REPORT OF THE CHIEF OF THE BUREAU OF AGRICULTURAL CHEMISTRY AND ENGINEERING, 1940

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF AGRICULTURAL CHEMISTRY AND ENGINEERING,
Washington, D. C., August 31, 1940.

Hon. HENRY A. WALLACE,
Secretary of Agriculture.

DEAR MR. SECRETARY: I present herewith the report of the Bureau of Agricultural Chemistry and Engineering for the fiscal year ended June 30, 1940.

Sincerely yours,

HENRY G. KNIGHT, *Chief.*

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INTRODUCTION

This is the second annual report of the Bureau of Agricultural Chemistry and Engineering, which was established October 16, 1938, by order of the Secretary of Agriculture.

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The functions of this Bureau are to coordinate and continue the scientific, technological, and engineering research on agricultural products formerly carried on in the Bureau of Chemistry and Soils and the agricultural engineering research formerly carried on in the Bureau of Agricultural Engineering, including studies of farm mechanical equipment, mechanical processing of certain farm products, farm structures, methods of heating, ventilating and lighting, and use of electricity on the farm, but excluding studies on irrigation and drainage. At the time the Bureau of Agricultural Chemistry and Engineering was created, it was also authorized and directed to administer and operate the four regional research laboratories, established by the Department pursuant to the provisions of subsections (a) to (e), inclusive, of section 202 of the Agricultural Adjustment Act of 1938 for the purpose of developing new uses and wider industrial outlets for farm products and byproducts.

The work of the Bureau includes a number of fundamental research projects authorized by the Secretary of Agriculture under the Bankhead-Jones Act of June 29, 1935, in addition to its regular research projects and those of the regional research laboratories. This work is supported by direct appropriations to the Bureau in the Department of Agriculture Appropriation Acts, by funds designated for the four regional laboratories in the appropriations for Conservation and Use of Agricultural Land Resources and by allotments made by the Director of Research from the special research funds appropriated for carrying out the purposes of the Bankhead-Jones Act.

Early in the fiscal year 1940 the Fertilizer Research Division, formerly in the Bureau of Chemistry and Soils and later in the Bureau of Agricultural Chemistry and Engineering, was transferred to the Bureau of Plant Industry. Reports of the research work on fertilizers in 1940 will therefore be found in the Report of the Chief of the Bureau of Plant Industry.

The more important results of the work of the Bureau of Agricultural Chemistry and Engineering during the fiscal year 1940 are reported in the following pages. Further information concerning many of the subjects discussed may be obtained from the 239 publications issued by the Bureau during the year and listed at the end of this report together with a list of the 12 patents issued to members of the Bureau personnel.

FOOD RESEARCH

VEGETABLES AND VEGETABLE PRODUCTS

At the Los Angeles Fruit and Vegetable Chemistry Laboratory, the work on vegetables included studies of the chemical composition and food value of lima beans, the possibility of using lima bean pods and vines as cattle feed, the suitability of California-grown red kidney beans for canning, and the preparation of soybean sprouts for use as food. This work was in collaboration with branches of the University of California and the California Agricultural Experiment Station.

Comparatively little work has been done heretofore on the composition of fresh lima beans, but during the past year analytical data were obtained on about 100 samples representing various strains produced in plant-breeding experiments under the direction of Professor

W. W. Mackie. The results obtained for fat, protein, sugar, starch, and individual mineral constituents revealed facts on the variations in different strains which are of interest in connection with both plant breeding and utilization. They have suggested several lines of investigation. Studies are in progress on the effects of quick freezing and methods of blanching on the composition of lima beans. It is hoped that vitamin studies can be made later. This work is expected to lead, eventually, to increased consumption of fresh and frozen lima beans.

In the past, lima beans were grown in California mostly for use in the dry form. The waste from the dry beans usually went back directly to the land from the thresher, although some was sold for use as a mulch around orange trees. Now large quantities of lima beans are quick-frozen in the green stage and the waste, mostly pods, accumulates at central locations. Last year 600 tons of such waste resulted from the operation of one plant and had to be hauled back to the land at considerable cost. A more profitable method of utilization is needed. Preliminary analyses of the green pods to ascertain their feeding value revealed the fact that they contain glucosides which yield noticeable quantities of the poisonous hydrocyanic acid. Lima bean packers and growers were warned of the possible danger of feeding the fresh pods and vines to cattle. The fact that the dried material yielded less than a proportionate amount of the hydrocyanic acid suggested that this constituent might be eliminated by siloing or other treatment. This question is now under investigation.

In the experiments on preparing soybean sprouts, it was found that with automatic sprinkling apparatus and controlled temperature a much larger yield of sprouts of better quality could be obtained than with the old earthen-jar method and manual sprinkling. Application was filed for a public-service patent covering design of the equipment. Soybean sprouts are both palatable and nutritious and especially useful for supplying certain vitamins in regions which do not have sufficient fresh vegetables. They have long been used in oriental countries and can now be produced economically in this country.

At the Seattle laboratory, attention was given to a number of problems connected with the quick-freezing method of preserving vegetables, especially garden peas. One of the major problems is that of determining the proper stage of maturity at which garden peas should be harvested for quick freezing. In further studies on the suitability of the tenderometer for determining raw-product grades in peas intended for freezing, correlations were made between tenderometer readings and Federal grades of collateral samples. The conclusion was that if the tenderometer is to be used for grading raw peas, the readings must not exceed 100 at time of packing in order to have the peas fall mostly within grade A, according to the Federal grade standards for maturity. For the greatest accuracy in predicting the raw grade of peas by means of tenderometer readings, the determinations should be on a sieve-size basis, rather than on field-run samples. To grade peas with the tenderometer on a field-run sample basis, without allowing for interfering factors, may work to the disadvantage of the packers, since many samples grading A, according to the tenderometer, may fall into grade B, according to the Federal grade standards for maturity. The use of the tenderometer for testing peas being bought

from growers should remove some of the disagreements as to the quality of the raw product delivered.

A delay of 3 hours between the times of harvesting and testing peas was found to result in higher tenderometer readings. Moreover, the higher the temperature during the delay period, the higher the readings become. With regard to the effects of temperature of peas on tenderometer readings, in general, it was observed that increases in temperature resulted in lower readings, averaging about 3 points for each 10-degree rise in temperature in the range of 30° to 100° F. This indicates that pea samples for tenderometer tests should be brought to a standard temperature or that a correction should be made for the deviation from a standard temperature. It is obvious that a correction should also be made for the effect of any delay between harvesting and testing for which the grower is not responsible.

In view of the fact that previous studies on the nitrogen content of frozen peas, representing two important commercial varieties, indicated a possible connection between the development of "off" flavor and protein decomposition, similar studies were made on the Monarch variety, grown at the Western Washington Experiment Station. It appeared that this variety is quite resistant to protein breakdown. Assuming that the development of off flavor in peas during freezing storage is due to protein break-down, the Monarch variety is superior to both the Improved Gradus and Tall Alderman varieties, previously studied.

Monarch peas, frozen raw and after blanching under different conditions and packed in both paper containers and tin cans, were also studied with regard to development of free fatty acids, believed to be a possible cause of off flavor. The results showed that raw frozen peas develop free fatty acids much faster than do blanched frozen peas; also, that frozen peas stored in paper containers develop more fatty acids than do similar peas stored in sealed tin cans.

The total loss of water-soluble solids from Monarch peas subjected to the water-blanching process was found to approximate one-half of an ounce per pound of peas treated. The greatest portion of the soluble material extracted by the blanching water was sugar. There were also small quantities of soluble proteins and very small quantities of minerals and ascorbic acid (vitamin C) in the water extracts. When water of boiling temperature was used, blanching for 60 seconds did not remove much more soluble solids than did blanching for 20 seconds. However, with water at lower temperatures, from 180° to 200° F., blanching for longer periods extracted greater quantities of soluble solids.

Examinations of frozen asparagus, blanched in different ways before freezing and stored at 0° F., indicated no protein break-down. Even asparagus that was frozen without any blanching and stored for 24 weeks at 0° F. was free from such deterioration. It was concluded, therefore, that the development of an off flavor in frozen asparagus cannot be attributed to protein break-down, as would be indicated by an increase in the nonprotein nitrogen content.

Repeated experiments have shown that under experimental conditions, at least, a scald for 1½ minutes in water or steam in the temperature range of 200° to 212° F. is adequate for the retention of quality in frozen asparagus, ⅜ to 1 inch in diameter, during stor-

age at −5° for at least 8 months. It was found that the qualitative test for catalase activity as an index of adequate scalding is unreliable and should be replaced by a qualitative test for peroxidase activity. The appearance of asparagus that had been frozen rapidly was better in the frozen state, and also after thawing and cooking, than was that of asparagus frozen slowly. However, no significant difference could be detected in the eating quality of rapidly frozen and slowly frozen asparagus after cooking. From experiments which have been in progress for several years, it is apparent that the toughness of much commercially frozen asparagus may be attributed to handling delays between harvesting and processing.

Experimental frozen packs of lima beans were made to determine the effects on quality of possible delays in handling. Similar lots of Henderson Bush Early Strain lima beans in the hull were held iced and uniced for 21 hours after harvesting and samples of each lot were frozen at intervals during that time. After 6 months of storage the frozen samples were cooked under standard conditions and judged for quality. The samples which represented beans held in iced condition for various periods up to 21 hours before freezing showed no bad effects from the delay in handling. However, those representing beans which were held in uniced condition for 12 hours or more before freezing were inferior in color and flavor. The sample representing beans held in uniced condition for 21 hours before freezing had decidedly objectionable color, flavor, and odor. The temperature of the uniced beans was 61° F. to start with, but had increased to 82° after 12 and to 86° after 21 hours.

During the 1940 vegetable-packing season, an extensive bacteriological or sanitary survey was made of freezing plants in the Puget Sound area to determine the influence of handling practices on the microbial content of frozen vegetables and the microbial load that could be tentatively considered normal or "allowed" in foodstuffs of this sort. As a result, recommendations were made of means by which excessive quantities of bacteria and other micro-organisms may be avoided.

Bacterial analyses of more than 200 commercial samples of frozen vegetables, representing the output of 10 plants and including 71 samples of peas, 41 of snap beans, and smaller numbers of asparagus, lima beans, spinach, cauliflower, broccoli, and mixed peas and carrots, showed wide variation in bacterial content. In the case of peas the range was from 2,000 to more than 3 million per gram. These wide variations point definitely to a lack of a standardized technique in the production of frozen vegetables, and apparently to a lack of a working knowledge of the bacteriology involved. It has been observed that when raw vegetables are handled promptly (or within a few hours if kept iced) in a reasonably well-cared-for plant, the bacterial count in the newly frozen vegetables does not often exceed 100,000 per gram, using glucose agar as the test medium; in many cases the number is considerably less.

A direct microscope test of frozen vegetables for their total bacterial content, including both viable and dead organisms, has been investigated and shows promise. Further work is necessary to evaluate the results of such a test. The usual cultural test detects only those organisms that have survived.

In efforts to determine the cause of the objectionable darkening of some frozen vegetables after thawing and cooking, pureed peas and other vegetables were inoculated with cultures of bacteria, known to cause darkening of green vegetables, and frozen. After 14 months of storage the frozen vegetables showed no darkening while still frozen or immediately after defrosting. However, darkening started 12 hours after defrosting at room temperature and was progressive. Peas which had been inoculated and held 2 and 4 hours before freezing were slightly faded in the first instance and noticeably blanched in the second. Spinach and green beans treated similarly showed no loss of color. The results indicate that micro-organisms in frozen vegetables are more likely to cause undesirable color changes between the times of packing and freezing than after the product is frozen. They also emphasize the necessity of freezing vegetables immediately after blanching and packing and of cooking them immediately after defrosting.

Studies at the Fruit and Vegetable Products Laboratory in Weslaco, Tex., developed satisfactory procedures for preparing a desirable relish and a new product, fresh dill tomato pickles, from green tomatoes. These products should help to furnish outlets for the small and blemished tomatoes that are discarded by the packing plants which ship wrapped green tomatoes in early spring. Often these culls represent as much as a third of the harvested crop.

Many experimental frozen packs of different varieties and strains of locally grown vegetables, including lima beans, snap beans, broccoli, sweet corn, and peas, were made at the Weslaco laboratory in cooperation with Substation 15 of the Texas Agricultural Experiment Station. The data obtained on shrinkage through cleaning, trimming, and sorting, on net yields of frozen products, and on flavor, color, and texture of fresh and frozen products before and after cooking helped to guide the State horticulturists in their selection of varieties to be recommended for commercial growing or in their further work on the development of more desirable varieties and strains. At the same time further information was gained on the preliminary handling and treatments best suited to yielding high-class frozen vegetables. The laboratory also cooperated with commercial firms interested in the vacuum dehydration of vegetable products, the packing of carrot juice, and the utilization of pomace remaining after extracting the juice from carrots.

The construction and equipping of a new building, completed early in the fiscal year, has provided far more effective facilities than were formerly available for continuing the work at Weslaco, Tex., on the utilization of vegetables and other agricultural products primarily grown for food.

Continued investigations on the manufacture of cucumber pickles under southern climatic conditions, in cooperation with North Carolina Agricultural Experiment Station, yielded further information on the causes for the formation of hollow pickles or bloaters. Production of bloaters in both salt-stock and dill fermentations is unquestionably caused by gassy fermentations associated with the acid fermentation. Two types of such gassy fermentations in pickle vats have been recognized thus far. One is brought about by carbon dioxide-forming yeasts and the other by hydrogen-producing bac-

teria. Analyses of cucumber fermentation liquors during the past 4 years, with respect to yeasts in brines of different concentration, have shown definitely that the yeast fermentation is a part of the general fermentation of cucumbers. This has not been recognized heretofore. It was found that salt concentration influenced the time of starting and duration of the yeast fermentation more than it did the yeast populations after the fermentation got under way. The addition of sugar to fermenting brines brought about no change in brine acidity, but it did produce a large increase in the proportion of bloaters in both salt stock and dills.

Sound salt stock has been held successfully for 3 years with only a slight loss of firmness. This stock was cured in 20-percent- and 30-percent-saturated salt brines and is being held in 70-percent-saturated brine.

Experiments on the pasteurization of dill pickles gave promise of a successful method for handling genuine dills in the climate of North Carolina so as to retain most of their original firmness over a storage period of several months.

Pasteurization of fresh cucumber pickle in slices at from 160° to 165° F. for 15 to 20 minutes, followed by prompt cooling, was successful in controlling organisms which cause rapid spoilage of unpasteurized pickle by fermentation, with loss of fresh appearance and crispness.

CITRUS-FRUIT PRODUCTS

Evidence was obtained through research at the Florida Citrus Products Station, in Winter Haven, that the off flavors which sometimes develop in canned orange juice are due, at least in part, to the oxidation of the fixed oil or fat in the juice. The fatty material obtained from the fresh juice of Florida Valencia oranges by petroleum-ether extraction had a bland taste and aromatic odor, but that obtained from old canned juice had a stale, tallowy odor, a rancid taste, and a bitter aftertaste. A number of tests showed that the profound changes which the fatty material of orange juice undergoes when the juice is canned and stored at elevated temperatures are brought about primarily by oxidation. Higher ketones and hydroxy acids were found in the extract from the old juice. Experimental packs of orange juice containing different antioxidants in various concentrations were put up for the purpose of learning more about the oxidative changes in canned orange juice and how to prevent them. Some of these packs have been examined, but others will be held longer in storage before examination.

In further efforts to utilize the bitter principle, naringen, obtained from grapefruit waste, attempts were made to hydrolyze naringenin to p-coumaric acid and phloroglucinol. Naringenin is a byproduct of the sugar rhamnose, previously prepared from naringen. The yields of p-coumaric acid and phloroglucinol were only about 12 percent of theoretical at first, but continued efforts increased them to about 51 percent. Work is being continued in the belief that higher yields are attainable.

Lactic acid and calcium lactate were prepared from the juice of cull grapefruits by fermenting them with organisms naturally present in the fruit. Yields of lactic acid represented from 71 to 84 percent of the sugar converted. Actual recovery of calcium lactate averaged 6.0 percent, based on weight of juice; recovery of 50-percent lactic acid

average 7.1 percent, based on weight of juice. A quantity of calcium citrate, corresponding to about 15 pounds per ton of fruit, was obtained as a byproduct.

Experiments on the production of ethyl alcohol by yeast fermentation of press liquor from citrus-waste drying plants indicated that it is necessary to increase the sugar concentration to about 10 percent and to adjust the pH to about 3.9 to permit economic recovery. Increase of sugar concentration could be attained by evaporating or freezing out some of the water. Increasing the acidity of the liquor with hydrochloric acid before inoculating with yeast cultures is necessary to suppress acetic acid and butyric acid fermentations. After the alcoholic fermentation was completed, about 2 ounces of dry yeast per gallon of liquor was obtained by centrifuging. This yeast is useful for feeding livestock.

Some work will be done on the preparation of feed yeast as the commercial product of fermenting press liquor, without any attempt to recover the alcohol, since the dried yeast could be added to the feed made by drying the solids from citrus waste to increase its nutritive value. Efforts are being made to obtain for these experiments a particular yeast which has been used successfully in Europe for feeding purposes.

Attempts to prepare butyric acid by fermentation of untreated press liquor were unsuccessful, but when the liquor was concentrated to a sugar content of about 12 percent and inoculated with a butyric acid-forming organism isolated from muck soil, the yield of butyric acid on the basis of total sugars in the liquor was about 42 percent. About 90 percent of the butyric acid present in the fermented liquor was recovered with considerable difficulty in concentrated form (99 percent).

Some profitable method for utilizing the press liquor from citrus-waste drying plants is badly needed. At the present time this liquid waste, in quantities of about 40,000 gallons per day at each plant, constitutes a public nuisance and health hazard which must be removed at considerable expense.

A rather extensive study was made of the manufacture and physical properties of grapefruit-seed oil. The crude oil is extremely bitter, probably due to the presence of limonin, but the refined and bleached product has a bland taste. This would permit its use in food products. Florida has a potential commercial production of nearly 4 million pounds of crude grapefruit-seed oil per year. At the present time only about 100,000 pounds of this oil is being produced annually.

Experiments on the preservation of lime juice by quick freezing, using various preliminary treatments, packing methods, and containers, indicated that this juice can be readily preserved by freezing if it is first deaerated and if the frozen product is packed so as to exclude air.

Work on the disposal of liquid effluents from citrus fruit canneries, in cooperation with the Florida Canners' Association and Florida State Board of Health, was completed. These liquid or semiliquid effluents were found to be of such chemical composition that they cannot be handled by the usual type of sewage-disposal system. The former practice of allowing them to flow into streams and lakes was found likely to produce a nuisance. Some lakes of insufficient area for proper dilution of the effluents showed positive evidence of pollution and danger to fish life. Trickling filtration,

which promotes biological action, was found to offer the best solution where flooding of isolated tracts of land or emptying into tidewater rivers or large bodies of water is impractical. This conclusion was reached after continued operation of an experimental unit of large size.

Addition of nitrogenous nutrient to the effluent in the form of blood albumen increased filter efficiency through greater biological activity, but was too costly to be practical. Partial clorination of the effluent also increased the efficiency of the filter, but this, likewise, was too costly. Under existing conditions, recirculation of the effluent had no beneficial effect, but it was observed that efficiency was promoted by increases in atmospheric temperature. Construction costs of a trickling filter in Florida would be high if Florida flint rock, such as was used in the experimental unit, had to be used. Cheaper materials can probably be found, but their suitability for the purpose should first be demonstrated.

Studies were made at the Los Angeles laboratory on the relation of enzymes of orange juice to the development of objectionable taste or flavor, on pasteurization treatments for orange and tangerine juices, and on the effects of light and storage temperatures on the keeping quality of citrus juices. So far, no definite conclusions have been drawn from the enzyme studies, but it is hoped that they will eventually show the reason for the bitter taste which develops in the juice of Washington navel oranges. It was found that orange juice pasteurized at low temperatures clears up within a short time after bottling, but that high pasteurization temperatures causes the cloudiness to persist. Storage temperature was found to be a major factor in the deterioration of bottled orange juice, whereas light has but a minor effect. An improved apparatus was developed for determining the gas content of citrus juices.

Experiments at the Fruit and Vegetable Products Laboratory in Weslaco, Tex., have demonstrated that grapefruit juice must be free from excessive peel oil in order to have the best flavor and keeping quality. It was found, however, that juice containing excessive peel oil, as the result of improper adjustment of mechanical extractors, can be improved by slight flash concentration under high vacuum, following deaeration. This treatment tends to remove the least stable constituents of peel oil selectively.

At the request of the owners of a dehydration plant for producing stock feed from citrus cannery waste, the Weslaco laboratory made a detailed study of their process and equipment and suggested the omission of pressing and the introduction of a two-stage drying system. These changes made it possible to prepare a feed of better quality without material increase in cost.

APPLE PRODUCTS

The high cost of transportation to distant markets is a serious handicap to vinegar manufacture in the Pacific Northwest. With the object of relieving this situation the Pullman, Wash., laboratory studied the possibilities of concentrating vinegar by freezing out some of the water. Preliminary experiments indicated that an excellent product containing 20 percent of acetic acid, about three or four times as much as in ordinary vinegar, can be made readily by this process.

Further investigations will be made to determine whether reconstituted vinegar, made by diluting the concentrated product with water, will meet market specifications and established standards for vinegar. Shipment of concentrated, rather than ordinary, vinegar will save considerable transportation cost. The product, without dilution, should find a commercial outlet in the manufacture of sauces, such as catsup.

Attention was also given to the preparation of apple concentrates and sirups as a means of reducing transportation cost on apple products of the Pacific Northwest. One manufacturer was assisted in the preparation of an experimental pack of apple concentrate, using the vacuum-concentration and ester-impregnating equipment developed in the Pullman laboratory. Another firm was assisted in the preparation of a trial pack of apple butter.

Studies are in progress to determine how reconstituted apple juice, made by adding water to concentrated juice, differs from ordinary fresh juice in composition, and in chemical, physical, and physiological properties. Preliminary tests have indicated that the only difference in composition is with regard to pectin fractions, which are altered by the concentration processes. A difference in viscosity, corresponding to the difference in pectin content, was also noted. It appears that bottled or canned apple juice which has been processed without concentration cannot be distinguished by chemical means from reconstituted juice made by adding water to concentrated juice prepared either by the vacuum-pan or freezing method. The reason for this is that the pectin-splitting enzyme used to clarify the fresh juice before packing alters the pectin fractions more than do the concentrating processes.

By means of freezing concentration, a modified apple juice was prepared which was judged to be an improvement over straight apple juice, with regard to "body" and flavor. A machine for continuous concentration by freezing was designed which will allow, in connection with continuous centrifuging, a rapid concentration and separation of apple juice. In the concentration of apple juice there is no appreciable loss of vitamins. The product fully retains its fresh-apple aroma and flavor. It should find increasing use as a baby food, table sirup, and base for fruit blends, if the cost permits.

The work on the preparation of d-galacturonic acid from polygalacturonic acid of pectin was completed. It was shown that this acid, which was previously listed by dealers in pharmaceutical and chemical products at $2 per gram, can be made from apple pectin or other pectin at about 5 cents per gram. As a result d-galacturonic acid may become more readily available for research on medicinal and other uses.

Increased demand for individually frozen apple slices by the baking trade has stimulated a keen interest in the apple industry of the Pacific Northwest. As a result, the Seattle laboratory was requested to aid in the development of such a product. One of the principal problems is the prevention of oxidative discoloration of the fruit during preparation, freezing, storage, and defrosting. After numerous chemical treatments for preventing this discoloration were tried experimentally with various degrees of success, a very simple, effective, and practical method was discovered. This consists in scalding

the freshly sliced apples with steam at 200° to 212° F. for 2 to 3 minutes before freezing. Contrary to the practice in scalding vegetables for freezing, the apple slices are not cooled before placing them on trays or conveyor belts for freezing. When sliced apples, frozen after such treatment, were used in pies, very satisfactory results were obtained. Apparently the scalding did not alter the flavor; the texture was very good; and the color of the fruit was even superior to that of fresh fruit made into pies. One packer of frozen fruits has put up a trial commercial pack and is distributing it to eastern markets to determine how it will be received by consumers.

MISCELLANEOUS FRUITS AND FRUIT PRODUCTS

In cooperation with plant geneticists of the Bureau of Plant Industry and of two educational institutions in California, who are working on the development of improved varieties of peaches and apricots for commercial use, the Los Angeles laboratory made practical canning tests on several dozen samples and later held demonstrations to obtain opinions as to relative quality of the canned fruit. Some samples were also frozen in sirup to ascertain their value for preservation by quick-freezing and use in ice cream and sherbert. Several of the varieties canned have been released to nurserymen or growers for commercial planting and seem to be an improvement over the older varieties. The development of new varieties of peach in California is important because the demand for the usual type of canned cling peach is declining. So far, no new peach variety has been found to make a satisfactory base for flavoring ice cream or sherberts, but the Bureau of Plant Industry's geneticist at Palo Alto has developed a very high-grade apricot for this purpose.

Experiments on the utilization of avocado culls for producing an edible oil and dried pulp for feeding purposes were partially successful. The oil was extracted from avocados by pressure and was refined to remove the off flavor due to skins and to lighten its color. Various methods were tried for further improving the flavor of the oil. It is believed that avocado oil can be sold without difficulty if it can be produced cheaply enough. A method was developed for treating avocado pulp to coagulate it and make it easier to dry. When dried and properly mixed with other components, avocado pulp is a valuable feed for cattle or rabbits and is worth between $20 and $30 per ton.

