REPORT OF THE CHIEF OF THE BUREAU OF CHEMISTRY AND SOILS, 1938

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF CHEMISTRY AND SOILS,
Washington, D. C., October 24, 1938.

Hon. HENRY A. WALLACE,
Secretary of Agriculture.

DEAR MR. SECRETARY: I present herewith the report of the Bureau of Chemistry and Soils for the fiscal year ended June 30, 1938.

Sincerely yours,

HENRY G. KNIGHT, *Chief.*

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INTRODUCTION

The Bureau of Chemistry and Soils is a research organization engaged in the application of chemistry, physics, and other sciences to the improvement of agriculture. This broad field includes classification and mapping of the soils of the United States; studies of soils with regard to their agricultural value, their characteristics in relation to productiveness, their origin and development, and their chemical and mechanical compositions; studies of the fertilizer resources of the United States and methods of manufacturing fertilizer materials, including nitrogen and its fixation, phosphates, potash, concentrated fertilizers, organic waste products, and miscellaneous soil amendments; studies on the composition, properties, preservation, and utilization of agricultural products and byproducts; studies of the physiological effects of food products and possible food contaminants on the human organism; development of improved processes for the production of rosin and turpentine; and development of means for preventing farm fires and dust explosions.

The organization consists of the offices of Chief, Assistant Chiefs, Adviser in Chemical Research, Business Administration Division, Information Division, and the following research divisions: Carbohydrate Research, Chemical Engineering Research, Fertilizer Research, Food Research, Industrial Farm Products Research, Naval Stores Research, Protein and Nutrition Research, Soil Chemistry and Physics Research, Soil Survey, and Chemical Investigations of Allergens in Agricultural Products.

The administrative, professional, and technical staff of the Bureau during the year averaged 347 persons, including 168 chemists, 12 physicists, 18 engineers, 6 technologists, 21 soil scientists, 36 soil surveyors, 4 cartographers, 21 draftsmen, 10 bacteriologists, 2 mycologists, 1 microscopist, 2 physiologists, 1 pathologist, 4 pharmacologists, 1 clinical specialist, 1 medical technician, 1 specialist in plant preservation, 8 skilled mechanics, 13 scientific aides, 13 cooperative agents, 3 business administrators, and 1 editor. About 128 professional and technical employees of the Bureau were located in various parts of the country in 21 field laboratories, where work was done on the utilization of fruits and vegetables, principally for food purposes, industrial utilization of soybeans and sweetpotatoes, industrial utilization of agricultural byproducts, production and utilization of turpentine and rosin, cane sugar and sirup investigations, damage to agricultural land from smelter fumes, and supervision of soil surveys. Forty-five scientists whose headquarters are in Washington, D. C., were in the field almost continuously on soil survey work. At the close of the year the total number of employees, both technical and clerical, was 583, of whom 180 were field employees.

Practically all the soil survey work as well as much of the research work was done in cooperation with State agricultural experiment stations, educational institutions, or other State or local agencies.

During the year the Bureau participated in the Department of Agriculture's general program of basic research in agriculture under the Bankhead-Jones Act of June 29, 1935, by carrying on research on enzyme action at low temperatures; plant mineral constituents derived from soils and their relation to nutrition and health; allergens of agricultural products; preserving plant specimens in natural condition; hemicelluloses and lignocelluloses of straws and forage crops; and industrial utilization of the soybean and soybean products. In addition, the Bureau collaborated with the Bureau of Plant Industry on a Bankhead-Jones project by making pathological and chemical studies on plant viruses, and in investigating the chemical eradication of weeds, and with the State Department by studying the extent of damage to agricultural land in northeastern Washington by smelter fumes originating in Canada.

The regular appropriation for the work of the Bureau during 1938 was $1,425,431. Additional funds were received by allotments from other appropriations, including $179,151 from the fund for special research under the Bankhead-Jones Act of June 29, 1935, $22,683 from the State Department for smelter-fumes work, $1,800 from the Farm Credit Administration for soil survey work, $17,691 from the Agricultural Adjustment Administration for the preliminary survey for determining the locations and programs of regional laboratories provided for in the Agricultural Adjustment Act of 1938.

Much of the time of administrative officers and certain division chiefs was given to a consideration of the possibilities for increased industrial utilization of agricultural products and the preparation of estimates of the funds that would be required to attack the problems of increased industrial utilization on

a comprehensive scale. These estimates formed the basis of legislation enacted by the Congress providing for extensive expansion in the research activities of the Department of Agriculture on the industrial utilization of agricultural products.

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 267 publications issued by the Bureau during the year and listed at the end of this report together with a list of the 14 patents issued to Bureau scientists.

CARBOHYDRATE INVESTIGATIONS

SUGARCANE AND CANE SUGAR

Studies on the composition and clarifying properties of sugarcane juices as affected by variety, fertilization, and soil conditions were continued in cooperation with the Bureau of Plant Industry. In tests by a standardized clarification procedure the varieties C. P. 28–11 and C. P. 28–19 gave large volumes of defecation mud as compared with that given by other varieties from the same fields. The variety C. P. 29–320 gave a relatively low volume of defecation mud and juice of excellent clarity. All the other newer varieties tested gave defecation mud volumes in excess of those found for older varieties, such as P. O. J. 36–M and C. P. 807. The use of nitrogen fertilizers alone tended to increase the defecation muds and to decrease the clarity of the juices, while a balanced fertilizer treatment had much less effect.

As the result of a freeze and subsequent unfavorable weather in Louisiana toward the close of the 1937–38 cane harvesting season, the cane still standing deteriorated to a marked degree, yielding juices that were very difficult to clarify and work in the factory. The Bureau found that the direct cause of this deterioration was partial fermentation of the sucrose to acetic acid, d-mannitol, dextran, and other products. Dextran, a gummy substance, was mainly responsible for the factory trouble because it increased the viscosity of the juices enormously and thus retarded filtration and rate of crystallization. Assistance was given to plantation sugar houses in developing methods for evaluating and handling damaged cane to the best possible advantage with existing equipment, and efforts are being continued along this line, particularly to discover a means of eliminating dextran from the juice of damaged sugarcane.

The method recently developed by the Bureau for air graining and curing of third sugars was tried in a plantation sugar factory and found to be practical. Higher yields and better quality of sugars were obtained in 7 weeks than in 6 months by the usual practice.

Work on the principle of clarification by thermo-scum filtration resulted in the design of a continuous juice clarifier for which a public-service patent has been requested.

In cooperation with the Bureau of Plant Industry, an investigation was made of the mineral composition of crusher juices, whole cane, and green tops. The values for the whole mill cane plus the green tops, in conjunction with the yields per acre, were taken to indicate the degree of soil depletion. Comparison of the characteristic mineral contents of varieties of sugarcane and of the effect of different fertilizer treatments on such composition, considered with reference to field costs and yields, should give practical information on selection of varieties and fertilizer needs. The correlation of the composition of the crusher juice with that of the mill cane plus green tops gives factors from which, in the future, soil depletion may be approximately estimated on the basis of crusher-juice analyses.

BEET SUGAR

In a chemical investigation in cooperation with the sugar-beet industry, composite samples of beet sugar representative of all the beet-sugar-producing areas in the United States were again collected in 1937 and subjected to detailed analysis. In general, the results showed still further uniformity of quality. Only 2 of the samples had an ash content above 0.02 percent; 67 samples contained less. In 1929 the average ash content was 0.043 percent; in 1937 it was only 0.011 percent. A tentative formula for the rating of granulated sugars was developed which takes into consideration the ash content as well as reflectance and color and turbidity of the solution as determined photoelectrically by the Brice-Keane instrument.

FARM-MADE SIRUPS

Public demand for extremely mild flavors in table sirups seems to have developed rapidly in recent years. As a rule, the characteristic sugarcane and sorgo flavors are well liked, especially in those sections of the country where people have become accustomed to these sirups. But increasing competition brought about by the sale of mild-flavored, blended sirups has reduced the demand for pure, unblended farm sirups except those of the finest quality. Since pure sugarcane, sorgo, and maple sirups are cash crops of well-recognized value, it is now more necessary than ever before that farmers meet the requirements of the market. Increasing attention must be given to flavor, color, freedom from sugaring and fermentation, absence of unsightly deposits of sediment (dregginess), and to attractive packages and labels. To the extent that farm-scale producers of sirups succeed in offering the trade a strictly quality product they may demand a retail rather than a wholesale price, or from two to four times as much.

Preliminary studies on the sediment in sorgo sirups were conducted in cooperation with the Mississippi Agricultural Experiment Station. Sediment results from spontaneous flocculation of nonsugar substances during concentration of juice to sirup and is influenced by soil and fertilizer, maturity of crop when harvested, and the method and equipment employed in making the sirup. Investigations were made of several varieties of sorgo grown under comparable conditions. In preparing a series of sirup samples from each variety the method was varied to ascertain the best procedure for securing sirups with a minimum amount of sediment. The characteristic behavior of each variety was likewise noted. The most promising procedure so far developed for farm-scale practice consists in sedimentation of the fresh juice in the cold, rapid evaporation with careful skimming to a somewhat higher semisirup density than usual, treatment of the semisirup with malt diastase, and adequate sedimentation of both the semisirup and the finished product.

Farmers' Bulletin 1791 on farm production of sorgo sirup was published. The results of work on the composition of the sorgo plant, with particular reference to the sugars, starch, and nonsugars contained in various portions of the stalk of different varieties at different stages of maturity, were prepared for publication.

In continuation of the investigation on the distribution of sugars in the sorgo stalk under different varietal and environmental conditions, attention was given to the possible commercial recovery of the sugars sucrose and dextrose separately. Applications were filed for two patents covering processes which under certain conditions may be suitable for industrial use.

Cooperation was continued with a number of agencies active in putting the results of the sirup investigations of the Bureau into farm-scale and commercial practice. Assistance was given in the construction and operation of a farmers' cooperative steam cane-sirup plant at Laurel, Miss., and of several smaller community plants in other sections of the South. These plants use improved methods developed by this Bureau in previous investigations. Noteworthy progress has been made in Alabama, where special assistance was rendered to the recently appointed full-time State extension service specialist in sirups.

Preliminary work was done in cooperation with the Bureau of Agricultural Economics to develop combined color and turbidity standards for maple sirup for use in commercial and farm grading.

HONEY

One of the most promising ways for increasing the consumption of honey is its use in the production of commercial baked goods. Honey possesses certain properties that make it particularly valuable for use in baking, especially hygroscopicity, or the ability to absorb and retain moisture. This property of honey makes baked goods in which it is used less likely to dry out and become stale. However, chemical reactions take place between the honey and the ingredients of the mix for certain types of baked goods, producing adverse color effects. Baking experiments in which honey was used to replace sugar showed that honeys of a number of floral types of known composition and color grades gave entirely satisfactory results with whole-wheat breads and various types of cookies. This was also the case with white bread, except that dark grades of honey, like buckwheat, caused objectionable color in the crumb of the loaves.

Cakes made by plain cake formulas in which one-fourth, one-half, three-fourths, or all of the sugar was replaced by honey were entirely satisfactory

except for color. When honey was used to replace one-tenth or less of the sugar, the color developed was negligible. It was found that the color resulted not only from colored substances in the honey but also from chemical reactions between the simple sugars of honey, dextrose and levulose, and certain ingredients of the batter during the baking process. Commercial invert sugar gave results somewhat similar to those obtained with honey, indicating that the nature of the sugars present in honey is responsible for the color development. Honey is entirely satisfactory for use in chocolate cake and similar types where color is not a factor in scoring.

The tendency of a honey to form sugar crystals is objectionable in bottled honey but might be turned to commercial advantage for the production of a smooth fondantlike spread if it were possible to control the size and distribution of the sugar crystals. From a preliminary study of the factors involved in the crystallization of honey, it appears that the concentration of levulose governs to a large degree the extent and nature of the crystallization of dextrose. It is expected that further investigation will lead to means of obtaining desired types of crystallization of dextrose in honey, so that commercially attractive fondantlike honey preparations can be obtained, thus making possible further extension of the market for honey.

STARCHES

An increasing industrial demand for root starches in the United States is indicated by import statistics. In 1937 about 470 million pounds of such starches, mainly cassava, were imported. This was an increase of about 57 percent over the amount imported in 1936. Agriculture would benefit directly from the development of a root-starch industry in this country sufficient to meet this growing demand. With this in mind, the Bureau has continued to give special attention to the sweetpotato as a source of starch because of its wide adaptability as an industrial crop and because its starch has properties that make it eminently suitable for use in sizing textiles, in laundering, and in the preparation of adhesives.

Technical assistance was again given to the farmers' cooperative sweetpotato starch plant at Laurel, Miss., which produced about 500,000 pounds of starch from the 1937 crop, and by operating the factory at full capacity expects to produce about 2,000,000 pounds from the 1938 crop. It was found that the methods used for determining starch in sweetpotatoes and residual pulp sometimes gave erroneous results. From a comparative study it was concluded that the malt diastase method was reliable, provided the samples containing plant tissues were pretreated with calcium or barium hydroxide to prevent certain nonstarchy constituents from being converted into reducing sugars and estimated as starch.

Microbiological investigations in connection with sweetpotato-starch manufacture were begun to discover means for controlling fermentation, particularly during warm weather, and to determine the types of micro-organisms involved and their effect on the quality of the starch.

Investigations were also started on the factors involved in the purification of sweetpotato starch by tabling and to determine the cause of the slow change in starch during storage, particularly as indicated by the viscosity of its pastes, and the proper conditions for improving stability during storage.

The suitability of sweetpotato starch for use in laundering, in comparison with that of various commercial laundry starches, was determined by a consideration of the properties imparted to laundered material after starching and ironing. This study involved the development of physical methods for testing starched materials for stiffness, resistance to folding or creasing, soilability, and degree of starch penetration. Formulas were developed for making from sweetpotato starch a noncongealing starch and other special starch preparations for laundry use.

The three fellowships established by the Chemical Foundation, Inc., terminated in March 1938. Until that time the incumbents continued investigations on a new method for the dehydration of sweetpotatos for storage and on the utilization of sweetpotato flour produced from the dried material. Besides being used primarily as a source of starch for continuous operation of a starch factory throughout the year, dehydrated potatoes when made into flour may find uses as adhesives and as an ingredient of foodstuffs.

CELLULOSE

Fundamental investigations on the chemistry of cellulose were continued, with special attention to the derivatives of glucose and cellobiose, the simpler hydrolytic degradation products of cellulose. The α- and β-methyl-d-glucosides were prepared and purified for use as reference compounds and for further investigation. The α- and β-octacetyl cellobioses were prepared, purified, and used for studies of deacetylation by the barium methoxide method. By means of a modification of the technique described in the literature, the yield of cellobiose by this method was materially increased. The phenylosazone and the osone of cellobiose were made, and the preliminary study of the alcoholysis of cellulose with methyl alcohol-hydrochloric acid mixture was continued. The soluble products are optically active, nonreducing, easily caramelized substances.

MISCELLANEOUS CARBOHYDRATES

Interest in agricultural waste products that are primarily of cellulosic and hemicellulosic nature has brought to the front the problem of extracting hemicelluloses from various plant materials. Therefore, extensive studies of the optimum conditions for extracting hemicellulose from sugar-beet pulp, rice hulls, and peanut shells were made, and the most suitable conditions for extraction with both acids and alkalies were determined. It was found that pectin interferes with extraction of other hemicelluloses (e. g. from beet pulp). When pectin is present the extraction should be carried out at a higher temperature or preliminary extraction of pectin should be performed. The principal constituents of these hemicelluloses are uronic acids and the sugars xylose and arabinose. These two sugars, although sweet to the taste, have little or no food value, but can be used whenever sugars are employed for industrial nonfood purposes.

Sirups of different sugar and dextrin contents were made from fresh sweetpotatoes by varying the time of hydrolysis, the pressure, and the concentration of acid used. Tests by a commercial laboratory showed that some of these sirups were useful adjuncts in the brewing of beer.

Previous investigations in the Bureau have shown that chicory roots are useful as a source of inulin and levulose sirup. Removal of water from the roots is a necessary preliminary step. It was found that by treating the ground roots with carbon tetrachloride vapors 75 percent of the water could be removed by pressing.

OIL, FAT, AND WAX INVESTIGATIONS

VEGETABLE OILS

The report for 1937 described the general characteristics of the oil obtained from the fruit seeds of the Brazilian palm (*Syagrus coronata*), which has recently become of commercial interest. In response to numerous requests for information concerning the composition of this oil, commonly known as ouricury palm-kernel oil, the mixed fatty acids from this oil were investigated and found to contain the following percentages of individual acids: Caproic, 1.66; caprylic, 9.1; capric, 7.64; lauric, 42.7; myristic, 8.43; palmitic, 7.15; stearic, 2.15; arachidic, 0.096; oleic, 12.18; and linoleic, 2.04. This oil, which exists in the seed kernels to the extent of about 70 percent, is well suited for the manufacture of margarine and soaps and for the preparation of mixed or fractionally distilled fatty acids.

The composition of American tung oil was investigated further, special attention being given to its content of linoleic acid. A previous investigation by this Bureau showed that eleostearic acid constituted the bulk of the mixed fatty acids, ranging from 85.5 to more than 89 percent of the total, and that oleic acid and saturated acids were present to the extent of 4 percent or slightly more for each. A report on the composition of Chinese tung oils published by German investigators showed that their mixed fatty acids contained more than 9 percent of linoleic acid and consequently a notably smaller quantity of eleostearic acid than previously reported by this Bureau. Estimation of linoleic acid in the mixed fatty acids from American tung oil by two improved methods indicated that no more than 0.9 percent of linoleic acid was present. The results of these analyses as well as those previously obtained indicate the presence of only a very small percentage of linoleic acid in the tung oils examined. It is believed that authentic tung oil from any locality will contain very small quantities of this acid, unless it has been expressed from decidedly immature seeds.

Preliminary investigations were made on the seed oils of the native tree *Sapindus drummondii* and the foreign tree *Moringa oleifera*. Both the oils were found to belong to the nondrying class. The first exists in the seed kernels to the extent of 43 percent, which represents about 8 percent of the weight of the berrylike fruits. It is rather difficult to recover because the kernels adhere firmly to the tough, thick seed coats and the oil must be expressed or extracted with solvent from the undecorticated seed after crushing. The second exists in the seed kernels to the extent of 49.2 percent, which represents about 35 percent of the combined weight of kernels and hulls.

The investigation of *Sapindus drummondii* as a possible source of oil was undertaken at the suggestion of the Soil Conservation Service. The fruits were collected in Oklahoma. Seeds of *Moringa oleifera* were received from Nicaragua, through an individual in Texas who was interested in the possibility of growing these trees on a commercial scale in the warmer parts of that State for the production of oil. These trees are reported to thrive on relatively poor soils, and if it is found feasible to grow them for oil production from their seeds it is proposed to plant them in soils not adapted to the production of other crops. They grow rapidly under favorable conditions and are reported to yield seeds when but 3 or 4 years old.

WAX FROM LEAVES OF DOMESTIC PALM

A preliminary investigation was made on wax from the leaves of the palm *Serenoa serrulata*, which is indigenous to southern Florida. This investigation was suggested by botanists in the Bureau of Plant Industry, who supplied a small sample of crude wax obtained from the dried leaves. The wax, originally in the form of a gray powder, was separated from plant debris by dissolving in hot chloroform, filtering, and evaporating, after which it was a hard, brittle, yellowish-brown solid. It softened at 75° and melted at 82° C. Tests indicated that it was a true wax somewhat similar to carnauba but contained slightly more uncombined acid and had a higher saponification value.

RESEARCH METHODS

Incidental to the investigations on vegetable oils, studies were made to determine the adaptability and dependability of several analytical procedures, including the volumetric titration of mixed fatty acids in cold alkaline solution with a very dilute standard solution of potassium permanganate, previously devised by this Bureau, the Meinel color reaction for the detection of conjugated double bonds, three procedures for determining unsaturated acids having conjugated double bonds, and application of the Bertram permanganate oxidative procedure to the qualitative and quantitative determination of unsaturated acids in ethyl ester fractions prepared directly from vegetable oil.

FOOD RESEARCH

CITRUS FRUIT PRODUCTS

The Texas Citrus Products Laboratory cooperated with 40 commercial firms, including grapefruit canneries, citrus-product manufacturers, and equipment manufacturers, on problems relating to canning methods, control of quality, aging, oil recovery, new products, and disposal of wastes. Methods of handling tender and pink grapefruit sections so as to preserve color and form were demonstrated to canners entering this field. Several formulas for marmalade bases were developed for a manufacturer, and a new formula was developed for making spice-flavored citrus-fruit butter. It is believed that the manufacture of this product, which has been undertaken by two firms, will provide a desirable outlet for the pulp separated from juice intended for canning. Methods for preparing bases for dry and sweet carbonated grapefruit beverages were demonstrated to several prospective manufacturers who contemplate beginning commercial production next season, using methods developed by the Bureau.

A method for estimating the peel-oil content of grapefruit juice extracted by various methods was developed and applied. Because of the general introduction of automatic extraction equipment, this work was of value to canners in judging the suitability of each type of such equipment.

In preparing different blends of juices from frost-injured California oranges and grapefruit, it was found that the addition of about 5 percent of lemon juice overcame to some degree the flat taste characteristic of juice from frozen fruit.

Orange juice up to 35 percent by volume gave increased sweetness and body to the mixtures. A blend of equal volumes of orange and grapefruit juices with 5 percent of lemon juice proved very satisfactory. The bitter taste of canned navel orange juice is well masked in mixtures with grapefruit juice.

A preliminary study was made of the cause and prevention of bitterness in navel orange juice on standing, with particular attention to the enzyme factor. As yet no explanation has been found for the formation of the bitter substance. This problem is of great importance to the orange growers of California because if this bitterness can be prevented commercial use can be made of the juice of navel oranges, which up to the present has not been possible.

Further experiments were made on the canning of various citrus fruits for table use and ice-cream toppings and of mixed citrus fruits for use as salads. The results indicated that a good commercial product can be made by canning navel oranges if care is taken to select well-matured fruit. The ice-cream toppings made from tangerines and mandarin oranges seem to have definite commercial possibilities. Blood oranges also made a pleasing product.

During the year special apparatus was devised and used satisfactorily for direct determination of carbon dioxide, oxygen, and nitrogen in citrus juices in studying the gas content of fresh juice prepared in different ways, of deaerated juice, and of processed juice. It was found that deaerators being used commercially in Florida remove only about 34 percent of the oxygen in fresh juice. Juice deaerated in the laboratory by means of the improved equipment recently developed by the Bureau contained only one-tenth as much oxygen as did juice deaerated commercially. One packer has installed this type of deaerator, and tests will be made under commercial operating conditions.

