to try to degrade lignin with alkali under somewhat milder conditions. For this purpose, methylated lignin in alcoholic solution was heated under pressure with sodium ethylate or sodium methylate at temperatures ranging from 160° to 180° C. A phenolic oil was obtained in a number of the experiments. An investigation of this oil is in progress.

The results of the study on the chemistry of the lignin from wheat straw given briefly in last year's report, were published. Some progress has been made in the study of the composition and nature of lignin from nut shells. *Fomes pini*, a parasitic fungus of trees that preferentially attacks the lignin, was shown to contain a substance similar to lignin in its chemical properties, in the proportion of more than 50 percent of its dry weight.

The effect of proteins on the determination of lignin by the hydrochloric acid method of analysis was ascertained by treating several plant proteins alone and in the presence of different proportions of lignified plant material with cold 42- to 43-percent and boiling 5-percent hydrochloric acid. The results indicated that the resistance to hydrolysis of the proteins used is quite different. Therefore, in determining the lignin content of materials rich in protein, it is not possible to apply a simple correction for the nitrogenous complexes in the lignin by determining nitrogen content, multiplying by the factor 6.25 to obtain protein equivalent, and deducting this value from that for crude lignin. When the nitrogen content of the crude lignin is small, the error introduced by using the factor 6.25 is not great.

HEMICELLULOSES AND LIGNOCELLULOSES

Investigations on the chemistry and structure of the hemicelluloses and lignocelluloses in cereal straws, hays, and other forage crops were continued as a basic research project under the Bankhead-Jones Act. Laboratory work on the hemicelluloses of alfalfa hay and wheat straw was completed, and two papers giving the results of the investigations were prepared for publication. The hemicelluloses from these materials were very similar. When fractionated according to

the method of Norris and Preece, they were found to consist chiefly of the B fraction, which on hydrolysis yielded *d*-xylose, *l*-arabinose, and a uronic acid that was probably glucuronic acid or one of its methyl derivatives. The hemicellulose of alfalfa hay consisted almost entirely of the B fraction, while that of wheat straw contained also a small proportion of the C fraction.

A white, lignin-free hemicellulose was isolated from sugarcane bagasse, and a study of the constitution of this hemicellulose is now in progress. Analyses of sugarcane juice and molasses showed the presence of methoxyl and uronic acids in both, with much larger percentages in the molasses. Pectin is probably the uronic acid-containing constituent, and the methoxyl group is probably of lignin origin.

Attempts to devise a satisfactory method for isolating the hemicelluloses from lespedeza hay for study have thus far been unsuccessful. The large quantity of coloring matter in this hay interferes with the isolation of the hemicelluloses, and those obtained were rather brown in color. More success was attained in the isolation of hemicelluloses from timothy hay. After much experimentation a method was finally developed that gives a lignin-free, nearly white hemicellulose preparation. In this method the hay is first extracted with an alcohol-benzene solution to free it from fatty, waxy, and resinous material. It is then extracted with hot water to free it from sugars, soluble pectin, and starch. The material is then extracted with a hot 0.5-percent ammonium oxalate solution to remove the protopectin, after which it is partly delignified by digestion with an alcoholic sodium hydroxide solution at room temperature. The residual material is then digested at room temperature with aqueous 5-percent sodium hydroxide solution and filtered. The hemicelluloses in the filtrate are precipitated by addition of alcohol. The crude hemicellulose preparation thus obtained is washed with alcohol and with acidified alcohol to free it from sodium hydroxide and is then made lignin-free by chlorination and extraction of lignin chloride with an alcoholic solution of ethanolamine.

Timothy plants were harvested at successive stages of growth, from the time of emerging until maturity. The composition and properties of the hemicelluloses and lignocelluloses at different stages of development of the plant are now under investigation.

FERMENTATION INVESTIGATIONS

The action of submerged mold growths on dextrose was studied with respect to the lactic acid, citric acid, and gluconic acid fermentations.

The production of dextrolactic acid from corn sugar by *Rhizopus oryzae*, which previously had been carried out successfully in small rotary fermenters in the laboratory, was tried out in the large rotary fermenter in the Agricultural Byproducts Laboratory at Ames, Iowa, and demonstrated to be feasible. It was found, however, that in this process there is more danger from contamination than in the previously studied gluconic acid and sorbose fermentations. Experience gained in this operation resulted in improvements of apparatus and procedure. A new process was developed for the preparation of pure dextrolactic acid from the fermentation liquors. It involves

the conversion of the lactic acid to the zinc salt, acidification, and extraction.

Preliminary experiments having shown that *Rhizopus oryzae* is effective for saccharifying corn mash and other starchy materials, work was begun on the utilization of corn directly for the production of lactic acid. This would provide fermentable material at a cost lower than that of refined commercial glucose. Yields of dextrolactic acid from corn mash, using *R. oryzae* both for saccharification and fermentation, compared favorably with those from refined glucose. Methods of preparing the mash are being investigated. It is believed that other processes, such as the citric acid, gluconic acid, kojic acid, and ketogluconic acid fermentations, might be successfully conducted with such material.

Progress was made in the fundamental investigation of the organisms inducing the citric acid fermentation. Experiments with 16 selected strains of *Aspergillus niger* recently received from outside sources and with those already in the laboratory collection revealed marked variation in acid-producing ability, in response to nutrient variations and in resistance to zinc, aluminum, and boron. Resistance to aluminum is especially important, because traces of this element may be present in the nutrient liquors when the process is conducted in aluminum fermenters. The studies showed that addition of calcium salts was effective in reducing the toxicity of aluminum to these organisms, and that addition of magnesium salts was even more effective. The required quantity of these detoxifying elements was approximately proportional to the quantity of aluminum present. Some experiments were conducted on the production of citric acid by submerged mold growths but were not very successful. Further studies along this line will be undertaken because new data indicate the possibility of developing promising procedures.

A repeat-batch, or semicontinuous, process was developed for the production of gluconic acid by submerged growths of *Aspergillus niger*. This process depends on the tendency of the submerged fungus to rise to the surface after the rotating fermenter has been stopped and the air pressure released. Since more than 90 percent of the active mycelium may be obtained in the upper one-fifth of the fermented liquor, the relatively clear lower layer is removed, fresh solution is added, and the fermentation is continued.

As many as 13 such repeated fermentations in the small drums and 5 in the large drums have been made with no decrease in activity. The optimum glucose concentration to yield the greatest amount of gluconic acid was 12 grams per 100 cubic centimeters of fermentation solution. With this concentration, the amount of acid that can be produced per hour in the small fermenter (based on calculations for 11 fermentations) is 4.33 kilograms for the semicontinuous process, as compared with 2.97 kilograms for the single-batch process. Such marked increase in production results from the elimination of the lag phase at the beginning of a fermentation, and the maintenance of a relatively high rate of oxidation of glucose to gluconic acid, with an estimated saving of 4 to 6 hours per fermentation.

With a boron-resistant strain of *Aspergillus niger* it was found possible to ferment more concentrated solutions of glucose to gluconic acid in the presence of boric acid. The addition of boric acid to the

sugar solution permits taking advantage of the rapid fermentation rate prevailing in neutral solution, by using sufficient calcium carbonate to neutralize completely the gluconic acid produced, without precipitation of the resulting calcium gluconate. It had been observed previously that, in the absence of boric acid, precipitation of calcium gluconate occurred when the sugar concentration was above 12 percent and that such precipitation caused almost complete cessation of enzymic activity. With suitable quantities of boric acid present, glucose solutions ranging in concentration from 20 to 40 percent can be rapidly fermented to gluconic acid, whereas in the previous process glucose concentration could not exceed 12 to 15 percent without retarding the fermentation rate.

Thirty-seven strains of *Acetobacter* were studied in the laboratory to determine their relative ability to produce organic acids from glucose in the absence of calcium carbonate, that is, in media of increasing acidity. As was expected from experience with other types of oxidative fermentation, aeration was found to increase the rate of fermentation. Most of the strains produced very little acid, but some readily attacked the glucose molecule, producing acids other than, or in addition to, gluconic acid. The best strains will be used in a more detailed study of gluconic acid production under acid conditions in the hope that a continuous process for the production of free gluconic acid can be developed.

Laboratory studies on the production of 5-keto-gluconic acid from glucose by *Acetobacter suboxydans* in rotary fermenters resulted in definite improvement. The time required for completely fermenting a 10-percent glucose solution was reduced from 7 days to about 3 days. The process comprises two phases. In the first, the glucose is oxidized to gluconic acid; in the second, the gluconic acid is oxidized to ketogluconic acid. Efforts are being made to hasten the over-all process by reducing the time required for the second phase, which proceeds more slowly than the first.

Two vat-type aluminum fermenters, designed for operation under pressure, were constructed and found to be satisfactory for the production of gluconic acid. Further studies are in progress to demonstrate their utility for the production of lactic acid, sorbose, the ketogluconic acids, and dihydroxyacetone by fermentation. If they can produce results equal to those obtained with the rotary fermenters, it is believed such vats will be preferred for large-scale industrial operations .

In studies to determine the possibility of producing paper pulps from crop residues by anaerobic fermentation with thermophilic bacteria, it was found that there was less decomposition of cellulose and pentosans in chopped wheat straw than in straw flour. However, the loss was great enough to indicate that this type of fermentation is not very promising for producing pulps.

MOTOR FUELS

The entire problem of motor fuels from agricultural materials was comprehensively summarized in Miscellaneous Publication No. 327, Motor Fuels from Farm Products, issued during the year. This publication discusses the scientific, engineering, and economic factors involved, and indicates the kind of additional data required and the

research necessary to acquire such data. It corrects some widely prevalent misconceptions relating to production and use of alcohol for motor fuel and has served to rationalize the discussions on the economy of agricultural motor fuels, which heretofore have been somewhat controversial. The publication has become an authoritative handbook on the subject.

It is believed that research is needed on many phases of the problem before alcohol production for use as motor fuel is undertaken. Under present conditions there would be grave risk of financial loss to investors in such manufacturing plants. Plans have been formulated for a research pilot plant at Peoria, Ill., in which essential problems relating to reduction in cost of producing alcohol, advantageous utilization of process byproducts, distribution, and use of products will be studied.

Pending the necessary experimentation in this plant or elsewhere, and the development of processes whereby low-cost alcohol and valuable byproducts can be produced from kinds and quantities of farm products that will have a significant bearing on the crop-surplus problem, the manufacture of power alcohol by private industry will be on an economic border-line, without chance of profit except under especially advantageous circumstances.

It is believed that the manufacture of power alcohol should be undertaken only under a definite plan specifically designed to meet existing economic handicaps. The reason for undertaking the production of motor fuels from agricultural materials, that is, whether the objective is assistance to agriculture or merely conservation of national fuel resources, should be clearly understood in advance, because with either objective there will be certain limitations, which must be considered.

CHEMICAL CONVERSION OF OILS, FATS, AND WAXES

The arylstearic acids and their esters previously prepared from oleic acid were found to be useful as intermediates for further synthesis. Many of them can be readily sulfonated with concentrated sulfuric acid and yield sulfoarylstearic acids. The sodium salts of such sulfonic acids have emulsifying properties and penetrant action, as measured by the Draves-Clarkson test. The following tentative conclusions have been drawn from experiments with these compounds: (1) Their penetrant properties in neutral solutions compare favorably with those of some commercial wetting agents; (2) their wetting efficiency decreases in very acid and very alkaline solutions; (3) in neutral solutions the decrease in wetting efficiency with increasing dilution is less for the sulfoarylstearic compounds than for most commercial wetting agents; (4) the resistance to precipitation by calcium salts is about the same for the sulfoarylstearic compounds as the average for commercial wetting agents; (5) the disulfonated products are less effective penetrants than are the monosulfonated products, but their calcium salts are more soluble. Experiments will be made on the fat-splitting properties of these sulfonated compounds.

In studies on the hydroxylation of oleic acid, an improved method was devised that is also applicable to the hydroxylation of other unsaturated fat acids, glycerides, and other esters and alcohols. It

was found that potentially valuable aldehydic products can be prepared from glycerides of fats and vegetable oils without isolating the unsaturated fat acids and also without isolating the intermediate hydroxy compounds. Using the improved hydroxylation method and an improved procedure for breaking down the products and recovering derivatives, pelargonic aldehyde (n-nonaldehyde) and azelaic acid were obtained from oleic acid and from its glycerides and other esters. Oleyl alcohol yielded pelargonic aldehyde and 9-hydroxypelargonic aldehyde. Castor oil yielded, besides azelaic acid, a volatile compound that was identified as α-nonenaldehyde. This compound should prove valuable as an intermediate for use in synthesis since it contains an ethylenic linkage in addition to the reactive aldehyde group. The 9-hydroxypelargonic aldehyde obtained from oleyl alcohol should also be valuable as an intermediate. These aldehydes may find application in the preparation of commercial products such as perfumes, flavors, plastics, synthetic fibers, and rubberlike materials.

PLASTICS

Work was continued on the utilization of dextrolactic acid in a new type of three-component alkyd resin involving the use of polyhydric alcohols, aliphatic hydroxycarboxylic acids, and polybasic acids. The resins which have been most intensively studied result from the reaction of glycerol dilactate with straight-chain aliphatic dicarboxylic acids. Some of the dibasic acids thus used are succinic, azelaic, and sebacic acids. In most instances the three components used in the preparation of such plastics are derived from agricultural materials.

A study of the several steps in the reaction is now under way. The production of glycerol dilactate, which finds direct use in the textile industry, has been given particular attention. The plastics obtained by the reaction of glycerol dilactate with aliphatic dicarboxylic acids of the series succinic to sebacic have rubberlike properties. Those containing azelaic and sebacic acids are practically insoluble in the aliphatic hydrocarbons. They are miscible with rubber and may find use for improving the resistance of rubber to solvents. The reaction product of glycerol dilactate and phthalic anhydride may find use in the preparation of coating compounds. It is compatible with cellulose nitrate in some commonly used solvents and produces tough elastic films.

Work on the preparation of methyl acrylate from dextrolactic acid showed that the three essential reaction steps, esterification, acetylation, and pyrolysis, proceed with fair yields. The results corroborated those of earlier British investigators, which indicated that an over-all yield of about 60 percent of crude methyl acrylate may be obtained. On polymerization, the redistilled methyl acrylate gave a transparent, tough, rubbery plastic. It is not likely, however, that this process can compete favorably with other methods now in use for the manufacture of methyl acrylate.

SOYBEANS AND SOYBEAN PRODUCTS

The Regional Soybean Industrial Products Laboratory at Urbana, Ill., continued to investigate soybeans and soybean products for the

purpose of gaining further fundamental knowledge bearing on industrial utilization and the suitability of different varieties for specific purposes. This is a basic research project under the Bankhead-Jones Act, and is carried on in cooperation with the Bureau of Plant Industry and the agricultural experiment stations of the 12 North Central States.

As an aid to the agronomic investigations of the Bureau of Plant Industry, in cooperation with the State agricultural experiment stations, chemical analyses were made of about 925 additional samples of soybeans of different varieties and strains and representing also variations in climate, soil type, fertilizer treatment, and other cultural conditions. All samples grown in 1936 and 1937 that possess immediate interest have now been analyzed, as well as 445 samples of the 1938 crop. Several hundred other analyses and special determinations were made in connection with the agronomic, chemical, and technological investigations.

Research was continued on the improvement of existing methods for the analysis of soybeans and soybean products and on the development of new methods. A method of extraction with 0.8 normal trichloracetic acid solution was developed as a measure of nonprotein nitrogen, the amount of nitrogen extracted being comparable with that removed by electrodialysis. This method, which provides an easy, rapid procedure for determining "dialyzable" nitrogen, was tested on a number of soybean-meal samples of widely varying nitrogen content with satisfactory results. A method for determining saturated fat acids in soybean oil, now being studied, seems to be satisfactory. It requires only about one-tenth of the time required for previous methods. By this method, which is based on the work of J. B. Brown of Ohio State University, the solid fat acids are separated from the liquid acids by crystallization from acetone solution at low temperatures. This procedure when checked with the Bertram permanganate oxidation method and the Twitchell method, as modified by the fat analysis committee of the American Chemical Society, gave results for soybean oil in close agreement with those found by the Bertram method, which is believed to be the more accurate of the two.

A critical study by statistical methods of the many data on iodine number and refractive index of soybean oils indicated a straight-line relationship between the two, within experimental error, but this line was different for soybeans of different years and for those of any one year, depending on the method of extraction. From a study of the influence of time of heating, storage, and other factors on this relationship, it appeared that differences in the equations worked out could not be attributed to such factors.

From a study of six samples of soybean oil having abnormally low to unusually high iodine numbers (102.9 to 151.4), with regard to composition of their fat acids, the following tentative conclusions were drawn: (1) The ratio of saturated to unsaturated acids in soybean oil is fairly constant, irrespective of the total acids present or iodine number of the oil; (2) the distribution of the unsaturated acids varies in a specific manner with the iodine number, but is independent of the total acids formed and stored by the seed in the form of various lipids; (3) the regularity of variation of the

oleic, linoleic, and linolenic acids with respect to the iodine number indicates that the various unsaturated acids are formed (*a*) by a progressively stepwise dehydrogenation of a completely saturated precursor, or (*b*) by a progressively stepwise hydrogenation of a polyethenoid, and at least a triethenoid, precursor.

