ENGINEERING RESEARCH
at the
EASTERN UTILIZATION RESEARCH
and
DEVELOPMENT DIVISION

A
25th Anniversary
Review

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ABSTRACT

Some of the outstanding developments of the Engineering and Development Laboratory during its first 25 years are reviewed. The facilities of the Laboratory are briefly described, and a summary is given of the development of such food products as potato flakes and flakelets, pumpkin powder, fruit essences and juice concentrates, powdered fruit juices, dried honey, dehydrated fruit and vegetable pieces capable of rapid rehydration, and vacuum-foam-dried whole milk; and such nonfood products and processes as tannin from canaigre, rutin from buckwheat, low-temperature fractionation of animal fats, and natural rubber from Russian dandelion.

ompany names are included for the benefit of the reader and do not infer any endorsement or preferential treatment of the products listed by the U. S. Department of Agriculture.

A report of work done at the

EASTERN UTILIZATION RESEARCH AND DEVELOPMENT DIVISION

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ENGINEERING RESEARCH AT THE

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A 25th Anniversary Review

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As a vistor enters the lobby of the United States Department of Agriculture's Eastern Utilization Research and Development Division in Wyndmoor, Pennsylvania, (figure 1) he encounters a large sign: "Utilization research seeks expanded uses for farm products, primarily those in surplus." In a nutshell, this has been the objective of the four Regional Divisions since they were established about 25 years ago. Each Division engages in both basic and applied research. In order that research can also be done on a pilot plant scale and in a manner to permit extrapolation to commercial use, each Division includes an Engineering and Development Laboratory (figure 2). This booklet tells something of what chemical engineering is and how research in that field at the Eastern Division has contributed to "expanded uses for farm products."

The basic disciplines of chemical engineering are chemistry, physics, and mathematics, and economics is its guide. The function of the Engineering and Development Laboratory is to evalutate the technical and economic feasibility of processes originating in any of the Laboratories in the Eastern Division. Many of these processes originate with the engineers themselves. Pilot plant research is conducted by chemical engineers using such equipment and scale of operation as are necessary to provide essential data from which design criteria can be established.

Figure 1. Headquarters of the Eastern Utilization Research and Development Division in Wyndmoor, Pennsylvania, a suburb of Philadelphia.

*Deceased

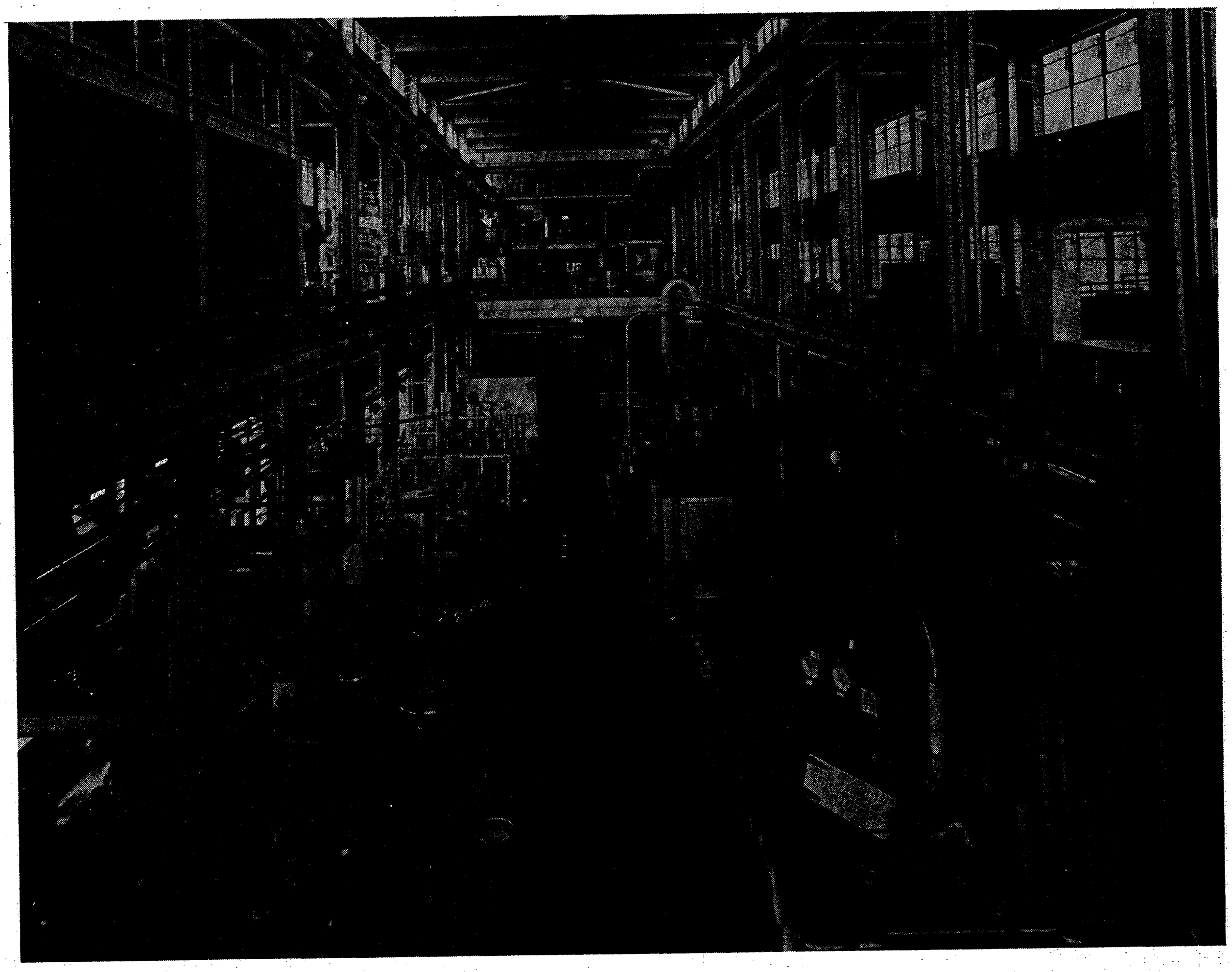


Figure 2. General view of the pilot-plant area of the Engineering and Development Laboratory of the Eastern Division.

These are used for projection of operations to semi-works or plant scale and for estimating commercial costs. The Laboratory also cooperates with industry to further commercial adoption of new processes.

This research is complemented by that of analytical chemists, a food technologist, a cost analyst, a mechanical engineer, and a bacteriologist on the Laboratory staff. The organization of the Laboratory is shown in figure 3 and its staff in figure 4.

The Engineering and Development Laboratory provides engineering counsel to other Laboratories of the Division and may prepare process cost estimates at various stages of a development to aid in evaluating the desirability of continued research.

The commodities assigned to the Eastern Division are fruits, vegetables, meat, dairy products, animal fats, tanning material leather, and tobacco. It is at once apparent that because of their nature, their high water content and high commodity cost many of these can only be used economically as food. Thus much of the engineering work at the Eastern Division is devoted to food process research and development, especially in converting perishable commodities to stable and convenient forms.

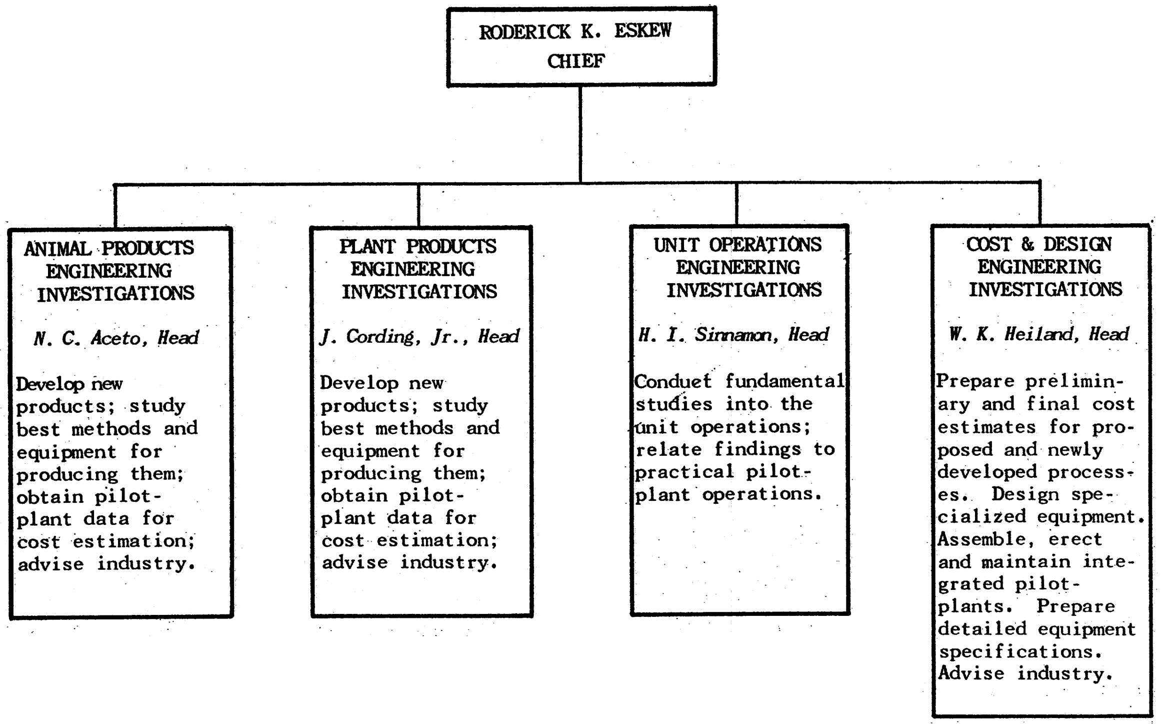


Figure 3. Organization chart of Engineering and Development Laboratory.

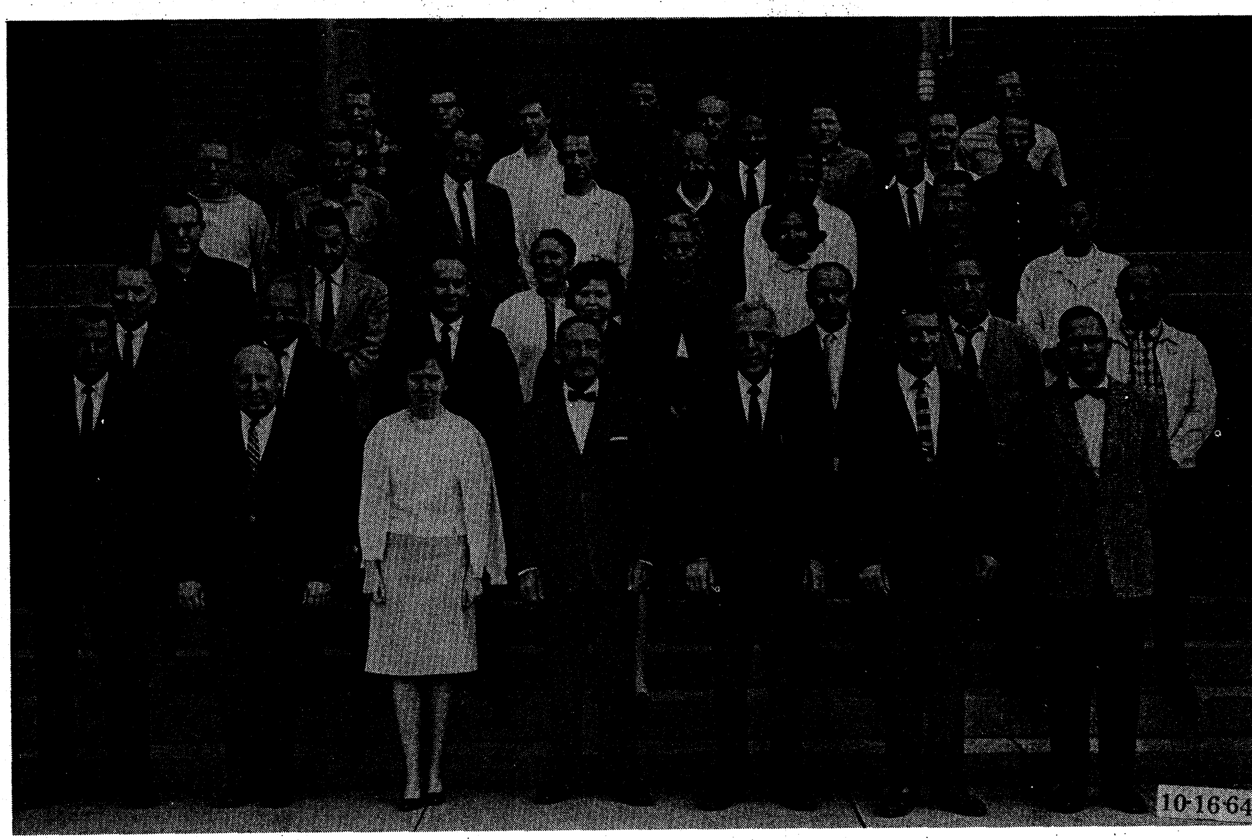


Figure 4. Engineering and Development Laboratory staff (October 16, 1964).

