Education and Research—Partners in the University

We have spoken of the university as the place for the generation of new knowledge, and have minimized its educational function. The two functions are truly inseparable. The university is an institution in which circumstances are arranged so that young people learn how to make new knowledge by working in apprenticeship with creative investigators who already know how to do so. Education is almost a by-product of the university. The university, in our society, is the self-renewing center for the creative solution of mankind's problems.

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WORLD-WIDE RESEARCH

Role of State Agricultural Experiment Stations in Agricultural Chemical Research

MARK T. BUCHANAN
Washington State University, Pullman, Wash.

Experience shows that state experiment stations have the technical competence and facilities to contribute significantly to chemical and utilization research. The stations, USDA, and private laboratories sometimes use similar approaches. However, professional intercourse, literature review, cooperative planning, and listings with the Science Information Exchange keep the programs complementary rather than competitive. The most nearly unique features of experiment stations' activities include emphasis on basic research at numerous dispersed locations, regional research, cooperation among chemists and scientists in other disciplines in the same university, and the combined teaching and research function.

STATE AGRICULTURAL EXPERIMENT STATIONS, as part of the land-grant university system, are responsible for agricultural research, much of which involves chemistry. Most agricultural scientists are a specialized form of biologist, physical scientist, or social scientist, and even agricultural economists use chemical research results—e.g., when determining the most efficient feed or fertilizer alternative.

Owing to the current interest in research directed to discovery of new and improved food, feed, and industrial uses for agricultural commodities, and to the importance of chemical research in this program, this discussion will be limited to those phases in which chemical research may be related to improving the utilization of agricultural products. Such research is in progress at all 53 stations.

Station chemical research plays a key role in facilitating understanding of the basic properties of agricultural products, in developing new products, and in improving present products. This program, while designed to serve agriculture, serves the total economy by supplying industrialists with new opportunities for investment and with trained personnel, labor with additional employment, farmers with new sources of revenue, and consumers with new and better products. Much of the current work is quite fundamental. As a by-product, additions to the storehouse of knowledge of basic chemical and biochemical phenomena accrue to the benefit of current and future generations. The research program is documented with the Science Information Exchange.

Scope of Program

About $12.3 million are expended on utilization research by the state agricultural experiment stations. This amount represents about 7% of the total funds expended in support of their agricultural research programs.

Additional information on the scope of the station's utilization and utilization-related research program is in Table I. Table I reveals that in 1964 a total of 471.6 professional man-years of research time was devoted to utilization research on the various commodities. The distribution of research effort among commodity groups provides further insight into the nature of the program and the relative emphasis given various phases. For example, the man-years devoted to research on fruits, vegetables, poultry, dairy, and animal products illustrates the major emphasis which is being given food uses investigations.

Comparisons of these data for fiscal 1964 with similar data for fiscal 1963 reveal an increase of 30.3 professional man-years for fiscal 1964. This increase in support for utilization research continues the trend of recent years and reflects the increasing attention being given this field of research.

Centers of competence exist in the many station agricultural chemistry and biochemistry departments and in more than 20 departments of food science and technology. An Institute for Utilization Research has been organized at the Indiana station to bring together an

Table I. Utilization Research Conducted at State Agricultural Experiment Stations, Fiscal Year 1964

Commodity Group	Professional Man-Years[a]
Cereal and forage crops	47.0
Cotton, wool and other fibers	13.7
Fruits and vegetables	133.0
Oilseeds	14.6
Poultry, dairy and animal products	185.4
New and special plants	38.1
Forestry	39.8
Total	471.6

[a] Professional man-year calculations based on $26,000 per professional man-year.

outstanding collection of scientists with diverse technical backgrounds to attack utilization problems. This group is led by R. L. Whistler, an international authority on carbohydrate chemistry. Stations with more than 20 professional man-years devoted to research on utilization in 1963 included California, Florida, Oregon, and Wisconsin. At these stations, 84% of the program was supported from nonfederal grant funds. The average support for all stations was 55% from nonfederal and 45% from federal grant funds.

Chemical and Biochemical Studies

Much of the fundamental chemistry research in progress at agricultural experiment stations has a present or probable bearing on utilization research objectives. Our Washington Agricultural Experiment Station scientists are expanding research relating to new crops and to the discovery of the chemical and biochemical properties of agricultural products. Our agricultural chemistry group is developing basic information about protein chemistry, metabolism of various compounds, and agricultural chemicals (pesticides). Fundamental information on the chemical and physical composition and properties of agricultural materials is being accumulated. A few examples of work at the Washington Agricultural Experiment Station may be of interest, although the impact of this research cannot be foretold.