A study was begun on the flash pasteurization of fruit pulps. If this method, which is widely used for preserving fruit juices, can be applied successfully to fruit pulps, the products should find a ready market because they would have advantages over frozen fruit pulps for some purposes. Transportation and storage costs would be less and handling by the retail trade would be easier.

At the Fruit and Vegetable Products Laboratory in Weslaco, Tex., strawberry pomace butter and candied fruit pomace were prepared from strawberry pulp, utilizing 90 percent of the weight of the berries in preparing products free from coarse fiber and seeds. The 10-percent residue was dried experimentally to determine its possible value for use in mixed feeds. Methods were demonstrated for economically preparing clear strawberry juice of excellent color and flavor, suitable for use in jellies and plain and carbonated beverages. South Texas winter strawberry plantings have been doubled annually for several years,

and need has arisen for an outlet for fruit ripened beyond the shipping stage.

The laboratory cooperated with a commercial firm in developing a method of preparing a new dehydrated strawberry product from fully ripe strawberries and invert sugar. The cleaned berries were cut in half, sugared, and dried on a screen in a steam-heated vacuum oven. Juice and sugar which drained through the screen were caught in a pan and also dried. The dried mixture was ground and added to the dried berries. The product, when mixed with twice its weight of water, makes a dessert of excellent flavor. It is also suitable for flavoring ice cream. When put up in packages similar to those used for gelatin dessert powders, the product can probably be retailed at a price equivalent to 12 cents per pound of fresh sweetened strawberries. This would represent a saving over the retail price of frozen strawberries or fresh strawberries shipped under refrigeration out of season.

Work at the Pullman, Wash, laboratory, in cooperation with the University of Idaho, resulted in the development of a prune nectar for beverage use. This product is considered the best prune by-product developed thus far. It has sufficient body, good texture, and superior color, flavor, and aroma. In view of the growing interest in fruit drinks, this product should furnish an outlet for occasional surpluses of fresh prunes grown in southern Idaho. The nectar is made from 1 part of fresh prune pulp and 1 part of sirup containing 15 to 20 percent of sugar. When the fruit is overmature, a small quantity of citric acid may be added to increase tartness.

The Los Angeles laboratory collaborated with Utah State Agricultural College in experiments to determine the relative value of different species and varieties of fully ripe fruits from the varietal orchards of the Utah Agricultural Experiment Station for use in the form of sweetened frozen purees for making ice cream and sherbets and as sundae toppings. Commercial firms assisted with materials and facilities in putting up semicommercial packs. Samples from these packs were sold at cost to ice-cream manufacturers who agreed to keep records and make reports on relative consumer acceptance of different varieties during the winter months.

Collaboration was continued with the California Agricultural Experiment Station at Davis on the preparation and use of frozen fruit purees in ice creams and sherbets. A new nectarine hybrid was found to be well adapted for freezing because it does not oxidize readily. A particularly attractive puree with an unusual exotic flavor that may become very popular was prepared from feijoa fruits.

A commercial development in the field of frozen fruit pulps is making some headway in Los Angeles. Starting 3 years ago with the preparation of a few hundred gallons of fruit purees, this concern put up 13,000 gallons in 1938 and over 40,000 gallons in 1939. There was good prospect of increasing sales in 1940 to over 100,000 gallons. Since this firm has made purchases and carried on work in the fruit-growing districts of Utah, the West, and Pacific Northwest, information on, and interest in, these products have spread throughout these districts. This new industry is expected to grow rapidly and to consume large quantities of nectarines, berries, and

plums when it becomes well established. Fully ripened fruits, rather than culls, will be used.

At the Pullman, Wash., laboratory experiments are in progress on the preparation of beverages consisting of fruit products mixed with milk. The use of fruit juices, sirups, or pulps in this way would overcome the objection of many children to milk because of its unappealing taste; it would add vitamins and other food elements to the milk; and it would probably increase the outlets for both fruit and milk. In preliminary work it was found that certain conditions are necessary to prevent the formation of milk curd. One part of fruit sirup or juice to 4 parts of milk seems to be about the upper limit of fruit product that can be added to milk without serious curd formation.

At the Seattle laboratory numerous experimental frozen packs of strawberries and bramble fruits were put up by standardized procedures in cooperation with horticulturists of the Bureau of Plant Industry and Oregon Agricultural Experiment Station to assist in the development and selection of superior commercial varieties for different areas in the Pacific Northwest. Similar experimental packs put up previously were examined to determine condition of the frozen fruits after storage at 0° F. It was noticed that in the majority of the better frozen packs, the pH value was low, giving a more distinct and tart taste. Color also seemed to be better in those packs having a lower pH value, or higher acidity.

Selected varieties of strawberry, previously developed at Corvallis, Oreg., did not display extraordinary qualities when grown at Hood River, although a few of them yielded frozen products which were bright in color and excellent in flavor. The reactions of some of the selections to the different environmental conditions at Hood River were disappointing and emphasized the fact that good qualities which are dominant in one location may be absent when the plant is grown under different soil and climatic conditions. It had been found previously that varieties imported from the eastern part of the United States were often inferior when grown in the Pacific Northwest, although they had proven to be excellent in their original environment.

Frozen strawberries which had been in storage at 15° F. for 7 years were examined with regard to their retention of vitamin C. Those in hermetically sealed containers were found to have retained more vitamin C than had those in containers which were not airtight. The berries sealed under vacuum contained the most vitamin C. Those packed in containers which were not airtight retained only a trace of the vitamin, regardless of whether sugar was used or not. Those containing sugar had a better color than did those without sugar.

Microbiological analyses were made on a large number of samples of various frozen fruits, representing the output of 12 leading plants in the Pacific Northwest, in connection with studies on the relationship between harvesting and handling practices and plant sanitation on the microbial content of fruits preserved by quick freezing. It was found that a definite correlation exists between the microbial content of frozen fruits and consumer quality. Overripe fruits of poor texture and fruits which have suffered losses of color and sugar

through physiological processes during delays of handling invariably support a microbial flora in excess of that normal to good fruit properly handled and packed.

Studies on the utilization for food products of fruits grown in the northeastern part of the United States were continued in cooperation with three divisions of the New York Agricultural Experiment Station at Geneva, N. Y. It was found that the pasteurization temperatures of 160°–165° F., formerly used, were not sufficient to inactivate the enzymes responsible for the deterioriation in processed fruits, even though they killed practically all of the micro-organisms. Greater enzyme inactivation and better flavored products were obtained when fruit juices were pasteurized for short periods at 170°–180°, so a change was made to this higher temperature range. It was found that rapid cooling of the pasteurized juices was particularly important for retaining flavor in the finished products.

In order to determine which variety of each kind of locally grown fruit is best suited to particular products, experiments were made with 9 varieties of strawberry, 13 of raspberry, 3 of sour cherry, 9 of plum, and 5 each of peach and pear.

A special procedure was developed for processing the juices of soft berries, particularly strawberry and raspberry, in an effort to avoid the damage resulting from rapid oxidation. The results were still not entirely satisfactory.

Fully ripened sour cherries were found to be better than less mature fruit for preparing cherry juice, but the undiluted juices were too sour for extensive use as beverages. Several hundred cases of blended cherry juice, diluted and sweetened, were packed and distributed through grocery stores to determine acceptability to consumers.

Studies on peach juices were expanded to include determinations of the carotenoid (provitamin A) content of different varieties and stability of this substance during preliminary processing, freezing, and storage. Frozen sliced peaches and peach pulps were found to contain about 75 percent of the original carotenoid content, even after storing for several months at −10°F. Pulpy peach juice contained more of the carotenoid than did juices separated from the pulp by pressing or centrifuging. Deaeration and pasteurization of the juices had no decided effects on their carotenoid contents.

Pulpy pear juices were found to have better flavor than the clear pressed juices, but they were too thick. Centrifuging at high speeds greatly improved their consistency. Pear juices are believed to be too mild, or lacking in flavor, to appeal to many people. However, they may have possibilities of blending with more highly flavored fruit juices.

In the experiments with frozen fruit pulps, four kinds of sugar in four concentrations were added to different portions of each type of fruit before freezing, for comparison with the unsweetened frozen product. The frozen strawberries were less satisfactory than raspberries or peaches. Strawberries containing 25 percent of sucrose were somewhat better than the unsweetened strawberries or other strawberry mixtures with sugar. It was decided that the use of any sugar other than invert-sugar sirup or sucrose with fruit pulps to be frozen is not practicable.

Ordinary beverage bottles, either plain or colored, with metal caps protected from the action of contents and enamel-lined cans were found to be suitable for packing the acid-containing fruit juices produced in the Northeastern States. No plain tin cans were found to be satisfactory for this purpose.

Morphological and physiological studies of industrial yeast strains were completed, a total of 111 strains of 2 species having been tested to determine differences between them. The differences found were so slight that for some purposes either species, or the 2 mixed, could be used. However, because various strains of each species impart characteristic flavors to wine, beer, ale, bread, and other edible fermentation products, it would seem desirable to use the two species separately.

A paper entitled "The Preparation and Bacteriological Examination of Fruit Juices" was presented at the Sixth International Chemical and Technical Congress of Agricultural Industries in Budapest, Hungary, in August 1939. The author, H. E. Goresline, was designated as chairman of the American delegation. At the close of the meetings Dr. Goresline made a survey of food industries, agricultural experiment stations, and universities in Hungary, Germany, Italy, and Greece.

CEREALS AND SEED PRODUCTS

Studies on the effects of storage on wheat and flour, with regard to the quality of the bread produced from them, indicated that sound wheat or flour may be stored safely at temperatures of from 0° to 70° F. for 1 year without marked deterioration in composition or baking value. A decided lack of uniformity was found in the composition of commercial wheat-germ preparations sold for use in bread making. Some contain greater quantities of bran or flour material, or of both, than do others. The addition of such material seems to be advisable because, as a rule, the purer the germ, the poorer was the quality of the bread. It was found, however, that bread of very acceptable quality can be made with even the purest germ by soaking it with water for several hours before incorporating with the dough. Good bread can be made with as much as 20 percent germ in admixture with white flour. Since the germ is a rich source of vitamin B_1, the use of 15-percent germ in admixture with white flour yields a bread having a vitamin B_1 potency equal to that of whole-wheat bread.

Information gained from a study of the mineral constituents of buckwheat should be of value to dietitians and students of nutrition, and may also lead to the modification of the procedures used in milling buckwheat. Samples of buckwheat and its milled products, obtained from three representative buckwheat millers, were analyzed for total ash, phosphorus, chlorine, potassium, sodium, calcium, magnesium, manganese, iron, and copper. As regards total ash, there was little difference between the hulls and whole kernels, but the more refined groats were lower in total ash and all ash constituents than were the coarser groats. Magnesium, sodium, and iron were about evenly distributed in the hulls and the outer layers of the kernels. The hulls were lower in copper, higher in potassium and manganese, and strikingly higher in calcium, than were other parts of the seed. They were higher in chlorine, lower in sulfur, and strikingly lower in phos-

phorus than were the groats. Buckwheat and its products were practically free from acid-insoluble ash or silica.

EGGS AND EGG PRODUCTS

Further studies on the chemical composition of hen's eggs and the behavior of various constituents toward enzymes, in connection with the problem of preventing deterioration during cold storage, led to the discovery that the liquefaction of thick white which takes place within the shell is not due chiefly to the action of a proteolytic enzyme, as previously supposed, but rather to a change of state in the egg mucin. The quantity of mucin in the white was the same after liquefaction as before, but there was a change in the physical properties of the mucin. This change of state may be caused by alkali, which is liberated during storage, or by sulfhydryl (−SH) groups, also found at times in old eggs. The liquefaction of the white in shell eggs is not of itself a decomposition, but the liberation of alkali or sulfide which brings about the liquefaction is evidently an independent process connected with a true decomposition of the egg constituents. The real effect of carbon dioxide, as regards the preservation of eggs, is probably due to the maintenance of a low pH value during storage which actually retards decomposition, as well as liquefaction of the white.

The undesirable darkening of color and decrease of water solubility exhibited by good grades of dried egg white when kept at room temperature were found to be caused by the presence of carbohydrate in the product. Egg white liquefied by trypsin digestion and fermented very briefly with yeast to eliminate carbohydrate was completely stable after drying.

ENZYME INVESTIGATIONS

Studies on the chemistry of enzymes were continued as a regular fundamental research project relating to foods, and additional studies were made under a Bankhead-Jones project on enzyme action at low temperatures.

Further attention was given to the papainlike proteolytic enzyme which had previously been separated from wheat bran and shown to be present, but less concentrated, in white flour. As pointed out in former reports, moderate activity of this enzyme on the proteins of flour is beneficial because it increases plasticity of the dough. Too great activity, on the contrary, makes the dough too soft. The enzyme is inactivated in the process of bleaching flour, but is reactivated by certain chemicals having a reducing effect. These facts were believed to explain the beneficial effects of certain bread improvers.

This past year a study was made of the natural activator of the protein-splitting enzyme in wheat flour. In order to obtain enough of the natural enzyme activator for study, a petroleum-ether extraction was made on 2½ barrels of fresh, unbleached, soft-wheat flour. The residue left on evaporating the solvent contained sterols, fats, lecithin, and a substance which gave tests for nitrogen and sulfur. By dissolving this mixture in ethyl ether and precipitating with acidified ethyl alcohol the substance which contained nitrogen and sulfur was isolated. It contained no fats or fatlike compounds. Moreover, it was insoluble in fat solvents, but soluble in water.

Analysis of this new substance indicated that it is a protein derivative having a molecular weight somewhere between 1,000 and 5,000 and a

sulfhydryl group, as has the amino acid cystine. It has the properties of a very reactive oxidation-reduction system. These and other properties of this substance make its discovery one of the most interesting in the field of cereal chemistry for some time. This substance may be an example of the lipoproteins, whose chemistry has been heretofore unknown. There is some evidence that this constituent of wheat flour may influence the flour proteinase and therefore contribute to the plasticity or lack of plasticity shown by the dough. The same or a similar substance was found in other grains. In view of the fact that it may have uses in the food industries, application was filed for a public-service patent.

Since the enzyme papain, as a constituent of commercial meat-tenderizing preparations, is now mixed with all sorts of meat products before they are eaten, several samples of commercial papain and meat-tenderizing preparations were subjected to bacteriological examination within the Bureau. Because of the excessive number of bacteria found, experiments were made to determine whether the enzyme itself or the bacteria tenderized the meat. Comparative tests with the isolated bacteria and with papain purified according to the Bureau's procedure, showed that the enzyme really had a tenderizing or proteolytic effect on meat, whereas the bacteria had little or no proteolytic activity under the conditions of the test. The Bureau has found that, by practicing proper cleanliness, it is possible to make commercial enzyme preparations that are relatively free from bacteria.

As a direct result of the Bureau's fundamental work on papain, it was able to devise a method for the preparation of papain for commercial use. The advantages of this preparation are that it is much more active; it is much cheaper; it keeps better; and, above all, it is cleaner than papain preparations now on the market. It is believed that the monetary value of the papain obtainable from a given patch of trees would be at least doubled by preparing the enzyme by the Bureau's method. This method consists, essentially, of mixing fresh papaya latex with sodium chloride (common salt), and drying the mixture to a paste instead of a solid. When the latex is dried to a solid about half of the original enzymic activity is lost, but when made into a paste with salt the total original activity is preserved.

Crystalline papain, which the Bureau isolated for the first time a few years ago, is now in demand for experimental use in medicine. It has been reported to be an efficient remedy for parasitic worms. Tests in the laboratory on isolated worms verified this report. Other applications of crystalline papain, depending upon its effect on the blood, are being studied in reputable hospitals.

Some attention was given to the isolation of bromelin from pineapple juice. This enzyme is similar to papain and can also be used for tenderizing meat. The problem of preparing bromelin economically is chiefly technical. Its solution depends on getting the bromelin from pineapple juice without destroying the value of the juice for other purposes. After some preliminary experiments, the Bureau devised a method which involves the precipitation of bromelin from low-grade pineapple juice (second or third pressing) by

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means of alcohol or ammonium sulfate. The bromelin recovered in this way is mixed with other proteins but is useful for tenderizing meat. If alcohol is used for the precipitation, it may be recovered by distillation, leaving the sugar in the juice. If ammonium sulfate is used, it may be recovered by precipitating with alcohol, after which the alcohol may be recovered by distillation. A paper describing this method was presented at the Sixth International Chemical and Technical Congress of Agricultural Industries in Budapest, Hungary, in August 1939. The Bureau's proposed method for recovering bromelin from pineapple juice appears to be the first practical suggestion on the subject, and has aroused a great deal of interest in certain food industries.

Studies on the meat-tenderizing effects of papain and bromelin preparations showed that they act in about the same manner. An appreciable break-down of the proteins into small units was observed in both cases, which means that the process is a true digestion rather than a mere disaggregation. The tenderizing process, in which the digestive action is limited, breaks down a little of the protein a long way, rather than a lot of the protein a little way. Tendon and connective tissues, as well as muscular tissue, are attacked rapidly by both enzymes.

Work was continued on the esterase previously found in muscular tissue with the object of learning if this enzyme contributes to changes in meat during cold storage. Only lower members of the methyl and ethyl ester series were hydrolyzed by this enzyme. With fatty acids containing more than 6 carbon atoms, the rate of digestion decreased; with fatty acids of more than 12 carbon atoms, it vanished completely. The enzyme did not attack any of the true fats, including butterfat. It was learned that this esterase has an extremely low temperature coefficient and operates very efficiently and rapidly on simple esters at low temperatures where most enzyme action is very slow. The observation that this muscle esterase digests esters of fumaric acid, but not those of maleic acid, suggests that the function of the enzyme in the tissue is not one of fat decomposition but rather is one connected with tissue respiration.

An extremely pure pancreas lipase, which is useful for comparison with other lipases, was prepared successfully, but no success attended the efforts to crystallize this enzyme. Tissue extracts or bile must be mixed with the purified material to make it active. Apparently, the activator for this enzyme is quite stable because bile can be heated for hours without losing its activating power.

PHYTOCHEMICAL INVESTIGATIONS

Further work, involving the application of methods of molecular distillation and low-temperature crystallization, was done in the fundamental study of the naturally occurring glycerides and other constituents of edible oils of plant origin. One of the objectives of this work, which is carried on in cooperation with the National Cottonseed Products Association, is a fuller knowledge regarding the natural individual glyceride constituents of cottonseed oil; another is information concerning the factors which determine the keeping quality or stability of cottonseed and other vegetable oils.

In order to identify the individual constituents in a complex mixture of glycerides like cottonseed oil, it is necessary to know what to look for and how to recognize each object of the search. For this reason it was necessary to purify certain fatty acids and to use them in synthesizing corresponding triglycerides. It was also necessary to determine the chemical and physical characteristics of each product in as pure a form as it could be obtained. Methyl oleate of high purity was prepared by fractional distillation and low-temperature crystallization of the methyl esters of the fatty acids of olive oil, and this methyl oleate was used for the preparation of pure oleic acid, which, in turn, was used for the preparation of its triglyceride, triolein. Pure linoleic acid, which had been obtained indirectly from linseed oil, was used in the preparation of trilinolein. These triglycerides were prepared by direct esterification of the corresponding fatty acid and glycerol in an atmosphere of nitrogen, using paratoluene sulfonic acid as a catalyst. The methods used for the preparation of pure methyl oleate, triolein, and trilinolein, and the physical and chemical characteristics of these products were described in two articles published in technical and scientific journals.

An investigation on methods of analysis applicable to mixtures of oleic, linoleic, and saturated fatty acid esters was completed and the results were published in a technical journal. It was found that accurate estimations of the fatty acid composition of mixtures containing oleic, linoleic, and saturated fatty acids can be made from iodine numbers, obtained by the Wijs method, and thiocyanogen numbers obtained from a 3-hour absorption period at 20°–23° C. By slight modifications of the Bertram procedure for determining small amounts of saturated fatty acids, it was found possible to obtain a precision of 0.1 unit-percent under optimum conditions.

The results of preliminary studies on the molecular distillation and low-temperature crystallization of cottonseed oil and the comparative stability of the distilled fractions were reported in a paper before the American Oil Chemists' Society at its annual convention in New Orleans in May 1940.

Investigations on the composition of two Puerto Rican fruits, submitted by the Puerto Rico Agricultural Experiment Station, were completed. The flavor of one of these fruits, guanábana, was found to be due principally to amyl and geranyl caproates. A manufacturer of ice cream flavors expressed the opinion that this fruit may have possibilities for that purpose. The other fruit, carembola, had very little flavor. Its tart taste was due principally to oxalic acid.

Youngberries and Boysenberries, grown in the Pacific Northwest, were found to contain citric acid, as their predominant organic acid, with a lesser amount of malic acid, and a still lesser amount of isocitric acid. Previous studies indicated that the predominant acid of the eastern blackberry, to which these improved berries are related is isocitric acid which had not been found in nature before.

Green Mountain potatoes from Maine were found to contain citric acid, some malic acid, and small amounts of oxalic and isocitric acids.

At the request of the Hill Culture Section of the Soil Conservation Service a chemical examination was made of the seed of *Daubentonia drummondii*, a leguminous plant. Although the seed is reported to be poisonous to sheep and goats, neither cyanogenetic glucoside nor alka-

loid was found. The seed contains about 4.5 percent of a drying oil and about 30 percent of protein. A substance that is soluble in cold water and is precipitated by 50-percent alcohol is present to the extent of about 10 percent. This resembles a hemicellulose or a polysaccharide. The economic possibilities of this plant do not appear to be promising.

The Soil Conservation Service was also aided in connection with a chemical problem relating to the rooting of walnut cuttings. In order to test out the theory that a constituent of walnut juice, juglone, was responsible for the lack of success in rooting cuttings, a synthetic juglone was prepared to try out its effect on root development. If this substance prevents rooting, a means of neutralizing its effect may be found.

PHARMACOLOGICAL INVESTIGATIONS

Investigations on the pharmacology of certain normal food constituents, and of certain organic and inorganic substances which may contaminate foods, especially through their use as insecticides, were continued in cooperation with Stanford University Medical School in San Francisco, Calif.

The results of the pharmacological study on the effects of naringen and hesperidin on albino rats were published in the journal Food Research.[1] From this study it appears that these glucosides which exist in grapefruit and oranges, principally in the peel, are not injurious to animals. The work of investigators outside of the Department has indicated that hesperidin, the glucoside of orange peel, has an important influence in maintaining normal permeability in the blood capillaries and in preventing the hemorrhagic manifestations often seen in scurvy. The name "vitamin P" has been suggested for hesperidin. The fact that hesperidin is nontoxic, established by the Bureau's recent work, will be an important factor if this substance is to be used extensively for therapeutic purposes.

In last year's report it was pointed out that cadmium produces a bleaching of rat incisor teeth, a defect similar to, if not identical with, that produced by fluorine. Further investigations have shown that the toxic effects of cadmium and fluorine are probably additive and not synergistic, and that the enamel defect probably can be induced by cadmium alone. Experiments in vitro have shown that cadmium, like fluorine, exerts a marked inhibitory action on the enzyme phosphatase, a concentration of 0.001 N reducing the enzyme activity to 8 percent of the value shown by the control. This observation suggests that the mechanism of cadmium poisoning may be the same as in the case of fluorine, that is, inhibition of the enzymatic processes associated with bone and tooth formation.

In the absence of information on the incidence of exposure of the public to cadmium, it is impossible to state whether cadmium has been an etiological factor in cases of mottled teeth. However, the Bureau's discovery of this manifestation of the toxic effect of cadmium will enable health officials to recognize this hazard and guard against it.

All of the experimental work that had previously been started on the pharmacology of certain organic compounds (phenothiazine,

[1] WILSON, ROBT., and DEEDS, FLOYD. EFFECTS OF NARINGIN AND HESPERIDIN ON ALBINO RATS. Food Res. 5 (1) : 89–92, 1940.

pentaerythrital bromide, 2-acetamino fluorene, diphenylene sulfide, dimethylacridan, and azobenzene) proposed for use as insecticides has been completed and the results have been prepared for publication. Chronic toxicity studies were started with phenazine and fluorene. Chronic toxicity data furnish a measure of the safety to consumers of fruits and vegetables of the materials in spray residues. The Bureau discovered that one of the organic chemicals proposed as an insecticide, namely, 2-acetamino fluorene, apparently causes a form of cancer in albino rats. Since many compounds related to this one are of interest because of their insecticidal action, several of the more important of them must be studied to see if they have this cancer-producing effect.

An article discussing the sunburn effect produced in orchard workers by a photosensitization resulting from ingested or inhaled phenothiazine spray was published in the Journal of the American Medical Association.[2] A knowledge of the fate of phenothiazine in the animal body, gained through the Bureau's pharmacological studies, made possible an explanation of the puzzling skin reactions experienced by orchard workers applying this material as a spray. Determination of the fate of potential insecticides in the animal body reveals the mode of detoxification, throws light on the mechanism of insecticidal action, and may yield information on the types of compounds most likely to prove effective.

MICROBIOLOGICAL INVESTIGATIONS

Bacteriological examination of 75 composite samples of beet sugar, each representing the 1939 output of a single factory, showed that about 13 percent of them contained excessive numbers of thermophilic-type bacteria, according to the standards established by the National Canners Association laboratories for canning-grade sugar. For the first time, the bacteriological examination was extended to include the determination of the numbers of bacteria, yeasts, and molds that might influence the usefulness of the sugar in the manufacture of dairy products, frozen desserts, beverages, and other food products. Very few of the samples contained questionable numbers of these micro-organisms.