In applying chemical engineering principles to food process development, certain peculiarities of the raw material and the end uses for the products must be considered. Agricultural commodities vary in composition and supply, both seasonally and geographically. Many are either perishable or tend to change chemically in storage. Many are living tissues with complex enzyme systems. Frequently their chief component is water; important flavor components, for instance, may be present only to the extent of a few parts per million. In processing, their appearance, texture, flavor, and nutrient value must be preserved as far as possible. Because of the high water content of many of the commodities and current emphasis on stability and convenience of processed foods, evaporation and drying as well as fluid flow and heat transfer are common unit operations.

In applying the principles of chemical engineering to food process development it is necessary to temper the relatively exact nature of that discipline with consideration for the unpredictable nature of agricultural raw materials. Food processing is still something of an art. Successful engineering research in this field requires a knowledge of that art as well as the technology of foods and some conversance with biochemistry.

In spite of the sophisticated analytical tools used in the laboratory for food evaluation, the most perceptive for detecting flavor, the characteristic that is basic for consumer acceptability, is the human tongue. Food products of the Engineering and Development Laboratory are prepared as they would be in the home and subjected to controlled taste-testing in a specially designed food appraisal laboratory (figure 5). The tasting is done by panels of Eastern Division personnel selected for taste acuity and carefully trained to identify specific flavors and off-flavors in food products.

There follow some examples of processes which originated through engineering research. These were developed in the pilot plant and the cost was evaluated by the Engineering and Development Laboratory. Some have become of commercial importance, others are in the process of adoption by industry, and some are in the early stages of pilot plant research.

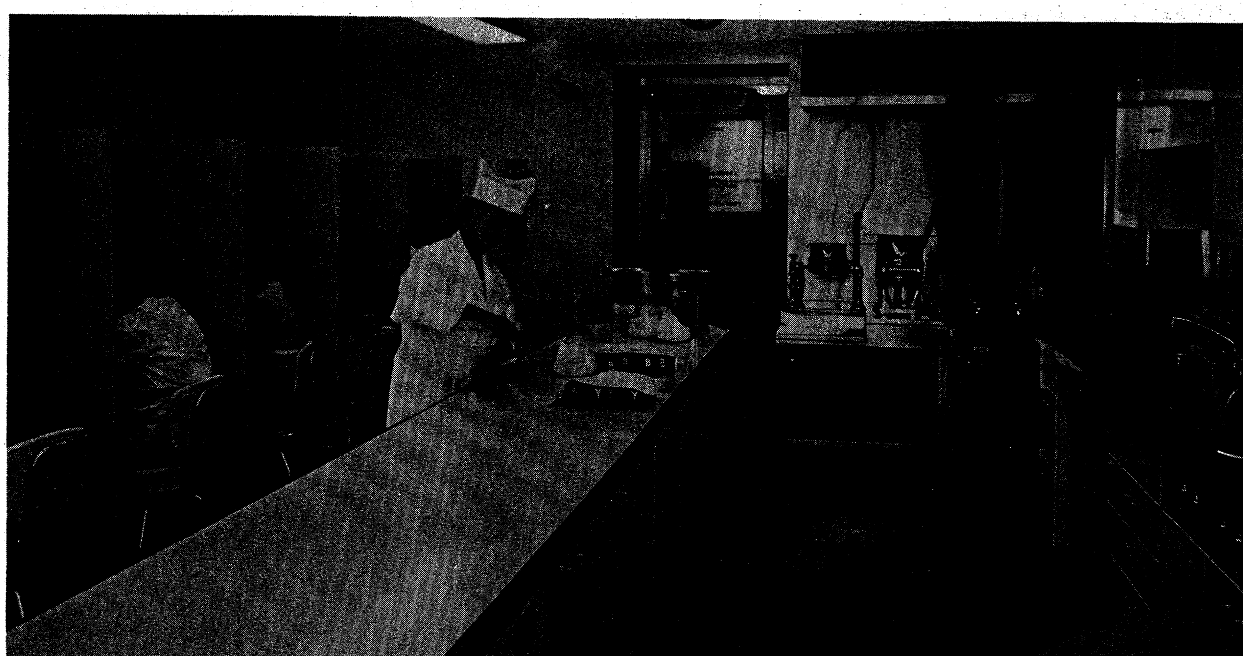


Figure 5. Taste testing at the Engineering and Development Laboratory. Trained tasters critically evaluate new food products developed through research.

Potato Flakes

Potato flakes, a new kind of dehydrated mashed potatoes, were developed through engineering research on the drum drying of food products (figure 6). Today, 7 years after their commercial introduction 17 plants are producing flakes with a combined capacity of at least 75 million pounds annually (figures 7 and 8).

It has been estimated that the entire cost of this development was less than $350, 000. The wholesale value of flakes made since production started in 1958 is estimated to be over $150, 000, 000.

Processing is comparatively simple. Potatoes are first washed, peeled, trimmed, and cut into 1/2-inch slices. The slices are precooked in water at 160 degrees F. for 20 minutes and then immersed in cold water for about the same length of time. They are then steamed long enough to permit ricing, and additives to preserve flavor and improve texture are incorporated into the mash. The mash is then applied to the surface of a steam-heated drum and dried to a parchment-like sheet that is broken up into 1/2-inch square pieces, or flakes. The flakes are usually packed in air-tight foil envelopes or boxes to preserve flavor. Retail packages contain 5-1/2 to 7 ounces of flakes--enough to make 8 servings of mashed potatoes.

The discovery that mashed potatoes can be drum dried without impairment of flavor or texture marked a significant advance in food technology. Later work developed the principles of precooking, cooling, and addition of monoglycerides to improve texture. Application of these principles permitted flakes to be made from low-solids as well high-solids potatoes, and thus made most of the potato crop suitable for processing into flakes. In addition, these principles had a wide applicability in many other food-processing operations. In recognition of this research, the Institute of Food Technology presented in May 1959 its first Food Technology Industrial Achievement Award to the Eastern Utilization Research and Development Division and the three chemical engieers directly responsible for the process. The award cited the origination, development, and industrial advancement of potato flakes and the process for making them, as well as the research leading to texture control.

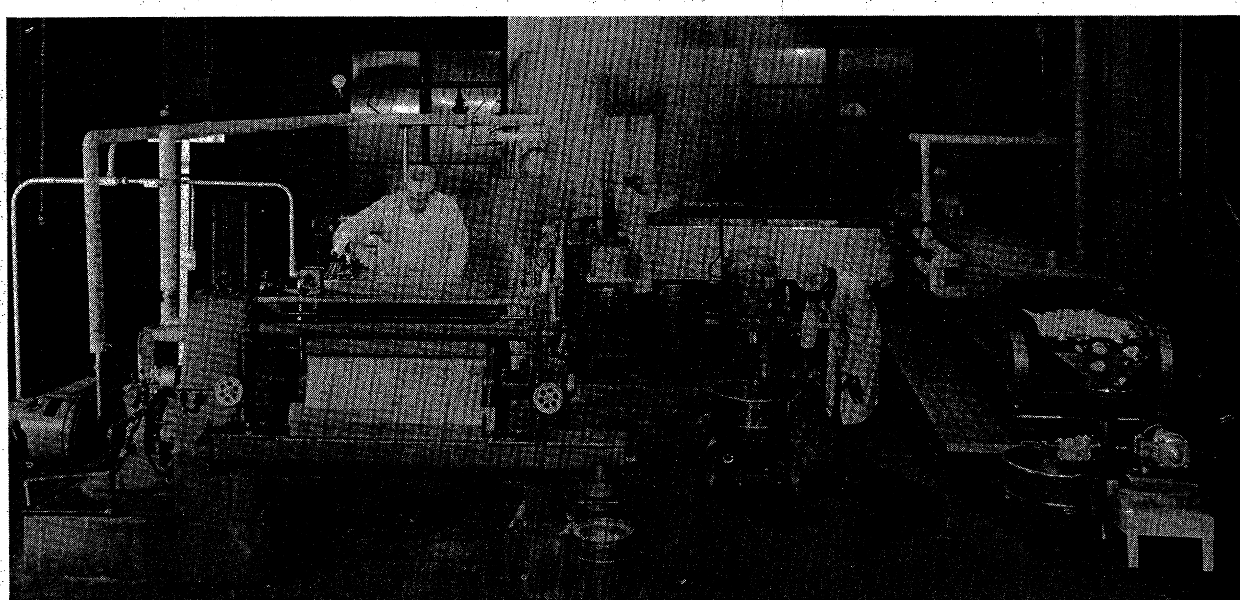


Figure 6. Integrated pilot plant used in developing the process for making potato flakes. The unit has a capacity of 30 pounds per hour of product. More than ten carloads of potatoes were processed here in the course of research and in preparing material for cooperative market tests.

Potato flakes are a nutritious food. About 75 percent of the vitamin C in potatoes, their most important vitamin, is retained in flakes--more than is often present in fresh potatoes after storage. Flakes can be further enriched by adding vitamin C and niacin and by fortifying with vitamins A and B_2, all of which are well retained. (See references 1-16 at the end of this report.)