A jellied grapefruit juice was prepared by adding edible gelatin (4.5 percent by weight) to grapefruit juice, dissolving it by heating gently, and then processing in the usual manner. At room temperature the juice is liquid, but upon chilling it solidifies so that the housewife may simply cut the top from the can and remove the jellied juice for salads. It is important to use gelatin of the finest grade in order to prevent objectionable odor and taste.

Owing largely to the preliminary research carried out at the citrus-products laboratories, small-scale commercial production of grapefruit-seed oil has been started in Florida. During the first season of production (1937–38) the output amounted to about 10,000 pounds. The oil is expressed from the cleaned and dried seeds and after settling is pumped through a plate-and-frame press. Examination of the press cake showed that less than half the oil is recovered. Obviously this is owing to the fact that the seed hulls not removed prior to pressing absorb and retain a large part of the oil.

The Texas Citrus Products Laboratory cooperated in studies of methods for reducing the cost of producing dried citrus meal and improving the quality of the product, handling sewage from canneries and dehydration plants, and converting citrus cannery waste to marketable fertilizer. Definite contributions were made toward the solution of the first two problems; work is still in progress on the third.

The Florida Citrus Products Laboratory cooperated with the Florida Canners' Association and the Florida State Board of Health in efforts to solve the serious problem of innocuous disposal of liquid effluents from citrus fruit canneries. Analyses of the effluent from different canneries were made throughout the canning season. The effluent from canneries packing grapefruit sections was more concentrated than that from canneries packing juice. After encouraging laboratory experiments on the treatment of cannery effluents by a biological process applied by means of an intermittent or trickling filter, the Florida Canners' Association provided funds for the erection of an experimental treating plant. The plant, which was designed by the Florida State Board of Health, was not completed until the end of the season, but during the very short time that it was in operation as much as 68-percent reduction in biological oxygen demand of the sewage was obtained when the filter was dosed at the rate of 1,566,000 gallons per acre per day. The time available did not permit experimenting with higher doses.

APPLE PRODUCTS

Further studies on the technology of canning apple sauce showed that sauce of satisfactory quality can be made commercially from western-grown apples. The yellow color of sauce from many of the western-grown varieties is not objectionable so long as it has a bright tone. The principal requirement for a bright, uniformly colored sauce was found to be rapid handling with minimum exposure to air after peeling.

It was found possible to lighten the color of apple sirup through the bleaching effect of sulphur dioxide. Sulphur dioxide resulting from sodium bisulphite added to the apples at the time of grinding is largely eliminated during concentration of the juice. Lighter-colored sirups and better flavor also result if the sulphurous acid is neutralized after, rather than before, concentration.

Apple powder is used to some extent, especially in foreign countries, in the treatment of intestinal disorders. To assist in studies designed to explain the therapeutic effect of apple powder a substantial quantity of galacturonic acid, the essential unit in the development of pectic substances, was prepared and supplied to the school of medicine of the University of Oregon for use in experiments with animals. Improvement in the method of producing this compound by enzymic hydrolysis of polygalacturonic acids has greatly reduced the cost of preparation, and the material should now be readily available to research workers and possibly for other uses.

MISCELLANEOUS FRUIT PRODUCTS

It was found that the juice from California-grown Black Tartarian cherries can be satisfactorily preserved for at least 18 months by preheating to 194° F., cooling, treating with a commercial clarifying agent, decanting after settling, filtering after addition of a filter aid, pasteurizing at 174° to 178° and sealing in charcoal-plate lacquered cans under vacuum. Bottles are not so good as cans for containers because the juice has a tendency to fade on exposure to light. The yield of juice was about 145 gallons per ton of fruit.

In cooperation with the Washington State Agricultural Experiment Station, canning experiments were made on freestone peaches grown in the Yakima Valley to determine the relative suitability of different varieties for commercial canning. Packs with satisfactory color, flavor, texture, and general appearance were obtained with J. H. Hale, Gold Medal, Elberta, State Champion, and Early Elberta varieties, while Up-to-Date, Slappey, Shalil, Rochester, Early Crawford, and Late Crawford varieties yielded products of either poor texture or ragged appearance. In collaboration with the Bureau of Plant Industry, canning experiments were also made on about 30 lots of peaches as an aid in the selection of improved varieties of canning peaches for commercial production in southern California.

Examination of experimentally canned Young dewberries after 2 years of storage at room temperature showed that they kept better in charcoal-plate enamel cans than in coke-plate enamel cans. One-fourth of the cans of the former type were still in good condition, whereas all of those of the latter type had developed into springers or swells. Holding at 38° F. lengthened the storage life of the canned berries; no swells could be detected in any of the lots stored at that temperature. Examination of canned Boysen dewberries after 1 year of storage also showed that the charcoal-plate cans held up better than the coke-plate cans and that storage at 38° was much better than storage at room temperature.

In cooperative work with the Food Products Industries Department of Oregon State College, undertaken to determine the best procedure for the extraction, clarification, and preservation of juices from blackberries, Logan blackberries, raspberries, and dewberries, it was found that cold pressing fresh berries resulted in low yields and poor quality of juice. Pressing berries that had been heated with constant stirring until they began to disintegrate gave yields of juice ranging from 65 to 70 percent. Such juice was judged to be far superior to cold-pressed juice, and the yield averaged 20 percent higher. Heating at a temperature of from 150° to 160° F. produced the best yield and minimum loss of flavor. Frozen-pack berries, pressed after defrosting, yielded 65 to 70 percent of juice equal or superior in quality to heat-extracted juices from fresh fruit. The use of a basket-type centrifuge produced 70 percent of juice from defrosted frozen-pack berries.

The juices from fresh or frozen-pack berries were found to be clarified satisfactorily by treating them at 100° F. with a commercial enzyme preparation (1 pound to 100 gallons) to precipitate pectinous material, allowing them to settle for 3 or 4 hours, adding bentonite (about 1 gram per gallon), and then allowing them to settle for an additional hour. The clear juice, separated from the flocculent precipitate by siphoning, was deaerated, flash pasteurized at 200°, cooled, and filtered. Berry juices clarified by this process were found to be ideal for making jelly. They were too tart to be used directly as fruit drinks, but were in good condition for bottling or canning, the product to be diluted and sweetened by the consumer.

Freshly extracted berry juices were canned satisfactorily by merely straining through cloth, deaerating, flash pasteurizing at 190° to 200° F., filling and sealing the cans while the juice was hot, and cooling them in cold water. Some sediment formed in juices packed in this manner, but the flavor was well preserved.

Efforts to discover the cause of sediment formation in apple juice after clarification were unsuccessful. It is hoped that further studies on the behavior of pectinase enzymes will reveal some clue. Experimental results showed that apple juice can be preserved satisfactorily by clarifying the expressed juice by pectinase enzyme treatment, filtering, flash pasteurizing, sealing in special enameled cans while hot, and cooling the cans rapidly.

The rapid evaporator recently developed by the Bureau was used for preparing concentrated juices and sirups from apples, pears, and cherries. The use of this improved evaporator offers distinct advantages over vacuum-pan concentration in that juices can be concentrated to a higher degree without caramelizing and without the development of a cooked taste. Sweet cherry juice was found to have an attractive color but was somewhat lacking in flavor and developed a bitter taste during storage.

Experiments were made on the dehydration of cull cantaloups and honeydew melons for use as stock food. The flesh (with rind) and contents of the seed cavity were ground and dried separately in a semicommercial dehydrator. Since the seeds are a component part of the material prepared from cavity contents, the product is higher in fat than most other stock foods made from fruits and vegetables. It is also fairly rich in protein and sugars. The material prepared from flesh and rind is low in protein and almost free from fat but has a high sugar content. Some difficulty was caused by stickiness of the concentrated material, but it was found that this could be eliminated by starting with a half-and-half mixture of cantaloup and alfalfa meal and adding more cantaloup repeatedly as evaporation proceeded. Mixtures containing as high as 85 percent of cantaloup solids were obtained in this way. Drying tests on a large scale and feeding tests with farm animals will be required to determine whether the use of cull melons for this purpose is commercially feasible. It has been estimated that about 75,000 tons of cull melons are wasted every year. This quantity would yield nearly 15,000 tons of dry materials; therefore the problem is of some economic importance.

FROZEN-PACK INVESTIGATIONS

Largely as the result of experimental work by the Bureau which demonstrated the commercial possibilities of preserving fruits and fruit pulps by quick freezing for desserts and for use in ice creams and sherbets, a beginning has been made in the commercial packing of frozen fruit products. Recently frozen nectarine and other fruit pulps have appeared on the market. There is a gratifying manifestation of increased interest in frozen fruit pulps, and it is believed that the industry will continue to grow.

Experiments on the freezing preservation of new varieties of fruits were made at the Corvallis, Seattle, and Pullman laboratories to aid horticulturists of the Bureau of Plant Industry and the State agricultural experiment stations in their selections of varieties for commercial production, especially for the frozen-pack industry. Different varieties of raspberries from the Western Washington Experiment Station which had been under test for several years were given a final classification on the basis of quality and suitability for frozen pack. Three varieties were classed as excellent, five as good, five as fair, and three as poor. One variety that was classed as excellent, and another as good, have been named Washington and Tahoma, respectively. They are described in Popular Bulletin 153 of the Western Washington Experiment Station, which gives credit to the Seattle laboratory of this Bureau for participating in the determination of their frozen-pack quality.

In preliminary work on fruits grown at the Prosser Irrigation Branch Experiment Station it was found that frozen-pack plums generally had a very pleasing appearance, and most of them had good color and texture. The major problem is the apparent toughening of the skin, which may be caused by dehydration of the subepidermal tissues due to early ice formation in the inner flesh of the ripe fruit. Sweet cherries gave very satisfactory frozen packs, as did peaches and most of the apricots. Wenatchee, Moorpark, and Hemskirke apricots were not so satisfactory for frozen pack. Owing to unwise promotion and planting, these varieties constitute the major surplus problem. Both in

canning and freezing the uneven ripening of the fruits is an almost unsurmountable barrier to the production of a high-quality product.

Frozen-pack peaches and other light-colored fruits become brown on the surface due to oxidative enzyme action. Browning develops mostly while the packed fruit is being cooled to freezing temperatures and during defrosting preparatory to utilization. It was found that the practice of steam scalding to facilitate removal of the skins stimulates subsequent browning, especially in the case of immature fruit when scalding is prolonged. Rinsing with fresh cold water after peeling and after slicing and rapid cooling help to prevent browning. Covering the surface of the fruit in the packages with disks of closely adherent, compact, and flexible cellulose sheet material is also helpful. Treatment of sliced peaches with 0.25- and 0.5-percent hydrochloric acid solutions for 2 or 3 minutes, followed by a fresh-water rinse before packing, and treatment with low concentrations of cysteine hydrochloride (2 or 3 parts to 1,000 parts of water) for short periods before packing were the most effective of the chemical treatments tried for preventing or lessening oxidative browning during defrosting. The former treatment delayed discoloration for 2 hours and the latter for 6.

Technological experiments on the freezing preservation of vegetables were made at the Los Angeles laboratory of fruit and vegetable chemistry in cooperation with the Fruit Products Division and the Home Economics Division of the University of California, the Division of Agronomy and the Truck Crops Section of the California College of Agriculture, and the California Consumers Corporation. Frozen packs were made of lima beans, peas, asparagus, brussels sprouts, broccoli, squash, and sweet corn. As a result of experiments on lima beans of different varieties grown on 156 plots under differing climatic conditions in California, a selection was made of commercial varieties best adapted to freezing on the basis of yields for 1 year and of freezing and cooking qualities. Cooking tests on asparagus frozen after truck transportation for 350 miles under ice refrigeration showed that it was equal to the product frozen immediately with solid carbon dioxide at the time and place of harvest. Asparagus frozen after similar transportation without ice refrigeration was inferior. Preliminary cooking tests on broccoli frozen shortly after harvest and after transporting 100 miles by truck, with and without refrigeration, showed that there was practically no difference in quality of the three lots.

Freezing experiments in cooperation with the Western Washington Experiment Station showed that, from the standpoint of quality of the frozen product, varieties of garden peas that have green-skin wrinkled seeds are well adapted to cold packing. Varieties that have green-skin, dimpled, or round seeds are poorly adapted to cold packing, and those that have pale-skin seeds are unadapted to cold packing. Varietal differences in skin texture, color, and flavor are sufficiently pronounced to permit selection within the well-adapted group. Consideration of cultural factors and quality of frozen pack has led to the selection of 26 varieties, out of all studied, as either well adapted or worthy of trial for commercial freezing in western Washington.

Quality in frozen snap beans is largely dependent on absence of strings and fibers and the retention of desirable form, texture, and color during cooking. Of the varieties studied, those that appeared best adapted include the following: White Creaseback (Blue Lake), Kentucky Wonder (Old Homestead), and White Seeded Kentucky Wonder, green pole varieties; Asgrow Stringless Green Pod, Burpee Stringless Green Pod, Tendergreen (New Stringless Green Pod), Giant Stringless Green Pod, Landreth Stringless Green Pod, Full Measure, Asgrow Stringless Valentine, and various strains of mosaic-resistant Refugee, bush green pod; Round Pod Kidney Wax and Keeney Stringless Kidney Wax, bush wax pod.

Both bush and pole varieties of lima beans differ markedly in adaptability to freezing from a quality standpoint. Green seed coats at freezing stage, tender texture, and high flavor are important requirements. Henderson Bush, which is now frozen commercially, is inferior in color and texture to several varieties having large, green seeds.

The best varieties of sweet corn for freezing on the cob are those having fairly uniform ears 6 inches or more in length, 1½ to 1¾ inches in diameter, and cylindrical or only slightly tapered in shape. Golden Bantam and its hybrids are among the best.

Cooperative experiments were made on the freezing of vegetables grown at the Prosser Irrigation Branch Experiment Station. As a result, selections were made of varieties of peas, snap beans, lima beans, and sweet corn best

adapted to this district. Only peas of the earliest varieties were suitable for frozen pack. Because the high atmospheric temperatures caused rapid aging at maturity, it was difficult to harvest and process peas to good advantage. It is doubtful, therefore, whether the Prosser district will ever prove suitable for commercial production of garden peas.

In order to obtain information regarding the proper stage of maturity for harvesting sweet corn for preservation by freezing, Golden Bantam corn was harvested on successive dates and put up by frozen-pack methods. Observations and chemical examinations will be made of the samples after storage. Experiments have shown that the qualitative test for peroxide can be substituted advantageously for the catalase test as a criterion of sufficient scalding in sweet corn being prepared for freezing. The catalase test is likely to be inaccurate, especially on corn in advanced stages of maturity.

Experiments made to determine the relation of temperature and time of scalding to the formation of split and wrinkled peas revealed that scalding temperatures were not significant for the formation of split peas until they reached or exceeded 200° F. At 200° and above the proportion of splits formed increased with the period of exposure. Wrinkling of scalded peas first became apparent when the temperature was 200° and the period of exposure was 2 minutes. Studies on the comparative effects of boiling water and steam scalding on the production of split and wrinkled peas have so far been inconclusive.

Efforts are being made to develop suitable methods for determining maturity and quality of peas intended for freezing. Examination of peas subjected after scalding to a so-called quality grading by brine separation and centrifuging showed that such grading is of doubtful value, especially when peas of suitable maturity are properly harvested and handled.

Samples of pea wastes from several frozen-pack establishments were taken and are being held in freezing storage. They will be analyzed to determine possible utility.

The results of 3 years' work on the microbiology of frozen fruits and vegetables were published. Types of micro-organisms and the numbers of each present were listed for the fresh materials going into the frozen packs as well as for the frozen products at various stages. The data should be useful in providing standards of purity for frozen-pack products of the kinds tested, which included blueberries, strawberries, green beans, lima beans, sweet corn, spinach, and kale.

Microbiological studies on experimental frozen packs of cultivated blueberries were completed. The data, which show the effects of two different methods of washing fruit, of several ways of packing, and of two storage temperatures, add to available knowledge regarding the survival of micro-organisms at freezing temperatures and should be of value to packers who desire to put out high-quality frozen fruit.

Microbiological tests on commercial cartons of frozen-pack peas removed from storage at 0° F. and held at higher temperatures before opening showed that microbial activity increased with temperature. At 70° the peas were definitely fermented in 24 hours or less, presenting a uniformly bleached appearance and emitting a strong sour odor. At 40° no significant microbial activity was apparent until at least the fourth day. At 34° the time required for bacteria to affect the quality of the product was extended to over 9 days, and at 28° the peas were still acceptable after 21 days. The predominating organisms in peas spoiled at 70° were lactobacilli. In peas held at 40° *Lactobacillus*, *Achromobacter*, and *Pseudomonas* were active. The principal organisms multiplying at 34° and 28° were *Achromobacter*, *Pseudomonas*, and *Flavobacterium*, with some "pink" yeasts (*Torulae*).

Experiments showed that some of the organisms naturally present in peas survive unusually long periods of scalding. Peas scalded for 8 minutes before freezing, after storage for 9 months at 0° F. soured rapidly when held in the sealed cans at 70°.

Microbiological studies were made on frozen fruits and vegetables to determine whether microbial distribution and destruction are uniform throughout the contents of a given container as well as the factors involved. This work was undertaken with the hope that the results might reveal some of the factors responsible for microbial survival at subfreezing temperatures and so contribute findings applicable to the preparation of frozen foods of low microbial count. Liquid and partly liquid packs were frozen in still air and stored at subfreezing temperatures. Under the experimental conditions, redistribution of microbial forms,

other suspended particles, soluble solids (sucrose, sodium chloride, total acids), and hydrogen ions was demonstrated. Solid and dissolved substances interfered with the degree of microbial concentration and with the redistribution pattern. Increase in concentration of some substances was favorable for microbial survival, while increase in concentration of other substances was unfavorable. Redistribution of dissolved and solid substances in a liquid medium during freezing establishes different environmental conditions within the frozen mass. Whether these environmental conditions do or do not favor microbial survival is of great significance in the preservation of foods by freezing.

VEGETABLE PRODUCTS

Studies relating to commercial production of cucumber pickles were continued at Raleigh, N. C., in cooperation with the North Carolina Agricultural Experiment Station. It was found that under southern climatic conditions cucumbers can be cured at low salt concentration, 5 percent for 1 week increased by 2 percent each week up to 15 percent, without decrease in quality of stock. Results with initial salt concentrations of 10, 15, and 20 percent were not so good. Lactic acid formation by the fermentation of sugars was most rapid and complete in the 5-percent brine, resulting in a shortening of the time required for curing. Moreover, fewer hollow cucumbers were obtained with 5-percent than with 10- or 15-percent brine.

The manufacture of genuine dill pickles under southern climatic conditions is usually accompanied by much spoilage. Efforts are being made to work out satisfactory methods for their production. Rolling the barrels occasionally during the first 10 days of curing to maintain a uniform salt concentration was found advisable. Addition of vinegar to the brine improved the stock. No benefit was noted from addition of lactic acid or sugar or from washing the cucumbers.

A pasteurization procedure was developed for fresh cucumber pickles which makes the slices retain their crispness to a high degree, avoids continued cooking, and prevents spoilage. A temperature of 160° F. for 20 minutes, followed by quick cooling, was found satisfactory for the production of a high-quality product.

Studies were made on the suitability for commercial canning of vegetables grown under irrigation in the lower Yakima Valley under conditions similar to those that would obtain in the proposed large Columbia Basin irrigation area. These studies indicated that garden peas satisfactory for canning cannot be produced in this area. Lima beans, however, yielded a good canned product. Further work is necessary to corroborate the findings of preliminary experiments, since some varieties that are more or less standard failed to show up as well as other newer or less well-known varieties.

In a study of methods for preparing carrot juice the procedure found to be most satisfactory included washing, lye peeling, quartering, steam blanching, fine grinding, and processing at 245° F. for 20 minutes.

In cooperation with commercial lettuce growers and shippers, experiments were made on the dehydration of cull lettuce, consisting of loose heads and trimmings, for possible use as a stock food. The dried product, reduced to about one-tenth of the original weight, had good color, aroma, and taste, with a moisture content of about 10 percent. Deficiencies of certain food values in dried lettuce could be remedied by supplementing it with other feeds. Experiments on a larger scale and animal-feeding tests are necessary to determine the commercial feasibility of dehydrating cull lettuce for stock food.

STALING OF BAKERY PRODUCTS

Recent experiments in the Bureau indicate that during the staling of bread there is not only a decrease in the proportion of soluble starch but also an increase in the proportion of soluble nitrogenous compounds. Bread 3 days old contains more than twice as much of such compounds as bread 1 hour old. The change in proportion of soluble nitrogenous compounds is relatively larger than that of soluble starch. The changes in both after 6 days are not appreciably greater than those after 3 days, indicating that staling takes place most rapidly during the first 3 days after baking.

Bread made with wheat flour containing a small proportion of rye flour, gelatinized rice flour, gelatinized potato flour, taro flour, or dried apple showed somewhat better keeping qualities than ordinary bread. Experiments on the

cold storage of bread and cake indicated that this is an effective means for retarding staling which might be of practical importance in emergency cases. Bread stored at 0° F. for as much as 4 months showed, when thawed out, the characteristics of bread 1 day old. When thawed out, cake similarly stored for 10 months was judged equal in quality and freshness to cake 1 day old. It was found that, contrary to the general belief, the storage of bread in an atmosphere containing formaldehyde did not retard staling.

RANCIDITY

Experiments in the Bureau showed that the enzyme catalase is somewhat effective in keeping oil-bearing foods from becoming rancid but not so effective as the exclusion of all light or light of wave lengths delimited by 4,900 to 5,800 angstrom units. Catalase-bearing products, such as oat flour, rice bran, rice polish, and nuts, remained free from rancidity so long as the catalase was potent. Since catalase is destroyed by high temperatures, care should be taken that the temperature does not exceed 60° C. when catalase-bearing products are heat treated for the purpose of destroying insects and insect eggs.

It was found that when vegetable oil was stored in contact with copper it became rancid regardless of whether the oil was exposed to light or kept in the dark.

A theory has been devised which accounts more fully than any previous one for the various phases in the development of rancidity in vegetable oils. It assumes that free hydrogen is liberated from the chlorophyll present in the oil, that this hydrogen unites with molecular oxygen to form hydrogen peroxide composed of two loosely combined OH groups, and that these OH groups become attached to the unsaturated bond of the glyceride, thus giving rise to the rancid compound. If this is true, the chlorophyll under the photochemical action of light acts as a photosensitizer and liberates free hydrogen. Since metals in contact with vegetable oils are known to produce hydrogen peroxide and to catalyze rancidity, it is logical to believe that they produce active hydrogen peroxide of the same nature as that produced by the action of light in the presence of a photosensitizer. The rancidity "induction period" of an oil or fat may therefore be defined as the time required for the photosensitizer, always present in oils and fats, or metal catalyzer to develop the reactive substances to a point where rancidity is recognized by taste and odor.

