THE PROCESS CHEESE INDUSTRY IN THE UNITED STATES: A REVIEW'

II. RESEARCH AND DEVELOPMENT

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Abstract

Research and development (R & D) in corporate laboratories of cheese processors and in other research facilities in the United States have contributed knowledge of analytical technology, microbiology, defects and their corrections, manufacturing techniques, equipment, emulsifiers, and the use of other ingredients. Methods of wrapping and protecting the product during distribution were improved. Cheese foods and spreads with higher moisture, lower fat, and altered consistency were developed. The technology of producing slices of processed cheese has been revolutionary. Packages of slices are replacing the original, and highly successful, 5-lb. loaf. Mechanically formed, individually wrapped, and sealed slices are produced at fantastic speeds. Trends of industry indicate greater production per plant, more low-fat, high protein cheese products, and use of vegetable fats and proteins. Trends of R & D indicate improvements in emulsifiers, packaging, keeping quality, new products, and more mechanization and automation for greater efficiency and improved protection of this valuable food and its related products. The industry provides opportunities for trained food scientists, engineers, marketing specialists, and business administrators.

The original United States patents described the first research and development (R & D) on process cheese in the United States. Most industrial R & D has occurred in the plants or laboratories of the processors. The numerous patents on products, emulsifiers, equipment, processes, and packaging show the productiveness and ingenuity of the workers. Organizations supplying ingredients, equipment, and supplies to processors have engaged in R & D which contributed directly to the progress and welfare of the industry (118, 217). Research in institutions or commercial research laboratories has often been initiated, or supported, or both, by industry. The National Cheese Institute or its members have usually provided such support.

All research which contributes to knowledge of cheese affects the process cheese industry directly or indirectly. This review will be limited of necessity to those developments which seem to us to be directed to the progress of the industry.

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ing lines at regular intervals to measure weight, fat, moisture, salt, and sometimes pH and melting properties. Representative packages were reserved for storage at selected temperatures to measure effects of storage on body, flavor, color, slicing, and melting properties. Temperatures approximating 100 F were used commonly to check keeping quality and to detect faults in color, body, and flavor.

When extraneous matter in cheese was recognized as a serious problem, it became the laboratory's responsibility to check all incoming vat lots until eventually spot checking could maintain control. In addition to these analytical functions, the laboratory provided the routine inspections and sanitary control of plant operations.

Directors of laboratories were generally required to maintain liaison with regulatory agencies and their requirements. They provided the technical advice to company lawyers engaged in court actions and at legislative hearings, probably the most notable of which culminated in the modern Standards and Definitions of cheese and cheese products. The improved keeping quality of processed cheese observed by the first producers in the United States was generally attributed to the "sterilization" of the cheese. The fact that bacteria did survive the heating process and did continue to change in numbers was known to some bacteriologists, but not generally appreciated despite the fact that the temperatures used were not high enough to produce sterilization. But the practical success of the temperatures used in improving keeping quality was well known when gassy fermentations occurred in process cheese was made heated by indirect steam, the treatment resembled that of vat pasteurization of milk. Even when heating was accomplished in a few minutes by injecting steam directly into the cheese, temperatures maintained during filling of packages and stacking for cooling were adequate to fully justify the term "pasteurized." This fact was recognized eventually in the standards of the Food and Drug Administration. The standards held that the heating process should produce a practically negative phosphatase content in the finished cheese.

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When gassy fermentations occurred in process cheese products containing pimentos, it became obvious that anaerobic spore-forming, gas-forming organisms could survive the heat treatments and produce undesirable effects. During and after World War II researchers investigated higher than normal pas
teurizing temperatures for process cheese products in cans for military use (154-156). Studies concerning the survival of gas-forming, spore-forming anaerobes in process cheese products showed that low pH, high salt, and proper refrigeration decreased the survival rates as well as effects of their growth (3, 122-124). Development of large numbers of gram-positive bacilli in cheese spreads held 90 days at 90 F was associated with increased firmness, low pH, and large amounts of lactose from nonfat dry milk and whey solids in the formula (168).

Detection of Type B botulism toxin in a process cheese spread led to extensive studies financed by the National Cheese Institute (88, 243). Staphylococcal enterotoxin A, which has been found in cheese, is not destroyed by the heat of cheese processing. When 2,112 vats of cheese were suspected of containing the toxin, a cheese processor initiated an intensive laboratory program to detect contaminated vat lots (254, 255). The presence of the enterotoxin was demonstrated in some lots even after two years of storage.