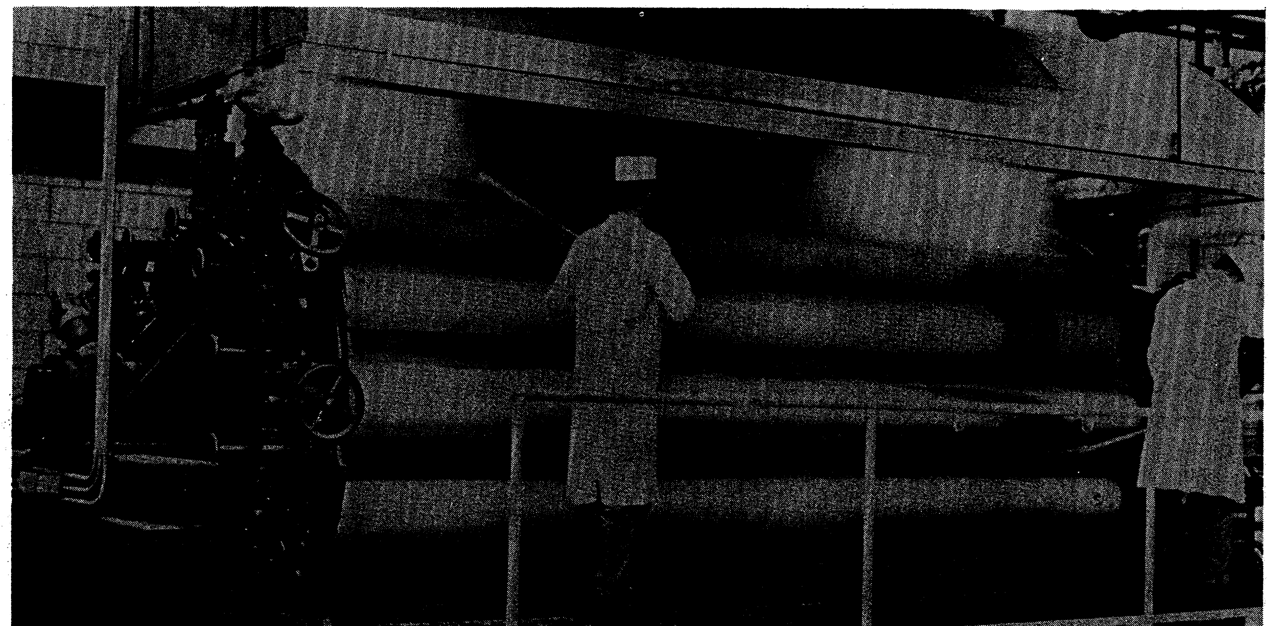


Figure 7. Mashed potatoes being applied to a production-size single-drum drier. The drum, 5 feet in diameter and 16 feet long, dries approximately 3700 pounds of mashed potatoes per hour. (Photo courtesy of Blaw-Knox Company, Buflovak Equipment Division.)

Figure 8. Dried mashed potatoes being removed from the drier at the rate of 750 pounds per hour. The sheets are later broken into flakes. (Photo courtesy of Blaw-Knox Company, Buflovak Equipment Division.)

Potato Flakelets

A denser product, called flakelets, has also been recently developed for institutional, military, and other uses where storage or transportation space is limited. Flakelets are made by mixing potato flakes with a small quantity of fresh mashed potatoes to give a moisture between 25 and 35 percent. When this is manipulated and compacted for a relatively short time, there results a product having a bulk density of about 45-50 pounds per cubic foot and possessing high-quality flavor and texture attributes. This product has been termed flakelets. Contrary to the implication of the name, the product is not simply small flakes. It comprises laminates, and aggregates of sheet fragments, a few individual potato cells, and cell agglomerates. Its consequent bulk density is far in excess of what can be obtained by merely breaking flakes to small size (figure 9). Because of their high bulk density and ability to absorb water approximately 160 servings of mashed potatoes can be made from the contents of a number 10 can. Their density also permits savings in packaging costs, enabling a sales price below that of flakes. They can be economically packed in nitrogen without an antioxidant, permitting them to retain good flavor for upwards of one year. (See references 17-21.)

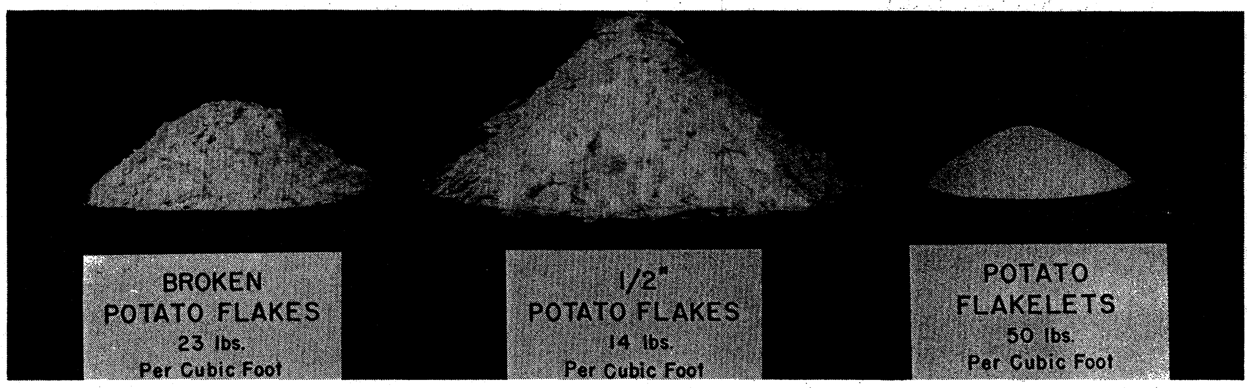


Figure 9. Volumes of different types of dried potato products that will yield the same volume of mash on reconstitution.

Pumpkin Powder

A process was developed for drying pumpkin puree without incorporating starch or sugar as is customary with existing commercial products. The product is 99% pure pumpkin. If sugar, spices, and dry milk are added to the powder an instant pie filling results. Use by commercial bakeries of the powder instead of canned puree affords savings in weight, space, and price.

The powder is made employing the same type of drum drier used with potato flakes. Thus the flake producer can extend his operating season and diversify his product line. (See references 19 and 20.)

Fruit Essences and Juice Concentrates

Essences are the highly concentrated volatile components of fruit juices. They are present in the juice only to the extent of a few parts per million but are responsible for its characteristic flavor. About 18 years ago engineering research resulted in a process for economically capturing and concentrating these elusive flavoring compounds (figure 10). With it volatile fruit aromas from a wide variety of juices could for the first time be recovered in substantially unaltered form by a commercially practicable process. At least 15 large commercial units are now in operation in the United States based on this development (figures 11-13). The same process has also found wide use in Europe.

With the advent of the essence recovery process, other developments became possible. Formerly the chief drawback of concentrated fruit juices was their lack of characteristic fruit flavor. In concentrating the juices most of the aroma which distinguishes one fruit from another was normally lost with

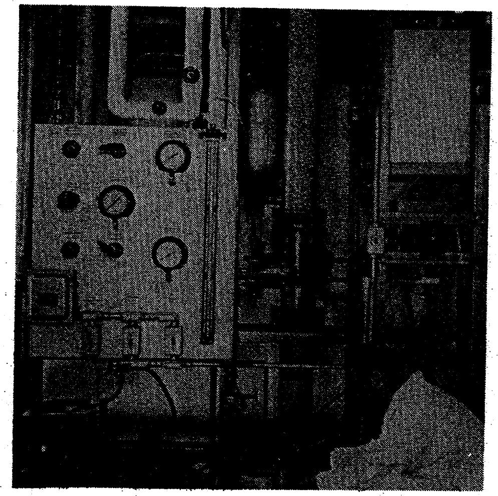


Figure 10. One of the pilot plant essence units used in the development of aroma-recovery processes. These units were designed by Laboratory engineers and were built in the Division's shops. Suitable research units could not be purchased.

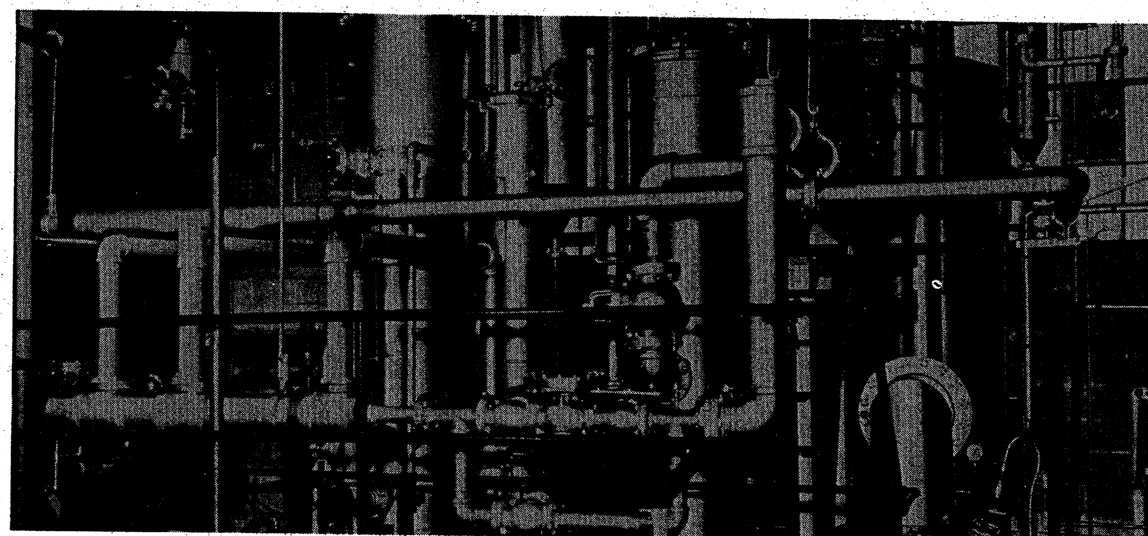


Figure 11. Commercial-scale essence recovery unit in the plant of the Keystone Cooperative Grape Association, Northeast, Pennsylvania, used in producing full-flavor concentrated grape juice by the process developed in the Engineering and Development Laboratory. (Photo courtesy of Blaw-Knox Company, Buflovak Equipment Division, suppliers of the unit.)

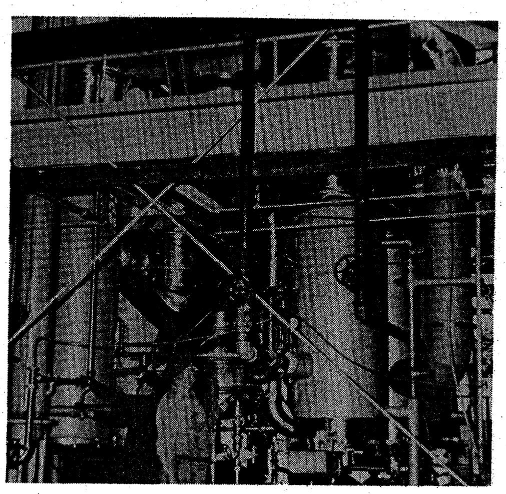


Figure 12. Commercial-scale essence recovery unit for grape and apple juice in the plant of A. F. Murch Company, Paw Paw, Michigan, (Photo courtesy of Food Engineering.)

the water vapor. Essence recovery, however, made it possible to first remove and capture the aromas before concentrating the juice. It thus became a simple matter to concentrate the juice and then add back the aroma to obtain a fruit juice concentrate that possessed all of the natural fruit flavor of the fresh juice. Essences and full-flavored juice concentrates are now being made commercially by this process from the juices of apples, grapes, cherries, raspberries, and other fruits. Essences are also used in jams, jellies, and preserves and have a potential use in ice cream, candy, carbonated beverages, and fruit juice powders.

Four-fold frozen concentrated apple juice employing the essence recovery process is now being made on a large commercial scale in the Pacific Northwest (figures 14 and 15).