MINERAL ELEMENTS IN FOOD PRODUCTS

The effects of boron, copper, manganese, zinc, cobalt, nickel, iodine, selenium, and nitrate nitrogen on the stimulation or depression of diastatic power were determined by a new procedure, developed in the Bureau, for studying malts on a small scale. While some of these elements depressed and others stimulated germination and growth, none had any appreciable effect on the diastatic power of barley malts.

A new method was developed for determining phosphorus in cereal seeds and other plant materials the ash of which has an acid balance.

Research on plant mineral constituents derived from soils and their relation to the soils on which the plants are grown, and to crop, animal, and human nutrition and health was continued as a project under the Bankhead-Jones Act of June 29, 1935, which provides for basic research in agriculture. The results of a survey of world literature and of unpublished data submitted by State agricultural experiment stations indicated that no systematic attempt had ever been made to discover the relation between the wide variation in the mineral content of crops and soil composition, soil treatments, and environmental factors. Although there is convincing evidence in the literature that soil composition does influence the health and well-being of man and other animals, no systematic study has ever been made of the role played by available soil minerals in influencing the healthfulness and composition of plants, the possibility of modifying the mineral content of plants through soil management and treatment, the relation of plant composition to animal disease, and the relation between mineral nutrition of crops and the commercial or nutritive value of such crops.

Data are now available regarding the mineral content of over 100 crops, particularly with regard to the more commonly occurring minerals. These are being tabulated so as to correlate the occurrence of certain deficiency diseases with the mineral composition of the crops consumed by the animals.

CALIFORNIA WALNUTS

Studies were continued on the effects of ethylene and other gases on loosening the hulls of walnuts, on the causes of lowering the color grade of the kernels, and on methods for determining the maturity of walnuts. In both laboratory and plant experiments to determine the effect of carbon dioxide in the ethylene treatment for loosening the hulls of walnuts, it was found that carbon dioxide up to 3 percent did not cause darkening of kernels nor retard hull loosening. Additional experimental evidence was obtained that there is marked deterioration in kernel color when mature walnuts in the hull are left lying on the ground exposed to hot sunshine. Neither field-hulled nor ethylene-treated walnuts showed any deterioration in kernel color after storage for 7 months.

Research on loosening the hulls of mature sticktight walnuts was practically completed, except for the assembly of data and preparation of the final report. This investigation resulted in a satisfactory commercial method in which ethylene gas is used in low concentrations. Before the introduction of this method growers had much difficulty in removing the hulls from this type of nuts. If harvesting was delayed until the hulls loosened naturally, the color of the kernels deteriorated, especially in the hotter, interior districts of California, with consequent financial loss. This method is of great economic value to walnut growers in these districts.

PHYTOCHEMICAL INVESTIGATIONS

The waxlike coating of grape skins, 7.4 percent of which was extracted with ether from air-dried pomace of Concord grapes, was found to contain the sapogenin oleanolic acid, together with glycerol, unsaturated fatty acids (oleic and linoleic), saturated fatty acids (palmitic, stearic, and higher members of the same series), hydrocarbons (nonacosane and hentriacontane), sitosterol, a mixture of primary alcohols of the series C 22 to C 28, and unidentified resinous substances. Grape pomace is an inexpensive and readily available source of oleanolic acid. This compound and also the closely related compound ursolic acid, which the Bureau previously found exists abundantly in the coating of apples and other fruits, is of much interest to organic research chemists and may have some practical uses.

In order to gain a better understanding of the natural synthesis of oils and fats, the Bureau has undertaken a fundamental study of the naturally occurring fatty acid glycerides which is dependent upon their isolation and purification without alteration or decomposition. The new method of molecular distillation seemed to offer a means for isolating oils and fats in their original condition, which heretofore has been very difficult to accomplish. In order to determine the actual value of this method for the purpose in mind, experiments were made on the preparation and molecular distillation of synthetic glycerides. A fairly satisfactory method was developed for the purification of oleic acid, the product being 99 percent pure. A preliminary synthesis of triolein was made, and the product appeared to be capable of molecular distillation without decomposition. Linoleic acid was prepared in a pure state from its crystalline bromide and was used in a preliminary study of the factors involved in its conversion to the beta form. The saturated glycerides, tristearin, tripalmitin, trimyristin, and trilaurin, were successfully purified by molecular distillation with the pot still.

It is believed that more definite knowledge as to the identity and composition of the various glycerides as they exist naturally in oils and fats will be of value in solving problems connected with the breeding of oil-producing plants, the utilization of such plants and their seeds, the deterioration in storage of oils and fats and foods containing them, and the digestion and assimilation of oils and fats by animals.

Fruit of the Amur corktree (*Phellodendron amurense*), submitted by the Division of Research of the Soil Conservation Service, was found to contain a volatile oil which consists mainly of myrcene (about 92 percent) with *n*-methyl nonyl ketone and apparently a little geraniol. Steam distillation yielded 2.2 percent of oil from the green and 3 percent from the ripe fruit. No use has yet been found for the oil. Material extracted from the residue left after steam distillation had a peculiar physiological reaction on the tongue and lips, causing a lasting tingling sensation. Preliminary tests on a sample submitted to the Bureau of Entomology and Plant Quarantine indicated that the extract may have some value as an insecticide.

PLANT VIRUSES

The Bureau continued to cooperate with the Bureau of Plant Industry in the study of plant viruses, a project conducted under the Bankhead-Jones Act of June 29, 1935, providing for basic research in agriculture. In a study of the trypsin method of virus purification it was found that mosaic virus and other proteins in tobacco can be distinguished by their different behavior toward trypsin and at least partly separated. As a result, it was possible to measure for the first time the virus and nonvirus proteins in the plant tissue itself instead of in incomplete extracts. Such measurements showed that the virus protein is not produced independently in very abnormal quantities, as was generally supposed. Instead, the virus protein occurs in relatively small proportion to the total protein and largely at the expense of nonvirus proteins. This fact may change existing ideas about the mechanism of virus-protein formation. The ratio of virus to total protein varies, however, in favor of the latter with the age of the plant and presumably with recovery from the mosaic disease. It was found, also, that the virus exists within the plant cells rather than in the fluid surrounding them.

A study of the amylase activity in leaves from normal and mosaic tobacco showed that virus causes a general disturbance of the plant's metabolism but did not indicate its mode of action, since virus protein had no effect on amylase directly.

PRESERVING BIOLOGICAL SPECIMENS

Fundamental research on methods for preserving specimens of organic materials related to agriculture in as nearly a natural condition as possible was carried on during the year as a project under the Bankhead-Jones Act of June 29, 1935, providing for basic research in agriculture. Methods for preserving agricultural specimens, such as roots, stems, leaves, flowers, fruits, and seeds of plants, and insects so that they will retain their natural color and shape for an indefinite period are highly desirable. Investigations were made on two interrelated processes that offer great promise of meeting the ideal requirements for the preservation of agricultural specimens. In one process fresh plant materials are treated chemically in such a manner as to toughen the tissues and set the natural color, after which they are treated with a transparent preservative substance and mounted directly on glass plates or between transparent films of cellulose. In the second process, the specimens, after preparatory treatment, are imbedded in transparent plastics of the methacrylate type while in the fluid state. This method permits the specimens to be encased without deformation in a solid, highly transparent, and nearly colorless substance which may be machined and polished. A number of plant and entomological specimens, preserved and mounted by these methods, were put on exhibition. While they attracted much interest and were the subject of much favorable comment, it should be pointed out that the preservative processes are still in the experimental stage, and a number of undetermined factors relating to their use and the permanence of results remain to be studied.

PHARMACOLOGICAL INVESTIGATIONS

Pharmacological studies on inorganic substances that may contaminate foods were concerned with the possibilities of chronic poisoning by cadmium and antimony. Cadmium administered in the form of chloride was found to be distinctly toxic to albino rats, even in concentrations as low as 30 parts per million parts of diet. At concentrations of 60 parts per million and above, it resulted in anemia, retardation of growth, cardiac hypertrophy, and occasionally in death. When rats receiving 120 parts of cadmium per million parts of diet were returned to a normal diet, the anemia disappeared and the normal rate of growth rapidly returned. Studies are still in progress on the distribution of cadmium stored in the tissues and evidence of injury as revealed by histological examination. Antimony administered in metallic form, as trioxide, and as pentoxide appeared to be without toxic effects in concentrations up to 2,560 parts per million. However, antimony in the form of potassium antimony tartrate caused death in 14 days when fed in the concentration of 2,560 parts per million. Preliminary to a study of the distribution of antimony stored in the tissues, work was done on the development of satisfactory colorimetric methods for the determination of antimony and also of arsenic, with which antimony is frequently contaminated.

Studies relating to the therapeutic use of phenothiazine in the treatment of infectious cystitis and pyelitis were completed, and the results prepared for publication. Phenothiazine, the value of which as a urinary antiseptic was unexpectedly discovered in a previous investigation on the pharmacology of this new insecticide, is proving to be not only a valuable aid in therapeutics, but promises to be useful to the veterinarian in the treatment of infections of the urinary tract in cattle.

The results of toxicological studies of derris were published. They indicated that further studies of a wider scope are needed before derris or any of its derivatives may be pronounced wholly innocuous when present in minute quantities on fruits and vegetables subjected to dusting or spraying with insecticides containing such material as the active ingredient.

Studies on the pharmacological and physiological effects of the glucosides naringin and hesperidin, which occur naturally in grapefruit and oranges, respectively, yielded no evidence that these compounds are injurious as food constituents.

Ursolic acid, which occurs naturally in the waxy coating on apples, and its sodium compound were found to have a negligible degree of toxicity and no diuretic effect.

ENZYME INVESTIGATIONS

In continued studies on the enzymic break-down of thick egg white, a recognized indication of deterioration in stored eggs, it was observed that the liquefaction of the thick white in the shell and that in the broken-out eggs are different chemical processes, liquefaction in the shell being more rapid. The Bureau of Animal Industry found that the rate of liquefaction in the shell is influenced by the strain of chickens producing the eggs. This Bureau found, however, that the rate of liquefaction is not proportionate to the amount of mucin laid down in the egg to start with, and must depend on the activity of some liquefying mechanism in the egg that has not yet been satisfactorily explained.

The inhibitor of proteolytic enzyme action in egg white was concentrated and studied with regard to its relation to the preservation of egg quality and to the indigestibility of raw egg white. The inhibitor itself is destroyed by pepsin, so it seems impossible that it should prevent digestion. On the other hand, it appears to play a part in keeping egg white from deteriorating.

A new method was devised and patented for converting the foam from vats of fermenting egg white into usable material. Upon being treated with pepsin the foam liquefies and can be dried in the usual manner.

Measurement of the surface area of broken-out egg white by means of special apparatus was found to provide a possible means for testing the efficiency of bulk grading methods. A statistical treatment of the results of such measurements is being prepared for publication.

An accurate and rapid method for determining the enzyme papain was developed. This method, which is based on the ability of papain to clot milk, has already been widely adopted in laboratories handling papain and such papaya products as meat tenderizers. An up-to-date bibliography on papain and bromelin was prepared.

Crystalline papain was prepared in the laboratory, and a study of the properties of this pure enzyme is still in progress. This is the first enzyme that has been successfully crystallized in the Department of Agriculture.

RETARDING DETERIORATION OF EGGS

Experimental work on treatments to retard the enzymic deterioration in the quality of shell eggs during cold storage was completed. Grading tests were made by the Bureau of Agricultural Economics on a 400-case lot shipped to New York by a cooperating commercial firm early in 1937 and held in cold storage for 6 months. The eggs in 100 cases were untreated: the same quantities had been machine-dipped in plain oil, machine-dipped in carbonated oil, and oiled by the Bureau's vacuum-carbon dioxide method. The difference in the percentages of U. S. Extras (top grade) going into and coming out of storage was 2.07 for eggs subjected to the vacuum-carbon dioxide oiling treatment, 26.82 for the eggs machine-dipped in carbonated oil, 33.27 for eggs machine-dipped in plain oil, and 66.52 for untreated eggs. In the same order, the differences in the percentages of U. S. Extras and U. S. Specials (taken together) going into and coming out of storage were 16.99, 43.68, 46.69, and 68.02, respectively. These results show conclusively the superiority of the Bureau's vacuum-carbon dioxide

oiling treatment for retarding the enzymic deterioration of eggs during cold storage.

ENZYME ACTION AT LOW TEMPERATURE

In continuation of research on enzyme action at low temperatures, a project conducted under the Bankhead-Jones Act of June 29, 1935, providing for basic research in agriculture, it was found that enzyme action in the frozen state may be detected without thawing out the material. This discovery may result in marked improvement of methods for food research at low temperatures. A proteinase that is active at low temperatures was isolated from beef muscle. This was identified as a cathepsin, which would not necessarily be influenced by the oxidation-reduction equilibria of the tissues. Its role in the decomposition of stored meat, while fairly obvious, remains to be demonstrated. Studies on milk clotting proved that an enzyme may produce different reactions at low and high temperatures.

Lipase, the fat-splitting enzyme, was found to be particularly active in the frozen state, but only on certain fats. The composition of the fat, which varies with the diet, would therefore seem to influence the keeping quality of frozen meat. Pancreas lipase appeared to digest only the esters of primary alcohols. This behavior is very different from that generally depicted in the literature. A new and more sensitive method of demonstrating lipase action was found, which greatly facilitated the investigation. This method was used to isolate esterase from beef muscle. This ferment, which is active at low temperatures and seems to be responsible for some of the changes in the fats of stored meat, is receiving further attention because of its apparent importance.

INDUSTRIAL FARM PRODUCTS RESEARCH

HIDES AND SKINS

In studies on the spoilage of salted calfskins completed during the year, a correlation was shown between moisture content, bacterial population, and chemical decomposition. These studies emphasized the critical dependence of spoilage upon the amount of moisture present. Reduction of salt content from 14 to 12 percent, accompanied by increase of moisture from 49 to 56 percent, increased the bacterial population more than 35 times in calfskins stored for 30 days at 30° C. This increase in bacteria and the ensuing microbial spoilage of the skin resulted in the formation of nearly 19 times as much ammonia nitrogen and over 3 times as many free carboxyl groups. These data explain in large measure the excessive spoilage sometimes experienced in commercial practice when hides and skins take up appreciable quantities of water, due to extremely humid weather, condensation of atmospheric moisture, inundation, or other causes, and suddenly decompose to the extent of almost complete ruin.

In continued efforts to improve the curing of hides and skins by adding small quantities of antiseptic chemicals to common salt, experiments were made with orthodichlorobenzene, which was found to be ineffective, and with zinc oxide, which increased preservation to a marked degree when added to the extent of 1.3 percent. The zinc oxide-salt mixture, however, was definitely less effective than salt containing 0.5 percent of sodium silicofluoride and 0.1 percent of paranitrophenol, a mixture used in previous experiments. Salt containing sodium pentachlorphenate was found to be inferior to the mixture of salt and sodium trichlorphenate previously used.

In semicommercial experiments to determine the effects of extended cold storage on the leather-making value of salted calfskins, opposite sides of the same skins, which had been in storage for different periods, were compared. Both lots were tanned similarly into chrome shoe-upper leather by a commercial tanner, one after being in cold storage for 14 months and the other for 26. The two lots of leather were of about the same grades and selections and, according to a disinterested leather sorter, there was little, if any, significant difference between them. Quantitative testing and rating of these leathers, however, have not been completed.

The Bureau entered into a formal cooperative agreement with the Bureau of Biological Survey providing for fundamental research on the influence of the life history of fur-bearing animals on the physical, chemical, and histological properties and hence the value of fur skins. These studies will be coordinated with the work of the Bureau of Biological Survey on raising fur-bearing animals.

TANNING MATERIALS

Canaigre was definitely decided upon as a plant worthy of reconsideration and study in the collaborative program of research with the Bureau of Plant Industry on the development of new domestic tanning materials, preferably in the form of new field crops. The root of this plant is rich in tannin, and it is hoped that through research valuable products in addition to tannin extract may be developed from the roots to help pay the cost of producing and processing the crop.

Plantings of canaigre were made at the New Mexico Agricultural Experiment Station to obtain data on yield and other cultural aspects, to start progeny plots for selective propagation of strains especially high in tannin, and to obtain a sufficient quantity of roots for laboratory studies. Selected roots were also planted at 12 points in Texas to obtain information as to localities in that State best adapted to the growing of canaigre.

Analyses were completed on about 100 samples of the stock used in the planting program. Laboratory studies are in progress to determine the optimum conditions for processing canaigre roots to obtain tanning extract and other products.

Many facts concerning the growing of canaigre, locations best suited to this crop, cost of production, yield of roots, merits of the tanning extract that might be made from them, and markets for the extract must be learned before any sound decision can be made as to the economic possibilities of this plant. Initiation of large-scale farming with canaigre should be deferred until such information becomes available. This will require several years.

LEATHER

Studies to obtain information on the minimum quantity of chrome for durable combination vegetable-chrome leathers were completed. It was found that resistance to rotting upon exposure to acid fumes is not directly proportional to the chromic oxide content but increases until about 1.5 percent of chromic oxide is present, after which it remains essentially the same up to about 3 percent. After 18 weeks of accelerated aging, leathers containing from 1.6 to 2.8 percent of chromic oxide lost from 43 to 48 percent of their original strength, whereas the controls, which contained no chromic oxide, lost 70 percent or more. A chromic oxide content of 1.5 percent was tentatively fixed as the minimum for the combination vegetable-chrome retanned type of leather. This degree of retannage may be secured readily while still maintaining predominantly the characteristics of a vegetable-tanned leather. Every retanned leather containing 1.5 percent or more of chromic oxide will not necessarily have increased resistance to acid rot. Additional evidence was acquired that in commercial practice the tannage may be supplemented by materials and processes that have deleterious effects sufficient to offset the added resistance imparted by chrome.

Acting upon the findings and advice of this Bureau, the Government Printing Office is now using only leathers of a chrome or combination vegetable-chrome tannage for binding. These leathers have displaced the straight vegetable-tanned leathers used heretofore.

The production from cattle hides of a combination vegetable-chrome leather, known as airplane weight, for upholstering airplanes is a comparatively recent development in the leather industry. A sample of such leather was obtained and tested with the thought that similar leather might be produced commercially in suitable weight for bookbinding. It had an initial pH value of 3.8 and a chromic oxide content of 2.2 percent. It showed moderate resistance to acid rot in the accelerated tests, losing 28 percent of its original strength after 12 weeks of exposure and 50 percent after 18 weeks.

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.

UTILIZATION OF FARM WASTES

Experiments were made on the production of moldable plastic from sugarcane bagasse by partly decomposing the cellulose into sugars and the pentosans into furfural by acid hydrolysis under pressure and allowing the residual lignin to react with the furfural and added aniline to form resins. The Forest Products Laboratory, which had prepared such plastics from the lignin in wood, cooperated in this work. Moldable plastic in powdered form was produced that

was equal, if not superior, to that prepared from wood. Preliminary experiments in which the resinified lignin was dissolved in alkali and then precipitated with acid indicated that a superior plastic might be produced in this manner. The thermoplastic flow of the molding powder produced from bagasse was much lower than that of the best commercial products but approached that of some of the molding powders in use. Suggestions regarding equipment required and procedures for making moldable plastic from bagasse were given to a sugar-producing firm which is planning to erect an experimental laboratory and pilot plant for the further study of this problem.

Preliminary investigations on the use of alcoholic nitric acid as a pulping agent for sugarcane bagasse were completed. Good yields of pulp with relatively high α-cellulose content were obtained. A study of its characteristics indicated that this pulp, which is high in pentosans but low in lignin, might be especially useful in papermaking as a substitute for the short-fibered pulps from deciduous woods in book and magazine papers.

Continued studies on the pulping of bagasse by the nitric acid process, in which a percolator type of liquor circulation was used, indicated that a lower ratio of total acid liquor to bagasse may be used advantageously by this means.

Experiments were continued, in cooperation with a commercial firm, on the production of improved paper pulp from straw. In view of the marked interest shown by industrial technologists in the possibility of applying to straw the sulphate process, now used for the production of kraft wrapping papers from coniferous woods, special equipment was obtained to continue the study of straw pulping by the kraft process for the specific needs of the boxboard and kraft-paper industries.

Results obtained in the study on direct causticizing of black liquors from the soda pulping process, to permit reuse, were correlated and published, thus completing this investigation. It was found that weak soda black liquors used in pulping fibrous farm wastes can be fortified by direct causticization for reuse about 10 times. After 10 cooks the organic matter has increased to such an extent that the usual soda-recovery method by ignition may be used.

The conductometric method for determining the degree of "spentness" of pulping liquors, mentioned in last year's report, was used in connection with the recausticizing of soda liquors and also for the examination of liquors from the nitric acid and sulphate pulping processes. By this method the quantities of nitric, oxalic, formic, and acetic acids, as well as some complex organic acids and amine and ammonia compounds, in used nitric acid pulping liquor may be determined rapidly and fairly accurately. The method also provides a means for rapid and fairly accurate determination of the hydroxide, carbonate, sulphide, sulphite, acetate, sulphate, and thiosulphate radicals in admixture in used sulphate pulping liquor. Experimental work with this method as applied to the examination of kraft (sulphate) pulping liquors is nearly completed. Results obtained in its use for control of direct causticizing of soda black liquors and examination of nitric acid pulping liquors were published.

In a study of the effects of temperature on the yields of products from the destructive distillation of corncobs, it was found that the maximum yields of useful products were obtained at about 700° F. The heating value of the non-condensable gases from corncobs was greater at the higher distillation temperatures.

LIGNIN

In order to determine the extent to which certain carbohydrates yield insoluble products when subjected to the action of strong mineral acids, such as those used for the isolation of lignin, and the degree of error in quantitative estimations of lignin resulting therefrom, experiments were made with fuming and dilute hydrochloric acid on arabinose, xylose, glucose, mannose, galactose, fructose, sucrose, maltose, starch, inulin, pectin, and cellulose. The only carbohydrates found to yield insoluble residues were fructose (1.8 percent), sucrose (0.9 percent), and inulin (1.8 percent). The same carbohydrates were the only ones that caused apparent increases in the results for lignin when definite weights of extracted wheat straw of known lignin content were added to individual carbohydrates before the acid treatments, and the apparent increases in lignin content of the straw were exactly equivalent to the insoluble residues obtained from the carbohydrates alone. It is reasonably certain that when a quantitative estimation of lignin in plant material is made by the method developed in this Bureau, no error will be introduced by the presence of carbohydrates likely to be associated with the lignin, because the method provides for preliminary

extractions, with 1:2 alcohol-benzene mixture, hot water, and boiling 1-percent hydrochloric acid solution in succession, which remove such interfering substances.