In connection with the Bureau's efforts to develop practical methods for storing sweetpotatoes for use as feed or in starch manufacture, nearly 200 small and semi-plant-scale tests were made on suggested methods for controlling the growth and activity of various types of micro-organisms which might interfere with the preservation of sweetpotatoes or cause starch losses during storage.

Bacteriological examination of sweetpotato starch, produced by the plant at Laurel, Miss., during 1939, showed that it contained thermophilic bacteria, and for this reason did not comply with the bacteriological standard established by the National Canners Association laboratories for starch to be used in the canning industry. Studies at the factory indicated that these bacteria, derived from the soil, are not completely eliminated from the sweetpotatoes during washing and hence accompany them as they enter the starch-making process.

[2] DeEds, Floyd, Wilson, Robert H., and Thomas, J. O. photosensitization by phenothiazine. Amer. Med. Assoc. Jour. 114: 2095–2097, illus. 1940.

Moreover, they are not completely eliminated during normal processing but appear in the finished starch in varying numbers. It was found that a special treatment of the starch, during processing, with large quantities of germicidal hypochlorite solution is necessary if the starch is to meet the requirements for use in the food industries.

During this past year some fundamental studies were started on the bacteriological problems involved in the preservation of fruit juices by quick freezing and storage at subfreezing temperatures. The question of whether or not microbial forms retain their viability longer in a supercooled than in a frozen medium at a given temperature has been partially answered by data collected from a series of experiments. Suspensions of *Eschericha coli* in different portions of distilled water, adjusted to pH values of 5, 6, and 7, were divided into two lots of duplicate samples, one of which was frozen at 20° F., while the other was supercooled to the same temperature. The greatest immediate destruction of bacteria occurred in the frozen samples. However, after a period of storage, varying from a few days to a few weeks according to the heaviness of the initial *coli* suspension, greater kills were usually observed in the supercooled samples. This relationship continued until only a few cells remained which seemed to retain their viability regardless of the state of the medium. When the reaction of the distilled water in which the bacteria were suspended was adjusted to pH 3 or 4, greatest destruction occurred in the frozen samples. In a similar suspension having a pH of 2, the destruction was extremely rapid in both frozen and supercooled samples.

Results obtained thus far indicate that greater microbial destruction takes place in unsweetened than in sweetened frozen fruit juice and that the higher the sugar concentration the greater is the retention of viability at subfreezing temperatures. Presumably the sugar desiccates the microbial cell and dilutes the acid content of the juice. Greater microbial destruction takes place in frozen than in supercooled orange and loganberry juices. These findings, however, may not be applicable to spores. Since the use of sugar in frozen fruits is an established practice, the experimental results emphasize particularly the importance of greater attention to sanitary conditions during processing. Moreover, they suggest that improved methods of freezing and storing may prevent the "freezing concentration" of sugar and thus eliminate or reduce the protective action exerted by sugar in retaining microbial viability.

Miscellaneous microbiological studies in connection with other research of the Bureau or undertaken to assist other governmental agencies included bacteriological examinations of fermented and unfermented blackstrap molasses, papaya products, a yeast starter submitted by the Bureau of Internal Revenue, and mineral-wool insulation blankets submitted by the Maritime Commission.

PLANT VIRUSES

Chemical studies were continued on the identification and characterization of plant viruses, particularly those of tobacco mosaic diseases, in cooperation with the Bureau of Plant Industry. This is a basic research project, supported by an allotment from the Bankhead-Jones special research fund. Special attention was given to the chemical changes involved in virus inactivation by means of ascorbic acid and

copper. The results of this work and those of previous work on the effect of urea on the virus protein of tobacco mosaic were presented at the Third International Congress for Microbiology. It has been shown, beyond reasonable doubt, that the virus of common tobacco mosaic and several other plant viruses are proteins and should be investigated as such. However, from biological studies it is evident that tobacco mosaic virus and its mutants possess the fundamental characteristics of genes.

ANIMAL VIRUSES

In the chemical studies on animal viruses and the proteins of tumors, a project supported by an allotment from the special research fund appropriated under the Bankhead-Jones Act, special attention was given to the virus of infectious myxomatosis, a neoplastic disease of rabbits. The virus of this disease was separated in what appeared to be a nearly pure state by means of an ultracentrifuge. The identity of some of the chemical constituents and the general character of others have been determined. At least three, and probably four, distinct chemical groups are combined to form a very complex substance, the general composition of which is gradually becoming known. The results of this research are important both to the science of biochemistry and the practice of medicine because they make it possible to attack the question of immunity from a new and more logical angle. Heretofore the possibility of immunizing against a virus disease has been studied with regard to the whole virus; it may now be studied also from the standpoint of the separate components of the virus complex. The results also help to clarify the known fact that infection with one virus disease may give immunity against inoculation with another. The principle involved in producing immunity to myxoma in rabbits, a relatively unimportant disease, is the same as in several other virus diseases; therefore, the same methods of experimentation may be expected to give similar results in other cases.

PRESERVING BIOLOGICAL SPECIMENS

The investigation of processes for preserving specimens related to agriculture in as nearly natural condition as possible was continued as a basic research project under the Bankhead-Jones Act. Further progress was made toward the perfection of the two processes mentioned in previous reports. One of the processes consists of treating fresh plant materials to toughen the tissues and set the natural color, after which the specimens are flattened, dried, and mounted on glass or between transparent cellulose films. In the other process, which is better suited to materials that cannot be readily flattened, the specimen, after drying, is immersed intact, or without distortion, in a transparent, nearly colorless plastic-forming composition in liquid form, which becomes solid on heating at a moderate temperature.

Progress on the first process during the past year includes: (1) Improved technique in treating the fresh plant material for greater color accuracy and extending the range of effectiveness of treating mixtures so as to reduce the number of formula modifications needed; and (2) improvements in both types of mounting (in film and on glass) to obtain more uniform results and to insure proper resistance to moisture and protection against injury.

With regard to the second process of preserving agricultural specimens, that is, by embedding them in a solid, transparent, synthetic plastic, progress has been made in the following directions: (1) Dehydration and preliminary treatment of specimens without shrinkage or subsequent loss of color; (2) control of polymerization of the liquid, monomeric methacrylate compound employed to encase specimens; (3) improvement in appearance of mounted specimens with respect to freedom from bubbles and other imperfections; (4) elimination or reduction of subsequent alterations in the plastic; and (5) improvement in finishing and polishing of the completed mounts.

For preserving certain types of specimens, these processes have now been developed to the stage where the essential steps may be generally practiced. By their use it will be possible to prepare specimens of considerable variety for scientific studies, exhibition, and other educational purposes. Further work is necessary, however, to perfect the processes in order to overcome certain difficulties and to make them applicable to a wider range of agricultural materials.

CARBOHYDRATE RESEARCH

SUGARCANE AND CANE SUGAR

The commercial value of new varieties of sugarcane depends in part on the ease with which their juices are clarified, in comparison with those of established varieties. Two newly released varieties, C. P. 29–103 and C. P. 29–120, were studied from this standpoint during the last sugarcane harvesting season in Louisiana. The results with each varied somewhat for different localities, but the indications were that sugarcane of either variety from most of the existing sugarcane fields would give no special clarification difficulties. However, when grown under adverse agronomic conditions, these new canes yield juices which are relatively low in phosphate and high in nitrogen. Such juices are difficult to clarify and give poorer sugar recovery.

In further studies on the effect of degree of liming on juice clarification, the best results, as regards color, ash, lime salts, and silica, were obtained when lime was added to the cold juice to a pH of 7.0 to 7.5. Depending on the concentration of phosphates in the juice and the duration of heating during settling, the juice limed to this degree in the cold will yield clarified juice which may vary from a pH of 6.2 to one of 7.2. This degree of liming is also necessary to obtain a satisfactory precipitation of phosphates. Additional liming is not justified, because the increase in precipitation of the phosphates is more than offset by increases in soluble lime salts.

Several varieties of cane obtained from an area of Louisiana muck land were found exceptionally low in phosphates and high in nitrogen. The juices from this cane, when lime-defecated, showed extremely poor clarification and contained an excessive amount of lime salts. However, when milled in small proportions along with cane of normal phosphate content, the mixed juices obtained clarified without this difficulty.

There have been numerous complaints from plantation sugarhouses in Louisiana during the past two seasons because of an unusual sediment which formed during the sirup and molasses stages of sugar production. This sediment prevented maximum sucrose recovery,

reduced the refining quality of the raw sugar produced, and caused corrosion or scaling of the heating surfaces with which it came in contact. A chemical investigation established the fact that the sediment was essentially a salt formed by the action of lime on aconitic acid existing in the cane juices. Analysis of the concentrated juices from different varieties of cane grown in various localities showed that this acid is present in some of the more recently adopted Louisiana cane varieties in quantities varying from 0.5 to 1.65 percent on solids, the largest quantity being found in the popular Co. 290 variety. It appeared that plant cane contains more aconitic acid than does rattoon cane. Heretofore, the aconitic acid in cane juice has been considered to have little or no effect on clarification, but the trouble caused by abnormal quantities of this substance in the juice of recently adopted sugarcane varieties warrants a thorough study of its effect on the clarification of cane juice in general. Obviously, a method must be devised to eliminate this acid in clarifying the juice. Aconitic acid might become a byproduct of sugar production if uses were developed to make its recovery from defecation muds or from molasses profitable.

In cooperation with the Bureau of Plant Industry a study was made of the composition of juices from different sections of the cane stalk at two stages of maturity, using two sugarcane varieties, C. P. 28–19 and Co. 290. In each case the top three elongated joints (after discarding the terminal bud and associated joints under 2 inches long) gave very different results than did the lower joints. From the results with C. P. 28–19, it was concluded that inclusion of the top three elongated joints in cane harvested for milling increased the tonnage of cane per acre without any increase in recoverable sugar per acre. From the results with Co. 290, it appears that the top five joints must be put into this category; the top three joints, when included in mill cane, would actually decrease the recoverable sugar per acre. The common plantation practice is to top Co. 290 too high and C. P. 28–19 too low. In the case of the latter some material is being discarded which would increase the yields of cane and sugar per acre.

A study in cooperation with the Bureau of Entomology and Plant Quarantine of the composition of sugarcane damaged by cane borers indicated that the damage results from material being actually removed or destroyed by the borers and not from chemical changes occurring in the remaining cane. Borer-damaged cane is likely to yield juices of lower sucrose and higher nonsugar content, especially when the damage includes destruction of substantial quantities of the high-sucrose softer core, as happens in the case of variety Co. 281.

Experiments were made on the use of raw and partially refined grades of cane sugar for production by industrial consumers of "liquid sugar," a refined sugar in a sirup rather than a crystal form, which can be used satisfactorily for some purposes in the food and confectionery industries. Cost data were obtained for the best processes. The results indicated that Louisiana washed raw and turbinado sugars are the grades most suitable for small-scale production of liquid sugar. Use of these special grades of sugar offers decided advantages over the purchase of raw sugar for the same purpose.

More data were obtained with regard to reducing the sulfite content of table sirups and high-grade molasses made by the sulfitation process. It was found that using twice the theoretical equivalent of hydrogen peroxide reduces the sulfite content to a satisfactory low percentage. Products may be treated at a low temperature, but subsequent heating to 90°–95° C. is necessary to restore approximately the original colors.

Further attention has been given to the loss of sucrose in harvested sugarcane by inversion and to the deterioration of cane by fermentation following freezing in the field. Loss of sucrose in sugarcane during the interval between harvesting and grinding is an item of great importance. In recent studies in cooperation with the Bureau of Plant Industry it was found that sugarcane subjected to a cold shock, short of actual freezing, acquires increased resistance to deterioration during storage, provided it is left standing so as to recover under natural conditions for a short period before harvesting. This means that it is advisable to wait a few days after a light frost before cutting and windrowing the cane. A comparison of the normal inversion characteristics of four varieties of plant cane from two locations having different kinds of soil showed that inversion was only half as rapid in canes from one location as in those from the other, although the initial purity was essentially the same in both lots. The canes showing the more rapid inversion were very high in nitrogen and low in phosphates. High nitrogen content, when due allowance is made for varietal characteristics, is an indication of physiological immaturity and it is likely that, in spite of satisfactory sucrose purity, the more rapidly inverting cane was actually less mature than that from the other location. A high nitrogen content of the soil would tend to prolong active growth and thus retard maturity.

After sugarcane has been exposed to freezing temperatures, fermentation frequently occurs with production of dextran, which increases the viscosity of sirups and molasses to such an extent that crystallization of sucrose is difficult and in many cases impossible. Development of means whereby freezing damage can be minimized is of the utmost importance. Cane was not damaged much by freezing weather last season, but studies on the effects of freezing were continued by artificially freezing selected samples of cane of two varieties at approximately 25° F. and noting the progress of deterioration during subsequent storage at a temperature of 65°. While the rate of spoilage following this freezing was not so rapid as has been found at times in cane frozen in the field, the final results were much the same. The first fermentation to appear was of the alcoholic type, involving the destruction of sugar solids with the formation of alcohol and carbon dioxide. Later the gum-forming fermentation appeared, as indicated by the presence of dextran and acetic acid. It was also found that juice expressed from frozen cane, even before fermentation within the cane was indicated, was very susceptible to rapid souring. After several hours the juice from unfrozen cane began to show a slow souring, but in the case of juice from the frozen cane the appearance of souring was almost immediate and progressed rapidly. It may be possible to judge the degree of freezing damage to cane by fermentation rate tests on expressed juices. It is also indicated that prompt process-

ing of juices milled from frozen cane is essential if spoilage in addition to that present at the moment of milling is to be avoided.

The causes of color formation in sugar-plant juices, sirups, and sugars were investigated with the object of developing more efficient methods for white-sugar production. Although the investigations are still in their early stages, it is becoming evident that one major cause for darkening of sugar-plant juices during the processes of manufacture is the decomposition of the sugars themselves by the hydroxyl ion. This is followed by reaction of the decomposition products with oxygen, and probably also by reaction between themselves by condensation. Additional causes of darkening, which remain to be studied, include the reactions of the nonsugars, such as iron, tannin, and nitrogenous compounds, between themselves and with the decomposition products of the sugars.

BEET SUGAR

The annual report dealing with the beet-sugar industry,[3] on the basis of chemical and microbiological studies made on samples representing the 1939 production, suggested certain changes in operating practices for increased efficiency. Continued investigation was made of various factors influencing composition of sugarbeets and quality of beet sugar. Further application and modification were made of the technical sugar-grading formula, recently introduced, so as to take into account additional factors which influence quality. To facilitate a better comparison of data pertaining to beet-sugar samples representing seasonal production, consideration was given to assembling in the same groups data from factories which are either in the same geographical area, or, possibly, factories which receive sugar beets of approximately the same sugar content and quality. In this way it may be possible to establish for each group or each section of the producing area the most efficient processing practices. The sugar-beet investigations thus far have contributed to the development of procedures for production of sugar of more uniform quality and have assisted thereby in improving marketing conditions. Attention is being given not only to improvements in beet-sugar technology in relation to minimizing the effect of variations in quality of sugar beets but also to the reduction in sugar losses which occur in handling sugar beets from the time of digging to processing in the factory.

FARM-MADE SIRUPS

Sugarcane sirup is a valuable subsistence product and a cash crop of considerable importance on thousands of small farms in eight southern States. The annual production is about 25 million gallons, of which about 60 percent is marketed. Since success in marketing requires, first of all, the production of uniform and high-grade sirup, the Bureau is studying the various factors which govern yield and quality of sugarcane and sirup in order to develop improved methods.

In cooperation with the Alabama Agricultural Experiment Station, a large number of samples of sugarcane from various locations in the

[3] U. S. Department of Agriculture, Bureau of Agricultural Chemistry and Engineering. Report of studies on uniformity of quality of sugars. U. S. Dept. Agr., Bur. Agr. Chem. and Engin. ACE–57, 23 pp., illus. 1940. [Mimeographed.]

State and representing a number of varieties grown under different agronomic conditions were made into sirup by a standard method. The data obtained threw considerable light on the influence of varietal and cultural factors on sirup yield and quality. Flavor appeared to be correlated with ash content and acidity of the sirup. Analyses were made of the sediments which formed in some of the sirups in order to determine the factors responsible for sediment in sirups and to devise means for its prevention or elimination. Cooperation was continued with the Extension Service sirup specialist in Alabama, and technological assistance was given to a number of farm cooperative and community sirup-making plants in Alabama, Florida, and Mississippi.

The fundamental problems underlying successful development of the farm-made sorgo sirup industry are much the same as for sugarcane sirup. From 15 to 20 million gallons of sorgo sirup are produced annually on small farms in 16 States situated between the Gulf of Mexico and the Great Lakes and to a moderate extent immediately west of the Mississippi River. About equal quantities are used in the homes of producers and marketed to increase cash income. The maintenance or expansion of the market, and the prices received, depend upon the quality and uniformity of the product. The profit from sirup making depends likewise on growing good varieties under suitable agronomic conditions and upon efficiency in processing. Since there are many varieties of sorgo and different local names for each, and inasmuch as these have characteristically different sirup-making properties, the problem of determining what varieties are consistently best for sirup making in different sections of the country is more complicated than in the case of sugarcane, of which there are relatively few commercial varieties. Work along these lines is being done at the Meridian, Miss., field station in cooperation with the Bureau of Plant Industry.

Investigations to correlate agronomic factors with the yield and quality of sorgo sirup are being conducted in Alabama and Georgia in cooperation with the State agricultural experiment stations. During the past year many samples of sirup were made by a standard method from sorgo of known varieties grown under known agronomic conditions, and analyses were made of the juices and sirups produced from them. The samples of sorgo cane, together with information on varieties, soil types, fertilizer, seasonal and maturity factors, and data on yields per acre were supplied by various substations of the State agricultural experiment stations. The yield and quality of the sirups produced from these samples were correlated with the varietal and agronomic factors. Analyses were also made of the objectionable sediment formed to different extents in samples of sirup from various sources, in order to obtain information on the nature and origin of this sediment which may lead to the adoption of preventive or remedial measures. Farm-made sirups free from sediment would have improved marketing possibilities.

Utilization of suitable varieties of the sorgo plant for the production of sugar and its byproducts is a possibility that may be of great importance under some circumstances, and renewed attention has been given to this problem. It now appears that the difficulties which previously handicapped this development may be overcome. Sorgo matures in about 4 months and can be grown over wide areas in the

United States. In certain sections it could be used to supplement sugarcane and sugar beets, making possible a longer and more profitable period of operation of existing cane- and beet-sugar factories and providing a new and profitable crop to growers.

Preliminary results obtained in experiments on a pilot-plant scale at the Meridian, Miss., field station showed that starch and its degradation products in sorgo juices are among the objectionable constituents that prevent efficient crystallization of sugar. Means for the removal of interfering starch and starch products by physical methods and by diastatic conversion were devised, with the result that primary crystallization of sucrose could be readily accomplished. Satisfactory analytical methods were developed for determining sucrose, dextrose, and levulose in sorgo juices. The results of a study on the diurnal variations in the sucrose, dextrose, and levulose contents of the sorgo stalk were not indicative that the synthesis of sucrose and starch occurs in the stalk juice. Promising results, from the standpoint of quality, were obtained in laboratory studies on the production of refined sugar in the form of sirup ("liquid sugar") from sorgo juice by the use of "carbonaceous" ion-exchange materials. Best results were obtained when the juices were passed through the cation and anion exchange materials alternately. Excessive wash water, however, was required to remove color after regeneration of the anion exchange material which is a serious objection. An investigation was begun on methods for the preparation of an ion-exchange material from fibrous materials impregnated with aniline dyes.

Maple sirup grading standards were prepared for the Agricultural Marketing Service and, as usual, sets of these master standards were supplied to the States which use them in connection with the preparation of larger quantities for State distribution. New turbidity-grading standards were also supplied.

HONEY

The annual production of honey in the United States is about 160 million pounds with a farm value of about 10 million dollars. Since there are nearly 500,000 honey producers, the value of this industry as a small cash-producing enterprise is readily apparent. The American people normally use about 70 million pounds of extracted honey and 16 to 25 million pounds of comb honey each year in their homes. Since this amount is less than 60 percent of the total annual production, the utilization of the rest, especially of such grades as are not suitable for home use, becomes a problem of considerable importance.

The results of experimental work on honey and the information secured from surveys in the food industries indicate that after sufficient information has been obtained on the chemical composition and properties of honeys of various floral types and grades, and as soon as honeys can be classified for the benefit of both producers and consumers in the food industries, honey will have a greatly improved prospective market. It has been estimated that if American honeys were used to supply only half of the sugar needed for one-tenth of the commercial pack of fruit jellies, jams, and preserves, this use would provide a new outlet for about 6 million pounds of honey.

The largest industrial outlet for honey is the baking industry, which is reported to use about 30 percent of the crop, possibly 45 to 50 million pounds a year. If several commercial types of honey, each having definite and uniform characteristics, were especially designated "for use in the bakery and confectionery trades," it is believed the industrial use of domestic honeys would be materially increased.

A field survey has been conducted to collect information on present practices in producing and handling honeys, and on the utilization of honey by the baking and confectionery industries. Tentative recommendations for a partial classification of domestic honeys, based on the requirements of these food industries and for use also by honey producers, have been formulated. These are now being further developed. A practical classification of all types of honey is regarded as of constructive value both to the domestic honey industry and to food industries in which honey may be used. Such a classification is dependent upon the investigation now in progress of the chemical composition and properties of honeys of different floral types.

STARCHES

Further progress has been made toward the establishment of a domestic sweetpotato starch industry. The Bureau continued its cooperation with the plant at Laurel, Miss., by furnishing technical advice and conducting needed investigations. By improvements in methods of operation and minor changes in equipment and process, the capacity of the factory was increased from 10 tons of starch per 24-hour day to an average of about 15 tons, and a maximum of about 20 tons. During the 1939 season 2,750,000 pounds of starch were produced, as compared with 1,700,000 pounds in 1938, and 500,000 pounds in 1937. Some of the starch is being used by laundries and by the baking and confectionery industries, but it is being sold principally to southern cotton mills for use in sizing and finishing.

By improvements in yield and quality of sweetpotato starch through continued development of processing methods, some of the most important obstacles to the establishment of a sweetpotato-starch industry have been satisfactorily overcome. A practical method, using chlorine, was developed for controlling objectionable bacteria during starch extraction and refining. Polariscopic methods for the rapid determination of starch, needed in the factory-control work, were investigated and improved to eliminate the error caused by pectic substances and other nonstarch components.

Research on the physical properties of sweetpotato starch in comparison with those of other starches helped to expand industrial utilization. It was found that sweetpotato starch has advantages over other starches for certain uses. Procedures and appropriate instruments for measuring five properties of starch which are of importance to the laundry industry were developed.

A study of the composition of sweetpotato pulp, the byproduct of sweetpotato-starch manufacture, showed the presence of a substantial proportion of pectin. This pectin was extracted by various methods and was found to be satisfactory for the preparation of jellies. It is believed that a suitable commercial process for extracting pectin from residual sweetpotato pulp can be developed and that the sale of pectin as a byproduct will be remunerative. Hitherto, this pulp

has been dried and sold as cattle feed. The effect of removing pectin upon the feeding value of the pulp remains to be determined.

In order to obtain an adequate supply of sweetpotatoes at a price that will enable both the growers and the processors to operate at a profit, it is necessary to develop sweetpotato varieties or strains of higher starch content and to improve farm practices and machinery for producing the crop. Development of a new strain of sweetpotatoes containing an average of 29.5 percent of starch was recently announced by Dr. Julian C. Miller, of the Louisiana Agricultural Experiment Station, with which this Department is cooperating in sweetpotato-breeding work. The average starch content of sweetpotatoes used at the starch plant in 1939 was 23.8 percent. Progress has been made likewise in the methods of producing and harvesting the crop. It was found that the number of plants per acre could be reduced and wider spacing employed with greater net return to the grower. The optimum number of plants per acre has not been finally determined but it is probably between 5,000 and 8,000, as compared with 10,000 to 12,000 customarily used. This reduction would materially reduce the cost of producing sweetpotatoes, since the cost of growing and setting the young plants is estimated at about 25 percent of the total cost of production. The Farm Mechanical Equipment Division of the Bureau, in cooperation with the Mississippi Agricultural Experiment Station, developed a bagging cart for hand picking of dug sweetpotatoes which reduces the cost of gathering by about half. A combination digger and bagger was also developed and was operated with a substantial reduction in harvesting cost, 2.9 man-hours per ton of sweetpotatoes being required, in comparison with 7 man-hours for the best farm practice at present and 16 man-hours for the usual farm practice. The quantity of sweetpotatoes left in the soil was less than with ordinary hand operation and the soil was left in a better physical condition. A mechanical digger which can be employed in connection with a trailer in the same manner as the combination digger-and-loader used for potatoes has been developed.

Thirty-five tons of dehydrated sweetpotatoes were produced experimentally during the last harvesting season in a pilot plant, employing 0.4 percent of hydrated lime to promote disruption of the cell walls of the ground sweetpotatoes, mechanical pressure to remove about 60 percent of the juice, and artificial drying of the residue to a moisture content of about 12 percent. The purpose was to provide material for experiments on the suitability of dehydrated sweetpotatoes for starch manufacture and livestock feeding, for tests on the stability of dehydrated sweetpotatoes in storage, and to supply information on the feasibility of the described method of dehydration. Various types of grinding, pressing, and drying equipment were tried out. As an outgrowth of this work, cooperating manufacturers of pressing equipment have undertaken to make certain alterations in their machines which may greatly increase their dewatering efficiency on vegetable material, especially sweetpotatoes. However, since no commercial press has fully met the requirements in dewatering sweetpotatoes, a new type of roller press, embodying the principles found to be most essential in this type of work, has been designed and a model will soon be ready for trial.