The U. S. Department of Agriculture recognized the significance of the essence recovery development by presenting its Distinguished Service Award to the engineering

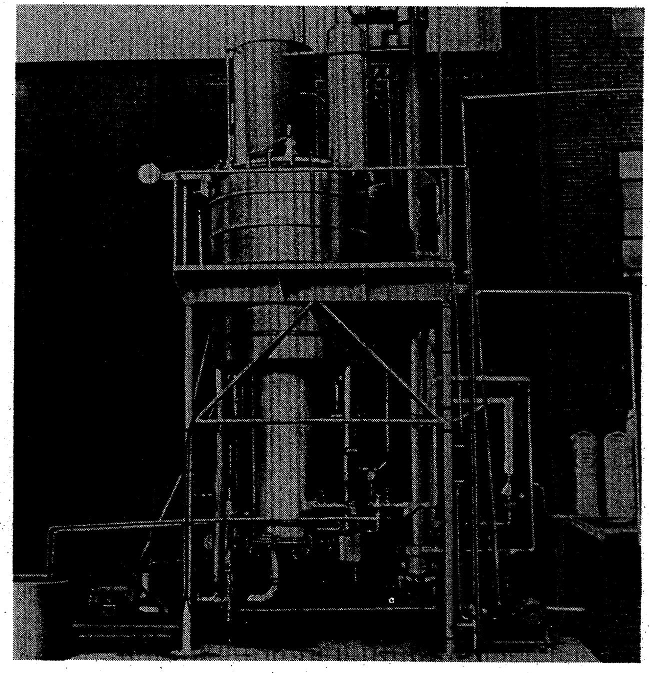


Figure 13. Another commercial scale essence recovery installation. (Photo courtesy of Mojonnier Brothers Company.)

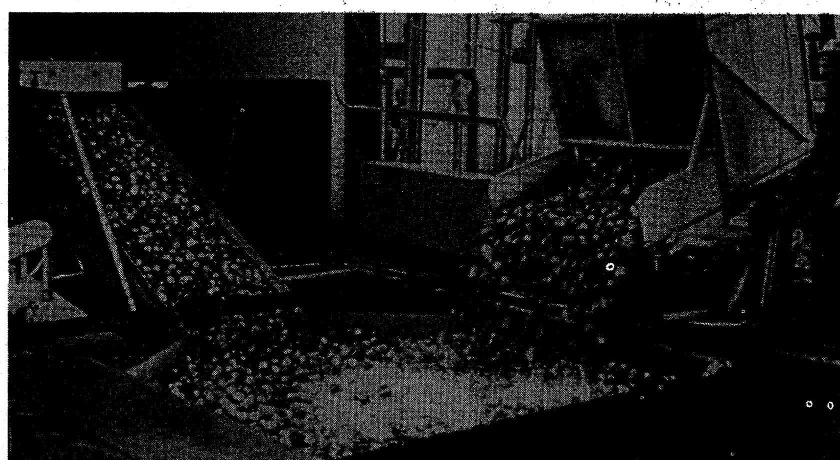
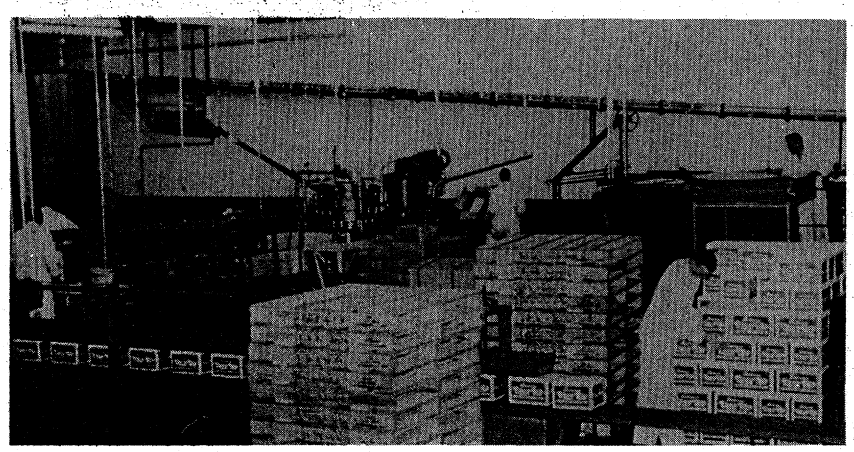


Figure 14. Apples for juice concentrate at start of processing line. A large bin (approximately 1,500 lb.) of apples is being dumped into the washing tank. Washed apples are being removed from the tank by a conveyor, and will next proceed over a sorting table and into the grinder. (Photo courtesy of Tree Top, Inc.)

Figure 15. Packaging apple juice concentrate. Concentrate tanks are at left background, and can filling and closing machines are just to the right of the tanks. In foreground. filled cartons coming off the end of the line are being stacked on a wooden pallet prior to transfer to frozen storage room. (Photo courtesy of Tree Top, Inc.)



group responsible for it and for its industrial promotion.

In the manufacture of preserves the more volatile aromas are normally lost. This was recognized as a situation wherein the principles of essence recovery might be profitably applied to obtain a valuable by-product. The vapors from the preserve kettles were collected on surface condensers yielding dilute solutions of the fruit aromas. These condensates were then subjected to the essence recovery process. The resultant product was a highly concentrated solution of natural fruit aromas which could be restored to the preserves to enhance their flavor. This extension of the essence recovery principle was adopted by industry. The engineers responsible for the work received the Superior Service Award of the Department of Agriculture. (See references 22-55.)

Powdered Fruit Juices

The ultimate in concentrating fruit juices is to carry them to dryness. This has been done in a continuous process that was developed through engineering research. Fresh juice is depectinized, the aroma is recovered by the now well established essence recovery procedure, and is further concentrated by fractional distillation to about 800 fold. The bland juice is evaporated to a sirup containing about 70 percent solids. The sirup is dehydrated in a single pass, agitated film, vacuum evaporator. It is discharged from the evaporator in a substantially dry but molten state. The highly concentrated essence is continuously injected into the molten material at super-atmospheric pressure. The material is then rapidly solidified by chilling on cold flaking rolls (figure 16). The resultant product is in the form of thin flakes, which when comminuted form a powdered dry fruit juice. On reconstitution this powder yields a juice possessing characteristic fresh flavor. The powder will retain its flavor for upwards of a year at room temperature without the necessity of vacuum or nitrogen packing. It is obviously of great value for military, stockpiling and export use. (See references 56-65.)

Dried Honey

The same process used to dry fruit juices was recently adapted to the drying of honey. This new product should be enthusiastically received by bakers who would find it much more stable and convenient to use than liquid honey. The same process has now been successfully applied to drying molasses without additives. (See references 66-67.)

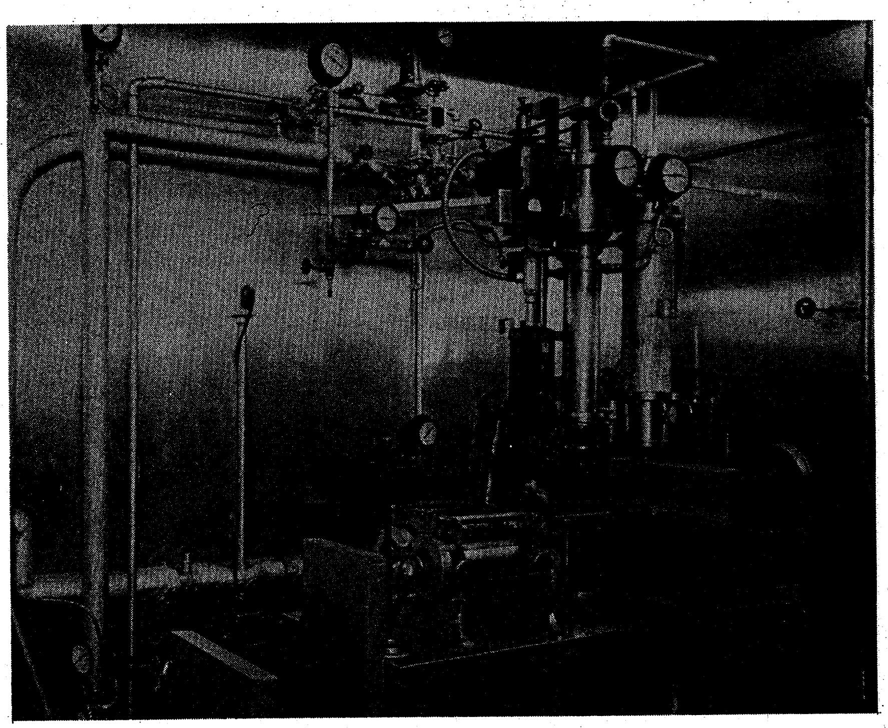


Figure 16. Pilot-plant unit used in developing a process for preparing full-flavor dry fruit juices and dried honey. More than a ton of dried products has been prepared with this apparatus, which has an output capacity of 30 pounds per hour.

Dehydrated Fruit and Vegetable Products Capable of Rapid Rehydration

Because of commercial interest in finding a process for making dehydrated fruit and vegetable products which are more nearly "instant" than those currently on the market, research was initiated in the Engineering and Development Laboratory to meet this need.

"Instant" dehydrated vegetables now on the market consist of, for example, thin slices of raw dehydrated potatoes to be used in preparing au gratin, scalloped or hash brown potatoes, potato salad and other forms where the identity of the piece must be retained. While these products are convenience foods in the sense that peeling, trimming, and slicing have been done they are nevertheless not instant because they require baking or boiling from 15 to 30 minutes in order to rehydrate and cook them sufficiently for use. Dehydrated diced potatoes, carrots, and other vegetables are used commercially in the preparation of soups and stews and may take even longer to rehydrate.

Similarly, dehydrated fruits are notably slow to rehydrate, frequently requiring long soaking prior to cooking and are therefore not truly convenience foods.

It was shown that dehydrated vegetable pieces can be made from potatoes, carrots, beets, rutabagas, or sweet potatoes which will rehydrate and be ready for serving with only 5 minutes simmering. In contrast, conventionally dried carrot dice (3/8 x 3/8 x 3/8 inch), for example, require 45 minutes in boiling water to rehydrate and cook sufficiently to eat. Even then, the pieces may still appear slightly shrunken or misshapen. Potato dice of the same size require about 20 minutes to prepare for serving. When dice from either of these vegetables are made by the new process, only about 5 minutes are required to prepare and the pieces regain their original shape. Apple segments, for pies or compote, which rehydrate in 2 to 5 minutes simmering in water, have also been made. When crushed and mixed with sugar, they reconstitute in 10 seconds when mixed with hot water to provide an instant applesause of good flavor, texture, and color. In contrast, hot-air-dried apple segments need long soaking before use. Application of the process to other dehydrated vegetables and fruits is now under study.

The new process is termed explosion puffing. In it, vegetable or fruit pieces of convenient size, suitably treated to inhibit enzyme activity if necessary, and to improve keeping quality, are partially dehydrated by any conventional method, as for example in belt, belt-trough, or tunnel driers. Moisture content at the end of this stage of drying is 20 to 35 percent, depending on the vegetable or fruit. A puffing gun designed specifically for fruits and vegetables by the Engineering and Development Laboratory is used to give a porous structure to the partially dehydrated pieces. The gun is a stainless steel cylinder, 10 inches in diameter fitted with a quick-opening lid. It is shown in figure 17.

Operation of the gun is as follows. Conditions of pressure and temperature shown are for 3/8-inch carrot dice charged to the gun at a moisture content of between about 20 and 30 percent, as an example.