It was found that when lignin, isolated from straw by means of fuming hydrochloric acid, was treated alternately with cold fuming hydrochloric acid and boiling 5-percent hydrochloric acid there was a loss in weight. When the alternate treatments were repeated four times, using in each case some of the residual lignin from the preceding experiment, there was a loss in weight each time, although such loss was less than in the first experiment. After each experiment the percentage of methoxyl in the residual lignin remained practically the same as in the original lignin, indicating that the loss in weight was due not merely to removal of impurity but rather to a degradation of the lignin complex. From these results it was concluded that, contrary to the generally accepted belief, lignin is not entirely resistant to hydrolysis by mineral acids. The possibility of using acid hydrolysis in determining the chemical structure of lignin is being investigated.

Lignin from wheat straw was separated into three fractions. The first and second fractions were isolated by successive and exhaustive extractions, first with a 2-percent alcoholic sodium hydroxide solution at room temperature and then by refluxing with a 4-percent aqueous sodium hydroxide solution. The third fraction was isolated with fuming hydrochloric acid from the straw remaining after the first and second extractions. From analytical data and a study of derivatives it was concluded that the first fraction had the empirical formula $C_{42}H_{48}O_{16}$ or the dissected formula $C_{33}H_{31}O_7(OCH_3)_4(OH)_5$. Of the five hydroxyl groups, three could be methylated with diazomethane, indicating that these three hydroxyl groups are probably more acidic than the others, being possibly phenolic or enolic. This lignin fraction, when fused with potassium hydroxide, yielded 4.5 percent of protocatechuic acid, based on the weight of lignin. The second lignin fraction was found by analysis to have the empirical formula $C_{40}H_{42}O_{16}$. Approximately four methoxyl and four hydroxyl groups were found to be present. The third lignin fraction contained substantially the same percentage of methoxyl as the first. The percentage of carbon in this fraction was greater than that in either of the other two fractions.

It was found that when lignin-containing materials, such as wood or various crop wastes, are heated under pressure with alcohols in the presence of a catalyst, such as hydrochloric acid, the glucoside linkage between lignin and the carbohydrates is broken and the liberated lignin possesses desirable adhesive properties. By means of this process, for which a public-service patent was requested, it is possible to prepare fibrous molded products from crop wastes, such as straw, stalks, leaves, hulls, and cobs, and from other lignin-containing materials without the use of synthetic resin or any other added binder.

HEMICELLULOSES AND LIGNOCELLULOSES

A fundamental investigation on the chemistry and structure of the hemicelluloses and lignocelluloses in cereal straws, hays, and other forage crops was started as a project under the Bankhead-Jones Act of June 29, 1935. Comparatively little is known about the hemicelluloses and lignocelluloses. In addition to the scientific interest in these substances, fuller knowledge concerning their chemical properties, structures, and possible derivatives may lead to the development of new uses for them.

Because of delays incident to the procurement of equipment and additional personnel, laboratory work has been in progress for only about 6 months. This time was given to the investigation of various procedures for separating the hemicelluloses of alfalfa hay and wheat straw from fatty and waxy materials, pectin, lignin, and cellulose. Much difficulty was encountered in completely delignifying the hemicelluloses without decomposing them to some extent. A satisfactory procedure was finally developed for isolating the crude hemicelluloses from straw and separating them into three fractions for subsequent investigation.

FERMENTATION INVESTIGATIONS

In studies on the decomposition and disintegration of cellulosic crop wastes by anaerobic fermentation, it was found that the cellulose and pentosans in cornstalks are readily attacked by bacteria, with the formation of combustible gases, at the temperature ranges of 28° to 30° and 50° to 55° C. The decomposition of cellulose was greater at 28° to 30°; that of pentosans, at 50° to 55°.

Lignin was decomposed to some extent in both temperature ranges. The optimum methane production occurred at pH 7.0 to 7.4 at both temperature ranges. The effect of temperature on the rate of gas production was influenced more by the size of particles attacked than by variation in the chemical composition. Glass and stainless-steel containers were satisfactory for the fermentation, but copper and galvanized iron were found to be toxic. Sheet-iron containers gave erratic results, with indications that there might be some toxicity involved.

Some of the cultures isolated and purified in the study of anaerobic processes that might be useful for retting flax and other bast fibers were found to be facultative species. Fat-splitting, proteolytic, and gelatin-liquefying micro-organisms were more prevalent in the earlier than in the late stages of fermentation.

An improved combustion pipette having structural and operative advantages was designed for use in gas analysis incidental to the fermentation investigations. It proved to be satisfactory for routine determinations of methane.

Mold fermentation studies on the production of dextrolactic acid from glucose by submerged growths of *Rhizopus oryzae* in aluminum rotary fermenters resulted in definite improvements in time of fermentation, yield, and purity of product. The fermentation of 12- to 13-percent glucose solution now requires from 30 to 35 hours with 75- to 80-percent conversion to dextrolactic acid. Small quantities of the rare dextrolactic acid and its salts were supplied to scientific workers, most of whom were engaged in medical research.

A series of fermentations of glucose with *Aspergillus niger* in the large rotating aluminum fermenter was completed, resulting in the production of about 3 tons of calcium gluconate. A 200-pound charge of commercial corn sugar in 140 gallons of water was converted to gluconic acid within 24 hours, using 200 liters of air per minute at 30 pounds gage pressure, the yield being 97 percent of theoretical. The fungus growth remaining at the end of a run was found to be still active and capable of converting glucose to gluconic acid. The transfer of a portion of this active growth to a new charge made possible a semicontinuous process by eliminating the pregermination stage and other steps. This semicontinuous method eliminates the lag of 6 to 8 hours usually necessary for sufficient mycelial growth and allows the fermentation to be completed in from 15 to 17 hours.

Representatives of commercial firms visited the Agricultural Byproducts Laboratory at Ames, Iowa, to acquaint themselves with the production of gluconic acid from corn sugar with the purpose of adopting this process. Another firm is contemplating the adaptation of the rotating-drum fermentation process to the production of acetyl-methyl carbinol (butter flavor).

Certain bacteria of the *Acetobacter* group are known to oxidize glucose to gluconic acid, and efforts are being made to use them in a practical fermentation process in which the formation of calcium gluconate, essential to the submerged mold process, would be eliminated. Preliminary studies indicated that high yields of free acid are possible since the presence of a high concentration of the acid (pH 2.1) does not interfere with continued fermentation, as it does in mold fermentation.

Studies on the production of levosorbose from dextrosorbitol by fermentation with submerged growths of *Acetobacter suboxydans* were completed. The small-scale laboratory experiments were adapted successfully to an industrial scale, resulting in the development of a highly efficient method for the manufacture of this hitherto rare ketose sugar. Levosorbose is of commercial importance because it is the starting material for the manufacture of levoascorbic acid, synthetic vitamin C. In both the laboratory and large-scale experiments, under the most favorable conditions, yields of levosorbose in excess of 90 percent of theoretical were obtained by fermenting 20-percent sorbitol solutions for 24 hours. About 70 percent of the sorbose produced in large-scale experiments was recovered in a high degree of purity by crystallization. The residual sugar is difficult to recover. Samples of the crystallized sorbose and the sorbose-containing molasses were sent to scientists for use in research.

MOTOR FUELS

The use of ethyl alcohol in combination with gasoline as a fuel for modern motor cars is technically possible, blends containing from 10 to 20 percent of alcohol probably giving better over-all efficiency than those containing lower percentages of alcohol. In view of this fact, there is widespread belief that the use of alcohol produced from cereal and root crops as a constituent of

motor fuels is highly desirable, since such production would benefit agriculture and help to conserve petroleum resources.

From information gained in the Bureau's general survey of the factors involved in the production of alcohol for motor fuel, it appears that the surplus and otherwise unmarketable portions of farm crops produced annually in the United States might yield alcohol equivalent to at least 2 percent, and possibly as much as 6 percent in an exceptional year, of the country's present gasoline requirements. The quantity and the production cost of alcohol obtainable from such sources would, however, fluctuate widely from year to year. Much surplus and cull material is low in alcohol yield or widely distributed and therefore unusable from an economic standpoint. Production of limited quantities of alcohol for use in motor fuels from agricultural materials might be possible in local areas without serious disturbance of crop prices, but the intermittent use of blended motor fuels containing varying concentrations of alcohol would probably result in operating difficulties. The present costs of producing anhydrous industrial alcohol do not permit direct competition of gasoline-alcohol blends with straight gasoline, but advances in the price of gasoline or reductions in the cost of producing alcohol in future years might favor the use of alcohol obtained from agricultural sources.

Certain difficulties stand in the way of the Nation-wide use of a blended motor fuel containing only 10 percent of alcohol. Sufficient agricultural raw materials to produce the alcohol required for such a blend could not be obtained at present production levels without affecting normal prices and markets. The additional alcohol-processing plants required probably could not be brought into existence in less than 5 years, and the capital investment for these plants would be very large. The use of motor fuel containing alcohol would increase Government costs in preventing tax evasion by illegal diversion of alcohol, since no denaturant is known that would be wholly effective in preventing such diversion. It is certain that the production of motor-fuel alcohol in small farm plants under individual ownership would not be economic.

A bulletin reporting the Bureau's survey of the possibilities of producing alcohol for motor fuel is now in press.

CHEMICAL CONVERSION OF OILS, FATS, AND WAXES

Special attention was given to the chemical conversion of oleic acid, one of the fatty acids present in lard and edible vegetable oils. Several readily available aromatic compounds were combined with oleic acid to form aryl-stearic acids and their esters. Some of the products so obtained have potential value as intermediates for the preparation of textile and leather-finishing assistants, soaps, cosmetics, synthetic waxes, polishes, coating compositions, fungicides, and addition agents for lubricants. The last-mentioned use alone would create a demand for about 15 million pounds of fatty oils annually if only 10 percent of the lubricating oil consumed in the United States were treated with 2 percent of these fatty acid derivatives.

The reaction of red lead in acetic acid upon the hydroxylated fatty acids and their derivatives was also studied. It results in the cleavage of the chains between adjacent hydroxyl groups, yielding two or more aldehydic products of lower molecular weight. By this means a great variety of aldehydes can be produced from fatty material, and these may be used directly or converted to other products. Pelargonic aldehyde, which was obtained in good yield from oleic acid, is used in fine perfumes. The half aldehyde of azelaic acid remaining in the residue after treatment of oleic acid with red lead may be converted to azelaic acid, from which a wide variety of esters having possible use as plasticizers can be synthesized. The aldehyde group lends itself well to further chemical reaction, since aldehydes can be oxidized to acids, reduced to alcohols, polymerized, or employed in substitution reactions.

PLASTICS

The Bureau began research on the preparation of plastics from materials derived directly or indirectly from agricultural products. Attention was first given to dextrolactic acid, a product obtained from corn sugar in the mold-fermentation investigations. This product was used for the synthesis of methyl acrylate, from which "organic glasses" are derived by polymerization by a process involving four steps. Attempts will be made to reduce the number of steps and thus provide a more economical procedure.

A new type of alkyd resin was prepared by first making glyceryl dilactate from lactic acid and glycerol and then esterifying the free hydroxyl groups with phthalic anhydride or other dibasic acids. The products were faintly yellow, tough, and resilient, and appear to be an improvement over the glyptal resins used commercially in the manufacture of lacquers. In a similar manner resins can be made from other hydroxy-carboxylic acids, such as saccharic, citric, and tartaric acids. The phthalic anhydride can be replaced by sebacic, azelaic, and other dibasic acids of agricultural origin.

SOYBEAN PRODUCTS

Research on soybeans and soybean products, designed to promote their industrial utilization, was carried on actively by the Bureau's Regional Soybean Industrial Products Laboratory at Urbana, Ill., in cooperation with the Bureau of Plant Industry and the agricultural experiment stations of the North Central States. This work is part of the Department's program of basic research in agriculture, provided for by the Bankhead-Jones Act of June 29, 1935.

Organization of the laboratory was completed, and material progress was made in some phases of the research program. Results were reported in eight papers published in various scientific and trade journals.

As an aid to the agronomic investigations, analyses were made of about 500 samples of soybeans, using standard methods and improvements developed by the laboratory. A large number of analyses and special determinations were also made in connection with the chemical and technological investigations.

The mechanical equipment for the preparation of soybean products was tested out by experimental runs to establish standard operating conditions.

Three samples of oil extracted from the same variety of soybeans but having very different iodine numbers were examined to determine what factors were responsible for this variation. They showed no significant differences in percentages of unsaponifiable matter or in total, saturated, and unsaturated fatty acids. However, calculation of the composition of the unsaturated acid fractions indicated that the oil of lowest iodine number contained nearly twice as much oleic acid and about half as much linoleic acid as the other two oils. Contrary to expectations, the low iodine number and relatively lower content of polyethenoid acids were not reflected in markedly greater stability of the refined or the hardened oil over that of normal oil.

To aid in studies of the composition of soybean oil, three molecular or short-path high-vacuum stills, representing both the pot and column types of construction, were set up and put into operation. The smaller pot still functioned satisfactorily for the distillation of the saturated triglycerides contained in hydrogenated soybean oil. Coloring matter and other impurities were concentrated in the fractions obtained at lower temperature ranges (up to 240° C.); fractions obtained at higher temperatures (240° to 260°) appeared to have a high degree of purity. In the column still, numerous distillations were carried out with crude and alkali-refined soybean oil. Appreciable fractionation occurred. It is expected that this apparatus will prove useful in isolating the minor constituents of soybean oil, particularly those that influence stability of flavor and odor.

Several new pieces of laboratory apparatus for refining and deodorizing soybean oil and determining color, stability, and "break" were installed and are being used to evaluate the expeller oil produced experimentally.

In a study of the usual methods for measuring the apparent conjugated double bonds in soybean and other vegetable oils, it was found that the presence of hydroxyl and peroxide groups causes erroneous results.

As part of the investigation of the film formation and durability of soybean oil used in coatings, 72 varnishes, 3 aluminum paints, 68 white paints, and 15 colored enamels were prepared and are being exposed to the weather on test panels. Considerable progress is being made in the development and perfection of varnishes containing soybean oil alone as the oil constituent. These varnishes are standing up well under test and have attracted the attention of varnish manufacturers. It was found that the drying properties of soybean oil used without metallic driers are improved somewhat by acetylation, but much experimental work remains to be done before the economic and practical value of acetylation and other chemical treatments for improving the drying properties of soybean oil can be ascertained.

Efforts were made to detect and isolate the product or products responsible for the production of rancidity, flavor reversion, and development of odor in

refined soybean oil, but thus far no conclusive evidence has been established concerning the products or mechanism involved in oil reversion.

The sterol glucoside previously found in expeller oil was purified and the sugar portion identified as dextrose. Stigmasterol, an important starting material for the synthesis of female sex hormones, was isolated from the sterol mixture obtained from expeller oil. It was found to constitute a substantial fraction of the sterols of the soybean.

It was discovered that the tendency of expeller oil to "break" on heating can be removed by stirring the oil with 4 percent by weight of adsorbent for 2 hours at 75° to 80° C. and filtering. It was also found that the use of adsorbent columns offers a method of separating the nitrogen and phosphorus compounds of the oil from each other.

In order to obtain information that will be useful for the production of purified protein fractions from oil-free soybean meal, studies were made on the effects of acids, alkalies, and salts on the dispersibility of soybean proteins in water. From 85 to 90 percent of the nitrogen compounds in defatted soybean meal can be dispersed by distilled water at room temperature. Dispersion is retarded by acids and is practically inhibited at a pH value of 4.1. Addition of dilute salt solutions reduces the inhibiting effect of acid, but neutral salts alone have a distinct inhibiting effect that is greater for salts of divalent metals than for those of monovalent metals. Alkalies increase the dispersion of soybean proteins in water. Evidence was found of the presence in soybeans of a protein-dispersing agent other than salts, probably lecithin, which is responsible for the completeness with which soybean protein is dispersed by water alone. It was noted that the amount of protein material that can be extracted from oil-free soybean meal with water or salt solutions decreases with the aging of the meal.

A study on the dispersion of protein from fat-free soybean meal in the presence of a hardening or tanning agent resulted in the discovery that the protein can be dispersed in a formaldehyde solution. Formaldehyde reduces the amount of protein dispersed, but dispersion of 60 percent or more of the crude protein seems to be possible at a pH of about 7.0. Extraction of protein from oil-free soybean meal by means of formaldehyde solution yields hardened protein that has possibilities of industrial utilization for plastics, adhesives, and other products.

It was discovered that soybean protein that had been treated with formaldehyde solution, and then dried and pulverized, possessed thermoplastic properties and could be shaped in hot molds, provided the moisture content was at least 5 percent. A commercial soybean-protein fraction treated in this way yielded fairly satisfactory molded products. Experiments are in progress on the preparation of improved molding powders by combining formaldehyde-hardened soybean protein with materials that will improve the plastic flow and increase water resistance, or with other thermoplastic products. Results thus far indicate that it may be possible to develop from soybean protein a high-grade plastic that will come from the mold in a finished state. This would be a great advance in protein plastics. Casein, the only protein plastic of commercial importance at present, requires a very long hardening process after being molded or formed to shape.

In a study of the effect of moisture content on the plastic properties of soybean protein and oil-free meal, it was found that these materials possess some plasticity independent of free water content. In this respect they resemble zein, the protein of corn, and differ from milk casein.

CHEMICAL WEED KILLERS

In further studies on the production of sodium chlorate, the efficiency of two types of electrochemical cells of improved design was determined on a semi-plant scale. The consumption of electric current by these cells corresponded to 3 kilowatt-hours of alternating current per pound of chlorate as crystals. This represents a reduction of 10 percent in this item of cost.

It was found possible to produce sodium chlorate of high purity by displacing it from solution with sodium chloride. Laboratory experiments indicated that this is a more economical method of separating sodium chlorate from electrolytic cell liquors than the evaporation procedure previously employed.

Studies are in progress, in collaboration with the Bureau of Plant Industry, on the herbicidal value of inorganic oxidizing compounds, nitric acid admixed with dehydrating mineral acids, certain coal-tar fractions, and water-soluble polynitro organic compounds.

BIOLOGICAL STAINS

About 30 biological stain samples were identified and analyzed for the Commission on Standardization of Biological Stains as part of its certification procedure.

In compliance with a request from the publishers, the dye monographs for the forthcoming new edition of the National Formulary were revised to conform to the recommendations of the Commission on Standardization of Biological Stains for certified stains and staining solutions.

Aid in the solution of problems relating to the use of biological stains for various purposes was given to the representatives of several Government agencies and to other individuals and agencies.

NAVAL STORES RESEARCH

CHEMISTRY AND TECHNOLOGY OF NAVAL STORES (TURPENTINE AND ROSIN)

Progress was made in the difficult separation of the liquid and solid portions of pine gum and in the fractional crystallization of the latter. Simple gravity filtration through cloth was used as a preliminary step. Not only is the gum filtrate so obtained practically free from crystallizable resin acids, but the residue is in good condition for recrystallization. A basket-type centrifuge was used for filtering the liquid from some of the crystal fractions.

In the investigations on rosin it was found that a special rosin, substantially free from the tendency to crystallize, can be prepared from the filtrate obtained by direct gravity filtration of settled pine gum. This product differs from ordinary rosin in being high in neutral products (resenes, etc.) and low in pimaric acids. It should prove useful for the manufacture of gloss oils, core oils, adhesives, soaps, and other products for which ordinary rosin is unsuitable. An application was filed for a public-service patent on this product.

Preliminary examinations were made to determine the absorption spectra of a number of the resin acids from pine gum and their hydrogenated products. This study may throw light on the purity, character of unsaturation, and other questions regarding the structure of these gum constituents.

It was found that so-called α-pyroabietic acid, for the preparation of which from rosin and rosin acids an improved catalytic method was devised by the Bureau in 1937, is not isomeric with abietic acid but is a complex mixture of dehydroabietic, dihydroabietic, and tetrahydroabietic acids, resulting from a reaction which is essentially dehydrogenation and hydrogenation but not isomerization, as was formerly thought. Experiments were made on the direct use of pine oleoresin, without previous conversion to rosin, for the preparation of the so-called pyroabietic acid and a stabilized rosin, using the catalytic method developed for rosin.

An investigation is in progress to determine the nonpinene constituents of gum spirits of turpentine that are separated in distillation as the first or most volatile fraction (heads or forerun) and the high-boiling residue (tailings). Preliminary findings indicated that the tailings are relatively high in hydroxyl compounds, methyl ethers, such as anethol, and monocyclic terpenes, such as dipentene.

Dehydration of turpentine is a growing practice among naval stores producers as a means for retarding the discoloration of turpentine when stored in iron containers. A simple test was devised for determining the effectiveness of any dehydration process. This consists in placing the processed turpentine in a number of test tubes, each bearing a thermometer, placing the tubes in a series of cold baths of different temperatures, and noting the highest temperature at which turbidity occurs, together with the degree of turbidity.

A method of detecting and measuring the tendency of rosins to crystallize was developed in cooperation with representatives of two commercial firms. This method requires that the rosin be subjected to a temperature of 100° C. for a long time. A much accelerated test is now in course of development by the Bureau.

In experiments on the use of the mixed copper salts of rosin acids for rotproofing small paper pots for growing plant seedlings, it was unexpectedly found that the copper-rosin compound stimulated plant growth. The pots treated with the copper-rosin compound gave better results in growing tomato seedlings than were obtained with several kinds of commercial treated and untreated pots of similar type. In preliminary vegetative experiments, in which the copper-rosin compound was added to greenhouse soil in two concentrations and com-

pared with the same soil containing equivalent quantities of copper in the form of sulphate and with untreated soil, marked stimulation of growth of tomato and corn plants was observed in the soil containing the copper-rosin compound but not in the others. Apparently the metallic component is not entirely responsible, since powdered rosin in the one experiment carried out with this material also showed a stimulating effect. Arrangements have been made with the Bureau of Plant Industry for cooperative research on this project.