These and other studies have alerted the industry to all aspects of ingredient quality. Control has now been extended to the type of material, sanitation of the cheese milk, composition, manufacturing methods of the individual ingredient, and storage of both ingredients and finished products.

Color

The color of blends of process cheese which are made with both colored and uncolored natural cheese has to be adjusted for uniformity. Cheese color was commonly used in the early years of the industry. Eventually butter color was sometimes added to increase the yellow tint and, hopefully, to minimize the pinking effect of acid cheese (96). Other colors were suggested, such as Apo-8’-carotenal (44). Canthaxanthin (4,4’diketo-beta-carotene) in diacetylated monoglyceride was patented for this same use (194).

An unnatural pink defect was often attributed to the use of acid cheese. It also was produced experimentally by prolonged heating or incorporation of semidry cheese adhering to the sides of an unwashed kettle when subsequent batches were cooked in it (183). Overheating was also identified with this defect (254).

Browning of process cheese was associated in the 1940s with the use of dried whey, dry skim milk, and malt sugar or glucose (111). When the browning appeared as a ring in the packaged cheese, it was believed to be caused by delayed cooling to under 90 F or to storing at room temperature or higher (76); some thought that penetration of oxygen caused the rings (91). Brown spots, which appeared only when the process cheese was cut, were observed in cheese food containing Swiss whey concentrate. Growth of such spots resembled colonies of chromogenic bacteria sometimes observed in the cut surfaces of Swiss cheese, but some suspected the spots were brown particles in the concentrates used (91).

Crystals

Crystals were detected in "sandy" or "gritty" process cheese in the 1920s. These crystals were isolated and identified in 1930 (215) and again in 1949 (48, 142), as calcium tartrate formed when Rochelle salts were used as emulsifier.

Packages of process cheese in slices in recent years have sometimes developed crystals or "bloom" on the surfaces of slices. The formation was sometimes mistaken for mold growth. X-ray diffraction studies have identified these crystals as the alpha form of Na4HPO4·12H2O (203). It was found that formation of crystals of disodium phosphate on process cheese in storage depended on temperature, humidity, pH, and abnormally high ortho-phosphate levels (201, 203). Later analysis by X-ray and infrared detected tricalcium citrate tetra-hydrate, which appeared under the microscope as a fine network of slender crystals (202). Formation of calcium citrate crystals on packaged cheese in other studies was most apparent on areas exposed to pressure, and was eliminated by avoiding the use of citrate as emulsifier (164). Certain emulsifiers (Na3PO4) have been discovered partially undissolved in process cheese (229).

Extraneous matter

As early as 1925, processors had discovered foreign materials in their raw cheese. They found such things as ball bearings, pieces of metal, hooks, bolts, nuts, glass, and even a watch (65). Today X-ray examination of processed cheese is used to detect X-ray opaque materials. But the presence in cheese of materials associated with insects and rodents was critical under the terms of the Food, Drug, and Cosmetic Act of 1938 (79). The definition of adulterated food in Section 402 of the Act clearly indicated the vulnerability of the food industry.

Research disclosed that certain solvents such as sodium citrate, phosphoric acid, and even some enzymes under proper conditions could disperse the cheese and release insoluble, critical material with minimum destruction. Such dispersions could then be filtered to disclose the insoluble material (209, 218, 238).

Studies sponsored in part by the National Cheese Institute evaluated methods of sampling and measurements for inspection and laboratory control purposes (161, 187). These studies recommended regular and frequent sampling of cheese from each factory, the use of nondestructive 50-g samples, dissolving the samples in 10% sodium citrate solution at 140-
150 F, filtering through poplin disks and microscopic examination to identify residues. Such examinations made possible the routine and regulatory evaluation of the sanitary history of cheese (80).

Processors commonly used the 227-g sample to test for critical material. Taking samples of this size or larger with cheese triers was so destructive of finished cheese that some buyers required the saving at the factory of samples of salted but unpressed curd to be delivered with the cheese from each vat lot. To avoid destructive plugging of cheese before curding, a special knife was designed to cut a V-shaped section in one slice across the flat surface of the cheddar before waxing (74).