With the closed gun rotating in the horizontal position, heat is applied externally to bring the surface of the barrel to a temperature of 340 to 350° F. The temperature is measured by a sliding thermocouple in contact with the external surface. During this period superheated steam under pressure is passed through the gun and adjustments are made in steam pressure and temperature to the levels required in subsequent charges. The gun is tilted to the discharge position, rotation is stopped and the lid opened (it should always be opened in this position; the recoil device will not stop the lid otherwise and damage would result). After tilting the gun to the charging position a charge of about 20 pounds of dice is put in and the lid is shut. The gun is tilted to the horizontal position, rotation is resumed and the barrel temperature is maintained between 340 and 350° F. by heating externally with gas burners. Steam at 305 to 310° F. and 35 p.s.i.g. pressure is immediately admitted while gun rotation and application of external heat to maintain the shell temperature at 340 to 350° F. continue. An

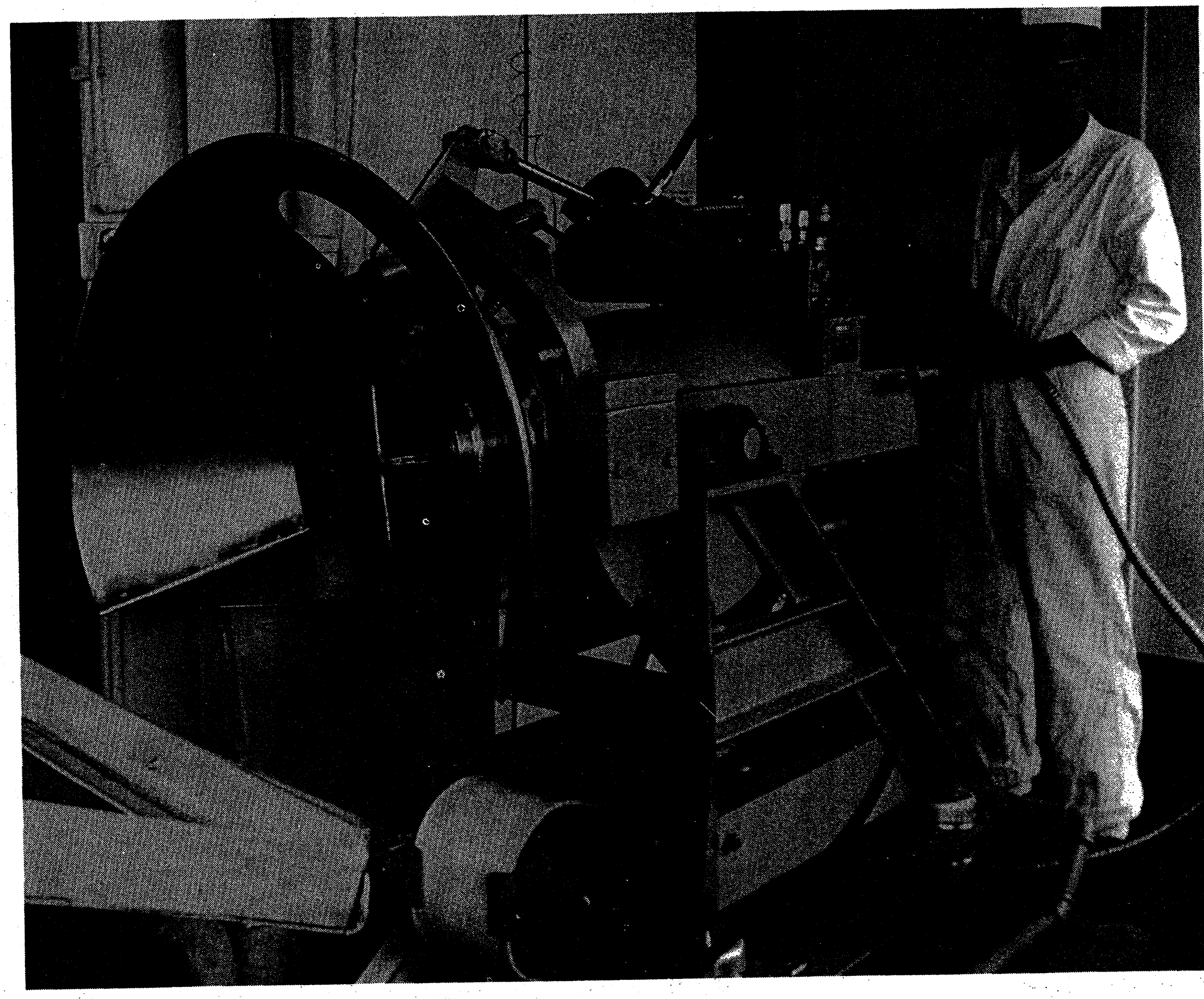


Figure 17. Pilot-plant gun for explosion-puffing partially dehydrated fruits and vegetables. This is a prototype of a commercial unit.

orifice in the lid permits escape of air and controls the flow of steam for direct heating of the charge. When the pressure in the gun reaches 35 p. s. i. g. (in about 1-1/2 minutes) the gas burners are turned off, the gun is tilted to 22-1/2° below the horizontal (muzzle down) which is the normal firing position, rotation is stopped, steam is turned off, and the lock on the lid is then tripped. These operations take about 15 seconds, making the total time of the charge in the gun about 1-3/4 minutes.

The charge, its water content slightly superheated, bursts from the gun and acquires a porous structure as some of the superheated water flashes instantly to vapor. The pieces are then subjected to further drying to a moisture content appropriate for storage (about 4 percent). This is done by any conventional means and the time required for this normally slow stage of drying is greatly reduced because of the porosity of the piece. The finished product retains the general shape of the raw piece and does not exhibit the case-hardening found in conventionally hot-air-dried carrot pieces. On reconstitution, the explosion puffed pieces (c in Figure 18) regain the size and shape of freshly cooked carrot dice (a) and are ready to eat, while conventionally dried pieces (b) remain shrivelled and uncooked.

This development is expected to have a strong impact on the dehydrated food industry. It will enable for the first time the use of relatively large pieces of vegetables in soups and stews which can be prepared for

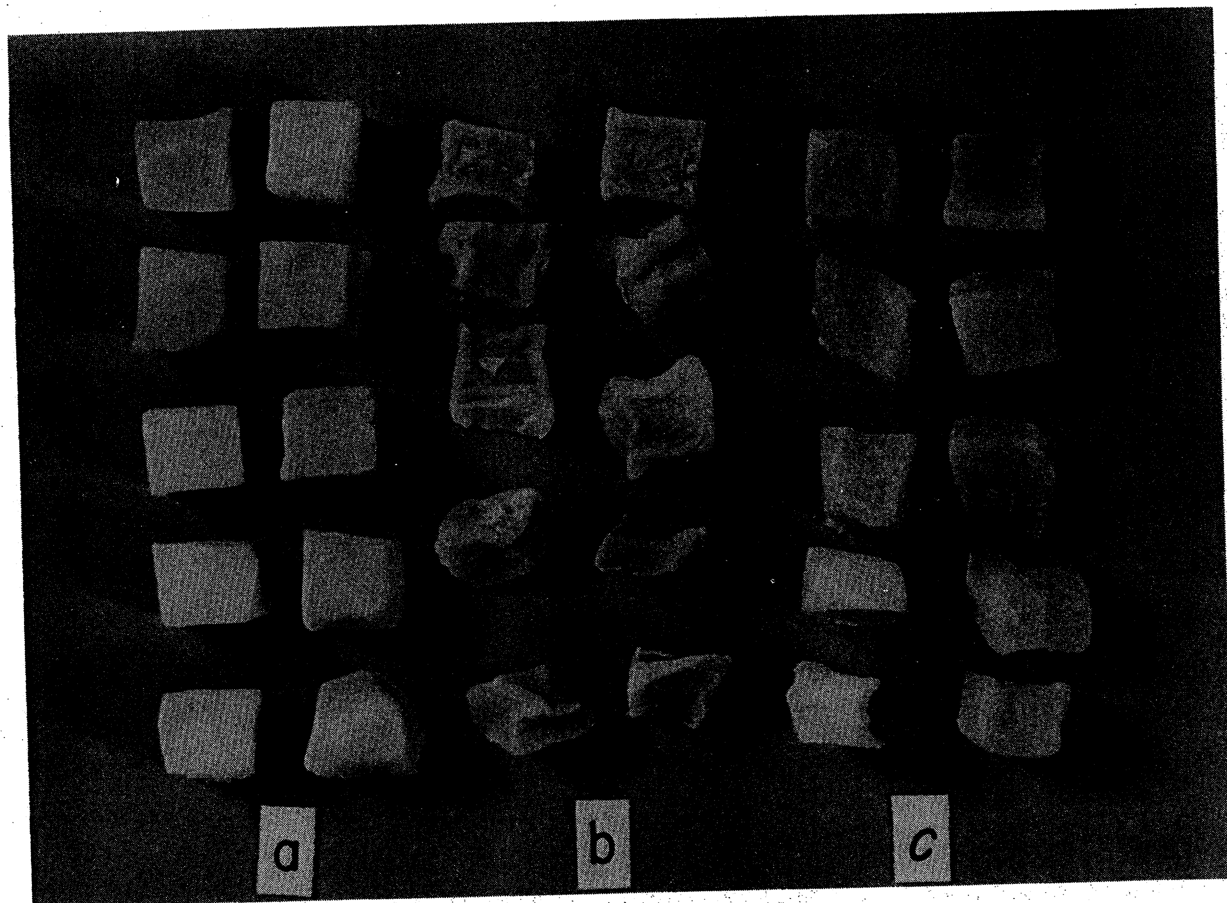


Figure 18. Carrot dice (3/8 inch) after 5 minutes' boiling. A is fresh carrots, B is conventionally hot-air-dried, C is explosion-puffed dried.

eating in as little as 5 minutes, a shorter time than now possible. It will also permit a great reduction in drying time with consequent savings and quality improvement. (See references 68-80.)

Vacuum-Foam-Dried Whole Milk

A process still in the pilot plant stage of development is one which yields a dry whole milk of unique properties. Although dry whole milk is an article of commerce it is not used for reconstitution to a beverage to any significant extent in this country. It is normally made by spray drying in air. This, combined with the heat treatment given the milk before drying, creates an unpleasant flavor. Moreover, its powdery form makes it difficult to disperse, requiring warm water for reconstitution.

Engineering research on a batch scale, and more recently with a continuous process, has produced a dry whole milk which many persons cannot distinguish from the fresh product and which dissolves quickly even in cold water by simple spoon stirring.

It is made by quickly concentrating milk under vacuum to about 45 percent solids. The concentrate is homogenized to finely disperse the fat globules. It is then quickly chilled so as to encapsulate each globule in a matrix of material (principally the naturally occurring lactose and protein) which will readily disperse when the dry product is reconstituted. After finely dispersing an inert, low-solubility gas, such as nitrogen, into the concentrate, the resulting foam is introduced into a vacuum chamber where it is expanded and quickly dried. The foam, when crushed, yields tiny flakes which dissolve in cold water to make a high-grade beverage milk (figures 19 and 20). Some technical and economic