The most extensive chemical use for rosin is saponification. Rosin is saponified alone for paper size and in combination with fatty acids for laundry soaps. It is not used extensively in the manufacture of toilet soaps, principally because it imparts certain objectionable properties to the product. With the hope of improving the quality of soaps, and possibly of paper size, that can be made from rosin, investigations were made on the extent and cause of color development in the saponification process. A laboratory method was devised for preparing rosin soap cakes containing 20 percent of rosin and also for evaluating their color. It was designed to give results similar to those obtained industrially by the full-boiled soap process rather than those obtained by the semiboiled and cold processes, since the first is more extensively used in the manufacture of rosin soaps. Photoelectric measurements of green light reflected by the specially prepared soap cakes in comparison with that reflected from a freshly deposited coating of magnesium oxide were found to provide a rapid and convenient means for evaluating the color. Experiments on the production of soaps from rosins of known history indicated that the source of the gum (whether longleaf or slash pine), cleanliness of the gum, the time of year when the gum was collected, and contamination with zinc, aluminum, and moderate quantities of iron, did not have any material influence on the color of the soap. However, rosins made from gum containing 20 percent or more of scrape gave more color to soap than did rosins made from gum free from, or low in, scrape.

Experiments on making soap with primary resin acids from pine gum, with rosin acids, and with resenes, and with the same materials after extended heating or exposure to the air in powdered form, indicated that acids of the abietic type give soaps of pronounced color, whereas pimaric acids and pyroabietic acid give stable white soaps. Soaps made from oxidized rosin and resin acids had the same hue as those made from rosin containing 20 percent or more of scrape but were darker. Resenes had little or no influence on color. It was concluded that the color imparted to soaps by a pale rosin is due primarily to the presence of abietic-type acids formed by heat isomerization of the primary resin acids, whereas the color imparted by rosins of lower grade is due chiefly to the oxidized rosin acids.

Experiments with rosins made from gum contaminated with iron and treated in two ways with oxalic acid to lighten the color of the rosin indicated that the presence of oxalic acid in the gum during distillation promotes isomerization to abietic-type acids and thus causes the rosin, although paler, to make dark-colored soaps. This detrimental effect can be prevented by adding the oxalic acid in solution and removing it before distillation.

Experiments on the use of turpentine, turpentine fractions, rosin, and salts of resin and rosin acids in motor fuel, to reduce engine knocking, did not yield promising results. Such experiments are being continued with other naval stores derivatives.

PRODUCTION AND PROCESSING OF NAVAL STORES

Research work on processing pine gum was continued at the Naval Stores Station at Olustee, Fla., for the purpose of developing and improving processes, equipment, and technique for new and improved products, and preventing deterioration and losses in the handling and processing of gum and its products. Turpentine and rosin from gum of known history were produced for the Bureau's research on chemistry of naval stores. The naval stores station also served as an educational center for producers and others interested in the production of naval stores. Personal instructions, often illustrated by demonstrations, were given to most of the 706 persons who visited the station during the year.

About 1,300 barrels of gum were distilled on a commercial scale with the fire still. Experiments to determine the temperature of the flue gases at various points in the fire path of a fire still showed that the temperature is influenced by the method of firing and location of fuel in the firebox. This information

led to an improved firing technique. The experiments also furnished data for determining the correct size and location of flues necessary for distributing the flue gases from the firebox to the fire path so as to provide an even distribution of heat and thus prevent overheating at some points. The data obtained in the operation of the fire still were made available to producers.

A bulletin giving plans, specifications, and bills of materials for different types of fire still buildings and equipment, and detailed instructions for setting a fire still, was prepared for publication.

An increasing number of farmers are producing turpentine gum for sale. Because of the rapid increase in buying gum and the accompanying tendency toward the development of central distillation plants of large capacity, the Bureau's research on methods for cleaning gum and on the steam still, which is especially adapted to cleaned gum, is assuming increasing importance. Work at the naval stores station along these lines will be of direct assistance to the industry, since the results can be applied without further pilot-plant experiments. During the year about 1,210 barrels of gum were run through the experimental gum-cleaning equipment, and about 770 barrels of cleaned gum were distilled with the steam still.

Experiments on cleaning gum showed that, with the type of equipment available, best results can be obtained by starting the filtration at the relatively low pressure of 15 pounds and gradually increasing the pressure to maintain a constant flow of gum through the filters. This avoids "plugging" the filters and the resulting necessity of frequently changing the filtering medium. By heating the gum to about 225° F. and filtering through paper in filters of a new type designed by the Bureau, an average filtration rate of 25 gallons per minute per square foot of filter area was obtained. Experience with the experimental gum-cleaning equipment at the naval stores station will lead to simpler and less costly equipment for use in the industry.

The steam still continues to show an advantage over the fire still. Because of better heat control, the steam still makes more uniform products. Moreover, it is faster and easier to operate, it practically eliminates the fire hazard, and it has a greater production capacity. The steam still was used to secure engineering data on heat requirements for distilling cleaned turpentine gum. The results indicated that diluted clean gum containing about 40 percent of turpentine, 5 percent of water, and 55 percent of rosin requires about 0.77 pound of steam at 185 pounds gage pressure per pound of gum. This means that approximately 2½ boiler-horsepower-hours are required to distill 100 pounds of cleaned, diluted gum with steam at 185 pounds gage pressure and boiler feed water at 70° F.

New experimental gum cups of various materials and designs were hung on new crops of slash pine to check the results of previous tests with similar cups on longleaf pine to determine relative durability, ease of cleaning, evaporation loss, and tendency to stain the gum. In the first series of experiments, completed last year, it appeared that all the metal cups caused some discoloration of gum. Lead-coated and galvanized iron had the most effect on color, and zinc and aluminum had the least. Gum collected in glass, clay, aluminum, and zinc cups made the highest grades of rosin.

The removal of suspended and dissolved water from turpentine at the time of production is necessary because turpentine containing water discolors rapidly when stored in most metal containers. The water that settles out of turpentine also weakens the glue lining of wooden turpentine barrels, causing leakage. All the turpentine produced at the naval stores station is conditioned by passing it through a dehydrator of simple design containing coarsely granulated rock salt as the dehydrating material. Experiments indicated that this type of dehydrator removes most of the suspended water but does not remove dissolved water, which may separate later. A small refrigerating unit was installed for cooling the turpentine between the separator and dehydrator in order to separate the dissolved water. A larger refrigerating unit than was available would be necessary to give additional benefit.

COOPERATION WITH STATES IN NAVAL STORES WORK

Information concerning improved practices and equipment developed at the naval stores station was carried to naval stores producers in Florida and Georgia by cooperative agents who made personal contacts with producers individually or in groups. These agents also disseminated information concerning approved, conservative woods practices developed by the Federal and State forest services for the production of naval stores.

In Florida, 232 visits were made to naval stores operators, factors, county agents, foresters, and timber owners in connection with problems relating to naval stores production. Twenty fire stills conforming to the Bureau's specifications were inspected for minor defects, and 12 demonstration charges were run. Twelve new still settings were built according to the Bureau's recommendations, seven under the direct supervision of the cooperative agent and the others by brick masons instructed by him. Nine new turpentine separators and dehydrators were installed, three under the direct supervision of the cooperative agent. Two still thermometers were installed, one was taken out, adjusted, and reinstalled, and two were checked for accuracy against a portable test thermometer.

In Georgia, 160 visits were made to naval stores producers, factors, county agents, and timber owners in connection with naval stores problems. Stilling demonstrations were given at a number of producers' plants to instruct stillers in the Bureau's method of regulating distillation according to thermometer readings and water-spirits ratio of the distillate. The cooperative agent supervised the construction of 13 complete fire-still settings according to the plans and specifications of this Bureau and gave advice in the construction of 3 others. He also supervised the construction of one double-still shed and one single-still shed and the installation of eight automatic turpentine separators and dehydrators and two still thermometers. Thirty-seven sets of plans and specifications were distributed for various pieces of equipment.

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, two statistical reports were compiled and published. One gave statistics as of September 30, 1937, and the other as of March 31, 1938, on production of turpentine and rosin of each class, stocks, exports, imports, and domestic consumption by industries. These reports were published more promptly after the closing dates of the half and full naval stores season than heretofore.

PROTEIN AND NUTRITION RESEARCH

DIGESTIBILITY OF PROTEINS

The proteins of raw soybeans alone do not promote satisfactory growth of animals. However, a diet of cooked soybeans or of cooked soybean meal or of raw soybeans to which a little cystine has been added enables animals to grow very satisfactorily. This improvement in the nutritive value of raw soybean proteins resulting from the addition of cystine might lead to the belief that soybean proteins are deficient in this amino acid. That soybean proteins contain a relatively large quantity of cystine has been shown repeatedly by analysis. In order to solve this apparent anomaly and other perplexing problems pertaining to the nutritional properties of soybean proteins, studies on the digestibility of these proteins in vitro were undertaken. It was found that after long periods of tryptic digestion of soybean proteins no free cystine could be detected in the digest, although casein readily liberated all its cystine when digested with trypsin. This result indicates that the cystine of soybeans is chemically bound in a protein fraction that is very resistant to digestion and consequently not made available for assimilation, or that, if cystine is liberated by tryptic digestion, some substance in the digest interferes with its detection and determination.

Studies on the comparative digestibility, in vitro, of raw and cooked soybean proteins are being made to learn the nature of the change that takes place in soybean protein as a result of moist heating, whereby its nutritional value is so much enhanced.

DECYSTINIZED CASEIN

A large quantity of decystinized casein was prepared for use in studying its biological properties by feeding experiments and for a closer examination of its chemical composition and physical properties. Casein of a high degree of purity was first separated from fresh skim milk and then repeatedly dissolved in dilute alkali and reprecipitated each time with acid. After five such treatments the product showed no detectable amount of cystine when tested by the Sullivan method. Extended analyses showed that there was but little dif-

ference between the composition of the decystinized product and that of the original casein with respect to tryptophane, tyrosine, arginine, histidine, lysine, methionine, and total nitrogen. However, the decystinized product contained only 64 percent of the sulphur and only 46 percent of the phosphorus originally present in the casein. There was practically no difference between the digestibility of casein and that of the decystinized product as revealed by digestibility studies in vitro with trypsin.

A striking difference was noted between the physical properties of decystinized casein and those of untreated casein, particularly with regard to dispersion in dilute alcohol. Untreated casein is not dispersed in alcohol of any concentration at any temperature. The decystinized product soon becomes translucent and sticky in 30-percent alcohol at room temperature. At boiling temperatures, it is dispersed readily in 30-percent alcohol and somewhat less readily in 60-percent alcohol. It is not dispersed at all in absolute alcohol. It separates from hot, dilute alcoholic solutions on cooling and settles as a soft, sticky precipitate that assumes a rubberlike consistency after standing.

Feeding experiments were started to determine the biological value of decystinized casein. It is believed that it will find useful application in feeding experiments in which a cystine-free diet is desired.

It was found that ammonia when used instead of sodium hydroxide for purifying casein does not cause destruction of cystine.

AMINO ACIDS IN BEANS

The seeds of the bean family have a prominent place in the human dietary as a source of protein, and it is important to know their nutritional value in comparison with other protein-containing foods. It is well known that the relative nutritional value of different proteins depends on their content of certain amino acids, but the practical application of knowledge gained from analysis of pure proteins is difficult because proteins are always consumed in the form of staple foods, some of which contain several kinds of proteins. The method developed by the Protein and Nutrition Research Division for determining amino acids in staple foods and used previously in the study of white flour, whole-wheat flour, middlings, and bran was applied to the study of the navy bean, the lima bean, and the Rokusun soybean, a type recommended for human consumption. Navy and lima beans were found to be rich sources of most of the important amino acids, but they were deficient in cystine, which limits their nutritive value. For satisfactory utilization as protein food they must be eaten with other protein food that will supply sufficient cystine. Compared with navy and lima beans, the Rokusun soybean contains appreciably more cystine, tryptophane and tyrosine, but less histidine and lysine.

EFFECTS OF STORAGE ON PROTEINS OF GRAINS AND SEEDS

Immense quantities of grain and other seeds are stored, sometimes for long periods, and most of the meals and flours consumed have been subjected to the effects of storing and shelf-aging. Very little is known about the changes that take place in the proteins of these products during storage or the extent to which these changes may affect their nutritive value. Acquisition of such knowledge, as well as knowledge concerning the most favorable conditions of storage whereby undesirable changes may be reduced to a minimum, is highly important, especially in view of the consideration that is being given to long-time storage of surplus crops.

Continuation of the study on the effect of storage on the proteins of soybean oil meal and similar studies, inaugurated during the year, with wheat, whole-wheat flour, and white flour, revealed that striking changes occur in the proteins. After storage for only 1 month significant decreases in the solubility of the proteins and true protein content and an increase in amino nitrogen were observed. These changes, which increased with time of storage, indicated a marked break-down of the proteins, presumably by enzyme action. Soybean oil meal showed reduction in digestibility of its proteins after storage for 1 month, which became very marked after 12 months. On the other hand, wheat and wheat flour showed very little, if any, change in digestibility of proteins after 4 months of storage. In preliminary feeding experiments rats fed ground whole wheat that had been in storage in glass jars for 1 month at room temperature made better growth responses than did those fed on the same wheat freshly ground.

From the results of the experiments made thus far it appears that the proteins in whole seeds change less during storage than do those in the meal or flour prepared from them. The rate of change is greater for white flour than for whole-wheat flour. Greater changes occur in soybean oil meals stored in bags than in those stored in sealed jars, and in meals stored at room temperature (76° F.) than in those kept in cold storage (30°). However, the changes in cold storage were greater than expected.

VITAMINS

Research was continued in cooperation with the Bureau of Entomology and Plant Quarantine on the vitamin content of royal jelly, the special food which bees feed to their larvae in order to develop queens for their colonies. Assays showed that it contained very little, if any, vitamin A. It was found, however, that royal jelly is a good source of vitamin B, having about the same potency as wheat.

A critical review was made of the literature dealing with the value of soybeans as a source of vitamins, and the conclusions drawn from a survey of the most reliable publications were given in a mimeographed circular.

Work is in progress on the development of a satisfactory formula for providing an adequate vitamin supplement to diet used in feeding experiments with decystinized casein. Experimental trials of a new method for the assay of vitamin B_1 in feeds by noting the quantity required to cure polyneuritis in young rats in comparison with the quantity of thiamin required for the same purpose showed that the method is reliable and less time-consuming than the one in general use.

International standards for vitamins A, B_1, C, and D were supplied in limited quantities to vitamin investigators in the United States who are working in colleges, universities, and agricultural experiment stations.

ALLERGEN INVESTIGATIONS

Investigations on allergens of agricultural products were continued as part of the Department's program of basic research in agriculture, provided for in the Bankhead-Jones Act of June 29, 1935.

Many products and byproducts of agriculture, including foods, fibers, and plant pollens, are known to cause hay fever, asthma, and other allergic disturbances. The distribution, stability, and chemical nature of allergens present problems that fall naturally within the field of agricultural chemistry. Moreover, these problems vitally concern agriculture because they may seriously affect the utilization of certain agricultural products and byproducts.

In studies on ragweed pollen, it was found that the allergens of both short and giant ragweed are soluble in glacial acetic acid, as well as in water and saline solutions. The short ragweed allergen proved to be far less stable to heat than corresponding solutions of the cottonseed allergen, an appreciable decrease in activity resulting from heating the water extracts for 5 minutes at 90° C. Preliminary tests of the stability of the ragweed allergen towards enzymes were conducted with autolyzed yeast, urease, emulsin, taka diastase, erepsin, and papain. No appreciable destruction of the active agent was observed. Evidence of the presence of more than one allergen in short ragweed was obtained by heating the water extracts. Differences in heat stability of the active components are being studied to correlate their physiological and chemical characteristics.

Further experiments substantiated the observations made during the previous year that ragweed allergen is not transmitted in the milk of cows receiving the pollinating blossoms of short ragweed in their ration.

Examinations of the blood and blood serum from allergic and normal subjects showed no demonstrable differences with respect to specific capacity to inactivate the allergenic components of short ragweed pollen. Substrates obtained in these experiments are being tested to determine their value in comparison with undigested ragweed extracts for diminishing sensitiveness to the air-borne pollen.

In studies on the allergens of cottonseed and its products, an exceptionally potent allergenic concentrate was obtained from the water-soluble material of the kernels of raw cottonseeds by chemical fractionation. Pending identification of its constituents, this concentrate is designated simply as fraction CS–1. It was prepared from that portion of the water-soluble material of the seed pre-

cipitated by alcohol. Its principal components, protein and carbohydrate, were separated by precipitating the protein with picric acid. Allergenic activity of the cottonseed kernel appears to be due primarily to the protein component of the fraction CS–1, which in the form of the picrate retains its capacity to induce allergic reactions in certain hypersensitive individuals. The protein of fraction CS–1 was differentiated from previously identified proteins of the cottonseed. The previously known proteins were separated and shown to possess no important degree of allergenic activity. The allergenic component of the fraction CS–1 lost none of its specific activity when separated from the carbohydrate portion of the whole fraction. Dialysis of fraction CS–1 against water resulted in rapid migration of the allergenic constituent through the collodion membranes. A subfraction obtained by this procedure was shown by anaphylactic tests on guinea pigs to be distinct from the undialyzed substance. This evidence indicates the presence of more than one antigen in fraction CS–1.

Both fractions CS–1 and the picrate derived from it proved to be more specific in their action as allergens than unfractionated cottonseed extracts. Only those individuals who exhibited specific sensitiveness to CS–1 and CS–1 picrate by skin tests were found to be clinically sensitive to cottonseed.

No trace of the CS–1 allergen was detectable in concentrated extracts obtained from refined, edible, cottonseed oil. Allergic subjects who manifested a high degree of clinical sensitiveness to CS–1 and other nitrogenous derivatives of the cottonseed kernel experienced no unfavorable results from continual use of edible cottonseed oil as food.

In view of the fact that cotton linters obtained from old upholstery sometimes yield potent allergenic extracts which induce positive reactions in individuals sensitive to house dust, experiments were continued to determine whether the house-dust allergen is generated by deterioration of linters on aging. Clinical tests of extracts from six lots of cotton linters, portions of which had been stored for a year under different conditions designed to accelerate or retard deterioration of the fibers, yielded no evidence of the generation of a specific allergen in cotton linters as the result of aging. While some individuals manifested signs of sensitiveness to water extracts of cotton linters, there appeared to be no correlation between sensitiveness to the linters and to the kernel of the cottonseed, nor between sensitiveness to either of these products and house dust.

CHEMICAL ENGINEERING RESEARCH

AGRICULTURAL FIRES

Laboratory and field investigations were continued on the causes, results, and prevention of spontaneous heating in hay, which is one of the main causes of fires on farms. The results of previous experiments indicated that microbial action favored by a high moisture content is responsible for the early stages of heating, after which a purely chemical reaction is initiated. Under certain conditions this may increase heating to the point of ignition. It was believed that the formation of unsaturated, easily oxidizable products by the heat of microbial action was responsible for the chemical reaction that followed. This belief was given support by the results of experiments in which alfalfa hay was heated in an inert atmosphere (nitrogen) at a temperature slightly above the limits of bacterial activity. Such heating increased the oxygen absorption of the hay. The effect of heating at higher temperatures is now under investigation.

The gaseous products obtained when hay is heated, both in an inert atmosphere and in air, are being studied to throw further light on the nature of the decomposition. Some evidence was obtained that carbon monoxide, a combustible and poisonous gas, is formed in small quantities at a temperature only slightly above 100° C. A special gas burette was designed for use in determining small quantities of this and other combustible gases.

The results of the investigation on the nature of the fatty substances of alfalfa hay, which are largely lost as the result of self-heating, were prepared for publication. The material extracted from alfalfa meal with cold petroleum ether amounted to 2.1 percent, on a moisture-free basis, and contained unsaturated fatty acids (chiefly oleic, with small amounts of linoleic and linolenic acids), a complex mixture of saturated fatty acids (principally palmitic), primary alcohols, sterols, a mixture of paraffin hydrocarbons, and a viscous odoriferous oil. This oil, which appeared to be a complex mixture of terpene-like hydrocarbons, contained most of the carotenoid pigments and other fat-

soluble vitamins. The unsaturated acids, sterols, and carotenoids are very susceptible to oxidation in a heating haymow, and it is possible that these substances may be a contributing factor in the spontaneous heating of alfalfa hay.

A field study was made of haying practices and new types of hay storage designed to prevent excessive heating, on a number of selected farms on the Eastern Shore of Maryland and in Chester County, Pa. Special attention was given to such factors as moisture content, temperatures, air velocities, and gases in the stored hay. The need for thorough and systematic procedure in handling mows of hay that have developed excessive heat was emphasized by a fire, caused by spontaneous ignition of oat hay, which resulted in the complete destruction of a barn near Monroe, Wis., with a loss of about $10,000. The owner had observed that his hay was dangerously hot and on the day before the fire called in his neighbors to assist in wetting down hot pockets and removing the heating hay. This activity was continued until the forenoon of the next day, when it was thought that heating had been checked and the danger of fire was past. Fire broke out, however, early in the afternoon of the same day in hay remaining in the barn, with destructive results.

A member of the Chemical Engineering Research Division's staff conferred with representatives of eight State agricultural experiment stations with regard to current and contemplated investigations on the spontaneous heating and ignition of hay, with the officials of three manufacturing firms interested in the production of special equipment for the safe storage of chopped hay and silage, and with the representative of an instrument-manufacturing firm regarding temperature and relative-humidity indicators and anemometers for use in proposed experiments on stored hay.

In connection with studies on the prevention and control of farm fires from miscellaneous causes, an inspection was made of the fire-fighting equipment of a rural fire-protection association in Wisconsin. Information was obtained on the organization and operation of this association, which is a model for efficiency and effectiveness in providing fire protection for farmer subscribers within a radius of 10 miles.

Conferences were held with representatives of a cement-manufacturing firm on the design and construction of an underground concrete tank for storing water to be used by motorized apparatus in fighting farm fires, and with officials of an insurance company and of an organization interested in farm equipment concerning the explosion and fire hazard from static electricity when rubber tires are used on farm machinery, and the cause and prevention of fires in the new type of corn picker which is attached to the front of the farm tractor.

Much educational work on rural fire protection was done through conferences with State and local officials, editorial staffs of farm journals, chambers of commerce, and officials of insurance companies, through informal talks before groups of firemen, and through addresses before conventions of firemen's associations, general public meetings, the National Safety Congress, civic clubs, and meetings of students at schools and colleges. Special attention was given to the need for safety programs for rural schools and the inspection of rural electric wiring.

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 (committees on farm fire protection and spontaneous heating and ignition), the National Fire Waste Council of the Chamber of Commerce of the United States and its agricultural committee, the American Society of Agricultural Engineers (committee on fire prevention and protection), and the National Safety Council.