Thirty tons of experimentally dehydrated sweetpotatoes, after grinding to a meal, were supplied to the west Tennessee, Georgia, and

Alabama Agricultural Experiment Stations for feeding tests with beef and dairy cattle. In addition, a half ton was supplied to the Alabama station for experimental use in poultry feeding. Final reports by the three experiment stations on the results of the feeding tests with beef cattle showed a favorable relation between cost and rate of gain in weight of steers fed with sweetpotato meal as the source of carbohydrates. The final report of the Alabama station which included the results of slaughtering the experimental steers, showed that the steers fed with sweetpotato meal gave higher beef yields, received a higher grading average, and made beef of better color than did the other experimental steers. These animal-feeding tests were undertaken to determine the relative value of dehydrated sweetpotatoes as a carbohydrate feed for balancing cottonseed meal, peanut meal, or other high-protein feed in a ration for developing the beef and dairy cattle industries in the South. Sweetpotatoes may prove to be more economical than corn for feeding in the South where the yields of corn are low and the cost is relatively high. The starch content of corn is higher than that of sweetpotatoes, but the production of starch per acre is much greater in the case of sweetpotatoes. It has been estimated that the recently introduced varieties with high starch content produce more total carbohydrate (starch and sugar) per acre than any other crop grown in the United States, with the exception of sugarcane in Louisiana and Florida.

Further experiments were made on the treatment of sweetpotatoes with sulfur dioxide prior to dehydration by pressing and evaporation of excessive moisture. This treatment affects the cells in such a way that the liquid can be more easily removed by pressure, even from relatively coarse material. Coarsely ground sweetpotato works better in the presses than does the finely ground material because less slippage takes place. For this reason, it was hoped that chipping of the sweetpotatoes could be used in combination with the sulfur dioxide treatment instead of fine grinding in combination with the lime treatment. When sweetpotatoes were chipped by a cutter fitted with sugar beet knives and exposed to sulfur dioxide gas (1 gram per pound of sweetpotatoes) overnight, a little more than 50 percent of the juice was removed by two types of presses in single pressing. Forty-nine percent of the juice was removed in a single pressing by one press after a 2-hour treatment with sulfur dioxide. Perhaps with slightly smaller chips of fresh sweetpotatoes the effect of sulfur dioxide will take place more rapidly, without sacrificing ease of working in the presses.

Efficient recovery of starch from dehydrated sweetpotatoes has been found more difficult than from fresh ones, apparently because drying of the plant tissues makes the cells more resistant to rupturing. For this reason, the so-called wet storage of sweetpotatoes (similar to siloing) has also been investigated as a means of extending the annual period of starch factory operation. Results to date indicate that wet storage of ground sweetpotatoes (with possible addition of certain chemicals in small proportion) may have important possibilities, particularly during the cooler months of the year, since the loss of starch by the action of enzymes and micro-organisms during storage may be kept quite low. Some large-scale tests have been made on the extraction and recovery of starch from wet-stored sweetpotatoes, but the results were not conclusive; further investigation is required.

MISCELLANEOUS CARBOHYDRATES

Progress has been made in studies of the chemical constitution of various hemicelluloses, a group of carbohydrates, constituting about 25 percent of the dry matter of plants, the chemical properties of which have been but little investigated. These relatively complex plant constituents have been shown by various investigators to contain certain sugar groups, principally xylose, arabinose, and galactose, in combination with so-called uronic acids, principally glucuronic and galacturonic acids. It is known that glucuronic acid acts as a detoxifying agent for removing poisons from the animal organism, and galacturonic acid, the main constituent of pectin, may behave in a similar manner.

The hemicelluloses of the sweetpotato were selected for study primarily because of the attention that is now being given to this crop as a possible source of carbohydrates to replace corn in feeding rations in the South. As the greater part of the hemicellulosic material of sweetpotatoes is pectin, particular attention was given to the pectin content of sweetpotato pulp, the residue after starch extraction. Because there is still considerable starch in sweetpotato pulp, the usual method of extracting pectin from plant material could not be used without modification. It was found that the pectic material can be extracted with acid at ordinary temperature, but the product differed in certain characteristics from the pectin obtained from starch-free sweetpotato pulp by ammonium oxalate extraction. Ammonium oxalate is only useful for laboratory work—not for technical extraction of pectin. In preliminary studies of methods which might be practical for commercial production of pectin from sweetpotato pulp, it was found that treatment of the pulp with 0.5 to 1.0 percent of hydrochloric acid extracts about 15 percent of pectic material. This pectin, however, had less jellying strength than did pectin extracted by some other methods. The development of an efficient commercial process for the production of a good grade of pectin from sweetpotato pulp would contribute an additional source for commercial pectin, and at the same time permit further utilization of this byproduct of starch manufacture which is now marketed as a high-grade feedstuff.

A systematic investigation of the composition of the various forage and feed crops, with respect to their hemicellulose content, and accompanying research on the physical and chemical properties and the feeding value of various hemicelluloses are needed to provide a reasonably adequate knowledge of this important group of carbohydrate plant constituents.

OIL, FAT, AND WAX INVESTIGATIONS

In collaboration with the Bureau of Plant Industry's studies on the culture of tung trees in southern States, 158 samples of tung fruits representing various cultural conditions were analyzed, and the oils extracted from them were compared with regard to quality. In a preliminary investigation of representative sampling, it was found that samples of 100 fruits each are adequate for determining variations in quantity and quality of oil due to different cultural conditions. Simplification of the sampling procedure and further improvements which

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have been made in a rapid method for determining the oil in tung fruits now make it possible to obtain the large volume of analytical data that will be required to determine the influences of varietal, cultural, and environmental factors on oil production by tung trees and the effects of storage under different conditions upon the oil content of tung fruits.

Studies on the solvent extraction of residual oil from tung-oil press cake were made in cooperation with a commercial firm. Extraction of several batches of press cake in a recently completed pilot plant at Picayune, Miss., indicated that additional oil, amounting to about 5 percent on the weight of press cake, can be recovered by solvent extraction. The extracted oil is inclined to solidify at ordinary temperatures, and a special heat treatment is required to make it permanently liquid. In preliminary experiments on the extraction of oil from tung nuts by solvent alone, it was found that as high as 98 to 99.5 percent of the oil can be removed from properly ground tung kernels in one extraction, that is, without the necessity of regrinding. Three-fourths of a ton of tung kernels were prepared and shipped to three commercial firms with whom cooperation has been arranged for developing the most efficient grinding technique. After grinding, the material will be solvent-extracted at the Picayune pilot plant.

Variations in soils and in climatic conditions affect the oil content of flaxseed and likewise the oil's composition and value as a drying oil. A series of linseed-oil samples expressed from representative samples of particular varieties of flaxseed grown in different parts of the United States has been collected by the Bureau and these samples are gradually being subjected to thorough chemical examination for the purpose of correlating oil content and oil properties with cultural and environmental factors. During the past year a study was made of the oils expressed from Bison and Punjab flaxseed grown in Texas, which has just recently begun the growing of flax for seed. The Bison oil had an iodine number of 161.4, in comparison with 168.4 for the Punjab oil. Determinations made of four saturated acids in each oil showed some differences, especially for palmitic and stearic acids. Preliminary tests indicated that both of these oils contained notably more oleic and less linoleic acid than oils from the same varieties of seed grown in California during the same crop year. However, examination of oils from several succeeding crops of seed will be necessary before drawing definite conclusions. Thus far, five samples of the series have been investigated, and the results in each case have been calculated in a form suitable for publication. Final results of this study on linseed oils will be of value to agriculturists, as well as to industrial users of linseed oil, such as manufacturers of linoleum, oilcloth, enamels, lacquers, paints, and varnishes.

An investigation on the chemical composition of the oil expressed from the kernels of the South American palm, *Cocos pulposa*, has been completed. The kernels contain about 60 percent of oil which is almost unique among palm kernel oils in that it remains liquid when cooled to 15° C. (59° F.). The fatty acids in the oil, by percent, were: Caproic, 1.6; caprylic, 10.2; capric, 14.2; lauric, 36.6; myristic, 7.0; palmitic, 1.8; stearic, 1.3; oleic, 23.4; and linoleic, 2.5. The iodine number was 24.6; saponification value, 260.3; and unsaponifiable matter 0.44 percent. The composition indicates that the crude oil is suitable for soap

making and, after refining, for use as an ingredient in the manufacture of margarine.

Rubber seeds produced in Florida were examined for the Bureau of Plant Industry to determine their value as a source of drying oil. Analysis of the oil indicated that it contained much smaller quantities of free fatty acids than did a sample of commercial oil from imported seed and might be more amenable to refining and use as a drying oil. The kernels, which constituted 47.1 percent of the seeds, contained 46 percent of oil, which had an iodine number of 129.1 and an acid value of 7.4.

Seeds of *Daubentonia drummondi* (Fabaceae) from Texas were found to contain an oil of the semidrying class, but the yield of oil (4.3 percent) was too small to give them any industrial value.

PROTEIN AND NUTRITION RESEARCH

DIGESTIBILITY OF SOYBEAN PROTEINS

Why the nutritive value of soybean meal is improved by heating is a question that has engaged the attention of nutrition investigators and the interest of feed manufacturers for years, but the problem still remains unsolved. Some believe that soybeans contain a toxic substance that is destroyed by heat; others believe that heating makes one or more of the essential amino acids in soybean protein more available for assimilation. This question has more than academic importance because the necessity of heating soybean meal before using it for feed materially increases its cost.

As a part of an investigation aimed at solving this problem, digestibility studies are being made on raw and cooked soybean protein (isolated from Mammoth Yellow variety), using enzymes that actually bring about digestion in animals, but conducting the experiments in laboratory glassware. Partially digested fractions have been separated from the raw and cooked protein after treating with trypsin and these fractions are being compared with respect to their physical properties, nitrogen content, and amino acid composition. The results obtained thus far show decided differences in the behavior of the raw and cooked protein, when digested with trypsin, as regards both the quantity and the nitrogen content of corresponding fractions. Analyses of the partially digested fractions, to determine the quantities of particular amino acids in each, will be made later.

AMINO ACIDS IN OATS

Data have been obtained on the amino acid content of whole oats and their edible products and byproducts which are of value to manufacturers and users of animal feeds and to dietitians. They enable those interested in animal feeds and feeding to evaluate the protein quality of oats in terms of amino acids, so that other feeds can be supplemented with oats on a more intelligent basis. The data obtained on the amino acid content of rolled oats help to reveal the nutritive value of this product as a human food and should be valuable as a guide in the choice of diets from the standpoint of protein adequacy. Although only about 2 percent of the oats produced in this country is used for the preparation of human foods, rolled oats and oatmeal are

important in human nutrition, since they amount to about 50 percent of all breakfast-cereal products manufactured in the United States.

The method previously used in the Bureau for determining the amino acids in wheat and wheat products had to be modified somewhat for rolled oats and the byproducts from milling of oats because steam used in the manufacturing process had coagulated the proteins. It was found that the basic amino acids could be determined in the acid hydrolysate of oats and rolled oats. The amino acids tryptophane and tyrosine in these materials were determined also by the improved methods described in a recent publication of the Bureau on the amino acids of corn.

The tryptophane, lysine, and histidine content of rolled oats was found to be higher than that of the oats used for their manufacture. This means that rolled oats not only contain more protein than the whole oat kernels from which they are milled, but that they also have a relatively higher content of some of the amino acids. The protein quality of the byproducts obtained in the manufacture of rolled oats is inferior to that of the kernels.

EFFECTS OF STORAGE ON PROTEINS OF GRAINS AND SEEDS

In view of the fact that large quantities of grains and their milled products are subjected to storage and aging, it is highly important to know what changes take place in their properties and food value as a result of storage and aging. Recently this question has assumed greater significance because the Federal Government has established an ever-normal-granary system in order to level out market supplies by carrying over surplus production of some years to times of shortage. In order to gain such information with particular regard to the proteins of grains and other edible seeds, and of their milled products, investigations were started in 1938 with wheat and wheat flours and in 1939 with corn and soybeans and their meals, with the intention of making chemical analyses and tests at intervals during a 2-year storage period. Samples of wheat, corn, and soybeans and of milled products prepared from the identical lots were placed in two types of containers, glass jars and cotton bags, and stored at two temperatures, 76° and 30° F., the first being a rather high indoor temperature and the second, a moderate cold-storage temperature.

The investigation of changes taking place in the proteins of wheat and its milled products during 2 years of storage has now been completed. Storage resulted in a marked break-down of the proteins, yielding simpler products such as proteoses and peptides which are generally classified as nonprotein nitrogenous derivatives. This breakdown was indicated by decrease in "true-protein" content, by decrease in the amount of nitrogen precipitable by trichloracetic acid, and by an increase in amino nitrogen. The first two conditions were probably brought about by the action of atmospheric oxygen or enzymes naturally present. The increase in amino nitrogen can be accounted for only by assuming action by proteolytic enzymes which cleave the proteins at the peptide linkages. Changes during storage were also indicated by decreases in solubility of the proteins in 3-percent sodium chloride solution, in 70-percent alcohol, and in 3-percent sodium salicylate solution. Determinations of digestibility made with pepsin and trypsin in laboratory glassware showed that the proteins became

less digestible with increasing time of storage. The total nitrogen and free ammonia nitrogen content of all the samples remained constant.

Changes were less marked in the samples stored in glass jars than in those stored in bags which were more exposed to the air. Both with samples stored in jars and those in bags, the changes, with only one exception, were materially greater in white than in whole-wheat flour. The exception, which was the solubility of the protein in 70-percent alcohol, may be accounted for by the fact that the white flour contained a relatively greater proportion of gliadin which is denatured less readily than other wheat proteins. Although quite significant, the changes in the proteins of unground wheat kernels were materially less than those in the proteins of white and whole-wheat flours.

In the experiments with corn and corn meal, tests made on the samples after 12 months of storage showed progressive decreases in true-protein content and in solubility and digestibility of the proteins. However, the rate of change during the last 6 months was not as rapid as during the first 3 months. In the case of corn meal stored in bags at 76° F. for 12 months, the total decrease in true-protein value was 28 percent, the decrease in solubility of the proteins in sodium chloride solution was 50 percent, and the decrease in digestibility of the proteins was 22 percent. Deteriorative changes were greater at the higher temperature. The samples stored in sealed glass jars did not show as great changes as those stored in bags.

Examination of soybeans and soybean meal after 12 months of storage revealed the same types of changes in their proteins as occurred in the corn samples, but they were not so extensive. In the case of the corn samples, the changes occurred more rapidly during the first 3 months of storage, but with the soybean samples they developed more gradually.

The results obtained thus far demonstrate that notable changes may occur in the proteins of wheat, corn, and soybeans, and of their milled products, as a result of storage even under the best conditions. Some of the changes are of such magnitude that they might be expected to affect the value of the products for utilization either for food or industrial purposes. The extent and rate of changes during storage vary with the kind of material stored and are influenced by temperature, moisture, and the type of container. Meals have been found to undergo more rapid and extensive changes than the unground seeds. The fact that freshly ground grains and seeds have higher nutritive value than meals which have been allowed to age is of significance in animal feeding and in human nutrition.

SELENIUM IN TOXIC PLANTS

Attempts were made some years ago to isolate a definite organic selenium compound from toxic wheat grown on seleniferous soil. Evidence was obtained that the selenium is combined or associated with the protein of the grain. Recent work has been done on another plant that absorbs selenium from the soil in much greater quantity, in the belief that isolation of the organic selenium compound from this plant could be more readily accomplished and that the experience would simplify its later separation from wheat. After many failures the Bureau has finally succeeded in isolating a crystalline selenium compound having the properties of an amino acid. This substance has

been obtained repeatedly from different lots of the same source material in the form of well-defined elongated prisms. Because the yields of this crystalline compound were extremely small, micro methods were required for its analysis. This required the assembling and standardization of microanalytical equipment for the determination of carbon, hydrogen, nitrogen, selenium, and sulfur, and a preliminary study of microanalytical technique.

Analyses of the crystalline organic selenium compound showed that it had the following percentage composition: Carbon, 33.38; hydrogen, 5.83; nitrogen, 10.98; selenium, 20.62; sulfur, 4.20; and oxygen, 24.99. These proportions correspond to the empirical formula $C_{21}H_{44}N_6Se_2SO_{12}$. The compound has an equivalent (molecular) weight of 130.5. It decomposes at 263°–265° C., leaving a clear, reddish oil. It is insoluble in alcohol and other organic solvents and is difficultly soluble in water. The nitrogen in the compound is all in the amino form, and the union with selenium is remarkably stable.

It has been assumed that the crystalline compound is a combination of two isomorphous compounds, $C_7H_{14}N_2O_4Se$ and $C_7H_{14}N_2O_4S$, in the ratio of 2 to 1, respectively. This agrees with the empirical formula based on analytical results, except for a slight discrepancy in the case of hydrogen. The following structural formula would agree with the suggested composition of the selenium compound in the assumed isomorphous combination: $HOOC–CH(NH_2).CH_2–Se–CH_2.CH_2.CH(NH_2)COOH$.

Whatever its structure, this compound represents a newly discovered type of naturally occurring amino acid of unusual scientific and economic interest. Evidence was obtained that the plant from which this selenium-bearing amino acid was isolated contains other selenium-bearing nitrogen compounds, and work on the isolation of these is in progress.

The fact that a toxic element such as selenium can become an integral part of an amino acid or protein opens up an entirely new conception as to the constitution and metabolism of plant and possibly animal proteins. It means that trace elements in the soil can and do take part in the metabolism of the plant. If selenium can do this, it may be possible for other elements to become integral parts of plant proteins if they are present in the soil. Several elements found in soils are toxic and their possible presence in foodstuffs will have to be taken into account. The organic sulfur compound associated with the recently isolated selenium compound, as indicated by analysis, had been predicated theoretically by several investigators as a possible metabolic substance formed in the body which converts methionine to cystine. Its isolation, therefore, is of great importance, both scien-halophilic organisms usually involved in salt-curing processes.

ALLERGEN INVESTIGATIONS

Fundamental research on the allergens associated with agricultural products was continued, being supported by an allotment from the special research fund appropriated for carrying out the purposes of the Bankhead-Jones Act. Special attention was given to the allergens of cottonseed, and a study of wheat allergens was begun.

COTTONSEED ALLERGENS

Previous reports have shown that, although refined cottonseed oil and the known proteins of cottonseed meal have no inherent allergenic activity, a highly potent allergenic concentrate can be obtained by chemical fractionation of the water-soluble material in raw cottonseed kernels. Pending investigation of its constituents this concentrate was designated as fraction CS–1, and similar symbols have been used to designate the preparations derived from this concentrate in the successive steps of its fractionation and identification.

The original allergenic concentrate, CS–1, was separated into an allergen-free carbohydrate portion, CS–2, and a protein-containing portion by precipitating with picric acid to form a protein picrate, CS–3, which retained all the physiological properties of the original concentrate. Fractionation of the protein picrate, CS–3, was effected by passing a solution of this material through a column of aluminum oxide and later recovering the selectively adsorbed constituents from two distinct yellow-colored layers and the unadsorbed constituents from the filtrate. The greater part of the allergenic substance was recovered from the upper layer as fraction CS–5. A smaller quantity of substance recovered from the lower layer as fraction CS–6 gave practically the same physiological reactions as CS–5. The substance recovered from the filtrate, CS–10, showed no allergenic activity.

During the past year further studies have been made on the protein-picrate fraction, designated as CS–5, to determine whether the allergenic property of this fraction is inherent to the whole fraction or due to an individual component that might be present in proportion too small to be demonstrated by chemical methods.

This protein picrate and other protein picrates exhibited anomalous behavior when solubility criteria were employed to determine their homogeneity. Measuring the effect of small additional quantities of picric acid on the solubility of the protein picrates led to a satisfactory explanation of the anomalous rise and decline in curves expressing the solubility of these substances. Two types of combination of protein with picric acid were demonstrated. A part of the picric acid was combined with the protein in the fixed proportion characteristic of a chemical compound, and an additional and variable quantity of picric acid was adsorbed by the protein picrate. By maintaining conditions so as to secure equilibrium between dissolved and undissolved substance throughout a succession of extractions of weighed samples with measured volumes of solvent, evidence was obtained that the protein-picrate fraction CS–5 was composed of more than one component and, further, that separation of these components could be accomplished by varying the conditions of the extraction. Following a procedure based on these observations, subfractions of CS–5, which were designated as CS–5–1, etc., were obtained.

Solubility curves for individual subfractions of CS–5 showed that CS–5–1 differed significantly from CS–5–6 and CS–5–10, and that the latter two were essentially alike. This evidence of a separation of components was confirmed by clinical tests. These showed that at least two different allergenic components were either partially or completely separated in fractions CS–5–1 and CS–5–6, and that CS–5–6 and CS–5–10 were indistinguishable in allergenic activity.

Clinical tests with CS–5 and CS–5–1, in comparison with the unheated aqueous extract of cottonseed embryo, indicated that neither chemically combined nor adsorbed picric acid affects the biological specificity of the allergenic component. However, for further chemical characterization of the allergenic component, complete removal of the picric acid was required. This was accomplished by a separate fractionation of CS–5 that resulted in recovery of a picric acid-free fraction, CS–13.

In chemical properties, CS–13 does not conform with any type of protein in existing systems of classification. It corresponds to secondary derived proteins with respect to some color and precipitation tests, but differs from them in rate of diffusion and in failure to precipitate with nitric acid. The name "proteoses" has been used for the split products of chemical or digestive action on proteins. In order to indicate a relationship to, but not actual identity with, such compounds, the Bureau has proposed the name "natural proteoses" for the proteinlike allergenic constituent of the cottonseed kernel isolated from the water extract, first in CS–1, then in CS–5, and finally as CS–13. There is a wide difference between proteoses and natural proteoses, physiologically. The former do not exhibit allergenic and antigenic activities, which appear to be characteristic of the latter.

In order to remove any doubt as to whether the allergenic component of CS–13 actually existed in the parent material, and to prove that it did not result from the chemical manipulations of the method used for isolating it, special physiological tests were made with animals. Animals sensitized with the fraction CS–13 exhibited sensitiveness also to the unfractionated water extract of raw cottonseed kernels and to intermediate precursors of CS–13. The evidence provided by the reactions of animals specifically sensitized to CS–13 justified the conclusion that this fraction is composed of protein and that this protein is native to the cottonseed.

Apparatus was designed for separating the constituents of relatively large quantities of partially purified allergenic protein fractions by means of electrophoresis. The principle of this method is that components differing in electrical charge will migrate through the solution to different electrodes under the influence of a high-voltage direct electric current. By employing this method, it is possible to avoid the use of chemical reagents which might change the molecular arrangements or chemical composition of original constituents. During electrophoresis the picric acid-precipitable or protein portion of the original allergenic concentrate, CS–1, and of a corresponding product, CS–1A, prepared by a modified chemical procedure, migrates toward the negative electrode. An allergenic substance obtained in the negative electrode cell through electrophoretic fractionation of CS–1A was precipitated by picric acid and from the precipitate a picric acid-free protein substance, corresponding to CS–13, was recovered. A solution of 1 part of this substance, CS–13A, in 1 million parts of water induced positive allergic reactions. By means of electrophoresis it was possible to separate components which have different degrees of physiological activity. In view of the promising results obtained, the capacity of the apparatus was enlarged in order to obtain adequate quantities of materials for use in further studies.

WHEAT ALLERGENS

Among staple foods wheat is recognized as one of the most frequent causes of allergic disorders. While this food has received much attention in clinical studies, there has been no satisfactory demonstration of the chemical nature of the wheat allergens. A study of the allergenic properties of wheat has been initiated by a series of experiments designed to determine whether methods employed in the concentration of cottonseed allergens would be applicable to the separation of wheat allergens.

When the procedure developed in the isolation of the allergenic fraction CS–1 from raw cottonseed kernels was applied to whole wheat, an active fraction containing 1.72 percent of nitrogen was obtained. The activity of this fraction, judged by a preliminary series of clinical tests, is about 10 times as great as that of the unfractionated water extract of whole wheat. Unlike the results obtained in working with the cottonseed allergens, no separation was obtained by reaction with picric acid or flavianic acid. The active extracts from wheat were similar to the cottonseed allergens in stability toward heat and in molecular size as determined by migration through cellulose dialyzing membranes.

INDUSTRIAL FARM PRODUCTS RESEARCH

HIDES AND SKINS

A 5-year cold-storage experiment with salted calfskins is nearing completion and the last lot of skins in this experiment is now being tanned. Comparative data that have been obtained during the year on grades, selections, and physical properties of leather from calfskins cold stored for over 4 years indicate that the skins suffered no deterioration during this period.

Laboratory studies are in progress on the influence of temperature and temperature gradients upon the moisture content of salt-cured skins stored at various relative humidities. This work is in line with recently completed studies on the effect of relative humidity on the weight equilibria of salted skins. Extensive data have been acquired to show that very high relative humidities of from 92 to 96 percent are necessary to prevent significant losses in the weight of stored salted calfskins and that the accurate maintenance of constant weight commercially through regulation of humidity would be very difficult, since within this narrow range in relative humidity variations of 30 percent in the moisture content of salted skins can occur. The results of this work will be published at an early date.