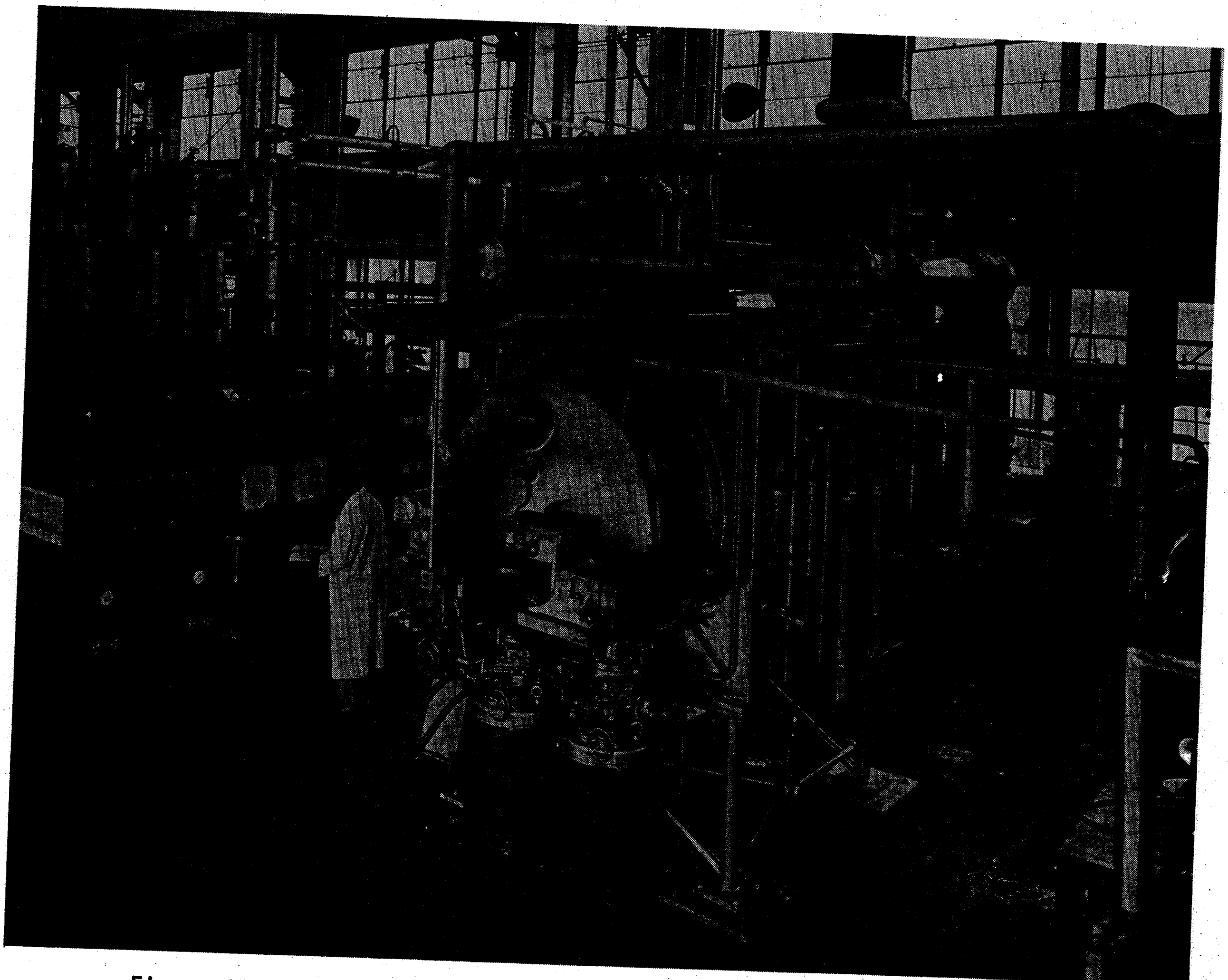


Figure 19. Pilot-plant model of a commercial high-vacuum solid-belt continuous drier. This is being used to determine the technical and economical feasibility of vacuum-foam drying of whole milk. The process was developed in the Engineering and Development Laboratory.

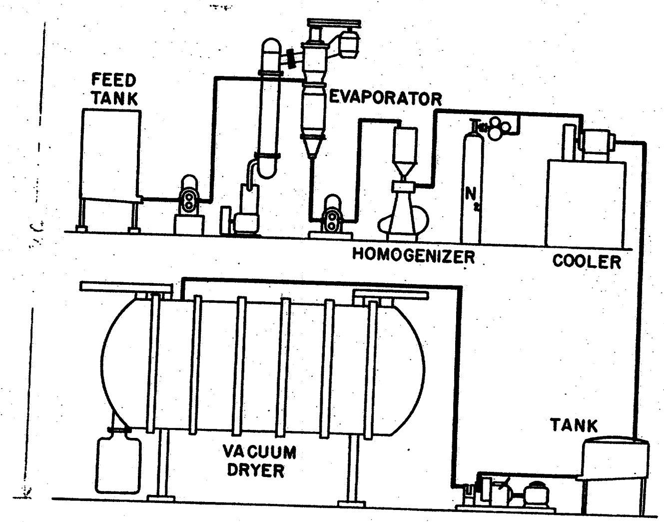


Figure 20. Flow diagram illustrating vacuum foam-drying process for whole milk.

problems have to be solved before the process can be recommended for commercial use.

In this unique process for drying milk, foam formation and behavior of the foam during vacuum dehydration must be strictly controlled because of their profound influence on product quality and drying rates. Moreover, it soon was discovered that the foaming properties of milk concentrates vary seasonally. Little if any information was available in the dairy science literature that was applicable to this problem. Thus, supplementary investigations were undertaken by the engineering research team. These resulted in the development of a quantitative foam test which permits the physical properties and chemical composition of milk to be correlated with its foaming characteristics. This work exemplifies how basic information, not otherwise available, must some times be generated through engineering research during process development studies.

The novel approach required and the complexity and variability of milk composition necessitate long-range experimental designs to study the effect on the process of some thirteen identified independent variables. The mathematical methods entail expressing the results in multivariable, nonlinear equations. A mathematical solution consists of a combination of all independent variables that give a maximum value, subject to product quality constraints. The most modern computer facilities are employed in this work. (See references 81-93.)

NONFOOD PROCESSES

Tannin From Canaigre

A continuous counter-current solvent-water extraction process for tannin from a native plant, canaigre, was originated in the Hides and Leather Laboratory. This was engineered into pilot plant scale as illustrated by the extractor shown in figure 21. A sufficient quantity of powdered tannin was made in the pilot plant to permit industrial-scale tanning tests. The industrial development of synthetic tanning materials later discouraged commercial processing of canaigre. (See references 94-97.)

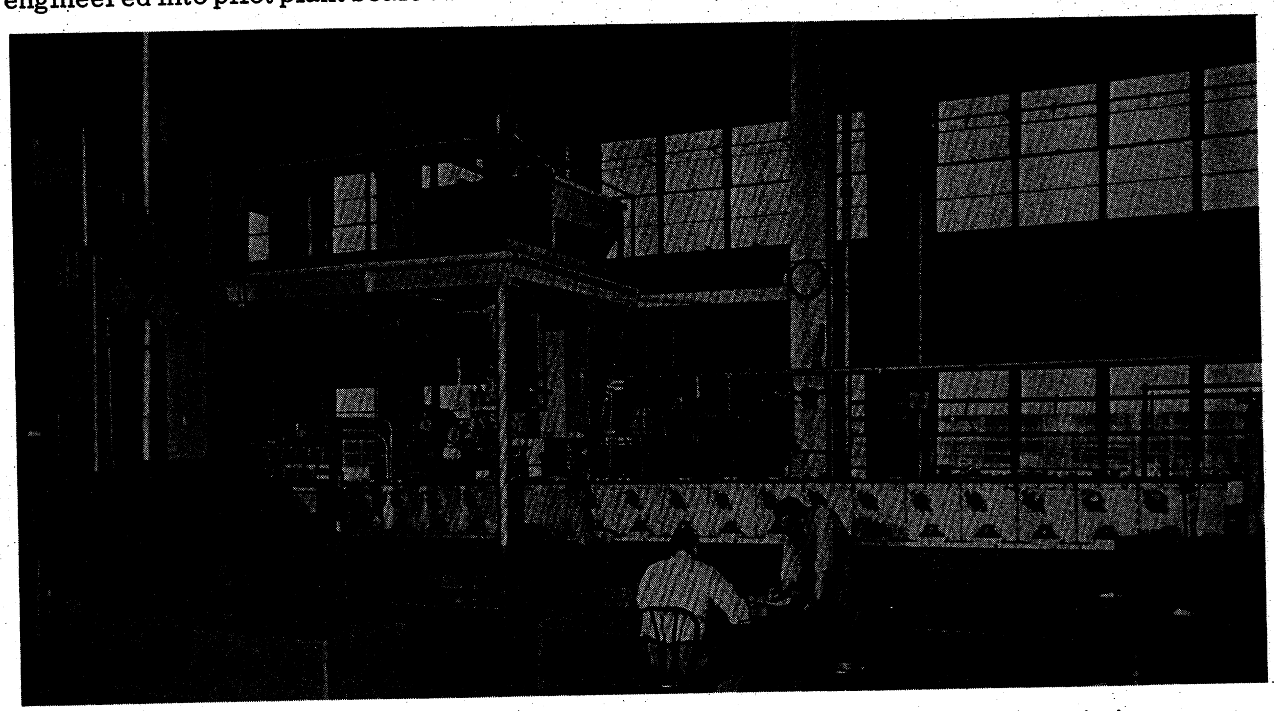


Figure 21. This is a counter-current extractor, part of an integrated pilot-plant unit for preparing tannin from a native plant, canaigre.

Rutin From Buckwheat

A commercially feasible process was developed (figure 22) for drying buckwheat plants to provide a concentrated fraction rich in the drug rutin. (See references 98-101.)

The same fractional drying process was also shown to be applicable to vegetable wastes, enabling the preparation of a vitamin-rich leaf meal for feeds. (See references 102-107.) Others later applied it to alfalfa for the same purpose.

Rutin is used to strengthen capillary walls. A solvent extraction process developed in the Analytical and Physical Chemical Laboratory was evaluated in the pilot plant and a sufficient quantity of rutin was made for clinical tests. A simpler aqueous extraction process was also developed in the Engineering Laboratory.

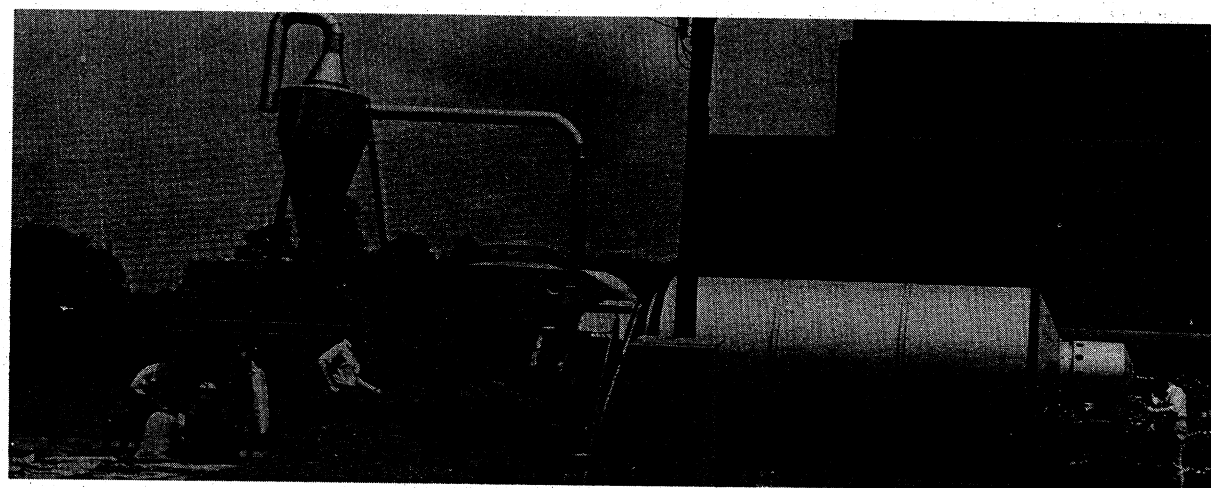


Figure 22. Using an alfalfa drier to fractionally dry buckwheat plants permitting isolation of a rutin-rich leaf fraction.

Low-Temperature Fractionation of Animal Fats

A continuous, integrated pilot plant was designed and employed to develop practical operating conditions for the fractional crystallization of animal fats employing water-saturated solvents (figure 23). This process was later used commercially. (See references 108-110.)

Natural Rubber from Russian Dandelion

As a consequence of the wartime natural rubber shortage, Department research was conducted to find alternate plant sources. Among those studied in the Engineering and Development Laboratory, two proved of potential commercial significance; guayule and kok-saghyz. Although rubber was being extracted from mature guayule plants in Mexico, there was no known method of recovery from young plants. A practical method was developed by the Engineering and Development Laboratory, and this was later used on a large scale.