The effects of regular inspection and testing definitely improved sanitary practices of milk production and cheese manufacturing. Equipment was modified and contents of vats were protected from falling oil, dust, or other material from vat agitators. Factories and warehouses were made rodent proof and doors and windows more carefully fitted with screens and closures. Buildings were fumigated when necessary. At some warehouses, cheese in boxes was fumigated under canvas tarpaulins with methyl bromide before being accepted for waxing and storage. Even clothing used by factory workers was required to have no pockets from which pencils or other small objects might drop into milk or curd. Sanitary inspections and control operations became more efficient.

**Manufacture**

**Formulation**

The compounding of process cheese developed first in the United States as an art described in the original patents. The objectives were to produce the sensory characteristics approximating natural cheese, to extend keeping quality, and to deliver it in convenient form to please the consumer. The controls established by law in Wisconsin and later by the Federal Government imposed limitations on composition, combinations of varieties, and additives (71, 238).

The effects of blending several lots of cheese of various ages, physical properties, and composition opened new possibilities of composition and quality control. Techniques varied according to the manufacturer's idea of what was economical and acceptable to consumers. High flavors, for example, which were important to some manufacturers, were sometimes rejected by some consumers with preferences for milder products (36, 37, 39, 42, 192). In the 1920s body characteristics were modified in the development of cheese foods and spreads by adding nonfat milk solids or whey solids, and stabilizer, as well as emulsifiers (225, 230). Combinations of highly flavored cheese like Limburger and Blue with Cream or Neufchatel cheese required introduction of homogenization and stabilizing guns. These mixtures became popular in the 1930s (34). Eventually spreads with maximum moisture and semifluid consistency were developed (31, 33, 35, 38, 41, 168, 204).

The earliest, systematic and published studies in the United States of composition and its relation to the characteristics of process cheese and cheese spreads began in 1927 and considered emulsifiers, temperature of treatment, moisture variation, and age of cheese. Principal observations of the finished products included measurements of moisture, pH, titratable acidity, body, slicing properties, color, keeping quality, appearance of the foil wrapper, and the relation between water-soluble nitrogen in the original and the processed product (217, 224, 227, 230). These studies provided some of the technical explanations of the art practiced in the United States or described in U. S. patents.

**Emulsifiers**

Much of the art of processing cheese lies in the areas of blending and emulsifying. The underlying principles of blending are generally well known while the use of emulsifiers is still something of a mystery with new emulsifiers and new combinations appearing almost annually, some with great success and others with alarming and costly failures.

Process cheese can be made without emulsifiers if the blend of natural cheese is carefully selected, heated, and stirred (71, 130). Before emulsifying salts were generally used, process cheese showing oiling
off, mealy body, and faulty consistency was not uncommon.

The documented use of emulsifying salts for process cheese in the United States began with the early work of Eldredge and Carpenter (55, 60). Subsequent studies and patents mentioned different salts and advanced explanations of their varied actions.

The effectiveness of emulsifiers at first was attributed to fat emulsifying ability; and to solvent action on cheese proteins (217) perhaps because processing increased the water-soluble nitrogen in the cheese (224). Later, electrophoretic studies of proteins in the natural and processed cheese showed no significant differences (95, 114). Some salts dispersed fat and were therefore considered to be good emulsifiers, but they did not always give the best body characteristics in the finished cheese. Other salts which produced desirable body characteristics did not act efficiently during heating and mixing of the blended cheese (114).

Studies of salts for process cheese have considered changes in water-soluble nitrogen, fat leakage, compressibility, knit, and flavor of the finished product. The results have indicated in general that satisfactory emulsifiers all have trivalent anions, form alkaline solutions, and precipitate or sequester calcium. But since all such compounds do not perform satisfactorily, the choice of salts or combinations of salts in practice has generally been determined by ability to disperse fat, to promote uniform melting and blending during processing, and to give the desired flavor, consistency, and melting properties in the finished cheese. In addition, the choice of salts, or combinations of them for processing, has also been influenced by the cheese chosen for processing.

Rochelle salts were used in the early days of commercial practice (71, 217), but the sodium salts of phosphates and citrates were more generally preferred. Other potential emulsifying agents have been mentioned including sodium and calcium gluconates, sodium mucate, lactates, and malates (55, 222), ammonium salts (115, 223), gamma and delta gluconic lactones (177), injections of carbon dioxide and hydrogen (85), and the use of proteolytic enzymes (196, 197).