Failure to remove heavy layers of fat from the flesh side of hides prior to curing has long been recognized as poor practice. Work published during the year has presented quantitative data on the extent to which such practices may interfere with dehydration and salt penetration. Curing may be so delayed as to provide a period of from 48 to 72 hours favorable to the development of bacterial spoilage and damage.

The completion of work that has been in progress for some time has shown important relationships between salt concentration, protein concentration, pH value, Eh value, and oxygen tension in the reproduction of salt-tolerant bacteria in laboratory media. This work is

now in final form for publication and provides basic information that will prove to be very valuable as a guidance in further studies of the halophilic organisms usually involved in salt-curing processes.

TANNING MATERIALS

The cooperative program of research with the Bureau of Plant Industry on the development of tanning materials has been actively pursued and its scope broadened to include the collaboration of the Soil Conservation Service in the selection of tannin-bearing plants that may also make for better land use practices. The work conceived by this program and that now in progress was presented at the annual meeting of the American Leather Chemists Association.

The second annual crops of canaigre from experimental plantings in New Mexico, Texas, Louisiana, Alabama, Georgia, and Florida have been harvested for collection of yield data and new plots have been planted. Such low yields were obtained at Houma, La., Auburn, Ala.; Tifton, Ga.; and Choctawhatchee National Forest, Fla.; as to indicate little promise for successful cultivation in these localities. In extending the adaptability-of-location studies, new trial plantings were made in September 1939 by the Bureau of Plant Industry at Sibley, La.; Meridian, Miss.; Griffin, Ga.; and Pontiac, S. C.

To establish more definitely the tannin content that may be anticipated from cultivated canaigre and from successive generations from individual parents grown under different conditions, analyses have been made of 202 samples of roots. The progeny studies have not been under way long enough to indicate the possibilities in building up tannin content by strain or parentage selections.

Work to determine the optimum conditions for handling and leaching canaigre roots for conversion into tanning extracts and other products is actively under way. Data are being acquired on fractional extraction, the effect of temperature, the volume of water used for leaching, and the time of contact. The best tanning extract produced so far has been obtained by flushing slices of canaigre roots with very cold water, followed by extracting with water at 35° C. in an adaptation of the Reed-Churchill extractor and evaporating to a powder in vacuum. Upon analysis, this sample showed over 61 percent of tannin and less than 2 percent of insolubles. The carrying over of these studies to a small pilot-plant basis is now in progress.

The study of sumac as a tannin crop has been actively continued in cooperation with the Bureau of Plant Industry and the Soil Conservation Service. Analyses of the second-year crop of leaves grown at Arlington, Va., from seed and rootstock of *Rhus copallina*, *R. glabra*, and *R. typhina* confirm previous observations by showing in all cases a tannin content below that which would be considered commercially satisfactory. The indications are that this particular locality is unsuitable for sumac of high tannin content.

Copallina seed from two locations, glabra seed from three locations, and a mixture of typhina seed from several localities were planted at Arlington, Va., in the spring of 1939. Analysis of random leaf samples collected in September of the same year showed 13.7 percent average tannin content for the typhina seedlings, 19 to 21

percent for the glabra, and 16 and 27.8 percent for the two lots of copallina seedlings. The wide difference in the tannin content of copallina seedlings raised from seed obtained from two locations is of particular interest. It is believed that these data are the first of the kind ever obtained in this country on the tannin content of sumac leaves from known seeding. They indicate possibilities in the use of seed for selection of strains of highest tannin content.

A collection of 53 samples of sumac leaves from wild and cultivated stock has been received from the Soil Conservation Service station at Floris, Iowa. The ranges in tannin content for the four species were: Aromatica, 16.5 to 25.7 percent; copallina, 23.5 to 31.6 percent; glabra, 20.9 to 33.8 percent; and typhina, 14.8 to 31.9 percent. Leaves gathered in September from seedlings of three varieties planted in the spring showed promising amounts of tannin. The tannin values were 24.1 to 25.2 percent for copallina, 23.5 to 24.7 percent for glabra, and 18.2 percent for one plot of typhina. In general these figures are higher than obtained at Arlington Farm, Va.

To supplement the data on the tannin content of domestic sumacs and to locate plants from which seed and roots might be obtained for planting, a survey of parts of Maryland and Virginia has been made. Sumac leaves from 37 locations have been collected and analyzed. These data are being used for guidance in a supplementary collection to be made this summer in the same region.

Considerable experimental tanning of sheepskins has been done to compare the three principal eastern species of sumac with Sicilian sumac. As judged by area yields, thickness, weight, tensile strength, and tear resistance, only minor differences were found between the various leathers. Sicilian sumac, in general, produced leather of the fairest color, although in several instances leathers of practically the same color were gotten with domestic sumac.

An address entitled "Western Hemlock Bark, An Untapped Reservoir of Tannin" was presented at the Washington State Chemurgic Conference, Seattle, Wash., November 4, 1939, giving a résumé of the work that the Bureau of Agricultural Chemistry and Engineering has done on western hemlock bark and presenting for the consideration of the conference a long-range, large-scale program of demonstrational research designed to answer definitely whether or not western hemlock bark can be salvaged profitably and processed into tanning extracts that would find a market in the leather industry.

LEATHER

Through membership, assistance has been given the Committee on Leather, of the Federal Specifications Executive Committee, in the drafting of specifications for round belting leather and on proposals to modify Federal Specification KK–L–261 for sole leather.

During the year 23 combination chrome-and-vegetable-tanned bookbinding leathers purchased by the Government Printing Office have been evaluated for permanence by exposure to accelerated aging followed by physical testing and analysis. Although a number of the leathers did not possess as high a degree of resistance to rot as was expected, they were in general superior to purely vegetable-tanned leather, and to this extent the permanence of leathers for public binding work definitely has been improved by use of the combination tannage.

A description of the recently developed gas chamber for the accelerated aging of leather has been published in the Journal of the American Leather Chemists Association [4] and several trade laboratories have expressed intentions of installing this equipment, primarily for research purposes in developing more permanent leathers. One tanner has stated that he has been using the gas-chamber principle for several years as a means of improving the durability of certain types of leather.

Studies to determine whether the type of chrome liquors used for retanning vegetable-tanned leather has any influence on the permanence of the resulting leather have been completed in part, but no significant differences in resistance to decay were found between leathers retanned with chrome liquors of the following types: Basic chrome alum; sodium dichromate reduced with glucose; and sodium dichromate reduced with sulfur dioxide.

In view of the similarity between chrome and alum tannages, a study has been started to determine the possible merits of vegetable-tanned leather retanned with alum. Alum would appear to possess several advantages in its lack of color as compared with chrome and also its availability from domestic sources. Preliminary results that have been prepared for publication show that vegetable-tanned leathers retanned with alum have an even higher resistance to accelerated aging than have combination vegetable-chrome-tanned leathers. After 12 weeks' exposure in the gas chamber vegetable-tanned leathers serving as controls lost 50 percent of their original strength; a chrome-retanned leather lost 14 percent; and an alum-retanned leather lost only 8 percent. It is quite remarkable that even after 18 weeks' exposure the pH value of the alum-retanned leather was still above 3. These are entirely new observations and must be considered preliminary ones at the laboratory stage. Further explorations of the possibilities in this retannage are planned with the inclusion, if feasible, of commercially made leathers.

FARM WASTES

A general report on the destructive distillation experiments with agricultural wastes over a period of 6 years was published in the February 1940 number of Industrial and Engineering Chemistry.[5] No further work along this line is contemplated.

An investigation on the preparation of moldable plastic from sugarcane bagasse and aniline was completed and information on the properties of such plastics and the optimum conditions for preparing and using them was published. Molding compounds prepared from bagasse by the aniline-digestion method were found to be suitable for many articles where low cost is of prime importance. This work was instrumental in focusing the attention of the automotive, building, and rubber industries on the possibilities of producing low-cost plastic products from lignocellulosic materials, including farm wastes, and led to the erection of a pilot plant for the production of molding powders from bagasse by a sugar-manufacturing firm in Louisiana. Aniline-

[4] FREY, R. W., and BEEBE, C. W. A PROPOSED STANDARD GAS CHAMBER FOR ACCELERATED AGING OF LEATHER. Amer. Leather Chem. Assoc. Jour. 35: 180–192, illus. 1940.

[5] JACOBS, P. BURKE. DESTRUCTIVE DISTILLATION OF AGRICULTURAL WASTES. Indus. and Engin. Chem., Indus. Ed. 32: 214–226, illus. 1940.

bagasse molding powders have been found to be useful for compounding with neoprene to produce various mechanical articles resembling rubber. Commercial production of a gasket material composed of neoprene and aniline-bagasse molding powder is planned for the near future.

Work on the use of monoethanolamine as an analytical reagent for the isolation and determination of cellulose was concluded with the development of a satisfactory method. The new monoethanolamine method of determining cellulose is particularly applicable to crop residues. It is simple and rapid and gives more accurate results than can be obtained by the Cross and Bevan and some of the other methods for the α-cellulose content of the material analyzed.

In the isolation of cellulose from crop wastes with monoethanolamine, it was found that a drastic change was produced in the lignin extracted by this reagent. In contrast with lignin extracted by alkalies this lignin was almost entirely soluble in dilute acids. By treating purified corncob lignin with monoethanolamine and fractionating the product, fractions were obtained which had very low methoxyl contents and greatly increased nitrogen contents. The reagent was found to have similar demethylation and amination actions on guaiacol and vanillin, which are decomposition products of lignin.

A crude lignin complex was prepared in substantial quantity from corncobs for use in further experiments on the removal of iron compounds from water. About half of the lignin originally present in the cobs was recovered by extraction with sodium hydroxide and precipitation with sulfuric acid. Preliminary tests indicated that this crude lignin was about as efficient as purified lignin for removing iron from water. The elimination of the purification step will decrease the cost of producing the lignin and thus make it more attractive for large-scale use in treating industrial water supplies.

In further studies on the use of dilute nitric acid as a pulping agent for crop residues it was found that digestion of sugarcane bagasse with alcoholic nitric acid causes a loss in both lignin and nonlignin constituents, varying directly with the time of digestion. However, the losses are less with alcoholic than with aqueous nitric acid of the same strength, probably due to lower hydrolytic effect of the alcoholic acid. That alcoholic nitric acid causes some degradation of the lignin remaining in the tissues is shown by a greatly increased solubility of this lignin in alkalies and by a lower methoxyl content of the lignin.

The results of a study on the application of the conductometric titration method to the analysis of commercial sulfite pulping liquors were incorporated in an article for publication. This method is simple and rapid and can be used for the analysis of all the common pulping liquors before and after use. It should facilitate the fundamental investigations on the course of pulping by the various processes.

In further experiments on the possibility of producing combustible gas by bacterial decomposition of cornstalks it was found that containers made of copper or galvanized iron are not conducive to a continuous thermophilic methane fermentation of cornstalk flour. Stainless-steel containers gave satisfactory results, although some of the iron was dissolved. Fermentations in containers made of black sheet iron gave erratic results. It was found that dissolved metals interfere more with the micro-organisms involved in gas formation

than with those which cause the initial break-down of the cornstalk constituents.

The results of studies on the anaerobic decomposition and gasification of cornstalks and wheat straw by thermophilic bacteria were submitted for publication. They showed that there is little possibility of producing paper pulp from wheat straw by such a fermentation process. The losses of cellulose were too high, being nearly as high as the losses of pentosans. It was found that gas production cannot be depended upon as a quantitative criterion of relative break-down of the various constituents during fermentation. The experiments indicated, however, that the anaerobic-fermentation procedure used may have value in composting and that a short fermentation period may be useful in making pulp for fiberboard.

LIGNIN

Further knowledge concerning the chemical structure of lignin was acquired through experiments on the action of bromine vapor on lignin. These showed that there is one ethylenic bond in lignin. This fact helps to explain certain reactions of lignin, particularly those with calcium bisulfite and sulfurous acid which are used industrially for the preparation of wood pulp by the sulfite process.

Since the presence of proteins in plant materials often causes errors in the results of lignin determinations by the usual methods, efforts were made to avoid the difficulty by first removing the protein. Digestion with individual proteolytic enzymes and successive digestions with different enzymes were tried, but it was not possible to remove all the nitrogenous complexes. Digestion with papain was found to remove about 70 percent of the nitrogen.

A study of methods for determining so-called nitrogen-free extract in feeding stuffs, especially with regard to the lignin content of such materials, showed the need for revising such methods to make them harmonize with present knowledge on the chemistry of lignin. Changes were suggested which would permit a much closer estimate of the nutritive value of lignin-containing feeding stuffs than is possible with the conventional method.

Analyses of several kinds of nutshells in connection with an investigation of the composition and nature of the lignin in them showed that, in general, nutshells contain much more lignin than is present in woods. In the shells of Brazil nuts, candle nuts, and pecans the percentages of lignin were unusually high. It was noted that the lignin from shells of highest lignin content contained less methoxyl than is usual. There may be a relationship between the lignin content of nut shells and the activity of the carbon prepared from them.

A public service patent was granted on a process for preparing a moldable lignin plastic. This process was based on an observation, made during the fundamental research on lignin, that when lignified plant material was heated with alcohol in the presence of a catalyst such as hydrochloric acid, the lignin that was liberated had adhesive properties and could be formed into solid bodies by means of heat and pressure without the addition of any cementing material.

HEMICELLULOSES

Fundamental research under the Bankhead-Jones Act was continued on the hemicelluloses of cereal straws and forage crops. The

principal hemicellulose of wheat straw was found to consist of 4.7 percent of uronic acid (calculated as anhydride), 3.6 of l-arabinose, and 92.3 of d-xylose. That from sugarcane bagasse had a similar composition, namely: 4.9 percent of uronic acid; 3.7 of l-arabinose; and 92 of d-xylose. The principal fraction (B, according to the Norris and Preece method) of the hemicelluloses isolated from alfalfa hay was found to consist of 12 percent of uronic acid (calculated as anhydride), 0.8 of l-arabinose, and 87.2 of d-xylose. The uronic acid was not definitely identified, but some evidence was obtained indicating that it was either glucuronic acid or one of its methyl derivatives. Thus far, efforts to develop satisfactory methods for the identification of glucuronic and galacturonic acids in small quantities have not been entirely successful.

In connection with the fundamental studies on the constitution and chemical properties of hemicelluloses in general and those of bagasse in particular, it was observed that these complexes form useful resinous condensation products or plastic substances when heated with various phenols in the presence of a catalyst. Accordingly, an application was filed for a public service patent on a process for making such materials from hemicelluloses and phenols.

FERMENTATION PRODUCTS

The previously reported repeat-batch process for the production of gluconic acid from dextrose by submerged mold fermentation with *Aspergillus niger* and recovery of the acid as calcium gluconate has been improved. Instead of retaining in the fermenter a portion of the fermented liquor containing floating mycelium to start fermentation of the next batch of sugar solution, all of the liquor may be now passed through a specially designed all-aluminum pressure filter. The recovered mycelium is returned to the fermenter by passing fresh sterile dextrose solution through the filter in the opposite direction.

The complete separation of mycelium from fermented liquor and reuse of the former result in greater economies than when only part of the mycelium, mixed with fermented liquor, is recovered by flotation and added to a fresh batch. Less time is required for separation of the media; higher concentrations of dextrose can be readily fermented; all of the calcium gluconate in each fermented charge can be recovered; and less preparation is required to obtain the same yields.

In connection with work on the development of a continuous fermentation process for the production of gluconic acid from dextrose in the absence of a neutralizing agent, such as calcium carbonate, experiments were made to determine the acids formed by 14 identified strains of *Acetobacter* when grown on a 5-percent dextrose solutions. Five of these strains, *A. suboxydans*, *A. gluconicum*, *A. xylinum*, *A aceticum*, and *A. acetosum*, were found to be very active producers of gluconic and other organic acids. *A. suboxydans* produced the highest total titratable acidity, but *A. gluconicum* gave the highest yield of gluconic acid, the desired product. It was found that aeration hastened acid production to such an extent that the fermentation could be completed in 4 days. Without aeration it required 14 days.

Excellent progress has been made in developing fermentation processes for the production of 5-ketogluconic acid and 2-ketogluconic acid from glucose. It is known that the former acid may be used as an intermediate in the manufacture of tartaric acid and the second, as a source of d-araboascorbic acid, which is an efficient antioxidant.

The process of making 5-ketogluconic acid has been developed to such a degree that it is considered ready for industrial application. Eighty-percent yields may be obtained in 33 to 50 hours by cultivating *Acetobacter suboxydans* on glucose nutrient solutions under suitable conditions, using rotary aluminum fermenters or vertical vat fermenters as culture vessels.

The unexpected production of 2-ketogluconic acid in one of the fermentation experiments designed to produce 5-ketogluconic acid, led to the isolation of a bacterium which continued to produce 2-ketogluconic acid in subsequent fermentations. Intensive investigation of the conditions favoring the 2-ketogluconic acid fermentation has resulted in the development of a process whereby 80 to 90 percent yields are obtained in 25 to 35 hours. This discovery of a previously unknown biological activity in bacteria while applying fermentation procedures developed by the Bureau is noteworthy and suggests that valuable results might follow the trial of other microorganisms in these procedures.

MOTOR FUELS

Some small-scale experimental work was done toward the development of a simple and economical method of producing fuel gases that can be used directly in internal-combustion engines and for general heating and lighting purposes. Although the work is not sufficiently advanced for any definite conclusions as to the economic and technical value of this method, the results obtained thus far encourage the hope that eventually a means will be developed whereby the individual farmer may provide a considerable portion of his motor-fuel requirements with fuel produced from his own surplus and waste materials.

CHEMICAL PRODUCTS FROM OILS, FATS, AND WAXES

Work was continued on the conversion of oleic acid, one of the principal constituents of vegetable oils and animal fats, and of naturally occurring and synthetic esters of oleic acid and other fatty acids into industrially useful products by methods of organic synthesis. Fundamental information was obtained concerning the conditions necessary for alkylation, acylation, and aralkylation of oleic acid. A dibenzyloleic acid was prepared by the reaction of oleic acid with benzyl chloride in the presence of zinc chloride. Of the three organic chlorides, acetyl, benzyl, and butyl, the first was the most, and the last was the least, active in reactions of this type. Some of the products appear to be valuable for addition to lubricants.

A satisfactory method was developed for the continuous production of pelargonic aldehyde from oleic acid. The product may be of potential importance in organic synthesis.

Further experiments to determine the utility of products made from oleic acid showed that the arylstearic acids can be used in the

form of calcium soap to improve the properties of a lubricant for Diesel engines, and that the sulfonated arylstearic acids have value as fat-splitting agents, as well as for use as wetting-out and emulsifying agents.

Arylstearic acids derived from oleic acid were nitrated in the aromatic nucleus. The nitro compounds may have industrial application, as such, or they may be used as intermediates in the preparation of oil-soluble dyes. Red oil-soluble azo dyes having good tinctorial power were prepared from them.

Improvements were made in the preparation of alkylarylstearates from an alkyl oleate and an aromatic compound by the Friedel and Crafts reaction. When lard or castor oil was substituted for the synthetic alkyl oleate in this reaction, arylation was also effected. The use of the unsaturated fat, instead of the unsaturated fatty acid or its alkyl ester, would be more economical and might increase the yield of the arylated product. It is believed that the alkyl and glyceride esters of arylated fatty acids have value as addition agents to lubricants.

Aralkylation, acylation, and alkylation methods were applied successfully to alkyl oleates, using a metal halide catalyst. In acetylation experiments it was found that the use of an alkyl oleate, rather than oleic acid, made the reaction proceed more smoothly.

A continuous method of hydroxylation and lead tetracetate oxidation gave satisfactory results with castor oil and ethyl oleate, but not with lard, olive, and peanut oils. The aldehydic products obtained are of potential importance in organic synthesis.

PLASTICS

As previously reported, lactic acid has been used as a starting point in the investigations on the synthesis of plastics from agricultural materials. These investigations led to the production of a new type of three-component alkyd resin by first preparing glycerol dilactate and then reacting this compound with organic dibasic acids. During the past year the esterification of glycerol dilactate with azelaic, sebacic, phthalic, and maleic acids was studied in detail and the physical and chemical properties of the products were measured quantitatively in comparison with those of commercial alkyd resins containing no lactic acid. Some of the resins produced experimentally, especially those made with maleic acid, were as flexible without added plasticizer as commercial alkyd resins containing modifying agents. Modification of the experimental alkyd resins with drying oils makes them soluble in low-cost petroleum solvents. Judging from the physical properties of the resins made from lactic acid, which are very similar to those of known commercial alkyd resins used for making lacquers, the lactic acid resins are suitable for the same purpose. The possibility of using lactic acid for lacquer resins, however, will depend largely on its price.

It was found that the new three-component alkyd resins gel at a lower average molecular weight than do the corresponding two-component alkyds. This difference is attributed to a different reaction mechanism, resulting from the presence of three secondary alcohol groups in glycerol dilactate.

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A public service patent (No. 2,181,231) on the process of preparing alkyd resins from lactic acid was procured.

Further technical and economic studies were made on the preparation of methyl acrylate from dextrolactic acid. These led to the conclusion that dextrolactic acid cannot compete successfully with ethylene and ethylene oxide which are used commercially in the synthesis of methyl acrylate and other acrylates for synthetic resins.

CHEMICAL WEED KILLERS

Further studies, bearing upon the electrolytic production of sodium chlorate from common salt, were directly concerned with the advantage of a central cooling compartment in rectangular cells, the relative durability of graphite anodes of different apparent density, the most economical means for recovering sodium chlorate from the cell liquor, advantages of electrolytic cells of the rod-cathode type, and the relative value of various construction materials for cells, cooling units, settling tanks, evaporators, and crystallizers. Data obtained on the characteristics of the rod-cathode cell facilitate the selection of a cell adapted to any particular recovery system, power cost, or financial policy.

The investigations have resulted in the design of electrolytic cells which make possible more economical production of sodium chlorate from common salt. They have shown how economies can be effected by using graphite anodes of high apparent density, and by using comparatively cheap, chromium-free chlorate cell liquors directly for weed-eradication work. Application of this newly acquired information should result in lower cost of sodium chlorate to the farmer.

SOYBEANS AND SOYBEAN PRODUCTS

The work on soybeans and soybean products, carried on as a basic research project under the Bankhead-Jones Act in cooperation with the Bureau of Plant Industry and the agricultural experiment stations of the 12 North Central States in a special regional laboratory at Urbana, Ill., resulted in continued progress along most of the lines mentioned in last year's report. Some of the problems were attacked from new angles.

Quantitative chemical analyses and tests were made on more than 600 samples of soybeans, including all of immediate interest from the 1938 crop and 270 samples from the 1939 crop. In addition, many special determinations and tests were made. Nearly 8,000 individual laboratory determinations were made in connection with the genetic and agronomic investigations and about 4,000 in connection with the chemical engineering investigations. Although this work is routine in character, it is essential to the research work. Variations in the oil and protein content of soybeans and in the iodine number of the oil apparently result from differences in the kind of soybean grown and in the environmental factors of both soil and climate. Hence the analytical work guides the plant scientists in their efforts to develop improved varieties of soybeans that possess not only desirable agronomic characteristics, but also the special qualities needed for industrial utilization, and assists them in determining the best soil and climatic conditions and cultural practices for producing beans for

different uses. It also contributes materially to the chemical and engineering investigations.

An additional laboratory has been provided for spectrographic and microchemical analyses. The spectrographic equipment, already installed, will be used for detecting and measuring traces of elements which may be of importance either in the agronomic work or in connection with the stability of soybean oils.

The analysis of soybean oil for its constituent fatty acids has been materially facilitated by the development of a low-temperature crystallization method for the determination of the saturated or solid acids. A study of a new liquid-liquid extraction method for the determination of unsaponifiable matter in oils, in comparison with the present official method of the American Oil Chemists' Society, indicated that the new method may give additional and more correct information on the unsaponifiable matter and sterol content of soybean oil.

Experiments on processing soybeans were directed particularly toward extraction of the oil by means of a solvent. Thirty-four runs were made with the batch solvent-extraction equipment. Nineteen of these were carried out as a part of a series intended to indicate quantitatively the roles played by such factors as flake thickness, moisture content, temperature, and solvent velocity in determining the rate of extraction and ultimate yield of oil, and the quality of oil and residual meal. It was observed that a maximum extraction rate occurred at a moisture content of 10 to 12 percent. The percentage of oil remaining unextracted decreased with the decreasing thickness of the flakes, and was found to be a logarithmic function of the thickness. Increasing the temperature resulted in a higher rate of extraction, but the possible range in adjustment of this variable permits much smaller changes than can be produced by altering either moisture content or flake thickness of material.

Experiments were made on the cracking of soybeans to learn the effects of moisture content of beans, roll clearance, and the number of passes through the rolls upon the distribution and uniformity of particle size obtained. The data are being used in connection with studies on the influence of particle size on oil-expeller operation.

Further investigations on the eliquibrium relationships of a number of the better selective solvents for soybean oil have shown that it is possible to subject soybean oil to the relatively inexpensive operation of liquid-liquid extraction in order to separate it into two fractions, one having a high iodine number which should enhance its value to the drying-oil trade, and the other having a low iodine value corresponding more nearly to those of the widely used edible oils. Development of this process to plant operation will permit material expansion in the use of soybean oil in paints and varnishes. The fractions possessing high iodine values appear to resemble linseed oil more closely than they do tung oil or dehydrated castor oil.