Taraxacum kok-saghyz, or Russian dandelion, was widely grown experimentally in the United States because of the high rubber content of the roots. A process for its isolation was developed by the Engineering and Development Laboratory, a large pilot plant was constructed, and sufficient rubber was produced for the commercial fabrication and testing of heavy-duty tires (figure 24). These proved fully equal in performance to tires made from hevea rubber.

Both of these rubber isolating processes involved primarily physical separations by milling, screening, and flotation. Termination of the war and the improvement in synthetic rubber eliminated the necessity for commercialization of the processes. (See references 111-113.)

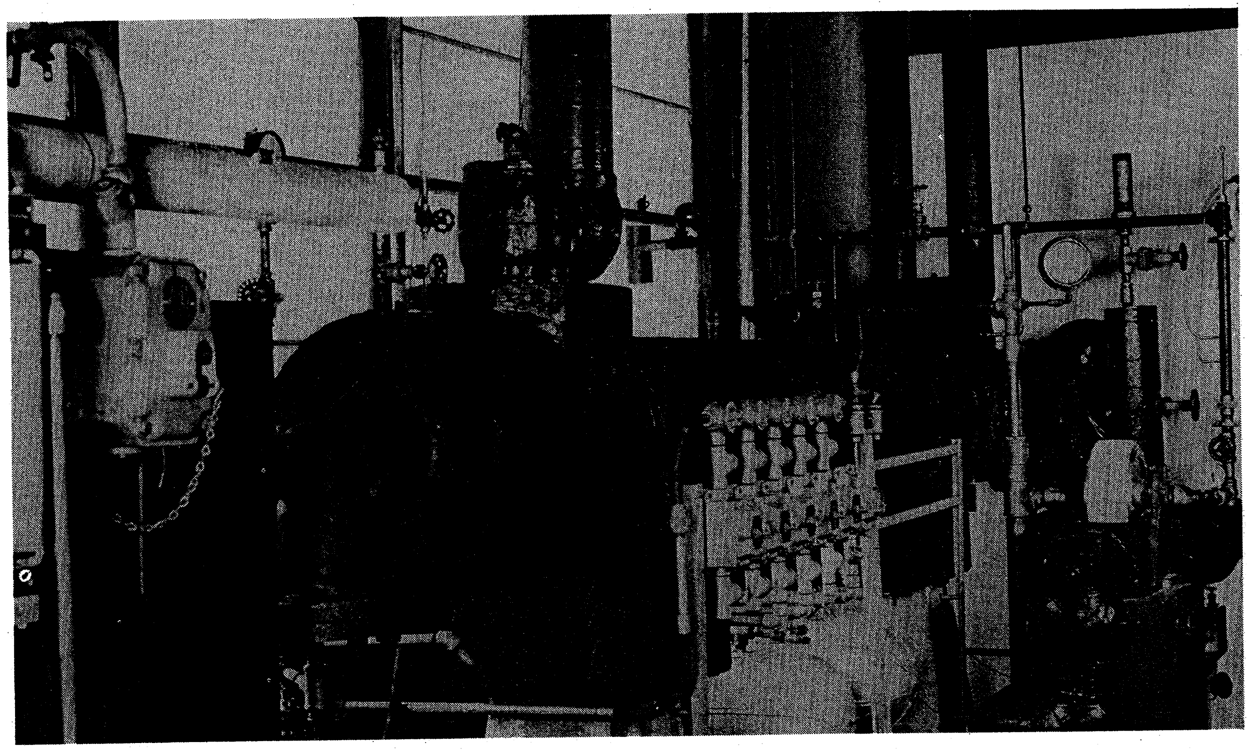


Figure 23. Apparatus for the low-temperature solvent fractionation of animal fats.

Figure 24. Blocks of kok-saghyz rubber. Left to right, Roderick K. Eskew and Paul W. Edwards, inventors of the process for isolation of the rubber.

OTHER DEVELOPMENTS

In order to upgrade the production of the domestic potato starch industry to meet foreign competition, a survey was made of European starch factories. Pilot-plant research was conducted to improve the technology of domestic strach production and the utilization of factory wastes. (See references 114-118.) Contributions to the utilization of large potato surpluses were made through engineering research to cheaply dry the potatoes for animal feeds. This work showed that several types of idle equipment in distilleries could be used for this purpose and to meet Europe's flour shortage after World War II. Significant quantities of potato flour made through these developments were airlifted into Berlin during the blockade. (See references 119-124.)

Engineering research on other processes included development of techniques for separating hemlock bark from chipped sawmill slabs to yield a source of domestic tannin (see references 125 and 126); improvement of methods for extracting nicotine (for insecticide use) from tobacco wastes (see references 127-131); the emulsion polymerization of ethyl acrylate to form the elastomer, Lactoprene EV (see references 132 and 133); and the pilot-plant production of allyl sucrose (see references 134 and 135).

These are some examples of how chemical engineering research can be profitably employed in developing both food and nonfood products and processes. The basic principles involved in fluid flow, heat transfer, evaporation, fractional distillation, and drying (all unit operations of chemical engineering) are the same in food processing as they are in any other field of chemistry.

REFERENCES

Potato Flakes

1. Cording, James, Jr., Willard, Miles J., Jr., Eskew, Roderick K., and Edwards, Paul W. U.S.D.A., Agr. Research Service, ARS 73-2, November 1954.

2. Cording, J., Jr., Willard, M. J., Jr., Eskew, R. K., Edwards, P. W., and Sullivan, J. F. U.S.D.A., Agr. Research Service, ARS 73-9, August 1955. 8 pp.

3. Willard, Miles J., Jr., Cording, James, Jr., Eskew, R. K., Edwards, P. W., and Sullivan, John F. American Potato Journal, 33, 28 (1956).

4. Eskew, Roderick K., Redfield, Clifford S., Cording, James, Jr., Willard, Miles J., Jr., Claffey, Joseph B., and Sullivan, John F. U.S.D.A., Agr. Research Service ARS 73-12, April 1956. 15 pp.

5. Cording, James, Jr., and Willard, Miles J., Jr. U.S. Patent 2,759,832, issued August 21, 1956.

6. Willard, Miles J., Jr., and Cording, James, Jr. U. S. Patent 2,780,552, issued February 5, 1957.

7. Cording, James, Jr., and Willard, Miles J., Jr. U.S. Patent 2,787,553, issued April 2, 1957.

8. Cording, James, Jr., Willard, Miles J., Jr., Eskew, Roderick K., and Sullivan, John F. Food Technology, 11, 236 (1957).

9. Cording, James, Jr., Sullivan, John F., and Eskew, Roderick K. U.S.D.A., Agr. Research Service, ARS 73-25, July 1959. 26 pp.

10. Eskew, Roderick K., Drazga, Fred H., Cording, James, Jr., Sullivan, John F., and Woodward, C. F. U.S.D.A., Agr. Research Service, ARS 73-30, September 1960. 20 pp.

11. Kissinger, John C. U.S.D.A., Agr. Research Service, ARS 73-32, June 1961. 7 pp.

12. Cording, James, Jr., Eskew, Roderick K., Salinard, G. J., and Sullivan, John F. Food Technology, 15, 279 (1961).

13. Claffey, J. B., Eskew, R. K., and Drazga, F. H. U.S.D.A., Agr. Research Service, ARS 73-36, October 1961. 20 pp.

14. Sullivan, John F., Cording, James, Jr., and Willard, Miles J., Jr. U.S. Patent 3,012,897, issued December 12, 1961.

15. Eskew, Roderick K. U. S. Patent 8,021, 223, issued February 13, 1962.

16. Hyde, W. U., and Cording, J., Jr. U.S. Patent 3,024,823, issued March 13, 1962.

Potato Flakelets

17. Eskew, R. K., and Drazga, F. H. Food Technology, 16 (4), 99 (1962).

18. Drazga, Fred H., and Eskew, Roderick K. Food Technology, 16, (12), 102 (1962).

19. Drazga, F. H., Eskew, R. K., and Talley, F. B. Food Technology, 18, 1201 (1964).

20. Komanowsky, M., Eskew, R. K., and Cording, J., Jr. Food Engineering, 36 (5), 107 (1964).

21. Turkot, Victor A., Komanowsky, Michael, and Eskew, Roderick K. Food Engineering, 37 (7), 78 (1965).

Fruit Essences and Juice Concentrates

22. Mottern, H. H., and Morris, R. H., U.S.D.A., Agr. Research Service, AIC-37, January 1944. 22 pp.

23. Milleville, Howard P., and Eskew Roderick K. U.S.D.A., Agr. Research Service, AIC-63, September 1944. 16 pp. (with supplement April 1945).

24. Milleville, Howard P., and Eskew, Roderick K. Western Canner and Packer, 38 (11), 51 (1946).

25. Griffin, E. L., Jr., Talley, Florence B., and Heller, Margaret E. Fruit Products Journal and American Food Manufacturer, 27 (1), 4 (1947).

26. Milleville, H. P. U.S. Patent 2,457, 315, issued December 28, 1948.

27. Homiller, R. P., and Griffin, E. L., Jr. U.S. Patent 2,479,745, issued August 23, 1949.

28. Griffin, Edward L., Jr., Davis, Lyle L., Eisenhardt, Nelson H., and Heller, Margaret E. Food Industries, 21, 1545 (1949).

29. Homiller, R. P., Phillips, G. W. Macpherson, Eskew, R. K., and Eisenhardt, N. H. Food Industries, 22, 1026 (1950).

30. Eskew, R. K., Phillips, G. W. M., Homiller, R. P., and Eisenhardt, N. H. Food Industries, 22, 2067 (1950).

31. Eskew, R. K., Phillips, G. W. M., Homiller, R. P., and Eisenhardt, N. H. U. S. D. A., Agr. Research Service, AIC-301, March 1951. 7 pp.

32. Eskew, Roderick K. Journal of Chemical Education, 28, 326 (1951).

33. Phillips, G. W. M., Eskew, R. K., Claffey, J. B., Davis, R. A., and Homiller, R. P. Industrial and Engineering Chemistry, 43, 1672 (1951).

34. Eskew, Roderick K., Redfield, C. S., Phillips, G. W. Macpherson. U. S. D. A., Agr. Research Service, AIC-315, August 1951. 17 pp.

35. Eskew, Roderick K., Phillips, G. W. Macpherson, Homiller, Richard P., Redfield, Clifford S., and Davis, Rudolph A. Industrial and Engineering Chemistry, 43, 2397 (1951).

36. Homiller, Richard P., and Eisenhardt, Nelson H. U.S. Patent 2,572,846, issued October 31, 1951.

37. Eskew, Roderick K., Homiller, Richard P., and Phillips, George W. M. U. S. Patent 2,573,699, issued November 6, 1951.

38. Eskew, Roderick K. Chemurgic Digest, 11 (5) 24 (1952).

39. Phillips, G. W. Macpherson, Eskew, Roderick K., Aceto, Nicholas C., and Skalamera, John J. Food Technology, 6, 210 (1952).

40. Eskew, Roderick K., Redfield, Clifford S., Eisenhardt, Nelson H., Claffey, Joseph B., and Aceto, Nicholas C. U.S.D.A., Agr. Research Service, AIC-342, September 1952. 16 pp. (with supplement).

41. Aceto, Nicholas C., Eskew, Roderick K., Phillips, G. W. Macpherson, Redfield, C. S., and Skalamera, John J. Glass Packer, 32 (1), 23 (1953).