DUST EXPLOSIONS

Eleven major explosions in industrial plants, involving dusts from agricultural materials, were investigated by the Bureau. Four of these were caused by grain dust, and one each was caused by dusts of cereal products, mixed feed, cottonseed meal, soybeans, starch, derris root, and cotton floc. These explosions resulted in the death of 8 men, injury to 39, and property damage amounting to about $546,000.

Some of the explosions investigated afforded an opportunity to observe the effectiveness of safety measures recommended by this Bureau for reducing dust-explosion losses. The use of vents, such as hinged windows, or light wall

construction recommended for the release of explosion pressure proved particularly effective in limiting the damage from explosion in several of the cases investigated. Excessive damage from one grain-dust explosion was caused by insufficient venting area in a concrete section of the plant to which the explosion spread through a tunnel from a wooden elevator section. An outstanding example of the effectiveness of structural features recommended for reducing property damage from dust explosions was furnished by a grain-elevator explosion where the property loss was less than $20,000, although 6 persons were killed and 16 injured. Because of the special structural features the explosion was segregated and its force dissipated. If it had spread to all sections of the plant, there would have been much greater property damage, as well as greater loss of life and personal injuries. The fact that this explosion was caused by the ignition of grain dust by the flash from an electric motor shows the necessity of using explosion-proof motors in locations where explosive dust clouds may be present. One of the more serious grain-dust explosions, which occurred while a carload of corn was being unloaded into the elevator, appeared to have been caused by sparks produced when some hard foreign material in the grain struck the metal buckets or casing of the elevator leg.

In order to study the conditions under which metallic sparks ignite dust clouds, provision was made for the erection of a steel bucket elevator alongside the tower at the dust-explosion testing station at Arlington Experiment Farm. With this elevator in operation it will be possible to maintain a continuous dust cloud within the tower. This equipment can be used also in demonstrations to show the possibility of venting explosions in elevator legs and to explain the operation of vents designed to relieve pressure.

Tests were made at the dust-explosion testing station to determine the effects of moisture content and atmospheric humidity on the explosibility of dusts. The results of these tests will be coordinated with those of laboratory studies. Tests were also made to determine the explosibility of sodium resinate at different concentrations. Scored glass, used in the construction of explosion vents, was found to break at one-seventh to one-fifth the pressure required to break the same kind of glass when unscored. Dust explosion demonstrations were given at the testing station for individuals and organizations interested in the subject.

Laboratory studies to determine the effect of moisture content and atmospheric humidity on the explosibility of wheat elevator dust were completed, and most of the pressure curves have been analyzed. The moisture content of the dust was brought to equilibrium at definite temperatures and at different relative humidities between 0 and 100 percent. Explosibility tests were made both in dry air and in air having a relative humidity corresponding to that used to bring the moisture content of the dust to equilibrium. The effects of ash content and particle size on the explosibility of corn and wheat elevator dusts were determined. The results will aid in the selection of typical elevator dusts to be used in research on the effect of atmospheric humidity on the explosibility of these dusts.

Forty-three samples of dust were tested in the laboratory for explosibility. The following materials were found to form explosive mixtures with air: Feed-mill dust; malt dust; flour middlings; bean-cleaning dust; cottonseed, linseed, and coconut oil meals; licorice and starch mixture; ginger, derris, and cube roots; pyrethrum; onion dust; garlic dust; paper dust; fiberboard dust; dust from rabbit fur; dust from cleaning crude drugs; resinates of lead, manganese, and aluminum; apple flour (at some concentrations); cellulose acetate; wood flour; molding compound containing equal parts of wood flour and phenol-formaldehyde resin; mixed raw materials for the molding compound; a urea-formaldehyde resin; another type of synthetic resin; and dust of rubber-compounding materials.

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 to city fire departments, student groups at high schools, colleges, and universities, and civic organizations.

In connection with their work on dust-explosion prevention, members of the chemical engineering staff cooperated with national organizations by participation 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 a leaflet, entitled "Fundamental Principles for Dust Explosion Prevention," and in the formulation of safety codes for

the prevention of dust explosions in sulphur plants and aluminum-manufacturing plants. Other committees of the same organization were assisted in the preparation of a code covering the installation of air-conditioning equipment and dust, stock, and vapor-removal systems, and in the revision of the safety code for fumigation of grain-storage and grain-processing plants and a brochure on static electricity. The committee on conveyors and conveying equipment of the American Standards Association was assisted in the preparation of a safety code covering air conveyors.

AGRICULTURAL ACCIDENT PREVENTION

At the request of the National Safety Council the chief of the Chemical Engineering Research Division, as a representative of the Department of Agriculture, accepted leadership in the organization of a new section on agricultural safety. Investigation by this section developed the fact that the number of accidental deaths is greater among agricultural workers than in any other industry. A statement was prepared and presented at the National Safety Congress in Kansas City, Mo., showing the urgent need for agricultural accident prevention. Representatives of various organizations attending the congress took action requesting the National Safety Council to organize a permanent section on agricultural safety. This movement is the first of its kind to be undertaken in the United States.

SERVICE WORK

One member of the chemical engineering staff was detailed during the entire year to the Naval Stores Research Division for engineering work in connection with investigations on the production and utilization of turpentine and rosin. Another made regular fire and safety inspections of the Bureau laboratories and gave special attention to the safe storage of inflammable solvents and other materials.

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. A report with drawings was prepared in connection with the work of a Bureau committee appointed to develop plans for a model chemical laboratory lay-out for field stations.

FERTILIZER RESEARCH

CATALYST AND HIGH-PRESSURE INVESTIGATIONS

In further studies on the kinetics of ammonia decomposition in the presence of hydrogen, it was found that with a singly promoted iron catalyst (containing 10.2 percent of alumina) increasing concentrations of ammonia tended to inhibit decomposition, while increasing concentrations of hydrogen tended to promote decomposition, in the temperature range of 385° to 445° C. This is a curious type of mechanism never observed previously by anyone working in the field of reaction kinetics. The fact that ammonia inhibits the reaction on the singly promoted catalyst but not on the doubly promoted catalyst (containing alumina and potassium oxide) explains the variation in pressure coefficient with different catalysts, which has been one of the most puzzling problems in the mechanism of ammonia synthesis. Since the reaction is reversible, a ratio of reacting substances that favors decomposition would also favor synthesis under different conditions of temperature and pressure. For a long time it was known that the efficiency of both singly promoted and doubly promoted catalysts for ammonia synthesis is high at atmospheric pressure and that at higher pressures the efficiency of the singly promoted catalyst drops rather rapidly, while that of the doubly promoted catalyst remains practically constant. The cause of this difference is now apparent, since ammonia retards the reaction on singly promoted catalysts but does not do so on doubly promoted catalysts.

The method which was developed originally for measuring the surface areas of iron synthetic ammonia catalysts by determining the adsorption isotherms of gases near their boiling points and which, as reported last year, has been used for measuring the surface areas of soils and soil-colloid particles, was found to be universally applicable to all adsorbent and finely divided materials. It was applied to unreduced magnetic iron oxide catalyst and also to a decolorizing carbon adsorbent that had a surface area per unit weight 100,000 times as great as that of the iron oxide. This method has wider applicability, is more

accurate, and requires less complex apparatus than any other method suggested thus far for measuring surface areas of finely divided particles.

The yield of oxides of nitrogen when nitrogen-oxygen mixtures are subjected to an ozonizer discharge at atmospheric pressure was found to increase with temperature, reaching a maximum at 70° to 100° C. Above 100° the yield at first decreased, but increased again with continued rise in temperature, finally becoming fairly constant. The behavior in the temperature range of 70° to 100° was caused by extremely rapid thermal decomposition of the nitrogen pentoxide existing at lower temperatures. At higher temperatures only the lower oxides of nitrogen were present.

FUNDAMENTAL PHYSICAL AND CHEMICAL INVESTIGATIONS

X-ray studies on the structure of soil minerals revealed that most of the common minerals present in the colloid fraction of soils have structures related to that of mica. The individual layers are superimposed in a somewhat random manner, a property that has been observed previously only in compounds that form liquid crystals. It was found that in clay mineral hydrates, such as bentonites, the water molecules are present in layers which owe their stability to the arrangement of oxygen ions of the mineral surfaces. The retention of uncombined water by clays and the swelling of bentonites in contact with water are also determined by this structural property.

The marked association of phenol in carbon tetrachloride solutions, in the range of 0.1 to 0.5 molal, was studied quantitatively by means of the infrared spectrograph. Halogen substituted phenols exhibited noticeably less association than phenol itself.

Ultraviolet absorption coefficients were determined on 15 derivatives of uracil and cytosine. The results showed that such measurements are a valuable aid in identifying urea derivatives of this type, which occur naturally in all kinds of cellular organic matter.

An estimation of the intensity and position of the far ultraviolet absorptions of nitrogen was made on the basis of existing data for the dispersion of nitrogen and the positions of the molecular levels. This concerns a spectral region that for practical purposes cannot be measured quantitatively. From the results a calculation was made of the sunlight absorbed by nitrogen in the atmosphere. It seems certain that this absorption leads to the formation of nitrogen oxides in the high atmosphere, but the amounts formed are difficult to estimate.

NITROGENOUS FERTILIZER MATERIALS

Treatment of peat with ammonia under conditions for obtaining a fertilizer material showing optimum activity of insoluble nitrogen yielded a product containing only 6 to 8 percent of total nitrogen. With the purpose of increasing the nitrogen content without producing a potentially acid fertilizer, commercial calcium cyanamide, an alkaline nitrogen carrier, was added to the ammoniated peat, and the mixture was treated in various ways. Under some conditions cyanamide forms urea, a desirable product, but under other conditions it forms dicyanodiamide, which is toxic to plants. In the experiments 30-percent conversion of cyanamide nitrogen to urea, the highest value observed, was obtained by treatment with sulphuric or carbonic acid. In view of this relatively low conversion, it appears impracticable to employ this method to raise the nitrogen content of ammoniated peat. In experiments along another line of attack, the nitrogen content of ammoniated peat was increased to between 10 and 15 percent by pretreating moist peat with chlorine gas at 28° C., boiling the chlorinated product with water to partly replace the chlorine with hydroxyl ions, and then ammoniating to replace the hydroxyl ions with NH_2 groups. Direct ammoniation of chlorinated peat gave a product containing about 10 percent of nitrogen, 55 percent of which was water soluble and the remainder highly active by chemical tests.

It was previously reported that the coating of urea crystals with small amounts of finely divided material, such as lime or calcium carbonate, reduced their tendency to absorb moisture from the air and to cake on storage. Urea crystals treated in this way are still able to react with fertilizer salts containing water of crystallization to form double salts, at the same time liberating water and producing a sticky mass. Attempts were made, therefore, to form a continuous coating over the surface of urea crystals to act as a deterrent or preventative for such action. The formation of urea-aldehyde resin coating on the surface of the crystals gave good results, but the heat treatment required

for hardening the resin makes the process too costly. The formation of a thin layer of ammonium phosphate or ammonium sulphate on the surface of the urea crystals was found to be an efficient and practical method for obtaining a continuous, adherent coating. The effects of such treatment were very different from those obtained by mixing the same quantity of the ammonium salts with urea crystals. Urea coated in this way has little effect on magnesium sulphate containing seven molecules of crystallization, but will still take up water from moist air and may cake on storage. This property was effectually overcome by employing on oil coating. Both types of coating are essential to prevent hygroscopic absorption and release of free water when urea is in contact with hydrated salts.

BIOCHEMICAL AND ORGANIC NITROGEN INVESTIGATIONS

Studies were made to gain information on the question of whether all the nitrogen consumed by *Azotobacter* is retained within the bacterial cells or part of it is excreted as soluble nitrogen compounds into the surrounding medium. From this work it appears that even in the youngest cultures not less than 10 percent of the nitrogen is excreted. This was true both for cultures grown in free nitrogen and those grown with fixed nitrogen. The presence of various trace elements did not increase the proportion of nitrogen excreted. Cultivation of *Azotobacter* in bags of cellulose film surrounded by a sevenfold greater amount of cell-free medium outside than inside produced no appreciable change in the efficiency of growth, the rate or amount of nitrogen fixed per unit volume, or the amount of the various nitrogen compounds excreted.

Numerous *Azotobacter* cultures were tested for the presence of hydroxylamine and oxime, which certain investigators have claimed are intermediate products in the biological nitrogen-fixation process. Only one, *A. vinelandii*, gave an occasional test for hydroxylamine, which apparently was present in small concentration. Three cultures were found to produce oxime, whereas a dozen others gave no test for this compound.

Experiments on the growth of legumes in close proximity to nonlegumes were carried out in a sand medium, using nitrogen-free nutrients and artificial illumination, to test the effect of several variables, not included in previous experiments, on the excretion of nitrogen compounds from growing legume nodules. The nonlegumes did not thrive. Excretion of nitrogen was not induced by an increased ratio of nonlegumes to legumes, by altering the proportions of mineral food materials in any one of a number of ways, or by increasing the particle surface of the sand. These negative results agreed with those previously published by the Bureau.

The presence of coenzyme R, the growth accessory discovered by the Bureau several years ago, was found to be necessary for appreciable growth of 19 typical strains of *Rhizobium meliloti*, *R. trifolii*, *R. phaseoli*, and *R. leguminosarum*. Neither reducing substances, such as thioglycollic acid and cysteine, nor iron could take the place of this growth-stimulating substance. The need for this factor was evident whether the nitrogen source was nitrate, ammonia, or asparagin. An occasional strain of rhizobia has been found that can synthesize coenzyme R.

From experiments in the culture of *Azotobacter vinelandii* on a medium made from highly purified salts and sucrose, in comparison with media made from ordinary commercial materials containing traces of impurities, it appeared that these bacteria can synthesize all the organic materials required for their essential metabolic processes, except simple nonspecific organic materials which seem to serve only as sources of energy.

In cooperative studies with James Bonner of the California Institute of Technology, it was found that as much as 0.14 mg of vitamin B_1 per gram of cell matter is synthesized by *Azotobacter*. There is, therefore, more of this vitamin in *Azotobacter* than in yeast, which is one of the main sources of vitamin B_1. The synthesis of vitamin B_1 in soils by *Azotobacter* may be of fundamental agronomic importance, since this vitamin has a stimulating effect on the growth of plants. A yellowish-green pigment isolated from the medium in which *Azotobacter* organisms grew was found to belong to the flavin type and to be related to, or identical with, vitamin B_2. From 0.7 to 1.0 mg of this pigment was present in 1 liter of medium. The characterization of this flavin complex is of interest because of the probable identity of the pigment with the Warburg yellow respiration ferment, which is an active participant in the liberation of energy from carbohydrates by the organism.

Further research on the possibility of fixing nitrogen by reaction with organic compounds apart from life processes showed that diphenyl acetylene combines with activated nitrogen to form a brown solid containing 16 to 18 percent of nitrogen. It appears to be a complex compound of high molecular weight. Tetrahydronaphthalene and benzonitrile were also found to react with atomic nitrogen to form amorphous nitrogenous solids having physical properties similar to those of the product from diphenyl acetylene. The reaction of isoprene with active nitrogen gave a nitrogenous liquid of low boiling point.

PHOSPHATES

Studies on the fluorine content of phosphate rocks from commercial deposits throughout the world showed that fluorine is a common constituent of phosphate rock; that within certain limits the fluorine content varies with the age of the phosphate deposit (being greater in the older ones), and that there is a close relationship between the fluorine and phosphorus contents of samples from different deposits of the same type. Analyses of many samples of phosphate rock from Idaho, Montana, Utah, and Wyoming showed that the western phosphates are high in fluorine but that their fluorine-phosphorus ratios are usually about the same as those for phosphates in other sections of the United States. The Willard and Winter method for determining fluorine was modified to prevent interference by chlorides, sulphides, and organic matter.

From a study of the relationship between the fluorine content of different types of phosphate rock and their solubilities in neutral ammonium citrate and in 2-percent citric acid solutions, it appeared that differences in the fluorine content, while an important factor, are not alone responsible for the differences in solubilities. It is believed that the results of this study will aid in the selection of types of phosphate rock best suited for direct use as fertilizer.

In the investigation on the composition and properties of superphosphate, it was found that the type of phosphate rock used, the ratio of sulphuric acid to rock, and the age of the superphosphate, all influence the solubilities of phosphorus, fluorine, iron, aluminum, and other constituents in water and in neutral ammonium citrate solution. There were no important changes in the solubilities of constituents after the superphosphate was 60 days old, and the greatest changes occurred within the 30-day period following preparation of the superphosphate. These changes were generally in the direction of increased solubilities in both solvents. Free water and free phosphoric acid decreased during aging, whereas water of crystallization showed little or no change.

The form of the calcium sulphate produced as a constituent of superphosphate when phosphate rock is treated with sulphuric acid was found to depend principally on the concentration of the acid and the temperature of the reaction mixture. Gypsum was the predominant form of calcium sulphate produced when the initial concentration of the acid was 44° Baumé and the temperature was kept below 20° C. Higher concentration of acid and higher temperatures favored the formation of hemihydrate and anhydrous calcium sulphate. With acid concentrations of 50° to 55° Baumé and temperatures of 105° to 110°, usually encountered in commercial manufacture of superphosphate, anhydrous calcium sulphate was either the predominant or only form of calcium sulphate produced. Transformation of the hemihydrate and of anhydrous calcium sulphate into gypsum did not occur to a marked degree when superphosphate was stored for long periods at atmospheric temperatures, when superphosphate was granulated, or when superphosphate was treated with anhydrous ammonia.

In comparative experiments on the fixation of inorganic phosphate (monopotassium phosphate) and organic phosphate (sodium glycerophosphate) by different types of soil, it was found that in Cecil clay the organic phosphate is converted to an insoluble form almost as rapidly and completely as the inorganic phosphate. In contact periods not exceeding a few days, only a minor amount of inorganic or organic phosphate was immobilized in Norfolk loam, whereas a minor portion of the organic phosphate and a major portion of the inorganic phosphate were converted to the insoluble condition in Las Vegas loam (containing about 0.5 percent of alkali). When the time of contact was increased, the percentage of organic phosphate immobilized increased. Experiments on fixation in sterilized Norfolk and Las Vegas soils and a study of the rate of conversion of organic phosphate to soluble inorganic phosphates in the raw soils showed that the increase of fixation of organic phosphate is essentially a secondary reaction, namely, the fixation of inorganic phosphate

formed by the action of soil micro-organisms on the organic phosphate. Several organic phosphates were synthesized for further studies on the rate of hydrolysis of organic to inorganic phosphate.

POTASH SALTS AND BYPRODUCTS

A study of methods for producing potassium nitrate from potassium chloride and nitric acid through the intermediate formation of potassium pentaborate showed that excessive quantities of boric acid were required to obtain satisfactory yields of the potassium borate when potassium chloride and boric acid were reacted directly in an atmosphere of steam at temperatures above 100° C. Moreover, much of the boric acid was volatilized with the hydrochloric acid formed. In the reaction between aqueous solutions of potassium chloride and ammonium borate the temperature-solubility relationships of the system were found to be favorable to the separation of potassium pentaborate and ammonium chloride by fractional crystallization. Potassium pentaborate obtained by either method may be readily converted to potassium nitrate and boric acid by reaction with nitric acid. The boric acid may be recovered and used again for preparing additional potassium pentaborate.

Nitrosyl chloride, a byproduct of one of the processes for converting potassium chloride to potassium nitrate, was found to be readily oxidized by nitric acid-sulphuric acid mixtures at temperatures between 40° and 90° C., with the formation of nitrosyl sulphate and chlorine. It was also readily oxidized to nitric oxide and chlorine when gaseous mixtures containing it and either nitric acid or oxygen were passed over activated silica maintained at a temperature of from 45° to 190°. The nitrogen and chlorine contents of nitrosyl chloride must be recovered and utilized for economic operation of the process in which this byproduct is formed.

A series of potassium metaphosphate products, prepared from potassium chloride and phosphoric acid at temperatures up to 800° C. and analyzed for total phosphate by the molybdate method, for metaphosphate by the barium chloride method, and for pyrophosphate by the zinc sulphate method, showed increasing amounts of metaphosphate and decreasing amounts of free phosphoric acid, pyrophosphate, and orthophosphate with increasing temperatures of preparation. Products prepared at 300° contained less than 0.2 percent of the water-insoluble form of potassium metaphosphate, whereas those prepared at 350° contained 73 to 74 percent, and those prepared at 800° contained 91 to 92 percent. Incidental to this work it was necessary to make an extensive study of methods applicable to the determination of the relative proportions of orthophosphates, metaphosphates, and pyrophosphates in phosphate products.

Vegetative tests in which potassium metaphosphate, supplemented by muriate of potash, was the source of potash and phosphoric acid in a 4–8–7 fertilizer mixture showed that the metaphosphate is equivalent to other sources of potash and phosphoric acid in fertilizing value.

Further studies were made on the physical and chemical properties of monocalcium chlorophosphate, the potential fertilizer material previously discovered by the Bureau in efforts to utilize the hydrochloric acid obtained as a byproduct in the conversion of potassium chloride to other potash salts. When this compound was heated for long periods at 120° C. it lost water of crystallization and was converted to the anhydrous form. At temperatures of 200° to 300° one-half mol of hydrochloric acid and two-thirds mol of water per mol of chlorophosphate were liberated, after which decomposition apparently ceased. At 500° the monocalcium chlorophosphate was completely decomposed to calcium pyrophosphate. When steamed at 250° approximately equivalent quantities of hydrochloric acid and water were liberated, and dicalcium phosphate was formed.

Monobarium chlorophosphate, prepared by treating dibarium phosphate with hydrochloric acid, was similar to the calcium salt in being water soluble and giving solutions neutral to methyl orange. This salt is anhydrous, whereas the calcium salt normally contains one molecule of water of crystallization.

Decomposition of Florida pebble phosphate rock with a mixture of sulphuric and hydrochloric acids yielded monocalcium chlorophosphate and calcium sulphate as the principal products and eliminated only a small portion of the fluorine by volatilization. Ammoniation of the mixed product with aqua ammonia equivalent to the chlorine content resulted in the conversion of the chlorophosphate to dicalcium phosphate, ammonium chloride, and water. The water was vaporized on drying, so the product after ammoniation weighed less, but contained more plant food, than it did before.

MIXED-FERTILIZER INVESTIGATIONS

Granulation of fertilizer mixtures by the method of rotary drying was found to be affected by the moisture content of the mixture, temperature during granulation, the ratio of organic to inorganic components, the physical properties of the components, and the fineness of the particles before granulation.