Studies of sodium citrate showed that it was a good emulsifier which, when compared to disodium phosphate, decreased fat separation during heating and produced cheese with firmer body and slightly preferred flavor (216, 217, 224, 233).

Generally the industry has moved away from the original and almost universal (often exclusive) use of sodium citrate to the phosphates, which include disodium orthophosphate, trisodium orthophosphate, sodium metaphosphate, tetra-sodium pyrophosphate, and sodium polyphosphates (217, 223). The versatility of phosphate salts has been indicated in numerous industrial patents which claim in general that certain salts can be used to control consistency (206) and to give the special melting properties desired for baked goods, meat products, frozen specialties, and other food products (256). Sodium metaphosphate, for example, has been indicated for making non-melting cheese desirable for novelty meat loaf (205). Other combinations of phosphates and protein peptizing agents have been proposed for preparing emulsified cheese for drying (221). In recent years the use of a complex of sodium aluminum orthophosphate (Kalisal) has been developed for rapid heating with less fat leakage and less tendency for formation of surface crystals in packages (22, 140, 141).

Use of phosphates is not without peril. Crystallization with orthophosphates is a prevalent and often experienced defect, particularly with some of the newer products and packages. The defect is related to the pH of the finished product—generally higher usage can be tolerated with a lower pH.

More recently there seems to be a trend back to use of sodium citrate to improve body. Generally it is used in combination with other emulsifiers. Such use in some of the newer sliced products does, however, often cause a defect known as citrate haze. This appears as a fine precipitation of calcium citrate on the surface and is probably related to physical abuse of the product as it is being processed and packaged (164). Then, too, when sodium citrate is used in combination with other emulsifiers, there is a very narrow usage range—exceeding the limits can seriously damage the melting and body characteristics.

Loss of melting properties when process cheese is
reworked into a new blend may be corrected by use of a small amount of surface active agent like phosphorylated stearyl monoglyceride to supplement the emulsifier (138).

References to studies in other countries have not been included in this section in accordance with the limitations of this review. The reader must not assume that developments in the United States have proceeded unilaterally (62, 178, 246, 247). The Germans, particularly, have had much success with the higher polyphosphates. A leader in this field seems to be Joha-Benckiser-Knapsack GMBH at Ludwigshafen-Rhein. No attempt has been made to describe practices which have not been reported in the U. S. literature. Much work is being done on emulsifiers and improved methods are certain to follow.

Ingredients

Cheddar and Swiss were the basic varieties of cheese used for processing when the industry was being established in the United States. Other blends of varieties soon followed in which Muenster, Limburger, and Brick cheese were used (12). Emulsifying salts, color, sodium chloride, and water were the first non-cheese ingredients commonly used. Other additives were gradually adopted: most of them were commercial innovations; some came from industrial or academic research; some were advocated and abandoned.

Melting properties, firmness, plasticity, and fluidity have been as important as flavor in the search for improvements. These characteristics have been controlled to a great extent, but not entirely, by the choice of the cheese, its variety, composition, acidity, and extent of curing. To these controls of properties have been added the actions of emulsifiers and effects of condensed or dried skimmilk, milk, whey, or whey proteins alone or in combinations (26, 35, 38, 41, 43, 102, 103, 226, 227, 239).

Low-fat cheese and skimmilk cheese have been used to make low-fat products desired by some customers and to decrease costs (31, 71, 102, 103, 119, 147). Skimmilk cheese, probably more than any other ingredient, aroused the intense antagonism to process cheese manufacture before standards were established.

Curd from whole-milk cheese was conditioned by some treatments to prepare it for immediate processing, such as the mixing of finely divided curd with an alkaline solution (127, 176), and the treating of granular or cheddared curd with acid (47, 110, 136). Hard rind of Swiss, after grinding and milling into small particles, was recommended for processing (53).

Unusual ingredients have been suggested. Cheese made slightly rancid by a special lipolytic enzyme imparted an improved flavor in the processed product, according to some researchers (29). Injection of green mold veins into melted cheese before packaging small portions altered its appearance (145). Flavors were modified with chocolate (105) or condiments (156, 228, 244).

Ingredients-not-cheese first used in processing in addition to emulsifiers, color, salt, and water were chosen to modify composition, or flavor, stability, and consistency, and included different sources of milk fat, vegetable gums, stabilizers, lecithin, acids, liquid smoke, spices, chocolate, meat, and vegetable products. Substances which might simulate cheese flavor, like red pepper, were excluded by regulation.