Liquid-liquid extraction has become a highly developed science in the petroleum field for refining lubricating oils, and has proved to be an extremely cheap process when carried out on a large scale. It appears, therefore, that the application of this process to soybean oil will make available greatly increased supplies of low-priced drying oil. Since the United States is largely dependent on foreign sources for drying oils, it is important that this process be developed from its

present laboratory stage to a point where it can be put in full-scale plant operation in case international relationships should curtail the supplies of drying oil to this country. Application of this process on a large industrial scale should also prove beneficial in diverting much of the soybean oil from present direct competition with lard and cottonseed oil. So far as facilities permit, the investigation of this development on a pilot-plant scale will be prosecuted as rapidly as possible.

During the early part of the 1939 harvest season an unprecedented situation was brought about by the appearance on the market of soybeans containing high proportions of greenish-colored beans. Early receipts of such beans were officially graded as damaged, and brought from 5 to 30 cents less per bushel than the standard price, because the green color was carried over into the oil and oil products. Laboratory examinations and tests indicated that the color was mostly superficial and probably resulted from too rapid drying in late summer; that the composition was normal in other respects; and that the color could be easily removed from the oil without detriment by additional bleaching. Cooperation of Department representatives with the processors and elevator operators resulted in more liberal grading and reduction or removal of penalties. To determine the extent to which the green color would disappear during storage 15 bushels each of two varieties were graded, analyzed and pressed while fresh and similar lots were graded, analyzed and pressed after 6 months of storage. The results will be used as a basis of recommendations in any recurrence of this situation.

In the hope of discovering a method for measuring the stability of soybean oils toward reversion, studies were made of the reduction of methylene blue by soybean oil and of the light absorption of soybean oil in various stages of processing. With regard to the nature of the methylene blue reaction, it was discovered that light from the blue region of the spectrum catalyzes a reaction between dissolved oxygen and soybean oil which must precede or occur simultaneously with the dye reduction. The actual dye reduction is catalyzed by light from the red region of the spectrum. The test seems to be essentially a measure of the rate of disappearance of dissolved oxygen by reaction with the oil. It has been applied to a number of oils and the results, in general, correlate with oil quality.

Spectrophotometric determinations on various types of soybean oils showed that the method of obtaining the oil from the bean has a profound effect upon its spectral absorption. There is a progressive loss of chlorophyll during refining processes. The loss of carotenoids occurs during the later stages of refining, notably during bleaching and deodorization. One conclusion from this study was that there is very little correlation between actual color transmittance and the Lovibond color value of the oil. A number of soybean-oil producers and processors have expressed the belief that, in grading oil for color, absorption measurements at definite wave length should replace color matching by use of Lovibond tintometer glasses. The results of this study, to be published soon, should be useful in evaluating the desirability of such a step.

In the study of refining processes, valuable information was obtained as to the best conditions of processing, and edible oils of a quality equal to good commercial oils were produced from both expeller and solvent-extracted soybean oils.

The results of recently completed analyses of soybean oils of high iodine number, considered in conjunction with those previously obtained for oils of low iodine number, show that there is a remarkable constancy in the percentage of saturated acids and of total unsaturated acids in oils of widely differing iodine numbers. In seven samples varying in iodine number from 102.9 to 151.4, the percentage of saturated acids averaged 12.7, with a maximum deviation of 0.3 percent, and the percentage of total unsaturated acids averaged 87.3, with a maximum deviation of 0.8 percent. The percentage of linoleic and linolenic acids increased in a fairly regular manner with increase in iodine number, while the percentage of oleic acid decreased.

Linoleic and oleic acids were found to have a eutectic containing 75 percent of linoleic acid. The melting point was −10° C. This information, obtained from experiments with the pure acids prepared in the laboratory, was applied in the separation of mixed fatty acids from soybean oil by direct crystallization. It is also of general scientific interest in connection with identification and separation of mixed fatty acids.

Further data were obtained and published on the durability of soybean-oil varnishes, in comparison with varnishes made from other oils. They showed that soybean oil alone or blended with other drying oils produced varnishes which were as durable as those made from the other drying oils alone. One characteristic of soybean-oil varnishes that may be objectionable under some circumstances is that they dry slowly. As a direct result of cooperative work at the laboratory, soybean oil is finding increased use in commercial formulations of paints and varnishes. Information is now available on the driers, resins, and other oils most suitable for use with soybean oil in varnishes and enamels, and this information is being widely disseminated. Soybean-oil paints made at the laboratory are standing up well in exposure tests being conducted by several agencies, including the National Bureau of Standards and commercial concerns.

Some of the uses of soybean meal studied by the laboratory have aroused marked commercial interest. Soybean processors are now working with many manufacturing companies who are investigating the applications of formaldehyde-hardened meal and formaldehyde dispersions of soybean protein to their own products as plastics, adhesives, sizes, coatings, and finishes.

For the purpose of throwing light on the mechanism of the reaction of soybean protein with formaldehyde, the reaction of single amino acids with formaldehyde has been studied with some success by means of X-ray diffraction patterns. These suggested the tentative conclusion that formaldehyde reacts with lysine and arginine to form polymerized products. While it is impossible to state the nature of the linkage involved, the most plausible explanation is that the formaldehyde furnishes cross linkages between the amino groups.

The infrared absorption spectra of unchanged and hydrolyzed soybean proteins were examined before and after treatment with formaldehyde. A distinct difference after treatment indicated that a different chemical product is formed.

The treatment of soybean protein with formaldehyde and carbon disulfide, combined, yielded a product which was less water-absorbent and more resistant to distortion and cracking on drying than was the protein-formaldehyde product.

The effect of hydrolysis on the adhesive strength of soybean protein is being studied in connection with the use of this material for coating paper. Results obtained thus far indicate that mild hydrolysis of soybean protein, that is, the action of 0.4-percent sodium hydroxide for 20 hours at room temperature, has no marked effect on its adhesive strength. However, if the protein is treated with sodium hydroxide solutions stronger than 0.4 percent for the same length of time and at the same temperature, adhesive strength will be decreased. There is an important relationship between degree of hydrolysis and dispersibility of the protein.

In further experiments on the use of formaldehyde-hardened soybean meal in conjunction with phenolic resins as a molding plastic, the best results were obtained with equal parts of soybean meal, phenolic resin, and wood flour. The wood flour appeared to increase both the strength and the water resistance of the molded articles. Because of the readiness with which protein takes dyes, the soybean-phenolic-wood-flour plastic can be given brighter and better colors having more depth and beauty than are possible with phenolic-wood-flour plastic.

Strength tests on laminated boards made from sheets of kraft paper impregnated with various concentrations of formaldehyde-hardened soybean protein, and subjected to various pressures, gave results which compared quite favorably with published figures for laminated materials made with phenolic resins.

Experiments are in progress on the combination of formaldehyde-hardened soybean meal with special types of phenolic resins or plasticizers to yield permanently fusible or thermoplastic material suitable for injection molding. Some recent experiments have indicated that phenolic resins are not in themselves plasticizers for the formaldehyde-hardened soybean protein. It is rather the free phenol associated with the phenolic resins that has this effect.

Chemical modification of soybean protein by such reactions as acetylation, halogenation, and hydrolysis is being studied with a view to improving its plastic-forming properties. Preliminary results of such a study on the reactions of ketene with proteins appear to be quite favorable. Ketene, made by heating acetone vapor, is used in the chemical industry for the preparation of anhydrides from acids. In the reactions with proteins, it appears to block off free amino groups as satisfactorily as formaldehyde without forming cross linkages, which are the postulated cause of the brittleness and lack of strength of protein-formaldehyde complexes.

Studies on the chemistry and utilization of the phosphatides, sterols, and associated compounds were continued at the Indiana Agricultural Experiment Station. Attention was directed particularly to the development of methods for isolating and identifying individual constituents. The sterol glucoside previously isolated proved difficult to hydrolyze without decomposition of the sugar. However, a satisfactory procedure for this hydrolysis was finally discovered, and the sugar was isolated and identified as d-glucose.

In the studies of respiration and storage behavior of soybeans at the Minnesota Agricultural Experiment Station, it was found that the free air space above soybeans in storage has a marked effect on the rate of respiration, particularly at higher moisture levels. When

beans containing more than 14.5 percent of moisture were stored for a month, there was a large increase in respiration and the beans became moldy. All experimental evidence thus far indicates that mold growth plays a major role in the spoilage of soybeans in storage.

NAVAL STORES RESEARCH

CHEMISTRY AND TECHNOLOGY OF NAVAL STORES (TURPENTINE AND ROSIN)

The chemical and technological investigations on naval stores include fundamental research on components and derivatives of pine oleoresin and of its principal products, rosin and turpentine, and applied research on problems relating to the industrial uses of pine oleoresin, rosin, and turpentine, and of their components and derivaties. The results of the first type of research are expected to serve as a basis for the development of a greater diversification in products obtained from the oleoresin of southern pine trees. The results of the second type of research have immediate value in maintaining or expanding the industrial outlets for pine gum and its products.

In further studies on pine oleoresin and its resin acids, it was discovered that the oleoresin contains a type of resin acid not previously found there, namely, a primary dihydro acid (probably dihydrolevopimaric acid). What was formerly believed to be homogeneous dextropimaric acid was found to contain small quantities of other resin acids, especially levopimaric acid. A more effective method of purifying dextropimaric acid was worked out. A new derivative, a hydroxylactone, was isolated from the reaction product of dextropimaric acid and cold concentrated sulfuric acid. The preparation and analytical study of this compound have provided information on its structure and on the limitations of the stability of dextropimaric acid, commonly regarded as one of the most stable resin acids. On the basis of the lactonizing action of sulfuric acid on dextropimaric acid, a method for estimating the maximum quantity of this acid in oleoresin or in rosin was developed. Use of this method indicates about 10 to 15 percent of dextropimaric acid in the oleoresin of longleaf pine (*Pinus palustris*) and about 15 percent in that of slash pine (*P. carribaea*).

Preliminary pilot-plant-scale experiments at the Naval Stores Station on the fractionation of pine oleoresin by means of the "multiple-leaf" filter, developed and patented by the Bureau, showed that pine oleoresin can be separated into a solid and a liquid portion. The filtrates obtained, both by gravity- and suction-filtration, were clean, of good quality and suitable for making noncrystallizing rosin, a desirable industrial product. The cake of resin acids was substantially free of liquid and averaged about 40 percent of the original gum. The filter required little attention during operation when a continuous supply of gum was provided.

In studies on the components and derivatives of rosin, special attention was given to lactonized dihydroabietic acid and to a saturated hydroxy acid derived from the lactone by hydrolysis. It was found that the same lactone (having a melting point of 131°–132° C.) could be made from any one of several dihydro resin acids, including dihydrolevopimaric acid, a dihydrolevoabietic acid showing high positive optical rotation, and other dihydroabietic acids having lower

optical rotation. Oxidation and acylation experiments indicated that the C–13 position in the structural formula for dihydroabietic acid is the particular point in the molecule where lactonization takes place, rather than the C–10 position, which was previously assumed on the basis of possible γ-lactone formation. In connection with this work, a rapid caustic-fusion method was developed for hydrolyzing the lactonized dihydroabietic acid in order to form the saturated hydroxytetrahydroabietic acid.

The lactone of the dihydro acids of rosin is a very stable neutral compound and may be prepared with a degree of purity unusually high for rosin derivatives. It offers promise for use in varnish and other surface coatings.

In the fundamental studies on the composition of gum spirits of turpentine, attention was given to the possibility of increasing the proportion of higher boiling constituents by modifying the conditions during steam distillation of the pine gum. By extending the period of distillation for 2 hours beyond the normal time for turning out the rosin, the composition of the last 10 percent of the total turpentine obtained was changed materially, the principal changes being a marked decrease in α-pinene, a smaller decrease in β-pinene, and decided increase in dipentene and methyl chavicol, the last being convertible to anethol.

Recently there has been a growing trend toward the marketing of individual constituents of turpentine, such as α-pinene, β-pinene, and constituents of the so-called "tailings," or least-volatile portion. The sources of terpenes for making synthetic camphor and terpineol are commercial α-pinene and mixtures of α-pinene and β-pinene. With other important syntheses being developed, there is an increasing demand for β-pinene without admixture. By correlating quantitative data obtained in the fractionation of commercial β-pinene with other data obtained in laboratory distillation procedures for testing volatile liquids, the Bureau has developed tests which may constitute part of the specifications of a standard for β-pinene.

If large-scale commercial fractionation of turpentine should be developed, the high-boiling, nonpinene constituents or "tailings," even though present in relatively small amounts, might assume considerable importance through their recovery as valuable byproducts, such as methyl chavicol. Overoptimism as to its possible value as a source of higher priced chemicals may lead to serious attempts by producers to increase the quantity of tailings artificially, for example, by prolonged distillation of pine gum. The information which the Bureau has acquired on the composition of turpentine and its various fractions, and on the component distribution trends during normal and "extended" distillation, may now be used by the naval stores industry as a sound basis for evaluating gum spirits as a possible source of terpenes and other chemicals derivable from gum turpentine.

Studies were begun on the mechanism and products of two types of chemical reaction, namely, isomerization and oxidation, by means of which new chemical complexes and compounds may be derived from turpentine and turpentine constituents. In connection with this work, special reaction and control apparatuses were designed and constructed. Work was also done on the development of methods for separating constituents of complex reaction products, ana-

lytical methods, methods for preparing known turpentine derivatives for use in identifying unknown products, and spectrophotometric methods of examination.

Special attention was given to the relative value of different methods for measuring the degree of unsaturation of terpene compounds, particularly when applied to turpentine components and their derivatives. Halogen-absorption and oxygen-absorption methods were found useful for comparing, in an empiric way, the approximate degrees of unsaturation, or the "drying power," of individuals in a series of compounds. Determinations of diene values were found to be useful for the same purpose and for indicating in a quasi-quantitative manner the conjugated type of unsaturation. Two types of apparatus and method were developed for the application of catalytic hydrogenation to terpene hydrocarbons as a means of measuring quantitatively the degree of unsaturation. One method was for hydrogenating at atmospheric pressure and room temperature, and the other was for hydrogenating at high pressures and temperatures. In the latter, Raney nickel catalyst was used. In the former, the catalyst was either palladium on zirconium oxide or Adams catalyst. Both methods gave consistent quantitative results with α-pinene and β-pinene. The low-pressure method was found to be equally satisfactory for a variety of other terpenes.

Preliminary experiments on the thermal isomerization of α-pinene, using a specially built assembly for isomerization in the vapor phase, showed that substantial proportions of the monocyclic dipentene (having two double bonds) and acylic allo-ocimene (having 3 double bonds in conjugated system) are produced. The latter compound yields condensation products of a resinous character which may be useful in the synthetic resin and plastics industries. The isomerization products of turpentine or α-pinene have good solvent properties, and when spread on surfaces and exposed to the air they form tacky or adhesive coatings. Specifications to be used in an application for a public service patent to cover these isomerization products of turpentine, which have the novel properties of combined paint thinner and drying oil, have been prepared.

Preliminary experiments on the isomerization of β-pinene showed that the products are very different from those of α-pinene. However, in this case, also, the trend is toward considerable increase in unsaturation, even greater than in the case of α-pinene.

Studies on the oxidation reactions of terpenes have thus far been confined to oxidation in the liquid phase, particular attention being given to the oxidation of α-pinene and β-pinene by means of selenium dioxide. Preliminary experiments indicated that a good yield of myrtenol may be obtained from α-pinene and that a good yield of pinocarveol may be obtained from β-pinene. These terpene alcohols are unique in that, unlike terpineol, they retain the original dicyclic pinene structure. Their properties and utility are under investigation.

Preliminary data on the composition of sulfate wood turpentine, obtained as a byproduct of kraft wood pulp from pine trees, showed that this product, contrary to the general belief, contains a substantial proportion of β-pinene.

Studies on the properties contributed to soaps by rosin, rosin acids, and the resin acids of pine gum were continued. Since the detergent properties of a soap are intimately related to its depressing effect on the surface tension of water, measurements of surface tension were made on standard solutions of soaps prepared from individual rosin acids, to get some idea of their relative value for soap making. It was found that the greater the number of hydrogen atoms in the rosin acid molecule, the lower was the surface tension of the soap solution. The solution of soap made from dehydroabietic acid had the highest surface tension, and that of soap made from tetrahydroabietic acid had the lowest surface tension. The differences in surface tension of solutions of the various rosin-acid soaps were more marked in 0.1-percent solutions that in 1.0-percent solutions.

Surface tension measurements of soap solutions made with the principal oils and fats used in toilet, laundry, and household soaps and solutions of the same soaps mixed with rosin soap in the ratio of 3:1 showed that the presence of rosin soap lowered the surface tension of the solutions of lauric and caprylic acid soaps, but did not materially change the surface tension of the other soaps.

The germicidal properties of soaps containing rosin or particular purified rosin acids were compared with those of soaps made of fats and oils alone, the bacteriological tests being made by the Hides, Tanning Materials, and Leather Section of the Industrial Farm Products Research Division. In the tests with laboratory cultures of isolated organisms, a solution of 0.5-percent rosin soap at pH 10.2 completely killed *Staphilococcus aureus* in 5 minutes at 30° C. Complete killing of *Eschericha coli* was accomplished in 2 minutes at 30° C. with a 2-percent solution of either rosin or coconut oil soap having a pH of 10.2. The germicidal activity of the soaps prepared from individual purified rosin acids (dehydroabietic, abietic, dihydroabietic, and tetrahydroabietic) was found to increase with the number of hydrogen atoms in the rosin-acid molecule when *Staph. aureus* was used as the test organism. However, this correlation of germicidal activity with molecular structure did not hold when *E. coli* was used as the test organism.

Soaps made from pyroabietic acid, prepared according to the Bureau's published procedure, were more active as germicides than were soaps made from the usual commercial grades of gum rosin. Oxidation of the unstable acids in rosin reduced the germicidal activity of the soap made from the rosin. Soap made from the rosin obtained from longleaf pine gum exclusively had the same germicidal activity as that made from the rosin obtained from slash pine gum exclusively.

Rosin soap solutions were more active as germicides against *Staphilococcus aureus* than were equivalent solutions of soaps made from the fat acids of natural fats and oils. Against *Eschericha coli* and *Eberthella typhi* coconut-oil soap was equally as active as rosin soap, but soaps made of other natural fats and oils were less active germicidally. Mixtures of rosin soaps and fat-acid soaps were germicidally more active than were the soaps of corresponding fatty acids against *Staph. aureus*, *E. typhi*, and *E. coli*.

Bacteriological tests were also made to determine the relative effectiveness of rosin soaps and rosin-free soaps for killing micro-organisms removed from the hands of laboratory workers and for actually killing

the organisms on the hands by washing with solutions of such soaps. These tests showed that the lathers of both a 10-percent coconut-oil-soap solution and a 10-percent coconut-oil-rosin-soap solution were germicidally active against organisms which had been removed from the hands. Three 2-minute washes with either a 10-percent coconut-oil-soap solution or a 10-percent coconut-oil-rosin-soap solution had little germicidal effect on the organisms residing on the hands, but similar washing with a 10-percent solution of rosin soap (sodium rosinate) had a marked germicidal effect against the resident flora (equivalent to that obtained by washing for 2 minutes with 70-percent alcohol). The lather of a commercial soap made in part from rosin was germicidally active against organisms removed from the hands, but three 2-minute washes with this soap had only a slight effect on the resident flora. The use of this soap regularly for 1 week reduced the numbers of both the transient and resident bacteria found on the skin of the hands.

A study on the use of copper rosinate as an impregnating material for retarding the disintegration of paper propagating pots was completed and the results were prepared for publication. Public service patents were obtained on the use of copper rosinate for treating propagating pots made of burlap or other woven material (U. S. Pat. 2,202,664) and of rosin as an amendment for greenhouse soils (U. S. Pat. 2,187,532). The latter patent is based on the discovery that rosin has a stimulating effect, somewhat like that of a plant hormone, on certain plants when grown in soils rich in organic matter. The factors which control this stimulating effect have not yet been determined.

Experiments were made to determine the value of copper rosinate and pine tar, both naval stores products, when added, separately or mixed, to an impregnating and pigmenting basic treatment for the purpose of preserving cotton mulching fabric. Tests on samples which had lain on the ground for 8 months on each side of a row of raspberry bushes showed that the one treated to show the effect of pine tar alone was somewhat stronger than any of the others. All showed excellent resistance to mildew. It is believed that if the mulching cloth were treated each year, in fall or spring, with a light spray of water-repellant impregnating solution containing pine tar or copper rosinate, it would last for several years. A woven fabric is superior to paper for mulching because it can be walked on. However, the fabric would have to be cheap. The experiments were made on coarse, open-mesh, cotton fabric designed for covering cotton bales.

Copper rosinate also offers some promise for controlling the infestation of cattle by the screwworm. Diphenylamine has been used for this purpose but a 1:1 mixture of copper rosinate and diphenylamine, submitted to entomologists for trial, was found to be as effective as diphenylamine alone. This is significant, because the diphenylamine is much more costly than the copper rosinate. Samples of copper rosinate alone and of the same material blended with bentonite were submitted for further trial.

A laboratory-distillation test for pine gum, which shows the yields of turpentine and grades of rosin that should be obtained in naval stores plant practice, has been perfected. This is coming into use by the industry for evaluating purchases of pine gum. A method for determining the turpentine content of very small samples of gum or

rosin was developed by modifying American Society for Testing Materials method D322–35 for testing crankcase-oil dilution. By inserting a thermometer in the distilling flask and substituting a water-glycerine mixture for water to be added to the sample, the distillation can be carried out without overheating.

Data on the production, distribution, industrial consumption, and stocks of turpentine and rosin were collected and tabulated for the Fourth Semiannual Naval Stores Report, covering the period, April 1 to September 30, 1939. This report was issued on November 15, 1939. Similar data were also collected and tabulated for the 1939–40 Annual Naval Stores Report covering the period, April 1, 1939, to March 31, 1940. The annual report was issued on May 15, 1940. The prompt issuance of these reports, making available to producer and consumer data upon which one may more intelligently adjust production to the needs of consumers, and the other, his consumption to available supply, promotes the interests of the naval stores industry.

PRODUCTION AND PROCESSING OF NAVAL STORES

The engineering research of the Naval Stores Station at Olustee, Fla., has been directed toward further improvement of gum-cleaning and distillation processes and equipment which will promote economy in turpentine and rosin production through the development of technically controlled central distilling plants. Chief attention was given to improving the methods and equipment for batch processing, pending the development of practical equipment for continuous processing.

The experimental gum-cleaning equipment formerly installed, and designed for operation under widely varying conditions including high pressures, was used with low steam pressures for melting and filtering the gum, in order to determine the practicability of lighter and less costly equipment. The results indicated that equipment designed for gage pressures as low as 50 pounds per square inch can be used satisfactorily to clean turpentine gum according to the Bureau's procedure. Such equipment would cost considerably less than that now in use.

A possible further reduction in the cost of cleaning gum was indicated by experiments which showed that gum diluted with an equal weight of turpentine can be filtered cold. Dilution with turpentine not only facilitates filtration but it also promotes separation of the oleoresin from the water originally present in the gum and from the water used to wash out soluble impurities. It was found previously that the specific gravity of the gum had to be reduced to about 0.95 for successful separation from water. In further experiments it was found that the upper and lower limits of dilution with turpentine necessary to obtain separation after washing in normal settling time were about 50 percent and 30 percent, respectively. Dilution to a 40-percent turpentine content gave the best results under conditions so far studied.

A gum cleaner of pilot-plant size, which embodies improvements suggested by experiments with equipment previously designed for this purpose, was built and used in comparative tests. The results with this small cleaner showed what might be expected when the large-scale gum cleaner is used.

The results of a series of gum-cleaning experiments in which temperature, pressure, dilution, and other factors were varied individually, while other variables were held constant, suggested the following procedure: Place the crude gum in a melter (a vessel equipped with steam coil and open steam inlets); add sufficient turpentine to raise the turpentine content of the mixture to between 40 and 50 percent by weight; heat the gum-turpentine mixture to 215° F.; pass the heated mixture through a filter medium of such character that no visible solid particles are left in the filtrate, using as low a pressure as possible to obtain a satisfactory rate of filtration; wash the filtered gum with water by one of several methods studied; allow the washed filtrate and water to settle; draw off and discard the lower layer of water; and transfer the filtered, washed, and settled gum solution to the still. Gum cleaned by this procedure and distilled with the steam still yields rosin that measures nearly 100 percent in brightness, whereas uncleaned gum from the same lot, run on the fire still produces rosin having a cleanliness factor of from 80 to 85 percent. Normal commercial rosins show 65 to 70 percent brightness. The greatest improvement in cleanliness was found to result from the washing, rather than the filtering operation. By giving the filtered mixture two washings, instead of one, the settling time may be reduced to 15 minutes, and still yield clean rosin.

The data obtained in the studies on gum cleaning and an outline of the method recommended have been prepared for publication. Specifications have also been prepared for a public service patent which has been applied for.

Experiments on the recovery of oleoresin from the chips, which are screened from crude pine gum, showed that exposure of chips for 10 to 15 minutes to the action of steam under a gage pressure of 30 pounds was effective, except when the gum contained scrape (dried and oxidized gum scraped from the "face" of the tree). The time required for cleaning chips with steam, when scrape was present, was so long that dissolving the scrape with hot turpentine was believed to be more practical.

The results of laboratory experiments on the removal of iron stain from pine gum, by using very dilute solutions of mineral acid to wash the gum diluted with turpentine, were very promising. Very low grades of gum were improved by several grades in this way.