Various lines of investigation were pursued in an effort to obtain information on the mechanism of reversion and rancidity phenomena of edible soybean oils; and material progress was made, especially with respect to suitable means of measuring and predicting the probable keeping quality of oils. From the investigation of the applicability of the Kaufmann diene method to the determination of the extent of conjugation in normal and oxidized soybean oils, which was completed, it was determined that the presence in fats and oils of hydroxyl groups, peroxides, and possibly other oxidation products influences the magnitude of the diene value, apparently as a result of the reactivity of these substances with maleic anhydride under the conditions of the Kaufmann and Ellis methods. Pure hydroxylated compounds having appreciable initial diene values were found to have little or no diene value after acetylation. Within the limits of experimental error, the diene value of soybean oils could be related to the hydroxyl and peroxide numbers by the following equation: Diene number = 0.226 hydroxyl number + 0.0127 peroxide number.

As a part of the investigation on the durability of surface coatings containing soybean oil, a total of 154 panels, representing 119 varnishes, 115 paints, 46 enamels, and 3 aluminum paints, have been prepared and exposed on the 45° and 90° test fences at Urbana. On the basis of exposure records up to the present, it may be concluded that soybean oil is as durable as tung, perilla, or linseed oil, when it is cooked with rosin ester or Bakelite 254 resin to form varnishes in which the only variable is the type of oil. The slower rate of drying and hardening of soybean-oil varnishes apparently does not interfere with their durability. Blending 100-percent tung-oil varnishes made with Bakelite and rosin ester with similar 100-percent soybean-oil varnishes in the proportions of 1:6, 1:3, 1:2, 2:1, and 5:1 did not increase durability or hardening over that of straight soybean-oil varnishes. Interesting new soybean-oil varnishes were made by adding blends of 15 and 25 percent of Bakelite resin BR 3360 with 85 and 75 percent of rosin ester. Such blends not only reduce the cost of the varnishes, but should also increase the durability of the rosin ester and decrease its tendency to soften on aging, which has been a disadvantage in rosin ester varnishes, especially when made with soybean and linseed oils.

Further experiments definitely established the fact that the oxygen absorption of soybean and certain other oils is increased, and the rate of drying accelerated, by heating the oil with an acylating agent, such as acetic, propionic, or butyric anhydride. Measurement of oxygen absorption by several well-recognized methods indicated that acylation of soybean oil increases the rate of oxygen absorption from 7 to 20 times over that of untreated crude soybean oil. Since the method of treatment is both practical and commercially important, application has been made for a public-service patent to cover the process.

An extensive series of experiments was made to determine the relative effectiveness of various activated bleaching earths and carbons

and combinations of earths and carbon for bleaching alkali-refined, expeller soybean oil. As compared with various commercial bleaching agents, official fuller's earth resulted in poor bleaching. The use of activated carbon alone resulted in inadequate bleaching, but it was of value in supplementing the action of activated earths and filter aid. Various commercial activated carbons showed little difference in bleaching action. Siliceous filter aids, when used alone, had no bleaching action, but when used in combination with activated earths and carbons to the extent of about 0.1 percent they materially assisted subsequent filtrations. The concentrations of activated earths were varied over a considerable range (2 to 12 percent), and although some additional bleaching resulted above 6 percent of earth and 2 percent of carbon, it did not seem to warrant the increased cost of the materials used. In laboratory bleaching, optimum results were obtained by the use of a mixture of 4 to 6 percent of activated earth, 0.5 to 1 percent of activated carbon, and 0.1 to 0.5 percent of filter aid.

In studies relating to the industrial utilization of soybean meal and its constituents, further attention was given to the extraction of protein and to the preparation of plastics from the protein- and oil-free meal. The principal problem encountered in work with soybean protein dispersed in formaldehyde solution was the preparation of dispersions of practical protein concentration that would not gel in a short time. The degree to which the protein had been hydrolyzed was found to be very important. Hydrogen-ion concentration was also found to influence the tendency to gel; a dispersion of pH 8.5 or higher gelled in a few hours, if not immediately. A formaldehyde dispersion of soybean protein was used to impregnate unsized kraft paper, which was then dried to about 10-percent moisture content. When 15 to 20 sheets of impregnated paper were pressed between the heated platens of a hydraulic press, an interesting laminated sheet was obtained. By placing sheets of paper impregnated with phenolic or urea resin on the top and bottom of the stack of other impregnated sheets, a laminated sheet could be obtained that was practically as water- and warp-resistant as one made entirely with phenolic or urea resin.

Experiments were continued on the preparation of thermosetting plastics from formaldehyde-hardened soybean protein mixed with synthetic resins. Work was concentrated on soybean meal rather than on the commercial soybean "alpha protein" because the meal is cheaper and more generally available. In the preparation of molding compounds the most satisfactory results were obtained by incorporating a soft two-stage phenolic resin with the formaldehyde-treated soybean meal by passing the mixture through heated calender rolls. A mixture of 60 percent of soybean meal and 40 percent of phenolic resin worked well on the rolls and gave a molding compound that could be handled similarly to phenolic resin-wood flour molding compounds, although the time of cure was possibly a little longer. Articles molded from such mixtures appear to be resinous on the finished and fractured surfaces. They are somewhat stronger than those made from straight resin, but not so strong as those made from the resin-wood flour mixture. Their water absorption is high in comparison with straight phenolic plastics, but very low in comparison with straight protein plastics. Some of the mixtures prepared were molded

without difficulty in regular production dies in the plants of two manufacturers, and the products compared favorably with those from commercial phenolic molding compounds. The results of these and other experiments have removed all doubts as to the possibility of making a soybean-phenolic plastic. The only question remaining is how the plastic should be modified to fit some particular industrial application.

Engineering and physical investigations have been concerned primarily with expeller processing and solvent extraction of soybeans. Standard operating conditions for the half-size expeller press have been established. The results of tests to determine the effects of particle size on expeller performance have shown that power usage per unit of throughput increases rapidly as finer particles are fed and simultaneously the oil content of the residual cake approaches a minimum. The importance of particle-size-frequency distributions resulting from diverse conditions of cracking has been demonstrated in all experiments relating to expeller and dryer operation. A study was completed on the effects of variety, feed rate, moisture content, and roll clearance upon size, distribution, uniformity, and bulk density of the products of single-stage cracking of soybeans.

Viscosities and specific gravities at various temperatures, and refractive indices, have been determined for mixtures of soybean oil with hexane, trichlorethylene, and ethylene dichloride. These data are essential for diffusion calculations, pump and piping design, and rapid determinations of miscella concentrations.

Observations were made on the resistance of various metals and alloys to corrosion under conditions analagous to those encountered during solvent extraction of soybeans or in the movement and storage of quantities of soybean oil. Nickel, Allegheny metal, Hastelloy A, and aluminum were found to be satisfactory, but copper and copper-bearing alloys showed poor resistance.

The mutual solubility of soybean oil and liquid sulfur dioxide has been determined, and the investigation is being continued to obtain physical constants and properties of the oils resulting from the two liquid phases at various temperatures.

Cooperative studies were made by Purdue University Agricultural Experiment Station on the sterols, phosphatides, and carbohydrates of soybeans. A large-scale preparation of stigmasterol from soybean oil showed that about 20 percent of the sterols can be isolated as stigmasterol. Sterols from the sterol glucosides appeared to be the same as those obtained by saponification of the oil. An extensive separation into fractions was made of the phosphatidic material separated by adsorption. Evidence was obtained that nitrogen-free compounds containing phosphorus may be separated from this material. Although no crystalline stachyose was isolated from the carbohydrates of soybeans, sirups were obtained that showed qualitative indications of stachyose, and the conditions under which crystallization may occur were studied.

In cooperative work by the Minnesota Agricultural Experiment Station, some preliminary results were obtained on the respiration of soybeans of varying degrees of moisture content. The data available at present indicate that increasing moisture content markedly accelerates respiration. The results showed that the respiration of soy-

beans at different levels of moisture content follows an exponential curve. The curve differs from that obtained in previous studies with the cereal grains in that there is a rather rapid increase in the rate of respiration with increasing moisture, rather than a sharp break at some particular moisture value. The adiabatic respirometer was improved by making it completely automatic. Considerable experimentation was carried out in developing suitable equipment for conducting bulk storage trials under adiabatic conditions.

CHEMICAL WEED KILLERS

A semiplant-scale investigation was completed on the performance of a recently designed electrochemical cell for the production of sodium chlorate. This cell has a structural advantage over the type formerly used in that it permits adequate cooling at high-current concentrations and also adjustment of the gap between anode and cathode. Cells of this type were operated at five times the current concentration used in the cells that served as a basis for the Bureau's first report on the cost of producing sodium chlorate. Thus, with the same investment in the new type of cells, a threefold output of chlorate can be obtained therefrom. The new cells are of comparatively simple and inexpensive construction and permit current efficiencies of from 80 to 85 percent.

A small glass laboratory cell of the rod-cathode type was operated at various current concentrations up to 5.4 amperes per liter. At this current concentration the power consumption was very low, only 2.9 kilowatt-hours of alternating current per pound of sodium chlorate as crystals. Work on similar cells of larger capacity is under way.

The Bureau collaborated with the Bureau of Plant Industry in a study to determine whether there is any relation between the acidity of sap in crop plants and the susceptibility of the plants to injury by sodium chlorate in soil following its application for weed control. About 200 determinations of hydrogen-ion concentration were made on expressed plant juices supplied by the Bureau of Plant Industry, but no correlation was found between the measurements and the reported susceptibility of the various plants to chlorate injury.

BIOLOGICAL STAINS

Approximately 45 samples of dyes were examined for the Commission on Standardization of Biological Stains, an increase of about 50 percent over the number examined during the previous year. Work on the development of a quantitative method for the analysis of alizarin red S yielded only negative results. A definite improvement in the method for the analysis of crystal violet was found and is now used in the standard procedure for analysis of this dye.

In addition to the usual requests from the Commission on Standardization of Biological Stains for chemical and spectrophotometric examinations, a large number of requests were received for information and services pertaining to biological stains from various universities and Government and other agencies. Cooperation was continued on the revision of the dye descriptions to be used in the dye monographs for the forthcoming new edition of the National Formulary.

NAVAL STORES RESEARCH

CHEMISTRY AND TECHNOLOGY OF NAVAL STORES (TURPENTINE AND ROSIN)

Fundamental studies on the nature of the acid complexes of pine oleoresin and rosin showed for the first time that both contain dihydro resin acids to the extent of about 3 or 4 percent of the total acids. The dihydro acids can be readily prepared by hydrogenation of pine resin acids and can moreover be easily converted into dihydro lactones. The latter nonacid derivatives, because of their high stability, may eventually become important naval-stores products.

In connection with the fractionation of pine gum, experiments involving separation of the crystalline from the liquid portion were directed toward slow filtration in the belief that such filtration would be economicaly feasible if it is made more or less continuous, self-operating, and coordinated with gum storage, which may become an essential factor for year-round operation at central distilling plants. Three types of multiple-filtration devices, combining simple construction with large filter area and requiring a minimum of attention, were designed and built with that in view. Preliminary tests with these gave promising results. One of the filters, possessing greatest simplicity in construction of the three types, was made for pilot plant-scale experiments. In testing this apparatus, it is contemplated that, in addition to obtaining operating data, a stock of noncrystallizing gum rosin will be prepared from the liquid portion of the gum in order that samples may be supplied to industrial consumers of rosin who have made numerous inquiries concerning this new product and requested samples. Similarly, products from the crystalline portion will also be prepared for industrial testing.

Fundamental studies on the nature of the so-called pyroabietic acid complex, prepared from rosin by catalytic means, showed that, due to a disproportionation reaction, it consists essentially of dihydro-, tetrahydro-, and dehydroabietic acids, each more stable than the original abietic-type acids, and not of isomers of abietic acid, as formerly believed. The dehydroabietic acid, which predominates, constitutes the first significant departure from the relatively unstable hydroaromatic types to the benzenoid type, which, despite its greater unsaturation, possesses a higher stability due to its partially benzenelike character. An isomeric dihydro acid of unusually high positive rotation (108°) was found in the catalytically prepared so-called "pyroabietic acid" complex. In the preparation of "pyroabietic acid" without the aid of catalysts it was found that the principal product is likewise the stable dehydroabietic acid, but in this case the disproportionation mechanism is different in that no tetrahydro acid and no isomeric dihydro acid having a positive rotation of 108° are produced.

Dextropimaric acid heretofore has been regarded as the most stable of all the resin acids in pine gum, and not isomerizable. It was found, however, that upon treatment with cold concentrated sulfuric acid it is isomerized in part to an acid having a negative rotation of 32° in contrast to a positive rotation of 73° for the dextropimaric acid. Dextropimaric acid is also converted by this treatment in part to a neutral product resembling a lactone in chemical properties.

Further investigations have been made on the composition of the nonpinene portion of authentic gum spirits of turpentine distilled from

the oleoresin of longleaf pine. The samples of turpentine used in this investigation were the first (richer in "forerun") and last (richer in "tailings") portions, respectively, of commercial distillations of gum, and were found to contain 0.07 percent of forerun and 7.7 percent of tailings, respectively. Because of the very small quantity of forerun available and its relative complexity, separation into its constituents by fractional distillation was not found possible.

The tailings were subjected to repeated fractional distillation and were found to have the following gross composition: (1) About two-fifths, monocyclic hydrocarbons; (2) about one-fifth, terpene alcohols and phenols; and (3) about two-fifths, principally ethers and esters.

The chemical and physical data of the final series of fractions obtained, when correlated and considered in the order of ascending distillation temperatures, showed the distribution of constituents in the tailings to be somewhat as follows: (1) A small quantity of an unsaturated hydrocarbon having properties similar to p-menthene; (2) considerable dipentene (about one-fourth) which appeared to contain a little d-limonene; (3) a small quantity of terpinolene; (4) a considerable proportion (about one-third) consisting essentially of a mixture—approximately equal quantities—of methyl chavicol and alcohols;[1] (5) a portion (about one-sixth) which was essentially bornyl acetate, but also contained alcohols and a small quantity of alkyl ether; and (6) the remainder of the tailings, containing hydroxy compounds which were in part phenolic, another alkyl ether, and esters other than bornyl acetate.

In this connection fractionating assemblies adapted to vacuum fractionation have been constructed.

In view of the possible use by naval stores producers of oxalic acid to raise the grade of rosin obtainable from oleoresin discolored by iron compounds, attention was given to the results obtained by and the health hazard of using oxalic acid in various ways. The oxalic acid may be placed in the still along with the gum, stirred into the hot molten rosin after straining, or placed in the crude gum before filtration and washing. The last procedure is best because the period of contact is short and the oxalates and unreacted oxalic acid are removed by filtration and washing. With the other methods oxalates remain in the rosin. Moreover, oxalic acid placed in the still may cause isomerization of the resin acids into forms partly responsible for the color in rosin soaps. Rosin produced from oxalic acid-treated gum, which had been filtered and washed before distillation, yielded soap having about the same amount of color as when rosin from the untreated gum was used. The same result was obtained with rosin treated with oxalic acid after straining, but a somewhat darker soap might result from treated rosin kept in molten condition longer than usual. Rosin treated with oxalic acid in the still generally yielded a darker soap than did the untreated rosin. It appears, therefore, that there is no advantage in using oxalic acid to raise the grade of rosin, so far as soap making is concerned.

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[1] The alcohols appeared to be a relatively complex mixture. Fenchyl alcohol, one of the predominant alcohols in the tailings of steam-distilled wood turpentine, could not be detected. A solid having the properties of pinocarveol hydrate was isolated, as was also an alcohol which was solid at low temperature and had properties similar to pinocarveol.

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The Bureau does not advocate the use of oxalic acid for bleaching rosin, especially by those not engaged in gum cleaning. A mimeographed circular was issued to point out the health hazard attending its use.

Preliminary tests in collaboration with the Industrial Farm Products Research Division of the Bureau on the germicidal properties of soaps made from various rosins, and rosin and resin acids, indicated that a 100-percent-rosin soap and, to a somewhat lesser degree, a 20-percent-rosin soap, have higher germicidal activity than the common fat-acid soaps.

Statistical analysis of the results of comprehensive experiments, in collaboration with the Bureau of Plant Industry, on the growing of plants in paper pots impregnated with copper resinate showed that the copper resinate stimulates plant growth. Impregnation with copper resinate also retards decay of the paper and permits field setting of the entire pot without any deleterious effect on the plant. A public-service patent covering this use of copper resinate has been granted.

Small-scale experiments indicated that the addition of powdered rosin to soil of high organic content exerted a remarkable stimulation on rate of growth and fruit production in the case of tomato plants which were very severely limited in their feeding range and food supply. The experiments are being repeated, with modifications, on a larger scale.