The pressure required to crush a fertilizer granule was found to vary with size, shape, moisture content, and the conditions under which it was prepared. The composition of a granulated fertilizer mixture of the ordinary type had less effect on the hardness of the granules than did the conditions of granulation, such as original particle size, moisture content, and temperature. The crushing strength of fertilizer granules decreased with increase of moisture content, the effect of moisture being more marked with some mixtures than with others. In the case of spherical granules, crushing strength was approximately proportionate to the square of the diameter.

Differences in the size of the fertilizer granules produced in the granulating process involved only slight variations in the composition of the individual granules when the mixture was ground to pass a 40-mesh screen prior to granulation. Variation in the composition of granules of different size was much greater in the case of mixtures containing coarse particles previous to granulation.

High-analysis commercial fertilizer mixtures containing 40 percent of plant food had about the same effect as low-analysis fertilizer mixtures on the concentration of the soil solution when equivalent quantities were used. Commercial fertilizers formulated with urea-ammonia liquor had less effect on the concentration of the soil solution than did those of the same grade formulated with Nitrogen Solution II. Differences in the effects of similar fertilizer applications on the effective concentration of the solution in soils of different types were found to depend on relative moisture contents of the soils.

In studies of the reactions of calcined phosphate with urea phosphate, it was found that dicalcium phosphate and free urea are formed by the primary reaction of the urea phosphate with the alpha-tricalcium phosphate in the calcined phosphate and possibly other products by a slower secondary reaction between dicalcium phosphate and any remaining urea phosphate. The mixed product is less hygroscopic than urea phosphate and contains more plant food than does calcined phosphate. If proper proportions of the reacting materials are used, the product is neutral or acid in reaction. This permits its admixture with ammonium salts, thus removing one of the principal objections to calcined phosphate.

In a study of the composition of the citrate-insoluble phosphates formed during storage of ammoniated fertilizer mixtures containing dolomite, it was found that the dicalcium and tricalcium phosphates in freshly ammoniated superphosphate are partly hydrolyzed to calcium hydroxyphosphate during storage at temperatures above normal and that the presence of dolomite increases this tendency. In the presence of fluorine the reactions proceeded to the formation of fluorapatite, even at ordinary temperatures. Increase in citrate-insoluble phosphoric acid in ammoniated mixtures stored at normal temperatures is therefore due mainly to the formation of fluorapatite; in mixtures stored at elevated temperatures it is due to the formation of both fluorapatite and calcium hydroxyphosphate. The proportions of these citrate-insoluble phosphates formed during storage depend on basicity of the mixture, moisture and fluorine contents, concentration of reacting components, and temperature and time of storage.

The citrate-soluble magnesium in samples of dolomite representing different sizes of particles and different degrees of reactivity, prepared for use in the study of the availability to plants of magnesium in dolomite, was found to increase regularly with the diminishing size of the particle.

A determination from statistical data of the equivalent acidity of commercial mixed fertilizers and the quantities of liming materials consumed during the period 1929–36 showed that the equivalent acidity of mixed fertilizers increased from 115 pounds of calcium carbonate per ton in 1929 to 152 pounds in 1933, and then decreased rapidly to 19 pounds per ton in 1936. That the recent drop in acidity is largely due to the use of liming materials, chiefly dolomite, is indicated by the fact that the consumption of such materials for mixed fertilizers increased from 34,000 tons in 1929 to 303,000 tons in 1936. The Bureau's research and publications on mixed fertilizers have been instrumental in furthering this desirable change.

From statistical and analytical data it was estimated that the average composition of commercial mixed fertilizers in 1935 was 3.44 percent of nitrogen, 9.36 percent of phosphoric acid, and 5.45 percent of potash, or a total of 18.25 percent of plant food. This slight gain in total plant-food content over the 18.17 percent found for 1934 indicates a continued trend toward higher analysis fertilizer mixtures.

SOIL CHEMISTRY AND PHYSICS RESEARCH

LIMESTONE SOILS

The study undertaken to determine what differences could be detected by chemical means between the various soils of limestone origin in the great valley extending from Pennsylvania to Alabama was completed, and the results were prepared for publication as a technical bulletin. In correlating the variations in soil composition with the factors of soil genesis it was concluded that differences in climate and parent rock were responsible for the variations noted. Climatic differences were responsible for the broad differences in composition between soils of the northern and southern ends of the valley, whereas variations in parent rock were responsible for local variations in soil composition. It was found that the total amount of bases present in the soil colloids correlated closely with the productivity of the soils.

ALLUVIAL SOILS

In the study of alluvial soils particular attention was given to 14 samples of sedimentary material deposited by the Ohio River flood of January 1937 and collected at different points along this stream. Mechanical and chemical analyses of these samples and extraction and analysis of their colloids have been completed, and the results are being prepared for publication. The sedimentary material was found to be very uniform in both chemical and mechanical composition. It was slightly calcareous and rich in the bases. Typical analytical values, nearly the average for all the samples, were as follows in percentage: Calcium oxide, 1.15; magnesium oxide, 1.27; potassium oxide, 2.52; sodium oxide, 0.50, and phosphoric oxide, 0.20. Every sample had a pH value above 7.0, indicating alkaline reaction. The colloidal fraction was very much higher in phosphorus and moderately higher in potash than the whole of the deposited material. The silica-sesquioxide ratio was about 2.1:1 and was remarkably uniform in the different samples. The average clay content was about 26 percent, and most of the clay particles were essentially submicroscopic. The silt content was very high and fairly uniform, around 65 percent.

SUBTROPICAL SOILS

In order to determine the physical and chemical properties of certain soils of the subtropics and the relationships between such soils and those of the United States where temperatures are not so high, an investigation was made on six Mexican soil profiles. The results, which have been prepared and submitted for publication, indicated that all the great soil groups are represented by the soils of Mexico, which have their counterparts in the United States both with regard to profile development and the chemical composition of their colloids. This information supplements data previously reported for soils within the United States showing the influence of certain climatic factors on soil classification characteristics and chemical composition.

In the investigation of soils from Hawaii, analyses were made of samples of soils and colloids representing 14 soil profiles. In the course of the analyses it was found that all these soils contained small but significant quantities of chromium, ranging from 0.2 to 0.3 percent as chromium oxide. The results of the investigation were published in Technical Bulletin 584.

DESERT SOILS

A study was made of the chemical and physical differences in the horizons of desert-soil profiles to learn the relation of these properties to the genesis and morphology of such soils and also to provide information on their agricultural value and treatment under irrigation and dry-land farming. The results indicated that the chemical composition of the soil colloids may be used to differentiate the various parts of the desert-soil profiles. Although differ-

ences within the soil profile were not so great as in areas of greater rainfall, they were distinct. There was sufficient moisture at a depth of 1 to 2 feet to cause marked, although incomplete, hydrolysis of the primary minerals. For the most part, calcium carbonate had been removed from the upper horizon and deposited at lower levels, and soluble salts were usually less than 500 parts per million in the soils of unimpeded drainage. Definite profile formation was indicated by concentration of clay between the first and second foot and by a change in chemical characteristics at this level.

NONFERTILE SOILS

Further work confirmed previous observations that the composition of the ash from leaves of trees growing on different soils is profoundly affected by the reaction and composition of the soils. The aluminum and manganese contents of tree leaves are governed by the degree of soil acidity and show very little relation to the quantities of these elements in the soil. On the other hand, the calcium content varies according to the quantity of calcium in the soil. The effect of the composition of soil on that of plants was strikingly illustrated in the case of a hickory tree growing on a soil formed from a vein of pegmatite containing rare-earth minerals. Analysis of the ash from leaves of this tree showed that it contained 0.2 percent of rare-earth oxides. Hickory leaves from a sandy Podzol soil contained no rare-earth elements. Incidentally, over 50 of the chemical elements were identified in the ash of hickory leaves from the pegmatite soil.

Determinations of arsenic in soil profiles representing various members of the great soil groups indicated that arsenic is present in small quantities in all soils. The quantities found ranged from 0.2 to 38 parts of arsenic per million parts of soil. The smallest quantities were found in the Podzol and coastal plain sandy soils, and the largest quantity was found in a Mexican soil. So far, no plant growing in soils to which arsenic has not been added has been found to contain arsenic in excess of 10 parts per million. Plants growing on soils to which liberal quantities of lead arsenate have been added take up arsenic in the leafy parts ranging from 1 or 2 to a maximum of 14 parts per million. Plant roots take up more. For example, mustard roots were found to contain 24 parts of arsenic per million. Although the search has not been exhaustive, no plant has yet been found which accumulates arsenic similarly to several plants that accumulate highly toxic quantities of selenium from soil. Apparently soils having excess soluble arsenic kill plants instead of producing healthy vegetation containing enough arsenic to be toxic to animals.

SELENIUM IN SOILS

Pot experiments with plants were made to determine the effect of soil colloids on the toxicity of different forms of selenium. Less than 1 part per million of selenium as selenate reduced the growth of millet in quartz sand by one-half, even when the sulphate supply was high. In soils of widely different character the selenate was only a little less toxic than in quartz sand. Since there is evidently no appreciable fixation of the selenate by most soil colloids, this form of selenium should have about the same toxicity in nearly all soils. Sodium selenite behaved quite differently from the selenate. Its toxicity was not affected by sulphate concentration but was affected by the colloidal material of the soil. The extent to which the selenite radical is fixed in an unavailable form by different soil colloids is still under investigation.

PHYSICAL PROPERTIES OF SOILS

Data obtained in a study of the densities of separate horizons of soil profiles, representing various members of the great soil groups, indicated that in most of the groups the density of soil minerals is at the minimum in the A horizon and the maximum in the C horizon. The density of the organic fraction in the A horizon is about 1.4 for the Podzol group and about 1.6 for the Gray-Brown Podzolic, Chernozem, Prairie, Red, and Laterite groups. This difference in density probably indicates fundamental differences in the character of the organic matter developed under different soil-making processes.

Density measurements on soils obtained when organic liquids were used instead of water as the pyknometer liquid varied less than 0.5 percent from those obtained when water was used. This close agreement tends to invalidate the opinion, often expressed in soil literature, that water is held so tightly

in soils that it is compressed and held by forces corresponding to a pressure of many thousands of pounds. It appears that water is held no more tightly than other liquids.

In the study of surface relationships in soils it was concluded that the variations in specific surfaces of soils and their colloids, as revealed by their absorption of gases, are not related to chemical composition or to the characteristics which determine classification in the great groups of soils. It was also concluded that heat of wetting and base-exchange capacity are not dependent on extent of surface alone.

In the groups of soils studied the average particle diameter of the colloidal fraction was found by the method used to range from 0.028 to 0.052 micron.

Further attention was given to the measurement of freezing-point depression as a means of gaining information concerning the moisture-retaining capacities of soils. When the Beckmann technique is used for measuring freezing-point depressions of soils, it is usually impossible to obtain results at moisture contents much below 10 percent. With the dielectric constant method this difficulty does not exist, and values for freezing-point depression as great as 8.4° C. have been obtained. Last year a technique was developed that apparently avoids difficulties due to supercooling.

From a study of samples from 12 soil profiles with regard to the volume of material that settles from suspensions in water and other liquids, it was found that the physical and chemical properties that determine the settling volumes of soils also control other soil characteristics, such as swelling and shrinkage, and are related to the movement of soil water.

Thermal-conductivity measurements with specially designed apparatus were made on 11 complete profile samples, representing various members of the great soil groups and three peats in the dry state. The values, expressed as calories per square centimeter for a temperature difference of 1° C. per centimeter, ranged from 0.000120 for peats to 0.000572 for sandy soils. The relation between porosity and thermal conductivity was found to be linear.

MINERAL COMPOSITION OF SOIL COLLOIDS

A number of soil colloids were examined by X-ray methods, both before and after removal of iron oxide, and the following mineral constituents were identified in some or all of them: Kaolinite, goethite, hematite, quartz, hydrous mica, and montmorillonite. The content of potassium was found to parallel that of hydrous mica. It is now possible to determine, within certain limits, the amount of a given constituent present. In most cases the crystalline constituents, as revealed by X-ray examination, compose 95 percent of the total colloid.

STRUCTURE OF PEAT

A number of representative types of peat and muck were investigated, and their acidic properties were determined both qualitatively and quantitatively. There were significant differences between different types of peat and also between different fractions of the same peat with regard to their total base-neutralizing capacities as shown by titration curves. The ratio of ammonia absorption to total base-neutralizing capacity appeared to be of special significance with regard to the quality of the acid constituents. Low ratios are believed to indicate the presence of predominantly weak acids, while relatively high ratios, obtained with sedimentary peat, woody peat, and muck, are believed to indicate the presence of stronger acids. The differences in acidic properties of various peats are undoubtedly related to their capabilities of supplying or conserving nutrients for plant growth when used as soil amendments and to other direct and indirect physiological effects upon plant growth.

QUICK CHEMICAL TESTS FOR SOILS

In the study of quick chemical tests for soils, analytical data were obtained by various methods on soils from several series of experimental plots in different States. Attempts to correlate the results of such tests with the fertilizer treatments and crop yields known for periods of from 5 to 40 years showed that there is no satisfactory method for judging from the results of quick tests the extent to which stimulation of crop growth may be expected from additions of various quantities of fertilizer ingredients to the soil. The tests serve to supplement the field information of experienced agronomists, but when taken alone may be very misleading.

In the investigation of electrical conductivity tests on soil extracts in relation to crop yields it was found that conductivity values may be useful for comparative purposes but are of very limited usefulness when considered alone. The best prospect for useful application of such tests is in the testing of very sandy soils, but such application has not yet been worked out.

SERVICE WORK

The service work of the Soil Chemistry and Physics Research Division includes chemical and mechanical analyses of soils, nitrogen determinations for the entire Bureau, and special physical and chemical determinations on soils. During the year such service work included about 160 complete chemical analyses of soils and soil colloids, about 1,600 nitrogen determinations, and about 750 mechanical analyses of soils. Most of the chemical analyses of soils were made in connection with research activities of the Division, although some were made for the Soil Conservation Service, the Bureau of Plant Industry, the Department of Justice, and several State officials. Out of the total number of mechanical analyses, 277 were made for the Soil Survey Division, 177 for the United States Housing Authority, and 45 for the Soil Conservation Service. The remainder were made for other organizations and for research projects within the Division.

SOIL SURVEY

Soil is the basic resource of agriculture. Since there are thousands of soil types in the United States with individual capabilities for use and responsiveness to management, accurate soil maps are essential to agricultural planning. Never before have the results of this research been in greater demand. Not only is there great need for the existing maps and for new maps in areas for which some are now available, but the interpretation of these in specific terms, applicable to problems of agricultural adjustment, has required greatly increased attention by scientists of the Soil Survey Division.

OBJECTIVES

The object of the soil survey is to classify and map the soils of the United States and to describe their characteristics, particularly in reference to the growth of various crops, grasses, and trees. The ultimate purpose of this research is to provide accurate soil maps of the country. These maps are necessary for the classification of rural lands, and for the factual basis in the development of rational programs of land use consistent with conservation and the welfare of the agricultural people, whether planned by public agencies or individual farmers. The work comprises the determination of the character of soils, definition of soil types, development of a uniform system of soil classification, delineation upon maps of the boundaries of each soil type, and the interpretation of the capabilities of the soils for the production of crops, grasses, and trees under different kinds of management.

Approximately 23,000 square miles of rural lands in the United States and Hawaii were mapped by the Soil Survey Division during the past year. The total area covered by the soil survey is more than one-half the arable lands of the Nation. The soil maps, together with the accompanying reports giving descriptions of the soils and their uses, provide farmers, research workers, extension leaders, and local officials with a practical working handbook of the land for the area covered. In order that the results of experiments on farm land may be utilized in connection with land use problems, it is necessary that information be given regarding the type of soil on which the experiments are made. Once an accurate map of the soil types is made, the results may be extended to individual farm areas having the same soil types. The continued extension in the use of soil maps wherever they are available for determining land use policies testifies to their accuracy and value.

STATE COOPERATION

All this research is accomplished in direct cooperation with local agencies, especially the State agricultural experiment stations. In this way both the broader perspective of the Federal organization and the more detailed local knowledge of the State agencies are utilized to the best advantage, each supplementing the other. For example, the Bureau is cooperating with the seven States having responsibilities for the programs of agricultural development in

the watershed of the Tennessee River. The agricultural experiment stations of these States are cooperating also with the Tennessee Valley Authority in expediting the completion of the detailed soil survey of that area and in conducting research on the various soil types in order to determine their capabilities for agricultural use. Accurate detailed maps showing the location of the various individual soil types having particular possibilities for use under different types of management are essential in developing systems of agriculture offering security to the farm family and for the improvement of the land, prevention of erosion, and the protection of streams and reservoirs.

Similarly, the Bureau is cooperating with a great many States in order to secure the information essential to a solution of their land use problems. For example, in several of the Western States, such as California, Oregon, Utah, and Washington, information on soils is essential for planning the extension of certain special crops and for the proper planning or extension of irrigation in order to avoid areas subject to accumulation of alkali or those having excessive water requirements or other draw-backs.

The problems in each State, and even in each county, are more or less individualistic and require somewhat different data for their solution. This fact emphasizes the necessity of cooperation among Federal, State, and local people in order that a balanced point of view may be obtained. The soil maps are made in such a way as to indicate those physical differences in the land which determine or influence its capabilities for use. Usually an area has more than one problem; the soil map must carry the physical information pertinent to all of them. Thus, from the soil map, other relatively simple maps, showing only one characteristic, may be made by interpretation. For example, supplemental maps showing only erodibility, slope, lime requirement, drainage, or similar features can be made from the soil map. Others may be prepared showing relatively simple groups of soils according to their adaptability to alfalfa, tree fruits, or to other crops or groups of crops. Using the soil map as the base, others may be prepared showing the general suitability of the land for agricultural or other uses as a means for developing plans for rural zoning. All these relatively simple maps would be different from one another, although each one would be taken from the master soil map. In North Dakota, for example, soil maps are used as the basis for rating rural land for tax assessments.

REGIONAL INVESTIGATIONS

Since it is of the utmost importance that the nomenclature of soil types, their definitions, and classification be everywhere consistent, regional comparisons of soil types are essential to the general program. These activities are conducted by the supervisory scientists of the Bureau who are also responsible for the nomenclature used on the detailed soil maps. Special regional studies have been continued in the western portions of the country, where the present information is inadequate for the proper conduct of more detailed surveys.

PRODUCTIVITY RATING

Continued progress was made in the establishment of systematized methods for relating the results of experience and experiments to the individual soil types (and phases) in order that each type that is shown on the soil map may be given a definite rating according to its productivity and crop adaptability. One of the major objectives of this work is to report on the productivity of individual soil types as influenced by different systems of management. An increased number of the soil surveys being published currently contain tables showing these productivity ratings, and it is expected that this research will be pushed to the point where such tables will accompany all soil surveys as soon as the system is broadened and fully developed.

PREPARATION OF SOIL MAPS

After the soil maps have been drawn in the field and the necessary description of the soils and their capabilities for use prepared, the maps are redrawn for publication, and the reports, including soil descriptions, recommendations for their use, agricultural statistics, and similar matters, are printed. These reports and maps are generally published in county units, although occasionally the unit of publication is more or less than one county, such as a stream valley or a watershed. When completed, the reports and maps are made available to the public and to all the Government agencies having need for them.

PROGRESS

The progress of soil mapping is shown in tables 1 and 2, and a list of soil surveys published during the current year is included with the list of publications at the end of this report. It will be noted that over 14½ million acres were surveyed during the year. The reports were issued for 38 areas, covering 16,984,960 acres.

TABLE 1.—*Individual areas surveyed and mapped during the fiscal year ended June 30, 1938*

State or Territory	Area	Area surveyed	
		Square miles	*Acres*
Alabama	Elmore County	[1] 98	62,720
	Lee County	[1] 316	202,240
Arizona	Yuma-Desert area [2]	[1] 168	107,520
California	Kings County	[1] 907	580,480
	Tracy area	375	240,000
Colorado	Washington County	[1] 399	255,360
Florida	Alachua County	[1] 259	165,760
	Collier County	102	65,280
Georgia	Candler County	86	55,040
	Union County	250	160,000
Hawaii	Hawaiian Islands	[1] 1,000	640,000
Idaho	Blackfoot-Aberdeen area [3]	[1] 110	70,400
	Idaho Falls area	88	56,320
Indiana	Franklin County	87	55,680
	Fulton County	[1] 320	204,800
	Johnson County	[1] 281	179,840
	Morgan County	[1] 379	242,560
Iowa	Allamakee County	[1] 255	163,200
	Tama County	[1] 402	257,280
Kentucky	Marshall County	327	209,280
Maine	York County	[1] 362	231,680
Michigan	Midland County	348	222,720
	Newaygo County	[1] 166	106,240
Minnesota	Rock County	229	146,560
	Washington County	[1] 95	60,800
Mississippi	Alcorn County	41	26,240
	Prentiss County	95	60,800
Missouri	St. Charles County	22	14,080
Montana	Big Horn River Valley area	79	50,560
Nebraska	Cherry County	[1] 1,637	1,047,680
	Lancaster County	[1] 572	366,080
	Otoe County	[1] 197	126,080
New Hampshire	Cheshire County	[1] 328	209,920
	Coos County	[1] 745	476,800
	Hillsboro County	119	76,160
New York	Niagara County	[1] 149	95,360
	Seneca County	336	215,040
	Sullivan County	[1] 770	492,800
North Carolina	Jackson County	[1] 306	195,840
	Mitchell County	67	42,880
	Swain County	[1] 210	134,400
	Transylvania County	[1] 210	134,400
	Warren County	[1] 165	105,600
Ohio	Tuscarawas County	[1] 108	69,120
Oklahoma	Choctaw County	[1] 107	68,480
	Creek County	[1] 201	128,640
	Noble County	153	97,920
	Okfuskee County	32	20,480
	Woods County	[1] 521	333,440
Oregon	Astoria area	79	50,560
	Baker area	[1] 91	58,240
Pennsylvania	Crawford County	[1] 350	224,000
	Fayette County	[1] 266	170,240
Rhode Island	Providence County	[1] 166	106,240
South Carolina	Charleston County	143	91,520
	Pickens County	[1] 38	24,320
Tennessee	Bedford County	[1] 289	184,960
	Cumberland County	[1] 417	266,880
	Rhea County	49	31,360
Texas	Dimmit County	[1] 638	408,320
	Fannin County	[1] 246	157,440
Utah	Beryl-Enterprise area	69	44,160
	Provo-Lehi area	[1] 122	78,080
Virginia	Mecklenburg County	65	41,600
	Princess Anne County	[1] 208	133,120
	Scott County	49	31,360
	Smyth County	[1] 246	157,440
	Tazewell County	[1] 424	271,360

[1] These figures do not include portions of these areas surveyed in preceding years.
[2] Previously reported as Yuma-Gila area, Ariz.
[3] Previously reported as Bingham County, Idaho.