In connection with the gum-cleaning studies, experiments were also made with the steam still. This still was used successfully for processing cleaned gum alone, and cleaned gum diluted with various proportions, up to 50 percent, of turpentine, but it was necessary to regulate the distillation differently for different dilutions. Definite procedures were developed for gums of certain dilutions. These were applicable, also, to scrape or mixtures of gum and scrape, diluted to the same extent. The cause for a high acid content in turpentine produced by a commercial steam still where distillation was speeded up with steam spargers was found to be the entrainment of oleoresin, as mist, with the turpentine vapors leaving the still. A trap to remove particles of liquid or solid from the turpentine vapors was installed that corrected the trouble.

In connection with the operation of turpentine fire stills, experiments were made with various types of condensers, including the conventional worm condenser with tubs of two sizes, a jet condenser, and

tubular condensers of different design and capacity. The jet condenser, which is very simple and inexpensive, was found to be extremely efficient as regards water consumption. A condenser of this type, about the size of a 5-gallon milk can, was able to handle the output of a 25-barrel still, when run at normal speed.

In order to determine how the type of fire-still setting now recommended by the Bureau would operate under extreme conditions, a commercial still having a setting of this type was operated 24 hours a day for 1 week. No fault was found with the setting. On the contrary, the fuel consumption per charge was less than with the old type of setting and the output of the still was practically doubled with no degradation of rosin from scorching.

Storage tests on rosin packed experimentally in paper bags of four, five, and six plies, showed that the paper containers, which held 100 pounds of rosin, were satisfactory after storage for 1 year under shelter on a wooden floor, in stacks from six to eight bags high, but were not satisfactory after storage for 9 months in the open on a raised platform. There was no serious distortion of the packages, even in hot summer weather. The four-ply paper bag, when filled, did not allow any of the molten rosin to pass through.

The results of extensive tests with the Bureau's glass turpentine gum cups, in comparison with aluminum cups and cups made of sheet iron coated with tin, lead, or zinc (with or without paint of several types), showed that the glass cups were superior, as regards degradation of the gum, and derived rosin, by staining. The gum from 1,000 glass cups, hung by a cooperating firm on fifth-year, raised faces on slash pine trees in the Osceola National Forest yielded grade 3A (nearly colorless) rosin at every dipping except the last, which yielded grade X (extra pale) rosin. The glass cups were tested in comparison with Herty clay cups by allowing them to hang on the trees during severe winter weather in the coldest part of the Turpentine Belt and also on trees in the Osceola National Forest while burning off undergrowth and trash against the wind. Around 8 percent of the cups of each kind were broken by freezing. The glass cups hung in a vertical position, while the clay cups were tilted at an angle of about 45°. Out of 50 glass cups subjected to fire, 48, or 96 percent were broken. Out of 15 clay cups subjected to fire, 6, or 40 percent, were broken. Out of the 1,000 glass cups which were left hanging in the Osceola National Forest throughout the winter, 26 were broken by freezing. More than 100,000 glass cups are now in commercial use. The results from these tests indicate desirable changes in the shape of glass cups. It is believed that the modified glass cups will show a great reduction in losses from freezing.

Since low grades of rosin are caused almost entirely by staining of gum with metallic contamination from corrosion of the cups and aprons used for collecting the gum, the comparative study of cup materials is important to the producer. The results not only show him what kind of cups to use to obtain the best grades of rosin, but they also enable him to know in advance, with a considerable degree of certainty, the grades of rosin he can expect to obtain, using whatever kind of cups he may have available.

Two cooperative agents, one employed by the State of Florida, and the other by the State of Georgia, have continued to carry to naval

stores producers in their respective states practical information based on the results of research work at the Naval Stores Station. This information is diffused through personal contacts, demonstrations at naval stores plants, exhibits, addresses at meetings, press releases, and the distribution of literature and drawings. There has been an increase in the number of central stills during the past year. These plants, which buy gum from small producers, are beginning to install gum-cleaning equipment and to use processing methods wholly or partly outlined by the Naval Stores Station. The gum producers, likewise, are following to a large extent the practices recommended by the Naval Stores Station for handling crude gum. This cooperation is probably the most effective way of informing naval stores producers of the results of the work at the Naval Stores Station and of other related research activities. Through personal contacts, the central still operators and other producers, gum farmers, and landowners have opportunity to present their problems and receive expert advice as to the best and most economical solution, according to available knowledge. In most instances, suggestions are readily accepted and put into practice. The numbers of inquiries and requests for assistance are increasing from year to year, showing a growing acquaintance with, and faith in the helpfulness of, this work designed to benefit gum farmers and turpentine and rosin producers.

CHEMICAL ENGINEERING RESEARCH

AGRICULTURAL FIRES

A laboratory investigation on the effect of heating undercured alfalfa hay in an inert atmosphere (nitrogen) at a temperature slightly above that at which micro-organisms exist (76° to 78° C.) on its oxygen-absorbing property was completed. A manuscript embodying the results of this investigation was prepared for publication.

It was found that heating under these conditions causes an increase in oxygen absorption and that the oxygen consumed in the oxidation of preheated alfalfa is far in excess of the carbon dioxide produced. The results prove that under the influence of heat supplied from external sources, with the exclusion of bacterial action, changes take place in alfalfa that render it more susceptible to oxidation. They also provide further indirect evidence of the formation of unsaturated substances in alfalfa hay by heat and chemical action without the intervention of micro-organisms. The conclusion appears to be fully warranted that in a haymow in which temperatures approximating those of the laboratory experiments have been reached as the result of respiratory and micro-organic processes, together with the more limited chemical reactions, the hay will undergo fundamental changes which render it more susceptible to oxidation, and that if this heat is sufficiently prolonged under favorable conditions, the hay will reach a condition that may appropriately be called pyrophoric, or spontaneously ignitible.

The results of the Bureau's work on fire prevention and control were presented in various parts of the country at conventions of firemen's associations and firemen's training schools, and at meetings and conferences of various other organizations. In this connection, members of the Bureau's chemical engineering staff actively cooperated with

national organizations by participating in the work of committees on which they held membership.

A survey was made of the public fire-protection system of the District of Columbia and a report was prepared showing the protection afforded buildings occupied by Government employees. This report was presented at the annual meeting of the Federal Interdepartmental Safety Council. At this meeting the Bureau exhibited some pieces of safety equipment which it had designed.

Assistance was given to a commercial moving picture concern in the preparation of a motion picture dealing with fire protection.

A member of the Bureau's chemical engineering staff obtained information on the public fire protection and water supplies at the regional research laboratories. On the basis of this study recommendations were drawn up for proper fire protection at these laboratories.

DUST EXPLOSIONS

Nine dust explosions in industrial plants were investigated by the Bureau during the past year. Four of these were caused by grain dust, two by flour, and one each by dusts of starch, cork, and sulfur. These explosions resulted in the death of only one person, injury to eight persons, and property damage amounting to only about $228,000. The most serious explosion, from the property-loss standpoint, occurred on December 18, 1939, at a grain-elevator plant in Houston, Tex., where the property damage was about $75,000. However, no injury or death occurred at this plant.

In addition to these, two explosions causing one death and property loss of about $300,000 occurred in soybean-processing plants. Although soybean dust is explosive, these two explosions could not be classified as dust explosions because they were caused by the ignition of vapors of hexane, the solvent used for extraction of soybean oil. Such explosions indicate the need for research work on all types of explosion hazards in plants handling agricultural products.

The possibility of using vents to relieve explosion pressure without structural damage was shown in a demonstration before 200 visitors at the Arlington Experiment Farm, Arlington, Va.

During the year laboratory experiments were continued on the effect of particle size on the explosibility of dust. Fractionations into four particle sizes (0–10, 10–20, 20–40, and 40–74 microns) were made of cellulose, dextrose, and sucrose, using the Roller particle-size analyzer. Explosibility tests were made with each of these fractions at concentrations of 100 and 500 milligrams per liter.

A number of samples of dusts were submitted and tested in the laboratory for explosibility.

The Bureau continued to make available to individuals, associations, and corporations literature showing the practical application of results of the research work on dust explosions. The results of the Bureau's work were also presented by addresses in various sections of the United States at conventions of firemen's associations and firemen's training schools, student groups, and at meetings and conferences of various other organizations.

In connection with the work on the prevention of dust explosions, members of the chemical engineering staff continued cooperation with

national organizations by active participation in the work of committees on which they held memberships or before which they were requested to appear. The Dust Explosion Hazards Committee of the National Fire Protection Association, of which the Chief of the Chemical Engineering Research Division was chairman, completed and approved the safety code for the prevention of dust explosions in sulfur plants. This committee also gave consideration to the preparation of a safety code for the prevention of dust explosions in country grain elevators.

The adoption of the measures recommended by this Bureau for preventing dust explosions and fire has resulted in a reduction of losses in life and property. However, the hazard exists in practically all plants where carbonaceous dusts are produced and handled, and the introduction of new processes and the development of byproducts have created new hazards which require further investigation.

SERVICE WORK

The regional research laboratories and many of the divisions of the Bureau were assisted in the preparation of designs and specifications for buildings and laboratory equipment and by drafting work. These services included: Technical supervision of the design and construction of equipment for the regional research laboratory buildings; supervision of construction of a building for the Fruit and Vegetable Products Laboratory at Weslaco, Tex.; assistance to the Division of Plans and Service in the preparation of plans and specifications for an addition to the building used by the Citrus Products Station at Winter Haven, Fla.; design of a laboratory building for tung oil investigations at Gainesville, Fla.; and preparation of a preliminary drawing for a proposed garage and workshop for the Farm Tillage Machinery Laboratory at Auburn, Ala.

Regular quarterly fire inspections of the Bureau offices, laboratories, and storerooms were made by members of the Chemical Engineering Research Division.

FARM-STRUCTURES RESEARCH

FARMHOUSE RESEARCH

Athens, Ga. Data obtained both in occupied farmhouses and in specially constructed test houses, which have been described in previous annual reports, have been analyzed and a bulletin prepared. Practical applications of the results are being made, and houses which are being built or improved by cooperating farmers will incorporate a number of the findings of these studies including the use of cottonseed hulls for insulation, improved ventilation, and waterproofed concrete slab floors with finished surfaces. In addition to providing improved houses for themselves, the cooperation of these farmers will enable the Bureau to check on the value of its findings under actual use.

Madison, Wis. Studies of winter comfort in cooperation with the University of Wisconsin in a number of occupied farmhouses showed that the major sources of discomfort in the occupied rooms of the average farmhouse are variability in air temperatures, large differ-

ences in temperature between the floor and the breathing level (or stratification) and cold floors, walls, and glass. In a number of cases the inability to heat the entire house during the winter resulted in crowding.

Some of these houses were remodeled, emphasis being placed on the use of farm material and labor to lower costs. Tests in the remodeled houses showed that conditions were greatly improved by attention to the tightness and thermal conductivity of the construction and to the type and proper installation of the heating equipment.

The lack of planning service and advice deters many farmers from making needed improvements and prevents many others, who have made such improvements, from getting the most for their money. This project shows an effective means whereby such services and advice can be made available to farmers who wish to improve their buildings.

A publication on closets and storage spaces for farmhouses has been prepared in cooperation with the Bureau of Home Economics. Farmers' Bulletin 1749, Modernizing Farmhouses, was revised. A mimeographed report on prevention of moisture in farmhouses and a farmers' bulletin on the construction of foundations for farm buildings, including farmhouses, were prepared.

POTATO STORAGE

Field studies of potato storages in Michigan were completed and a report for publication by Michigan State College was prepared. This report includes designs of storages of various sizes suited to Michigan requirements. Studies of potato storage problems in the semiarid irrigated district of western Nebraska were undertaken in cooperation with the University of Nebraska with headquarters at Scottsbluff. In this area low humidities and relatively high temperatures introduce storage difficulties not found in the colder and more humid States. Several potato growers in eastern Colorado and Wyoming as well as in Nebraska are cooperating in these studies.

FARM BUILDING PLAN SERVICE

By completion of the Southern Plan Service and issuance of Miscellaneous Publication 360, Plans of Farm Buildings for Southern States, all States now are able to supply fully detailed working drawings of approved types of farm buildings to farmers who wish to build or improve their structures. In developing this plan service all the Southern States cooperated with the Bureau to pool the best available plans for farmhouses and other farm buildings suited to the South. All of the plans have now been made available to each State.

SILAGE-PRESSURE STUDIES

The growing use of grass silage, with the accompanying greater stresses and corrosion in silos, has made necessary the development of stronger and more corrosion-resistant silo construction. Economical design requires curves or tables permitting a comparison of the pressures exerted on the side walls of silos of different diameters when filled to various depths with (1) ordinary corn silage and (2) grass silage containing the maximum quantity of water. For several years this

Bureau, in cooperation with the New Jersey Agricultural Experiment Station, has been measuring the lateral and vertical pressures exerted by corn silage and grass silage of known moisture content at different depths in silos of various diameters.

It was found that the lateral pressure on 12-foot-diameter silos at a 40-foot depth was 338 pounds per square foot with grass-and-molasses silage containing 70 percent of moisture and 696 pounds per square foot with grass-and-molasses silage containing 78 percent of moisture. In 18-foot-diameter silos pressures per square foot for corresponding depths were 734 pounds with grass-and-molasses silage containing 72 percent of moisture and 1,189 pounds with 77 percent of moisture. Grass-and-phosphoric acid silage containing 77 percent of moisture gave 950 pounds pressure per square foot at the 40-foot depth. With corn silage in 14-foot-diameter silos the pressure changed from 320 pounds per square foot to 360 pounds per square foot for a 40-foot depth as the moisture content increased from 68 percent to 72. In 18-foot-diameter silos the pressure with 74-percent-moisture corn was found to be 570 pounds per square foot at a 40-foot depth. The data have shown consistently that the pressures exerted by grass silage are greater than those exerted by corn silage and that the pressures do not vary directly with depths. However, there are not yet sufficient data to distinguish the effect of diameter from that of moisture content.

Preliminary studies indicated that prestressing of silo reinforcing on some types of silos is effective in stopping leaks and the attendant deterioration of the silo. Drains in the foundation walls were found to be effective when the moisture content of the silage was not excessive but did not function satisfactorily when the silage contained excessive moisture.

CORN STORAGE

Research on corn storage was continued as a regular project under farm structures and related investigations and as a basic-research project under the Bankhead-Jones Act. The studies were intended to be as helpful as possible to farmers and units of the Department concerned with the ever-normal-granary program. Most of the work was in cooperation with State agricultural experiment stations. Observations on corn-storage structures and practices, and determinations of the condition of stored corn from particular cribs at 6-week intervals, were made in four counties in Iowa, two in Illinois, one in Minnesota, and one in Indiana. Because of unusually favorable weather, most of the corn was in excellent condition after storage; little damage by molding or heating was found. This is leading farmers to think that storage regulations based on experience in earlier years might be relaxed, and also that they can safely grow later-maturing varieties of corn. Both of these beliefs will, no doubt, result in difficulties in carrying out a Government corn-storage program when an unfavorable season occurs. It is expected that these studies on corn storage will provide a reliable guide as to the maximum allowable moisture contents at which corn can be stored, and as to safe crib width and ventilation requirements, in relation to geographic location.

Further studies were made in widely separated geographic regions on the variation of the moisture content of stored ear corn of several varieties with the changes in weather conditions that determine relative humidity of the air. The data, with those previously obtained,

are being compiled and correlated with average relative vapor pressures of the atmosphere during the same time and in the same areas. Some of the moisture determinations were on corn left on the stalk in the field; others were on bulks of corn stored in cribs; and still others were on individual ears of corn hung under a well-ventilated shelter. As might be expected, the moisture content of corn in a crib, especially in the middle and lower parts, did not fluctuate as rapidly or as much with changes in weather conditions as did the moisture content of individual ears fully exposed to air under shelter. The data show the limitations imposed by weather, not only on the moisture content to which corn may dry, but also on the length of time that may be required for corn to dry to this moisture content, under particular weather conditions.

The fact that corn dried much more slowly in a crib than in the field, or as individual ears under open shelters, means that there is room for improvement in the design of cribs to promote drying. Data on the moisture content of different varieties of corn during the later stages of maturity show that the problem of safe storage may be aggravated by picking corn too early or by growing late-maturing varieties. With our present knowledge it is not practical to design simple cribs for conditioning high-moisture or "soft" corn in seasons of extremely unfavorable weather for drying. The results of studies to date emphasize the importance of complete maturity of corn when harvested and of providing cribs with adequate ventilation. It is desirable that cribs be located where they will be fully exposed to sunshine and drying winds.

From data obtained in a study of the equilibrium moisture content of corn under various controlled atmospheric conditions of relative humidity and temperature, it is possible to estimate, with a reasonable degree of accuracy, the moisture content of corn that has been exposed under known atmospheric conditions. However, the previous temperature and atmospheric humidity to which corn has been exposed were found to have a marked effect on its later moisture content, even after equilibrium is established. A drop in temperature from 77° to 17° F. will cause an increase in the equilibrium moisture content of corn of about 1 percent.

In a reconnaissance survey of noncommercial corn-producing areas east of the 100th meridian and outside of the Corn Belt, it was found, in general, that the farther south corn is stored, the less important ventilation becomes. In the latitude of southern Georgia corn can usually be stored in tight bins, because the moisture content at time of harvesting is below 13 percent. Storage in bins or tight buildings facilitates fumigation to kill stored-grain insects that are generally prevalent in the South. However, there are large areas where the moisture content and insect infestation are such that both ventilation and fumigation are necessary. A type of crib is needed that can be opened for ventilation, and conveniently closed for fumigation when needed. Fumigation is practiced on less than 1 percent of the farms where needed. This is because farmers are not fully aware of the benefits of fumigation and buildings are not adapted for this purpose.

The Bureau cooperated with the Agricultural Adjustment Administration in preparing specifications for the procurement in 1939 of around 41,000 commercial bins for the storage of 63 million bushels of

shelled corn owned by the Commodity Credit Corporation. Representative bins were inspected before delivery to insure that the structural strength and weathertightness of the bins were adequate to meet the requirements for safe storage. Inspections and tests were also made of representative bins of all types after they had been erected and filled with corn for the purpose of developing improved structures for future use. As a result of these studies the Bureau's engineers were able to design an improved type of bin that is also considerably lower in cost. The saving to the Commodity Credit Corporation in the purchase of 22,000 bins in 1940 for the storage of 60 million bushels of shelled corn was approximately $1,250,000.

The storage of corn after shelling has not been practiced on a large scale until recently. The rapid increase in this practice makes the studies of bins for shelled corn particularly important. Losses due to rat damage were greatly reduced when corn was removed from the cobs and stored in tight bins. However, the presence of insects and insect eggs in some of the shelled corn requires careful supervision and fumigation of infested bins, or disposal of the grain before damage is serious. Many shelled-corn samples that did not contain live insects when first taken from the bins were found to contain some after incubating at 77° F. for periods up to 15 weeks.

An increased amount of rat damage was observed in the cribs inspected the past year. In fact, not one of the cribs inspected appeared to be entirely free from rat infestation. It was pointed out that good protection against rats could be provided at moderate cost by methods already well known.

WHEAT STORAGE

Investigations on wheat storage, supported by an allotment from the special research fund under the Bankhead-Jones Act, were continued in cooperation with other units of the Department and several State agricultural experiment stations. Data were obtained from a number of experimental storages and from surveys in Ohio, Michigan, Indiana, and Kansas to determine the condition of wheat in typical farm storages.

The results of the wheat-storage studies emphasized two facts: (1) Low moisture content is the most essential requirement for safe storage of wheat at usual temperatures; and (2) the rate of deterioration of undried or tough wheat can be materially decreased by storing at low temperatures. The maximum moisture content for safe storage of sound wheat for 1 year in unventilated bins is probably not more than 13.0 percent in western Kansas, 13.5 to 14.0 percent in Illinois and Maryland, and 14.0 to 14.5 percent in North Dakota. The variation for different geographic regions is due to different climatic conditions during storage and to differences in the temperature of the wheat when put in storage. For longer periods of safe storage, lower moisture contents or lower temperatures are necessary.

The effectiveness of ventilation for lowering the moisture content of wheat in storage and dissipating excessive heat varies with geographic location and type of ventilation system used. In some cases the benefit of ventilation results from dissipation of heat, rather than from rapid drying of the grain. Several methods of ventilating wheat in bins were tried experimentally. One in which wind pressure is utilized to force air outward in all directions from the center of

the mass of grain gave good results and appears to be suited to commercial development.

Underground storage in 1,000-bushel unventilated bins at Hays, Kans., maintained wheat at temperatures averaging 20° F. lower during summer months than those of wheat in similar bins above ground. However, even in such bins the stored grain sometimes became musty because the wheat cooled so slowly below its initial temperature and the moisture content actually increased as the grain cooled. By a simple ventilating system, employing a wind-pressure cowl and a bin wall lining of wire screening, this trouble was corrected.

In the Northern States it is sometimes more difficult to make a bin tight against snow than against rain. Experimental bins at Fargo, N. Dak., that were well built and excluded rain, allowed several inches of snow to blow in on top of the grain in one blizzard. Such snow in a metal bin was observed to melt on a sunny day when the outside temperature was −2° F. The water from slowly melting snow on top of wheat causes an increase in the moisture content of the wheat near the surface. In the spring, water from a melting snowdrift on the south side of a bin may be trapped by unmelted snow farther away, the trapped water running into the joint between the side wall and floor of the bin. To avoid such accidents, all joints in bin walls and roof should be made weathertight; ventilators should be closed in winter months; and the bin should be put on a foundation high enough to give proper drainage from the rain and melting snow.

Surveys of wheat storages in Michigan, Ohio, and Indiana showed that insect infestation was one of the most frequent storage hazards. Wheat from the 1938 crop was found to be infested in about 20, 44, and 50 percent of the storages, respectively, in the progressively warmer climates of Michigan, Ohio, and Indiana. It was also observed that the frequency of insect infestation increased progressively with moisture content of the stored wheat.

On the basis of tests previously made with two types of portable drying machines for wheat, described in last year's report, a modification of one type, in which the grain is heated in a revolving drum and cooled by unheated air, was constructed in a smaller size. It is designed for handling 50 bushels per hour, at which rate it is expected to remove 2 percent of the moisture from wheat containing 16 percent. It is cheaper and simpler than those previously used and is suitable for farms where the quantity of damp wheat is small.

Laboratory work included studies on the relation of atmospheric temperatures and relative humidities to the equilibrium moisture content of wheat. The results showed the minimum moisture contents that can be maintained under particular atmospheric conditions.

GRAIN-SORGHUM STORAGE

In connection with the study of farm storage of grain sorghum, a Bankhead-Jones project in cooperation with other units of this Department and the Kansas Agricultural Experiment Station, inspections were made of farm storages in Kansas and in areas southwest of that State. More than three-fourths of the structures examined had some serious structural defect, such as inadequate foundation, leaky roof, or failure in walls or floor.

Experimental storages were made at Hays, Kans., in tight bins and in different types of ventilated bins. Grain sorghum that contained from 13.5 to 13.9 percent of moisture when put in storage in March 1939 was still in good condition after 8 months of storage, even in a tight bin. Grain sorghum that contained about 17 percent of moisture when put in storage in November 1939 began to heat in a short time and had to be cooled by forcing air through it with a blower. After cooling, it dried very little and became musty in a bin equipped with a small revolving wind-suction cowl drawing air up through a perforated floor and 8 feet of grain. The temperature and moisture content of the grain in the better ventilated bins fluctuated somewhat with changes in condition of the outside air. However, the moisture content of the grain stored in tight and in poorly ventilated bins appeared to be practically unaffected by changes in atmospheric humidity. A difference of 10° F. between atmosphere and grain temperatures appeared to change the temperature of 1,000 bushels of grain stored in a tight metal bin at the rate of about 1° per day.

Certain types of wind-ventilated bins that introduce the air near the center of the mass of grain have kept, without damage, grain sorghums that contained from 1 to 4.3 percent higher moisture content than is safe in present types of bins used on farms under the weather conditions prevailing during the tests. It appears that these bins will greatly reduce the hazard of storing grain sorghum harvested in unfavorable seasons. They will be tried under typical farm conditions during the coming season.

FARM MECHANICAL EQUIPMENT

PEST-CONTROL EQUIPMENT AND METHODS

As a result of the studies on pest-control equipment, improved types of wheelbarrow power sprayers and dusters are now on the market. These have been demonstrated to be practical for controlling the European corn borer on small acreages of sweet corn and they are undoubtedly also suitable for combating pests on other truck crops. Tests with various arrangements of the nozzle on wheelbarrow power sprayers showed that the chances of producing borer-free ears of sweet corn are best when the spray is concentrated in a band along the plants at ear height. Laboratory studies on delivery characteristics of dust nozzles showed that in many cases the poisonous dust is partially separated from the diluents and a uniform mixture is not delivered by the nozzle. Efforts are being made to remedy this condition.

A new type of trash guide, which has advantages over others previously designed by the Bureau, was developed for attaching to the frame of plows to cover cornstalks and other trash better and thus help to control the corn borer. Changes were also made in the self-aligning disk-jointer plow attachment, previously developed for the same purpose. These attachments not only improve plow performance but the changes made in the disk-jointer attachment eliminate breakage of shanks and spindles which heretofore has happened occasionally when working in heavy or hard dry soils and rank trash. With general usage of the improved trash guide and self-aligning disk jointer, control of the European corn borer in fields where plowing is done

would be effected at a cost little more than that of the plowing operation.