Protein Chemistry. The field of protein chemistry has presented some of the most fundamental questions of biochemistry to research workers in recent years. One of the problems being studied by our chemists concerns the nature of pea proteins and changes in them and related nitrogenous compounds during seedling growth.

The nitrogenous compounds in peas and pea seedlings are many and varied. Attempts to utilize them will be furthered by increased basic knowledge about their nature and occurrence. Most of the nitrogen in the mature seed is in the form of proteins, and some of the more important of these, the globulins, have been studied in detail. Use of the most powerful protein separation technique, gel electrophoresis, has confirmed that there are only two globulins. End group analysis has shown that each is made up of several peptide chains and is subject to change by association and dissociation under conditions of alkalinity, or presence of detergents and other dissociating reagents.

The seed proteins act as reserve food for the seedling. When the seed germinates, proteins are broken down to amino acids and amides, which are interconverted to form the right combination of building blocks for the new seedling proteins. Current studies show unusually high concentration of free amino acids in the shafts of roots and shoots of young pea seedlings—one quarter of the total dry weight of the tissue. Much of this accumulation is represented by the rarely occurring amino acid, homoserine. In fact, nearly 12% of the dry weight of the root and shoot shaft tissue of the 5-day seedling is homoserine. A number of other unusual amino acids were found in comparatively small amounts.

Present research centers on the function of homoserine in the seedling metabolism and the mechanism of its formation (*5, 6*).

Flood Flavor Research. Since man first became aware of the possibility of improving the taste of his food, scientists the world over have been striving to make our food more palatable. Volatile food constituents that serve as taste and odor stimuli also have biological importance in that they frequently determine whether foods will be accepted and eaten. With the development of new and more sophisticated instrumentation for chemically measuring flavors and odors, the problem of defining food flavors is being actively researched. The ultimate goal of this research is to identify the compounds responsible for the characteristic flavor and odor of foodstuff and to determine the mechanism of their production and preservation.

Food flavor research is in progress at a number of the state stations. The Washington station has worked hard to identify and characterize the typical flavor of lamb. Chemical, physical, and sensory techniques of identification have been used to investigate the components of flavor of fresh and cooked lamb and mutton.

Components of lamb flavor have been studied in the volatile and water-soluble fractions. In the volatile materials from roasting lamb, carbonyl compounds were important contributors to aroma. These components were further investigated by precipitation as 2,4-dinitrophenylhydrazones from vapors of simmering lamb. The 2,4-DNPHs were separated by column chromatography and characterized by infrared and melting-point analysis.

Monocarbonyls present were identified as *n*-alkanals of 2- to 10-carbon atoms, 2-alkanones of 5- to 10-carbon atoms, and possibly 2-methylcyclopentanone. Polycarbonyls are undergoing fractionation and identification. Carbonyls collected from simmering lamb were saturated compounds.

Water-soluble compounds of raw and cooked lamb were separated by dialysis and ion exchange. These included glucose, fructose, and inositol, and 19 amino-containing components. Among three breeds of sheep (Southdown, Hampshire, and Columbia), no differences were evident in analyses of volatile or soluble components (*4*).

In 1963, Hall was able to detect a difference in flavor between chicken and turkey meat in water extracts and dialyzates prepared from roasted meat. In this same study, flavor components or "notes" which were common to chicken and turkey were described. Among the more prominent of these notes were meaty, brothy, sour, and bitter components (*7*).

Work with other species has provided descriptions of the taste of inosine-5'-monophosphate (IMP) as salty-acid flavor with a strong overtone described as meaty-extract. The degradation products of IMP, inosine and hypoxanthine, were described as having a bitter taste.

Because differences in the intensity of the meatiness were recognized between chicken and turkey, studies of the role of IMP, its precursors ATP, ADP, and AMP, as well as its degradation products were undertaken.

Paper chromatographic techniques were developed which gave good quantitative separations of these compounds. There were no differences between chicken and turkey *Biceps femoris* muscles for any of the compounds being studied immediately after slaughter (4 to $4^1/_2$ minutes) or after 1, 3, 5, or 7 days' storage at 1° C. The most interesting finding was that there was an almost complete conversion of ATP, ADP, and AMP and IMP by one day of storage. This conversion may explain the increase in flavor intensity of 3-day-old chicken carcasses as compared with freshly slaughtered carcasses. An attempt will now be made to relate these chemical findings to taste panel determinations using fractions from the same chickens (*2, 3*).

Regional Research. Starch is the major constituent of our nation's great cereal crops, corn and wheat. Starch has film-forming, adhesive, coating, sizing, and other properties that can be specifically modified to fit a variety of uses. Many opportunities for expanded use are thought to exist in the paper, textiles, plastics, building materials, and chemical industries.