A public-service patent was granted, covering the use of rosin in an expansion-joint filler, as developed in previous work.

The rapidly increasing practice of selling small lots of pine gum to central distilling plants has created a need for standards to be used in grading the gum and methods for determining the turpentine and rosin contents of the crude gum and the grade of rosin that should be produced from it. Samples of crude pine gum were carefully selected by the staff of the naval stores station for use as grading standards. The standard sample for No. 1 gum will make WG rosin; that for No. 2 gum will make K rosin; and that for No. 3 gum will make F rosin. Since these gums must be stored in glass containers and change in appearance due to settling, they can only serve as prototypes. For actual use in gum grading, small panels were painted in oil colors to simulate, as nearly as possible, the appearance of the gum when freshly mixed and placed in museum jars. These secondary standards have been submitted to the industry for trial. The laboratory method previously developed for the testing of pine gum to determine its probable yield of turpentine and rosin, and probable grade of the rosin, was tried out by the largest buyers of pine gum. They reported that this method is superior to any they have tried previously and gives results comparable with those obtained with their large stills.

In connection with the studies on deterioration of turpentine in storage, turpentines of various degrees of deterioration were subjected to tests for aldehydes, peroxides, and acids. Although sufficient data have not been obtained to draw definite conclusions as to the relative value of the different tests, those obtained so far indicate that the peroxide number will be of value as a criterion of the degree of deterioration.

PRODUCTION AND PROCESSING OF NAVAL STORES

Turpentine and rosin producers manifested increasing interest in the possibilities of gum cleaning and steam distillation. These subjects are assuming greater importance because of the progressive development of central stilling as the result of the increasing sales of pine gum by small producers. Steam distillation of cleaned pine gum is especially suitable for extensive plants.

Additional engineering data on the heat requirements for steam distillation have been collected. Such information should be useful in designing large stills and condensers for use in central gum-cleaning and distillation plants.

An experimental steam-and-fire still was built from a 10-gallon aluminum pressure cooker to permit runs on small volumes of gum. Many producers and gum buyers saw the possible value of such equipment for running check charges of gum in connection with gum buying. In response to requests, a drawing of the still was prepared for distribution.

Improvements in the gum-cleaning process were made by simplifying the various steps involved and equipment required. Small-scale equipment for studying problems of gum cleaning is now under construction. This will permit close observation of conditions in each step. Two commercial plants have inaugurated gum cleaning, using an adaptation of the equipment developed at the station.

The improved type of fire still installed at the naval stores station serves as a model for the industry in the field. Additional data obtained in the study of heat distribution in the fire path of the turpentine fire-still setting indicated that slight changes were desirable in flue and fire-path design. This still is operated principally as a demonstration for the benefit of visiting producers, stillers, and others. In addition, the results of runs made on the fire still have constituted an excellent basis for evaluating the results of steam-distillation and gum-cleaning processes, since the fire-still operation is well standardized. Occasionally it is necessary, in commercial practice, to rerun rosin already packaged. Several runs were made on the fire still to determine the decline in grade that may be expected under these conditions. The results indicated that it is possible to make such reruns with a loss not in excess of one grade.

In connection with the collection of gum from the trees a new series of tests was started with turpentine gum cups made of different metals and other materials and some having special protective coatings. As was expected from previous tests, there was very little difference in the effects of the different materials on the grades of rosin produced from the gum collected during the first year, the deterioration being manifested in the second and later years of use. A lot of glass cups made according to the specifications of the Bureau were received and hung. One thousand cups were hung in the Osceola National Forest; 100 in Georgia, and 100 in Florida, on private operations. A special type of hanger for the glass cups was developed. The design of the original glass cup was modified, and cups of this new design will be added to the tests.

In cooperation with the Forest Service, samples of pine gum obtained in experiments to determine the effect upon trees and gum yields of treating fresh-cut streaks with acids and alkalies were ex-

amined in the laboratory. No differences were found between gums from untreated check faces and gums from the treated faces as regards yield and grade of rosin or yield and properties of turpentine. However, further investigations may be made to determine what effects the chemical treatments have on the suitability of the products for industrial uses.

Experiments to determine the extent of losses from uncovered dip barrels showed that there is no appreciable reduction in turpentine yield when the gum is stored for a period of 12 weeks in covered or uncovered wooden or new galvanized-steel dip barrels. The observed loss of gum from some of the wooden barrels was due to leakage and not evaporation. There was a decline of one grade in the quality of rosin resulting from 12 weeks' storage in both kinds of barrel, whether open or closed. Gum in galvanized-steel dip barrels suffers little discoloration if left in the barrel for only about 1 week. The metal barrels are corroded less by slash than by longleaf pine gum.

Further work was done on methods for conditioning turpentine so that it can be stored without loss and with minimum deterioration. Attention was given to the removal of acids as well as all free and dissolved water from the turpentine. Preliminary experiments indicated that the extraction of some of the organic acids can probably be accomplished by washing the turpentine at the still once or twice with water, after which the turpentine may be dehydrated by settling and passing through coarse salt. Studies are being continued to develop the most efficient means of washing turpentine at the still. Equipment for such washing has been designed and will be tried out.

Tests were continued on metal drums of various kinds in comparison with wooden barrels as shipping and storage containers for turpentine. A stainless-steel drum held dehydrated turpentine for 2½ years before the turpentine became unmerchantable because of dark color and high specific gravity. A drum lined with baked lacquer held dehydrated turpentine for 3 years before the color of the turpentine became so dark as to make it unmerchantable. The specific gravity was still within acceptable limits. In both cases the drums were still in good condition. Turpentine was stored in a galvanized drum with a bag of oxalic-acid crystals suspended in it for 2 years before its color became so dark as to make it unmerchantable. Eight to ten months is usually as long as turpentine normally remains in a retail shipping container. In addition to the three containers mentioned, five other drums coated on the inside with various kinds of lacquer kept turpentine in good condition for this length of time. A wooden spirit barrel, thoroughly air dried, glued inside, and painted white on the outside after tightening the hoops, held turpentine without leaking or material deterioration for 15 months, during which it was subjected to frequent handling designed to simulate the treatment received in commerce. This is significant because from 10 to 15 percent of the wooden turpentine barrels now used by the industry for foreign shipments leak by the time they reach the port.

Continuation of the experiments with rosin packages showed that wooden barrels made of ⅞-inch rough or planed pine staves, when stored on end in the open directly on sandy soil, will not last longer than 1½ to 2 years before becoming unmerchantable, requiring breaking down the packages and rerunning through the still or recooper-

ing for marketing. Proper storage on poles in the open approximately doubles the life of the barrels. Galvanized drums which have been sitting on end directly on the ground in the open for 2 years are still in good condition. Tests were started with multiple-ply paper bags for packaging rosin to determine the durability of such packages when stored in the open on boards about 4 inches off the ground and under shelter on a wooden floor in stacks from six to eight bags high.

During the year the naval stores station was visited by 582 persons, including 42 senior forestry students from the University of Georgia who spent 2 days studying equipment and operations.

With assistance from the naval stores station, a complete lay-out and still plant was designed and constructed strictly according to Bureau design. This is probably the first time that a still shed and setting has been built in strict accordance with the Bureau designs, previous plants having been modified to some extent to suit personal preferences of the owner or to meet local conditions.

COOPERATION WITH STATES IN NAVAL-STORES WORK

Educational and demonstration work in connection with the production and processing of naval stores was carried on by cooperative agents in Florida and Georgia.

In Florida 87 naval-stores operators were visited and assisted by the cooperative agent. Under his supervision, 16 new stills were built and 1 was repaired; 1 new still shed was built and 2 were remodeled according to the Bureau's plans; 8 turpentine separators and 6 dehydrators were built; 6 recording thermometers were installed; 1 leaking tail gate was adjusted; 2 sets of rosin strainers were constructed and 4 other strainers were improved. The cooperative agent inspected 2 still thermometers for accuracy, ran 23 demonstration charges, and taught 2 stillers the Bureau's method of regulating distillation by use of the thermometer and graduated receiver for distillate. He also exhibited the tentative standards for gum grading and demonstrated the method of gum grading to producers who sell gum and to processors with the idea of helping them blend gums for desired rosin grades.

In Georgia 151 visits were made to naval-stores producers by the cooperative agent. Under his supervision 11 still settings and 2 still sheds were built; and 17 turpentine separators, 2 dehydrators, and 2 still thermometers were installed. He inspected 9 still settings and 5 dehydrators as to performance and instructed 5 stillers in the Bureau's method of regulating distillation. Test charges were run and assistance was given in gum grading at 9 central stills. Clay and glass gum cups, to the number of 100 of each, were hung in the northern part of the State in connection with the experiments of the naval stores station on cups and for the special purpose of determining relative breakage from freezing.

NAVAL STORES STATISTICS

In compliance with the act of Congress, effective August 15, 1935, which authorizes the Secretary of Agriculture to collect and publish statistics on turpentine and rosin, 2 statistical reports were compiled and published. One gave statistics as of September 30, 1938, and

the other as of March 31, 1939, on production of turpentine and rosin of each class, stocks, exports, imports, and domestic consumption by industries. The first report was issued on November 15, 1938, and the second, on May 15, 1939. The further shortening of time between the closing dates of the statistical periods covered and dates of issuing reports has made the reports more valuable to the naval stores industry. Approximately 5,000 copies of each report, one covering the first half, and the other all of the last naval stores season, have been distributed in response to requests originating in this country and abroad.

FERTILIZER RESEARCH

The investigations in connection with fertilizers and fertilizer materials are primarily intended to promote efficiency in and reduce the cost of producing agricultural commodities by discovering and demonstrating how better and cheaper fertilizers can be made. Incidental to this practical objective, some of the studies on the chemical and physical properties of the numerous elements and compounds which enter into fertilizer manufacture, and on the chemical and biochemical reactions involved in converting elements and compounds into forms assimilable by plants, are exploratory in character and yield new and fundamental scientific knowledge which may be of value in other connections. Since it is equipped with the most up-to-date instruments and devices for physical, physicochemical, and biochemical research, and its personnel is experienced in their use, the Fertilizer Research Division is frequently called upon by other scientific units of this and other Departments to obtain by experiment needed scientific data which they are not prepared to obtain for themselves. A considerable part of this work, therefore, is in collaboration with other Government agencies.

MIXED FERTILIZER INVESTIGATIONS

A statistical study of the average annual crop yields by decades for the 70-year period from 1866 to 1935 for 10 of the principal crops grown in the United States showed that crop yields in the older or eastern part of the country are increasing rather than decreasing, and that the rate of increase is greatest in the section where most fertilizers are used. For the country as a whole, the average yields of all 10 crops increased to a maximum during the fourth, fifth, or sixth decade and then, with the exception of potatoes, decreased somewhat. This decrease, which was particularly marked in the case of corn, was apparently due in part to the upward trend in temperature and downward trend in rainfall for the United States as a whole during the period 1909–36, and in part to the expansion within the past 3 or 4 decades of cultivated areas into the drier and less-productive sections of the Western States.

Further evidence was obtained from experiments with a number of commercial mixed fertilizers that there is less danger of burning crops with most of the high-analysis fertilizers recently introduced than with the low-analysis types. For equivalent applications of plant food, the double-strength mixtures examined had an effect on the concentration of the soil solution that was either equal to or less

than that of the corresponding single-strength mixtures manufactured by the same company.

A complete chemical analysis of 44 representative samples of commercial mixed fertilizers showed that all contained significant quantities of the secondary plant-food elements, such as calcium, magnesium, sulfur, copper, manganese, boron, and zinc, in addition to the three primary plant-food elements—nitrogen, phosphorus, and potassium. Except in the cases of copper, zinc, and boron, the proportions of the secondary elements relative to primary elements was less in double-strength mixtures than in single-strength mixtures. However, the total quantity of secondary elements per ton of fertilizer was about the same in the 2 classes. The principal difference in composition between the 2 classes, other than percentages of nitrogen, phosphorus, and potassium, was the larger amount of acid-insoluble matter in many of the single-strength grades, indicating addition of inert filler in their manufacture.

The proportion of magnesium in high-analysis mixtures relative to the requirements of the average crop was found to be less, as a rule, than that of any other essential plant-food element. The quantities of magnesium and calcium in double-strength mixtures may be inadequate for some crops. Therefore, as much attention should be given to the content of calcium and magnesium as to that of the primary elements in the formulation of double-strength fertilizer mixtures.

Studies in cooperation with the American Society of Agronomy showed that the magnesium in dolomite is about 80-percent available to plants. Dolomite, therefore, may be used as a source of available magnesium in mixed fertilizers, as well as for correcting physiological acidity. Due to the varying reactivity of different-sized particles of the same dolomite, and also to the wide variation in particle size of dolomites similarly ground, it is not advisable to classify dolomites on the basis of the solubility of material ground to pass a screen of any given mesh. The use of such a method may lead to erroneous results.

A method and apparatus were devised and used for accelerating the caking of fertilizer materials and mixtures with a view to comparing their relative caking tendency. The data obtained showed that the tendency of sodium nitrate to cake exceeded that of any other material used in the tests when the moisture content was the same. The difference in the caking tendencies of different fertilizer mixtures was small in comparison with the caking range of fertilizer materials. Caking tendency increased with increase in moisture content up to a certain limit which varied with different materials.

In continued studies on granulation of fertilizer mixtures it was found that an increase in the proportion of an organic ammoniate increases the moisture required to granulate the mixture, thereby also increasing the cost of granulation. Readily soluble nitrogeneous materials, such as urea or ammonium nitrate, differ from the organic ammoniates in that they tend to decrease rather than increase the moisture required to granulate the mixtures in which they are included. It was found that den superphosphate can be granulated at a temperature of 80° C. within a few hours after the acidulation of the phosphate rock, and without any additional moisture.

A study of the granulation of miscellaneous fertilizer materials showed that plasticity and fineness of particle size, rather than content of soluble salts, determines the ease with which a material or mixture can be granulated by the rotary-drying method. The presence of a nonhygroscopic soluble salt in a granulated product tends, as a rule, to increase the hardness of the granule, but a soluble salt is not essential to the formation of fertilizer granules. Dicalcium phosphate, a finely divided water-insoluble material, granulates more readily than does ammonium sulfate or potassium chloride.

In a collaborative study of the official methods for the analysis of phosphatic materials, undertaken on the recommendation of the Association of Official Agricultural Chemists, it was found that slow washing of fertilizer mixtures of the ordinary type gives higher results for both water-soluble and citrate-insoluble P_2O_5 than does rapid washing, because of the formation of free phosphoric acid and fluorapatite by hydrolysis of the citrate-soluble phosphates present. Neither freshly prepared nor cured fluorine-free phosphate mixtures undergo any appreciable reversion during the process of analysis. Freshly prepared ammoniated mixtures that contain a soluble fluorine compound undergo a marked reversion in the process of analysis, but the reversion that occurs in cured ammoniated mixtures that contain fluorine is insignificant if each of the different steps in the process is completed within an hour. A comparison of the MacIntire-Shaw-Hardin method with the official method for determining available P_2O_5 showed that the former method gives higher results than are obtained with the official method in the analysis of basic phosphates, such as tricalcium phosphate, calcined phosphate, and highly ammoniated superphosphate.

POTASH FERTILIZER INVESTIGATIONS

The methods devised during the previous fiscal year for the determination of orthophosphate, pyrophosphate, and metaphosphate in mixtures were used in further studying the products obtained by the action of phosphoric acid on potassium chloride. Equimolecular mixtures of potassium and sodium chlorides heated to 500° and 600° C. with the equivalent phosphoric acid required to produce metaphosphates yielded glassy products soluble in water; under similar conditions but in the absence of sodium chloride, mixtures of phosphoric acid and potassium chloride are largely converted to insoluble potassium metaphosphate. By differential thermal analysis potassium metaphosphate was found to undergo endothermic transitions of 263°, 452°, and 649° before fusion at 807° C., that at the lowest temperature being the only one that was irreversible. As a result and with the exception of the soluble amorphous form produced in small amounts by extremely rapid cooling of the molten salt only insoluble modifications of potassium metaphosphate could be obtained with certainty. In contrast, sodium metaphosphate exhibited only two transitions before fusion, both irreversible; the first at 348° C. being endothermic and the second at 499° C. being exothermic. The modification occurring below the higher transition temperature was only slightly soluble in water, whereas the modification obtained above that temperature and also the glassy product resulting from fusion were both very soluble.

Crude potassium metaphosphate prepared by heating equimolecular mixtures of potassium chloride and phosphoric acid to 800° C. and exposed at room temperature to an atmosphere of 81 percent relative humidity was found to have absorbed only 2.7 percent of moisture and to be free flowing at the end of 30 days.

The reaction between solid dry potassium chloride and liquid nitrogen tetroxide was studied at room temperature under superimposed oxygen pressure of 200 and 1,000 pounds per square inch. The over-all reaction yields potassium nitrate, the desired product, together with chlorine but proceeds too slowly under these conditions to be of commercial interest. Introduction of moisture into the system intensifies the corrosion problem.