As demand has developed for products to serve special diet needs, or to provide different physical characteristics, new and different emulsifiers and food materials or combinations of them have been introduced. All have been examined by regulatory officials as well as industry and, when acceptable to all interests, have been included in the 1950 Definitions and Standards of the Food and Drug Administration (81) and in subsequent revisions of those regulations.

Equipment

The equipment first used in processing was typical of that used in the food industry; it was adapted to processing cheese. Advances since then represent the combined efforts, observations, and ingenuity of processors who saw the needs, the engineers who developed solutions, and fabricators who aided in perfecting specialized equipment. Fig. 2 indicates the diversity of operations which depend on mechanical devices.

In the early 1920s, the cheese selected for processing was placed on tables where wax and bandages were stripped from it by hand. Early operators some-

Figure 5. Lay-down cheese cooker, circa 1935. (Courtesy of E. C. Damrow Brothers Co.).
times dipped the cheese into hot water to facilitate stripping bandages. Sharpened scrapers and hand knives were used to remove hard rind and damaged spots or mold. The placing of cheese on roller conveyors instead of tables simplified cleaning and conveying cheese to the next operation.

Development of flexible wrappers (1, 126) to cover 20- and 40-lb. blocks simplified the cleaning operations. Wrappers easily stripped from blocks and blocks required little or no other preparation for subsequent operations. Ultimately, development of pressing cheese curd in barrels for curing further simplified preparation of cheese for processing and greatly reduced labor cost and minimized surface cleaning.

After cleaning, cheese was divided into pieces to fit the hoppers of the meat grinders which were first used to comminute the cheese. Dividing was done by pulling a wire through the cheese first by hand; later this was done by machine.

Meat grinders were replaced with powerful mills or shredders which could accept cheese in 20-lb. pieces and eventually much larger, as units of barrel cheese replaced cheddars. Capacities up to 50,000 lb. per hour are now possible with motors of 100 hp and over.

From the grinders, the product went first to steam-jacketed kettles. In the 1920s these were equipped with double acting agitators and scrapers. Later models injected steam to heat the cheese during the mixing process. At first the cheese was drawn from the kettles directly into foil-lined 5-lb wooden boxes. Later, as production speed was increased, the 200- to 400-lb. batches were conveyed or dropped into hoppers of fillers.

Kettles for large scale operations with greater capacity and more efficient stirring and heating were designed by processors in the 1920s, but subsequently much improved in mechanical efficiency and sanitary construction. The horizontal or "lay-down" kettle consisted essentially of a covered, horizontal, round-bottomed trough in which the cheese was heated by direct steam injected through side openings. Cheese was stirred by helical type screws which mixed and forced it from the hopper opening to the opposite, discharge end. As the hopper filled and the cheese melted, the cheese flowed back above the horizontal screw toward the hopper end and was thoroughly mixed and homogeneous before it was released to flow to the hoppers of the filling machines. The time to complete the filling-to-discharge cycle approximated 3 to 6 min. Several modifications of the "lay-down" kettle were proposed as the industry developed (49, 133, 153, 180, 182, 217, 248). The design and capacities of "lay-down" kettles allowed continuous operation, but in practice these kettles were operated by the batch method with the hot cheese delivered into the hoppers of the filling machines and held with gentle agitation until packaged. Continuity was achieved by using several kettles to deliver in regulated sequence to the filling machines.

In 1925 a novel method of heating was patented (173-175) in which the cheese was emulsified by forcing it through staggered rows of heated tubes or by heating it by passing an electrical current directly through the cheese itself as it passed between the rows of tubes. Recently, another system has been developed to heat, mix, and move the cheese in a closed system from intake to packaging line (49).

Small capacity kettles have been designed for experimental work (137, 217, 224, 327); some have been of the vertical type with provisions for steam injection, others of the horizontal type. Much of the early research work was done with such small devices. Some modern processors have small kettles designed and built especially for research and development work to duplicate the action of the commercial models.

Highly sophisticated equipment has been developed to deliver the exact amounts of hot, fluid cheese into packages, pouches, or envelopes. These packages may be formed continuously immediately before filling and are mechanically closed, sealed, and placed in containers for merchandising. Such machines are dramatically different from the simple operations of the pioneer industry when boxes were nailed together, lined with foil shaped on a mandrel to fit the box, all by hand. Boxes were filled with a hand-operated gate, check-weighed, and closed by hand-folding the foil over the hot cheese, then passing the filled box to the operator who nailed on the cover.