The grasshopper-poison-bait distributor developed in cooperation with the Bureau of Entomology and Plant Quarantine was found capable of spreading the desired application of from 15 to 20 pounds of bait per acre at a uniform rate of delivery. When operating at the recommended speed of 10 miles per hour, it had a maximum effective coverage of about 50 acres per hour. More than 1,000 of these poison-bait distributors were put into use in 1939. A low-cost, continuous-flow mixer for preparing poison bait for the spreader was designed and built. Preliminary tests indicated a capacity of over 15 tons per hour with a crew of 4 or 5 men supplying the materials to the machine and sacking the mixture as discharged. The Bureau of Entomology and Plant Quarantine is having 15 mixers built according to this design.

Further experiments on the effects of electric currents of various densities on the living roots of bind weeds showed that electricity holds little promise of becoming an economical weed-control medium.

The forced-draft sulfur burner, previously developed for use in fumigating mushroom houses to control mites, was remodeled to permit the introduction of small amounts of sulfur into the combustion chamber after combustion has started, thereby increasing the concentration of sulfur dioxide in the air, if desired.

FERTILIZER-DISTRIBUTING MACHINERY

During the crop season of 1939 the Bureau participated in 47 cooperative fertilizer-placement experiments at 30 locations in 12 States with 16 different crops, principally for the purpose of determining how fertilizers should be applied to be most effectively used and in what degree the recent types of distributing machines and placement devices meet the known requirements. In the spring of 1940 observations were made of the performance, under actual farming conditions, of several commercial cottonseed planters equipped by the manufacturers with new fertilizer depositing devices designed to obtain the recommended side placement of fertilizer. Some of these machines failed to accomplish the desired purpose, due to various shortcomings.

The information obtained in the fertilizer-distributing-machinery studies has been and is being used by implement manufacturers as a basis for developing improved fertilizer placement equipment. Several improved machines have been recently put on the market. The results are also brought to the attention of farmers to enable them to select suitable machines, or apply fertilizer in other ways, which avoid early injurious effects and permit the greatest possible benefits from the fertilizer to the crop.

CROP-PRODUCTION MACHINERY

Additional studies at the Tillage Machinery Laboratory at Auburn, Ala., on different methods of turning under winter legume crops to increase the yields of cotton showed the advantage of using moldboard or standard disk plows operating at a depth of at least 6 inches. When speed is an important factor it is better to use the vertical disk plow with disks spaced at least 10 inches apart.

Extensive field tests with two new types of commercial moldboard plows, designed especially for abrasive soils of the Southeast, showed an advantage in operating cost over conventional types. The steel shares cost less in the beginning and also retain their shape and suction longer than those commonly used.

In tests with disk plows it was found that, with disks in a vertical position, the draft is doubled when speed is increased from 2½ to 5 miles per hour. The depth to which the disks penetrated the soil decreased with increase in speed. Variations in diameter of disks when cutting the same depth and width had little influence on draft and penetration. Disks having deep concavity penetrate better than those having shallow concavity, but the latter may be operated with a wider range of disk-angle settings and under more varied field conditions. In the Davidson Loam and Norfolk Sand soils, the minimum draft of a disk with a 4⅛-inch concavity was observed at an operating disk-angle of between 40 and 45 degrees; the greatest penetration was obtained with a disk-angle of about 45 degrees. A comparison of drafts of disk plows with those of moldboard plows equipped with rolling colter and jointer showed that the draft per square inch of soil turned is approximately the same with both types of plow, under normal operating conditions.

As a result of the experimental work previously done by the Bureau's engineers on special planters for beet seed, growers of sugar beets were able to buy this year, for the first time, improved planters designed to deposit one seed ball at a time, instead of several (as frequently happens with the usual planter). On account of uniformity of seed spacing a crop planted with this equipment requires from 10 to 20 percent less seed, grows more uniformly and lends itself to more effective blocking, with the result that the amount of tedious "stoop" labor necessary in thinning the crop is greatly reduced. Commercial plantings by this system, made in many parts of the country, have demonstrated its advantages.

Further experiments with mechanical equipment for blocking sugar beets, comparing the effects of different sized blocks and different spacings on the amount of hand labor subsequently required for thinning, showed greater possibilities in that direction than were indicated by the experiments of the previous year. On the basis of data obtained in experiments with various beet-harvesting systems, plans have been drawn for a harvesting scheme which combines some hand labor with machine methods. This seems to be economically sound.

Experiments with sugar beets to determine the shrinkage and sugar losses, during normal storage periods, showed no significant differences in classes of beets (1) when grown largely by use of machinery and (2) when produced with regular hand labor methods. Shrinkage, or loss in weight from drying, averaged 7.9 percent for a storage period of 47 days. In order to minimize sugar loss it is recommended, in general, that the beet pile have good air circulation and be kept as cool as possible without freezing.

Further progress was made in the development of mechanical equipment needed for producing sweetpotatoes on a large scale, and preparing them for storage in dehydrated form. In cooperation with the Mississippi Agricultural Experiment Station, a two-row

transplanter was designed and built at low cost from parts obtainable in most sweetpotato-growing centers. This unit, used in conjunction with a tractor equipped with bedding and fertilizing attachments and operated by a crew of five men, was capable of bedding, fertilizing, and transplanting an acre of sweetpotatoes in an hour. The total number of man-hours required for pulling the plants and setting them by means of this mechanical equipment was less than half of that required for pulling and setting the plants by hand, using water, and substantially less than that required for hand methods, using no water. With mechanical transplanting, the percentage loss of stand was somewhat greater than with transplanting by hand, using water, but was much less than with transplanting by hand, using no water.

An experimental two-row rotary hoe, previously used in cotton culture, was used satisfactorily for the first three cultivations of sweetpotato plants. This was drawn by one mule.

A reconstructed potato digger was used satisfactorily for harvesting sweetpotatoes in a 20-acre field. Fewer sweetpotatoes were lost than by the conventional method of using a middle buster to bring them to the surface.

An experimental drier was constructed and used successfully for drying ground sweetpotatoes. Several mechanical improvements were made in the equipment needed for the commercial production of starch and feed from sweetpotatoes. The most promising development is a variable press which has several pairs of rollers for extracting the juice from ground or chipped and treated sweetpotatoes.

Some changes were noted in the commercial equipment previously built for harvesting and chopping forage crops for silage, although the machines are still in the process of development. Some changes were made in the vertical drag-type elevator built the previous year to elevate field-chopped forage in silo filling.

Two tractors of different size were used in a study of their relative advantages for preparing the seedbed, planting, and cultivating corn. The total labor expenditures in these operations were 2.74 man-hours per acre with a 16–25-horsepower tractor and 5.60 man-hours per acre with a 10–14-horsepower tractor. The small farm tractor, having about 10 horsepower at the drawbar, appears to have sufficient capacity for the average 160-acre farm in the Corn Belt.

New equipment developed for use in connection with corn production included: A self-propelled wagon, which may find application on smaller farms where corn is husked by hand; a left-hand disk jointer for a moldboard plow, which effected a reduction in plow draft of 25 percent under some conditions; and a new type of telescoping wagon tongue, which is stronger and easier to make than any previously designed.

MECHANICAL PROCESSING OF FARM PRODUCTS

GINNING AND PACKING OF COTTON

Cooperative research by this Bureau and Agricultural Marketing Service was continued at Stoneville, Miss., on the problems relating to cotton ginning and the high-density packing of cotton at gins. The latter project is supported by an allotment from the special research fund under the Bankhead-Jones Act.

During the year some 3,000 scientific tests were conducted in the laboratory on ginning, cleaning, extracting, reginning, and conditioning of seed cotton and lint cotton. In addition, about 300 handling tests were made on fan-wheel shapes and designs in connection with fan-speed and pipe-size studies involving mechanical readings. These were made in continuation of the field tests and power surveys previously started on cotton gins in the Mississippi Delta section. Some important bulletins and articles in mimeographed form were released.

Cotton producers and the cotton industry as a whole have been benefited by the cooperative research on cotton processing through the development of improved equipment and practices for drying damp or wet seed cotton, for removing dirt and trash, for efficient and economical ginning, and for packaging cotton with as little damage as possible to the natural qualities of the fiber. Recommendations of the laboratory regarding harvesting, drying, cleaning, extracting, ginning, and packaging of cotton have been widely adopted.

During the past year particular emphasis has been placed on the development of equipment for handling pure seed at cotton gins. Studies showed that on the average each gin is patronized by 160 farmers, many of whom have strains of cottonseed which they desire to recover from the gin for use in reseeding. In order to keep one lot of cottonseed separate from all others, new devices are required for the cleaning out of the gins and seed conveyors before and after each lot is ginned. Considerable progress has been made in the development of such equipment which promises to be very valuable to all cotton growers.

Four types of presses and a specially designed hydraulic pump capable of providing pressures up to 5,550 pounds per square inch for operating the various presses, together with special instruments for accurate observation and recording of conditions and results, were used in the experiments on packaging of cotton. The tests were made in triplicate on lots of cotton which represented a wide range with respect to staple length, moisture content, foreign-matter content, place of growth, and conditioning during ginning. The effects of the method of packing and bale density on the spinning value of the cotton, after various periods of storage, were determined by means of commercial classification and fiber-analysis techniques. This was done by the cooperating agency, the Agricultural Marketing Service. Laboratory spinning tests, now in progress, will provide a check on the results.

Shipping tests indicated that, with regard to protection for the cotton, round bales and high-density gin bales have advantages over bales of the customary type. Bales covered with cotton bagging withstood handling and shipping somewhat better than did bales covered with jute bagging.

A preliminary analysis of costs indicated that a 500-pound rectangular bale package, with a density of about 25 pounds per cubic foot, would have advantages over other types of gin package. Bales of this density are more acceptable to domestic spinners than are bales of high density as prepared for foreign shipment. A press for making a bale of standard size having a density of 25 pounds per cubic foot has been designed and will be built and installed in the laboratory for tests during the coming year.

Field studies at commercial compresses and ginneries with regard to damage to cotton during recompression yielded information on the prevalence of such damage and possible contributing causes, but were not conclusive. Further investigations are needed to solve the problem of eliminating press cutting. Present practices and equipment at both gins and compresses are believed to be responsible for this condition which occurs in about 30 percent of the bales subjected to recompression. Indications are that uneven packing of bales at gins, thought to be one of the causes for press cutting in the compress, can be eliminated by a new design of press dog.

FIBER-FLAX PROCESSING

Research designed to reduce the cost of harvesting and processing fiber flax, which was begun in July 1938, in cooperation with the Bureau of Plant Industry, the State of Oregon, and three cooperative associations of flax growers in that State, is yielding encouraging results.

The only area in the United States where fiber-flax production approaches an industry is the Willamette Valley of Oregon. Growing of flax for fiber was started there many years ago but, although actively promoted by the State, it has never attained the prominence that market, soil, and climatic conditions would seem to justify, largely because the high costs of harvesting and processing have made profits very uncertain. If harvesting and processing equipment and practices can be improved sufficiently to make flax production profitable in Oregon, the industry will undoubtedly expand there and spread to other sections of the United States suitable for fiber flax production. In view of present difficulties in securing either flax or articles manufactured from flax from European sources, it is especially important that everything possible be done to increase the ability of this country to supply at least a part of its requirements for flax fiber.

Except for a number of flax pullers constructed years ago in the Oregon State Penitentiary, fiber-flax harvesting and processing machinery has not been manufactured in the United States. Heretofore the relatively small requirements for processing machinery have been met by importations from Europe. However, in view of disturbed conditions in Europe it may be necessary, in the near future, for flax machinery to be constructed in this country, possibly by local machine shops. In that event, some of the changes in existing machines and designs for new types of machines made by the Bureau's engineers would be useful as guides in the construction of such equipment.

A Belgian-made flax harvester or puller, introduced by the Bureau and used on the 1939 crop, proved to be superior in some respects to the ones in general use in Oregon. This machine was completely overhauled following the 1939 harvest season, and the alterations made seem to have improved its performance, as indicated by tests on small fields of winter flax. Several Belgian pullers have been imported by the State Flax Industry, presumably as a result of findings with the experimental unit. A puller of the type commonly used in Oregon was rebuilt with changes in design and construction. Results of preliminary trials on winter flax indicated that this machine will work satisfactorily if the flax is not lodged.

Observations were made on the performance of two flax deseeders, one an experimental machine designed and constructed by the Bureau and the other a commercial machine imported from Belgium, which were used by two plants in processing the 1939 flax crop. The experimental deseeder had the greater capacity, but the commercial machine had the advantage of combing the root ends, as well as the seed ends, of the flax. On the basis of these observations, a new deseeder was designed and constructed which embodies the desirable features of both, and includes a thresher cylinder of conventional design to recover and clean the seed. This machine is more compact and rugged than either of the other machines. Preliminary trials indicated that it will perform satisfactorily. The first experimental deseeder was overhauled to replace worn parts and was altered to avoid excessive wear.

Tow shakers of the type developed by the Bureau continue to give satisfactory service. The State Flax Industry constructed five of these units for use in its flax-processing plant.

Efforts are being made to design a breaker and scutcher which will produce a minimum quantity of tow, an inferior product, and a maximum quantity of line fiber. Many factors contribute to the formation of tow, which sometimes constitutes as much as 50 percent of the fiber obtained, but machine design is one of the most important. The design of the breaker now under construction is a radical departure from that of breakers in common use, and new ideas are also being applied in the design of the scutcher.

RURAL ELECTRIFICATION RESEARCH

The Bureau of Agricultural Chemistry and Engineering, in cooperation with other units of the Department of Agriculture, State agricultural experiment stations, and some educational institutions, is trying to find ways for using electricity profitably in farming operations, as well as for saving labor and increasing the convenience and comfort of farmhouses. This work is important because electricity is becoming more generally available and less costly in rural areas. Close to 2 million farms now use electricity to some extent.

In studies being conducted on the resettlement farms of the Farm Security Administration at Irwinville, Ga., to determine the possibilities for using electricity profitably on low-income farms, it was found that when farmers want to use electricity they need guidance, even in uses that are quite common. They also need help in making their products acceptable and in finding markets for them if the use of electricity is to net a profit.

Cooperative studies have indicated that it is feasible to heat outdoor chick brooders and pig brooders with electricity. The cost of heating chick brooders with electricity is not so low as heating with oil burners but it is within economical limits and compares favorably because of greater safety and the saving of time. Experiments with electrically heated pig brooders in comparison with unheated farrowing houses showed that a higher percentage of pigs survived when kept in the brooders for a week or more. The pigs also gained weight at a faster rate in the brooders.

Studies on the warming of drinking water for livestock by means of lead-covered electric heating cables indicated that there would be some danger of lead poisoning in the case of soft water and possibly

in the case of moderately hard water. However, it appears that when water has a total hardness equivalent to 80 parts per million or more of calcium carbonate, or when a small quantity of sodium bicarbonate is added to soft water, there is little or no danger of lead poisoning because some of the dissolved substances combine with the lead to form a coating which retards the passing of lead into solution. Further tests are necessary to determine the durability of the coatings. Although there is a diversity of opinion as to the value of warming drinking water for livestock purely on the basis of gain in weight or milk production, many farmers warm the water in order to eliminate the job of chopping ice from the watering troughs or tanks.

Investigations in cooperation with Maryland Agricultural Experiment Station on the lighting of dairy barns with electricity showed not only that most dairy barns are inadequately lighted, but also that, in most cases where dairy barns are illuminated with electricity, farmers are receiving much less than the maximum light obtainable with their equipment. No less than 2 footcandles of light is needed in the feed alleys if feed is weighed at the stanchion. The production of grade A milk is largely dependent upon sanitary conditions in the stables and milking sheds or barns, and upon proper methods of handling the milk. Stringy milk from cows suffering from mastitis cannot be detected in poor light. The light should be sufficient to allow the attendant to tell at a glance if a cow is ailing and permit him to work safely and without waste of time.

The results of the cooperative studies in northeastern Indiana on the use of electric light traps for capturing moths of the European corn borer, mentioned in last year's report, were published in the March 1940 issue of Agricultural Engineering.[6] They indicate definitely the possibility of reducing infestation and perhaps controlling this pest which has already spread to northern Illinois and southern Wisconsin.

A paper on the use of electricity in milk production was presented on the Farm and Home Week program at the University of Georgia, and three papers dealing with rural electrification research were presented at sectional and general meetings of the American Society of Agricultural Engineers. Copies of these are available in mimeographed form. A bulletin on Electric Motors for the Farm is in process of publication.

REGIONAL RESEARCH LABORATORIES

During the past year material progress has been made toward the establishment and organization of the four regional research laboratories authorized by the Agricultural Adjustment Act of 1938. These laboratories are located in the four major farm producing areas as follows: Northern Regional Research Laboratory, Peoria, Ill.; southern laboratory, New Orleans, La.; eastern laboratory, Philadelphia, Pa.; and western laboratory, Albany, Calif. The buildings are nearing completion and equipment has been designed and ordered. All four of the laboratory buildings are of the same general design and basic plan, consisting of three stories and a basement constructed in

[6] FICHT, G. A., HIENTON, T. E., and FORE, J. M. THE USE OF ELECTRIC LIGHT TRAPS IN THE CONTROL OF THE EUROPEAN CORN BORER. Agr. Engin. 21 : 87–89, illus. 1940.

the form of a U. The administrative offices are in the base of the U; the majority of the research laboratories are in one wing; a few research laboratories and the pilot-plant space are in the other wing. Because of the necessity for erecting these buildings out of funds provided by successive annual appropriations, the construction of each was handled in two or more contracts. For the most part, the first contracts covered construction of the office and research-laboratory portions of the buildings, while the second contracts provided for the pilot-plant wings which could, because of the special uses for which they were planned, be completed at a later date without in any way hindering the research. Although somewhat delayed by construction difficulties, three of these buildings will be occupied during the calendar year 1940, and it is anticipated that the other will be ready early in the calendar year 1941.

As soon as the plans and specifications for the buildings and the fixed equipment had been completed, it was necessary to give consideration to the design of laboratory equipment, such as desks, hoods, tables, sinks, etc., as well as other items of special significance. This work has also progressed and the first contract for laboratory equipment was let in June 1940. Special emphasis during the fiscal year 1941 will be laid on providing additional equipment, both standard and special.

While construction of the buildings was in progress it was obviously impossible to do any actual research work in the laboratories themselves, but it was necesary to plan for the assembling of personnel under Civil Service regulations, to plan the research program on the commodities assigned to the laboratories, and to take care of the many details of administration which precede and accompany the establishment of a research project of this magnitude. These things have been done. While, of course, no attempt has been made to procure anything like the full personnel which will eventually be housed in the laboratories, there has been very satisfactory progress in the procurement of competent leaders for the various research projects which will be carried out in these laboratories. Only a few positions among those of greatest importance are still vacant.

The development of a research program is a complicated procedure. Especially in these days of practically country-wide research, it is necessary that a productive research project take cognizance of two important things. The first is the need to attain the objective; knowledge of this need must be based on economic studies of raw material and the possible use of the finished product. The second is all available information on what has been and is being done. Research which duplicates other work is usually a waste of time and funds. Therefore, the first steps in the development of a research project include a literature search, to learn what has already been published on the particular subject, a patent search, and innumerable conferences with directors of outside laboratories in the hope of receiving confidential information regarding the nature of research going on in their respective organizations. The planning of a research project also involves the selection and purchase, or the design and specification, of special equipment which is necessary for the proper prosecution of the activities planned. It is obvious, therefore, that a reasonable number of scientific and clerical workers must be engaged and

put to work some time in advance of the beginning of actual laboratory research. The personnel already employed in the regional laboratories has been occupied on problems in connection with the research planning for many months, and it is anticipated that after completion of construction work on the laboratory buildings, the purchase and installation of the necessary equipment, and the appointment of the full staff, active research will be ready to proceed at once on a wide front.

During the fiscal year 1940 the following additional commodities were assigned to the regional laboratories for investigation: Western Regional Research Laboratory—poultry products and byproducts; Eastern Regional Research Laboratory—animal fats and oils; hides, skins, tanning materials and leather (transferred from the former Industrial Farm Products Research Division in Washington).

The foregoing statement gives some idea of the work which has been done on the regional laboratories project during the fiscal year 1940. While not completely satisfactory, excellent results have been obtained, and it is anticipated that active research will be well under way in at least three of the four laboratories early in the calendar year 1941.

INFORMATION AND PUBLICATIONS

The Bureau published 1 Technical Bulletin, 2 new Circulars, 1 revised Circular, 2 Miscellaneous Publications, 1 Farmers' Bulletin, 6 articles in the Journal of Agricultural Research, 2 Leaflets, 4 Yearbook articles, 1 article in Extension Service Review, 1 annual report, 44 mimeographed publications, and 174 articles in outside journals and proceedings. The Bureau also furnished information on various phases of its research through the press and radio services of the Department.

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

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

LIST OF PUBLICATIONS

FOOD RESEARCH DIVISION

Preserving the dietetic value of frozen foods. By E. M. Chace. Amer. Dietet. Assoc. Jour. 16 (1) : 34–38. 1940.

Preservation of fruits and vegetables by freezing. By D. G. Sorber. Ann. School for Canning Crop Growers and Fieldmen Proc. 4 : 14–16. 1940.

The preparation of frozen fruit pulps and their use in ice cream and related products. By D. G. Sorber. Ann. Conv. Internatl. Assoc. Ice Cream Mfrs. Proc. 2 : 7–15. 1939.

The use of ethylene in the walnut harvest. By D. G. Sorber. Diamond Walnut News 21 (5) : 10–12, 14. 1939.

A proteolytic enzyme of lima bean (*Phaseolus lunatus* L.). By Ward B. Davis. Food Res. 4 (6) : 613–619. 1939.

A substitute for the laboratory food grinder. By W. B. Davis. Indus. and Engin. Chem., News Ed. 17 (23) : 752. 1939.

Drying method changes composition of grapefruit by product. By George N. Pulley and Harry W. von Loesecke. Food Indus. 12 (6) : 62–63, 100–101. 1940.

Gases in the commercial handling of citrus juices. By G. N. Pulley and H. W. von Loesecke. Indus. and Engin. Chem. 31 (10) : 1275–1278. 1939.

Possibilities of preparing lactic acid from grapefruit juice. By Arthur J. Nolte and Harry W. von Loesecke. Fruit Prod. Jour. and Amer. Vinegar Indus. 19 (7) : 204–205, 216–217, 220. 1940.

Types of organisms surviving in commercially pasteurized citrus juices in Florida. By Arthur J. Nolte and Harry W. von Loesecke. Food Res. 5 (1) : 73–81. 1940.

Enzymic preparation of d-galacturonic acid. By H. H. Mottern and H. L. Cole. Amer. Chem. Soc. Jour. 61 (10) : 2701–2702. 1939.

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Strawberry vitamin C content—Notes by the United States Frozen Pack Laboratory on the survival of vitamin C in frozen strawberries after a long period of storage at 15° Fahrenheit. By William Rabak. West. Canner and Packer. 31 (13) : 49. 1939.

Freezing studies with new bramble varieties and selections, 1937–1938 progress report. By E. H. Wiegand, C. F. Waldo, and H. C. Diehl. ACE–32 (Mimeographed.) 1940.

Nature of a yellow deposit in jars of home-canned green asparagus. By Horace Campbell. Food Res. 4 (4): 397–399. 1939.

Frozen food in relation to the farm. By Horace Campbell. Ann. Proc. Idaho Com. on the Relation of Electricity to Agriculture, 1939. April 1940.

Utilization of crops by canning, freezing, drying investigated. By J. L. Heid. Mission Times. 31 (15): 1, 5 (sect. 6); Fruits and vegetables in the Rio Grande Valley. Canner 90 (18): 13–14. 1940.

Freezing fruits and vegetables in the southwest. By J. L. Heid. Refrig. Engin. 38 (5): 286–288. 1939.

The utilization of fruits and vegetables in the Rio Grande Valley. By J. L. Heid. ACE–30 (Mimeographed). 1940.

Losses in making hay and silage. By J. A. LeClerc. U. S. Dept. Agr. Yearbook Separate 1721 pp. 992–1016. 1939.

Development and use of baking powder and baking chemicals. By L. H. Bailey. U. S. Dept. Agr. Cir. 138. (Revised May 1940.)

Effect of storage temperatures upon the viability and baking properties of compressed yeast. By L. H. Bailey, M. T. Bartram, and S. C. Rowe. Cereal Chem. 17 (1): 55–66. 1940.

Hydrolytic treatment of cottonseed hulls. By W. H. Baldwin and J. A. LeClerc. Oil and Soap 16 (9): 178–180. 1939.

Fresh, frozen, and dried eggs and egg products (their uses in baking and for other purposes). By J. A. LeClerc and L. H. Bailey. Cereal Chem. 17 (3): 279–312. 1940.

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The preparation and bacteriological examination of fruit juices. By Harry E. Goresline. 6th Proc. Internatl. Cong. Compt. Rend. 1: 94–100. 1939.

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Cooperative research on fruit juices at Geneva, New York. By Carl S. Pederson, E. A. Beavens, and D. K. Tressler. Fruit Prod. Jour. and Amer. Vinegar Indus. 18 (11): 330–331. 1939. (With N. Y. State Agr. Expt. Sta.)

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The incidence of yeasts in cucumber fermentations. (Abstract.) By John L. Etchells. Fruit Prod. Jour. and Amer. Vinegar Indus. 19 (7): 212. 1940.

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Some observations on the colorimetric method for vanillin. By A. L. Curl and E. K. Nelson. Assoc. Off. Agr. Chem. Jour. 22: 684–688. 1939.

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The synergistic action of thyroid on fluorine toxicity. By Robert H. Wilson and Floyd DeEds. Endocrinology 26 (5): 851–856. 1940.

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