Further work was done on the utilization of hydrochloric acid for the production of available phosphates. In the preparation of crude monocalcium chlorophosphate by treating phosphate rock with hydrochloric and phosphoric acids, it was found that the major portion of the fluorine content of the rock was retained in the product, possibly as the analogous fluorophosphate. However, attempts to prepare the fluorine analogue of the chlorophosphate failed to give positive evidence of its existence. The conditions under which monocalcium chlorophosphate dissociates with formation of calcium pyrophosphate were determined by differential thermal analysis.

Crude potassium metaphosphate and monocalcium chlorophosphate were prepared in quantity and supplied to the Bureau of Plant Industry and to the State experiment stations of Idaho, Montana, and Wyoming for use in vegetative tests with several crops under varying climatic conditions on different soil types.

PHOSPHATE FERTILIZER INVESTIGATIONS

The chemistry of phosphates is one of the most complicated and imperfectly understood branches of fertilizer technology, and further progress in the production of cheaper and more efficient phosphatic fertilizers depends primarily upon the establishment of the fundamental relationships between the compounds present in the various systems involved in the production of available phosphates. Additional equipment for a high-temperature phase study of the system CaO-P_2O_5-SiO_2, which is of primary importance in the production of defluorinated phosphates (calcined phosphate and fused phosphate rock) and basic slag, was assembled and used. The investigation, thus far, has been confined largely to the region lying within a triangle with its base on the CaO-SiO_2 side between 35- and 65-percent SiO_2 and its apex at the point representing $Ca_2P_2O_7$ on the CaO-P_2O_5 side of the ternary diagram. Although melting points have been realized with certainty where the primary phase is a binary compound of CaO and SiO_2, considerable difficulty has been encountered deep in the ternary system, where the primary phase is, in general, a phosphate. The almost identical refractive indices of several of the phases makes their identification tedious and slow.

Although superphosphate has been manufactured on a large scale for nearly 100 years, many phases of the chemistry of the complex systems involved therein are still obscure. A complete knowledge of the chemistry of superphosphate will lead, no doubt, to improvements in the manufacturing process and will result in the farmer receiving a

better product at a lower cost. In continuation of the Bureau's investigations, which are producing valuable contributions to the technology of superphosphate, it was found that equilibrium systems obtained by mixing tricalcium phosphate and sulfuric or phosphoric acid afford a convenient reference basis for the graphical comparison of widely different superphosphates. The comparison is based primarily on the degree of acidulation, which is expressed quantitatively by a coefficient of acidulation or corrected acid-rock ratio and which takes into account the acid consumed by the aluminum and iron in the rock as well as the acid value of the fluorine. The results of this study point the way to (1) improved methods for estimating the acid requirements of phosphate rocks, (2) the prediction of the course of the curing processes in any given case, and (3) a favorable choice of conditions for the separate study of the several factors that affect the quality of superphosphates.

In continuation of investigations of the chemical composition of mineral phosphates, analyses of samples from deposits throughout the world showed the presence of 1 to 250 parts per million of acid-soluble arsenic expressed as the trioxide. With domestic materials, the smallest quantities (1 to 12 p. p. m.) were present in Virginia apatite and Florida hard-rock phosphate and the largest (40 to 120 p. p. m.) in phosphates from Arkansas, South Carolina, and certain sections of Montana.

Analyses of samples from cross sections of several phosphate deposits in Idaho and Utah showed that in a given deposit the fluorine contents of the different strata are usually closely related to the phosphoric oxide contents, and that the $F:P_2O_5$ ratios in the higher grades of rock are, in general, close to those previously found in similar grades from deposits in other sections of the country. Samples that contained less than 5 percent of P_2O_5 frequently showed exceptionally high $F:P_2O_5$ ratios.

Greenhouse pot experiments, in cooperation with the Bureau of Plant Industry and several State experiment stations, indicated that calcined phosphate (40-mesh or finer), fused phosphate rock (80-mesh), and the high-temperature form of calcium metaphosphate (80-mesh) are excellent sources of phosphorus for the growth of plants on acid and neutral soils, but give poor results when used on highly alkaline soils. For a given material, a much better correlation of the results of the various experiments was obtained when the fertilizing value of the phosphorus was reckoned on the basis of the increases in the dry weights of the harvested plants than when it was reckoned on the increase in the phosphorus contents thereof.

Because of the failure of phosphoric acid in the ordinary phosphatic fertilizer materials to penetrate soil to any considerable depth and the tendency of soluble phosphoric acid to be fixed by the soil colloids in a form that is largely unavailable to plants, further attention has been given to the comparative value of organic phosphates. It was found in experiments with two types of soil, that the rate of hydrolysis and conversion of sodium glycerolphosphate into an insoluble form increased greatly with temperature. At the highest temperature used (35° C.) all of the organic phosphate was hydrolyzed within 2 weeks and its behavior in the soil thereafter was similar to that of monopotassium phosphate. An extensive study is being made of the be-

havior of other organic phosphates in various soils under a variety of conditions with respect to concentration, sterility, temperature, and oxygen supply.

NITROGENOUS FERTILIZER MATERIALS

In recent years there has been increasing replacement of organic nitrogenous materials in fertilizer mixtures by inorganic and synthetic nitrogen products which cost less than half as much per unit of nitrogen. However, there is still a demand for less expensive organic nitrogenous material, the nitrogen of which will not be lost by leaching but will become gradually available for plant growth. With the object of supplying this demand, experiments were continued on the ammoniation of peat. Different kinds of peat, various preliminary treatments, and various conditions of ammoniation were tried. Of all the ammoniated-peat products prepared, the only ones containing insoluble nitrogen of fairly good reactivity and giving favorable results from nitrification and vegetative tests were prepared by ammoniating peat containing from 25 to 40 percent of moisture at a temperature of 130° C. and a pressure of 500 pounds per square inch. The products obtained from different kinds of peat were very similar under different treatment and the insoluble nitrogen in them showed practically the same activity.

Efforts to employ double compounds of urea and magnesium salts to ameliorate some of the objectionable properties of urea alone for use as a fertilizer resulted in the formation of several double compounds. The most promising of the compounds is $MgSo_4.5urea.2H_2O$, containing about 31 percent of nitrogen, 5 percent of magnesium, and 7 percent of sulfur. A simplified method of preparing this compound consists of heating a mixture of ordinary crystalline magnesium sulfate and urea in theoretical proportions to 60° C., whereupon it dissolves in the water of crystallization, and then adding sufficient alcohol to give a 10-percent alcoholic solution with the released water of crystallization. The double compound separates on cooling.

In efforts to prepare double compounds of urea and acids, no compounds were obtained with metaphosphoric acid but several were formed with organic acids, the most interesting being formyl urea. This unusual compound is formed by reacting urea and formic acid in unimolecular proportions. The formic acid radical attaches to one amide group in urea with elimination of water. The product is a white, finely crystalline compound, slightly soluble in water, containing 31.8 percent of nitrogen, and melting at about 165° C. It shows many desirable properties as a fertilizer material. It is not hygroscopic under ordinary conditions, like urea, and in an atmosphere of 90 percent relative humidity it remained unchanged for 24 hours. In the soil its nitrogen is converted to nitrate almost completely in about 4 weeks, thus giving positive evidence of its plant-food value.

A simple and inexpensive treatment was devised for urea crystals to reduce their tendency to cause caking when used in fertilizer mixtures. It consists of treating commercial crystalline urea containing a few percent of neutral powder with ammonia for a short time at room temperature, whereupon the crystals receive a firmly attached coating of the powder and are made granular and free flowing. The

treated urea will still absorb moisture from the air at high humidities, but on drying returns to the easy flowing, granular condition. The same treatment, with slight modifications, was found applicable also for improving the physical properties of inorganic nitrogen carriers, such as calcium nitrate, sodium nitrate, and ammonium nitrate.

BIOCHEMICAL NITROGEN FIXATION

In further studies dealing with the chemical mechanism of nitrogen fixation by the free-living bacterium *Azotobacter*, special attention was given to the catalytic role of molybdenum. Previous work had shown that the addition of a few parts per billion of this element to an ordinary culture medium commonly increases the fixation of nitrogen about twofold to fivefold. The experimental evidence indicated that molybdenum is essential for nitrogen fixation, but has little or no effect on the utilization of fixed-nitrogen compounds. Work carried on during the year showed even more strikingly the importance of this catalyst in the fixation process, a twentyfold effect being observed in some cases, but there were also indications that under some conditions and with certain types of combined nitrogen, traces of molybdenum hasten their utilization.

Further studies dealing with the mechanism of nitrogen fixation as it occurs in the root nodules of leguminous plants showed that the amount of available carbohydrate that reaches the roots is usually the chief, but not the only, factor that affects nodulation and nitrogen fixation. The inhibition of nodule growth produced by additions of nitrogenous fertilizers is due primarily to the lowering of the supply of carbohydrates to the roots. The carbohydrate-nitrogen ratio of the plant at any given time is of far less importance than the absolute quantity of carbohydrates available for use in nodule growth and nitrogen fixation. The laboratory studies showed that most of the carbohydrate is consumed in the growth of the nodule bacteria and host plant, and is not used to any extent in the fixation process itself apart from growth.

In studies on the metabolism of rhizobia, it was observed that the rate of respiration indicates rather definitely the degree of activity of the organisms. Nongrowing bacteria show a low rate of respiration, whereas the rate of respiration of growing organisms varies directly with the rate of growth. Coenzyme R, the growth factor essential for these bacteria, markedly increased respiration only under conditions where a subsequent growth stimulation occurred. This indicates that there is an interrelation between its effects on the two processes.

Two strains of rhizobia out of a total of 30 tested showed the ability to actively synthesize the growth substance, coenzyme R, and liberate it into the medium. Two other strains synthesized the substance in small amounts. Most rapidly growing rhizobia require additions of coenzyme R to the medium. These recent results are in agreement with previous conclusions as to the necessity of coenzyme R for the growth and respiration of these symbiotic nitrogen-fixing bacteria. Investigations were continued on the isolation and identification of coenzyme R. While it has not been identified, further information was obtained with regard to its properties.

Work was started on composting and closely related methods of converting farm wastes and other organic material into suitable artificial manures as supplements to animal manures and commercial fertilizers.

CATALYST AND HIGH-PRESSURE INVESTIGATIONS

Synthetic ammonia is the principal source of nitrogen in the manufacture of nitrogenous fertilizers. The synthesis of ammonia is effected through passage of a 3:1 hydrogen-nitrogen mixture compressed to several hundred atmospheres over a catalyst at elevated temperatures. The Fertilizer Research Division published a complete set of its own experimental data on the compressibility of four hydrogen-nitrogen mixtures at six temperatures from 0° to 300° C. and at pressures up to 1,000 atmospheres. In addition to the immediate utility of the pressure-volume-temperature relationships, a number of other physical properties such as high-pressure specific heats and expansion coefficients may be obtained by computation. This is being done in the laboratory and should assist in a more accurate control of the process of ammonia synthesis.

In the manufacture of hydrogen for the synthesis of ammonia, carbon dioxide often occurs as an undesirable impurity. It is removed by scrubbing with water under pressure. For this reason it is necessary to know what are the most advantageous conditions for this purification process. The solubility of carbon dioxide in water was measured at eight temperatures from 18° to 100° C. and at various pressures up to 700 atmospheres. It appears that beyond a critical pressure, which decreases with decreasing temperature, carbon dioxide and water are miscible in all proportions. When suitable equipment has been provided this phenomenon will be investigated further.

Research on the kinetics of ammonia synthesis was continued through an investigation of the reverse process, ammonia decomposition. A detailed study was made of the reaction over unpromoted, singly promoted, and doubly promoted iron catalysts. Throughout the range of temperatures used—335° to 430° C.—and with hydrogen-ammonia ratios ranging from 3:1 to 7:1, the rate of decomposition over the doubly promoted catalyst (1.3 percent of Al_2O_3 and 1.6 percent of K_2O) was directly proportional to approximately the 0.7 power of the ammonia partial pressure and inversely proportional to the 0.8 power of the hydrogen partial pressure. The apparent energy of activation throughout the entire range is 43,500 calories. No such regularity was found in the mechanism of the decomposition over the singly promoted catalyst (10.2 percent of Al_2O_3). The dependence of the rate upon the ammonia and the hydrogen partial pressures varied widely with temperature and gas composition. In certain regions the usual kinetics were even reversed, the rate becoming directly proportional to some power of the hydrogen partial pressure and inversely proportional to the ammonia pressure. The apparent energy of activation was very small—in an extreme case even negative. The mechanism of ammonia decomposition over the pure iron catalyst was similar to that over the singly promoted catalyst. The reversed kinetics over the singly promoted and pure iron catalysts is believed to be due to the action of a complex, possi-

bly a nitride, an imide, or an amide which forms and decomposes on the surfaces of the catalysts, depending upon the conditions of temperature and gas concentration.

In the investigation of the chemisorption of gases on iron synthetic-ammonia catalysts, definite proof was found for the first time that the adsorbed nitrogen, hydrogen, and oxygen are in atomic form, whereas the adsorbed carbon monoxide and carbon dioxide are molecular.

Through collaboration of two Bureau scientists with one on a university faculty, a theory has been completed for explaining under one general equation all of the five different types of Van der Waals' adsorption isotherms that are found in scientific literature. This equation permits an evaluation of the surface area of the adsorbent, the average pore diameter in the adsorbent, and the heat of adsorption of the gas in the first and last layers.

FUNDAMENTAL INVESTIGATIONS RELATING TO FERTILIZERS

A method was developed for the quantitative spectroscopic analysis of mixed fertilizer materials for certain important minor-element constituents. These elements are copper, manganese, boron, and zinc. Spectroscopic analyses for the first three of these elements have already given very satisfactory results on more than a dozen mixed fertilizers for which chemical analyses were also available. A rotational spectrum analysis was completed which identifies ultraviolet bands of nitrogen (the so-called A–X bands) as actually belonging to the nitrogen molecule.

From analysis of the experimental measurements of infrared absorption bands arising from the presence of the OH group in several organic molecules, it was concluded that, as a general phenomenon, the OH group, and probably also the NH and CH groups, may exist in more than one stable position of orientation in the molecule, which results in isomeric forms of the molecule differing from one another by the orientation of the group. The work of measuring the thermodynamic quantities pertaining to the nitrous acid equilibrium by means of infrared absorption has progressed and has led to the discovery of what appears to be a new continuous absorption characteristic of one of the components of the system $NO–NO_2–H_2O$. The molecule which is responsible for this absorption will undoubtedly be identified. Nitrogen trioxide and a dimer of nitrous acid both seem to be possibilities at the present stage of the work. Many important and unknown chemical data on this system, which is significant in the production of nitric acid and in nitrogen chemistry generally, can be obtained by studies of absorption in the near infrared.

Methods depending upon differential thermal analysis, X-ray diffraction, and chemical analysis have been devised that are adequate for approximate mineral analysis of clays. Mineralogical information on clay minerals including the micas has been very fragmentary. Structures and causes for polymorphism of the kaolins have now been worked out. A century-old argument has been settled in showing by extensive X-ray-diffraction work that mica exists in many forms, one of which is hexagonal; others belong to the monoclinic

and triclinic crystal systems. This work on micas is particularly important since they are the greatest storehouse of potassium in the soil and methods for making this supply available as a fertilizer will depend upon a knowledge of the way in which the mineral weathers. Results obtained are of fundamental value in that they give an insight into the way in which crystals are built up.

A thermal diffusion method was developed for the separation of gases having different masses and for the separation of isotopes. It works on an entirely new principle involving the diffusion of gases between contiguous streams of gases heated to different temperatures. Special apparatus for carrying out the method was constructed and operated successfully. The results indicated the method to be cheaper and more efficient than any other method now used for the same purpose. The new method can be used for commercial production of gases enriched in certain isotopes which are in demand for the investigation of biological and chemical processes.

CHEMICAL ENGINEERING RESEARCH

AGRICULTURAL FIRES

Field investigations were conducted on a number of selected farms on the Eastern Shore of Maryland and in Chester County, Pa., for the purpose of observing haying practices, types of barns, and the moisture content and heating tendencies of the hay stored. The general practice, in the sections visited, of leaving cut hay in the swath until almost cured does not give as high quality of hay, especially in the case of alfalfa, as when the side-delivery rake is used within a few hours after cutting, but it does lessen handling and reduces shattering to some extent when sudden rains occur before the down hay has cured. The length of cut of chopped hay is very important because it affects the keeping quality of the hay when stored in barns and other containers. Unless the chopped hay is unusually well cured, a cut of 1½ to 2 inches is more desirable than the customary cut of ¾ to 1 inch. The shorter cut results in a denser mass which is difficult to aerate. The old type of bank barn, with the hay compartments extending to the ground level and the lower 8 or 10 feet of the compartments enclosed by solid masonry, appears to be conducive to severe self-heating of the hay in this section of the mow because of lack of aeration and decreased dissipation of the heat produced within the mass.