State stations conduct a continuing program of basic research on the chemistry of cereal starches. An understanding of the structure of complex carbohydrates and the mechanism of their function and breakdown is sought. Starch granules are treated with enzymes, salt solutions, specific solvents, and chemical reactants to determine in great detail the microstructure and reactability of starch granules. Starches with unique properties, such as that obtained from high amylose corn, receive careful study.

One regional project, NC-60, is directed to the modification of starch for industrial uses. Participating states are seeking to: determine the fundamental reactions in the nonenzymatic dextrinization of starch; investigate chemical polymerization of D-glucose derivatives for the production of new types of synthetic polymers; determine the mode of action of oxidants on starch; modify the basic structure of the D-glucose units in starch; discover enzymatic reactions that can modify starch and the effect of structural characteristics of starch on the action of enzymes; and develop methods by which nitrogen can be chemically attached to starch.

This regional study has been under way for about a year and a half. Results to date indicate that valuable information is accruing concerning the effect of gelatinization on starch, amino starch derivatives, starch dextrins, and the chemistry of the industrial carbohydrates used for degrading starch and upgrading starch degradation products.

Scientists of six stations are actively participating in achieving the objectives of this project. In addition, representatives of six other North Central states and of the United States Department of Agriculture are cooperating in the planning and coordination of this project. This is made possible by the use of Regional Research Funds and the regional concept which permits two or more states to pool their resources to solve a common problem. In all, about 200 regional projects have been developed and are in progress under this plan.

New Crops. One of the main objectives of the research program on new crops is to find new and different plant species which will provide new sources of industrial chemicals and which can be grown profitably on land now producing surplus crops. To replace successfully crops now in oversupply, a new crop must offer definite advantages for large scale use, especially for industrial purposes.

High amylose corn is a promising new crop. The best example of a crop relatively new to the United States is the soybean. Soybean acreage in the United States has increased by about 30 times during the past 30 years. Soybeans attained their present importance when chemical analysis and characterization of soybean oil indicated its value, both as a food oil and as an industrial raw material for the chemical process industries.

Since World War II even greater effort has been made in the search for new crops. Four regional projects, one in each of the four geographic regions, facilitate the location and introduction of new plant materials. New pharmaceuticals or botanicals, new sources of tannin, guar, and seed oils, with specific properties are sought. In the case of the seed oils, research chemists seek variations in the fatty acid composition, in chain lengths, degree of unsaturation, ring structures, and oxygen function which will lead to new or special industrial uses.

The effort to develop new crops involves three-way cooperation among the state agricultural experiment stations, the New Crops Research Branch, and the Utilization Research and Development Division of ARS. The New Crops Research Branch cooperates in procurement of materials. The Utilization Divisions participate in chemically screening the new plant materials to determine the content of potentially valuable substances; and state stations evaluate and determine the potential, cultural adaptation, and economic possibilities of promising species. Once these are determined, the introduced species are improved via extensive plant breeding and related programs. Safflower, sesame, and castor beans are examples of recent new crops which have attained some commercial importance. The estimated acreages in production are: safflower 500,000 acres; castor beans 50,000 acres; and sesame 10,000 acres.

Agricultural Chemicals. Agricultural chemists play a significant role in the production, processing, packaging, and distribution of our food and fiber supply. Great strides have been made in the past 50 years, partly as a result of the use of many chemical substances in support of the entire pattern of food production, processing, and preservation, and health and sanitation. These have included: chemical fertilizers, insecticides, herbicides, antibiotics, preservatives, fungicides, growth regulators, nematocides, and nutritional supplements.

Paralleling these modern developments in the use of chemicals have been developments in safeguarding the purity of our food and water supplies and in recognition of the responsibility for public health and welfare. Despite these developments, there is a great deal of confusion and misinformation about the use of chemicals in agriculture. The current concern over pesticide residues and their effects on fish and wildlife is a case in point.

Within the Washington station, the persistence of agricultural chemicals in the soil is a matter of much concern and is another of the fields being actively studied. Residues may persist in plant material, not only as the original materials applied, but as degradation products which may or may not be biologically active.

We have in particular studied the reactions of organic phosphates. Residue data have been determined on dozens of crops and chemical combinations to establish residue tolerances and to determine whether or not existing control measures are within the limits of safety. This is a field of continuous endeavor, since new chemicals and new uses for older chemicals are constantly being found. Bioassay procedures are developed. Radioactive isotopes are used in synthesizing and studying the metabolism of specific compounds.

Extensive field experiments are also carried out to determine the effect of growth on chemical retention. Toxicity curves are established. Participation and cooperation with other state and federal agencies are maintained to maximize knowledge and understanding of safe use (*7*).