Today's package filling operations represent highly
technical solutions to the problems of labor costs, product flow, sanitation control, accurate measurement, exclusion of air, sealing, assembling, and labeling containers without hand labor and all at the speed required by modern standards of economy and efficiency. Packaging equipment is so diversified to meet the requirements of the type of cheese, size, shape, shelf-life, and packaging material that it is possible in this review only to suggest the complexity of the developments attained in these efficient operations. All operations in the production of process cheese, beginning with procurement, classification, and curing of natural cheese to provisions for holding before shipping to the merchandising outlet depend on efficient use of the capacity for packaging.

Movement of raw materials and finished products are an integral part of processing. In the early days, the cheese at all stages of processing was lifted, carried, and placed on trucks and moved by men. In today's operations manual labor is minimized with mechanical devices, palletizing, power-operated mechanical conveyors, and power lift trucks. Conveyors and sorting systems which are controlled by computers can now be used to mechanize the movement of cheese from packaging lines, through storage or holding areas, and finally into the trucks.

Packaging of natural cheese has assumed an important place in the operations of the processing plant. The processor has developed expertise and experience in selection and use of wrapping materials which can protect and display cheese for merchandising. The processor can provide and operate the elaborate machinery required to wrap, seal, and containerize the consumer-size units; he has the system established for merchandising the finished product; and finally he can make the fullest use of odd-shaped pieces and remnants from cutting and check-weighing operations without waste.

Wrappers

The rapid market acceptance of process cheese resulted, in large part, from the tinfoil-lined wooden boxes used to package the cheese. The hot cheese filled the boxes and excluded air; the foil clung tightly to all sides of the loaf when the package was closed. Properly filled boxes were practically mold-free during normal merchandising. The sandwich-size cross section could be easily sliced. This package was far better for the U.S. market than the cans and glass containers that were tried first (131, 190).

Foil had been used for wrapping natural cheese as early as 1904. It was being used successfully for wrapping 3-oz. packages of Club cheese (Cold Pack) in 1915. The Kraft patent which specified metal foil which would stick to the cheese, not the box, might have been the most valuable patent owned by the first of the U.S. processors. It commanded valuable royalties (131).

Tinfoil tended to blacken in the container, especially when phosphates were used and when the pH of the cheese exceeded 5.8. Uncoated aluminum foil tended to pit; coated aluminum foil developed in the 1930s resisted corrosion and pitting but was difficult to manipulate in the packaging machines. Lead foil discolored the cheese in a few days. Non-metal films, like Pliofilm and Cellophane, were first tried with little success (233).

World War II demands for tin were critical. A substitute was essential. Research workers at the
Marathon Paper Mills began to develop the semi-transparent modern film by coating Cellophane with a layer of Parafilm, a mixture of wax and latex. The first films tended to taint the surface of cheese. Eventually this fault was eliminated and the new coated film produced showed the necessary clinging properties and imperviousness to gas transmission required to protect the product. It was manufactured in rolls and preformed bags to line the boxes. This film was licensed exclusively to a leading manufacturer until a comparable film with essentially equivalent properties was developed and sold by General Felt Products Company. By 1940 the transparent films were being used with complete success and were regarded as satisfactory or even better than the original foil (72, 73).

Combinations of wrapping materials were made to obtain the best qualities of each in laminated film. Such combinations became widely used in packaging sliced processed cheese and natural cheese. They provided the impermeability to oxygen, nitrogen, and carbon dioxide, with strength and transparency essential for the U. S. market (195, 252).

Sliced processed cheese in packages sometimes developed mold when small air cavities were formed in packaging. By one method, stacks of slices were successfully heat-sealed with pressure against the sides and ends to expel the air (77). Packaging sliced cheese eventually involved various methods for preventing mold growth such as vacuum (61, 116); vacuum released with nitrogen, carbon dioxide, or specific ratios of mixtures of these gases (58); film combinations (61, 252); mold inhibitors (61, 101, 172); and heat shrinkable film (172).

Some of the research and development work was directed to protect cheese between the factory and the processing-packaging operations. In addition to the wrappers for covering blocks of cheese, films were applied to line barrels (78); impervious films were developed for use in combination with porous material to remove whey in pressing and to close openings in the surfaces (214).