During the course of the haying period, 31 samples of hay were collected and moisture determinations were made on them in the field, using the distillation method. Included in the collection were red clover, barley, alfalfa, timothy, whitetop, and soybean hays. Investigations were made on both chopped and unchopped hays in storage. The maximum temperature recorded was 58° C. (104.5° F.), in chopped barley hay having a moisture content of 41 percent, 2 days after the hay was stored. The farmer who put up this hay realized that it had not been sufficiently cured and insisted upon having it pitched out on the second day after storage for further curing. On all the farms revisited it was found that the hay had come through the heating or sweating stage in good condition. The results of these field investiga-

tions apparently confirm the findings of previous experiments conducted by the Bureau at Beltsville, Md., namely, that the moisture range for the safe storage of unchopped hay, consistent with good quality, is 25 to 30 percent, while that for chopped hay is 20 to 25 percent. In the latter case the shorter the cut, the lower the moisture content should be for the same quality of the cured hay. Unchopped red clover hay apparently can be safely stored with a moisture content somewhat higher than that for unchopped alfalfa hay.

The results of previous investigation had shown that when undercured alfalfa hay is heated in an inert atmosphere (nitrogen) at a temperature slightly above the limits of bacterial activity, some change occurs which increases the oxygen-absorbing property of the hay. Recent results have confirmed the previous findings. It has been found further that the oxygen absorption increases with increase in time of preheating. The conclusion seems warranted that, in haymows where conditions are favorable to prolonged maintenance of temperatures above normal, the changes that render the hay susceptible to very rapid oxidation and ignition may be due to thermal decomposition. Preliminary experiments in the laboratory indicated that the presence of ammonia also increases oxygen absorption in alfalfa hay.

Experiments with a commercial rat poison indicated that the phosphorus contained therein involves a considerable fire hazard when in contact with a combustible material such as hay or chaff, particularly when moist. A smouldering fire in a barn in Vermont had evidently been caused by contact of this rat poison with chaff which became wet during the night from rain through a leaky roof.

Two members of the chemical engineering staff made a field trip to Texas and other Southern States in order to obtain information on the susceptibility of cottonseed to spontaneous heating and ignition and to ascertain the present situation with respect to cotton-gin fires. The consensus of opinions held by cottonseed-oil mill operators and others appears to be that stored seed having a moisture content of 10 to 12 percent or more will heat dangerously. Specific information was obtained concerning two cases of smouldering and fire in stored cottonseed which definitely indicated that the cause was spontaneous heating and ignition. Investigation was made of two systems for aerating stored cottonseed. One system, employing numerous vertical, triangular-shaped, wooden flues resting on a crackboard floor and extending above the top of the pile of seed was used for naturally aerating relatively small piles of seed. The other system, employing a fan connected to horizontal main ducts with numerous horizontal laterals reposing on the floor level, was used for aerating large quantities of seed. Investigations were conducted at selected cotton gins in north and west Texas and in Mississippi. Conferences were held with numerous officials in regard to cotton-gin fires. Static electricity, matches, and foreign material in the cotton, and friction produced by cotton stuck in the ginning equipment appear to be the main causes of fires in cotton gins. Fire-packed gin bales continue to constitute a serious fire hazard. The modern cotton-gin plant represents a marked advance in design and construction. The building has only one floor level, and is of all-metal construction with a concrete floor. The ginning equipment also is all

metal, and provision is made for artificially drying green, damp, or wet cotton. However, the old-type wooden gin plant predominates throughout the Cotton Belt and will continue to do so for a long period.

In the all-steel gin plant there is still the possibility of considerable damage being done to machinery by warping of metal in case of fire within the equipment during ginning operations. Static electricity creates a fire hazard in cotton gins in two ways: (1) By direct ignition, and (2) by causing the fibers to stand out and be separated so that they are more readily ignited by other sources of ignition. The two factors chiefly responsible for the generation of electrostatic charges in gin plants are climatic conditions, especially when the relative humidity is 40 percent or less, and dirty seed cotton. This dirt in cotton is apt to be chiefly sand and other inorganic material picked up from dust-laden air.

A member of the chemical engineering staff conferred with staff members of agricultural experiment stations and with manufacturers of farm structures on the development of new-type barns for chopped hay, separate and apart from barns for housing livestock. Conferences were held with members of the Industrial Commission of Wisconsin and of the Underwriters' Laboratories on rural fire apparatus, lightning-protection systems, rural electric wiring, and electric fences. The use of a tank truck holding several hundred gallons of water (generally 500) is spreading among rural fire departments in Wisconsin and several other Middle Western States.

The literature on fires in raw and refined sugar has been reviewed and a program has been formulated to be undertaken by a special committee on the investigation of fires in this material which are thought to have been caused by spontaneous ignition.

Members of the Bureau's chemical engineering staff cooperated with organizations interested in fire protection by participating in conferences and meetings, and in the work of committees on which they held membership. These organizations included the National Fire Protection Association, the national fire waste council of the Chamber of Commerce of the United States, the American Society of Agricultural Engineers, and the National Safety Council.

DUST EXPLOSIONS

Thirteen major explosions in industrial plants, involving dusts from agricultural materials, were investigated by the Bureau. Nine of these were caused by grain dust, 2 by malt dust, and 1 each was caused by dusts of fertilizer and gluten meal. These explosions resulted in the death of 10 men, injury to 32, and property damage amounting to about $3,927,000.

The outstanding dust-explosion loss of the year and, in fact, the largest or second largest loss of this kind on record, occurred on May 11, 1939, in Chicago when 5 large grain elevators were destroyed. In this explosion 9 men were killed, 30 were injured, and the property loss was $3,500,000. With the exception of this major explosion, there was only 1 loss during the year which exceeded $100,000, indicating that many of the industries subject to the dust-explosion hazard have succeeded in segregating the more hazardous units in

their plants or have provided means of releasing explosion pressure before it builds up to the point where structural damage occurs. For some time it has been realized that grain-handling plants require special attention in providing protection against dust explosions. In new plants it has been possible to install safeguards against explosions and fires, but there are still many grain-handling plants in the country similar to the elevators destroyed with such a heavy loss at Chicago. These plants of frame construction are quickly enveloped in flames when an explosion occurs and the fire is frequently beyond control before firemen reach the scene.

Laboratory studies were continued on the effect of particle size on the explosibility of dust. The air elutriator is being used to obtain samples of dust of very small particle size for testing in the explosibility apparatus. Fractionation of cellulose has been carried on in this series of tests, yielding three fractions finer than any previously obtained with screens in the course of this work.

The abstract literature on dust explosions has been reviewed and summarized from 1926 to recent date. A search of technical and trade literature has also been made for instances of explosions in the handling of carbon disulfide, commonly used for killing weevils in grain.

Forty-seven samples of dust were tested in the laboratory for explosibility. The following materials were found to form explosive mixtures with air: Fertilizer dust, walnut-shell flour, synthetic resins of two types, cocoa, malt dust, carbon, pitch dust, zinc stearate, accumulated dust (mostly zinc stearate and aluminum stearate), dried blood, alfalfa meal, sawdust-sand mixture (floor-sweeping compound), insecticide mixtures containing walnut-shell flour, derris, and wheat flour.

The results of the Bureau's work on prevention of dust explosions were presented at firemen's training schools and conventions of firemen's associations and at meetings of various other organizations.

In connection with their work on dust-explosion prevention, members of the chemical engineering staff cooperated with national organizations by participating in the work of committees on which they held membership. The dust explosion hazards committee of the National Fire Protection Association, of which the Chief of the Chemical Engineering Research Division is chairman, was assisted in the preparation of safety codes for the prevention of dust explosions in sulfur plants and aluminum manufacturing plants. The same organization was also assisted in the preparation of a safety code covering the installation and operation of air-conditioning systems and blower and exhaust systems for the handling of dust, stock, and vapor. The American Standards Association was assisted in the preparation of a code for the safe installation and operation of different types of conveyors. The Chief of the Chemical Engineering Research Division, as vice president of the National Fire Protection Association, assisted in the preparation of programs and the outlining of projects designed to reduce fire and explosion losses. Conferences were held with representatives of companies interested in fire and explosion prevention concerning the development of devices or equipment to provide protection against these hazards. The total number of publications and addresses on dust explosions and related subjects was 18.

SERVICE WORK

The Chemical Engineering Research Division served as the contact between the Plans and Service Division and the regional research laboratories organization in the preparation of drawings and specifications for the four regional laboratories. Considerable preliminary work had to be done before working drawings and specifications could be prepared for the buildings. Two members of the Division made a comprehensive survey of eight large industrial research laboratories for the purpose of studying features of design and construction, facilities, and equipment. Many of the features decided upon for the regional laboratories were previously incorporated in the plans for the three departmental laboratories being erected at the Agricultural Research Center at Beltsville, Md. This afforded an opportunity to give the model chemical laboratory layout further study in its application to a modern air-conditioned laboratory building. Standard laboratory equipment was designed for the regional laboratories which will also be used for the departmental laboratories at Beltsville.

Particular attention was given to the design of the fume hood, whereby used air from the air-conditioning system will be delivered to the hood, instead of drawing conditioned air from the room. Each hood will operate independently from all others. Tests were made with a working model to be assured of satisfactory air flow and operation. Occasional tests were made of materials for the purpose of selecting a particular material of construction for resistance to definite exposures. Small-scale and occasional full-scale models were developed to facilitate decisions. A fund of information, to be drawn upon in the planning work, was assembled by contacts with industrial concerns.

Plans and estimates were made and specifications written for all the principal items of the mechanical shops. Equipment lay-outs were also developed for the library, chemical stockroom, mechanical stores, and general services for the laboratories.

The pilot-plant wing of each laboratory was given a great amount of study. The proposed industrial-alcohol unit for the Northern Regional Laboratory was discussed with those interested and preliminary sketch plans were twice prepared in order to include certain features and rearrangements of equipment.

Most of the divisions of the Bureau were assisted by the preparation of designs and specifications for laboratory equipment and by drafting work, including graphs, charts, diagrams, drawings, curves, signs, and lettering. The regular quarterly fire inspections of the Bureau offices, laboratories, and storage spaces were made by members of the Division.

ARCHITECTURAL AND ENGINEERING SERVICE WORK

The principal activity of the Division of Plans and Service concerned plans for the four regional research laboratories, establishment and organization of which are discussed elsewhere in this report. On the basis of needs established by the Special Committee on Regional Laboratory Plans and Specifications, this Division prepared detailed plans and specifications after first studying with the

scientists the physical factors determining the actual architectural and engineering designs. Among the factors evaluated in this study were: (1) The type of architecture that would most suitably express and house the research functions of the laboratory and which would at the same time meet the local conditions, accommodate itself to the physical requirements of the building, and harmonize with the architectural atmosphere of the particular locality in which the laboratory is located. (2) The foundation conditions including the type of soil encountered; its bearing value; the subsurface water conditions; the presence of rock or the need for pile foundations or the need to provide against stresses due to earthquakes. (3) The determination of the available supplies of water, together with its chemical analysis and available pressure; the supply of gas, together with its British thermal unit content and available volume and pressure; the sewer capacity for storm and sanitary drainage, together with the present flow, the probable future flow and the available surplus capacity to accommodate the laboratory; the available supply of electric power including the voltage at which most economical metering could be supplied; the available railroad or other delivery for fuel and the topography of the site upon which the building would rest. (4) The probable demand by the laboratory for steam at various pressures; for vacuum; for compressed air; for gas; for hot water; for cold water; for distilled water; for soft water; for electricity at a number of different voltages, amperages, cycles, and phases in alternating current and direct current. (5) The climatic conditions by which would be determined steam requirements for heating and hot water, refrigeration, and ventilation requirements for air conditioning. (6) The orientation of the buildings from which to determine the sun load of heat and the prevailing wind directions by which to design suitable zone controls of heating and air conditioning. (7) The preparation of suitable budgetary estimates of costs by which to control the costs of the design.

The actual design of the 4 laboratories required the services of a force of 170 architects and engineers of various kinds, estimators, draftsmen, and assistants. The architectural force included men talented in the field of design for architectural appearance and for creative design, delineation, and the preparation of suitable renderings by which to coordinate all the factors entering into the general design composition. There were also among the architects those skilled in the practical details of construction, those experienced in the selection of materials and methods of workmanship, and the preparation of suitable specifications, delineating such materials and workmanship so as to keep costs within prescribed limits. The structural engineers were required to meet foundation requirements varying from a soft marsh requiring the use of long piles to bedrock requiring blasting in order to obtain suitable bearing value to support the building. The site engineers determined the availability, location, and accessibility of all utilities including electricity, storm and sanitary sewers, water supply, telephone, gas, and fuel, as well as the configuration of the land upon which the building rests. They were required also to prepare drawings indicating suitable grades and slopes around the building, together with roads and walks for

access to the building and suitable parking areas. The mechanical engineers produced designs covering illumination, electric wiring, transformers and electric substations, power plants, refrigeration, sanitation, water purification, heating, and air conditioning.

In the design of the heating and air conditioning, it was determined to be economical to use double windows with heat-resistant glass where exposed to the direct rays of the sun and insulation against the exterior walls and the ceiling of the upper floor. In the design of the air conditioning a special condition is encountered in the laboratory rooms because of the use of at least one fume hood in each laboratory room. In order to reduce operation costs the design of the ventilation system provided that the usual quantity of discharged air, replaced by a like quantity of fresh air taken in from the outside, should be used to ventilate the fume hoods and remove from them all noxious gases and odors. This is accomplished by an ingenuous arrangement of ducts, automatic dampers, and fans which supply an exact amount of fresh air to each fume hood regardless of how many or how few of them may be in operation at a time.

There will be about 15 acres of usable floor space in the four laboratory buildings, and about 5 acres of roof. There will be about an acre of windows to furnish outside light to the buildings, which will involve the use of about one-half acre of heat-resistant glass and about 1½ acres of window glass. The foundations of the southern laboratory require the use of about 30 miles of wood piles. The design of the western laboratory requires the use of special reinforced poured concrete construction for exterior and cross walls and floor and roof slabs to insure that the building will withstand earthquakes.

In addition to the design of the regional laboratories, the work included a large amount of design work covering buildings of many different kinds and classes in a number of different sections of the United States. A list of the more than 100 jobs handled would occupy more space than can be given in this report. The estimated total cost of these projects for design and construction, including the 4 regional laboratories, amounted to a little less than $15,000,000.

Included in the buildings designed, of particular interest are a film-storage vault for the storage of inflammable moving-picture film, departmental laboratories at the Agricultural Research Center, and greenhouses and palm house at the horticultural station at Beltsville affording approximately a quarter of a million square feet of greenhouse space, as well as numerous projects covering the many phases of architecture and structural, site, sanitary, plumbing, heating, air-conditioning, and refrigeration engineering. Of special interest is the $500,000 plant-quarantine building at Hoboken, N. J.

FARM-STRUCTURES RESEARCH

Research directed toward the improvement and economy of farm structures and equipment covered a variety of activities principally related to problems of farmhouse design and remodeling; storage of small grain, corn, and potatoes; design of silos for holding grass

silage; design and operation of orchard heaters; problems in the transportation of farm products; and investigation of various factors in livestock shelters.

FARMHOUSES

That the study of farmhouse problems is of high importance is indicated by estimates that there are about 7¼ million farmhouses in the country, valued at more than $7,000,000,000, or about 15 percent of the value of all farm real estate. Surveys have indicated that in general farmhouses are much below desirable standards, that hundreds of thousands are in need of replacement, and a high percentage are in need of repairs and remodeling. That there is much interest in the problems of building and remodeling farmhouses is shown by the fact that nearly 90,000 requests were made for one or the other of 2 Farmers' Bulletins, 1738, Farmhouse Plans, and 1749, Modernizing Farmhouses.

In addition to its work of preparing publications and answering direct inquiries the Bureau is carrying on 2 research projects on various problems of design and construction of farmhouses, 1 under northern conditions in cooperation with the University of Wisconsin, and 1 under southern conditions in cooperation with the University of Georgia. The object of the Wisconsin work is to find out what improvements in their houses farm families find most worth while and how they may best utilize their own resources in getting them. The studies were begun in the houses of farmers who were planning to make improvements, and continued during and after construction. Descriptions of the manner in which this research is carried on have appeared in previous annual reports of the former Bureau of Agricultural Engineering. The results of the work cover so far a total of 10 old houses, 6 houses after remodeling, and 2 new houses. In each case the owners of new or remodeled houses are well satisfied with the planning and the innovations in use of material and equipment. Experience to date has shown that the method followed is one of the most direct and reliable ways of solving many of the farm-housing problems. It enables the cooperating owners to carry out the improvement work under expert direction. The finished houses serve to stimulate a large amount of repairing and remodeling of other farmhouses in the locality.