Teams of scientists representing a number of disciplines can be readily assembled by stations. Even when large groups of scientists or large pilot plant facilities are unavailable, stations have a number of scientists on their own and in the university staffs with knowledge and interest in fundamental chemistry which may ultimately find application in utilization research. Station scientists represent a broad base or "reservoir for ideas" for utilization research. In addition, much of the graduate research affords training and develops scientists for employment in chemical research.

Certain differences in concept, approach, and responsibility of state stations and the United States Department of Agriculture should be noted in relation to utilization research. Station scientists are dispersed at many locations. This dispersion provides a geographic distribution of competence in basic science close to the source of problems. In contrast, the regional laboratories of the Department of Agriculture provide centralized facilities and equipment for a concentrated attack by a group of scientists on major problems of regional or national significance. Industrial uses are emphasized, and pilot plant facilities permit developmental operations and studies.

These programs are complementary. Despite the somewhat different approaches, there are mutual interest and concern for expanding uses of agricultural products through agricultural chemical research.

The work in private laboratories also can have major consequences, both for agriculture and for its customers. The development of synthetic fabrics by industrial chemists, for example, gave us valuable new products. It also gave wool and cotton producers a scare. However, the new products were more than a threat—they provided stimulating competition. U. S. Department of Agriculture research produced striking improvements in cotton and wool textiles. The decline in per capita consumption of cotton and wool seems to have been checked and consumers have textiles that combine the merits of the natural fabrics with many of the advantages of the synthetics (*8*).

University and Station Role in Training

The land-grant college system, concept, and idea now represent more than 100 years of experience in higher education and research. It is based upon the idea that progress or advancement is most likely to come by increased educational opportunity and by advancement of science through investigation and experiment.

The Hatch Experiment Station Act provided for participation with the U. S. federal Department of Agriculture in a nationwide agricultural research program. This act, as amended, has assisted in the establishment and maintenance of an agricultural experiment station in each state. It is recognized, I believe, as providing the first system of institutional grants. Through the years, the partnership between the states and the USDA has stimulated cooperative research. Technological developments in agriculture stemming from research in the USDA and state stations and education in the land-grant institutions have done much to enable us to attain the high standards of living we enjoy today.

The role of the land-grant institutions in the education of undergraduate and graduate students has been of great significance. Such education has helped provide trained scientists for the chemical industries, government, state, and private laboratories. Graduate students also have made significant contributions as research assistants.

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WORLD-WIDE RESEARCH

Expanding the Use of Farm Products

F. R. SENTI and G. W. IRVING, Jr.

Agricultural Research Service, U. S. Department of Agriculture, Washington, D. C.

Research in chemistry and allied sciences has contributed much to the development of new or improved food and industrial products from farm crops. Such research is being conducted more in the United States than elsewhere, undoubtedly because of our plentiful supply of agricultural materials, but other countries are awakening to its need and value. In the United States, the major stimulus on problems of national or regional importance is provided by USDA, primarily through the four Regional Research Laboratories, which began operations in 1941 when surplus crops were becoming an increasingly important problem in the agricultural economy. The in-house research at the Regional Laboratories is supplemented by a sizable domestic contract program; additionally, important results are being obtained under a program of grants to foreign institutions. The presentation reviews some of the accomplishments of USDA's utilization research program and some of the problems currently being attacked.

In this symposium, papers presented by scientists representing laboratories here and abroad, on widely varied subjects, illustrate the diversity of present-day agricultural chemistry, and emphasize the fact that many of the world's outstanding scientists are now engaged in such research. Agricultural chemistry is no longer a pursuit where simple analyses for nitrogen, phosphorus, potash, and crude fiber constitute a significant part of the agricultural chemist's daily work. It is a discipline where the best of organic chemists, biochemists, and physical chemists utilize and develop the most modern of techniques to increase our information concerning agricultural products, their production, and their use.

Since much of the work described is being done under support by the Department of Agriculture or with its collaboration, it is fitting to provide more detail concerning that part of the Department of Agriculture—the Utilization Research and Development Divisions—which is primarily concerned with the kind of agricultural chemistry discussed in this symposium.

The current USDA utilization research program began with the establishment of four Regional Laboratories, beginning in 1941, in Peoria, Ill., New Orleans, La., Philadelphia, Pa., and Albany, Calif. A fifth Regional Laboratory will be constructed at Athens, Ga., to provide for concerted research on the principal agricultural commodities of the Southeast. In addition, there are 10 associated field stations, and a sizable domestic program of contracts and grants in which utilization research is conducted at other institutions.

Currently, about 1000 scientists and an equal number of supporting per-