TABLE 1.—*Individual areas surveyed and mapped during the fiscal year ended June 30, 1938*—Continued

State or Territory	Area	Area surveyed	
		Square miles	*Acres*
Washington	Clallam County	1,673	1,070,720
	King County	[1] 490	313,600
	Pierce County	531	339,840
	Skamania County	32	20,480
West Virginia	Greenbrier County	[1] 346	221,440
Wyoming	Campbell County	[1] 1,090	697,600
Total		22,696	14,525,440

[1] These figures do not include portions of these surveyed in preceding years.

TABLE 2.—*Areas surveyed and mapped in the several States during the fiscal year ended June 30, 1938, and the areas previously reported*

DETAILED

State or Territory	Work during 1938	Work previously reported	Total	
	Square miles	*Square miles*	*Square miles*	*Acres*
Alabama	414	60,502	60,916	38,986,240
Arizona	168	5,069	5,237	3,351,680
Arkansas	----------	15,547	15,547	9,950,080
California	1,282	39,972	41,254	26,402,560
Colorado	399	6,733	7,132	4,564,480
Connecticut	----------	1,704	1,704	1,090,560
Delaware	----------	2,276	2,276	1,456,640
Florida	361	15,389	15,750	10,080,000
Georgia	336	36,680	37,016	23,690,240
Hawaii	1,000	2,668	3,668	2,347,520
Idaho	198	12,965	13,163	8,424,320
Illinois	----------	6,770	6,770	4,332,800
Indiana	1,067	22,371	23,438	15,000,320
Iowa	657	52,204	52,861	33,831,040
Kansas	----------	16,854	16,854	10,786,560
Kentucky	327	5,954	6,281	4,019,840
Louisiana	----------	17,431	17,431	11,155,840
Maine	362	2,475	2,837	1,815,680
Maryland	----------	13,959	13,959	8,933,760
Massachusetts	----------	8,811	8,811	5,639,040
Michigan	514	33,267	33,781	21,619,840
Minnesota	324	13,020	13,344	8,540,160
Mississippi	136	31,168	31,304	20,034,560
Missouri	22	37,177	37,199	23,807,360
Montana	79	3,287	3,366	2,154,240
Nebraska	2,406	70,448	72,854	46,626,560
Nevada	----------	652	652	417,280
New Hampshire	1,192	5,120	6,312	4,039,680
New Jersey	----------	9,895	9,895	6,332,800
New Mexico	----------	2,565	2,565	1,641,600
New York	1,255	37,993	39,248	25,118,720
North Carolina	958	49,743	50,701	32,448,640
North Dakota	----------	23,049	23,049	14,751,360
Ohio	108	18,782	18,890	12,089,600
Oklahoma	1,014	26,339	27,353	17,505,920
Oregon	170	16,274	16,444	10,524,160
Pennsylvania	616	23,015	23,631	15,123,840
Puerto Rico	----------	3,765	3,765	2,409,600
Rhode Island	166	1,921	2,087	1,335,680
South Carolina	181	27,254	27,435	17,558,400
South Dakota	----------	8,286	8,286	5,303,040
Tennessee	755	13,764	14,519	9,292,160
Texas	884	67,425	68,309	43,717,760
Utah	191	3,215	3,406	2,179,840
Vermont	----------	1,175	1,175	752,000
Virginia	992	16,535	17,527	11,217,280
Washington	2,726	13,394	16,120	10,316,800
West Virginia	346	24,335	24,681	15,795,840
Wisconsin	----------	26,659	26,659	17,061,760
Wyoming	1,090	14,787	15,877	10,161,280
Total	22,696	970,643	993,339	635,736,960

TABLE 2.—*Areas surveyed and mapped in the several States during the fiscal year ended June 30, 1938, and the areas previously reported*—Continued

RECONNAISSANCE

State or Territory	Work during 1938	Work previously reported	Total	
	Square miles	*Square miles*	*Square miles*	*Acres*
Alaska		31,915	31,915	20,425,600
Arkansas-Missouri		58,000	58,000	37,120,000
California		32,135	32,135	20,566,400
Kansas		39,960	39,960	25,574,400
Michigan		1,322	1,322	846,080
Minnesota		12,744	12,744	8,156,160
Montana	65	54,878	54,943	35,163,520
Nebraska		53,064	53,064	33,960,960
North Dakota		39,240	39,240	25,113,600
Ohio		41,420	41,420	26,508,800
Pennsylvania		41,405	41,405	26,499,200
South Dakota		41,400	41,400	26,496,000
Texas		152,855	152,855	97,827,200
Vermont		9,124	9,124	5,839,360
Washington		18,409	18,409	11,781,760
Wisconsin		14,425	14,425	9,232,000
Total	65	642,296	642,361	411,111,040

SPECIAL WORK OF THE SOIL SURVEY

For the successful prosecution of many of the activities of the Federal Government and cooperating State agencies it has been necessary for scientists in the Soil Survey Division to interpret the available soil data in terms of the particular objective at hand. As the soil-survey data are basic for almost all kinds of agricultural activities, thousands of private individuals and organizations, as well as public agencies, seek the advice and assistance of soil scientists of the Bureau as to the location of soil types adaptable to various crops and how the various soil types may be managed. Requests of this kind have greatly increased in the last few years.

For many years scientists in the Soil Survey Division have called attention to the serious injury, through erosion, to soils when they are improperly used. The characteristics of the soil type determine its erodibility under different kinds of use and methods of management. The necessity for proper definition, classification, and correlation of the soil types is recognized as fundamental to soil conservation and land use adjustment programs. The Bureau has this responsibility through the Soil Survey Division. The soil maps serve as a basis for erosion surveys and erosion-control projects. In many instances where these maps have been unavailable, soil scientists of this Bureau have assisted in making special studies and maps for the use of Federal and State agencies. Scientists of the Bureau are assisting the Tennessee Valley Authority, Soil Conservation Service, and other agencies in making such studies and maps.

In addition to the attention given to the possibilities of land for irrigation in connection with the regular soil-survey projects, special reports have been prepared in regard to the suitability of land for irrigation in areas under the jurisdiction of other governmental agencies.

Work has been continued on the investigation of peat lands in cooperation with other Federal and State agencies, particularly from the point of view of the relationship of such soils to the conservation of land and prevention of floods and their utilization for wildlife. Special studies and reports have been made of peat areas in connection with the work of the Bureau of Biological Survey and the Bureau of Entomology and Plant Quarantine and other agencies having special problems in the utilization of these lands.

Special work of particular interest was the preparation of a series of land-classification maps of 96 representative counties having comparatively recent soil-survey maps and reports, for the Highway Planning Division of the Bureau of Public Roads. These maps were requested as a part of the data for planning and locating farm-to-market roads. The following classification, based on current productivity and land use, was shown: Excellent cropland, good cropland, fair cropland, poor cropland, pasture and grazing land, forest land, and waste land.

Special field mapping of soils in the commercial apple orchards of the limestone valley was carried on for the Farm Credit Administration in cooperation with other government and State agencies in order to provide adequate data for the determination of loan policies.

The services of an experienced fieldman were furnished for a period of several months to the Bureau of Agricultural Economics as an aid in developing land programs in the northern Great Plains.

YEARBOOK FOR 1938

In accordance with the Secretary's memorandum of January 27, 1937, whereby the Yearbook of Agriculture for 1938 was delegated to treat with departmental activities in soils, considerable time was spent by scientists of the Soil Survey Division in preparing papers on the various aspects of soil science and its development. Among the subjects discussed are the physical properties of soils, organic matter, processes and factors responsible for the formation of soil from parent material, principles of soil classification, zonal, intrazonal, and azonal soils, soil maps and their use, the soil requirements of economic plants, extent and nature of soil losses, and the need of coordinated research in soil survey, soil chemistry, and soil management. A special feature of the Yearbook is the inclusion of a map of the soil associations of the United States, including the insular possessions. Each area takes its name from the dominant soil series. An accompanying text briefly describes each area as to geographic setting, climate, vegetation, parent materials, soils, and land use.

INFORMATION AND PUBLICATIONS

The Bureau published 38 soil-survey bulletins, 7 technical bulletins, 1 circular, 1 miscellaneous publication, 2 farmers' bulletins, 4 revised bulletins, 3 articles in the Journal of Agricultural Research, 1 annual report, 22 mimeographed publications, and 188 articles in technical and trade journals. The Bureau also furnished information on various phases of its research through the press and radio services of the Department.

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

The following lists show the publications and patents of the 10 research divisions of this Bureau:

LIST OF PUBLICATIONS

CARBOHYDRATE RESEARCH DIVISION

New sirup method success. By Henry G. Knight. South. Agr. 68 (1) : 8 and 19. 1938.

New method enables farmers to make better sirup. By Henry G. Knight. Farm Sec., Mobile Press Register, pp. 9 and 23. Jan. 30, 1938. Mobile, Ala.

The extraction of certain nonsugars of sugarcane during milling. By C. A. Fort and R. L. Holmes. Sugar Bull. 16 (4) : 3–4. 1937. (With Bur. Plant Indus.)

Relative inversion of sucrose in mill and windrowed cane of commercial and seedling varieties in Louisiana. By J. I. Lauritzen, C. A. Fort, and R. T. Balch. Sugar Bull. 16 (2) : 5–8. 1937. (With Bur. Plant Indus.)

Estimation of degree of souring in sugarcane juice. By C. A. Fort and J. I. Lauritzen. Indus. and Engin. Chem., Analyt. Ed. 10 : 251–253. 1938. (With Bur. Plant Indus.)

Preliminary studies on the composition of the whole cane of varieties Co. 281 and Co. 290. By C. A. Fort and R. L. Holmes. Sugar Bull. 16 (6) : 2–4. 1937. (With Bur. Plant. Indus.)

A preliminary study of the use of air agitation for graining and curing of Louisiana string sugars. By Emil K. Ventre. Sugar Bull. 15 (24) : 10 and 12. 1937.

Evaporator for research on sirup manufacture. By C. F. Walton, Jr., and E. K. Ventre. Internatl. Sugar Jour. 39 '497) : 430–431. 1937.

Recent developments in the production of sweet potato starch. By H. S. Paine. Potato World 6 (8) : 8–13. 1937.

Temperature and starch-sugar change in sweet potatoes. By E. F. Hopkins and J. K. Phillips. Sci. 86 : 523–525. 1937.

A simple gas thermoregulator. By R. M. Kingsbury. Indus. and Engin. Chem., Analyt. Ed. 9 : 333. 1937.

A new and rapid dehydration process for vegetables. By E. F. Hopkins. Sci. 87 : 71–72. 1938.

Hygroscopic properties of honey. By R. E. Lothrop. Gleanings Bee Cult. 65 (11) : 664–666. 1937.

Utilization of honey in commercial baking and in other industries. By R. E. Lothrop and L. H. Bailey. Amer. Bee Jour. 78 (2) : 54–57. 1938.

Recent progress in industrial utilization of honey. By C. A. Browne. Amer. Bee Jour. 57 (12) : 563–565 and 593. 1937.

The composition of expressed lumbang oil. By G. S. Jamieson and R. S. McKinney. Oil and Soap 14 (8) : 203–205. 1937.

A further study on the composition of American Tung oil with special reference to the linoleic acid content. By R. S. McKinney and G. S. Jamieson. Oil and Soap 15 (2) : 30–33. 1938.

The chemistry of the acyclic constituents of natural fats and oils. By G. S. Jamieson. (Abstract) Ann. Rev. Biochem. 7 : 77–99. 1938.

Distribution and variation with maturity of dissolved solids, sucrose and titratable acidity in the sorgo stalk. By Emil K. Ventre and S. Byall. Jour. Agr. Res. 55 : 553–562. 1937.

Farm production of sorgo sirup. By C. F. Walton, Jr., E. K. Ventre, and S. Byall. U. S. Dept. Agr. Farmers' Bull. 1791.

The effect of applications of common salt upon the yield and quality of sugar beets and upon the composition of the ash. By J. G. Lill, S. Byall, and L. A. Hurst. Jour. Amer. Soc. Agron. 30: 97–106. 1938. (With Mich. Agr. Expt. Sta. and Bur. Plant Indus.)

CHEMICAL ENGINEERING RESEARCH DIVISION

Rural losses $225,000,000 yearly. By D. J. Price. Volunteer Firemen 4 (12): 5. 1937.

Development in farm and rural community fire prevention. By D. J. Price. W. Va. Univ. Bull. Series 38 (6–IV): 30–34. 1937.

What have we learned from the New London, Tex., school explosion. (Kansas City, Mo.) By D. J. Price. Lessons from the New London, Tex., school explosion. (Oklahoma City, Okla.) BC&SMC—15. 1937. (Mimeographed); Lessons from the New London, Tex., school explosion of importance to firemen. Ann. Conv. Pa. State Firemen's Assoc. Proc. 58: 16–27. 1937; New London, Tex., school explosion findings. Weekly Underwriter 137 (19): 985–987. 1937; New London, Tex., schoolhouse explosion. Pa. State Alumni News, pp. 16–17. Sept. 1937; Explosion at consolidated school, New London, Tex., W. Va. Univ. Bull. Series 38 (6–IV): 16–26. 1937.

Urgent need for program on agricultural accident prevention. By D. J. Price. BC&SMC—16. 1937. (Mimeographed.)

Prevention and control of dust explosions in industrial plants. By D. J. Price and Hylton R. Brown. Quart. Natl. Fire Protect. Asso. 31 (1): 496–502. 1937.

Developments in farm and rural community fire prevention. By D. J. Price and Harry E. Roethe. Quart. Natl. Fire Protect. Assoc. 31 (1): 385–389. 1937.

Spontaneous heating and ignition of hay. By Harry E. Roethe. Agr. Engin. 18 (12): 547–550 and 554. 1937; Weekly Underwriter 138 (6): 351–353. 1938.

Safe use and storage of gasoline and kerosene on the farm. U. S. Dept. Agr. Farmers' Bull. 1678. (Revised 1938.) (Issued by Burs. Chem. and Soils, Agr. Engin., and Agr. Econ., and Natl. Fire Protect. Assoc.)

Fire-protective construction on the farm. U. S. Dept. Agr. Farmers' Bull. 1590. (Revised 1938.) (Issued By Burs. Chem. and Soils, Agr. Engin., and Agr. Econ., and Natl. Fire Protect. Assoc.)

Fire safeguards for the farm. U. S. Dept. Agr. Farmers' Bull. 1643. By V. N. Valgren, Harry E. Roethe, Wallace Ashby, and William H. Rowe. (Revised 1938.) (With Farm Credit Admin. and Burs. Agr. Engin. and Agr. Econ.)

Fires on farms. U. S. Dept. Agr. Leaflet 44. By Harry E. Roethe. (Revised 1938.)

Down on the farm. By H. E. Roethe. Safety Engin. 75 (1): 37–38; (2): 39. 1938.

The part dust plays in industrial plant fire hazards. By D. J. Price. Fire Engin. 90 9: 462–465. 1937.

Dust explosions during fire fighting. By D. J. Price. Fire Protect. 103 (4): 6. 1938.

CHEMICAL INVESTIGATIONS OF ALLERGENS IN AGRICULTURAL PRODUCTS

What's ahead in the cottonseed industry. By Henry G. Knight. Ann. Conv. Natl. Cottonseed Prod. Assoc. Proc. 42: 8–10. 1938.

FERTILIZER RESEARCH DIVISION

Report on phosphoric acid. A. Effect of the method of filtering on the determination of water-soluble P_2O_5. B. Variation in the citrate-insoluble P_2O_5 with the time interval between the water extraction and citrate digestion. By J. R. Adams and W. H. Ross. Jour. Assoc. Off. Agr. Chem. 21: 268–273. 1938.

Hygroscopicity of fertilizer mixtures. Effect of calcined phosphates. By C. W. Whittaker, J. R. Adams, and K. D. Jacob. Indus. and Engin. Chem. 29: 1144–1148. 1937.

Heat developed in the ammoniation of superphosphates with anhydrous ammonia. By J. O. Hardesty and W. H. Ross. Indus. and Engin. Chem. 29: 1283–1290. 1937.

Chemical reactions in fertilizer mixtures: Reactions of calcined phosphate with ammonium sulfate and superphosphate. By K. C. Beeson and K. D. Jacob. Indus. and Engin. Chem. 30: 304–308. 1938.

Chemical reactions in fertilizer mixtures. Decomposition of dolomite. By K. C. Beeson and W. H. Ross. Indus. and Engin. Chem. 29: 1176–1182. 1937.

Phosphate fertilizers by calcination process: Reversion of calcined phosphate at temperatures below 1400° C. By H. L. Marshall, D. S. Reynolds, K. D. Jacob, and T. H. Tremearne. Indus. and Engin. Chem. 29: 1294–1298. 1937.

Phosphate rock. By K. D Jacob. Mineral Indus. 45: 471–484. 1937.

Phosphate fertilizers by calcination process: Composition of defluorinated phosphate. By W. L. Hill, S. B. Hendricks, M. E. Jefferson, and D. S. Reynolds. Indus. and Engin. Chem. 29: 1299–1304. 1937.

Factors affecting the granulation of fertilizer mixtures. By J. O. Hardesty and W. H. Ross. Indus. and Engin. Chem. 30: 668–672. 1938.

Report on phosphoric acid. Citrate-insoluble phosphoric acid in ammoniated mixtures containing dolomite. By W. H. Ross, L. F. Rader, Jr., and K. C. Beeson. Jour. Assoc. Off. Agr. Chem. 21: 258–268. 1938.

The effect of various grades of fertilizers on the salt content of the soil solution. By L. M. White and W. H. Ross. Amer. Fert. 88 (5): 11. 1938.

The phosphate rock reserves of the United States. By K. D. Jacob. Com. Fert. Yearbook 57 (1): 28–43, 55, and 59. 1938.

The use of low temperature Van der Waals adsorption isotherms in determining the surface area of iron synthetic ammonia catalysts. By P. H. Emmett and S. Brunauer. Jour. Amer. Chem. Soc. 59: 1553–1564. 1937.

The measurement of surface areas of soils and soil colloids by the use of low temperature Van der Waals adsorption isotherms. By P. H. Emmett, S. Brunauer, and K. S. Love. Soil Sci. 45 (1): 57–65. 1938.

The use of low temperature Van der Waals adsorption isotherms in determining the surface areas of various adsorbents. By S. Brunauer and P. H. Emmett. Jour. Amer. Chem. Soc. 59: 2682–2689. 1937.

Adsorption of gases in multimolecular layers. By Stephen Brunauer, P. H. Emmett, and Edward Teller. Jour. Amer. Chem. Soc. 60: 309–319. 1938.

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On the crystal structure of talc and pyrophyllite. By S. B. Hendricks. Ztschr. Kristallographie 99: 264–274. 1938.

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On the crystal structure of the clay minerals dickite, halloysite and hydrated halloysite. By S. B. Hendricks. Amer. Mineralogist 23 : 295–301. 1938.

The hydrogenation of ethylene by iron synthetic ammonia catalysts. By Rowland C. Hansford and P. H. Emmett. Jour. Amer. Chem. Soc. 60 : 1185–1190. 1938. (With George Wash. Univ.)

A spectrophotometric study of the equilibria in the gaseous system nitric oxide, nitrogen dioxide, and water. By E. H. Melvin and O. R. Wulf. Spectroscopy in Sci. and Indus. Proc. 5th Summer Conf. in Spectroscopy and its applications, pp. 110–113. 1938.

The absorption coefficient of nitrogen pentoxide and the visible absorption spectrum of NO_3. By E. J. Jones and O. R. Wulf. Jour. Chem. Phys. 5 : 873–877. 1937.

The atmospheric ozone equilibrium and its rate of maintenance. By Oliver R. Wulf. (Abstract) Jour. Wash. Acad. Sci. 28 : 32. 1938.

The solubility in liquid ammonia of hydrogen at 0° and of nitrogen at 0, 50, 75, 90, and 100° C. at pressures to 1,000 atmospheres. Critical phenomena of ammonia-nitrogen mixtures. By R. Wiebe and V. L. Gaddy. Jour. Amer. Chem. Soc. 59 : 1984–1987. 1937.

A glass sealing furnace. By J. R. Dilley. Rev. Sci. Instruments 8 (10) : 394–395. 1937.

Review of "Interpolation and allied tables. By L. J. Comrie." By W. E. Deming. Jour. Amer. Statis. Assoc. 32 : 587–588. 1937.

Chemistry—Response to the award of the Hillebrand prize for 1937. By S. B. Hendricks. Jour. Wash. Acad. Sci. 28 : 247–250. 1938.

The calcium, magnesium, sulphur, and chlorine contents of fertilizers. By A. L. Mehring and F. O. Lundstrom. Amer. Fert. 88 (2) : 5–10. 1938.

The solubility and chemical and physical absorption of nitrogen gas in Azotobacter cells. By Hans Lineweaver. Jour. Biol. Chem. 122 : 549–567. 1938.

Physical characteristics of cells of Azotobacter, Rhizobium, and Saccharomyces. By Hans Lineweaver. Jour. Bact. 35 : 501–510. 1938.

The availability of different forms of nitrogen to a green alga. By C. A. Ludwig. Amer. Jour. Bot. 25 : 448–458. 1938.

Fertilizer Research. By Henry G. Knight. Fert. Rev. 12 (4) : 9 and 13. 1937.

An adjustable leak valve. By W. L. Edwards and L. R. Maxwell. Rev. Sci. Instruments 9 (6) : 201. 1938.

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A mass spectrographic determination of the isotope abundance and of the atomic weight of rubidium. By A. Keith Brewer. Jour. Amer. Chem. Soc. 60 : 691–693. 1938.

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Radioactivity of potassium and geological time. By A. K. Brewer. Sci. 86 : 198–199. 1937.

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Alabama

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Wilcox County.

Arizona

Upper Gila Valley area.

California

Barstow area.
Napa area.

Georgia

McDuffie County.

Indiana

Dubois County.
Pike County.

Iowa

Franklin County.

Kansas

Kingman County.

Michigan

Oceana County.
Saginaw County.

Mississippi

Marion County.

Nebraska

Boyd County.
Garfield County.
Gosper County.
Holt County.
Keya Paha County.
Loup County.

New York

Onondaga County.
Wyoming County.

North Carolina

Brunswick County.
Chatham County.
Jones County.
Pamlico County.
Surry County.

Ohio

Licking County.

Oklahoma

Carter County.
Greer County.
McIntosh County.
Mayes County.
Pittsburg County.
Woodward County.

Pennsylvania

Wayne County.

South Carolina

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Virginia

Halifax County.
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