At the University of Georgia, engineers of the Bureau and the university have constructed eight small test houses, representing different types of construction using various materials common to the South. The foremost factors for consideration in this work are comfort, durability, and economy. The tests so far have led to a number of important conclusions regarding the maintenance of summer comfort in southern farmhouses. Among these conclusions are:

(1) Contrary to prevailing opinion in the region, houses with high ceilings as customarily built do not appear to be any more comfortable in summer than those with ceilings of average height. This suggests the possibility of lower cost without sacrifice of comfort.

(2) Loosely constructed houses which permit considerable air movement within the walls, over the ceilings, and under the floors are generally more comfortable in summer than those tightly constructed,

but are decidedly more uncomfortable in winter even when using excessive amounts of fuel.

(3) Ceiling insulation of tightly constructed houses aids in keeping out solar heat, but this advantage is offset to some extent by the fact that heat from cooking is kept in unless ample ventilation is provided.

(4) Ordinary gable ventilators in the attic were found relatively ineffective and indications are that better means of ventilating houses must be devised if summer comfort is to be much improved.

Cottonseed hulls, a widely available waste product in the South, were used successfully in these houses for insulation. The hulls were made fire-resistant by a simple treatment which farmers could apply at low cost.

The various tests on the experimental houses during the winter show the value of simple, economical precautions in improving comfort and reducing fuel consumption. For example, calking of a loosely constructed house to approximate the effect of building paper in the walls and weather-stripping resulted in fuel savings of 15 to 45 percent. Closing up the spaces between the supporting piers of some of these houses reduced the heat loss through the floors and, together with calking, saved as much as 60 percent of the fuel.

The problem of building a house that will be as satisfactory in winter as in summer, without resorting to mechanical cooling in summer, has not yet been solved. The investigators commented that none of the standard methods of construction appear to be entirely satisfactory. It seems likely, however, that a type that permits air movement under the floor and in the wall and attic spaces in the summer but shuts this off during winter can be designed and will improve farmhouse comfort in the South to a considerable extent. Materials used in the construction of these test houses were selected with such qualities in mind as fire resistance, durability, and resistance to the attack of insects and rodents. Those materials include ordinary type of lumber construction; precast-concrete slabs for walls, sills, piers, and steps; metal as wall and roof covering; and stucco on metal lath that has been back-plastered to form a wall. The primary difficulty has been to meet the requirements of low cost, but it looks as if a number of these types of construction can be used satisfactorily and economically, since much of the work can be done with farm labor.

During the coming year studies will be made on various other methods of house and attic ventilation, and it is proposed to make studies in a limited number of occupied farmhouses which will be improved by the owners as a means of more thoroughly investigating various other aspects of farmhouse planning and construction.

APPLE STORAGE

Modern trends of motor transportation have introduced several new problems relating to apple storage on the farm. At present most farm storages are air-cooled storages which give only moderate success unless properly located as to climate and efficiently operated.

Studies have been made in Virginia and a manuscript for a bulletin prepared showing existing practices and giving suggestions for improvement of structures and methods of management.

POTATO STORAGE

Following the research on potato storages in Maine, which was productive of improved design from the standpoints of saving potatoes and of the durability of the structure itself, work of a similar nature has been carried on in Michigan and North Dakota and further studies will be made in Nebraska the coming year. The work in North Dakota has been continued, but the Michigan studies are practically over except for periodical inspections of storages that were designed or remodeled in connection with this project. As a result of the Michigan work, storages incorporating principles of moisture control have been designed and plans are being made available to farmers. Because of the great variation in acreage of potatoes on individual farms in that region and because most of the potatoes grown there are stored on farms, a large range of sizes of storage houses has been provided in the designs. These recent studies have brought out ways of controlling condensation of moisture on ceilings. It was found for example that in bank storages humidity can be controlled by permitting condensation on the ceiling and disposing of the condensed water.

Box storage of potatoes resulted in less shrinkage and a higher grade of potatoes than bulk storage, but the cost of boxes tended to offset the advantage. The common practice of grading potatoes at the time they are put into storage was found less desirable than storing the potatoes without grading. Handling the potatoes in grading operations apparently produced injuries that caused deterioration.

SILAGE-PRESSURE STUDIES

Because of the rapidly increasing use of green crops other than corn for silage, studies of side-wall pressures exerted by different kinds of silage under varying conditions have been carried on by the Bureau in cooperation with the New Jersey Agricultural Experiment Station. The evidence collected shows that grass silage may exert considerably greater pressure than corn silage. Analysis of the data shows that the pressure on the silo walls is affected by moisture content of the silage and the diameter of the silo as well as by type of silage and the depth to which the silo is filled, but further studies are needed to provide a fully satisfactory basis for safe and economical design.

In handling green hay and grass silage excess juice is often a problem resulting in leakage through the silo walls with accompanying odor, mud, unsightliness, and probable deterioration. In two tests, drains placed through the foundation of the wall were effective in carrying away much of the excess juice from hay and molasses silage and from hay and acid silage.

CORN STORAGE

Experimental work on corn storage was carried on at Ames, Iowa, Urbana, Ill., and at the Arlington Experiment Farm in Virginia. This work was closely coordinated with a survey of corn storage on farms, under an allotment from the Bankhead-Jones special research fund, in the principal corn-growing States. These coordinated studies were planned to be as helpful as possible to the Agricultural Adjust-

ment Administration and Commodity Credit Corporation in the corn-loan program, as well as to help solve farmers' corn-storage problems.

The tests at Ames covered more than 20 types of storages for ear corn. While the 1938 corn crop was one of the driest on record and no critical storage conditions occurred, investigators obtained valuable information on structural and ventilation characteristics from various cribs. Similar tests on 8 cribs were made at Urbana. Where samples were taken from a crib with an ear-corn probe made of ¾-inch pipe the corn around the opening made by the probe dried faster than that in the rest of the crib. A test was carried out by making many probe openings in an entire crib. The improvement in rate of drying was encouraging and indicated that this method may be of value in soft-corn years. The 3 corn crops since this storage study was started have been above average in quality and there has been no opportunity to study soft or frosted corn which constitutes the most serious problem in corn storage.

A relatively new development in farm storage of corn was the shelling of ear corn at the end of the first year and storing in tight bins, which results in economy of space and protection against damage by rats and mice, and affords opportunity to fumigate for protection against insects. The Bureau studied this practice and believes it to be sound provided certain safeguards as to moisture content of grain and bin construction are observed. The Commodity Credit Corporation recently ordered about 41,000 bins for such storage.

A research project is under way to determine safe dimensions and ventilation requirements for corn-storage structures in various localities. Information of this kind is of basic importance in determining the eligibility of farm storages for Government loans. To this end weather data are being analyzed, many cribs in different localities have been sampled periodically, and large numbers of ears of corn of different varieties, sizes, and degrees of maturity have been weighed to determine the effect of weather on the rate of drying and moisture content throughout the storage season.

The Weather Bureau provided much detailed information on temperatures and vapor pressures. The investigators are relating this information to the corn-moisture and drying rates observed in field and laboratory studies and the combined information will be used to lay out more accurate geographical zones on a basis of desirable widths and ventilation requirements for corncribs. These more accurate designations will be of particular value in years when the corn crop is not well matured since cribs of proper width for the locality provide the most economical safe storage.

A special survey of corn storage on farms covering 6 counties in Iowa, Minnesota, and Indiana was conducted during September and October 1938, and included 294 cribs containing corn of the 1937 crop under an allotment of Bankhead-Jones special research fund. The information was furnished the Agricultural Adjustment Administration for use in setting up storage regulations for loans on the 1938 crop. Further studies were made on corn of the 1938 harvest and some held-over ear corn and shelled corn of the 1937 harvest in 11 selected counties in Iowa, Minnesota, Illinois, and Indiana. In most of the counties corn was much drier than usual and there was less than the

ordinary amount of loss due to moisture. However, there was a large amount of damage to ear corn by rats and mice and some damage by insects in all of the counties studied.

The 1937 shelled corn, which went into storage in good condition, suffered practically no damage. The surface layer of corn in some cases took up more than 4 percent of moisture during the winter but soon dried out again with the coming of warm weather.

WHEAT STORAGE

The studies of wheat storage under the Bankhead-Jones special research fund were continued.

The wheat-handling problem differs markedly from that of handling corn in that practically all the wheat leaves the farm as such, whereas most of the corn is fed on the farm. However, a considerable part of every wheat crop is stored on the farm temporarily and under crop-adjustment procedure reserves will be carried on the farm for a longer period, as, for instance, in 1938 when about 40,000,000 bushels were sealed in farm storages under the ever-normal-granary program. These new conditions in the handling of wheat emphasize a need for better storage and for means of artificial drying adapted for farm use.

The fact that the Bureau now has in storage wheat from a number of crops, including those of all years from 1935 to 1939, most of it in good condition, indicates the practicability of season-to-season storage on the farm when suitable wheat and the right type of bins are available.

Information gained in the early part of the storage investigations formed the substance of a bulletin issued by the Agricultural Adjustment Administration, Wheat Storage in the Ever-Normal Granary. Circular 544, Methods of Ventilating Wheat in Farm Storage, contains information on the advantages and limitations of ventilation in wheat storages on the farm.

Two experimental wheat driers were built and tested during the past year in drying newly harvested wheat on farms. One of these when handling 100 bushels per hour removed from 1½ to 2½ percent of moisture from new wheat that had a moisture content range from 14.75 to 17.25 percent. Fuel costs for both drying and the mechanical operation of the machine ranged from one-fourth to one-half cent per bushel for each percent of moisture removed. The machine was designed especially for handling wheat which cannot be stored safely because it has 1 or 2 percent of moisture above the safe maximum.

The other drier which was built in cooperation with the University of Maryland is so designed that the amount of moisture removed is determined by the time the grain is left in the machine. Decreasing the capacity in bushels per hour increases the percent of moisture removed. For example, when wheat of 18.9-percent moisture went through the machine at the rate of 24 bushels per hour 7 percent of moisture was removed. When the rate was stepped up to 40 bushels with wheat of 19.5-percent moisture, the moisture content was reduced 4.1 percent. In general with this machine wheat containing too much moisture for safe storage can be reduced to 13-percent moisture content at rates of from 25 to 100 bushels an hour. The same machine

has been used successfully in drying seed barley which had been treated for smut by the hot-water method. These machines work satisfactorily, but simplification is needed to cut their initial cost.

GRAIN SORGHUM STORAGE

Because most of the grain sorghum is harvested in the late fall when its moisture content is often above 13 percent, farmers generally consider this crop harder to store than wheat. In an attempt to overcome some of the difficulties, the Bureau, with money provided from the Bankhead-Jones special research fund, carried on storage studies with experimental bins and made surveys on farm storages and collected experiences of farmers. Sixty farms were visited and records made of the condition of the grain in March and again in June.

Since the 1938 crop was harvested under unusually dry weather conditions, practically all of the sorghum had less than 13 percent of moisture. Little change in this respect occurred between March and June. Samples from bins as much as 4 years old substantiated farmers' claims that grain sorghum stored in a dry condition offers no unusual storage difficulties in comparison with wheat. The more cautious farmers use corn binders for harvesting and thresh after the grain has become sufficiently dry. However, farmers who use combines and harvest only when the grain is dry experience little difficulty with moisture in the stored grain.

Where there is insufficient storage space the sorghum is often headed and the heads are stored outside in ricks, but the survey showed that by June there was severe weevil infestation in the grain so stored and practically no damage to that stored inside. The grain stored outside or in loosely constructed barns was also badly contaminated by dust in areas where dust storms had occurred. The investigators concluded that outside storage should be considered at best only a temporary expedient, and recommend threshing as soon as moisture conditions permit and placing the grain in bins. Fumigation is not commonly practiced, but the survey indicates it is generally necessary for successful long-time storage.

In addition to the surveys, 2,200 bushels of sorghum was stored in experimental bins and periodic observations were made on the condition of the grain.

Two types of bins using the force of wind to produce ventilation gave good results in drying grain sorghum and are economical in construction. With an initial moisture content of 13.9 percent, one type resulted in a reduction of 2 percent and the other a reduction of 3 percent of moisture. No drying occurred in a tight bin of similar grain.

ORCHARD HEATERS

Heating of citrus orchards in California has been done mostly with oil burners of the so-called vaporizing or distilling types which have not proved entirely satisfactory because of excessive smoke production when cold weather requires the burning of large amounts of fuel. During such a period in the winter of 1937, smoke caused much damage to household goods and even became a menace to health and traffic. Starting out with extensive experience acquired in studies of other oil-burning heating equipment, Bureau engineers

built experimental atomizing-type burners for the burning of the heavier oils. One development is a pressure-atomizing type requiring oil at 75 to 100 pounds pressure per square inch, supplied through pipe laid in the orchard. The other is an air-atomizing type which uses compressed air at relatively low pressures. Tests showed these burners, using reasonably heavy fuel, produced virtually no smoke.

Although the atomizing burner seemed to operate better, installation costs were measurably greater than for the simpler distilling type, and the problem of distributing the air and oil to the scattered burners has not been satisfactorily solved. Improvements which reduce smoke have been devised for the distilling type, but it is not expected that they will be completely successful in burning the heavier fuels.

FIREPLACE CONSTRUCTION

A survey was made of a large number of fireplaces to determine the best design to reduce smoking and increase efficiency. Tables based upon these studies will be prepared for publication in bulletin form.

FARM-BUILDING PLAN SERVICE

Through arrangements with the Extension Service in cooperation with the State agricultural colleges, the Bureau carries on a farm-building-plan service designed to provide farmers with plans for economical farm buildings and equipment adapted to the different regions and States.

In addition to the various farmers' bulletins, leaflets, and circulars on construction of farmhouses and other farm buildings, the Bureau and the cooperating agencies have been preparing regional plan books covering plans of a variety of structures, including farmhouses, barns, storages, and many kinds of equipment, which are placed in the hands of county agents and with State extension workers where they serve as catalogs from which farmers may select the plans needed. The working drawings are obtained at small cost from the State extension service. During the year such a regional building-plan book was issued for the Western States, and another was prepared for the Southern States and submitted for publication. Earlier a similar book was prepared for use in the Northeastern States. These plan services lessen the load on the Bureau in supplying plans direct to farmers, which formerly involved considerable time and expense. They also make complete plan services available to States that formerly lacked such facilities.

Information was collected on the lighting of farm buildings, the need for which has become more apparent with the rapid increase in rural electrification. There are now almost 1½ million farms having access to electric power-lines. A manuscript for a Farmers' Bulletin, Electric Light for the Farmstead, was prepared by the Bureau in cooperation with the Bureau of Home Economics and outside agencies, including the Illuminating Engineering Society.

Information was compiled on farm fences and a manuscript prepared for a Farmers' Bulletin which was submitted for publication.

Technical assistance was given in the design of special livestock structures and laboratories costing about half a million dollars which are now being built at the Agricultural Research Center.

TRANSPORTATION OF FARM PRODUCTS

A test made in cooperation with the Bureau of Plant Industry on a shipment of oranges from California to New York verified previous results which showed that savings can be made in shipping cost by using ice in the upper half only of the bunkers in refrigerator cars. The saving in ice averages 20 percent over the cars with normally iced bunkers.

Engineers of the Bureau reported further progress in the development of the electric-type anemometer for use in measuring low air velocities in inaccessible places in storages and railroad cars for fruits and vegetables. They worked out a means for using a number of these instruments having the same current adjustments at different locations in the car, which makes it possible to obtain readings of air movement at different points almost simultaneously. This sensitive instrument enables investigators to measure air movement at very low velocities in studies of refrigeration, ventilation, and heating.

FARM MECHANICAL EQUIPMENT RESEARCH

Studies of mechanical equipment, directed toward the improvement and development of crop-production and processing machines and better methods of using them, are constantly being made by the Bureau. This includes basic research on the requirements of machines for more effective tillage of the soil and more efficient handling and processing of the crops. With the new Bureau set-up, which includes chemistry and engineering under one head, work on mechanical-equipment problems which have arisen as a result of uncovering new uses for farm products can be more closely correlated.

PEST-CONTROL MACHINES AND METHODS

Cutting crop losses through better equipment for pest control has long received attention as one of the important means of increasing returns. Work in this field during the year has had to do with corn-borer control, machines for control of other insect pests and plant diseases, and weed control. In most cases this work has been carried on in cooperation with other bureaus and with State agricultural experiment stations.

Further improvements in design to effect better performance and increase durability were made on the self-aligning disk-jointer attachment for plows, a device worked out in the Bureau as one means of getting better coverage of cornstalks and therefore better control of the European corn borer. Improvements were also made in the trash-covering attachment which helps to gain this same result. Both of these devices can be attached to almost any make of wheel plow. These changes were found necessary because (1) the problem of cutting through and covering trash in the plowing operation has greatly increased with the advent of the combine harvester, which spreads loose trash over the field frequently in a badly bunched condition, and (2) the recent introduction of hybrid varieties of corn having ranker stalk growth and heavier root system has brought about more difficult conditions in the problem of trash coverage.