42. Redfield, Clifford S., and Eskew, Roderick K. Glass Packer, 32 (2), 33(1953).

43. Aceto, Nicholas C., Eskew, Roderick K., Phillips, G. W. Macpherson, Glass Packer, 32 (9), 54 (1953).

44. Morgan, Donald A., Veldhuis, M. K. Eskew, R. K., and Phillips, G. W. M. Food Technology, 7, 332 (1953).

45. Phillips, G. W. Macpherson, Aceto, Nicholas C., Redfield, Clifford S., and Eskew, Roderick K. Food Technology, 8, 110 (1954).

46. Eskew, R. K., Phillips, G. W. M., and Aceto, N. C. Glass Packer, 33 (3), 37 (1954).

47. Aceto, Nicholas C., Eisenhardt, Nelson H., Eskew, Roderick K., and Phillips, G. W. Macpherson. U.S.D.A., Agr. Research Service, ARS 73-3, January 1955. 5 pp.

48. Eisenhardt, Nelson H., Aceto, Nicholas C., Claffey, Joseph B., and Redfield, Clifford S. Food Engineering, 30 (1), 95 (1958).

49. Claffey, Joseph B., Eskew, Roderick K., Eisenhardt, Nelson H., and Aceto, Nicholas C. U.S.D.A., Agr. Research Service, ARS 73-19, February 1958. 7 pp.

50. Eisenhardt, Nelson H., Eskew, Roderick K., Claffey, Joseph B., and Aceto, Nicholas C. U.S.D.A., Agr. Research Service, ARS 73-20, October 1958. 7 pp.

51. Eisenhardt, Nelson H., Aceto, Nicholas C., Claffey, Joseph B., and Redfield, Clifford S. U.S.D.A., Agr. Research Service, ARS73-21, October 1958. 9 pp.

52. Eskew, Roderick K., Claffey, Joseph B., Aceto, Nicholas C., and Eisenhardt, Nelson H. Food Engineering, 31 (1), 70 (1959).

53. Roger, Norman F. Food Technology, 15, 309 (1961).

54. Arbuckle, W. S., Venter, William Jr., Mattick, J. F., and Aceto, Nicholas C. University of Maryland Agricultural Experiment Station Bulletin A-118, December 1961. 43 pp.

55. Roger, N. F., and Turkot, V. A. Food Technology, 19, 69 (1965).

Powdered Fruit Juices

56. Eskew, Roderick K., Sinnamon, Howard I., and Turkot, Victor A. Food Technology, 8, 27 (1954).

57. Sinnamon, Howard I., Turkot, Victor A., Eskew, Roderick K., and Phillips, G. W. Macpherson. Food Engineering 26, (7), 78 (1954).

58. Turkot, Victor A., Sinnamon, Howard I., Eskew, Roderick K., and Phillips, G. W. Macpherson. Food Technology, 9, 506 (1955).

59. Eskew, Roderick K. Chemurgic Digest, 15 (2), 12 (1956).

60. Turkot, Victor A., Eskew, Roderick K., and Aceto, Nicholas C. Food Technology, 10, 604 (1956).

61. Eskew, Roderick K. U.S. Patent 2,816,039, issued December 10, 1957.

62. Turkot, Victor A., Eskew, Roderick K., and Aceto, Nicholas C. U.S. Patent 2,816,840, issued December 17, 1957.

63. Turkot, V. A., Eskew, R. K., and Aceto, N. C. U.S. Patent 2,906,630, issued September 29, 1959.

64. Eskew, R. K. U.S. Patent 2,929,717, issued March 22, 1960.

65. Strolle, Eugene O. Food Engineering, 37 (1), 70 (1965).

Dried Honey

66. Turkot, Victor A., Eskew, Roderick K., and Claffey, Joseph B. Food Technology, 14, 387 (1960).

67. Claffey, J. B., Turkot, Victor A., and Eskew, Roderick K., U.S.D.A., Agr. Research Service, ARS 73-33, August 1961. 16 pp.

Dehydrated Fruit and Vegetable Pieces Capable of Rapid Rehydration

68. Eisenhardt, N. H., Cording, J., Jr., Eskew, R. K., and Sullivan, J. F. Food Technology, 16, (5), 143 (1962).

69. Cording, James, Jr., and Eskew, Roderick K. U.S. Patent 3,038,813, issued June 12, 1962.

70. Eskew, Roderick K., Cording, James, Jr., and Sullivan, John F. Food Engineering, 35 (4), 91 (1963).

71. Cording, J., Jr., Eskew, R. K., Sullivan J. F., and Eisenhardt, N. H. Food Engineering, 35 (6), 52 (1963).

72. Sullivan, John F., Cording, James, Jr., and Eskew, Roderick K. Food Engineering, 35 (11), 59 (1963).

73. Cording, J., Jr., Sullivan, J. F., and Eskew, R. K. Food Engineering, 36 (6), 49 (1964).

74. Eisenhardt, N. H., Eskew, R. K., and Cording, J., Jr. Food Engineering, 36 (6), 53 (1964).

75. Gelber, Paul, and Eskew, Roderick K. Food Processing, 25 (10), 70 (1964).

76. Heiland, Wolfgang K., and Eskew, Roderick K., U.S.D.A., Agr. Research Service, ARS 73-47, April 1965 8 pp.

77. Turkot, V. A., Eskew, R. K., Sullivan, J. F., Cording, J., Jr., and Heiland, W. K., U.S.D.A., Agr. Research Service, ARS 73-49, August 1965, 20 pp.

78. Sullivan, J. F., Cording, J., Jr., Eskew, R. K., and Heiland, W. K. Food Engineering, 37 (10), 116 (1965).

79. Sinnamon, H. I., Eskew, R. K., and Cording, J., Jr. U.S.D.A., Agr. Research Service, ARS 73 - 50, October 1965, 6 pp.

80. DellaMonica, E. S., and McDowell, P. E. Food Technology, 19, (10), 141 (1965).

Vacuum-Foam-Dried Whole Milk

81. Sinnamon, H. I., Aceto, N. C., Eskew, R. K., and Schoppet, E. F. Journal of Dairy Science, 40. 1036 (1957).

82. Eskew, R. K., Aceto, N. C., Sinnamon, H. I., and Schoppet, E. F. Journal of Dairy Science, 41, 753 (1958).

83. Sinnamon, Howard I., Aceto, Nicholas C., and Eskew, Roderick K. U.S. Patent 2,964,407, issued December 13, 1960.

84. Craig, J. C., Jr., Aceto, N. C., and Dellamonica, E. S. Journal of Dairy Science, 44, 1827 (1961).

85. Aceto, N. C., Sinnamon, H. I., Schoppet E. F., and Eskew, R. K. Journal of Dairy Science, 45, 501 (1962).

86. Sinnamon, H. I., Komanowsky, M., and Aceto, N. C. Journal of Dairy Science, 47, 90 (1964).

87. Holden, T. F., Aceto, N. C., and Schoppet, E. F. Journal of Dairy Science, 47, 359 (1964).

88. Komanowsky, Michael, Sinnamon, Howard I., and Aceto, Nicholas C. Industrial and Engineering Chemistry. Process Design and Development, 3, 193 (1964).

89. Aceto, N. C., Sinnamon, H. I., Schoppet, E. F., Craig, J. C., and Eskew R. K. Journal of Dairy Science, 48, 544 (1965).

90. DellaMonica, E. S., Calhoun, M. J., Lawson, M. J., Craig, J. C., Jr., and Aceto, N. C. Journal of Dairy Science, 48, 602 (1965).

91. Schoppet, E. F., Aceto, N. C., Eskew, R. K., Craig, J. C., Jr., and Holden, T. F. Journal of Dairy Science, 48, 1436 (1965).

92. Dellamonica, E. S., Holden, T. F., Calhoun, M. J., and Aceto, N. C. Journal of Dairy Science, 48, 1585 (1965).

93. Aceto, N. C., Craig, J. C., Jr., Eskew R. K., and Talley, F. Proceedings of XVII International Dairy Congress (1966).

Tannin from Canaigre

94. Rieder, Robert M., Roger, N. F., Phillips, G. W. Macpherson, and Eskew, Roderick. Journal of the American Leather Chemists Association, 46, 188 (1951).

95. Rieder, Robert M., Turkot, Victor A., Eskew, Roderick K., and Phillips, G. W. Macpherson. Journal of the American Leather Chemists Association, 46, 264 (1951).

96. Griffin, E. L., Jr., Turkot, V. A. and Roger, N. F. Journal of the American Leather Chemists Assn., 52, 176 (1957).

97. Griffin, E. L., Jr., Roger, N. F., Redfield, C. S., and Eskew, R. K. U.S.D.A., Agr. Research Service, ARS-73-22, March 1959. 29 pp.

Rutin from Buckwheat

98. Griffin, E. L., Jr. U. S. Patent 2,425,094, issued August 5, 1947.

99. Eskew, Roderick K., Phillips, G. W. Macpherson, Griffin, E. L., Jr., Shaines, A., and Aceto, Nicholas C., U.S.D.A., Agr. Research Service, AIC-114, Revision 1, June 1948. 21 pp.

100. Eskew, Roderick, K. U. S. Patent 2,448,175, issued August 31, 1948.

101. Eskew, Roderick K. U. S. Patent 2,478,168, issued August 9, 1949.

Processing of Vegetable Wastes

102. Morris, R. H., Colker, D. A., and Chernoff, M. F., U.S.D.A., Agr. Research Service, AIC-51, August 1944. 61 pp.

103. Colker, David A., and Eskew, Roderick K. U.S.D.A., Agr. Research Service, AIC-76, March 1945. 17 pp.

104. Willaman, J. J., and Eskew, R. K. U.S.D.A. Science in Farming, Yearbook of Agriculture, 1943-47. pp. 739-743.

105. Willaman, J. J., and Eskew, R. K. U.S.D.A. Technical Bulletin No. 958, October 1948. 102 pp.

106. Aceto, Nicholas C., Edwards, Paul W., Eskew, Roderick K., Redfield, Clifford S., Hurley, Rita R., and Hoersch, Albert, Jr. U.S.D.A., Agr. Research Service, AIC-286, December 1950. 8 pp.

107. Edwards, Paul W., Eskew, Roderick K., Hoersch, A., Jr., Aceto, Nicholas C., and Redfield, C. S. Food Technology, 6, 383 (1952).

Low-Temperature Fractionation of Animal Fats

108. Cording, James, Jr., and Shaines, Alfred. Journal of the American Oil Chemists' Society, 28, 344 (1951).

109. Cording, James, Jr., Willard, Miles J., Edwards, Paul W., and Eskew, Roderick K. Journal of the American Oil Chemists' Society, 30, 66 (1953).

110. Cording, James, Jr., Willard, Miles J., Edwards, Paul W., and Eskew, Roderick K. Journal of the American Oil Chemists' Society, 30, 111 (1953).

Natural Rubber from Russian Dandelion

111. Eskew, Roderick K. India Rubber World, 113, 517 (1946).

112. Eskew, Roderick, and Edwards, Paul W. U.S. Patent 2,393,035, issued January 15, 1946.

113. Stamberger, Paul, Eskew, Roderick Koenig, and Hanslick, Roy S. U.S. Patent 2,399,156, issued April 23, 1946.

Potato Starch

114. Howerton, W. W., and Treadway, R. H. Industrial and Engineering Chemistry, 40, 1402 (1948).

115. Eskew, Roderick K., Edwards, Paul W., and Redfield, Clifford S. U.S.D.A., Agr. Research Service, AIC-204, September 1948. 7 pp.

116. Eskew, Roderick K. American Potato Journal, 25, 409 (1948).

117. Treadway, R. H., and Howerton, W. W. U.S.D.A., Crops in Peace and War, Yearbook of Agriculture, 1950-51. pp 168-172.

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