Two identical experimental wheelbarrow power sprayers were constructed for spraying sweet corn for borer control and were tested out

with a number of insecticides. The cooperating entomologists found that liquid sprays applied with this equipment, at the rate of 150 gallons of spray per acre, were more effective than insecticidal dusts applied with a commercial duster powered by a ½-horsepower engine and mounted on a chassis similar to that used for the wheelbarrow sprayer. The quantities and costs of insecticidal materials used per acre and the effectiveness of the materials applied by the two methods are shown in the tables 1 and 2.

TABLE 1.—*Quantities of spray materials used, cost per acre per application on Golden Cross Bantam Corn and percentage of borer-free ears*

Agent	Quantities used per acre per application [1] (150 gallons of spray)	Cost			No. 1 ears, borer-free
		Agent	Spreader	Total	
		Dollars	*Dollars*	*Dollars*	*Percent*
Phenothiazine	6 pounds	3.60	0.32	3.92	79.90
Calcium fluosilicate	9 pounds	.90	.32	1.22	92.96
Calcium fluosilicate, bentonite clay.	9 pounds+3 pounds	0.90+ .06	.32	1.28	97.46
Sodium fluoaluminate	3 pounds	.32	.32	.64	88.78
Sodium fluoaluminate, bentonite clay.	3 pounds+3 pounds	.32+ .06	.32	.70	96.00
Potassium fluoaluminate, bentonite clay.	do	(2)	.32		95.85
Tank-mixed nicotine, bentontonite clay.	1.95 pints nicotine sulfate+6 pounds.	1.83+ .12	.32	2.27	80.50
Dual fixed nicotine	6½ pounds	1.56	.32	1.88	75.61
Nicotine tannate (standard)	1½ pints free nicotine (50 percent)+4½ pints gallotannin.	1.62+1.17	.32	3.11	75.00
Quebracho nicotine tannate	18 pounds	2.70		2.70	81.07
Ground derris	6 pounds	2.64	.32	2.96	98.06
No treatment					55.14

[1] 0.625 pound of spreader used in all except quebracho nicotine tannate to which no spreader was added 4 applications made.
[2] No price available.

TABLE 2.—*Quantities of dust materials used, cost per acre per application on Golden Cross Bantam Corn and percentage of borer-free ears*

Agent	Quantity used per acre per application [1]		Cost			No. 1 ears, borer-free
	Insecticide	Carrier	Insecticide	Carrier	Total	
	Pounds	*Pounds*	*Dollars*	*Dollars*	*Dollars*	*Percent*
Dual fixed nicotine	50	0	7.25	0.00	7.25	75.11
Ground derris	4	16	1.76	.20	1.96	71.43
Calcium fluosilicate	5½	16½	.55	.21	.76	67.29
Potassium fluoaluminate	6⅔	23⅓	.67	.32	.99	66.04
Bancroft clay		40		.50	.50	49.10
No treatment						34.31

[1] 4 applications of dust were made, June 26, June 30, July 7, and July 12.

Power sprayers of the wheelbarrow type designed by this Bureau have already been placed on the market by one commercial manufacturer.

The Bureau has set up apparatus for investigating performance of dust nozzles, since one important need is for uniform distribution of insecticidal dust for effective and economical control of insects. Many of the machines studied did not deliver dust equally from various nozzles nor uniformly from individual nozzles, and alterations are being made which it is hoped will cut costs of materials to farmers

and improve control. Further tests of the relative effectiveness of insecticides applied by hydraulic and vapor sprays were carried out on grapes, apples, sour cherries, and peaches. Checks by cooperating entomologists showed that the hydraulic spray was more effective than the vapor spray on the grape leafhopper.

In comparative tests, the steam-vapor method of applying sulfur fungicides gave as good or superior control of peach leaf curl, apple scab, and cherry leaf spot as was obtained with the power sprayer; the efficiency of bordeaux mixture was reduced when subjected to the heat developed within the steam sprayer and the effectiveness of sulfur and combinations of sulfur and lime was markedly increased when applied with the steam vapor sprayer.

About one-third the amount of water and fungicide was required for adequate coverage when using the steam sprayer as compared with the power sprayer, but considerably more time was required to apply sprays with the former.

Tests on soil sterilization carried on in cooperation with the Ohio Agricultural Experiment Station in connection with ginseng and celery plantings showed that buried pipes for injecting steam into the soil under an inverted pan was much better than simply releasing steam under the pan. In order to effect the most rapid sterilization of the soil it was found that it should be well spaded and pulverized, but packed tightly over the steam pipes so that holes would not be blown open to the surface. Beds thus prepared could be raised to temperatures around 200° F. in 35 to 40 minutes.

A grasshopper-poison-bait distributor was developed in cooperation with the Bureau of Entomology and Plant Quarantine, and construction plans were distributed. A check up of the results obtained during the spring with more than 1,000 distributors built according to these plans showed excellent performance.

In the studies of machinery and methods of applying chemicals for controlling such weed pests as bindweed, whitetop, Canadian and perennial sowthistle, and horsenettle, in Utah and Idaho, considerable time was devoted to surveying present practices and considering suggested means of control. Among the suggestions recently made is that electricity can be used as a weed killer. Results of preliminary studies with weeds indicated that when a small current from a 9,300-volt circuit was applied, plants were killed above ground but new shoots soon appeared. Lowering the voltage to 532 and increasing the amperage had little apparent effect on the weeds. When current was passed through water in which a large number of morning-glory root stalks had been immersed a high percentage of them were killed. A similar result might be expected when passing a current through soil wet from irrigation water or rain.

Manure frequently causes heavy infestation of fields with weeds. Tests were made which showed that seed-infested chicken manure treated with live steam for periods of 2, 4, and 6 minutes produced a 100-percent kill of the weeds in all cases.

FERTILIZER-DISTRIBUTING MACHINERY

Studies of fertilizer placement for various crops and in various parts of the country have been carried on in recent years in cooperation with the Bureau of Plant Industry, many of the State agricultural experi-

ment stations, the National Joint Committee on Fertilizer Application, and the National Fertilizer Association. The variety and extent of this work in the past year are indicated by the following list of crops fertilized and the States where tests were made: Barley in Michigan; beans in Georgia, Michigan, and New York; cabbage, cauliflower, and celery in New York; corn in North Carolina; cotton in Georgia, Mississippi, North Carolina, and South Carolina; pasture in Indiana, Michigan, and Ohio; peanuts in Georgia and Virginia; peas in Maryland, Michigan, and New York; sweetpotatoes in Delaware, Maryland, and Virginia; sugar beets in Michigan, Ohio, and Wyoming; soybeans in Mississippi; spinach in Virginia; tobacco in Georgia, Maryland, Pennsylvania, North Carolina, and South Carolina; and tomatoes in Maryland, New York, and Virginia. This work included development of special equipment for experimentally placing fertilizer in various positions with respect to the seed and seedling, and the engineering phases of application. The Bureau now has 20 machines especially equipped for fertilizer-placement experiments. These are adapted for use on most of the crops grown under usual conditions.

As a result of the large number of tests on various crops, the investigators have concluded that the placement of fertilizer in a band at the side of the row gives the best results. But the best distance to the side of the seed or seedling differs for various crops as indicated by the following examples: With sweetpotatoes, in Delaware, the application of standard fertilizer over a 2-year period gave best average results when placed in a band 5 inches to each side of the row. With sugar beets, in Michigan, best results were obtained from the fertilizer when it was placed directly under the seed or one-half inch to the side. In the case of sweetpotatoes, side placement of fertilizer at the time of setting the slips produced 119 bushels per acre more than did broadcasting the fertilizer 2 weeks before planting.

Examples are accumulating which show the importance of precise placement of fertilizer for a variety of crops. Tests with cannery peas in Michigan showed that placement of plant food 2 inches to one side of the row gave a yield of 2,285 pounds per acre, whereas, when it was placed in a furrow with the seed, as is done with commercial machines, the yield was only 1,096 pounds and the stand of plants was only 50 percent of what it was in the other case.

The work on fertilizer machines and placement is already exerting a very noticeable effect on fertilizer practices and on the design of machines on the market. New machines, and attachments for use on old-type machines, are being put out by many companies for use with a great number of crops. Large numbers of growers throughout the country have adopted the improved methods, and in certain areas striking improvements have been observed.

CROP-PRODUCTION MACHINERY

The work on crop-production machinery included investigations of machines used in the production of sugar beets, cotton, corn, and sweetpotatoes, also general tillage-machinery investigations.

In recent years much progress has been made in improving and adding to the mechanical equipment for sugar beet production, which promises to do away with much of the stoop labor characteristic of this crop. Circular 488, entitled "Developments in Mechanical

Equipment and Methods in Sugar Beet Production," was published last year.

Studies were made of two different types of furrow openers for sugar-beet planters. They showed that planters equipped with disk openers gave a 40-percent larger stand than those equipped with shoe openers. The single-row, chain-feed, single-seed planter developed in 1937 was this year built on a multiple-row unit, and the plots planted with it were thinned about 15-percent faster than plots planted with a conventional planter. One result of using this new mechanism was a larger number of single seedlings which required less finger work in thinning.

A number of beet harvesters were studied, and an experimental variable-cut topper was devised to obtain better topping of the beets regardless of the variability in the height of the beet crowns above the ground. Two devices for cutting off the tops, the rotating disk knife and the straight stationary knife, have not been entirely satisfactory. An attempt has been made to design a cutter that would retain the good points of these two devices without the drawbacks. The result is an oscillating knife operated by a simple reaction drive which gives the knife 80 strokes a second with negligible power consumption.

In the studies of corn-production machinery carried on in cooperation with Iowa State College at Ames, various results have been obtained of interest to Midwest corn growers. Field studies showed little difference in yield between drilled corn and standard check row, but when corn was planted in 21-inch checks there was considerable increase in yield over the standard or 42-inch checking, the same number of seeds being planted per acre in both cases.

Tests of mechanical corn pickers showed much less field loss with certain hybrid varieties than with others. A new experimental snapping mechanism for picking reduced losses of shelled corn to about one-sixth of the losses caused by the standard snapping rollers. Since there is a steady increase in the number of corn pickers in use the significance of such a saving becomes apparent.

In attempts to get around the difficulty frequently experienced in controlling weeds in drill-planted corn, particularly in the early stages of growth during adverse weather conditions, efforts have been made to improve cultivation technique, and promising experimental attachments have been devised for the purpose. The development of a successful means of cultivating drill-planted corn would no doubt result in rapid abandonment of the more irksome check-row method of planting. This type of planting is particularly advantageous in contour farming, where the land is subject to erosion, and may result in the elimination of an important objection to terracing in the Corn Belt.

The need for developing methods and equipment for harvesting and handling sweetpotatoes so that the farmer can preserve his waste and surplus for stock feed has received attention in some exploratory studies. In this connection investigators are giving attention to such factors as seedbed preparation, planting, harvesting, and handling of the vines for silage. The work so far done in studying different ways of preparing and planting slips indicates that a considerable reduction in cost for these operations is possible.

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The rapid rise in popularity of green silage crops other than corn has led to studies of various phases of the problem including time, labor, power, machinery, and machinery investments for harvesting and ensiling these crops. The work was started in the spring by the Bureau in cooperation with the New Jersey Agricultural Experiment Station. Two silos were filled with cut grass, molasses preservative being used in one instance and acid preservative in the other. The grass was cut with a tractor-mower having a swath attachment, loaded by a hay loader into a truck, and hauled to the silo filler which chopped the grass and applied the preservative.

Indications are that the yields of silage grasses may fluctuate to a marked degree, which emphasizes the necessity of planning the work so as to keep the silo filler busy. This was done in one instance by the use of a windrow attachment, a field loader, and three trucks. Amounts up to 41 tons of silage per day were put up from a field yielding 10 tons per acre. Loading from the tractor swath and using two trucks on a field yielding 6 tons per acre, 25 tons were ensiled in a day. In the first case the silo-filling crew was busy 66 percent of the time and in the second case was busy only 42 percent of the time.

Observations showed that an experimental field harvester and chopper patterned after the grain combine has promise of usefulness in speeding up the job of ensiling grasses. When the grass was brought to the silo filler already properly chopped it took 25 percent less time to put it away in the silo than when it had to be chopped as well as elevated by the conventional silo filler.

An experimental conveyor-elevator built by the Bureau for putting this type of material into the silo was operated with a 3-horsepower electric motor, the only size available at the time. It seems probable that considerable savings in power and labor may be made in this phase of the work, the indications being that a 1-horsepower motor might be adequate for the purpose.

TILLAGE MACHINERY

Ever since the establishment of the Tillage Machinery Laboratory at Auburn, Ala., in 1935, studies have been made of the influence of various factors in design and equipment on tillage machines, on power requirements, and on the resulting condition of the seedbed and the yield and quality of crops. Nine distinct types of soil from the major crop-producing areas of the country have been assembled at the laboratory and placed in plots 250 by 20 by 2 feet in size. Fundamental studies are being carried on to determine for each soil type the draft, scouring qualities, abrasive action on soil-rubbing surfaces such as moldboards, and of soil packing by steel- and rubber-tired tractor wheels.

Tests of various plow shapes seemed to show that a moldboard conforming to the shape of a cylinder, fitted with a bevel-pointed share, offers less draft, scours better, and wears off less than a plow having a moldboard of conventional shape and a long-pointed share. Results obtained thus far tend to show that tractors equipped with rubber tires pack the soil more than do those having steel wheels with spade lugs.

By the use of the special equipment at Auburn, the investigators have shown that by reducing the angle between the moldboard and

the line of travel within certain practicable limits the draft of stubble-type plows can be lowered without noticeably affecting the quality of the plowing, although the capacity decreases slightly. Tests with conventional general-purpose moldboards and shares, with the angle between the moldboard and the direction of travel varying from 2½° greater than normal to 7½° less, showed that increasing or decreasing the angle 2½° did not affect the draft or quality of work appreciably but that if the angle were reduced more than 2½° the draft was increased and the plow did inferior work.

Observations on the performance of disk plows have brought out the importance of such factors as speed of the plow, the angle between the disk and the line of travel, the use of scrapers to take off adhering soil, the resistance of the disk bearing to rotation, and the soil condition. Indications are that as the colloid content of the soil increases (that is, as soil becomes more clayey) the draft, the vertical reaction upon the disk, and the side reaction increase.

A review of experiments during the past several years on seedbed preparation on a certain soil type in the Cotton Belt supports a former conclusion that a coarse, cloddy seedbed prepared 60 days before planting with a few simple operations, is superior to a finely pulverized seedbed produced by a large number of operations.

The variable-depth cotton planter, designed a number of years ago in the Bureau, continues to give good results. In most of the recent seasons this planter produced a stand of cotton in one planting as compared to replanting from one to four times when the ordinary method of planting at constant depth was used.

After 3 years of work with various methods of turning under leguminous cover crops to increase the yield of cotton it appears that the one-way disk harrow, with disks spaced 10 to 12 inches, and a wide-base plow (18-inch) are the most effective tools for this purpose.

RESEARCH IN MECHANICAL PROCESSING OF FARM PRODUCTS

Research work on the engineering phases of processing farm products is limited at present to problems of cotton picking, handling, ginning, and packaging, and of flax pulling, retting, and scutching. A peculiarity common to both of these crops is that the preliminary processing is carried on in the immediate neighborhood where they are grown. Cotton as a rule remains the property of the grower until after it has been ginned and baled. These studies in preliminary processing are of direct interest to the producers.

COTTON GINNING

The principal objectives of the cotton ginning investigations are to determine the effects of different methods of conditioning, cleaning, extracting, and ginning, and their interrelationship and correlation with the elements of quality of lint and ginned cottonseed, in order to improve quality of ginned cotton with resulting increased returns to cotton planters.

Studies were conducted to compare the handling of seed cotton through a separator and a Rembert-type fan. The saving in power and reduction in ginning cost were significantly in favor of the Rem-

bert unloading system. This is due to the fact that all air handled through the Rembert-type fan is doing useful work, whereas in the separator set-up much loss due to leakage is encountered. The improved cone-shaped Rembert-design unloading fan developed by this laboratory has an efficiency of approximately 56 percent as compared to 35 percent for flat-disk-type Rembert fans. Also, the cracking of seed which was noted with flat disks when a velocity of 4,000 feet per minute or greater was used was not noticeable in the new laboratory-designed fan. A large percentage of the cotton passing through the new-design fan never strikes the screened cone, and this fan is especially adapted to the latest double-fan, wye-system, tower-type drier set-ups.

A survey of mechanical equipment in commercial gins has revealed that a considerable saving in power can be made by modernizing present gins. The power being used to unload cotton for a four-stand gin ranged from 13 to 31 horsepower and the separator losses in volume of air ranged from 25 to 50 percent. Some of the air-blast gins were using nozzle pressure ranging from 11 to 18 inches on the water gage, which caused the air-blast fan to use from 9 to 36 horsepower. The data from the 32 ginneries surveyed showed that almost 50 percent of the power used in the entire plant was required to operate the fans.

Walrus hide has been principally used on roller gins, but recent tests at the laboratories have shown satisfactory results with such substitutes as rubber and canvas pump packing. In fact these substitutes for the walrus hide turned out samples of cotton slightly better in grade and staple than that ginned on the walrus-hide rollers.

Comparative ginning tests made with the roller and saw gins using various types of rollers and saws of different design on sea-island cotton grown in Georgia, Alabama, and Mississippi, confirm the belief that sea-island cotton or cottons longer than 1½ inches in staple length ginned by a roller gin are superior in quality and that the fiber is longer than when the same cotton is ginned on saw gins. When ginned on a saw gin the long cottons are very neppy while the roller-gin sample of the same cotton is free of neps.

Tests on new and worn gin saws with teeth of different shapes were continued and showed that roached-tooth saws normally give less lint turn-out than new straight-tooth saws. But when wear and filing reduce the diameter the roach tooth becomes straighter and the loss in cotton turn-out is not so noticeable as when straight-tooth saws are reduced in size by wear and sharpening.

Roll-box studies were started on a commercial 70-saw gin stand having a large, circular roll box. This gin was reduced to a 40-saw stand. The roll box was reduced in size, and tests were made of small circular, horizontal oval, and vertical oval boxes. The data from one season's tests indicates that by reducing the size and altering the shape of the roll box to form a small circular or vertical oval design, the ginning capacity is increased by 10 and 14 percent, respectively, with no loss in lint quality or turn-out. The horizontal oval box showed no significant advantages over the large circular roll box.

The laboratories experimented on cleaning seed cotton harvested with the mechanical cotton picker. Cotton thus harvested from 4

fields and cleaned with a 12-cylinder overhead cleaner and extractor in addition to the use of an extractor feeder averaged Low Middling in grade, a grade lower than the corresponding hand-picked cotton handled only through an extractor-feeder. Tests in cooperation with the Delta Experiment Station brought out that the differences in grade between hand-picked and machine-picked cotton are greater in some varieties than in others.

Tests were made in an effort to devise cheaper means of drying cotton that would be feasible for the smaller gin. A large-size house-heating furnace equipped with a fan having a capacity of 200,000 British thermal units per hour provided a drying temperature of 140° F. at the inlet of the drying chamber with 3,500 cubic feet of air per minute, which provided ample suction using the split-suction unloading system to accommodate not more than two gin stands. This process appears suitable for small ginning establishments, especially those handling short-staple cotton.

Some further study was given to the methods of utilizing exhaust heat and cooling water heat from Diesel engines for drying, and some improvements have been devised in the heat exchanger where experience indicated that greater strength was necessary.

Ten different designs of cleaning screens in a six-cylinder cross-drum flow cleaner were tested on both hand and mechanically picked cottons, and the results indicate that the standard hardware-cloth screen of ½-inch mesh was as effective in screening out trash as any of the other more expensive types. Some of the larger mesh screens were found to be unsatisfactory because they allowed small or single locks of cotton to pass through with the trash which in turn caused losses in turn-out without any material improvement in grade.

HIGH-DENSITY PACKING OF COTTON AT GINS

Last January authorization was given the Bureau to carry on studies of high-density packing of cotton, funds being provided from the Bankhead-Jones special research fund. The principal objectives are to ascertain the engineering and mechanical feasibility of packaging cotton in high-density bales at gins; the comparative costs and advantages of high-density gin compression as compared with the present procedures of gin packing and recompressing; the effect of high-density gin compression on the spinning value of cotton; and the requirements for a high-density gin bale satisfactory for conserving the quality of cotton and for transportation, storage, and handling.

The experimental equipment now comprises a revamped 3-stand ginnery, a 12-roll Clayton round-bale press, a 400-pound high-density Brazilian gin press, a special pilot press to be used as laboratory apparatus, and a 500-bale flat press, all complete with conditioning and extracting equipment.

The round-bale press provides cylindrical packages of cotton weighing 250 pounds each, with a nominal density of 33 pounds per cubic foot. This bale requires no steel ties or bands and permits samples to be withdrawn by an augur before the heads are sewed on, so the bale does not need to be cut. The 400-pound Brazilian press normally turns out a bale 20 inches wide by 40 inches long by 26 inches high with nominal density of 32 pounds per cubic foot.

The special pilot press permits packaging of bales containing 1 cubic foot of cotton and may have a density of 11, 22, 33, or 44 pounds of cotton per cubic foot. These small specimens and spinning-test bales may be covered with any one of various types of commercial bagging.

The laboratory has also obtained a wide variety of instruments for making records during tests. Among them are electrical instruments for measuring power; gas and electric meters; temperature recorders; recording psychrometric instruments; and various pressure gages for air, steam, gas, and hydraulic lines. The ginning plant set-up for packaging studies contains a 3–80 gin outfit and various pieces of modern auxiliary equipment.

This experimental project is carried on cooperatively with the Bureau of Agricultural Economics which undertook to compile a survey of as many commercial cotton compresses as possible by the end of the fiscal year. At the same time extensive studies were made at several cotton compresses in New Orleans, La., Greenville, Miss., and Memphis, Tenn. Among other things, studies were conducted to explain the causes of bale-press cuts to which spinning mills have frequently objected. Informal reports from the spinning laboratories indicate that fiber damage resulting from these cuts is not significant but the amount of waste may be increased and the damage to the covering causes more rapid deterioration of the lint. The investigators concluded that since these cuts have been encountered for many years in the standard-density compression of cotton their presence is more objectionable from the standpoint of appearance than from that of actual fiber damage.

FIBER-FLAX PROCESSING INVESTIGATIONS

Under the authority of the Agricultural Appropriation Act for the fiscal year 1939, investigations directed toward the improvement of fiber-flax production in the United States were begun in July 1938, with headquarters at Corvallis, Oreg.

The first step in these investigations was a study of the work under way at the three cooperative retting and scutching plants located at Canby, Mount Angel, and Springfield, Oreg., to obtain records of the time and labor required and their costs for the different operations in retting and scutching flax. A study was also made of the equipment farmers use for pulling flax. From this work it became apparent that there is a possibility of improving equipment for pulling flax and that there are apparently opportunities for adjustments in operations that might reduce costs in the retting and scutching plants.

The investigators obtained a flax puller of the type in common use in Oregon and rebuilt it in an effort to improve its reliability in operation. Preliminary tests in June indicated that some progress had been made, but that further changes are desirable. A flax puller of a type widely used in Europe was imported from Belgium and preliminary tests indicate it will operate satisfactorily under Oregon conditions.

One of the problems of the flax industry everywhere has been the separation of the shives from the tow. A tow shaker was designed, built, and placed in use at one of the cooperatives. It separates the tow from the shives so much more efficiently than the equipment formerly used at this plant that the weight of the partially cleaned tow

was reduced 50 percent. This represents a saving of 50 percent in handling and transportation cost to a tow-scutching machine located in a nearby town.

The deseeders in use at the cooperatives were of limited capacity and their operation required considerable labor. A design for a deseeder of another type was prepared and the machine constructed. It operated satisfactorily. The Bureau bought a deseeder of the type in common use in Belgium, which will be available for test during the 1940 fiscal year.

One problem that has been giving considerable trouble to the flax cooperatives is that of disposal of the retting water. Facts already obtained indicate it may be possible to work out a method of disposing of the waste water by furrow irrigation without creating a nuisance. As time permitted, the investigators studied the operations of the retting and scutching plants. The problem of reducing the cost here is more complicated than in the operations previously mentioned, but they believe that eventually improvements can be made that will materially reduce the cost of producing fiber-flax at the plants.

A small building which can be used as a laboratory for testing machinery and methods and for storing equipment was constructed on the farm of the Oregon Agricultural Experiment Station.

FARM-OPERATING-EFFICIENCY INVESTIGATIONS

For a number of years the Bureau has carried on continuous investigations on farms in a number of States with the object of improving engineering factors in farm operation and coordinating them with various other factors. The object has not been to determine the exact benefits of development of individual projects such as, for example, drainage improvements, land clearing, buildings, machinery equipment, rearrangement and enlargement of fields, etc., but to determine the good results that can be obtained through proper planning and operation of the whole farm.

Since 1929, 120 typical farms have been studied throughout the humid region from northern Minnesota to southern Georgia, to determine their engineering problems in development and organization. The studies have shown that every farm, regardless of its size, type, and location, is capable of improvement through better use of available resources and the improvement of the organization.

On a large number of farms, efficient farming is prevented by the lack of balance in land condition, power, machinery, buildings, labor, crops, and livestock. Patchy fields of irregular size and shape with wet spots, gullies, stumps, stone, misplaced ditches, and overgrown fence rows prevent low-cost crop production. Improper and inadequate power prevents timely field work and machinery of unsuitable size, design, or condition prevents thorough and timely tillage. Misplaced roads, fences, and lanes increase the overhead costs of labor, power, and machinery. Inadequate buildings prevent the proper care of livestock, crops, and equipment. The initial studies of farms provide for the correction of these maladjustments through the development of balanced operating plans.

Records obtained from 90 farms in Minnesota, Michigan, Ohio, and Virginia indicate that a large proportion of them are being im-

proved according to the operating plans. The 25 farms studied in 1 State showed the following range of problems and progress:

About three-fourths of the farms lacked adequate drainage; 18 had land-clearing problems to solve before fields could be properly shaped; 16 had suitable land and water for the development of irrigation, while only 4 were equipped for irrigation. Soil erosion was active on 24, but about one-half of the area subject to erosion is being protected with terraces, strip cropping, and soil-saving dams. About 50 percent of the recommended field improvement has been completed. This resulted in increasing the average size of fields from 4.4 acres per field to 11.6 acres. Power changes represent a decrease of 5 percent in the number of work horses and an increase of 22 percent in the number of tractors. Construction on 25 farms has included 7 barns, 12 silos, 5 fruit- and vegetable-storage houses, 9 tenant houses, and the remodeling of 8 farm homes. About two-thirds of the farms and one-third of the tenant houses have electric service.

RURAL ELECTRIFICATION RESEARCH

The Seventy-fifth Congress appropriated $30,000 to be used for rural electrification research in the Bureau during the fiscal year 1939. A project was prepared with the following objectives in mind: (1) Survey and collate information on rural electrification research in the State agricultural experiment stations; (2) make case studies of farms in various parts of the country, and by careful engineering analysis discover how the use of electrical equipment may be fitted economically into the farm program; (3) discover new uses, design new equipment, or redesign existing equipment to meet the needs of farm operations requiring both stationary and tractive power, keeping in mind always the low-income farm and the fact that applications of electricity on those farms must be at least self-sustaining or income producing; (4) study fundamental problems, such as those relating to the influence of electricity, light, heat, magnetism, and other associated phenomena upon plants and animals.

Seven men experienced in rural electrification were borrowed for 1 month each from colleges and sent to visit State experiment stations in 37 States where research has been or is now being conducted in the applications of electricity in agriculture. The survey was concerned primarily with applications in the dairy and poultry industries. Many studies have been conducted in these enterprises and results published by the several stations. Of the studies or observations made most were concerned with energy requirements, immediate costs, and immediate results, and but few with the basic principles involved.

Information obtained in the survey revealed considerable disagreement among research workers. Some of these differences are traceable to different climatic and economic conditions, others to types of agriculture followed, while yet other variations are no doubt due to methods of and care with which experiments were conducted. An example of the first is that of separating cream and churning. In Wisconsin most of the milk is sold in bulk to dairy-manufacturing concerns, and very little butter is made on the farm. On the other hand Penn-

sylvania farmers market about 1 million pounds of butter annually.

Cooperative associations find that a uniformity of product works to their advantage, consequently uniformity of feed is essential. (This is especially true of poultry.) For this reason poultry cooperatives like to have grinding and mixing done by a limited number of mills. New England farms do not produce all of the ingredients of poultry feed and since the farmer must buy them, he usually has them mixed at the mill where the mixing is included in the cost.

Cooperative agreements have been made between the Bureau and the State agricultural experiment stations of Virginia, Indiana, and Nebraska to carry on research in rural electrification. Under these agreements, case and equipment studies are now in progress. These studies include the use of electricity in irrigation of home gardens; the needs of farm refrigeration, and the control of the European corn borer by means of electric-light traps.

Work at these stations has not been in progress long enough to yield definite results, but records of work carried on show that they are being obtained. A preliminary report from Indiana on electric pig brooders reads as follows:

> During the winter of 1938 five sows farrowed 52 live pigs which were all raised to weaning time. At the same time two sows, which farrowed 24 pigs in houses without electric heaters, crushed four of them by lying on them. This loss is attributed to the pigs lying close to the sows to keep warm. An underheat type of heater designed and developed in the work at this institution will be manufactured by an Indiana firm and available for use in the spring of 1940.

Another report from the same station on the control of the European corn borer is also of interest:

Ten electric traps destroyed 11,167 corn-borer moths in a 10-acre field of corn in Northeastern Indiana from June 19 until August 26, 1939. These results furnish definite indication of the possibility of reducing infestation, perhaps controlling, this pest, since more than 60 percent females were caught. Examination of the females captured disclosed a large percentage of them to be gravid. The following table indicates the reduction in the area lighted by the traps when compared with similar areas.

Populations and infestations in check fields as compared to lighted block

Check area	Percent of plants infested	Number of borers per 100 plants	Percent reduction in lighted area
Lighted block of 10 acres	52.5	78.75	
Unlighted block of 7 acres—same field	80.0	234.40	71.30
Unlighted field ¼ mile away planted on same date	89.0	320.40	77.91
Unlighted field ¾ mile removed	79.0	308.60	74.12
Unlighted field 1 mile removed	88.0	316.00	75.08

The capture of larger numbers of moths by some traps than others is difficult of explanation, although wind direction and elevation in the field seem to be possible reasons. The economy of using such equipment for field corn is as yet debatable, although its use for protecting sweet corn in heavily infested areas may be advisable from present knowledge. The 1939 results have been so favorable that more extensive work in succeeding years should be made. This is especially advisable since reports from State entomologists indicate that the corn borer was found in Northern Illinois and Southern Wisconsin during 1939.

REGIONAL RESEARCH LABORATORIES

During the first year following the enactment of legislation authorizing the establishment and maintenance of four regional research laboratories by the Department of Agriculture, there were important accomplishments toward that end. The four major producing areas and the commodities to be given initial research attention in specific areas have been designated as follows:

Northern area—Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin, and Michigan. Commodities—corn, wheat, and crop residues.

Southern area—Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Oklahoma, South Carolina, and Texas. Commodities—cotton, sweetpotatoes, and peanuts.

Eastern area—Connecticut, Delaware, Kentucky, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Rhode Island, Tennessee, Vermont, Virginia, and West Virginia. Commodities—tobacco, apples, potatoes, milk products, and vegetables.

Western area—Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. Commodities—fruits (other than apples), vegetables, potatoes, wheat, and alfalfa.

A survey was made to determine the location of the regional laboratories and the scope of the investigations to be undertaken, and to coordinate the investigations with current research work. The report of this survey was published as Senate Document No. 65, Seventy-sixth Congress, first session. On the basis of the survey, locations for the laboratories were selected as follows: Northern laboratory, Peoria, Ill.; southern laboratory, New Orleans, La.; eastern laboratory, Philadelphia area, Pa.; and western laboratory, San Francisco Bay area, Calif. The definite locations finally selected for the eastern and western laboratories were Wyndmoor, Pa., and Albany, Calif., respectively.

Plans and specifications for the four regional laboratory buildings were prepared and contracts were awarded for their construction. Directors were appointed for the four laboratories, and a few of the other key positions were filled. Regional headquarters were established in each area near the site of the proposed laboratory. Preliminary work was done on planning and coordination of research programs.

Throughout this first year the public has manifested marked interest in the regional laboratories. The many departmental and State groups and private organizations consulted have given generously of their time and attention. Many letters containing suggestions and comments have been received, and a large number of requests from local, State, and National organizations for information about the projected work have been answered by addresses and papers presented by members of the regional research laboratories staff.

INFORMATION AND PUBLICATIONS

The Bureau published 3 Technical Bulletins, 3 Circulars, 3 Miscellaneous Publications, 3 Farmers' Bulletins, 3 articles in the Journal of Agricultural Research, 2 Leaflets, 4 Yearbook articles, 1 article in The Agricultural Situation, 1 annual report, 1 Senate Document, 45 mimeographed publications, and 241 articles in out-

side journals and proceedings, 8 of which were also mimeographed. The Bureau also furnished information on various phases of its research through the press and radio services of the Department.

Thirteen patents were issued to scientists of the Bureau during the year.

The following lists show the publications and patents of the research divisions of this Bureau:

LIST OF PUBLICATIONS

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Preparation of rhamnose from naringin. By G. N. Pulley and H. W. von Loesecke. Amer. Chem. Soc. Jour. 61: 175–176. 1939.

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Observations of the effect of ethylene on the softening of Yakima grown bartlett pears. By William Rabak. West. Canner and Packer 31 (4): 26–28. 1939.

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The acid-base balance of cereals and some related food materials. By Jehiel Davidson and J. A. LeClerc. Food Res. 3 (4): 393–402. 1938.

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