The desirability of screening out ultraviolet light for retarding oxidation of process cheese was attempted in 1958 by incorporating a light-screening additive to Cellophane (89). Such problems had been anticipated and investigated at least 20 years earlier (163).

As the production of cheese spreads expanded in the 1930s, glass containers with vacuum closures were used. The vacuum which held the caps on the glasses was produced by flowing steam under the caps to exclude air, closing the containers, and cooling to condense the trapped steam to make the vacuum-sealed glass. Plastic cups and aluminum containers with tight closures were used. Sausage-shaped links of process cheese were also tried in this same period (100).

Various antmycotics were used by industry to protect wrapped packages of slices. These mold inhibitors were used in the process cheese itself in prescribed amounts or on the wrappers, providing the absorption of antmycotic from the wrapper did not exceed the limit prescribed by the FDA. Dichloromethyl succinate was used but abandoned when the FDA did not approve its use. Propionic acid and its calcium salt proved to be acceptable and effective (213); the products formed when they were decomposed by mold action were harmless. Propionic acid and calcium and sodium propionates were generally effective and were accepted by the FDA but imparted a slight Swiss-like flavor.

Wrappers have been modified in strength, permeability to O2, CO2, and N2, transparency, scaling properties, and behavior in packaging machines. These modifications have improved keeping quality of the cheese and increased the protective properties and sales appeal of the packages, simultaneously adapting them to the requirements of complicated, high-speed machines made to deliver units in a multiplicity of sizes and shapes. The complicated interrelationships solved cooperatively by processors and manufacturers of wrappers and machines are a tribute to their combined research and development programs and practical know-how of production methods and standards.

Cheese Products

Cheese foods and spreads

Process cheese foods and spreads were developed in the 1920s. E. E. Eldredge, formerly with Phenix Cheese Company, began research for Fred Pabst, Sr. at Pabst Farms, Oconomowoc, Wisconsin, and in 1922 started a processing operation with Swiss cheese made at the Farms. Whey disposal was a problem. Eldredge precipitated the whey protein to put into the process cheese; then he concentrated whey in the Pabst brewery in Milwaukee and used the concentrate in the processing operation. The resulting cheese was soft in body, pleasing in flavor, and was first offered under the name Cheesette, but when this name was not allowed, it was called Pabst-ette and was soon marketed widely in the U. S. (88). Competitors introduced Nu Kraft (Kraft Cheese Co.) and Phen-ette (Phenix Cheese Company (12). Within a few years Velveeta displaced Pabst-ette after Pabst had been purchased by the Kraft Company.

By 1947 the production of cheese foods and cheese spreads was well established, and industry was cooperating with the FDA of the Federal Security Agency to develop definitions and standards for these and other cheese products. The definitions recognized
that cream and concentrates of milk, skim milk, and whey produced softer body and mild flavors when added to process cheese. These additions were desirable when moisture did not exceed 44% with fat not < 23%, except when the mixture contained fruits, meat, or vegetables. Such mixtures were designated "Pasteurized Process Cheese Foods." "Spreads" were defined with not over 60% moisture (but over 44%) and with not < 20% fat. In making these process cheese foods, the blends were to contain > 50% cheese in the finished products. Emulsifiers were permitted within limits, as in process cheese, and so were acids, water, salt, and color.

The pasteurized process cheese spreads were like the cheese foods except for lower fat, higher moisture, and use of sweetening agents and gums. Definitions and standards of cheese foods and spreads promulgated by the Food and Drug Administration of the Federal Security Agency in 1950 established specific limits for these products in composition and ingredients (81).

The earliest cheese foods and spreads sometimes developed "sandiness" when excessive amounts of whey or skim milk concentrates were used. Insolubility of lactose at concentrations exceeding 16.9% of the moisture in the cheese was demonstrated (82, 83, 168, 226). Excessive moisture, low fat, and lack of acidity were also associated with defects in body and keeping quality (225).

When the restrictions of the original processing patents began to expire in 1938, new manufacturers were looking for information on the manufacture of all pasteurized process cheese products. Trade papers began to feature discussions on formulation, ingredients, composition, reaction, methods of heating, use of gums and emulsifiers (33, 34, 38, 41, 54), and have continued to do so as new blends and products for aerosol dispensers have developed (31, 98, 146, 147).

Research during and after World War II on stability and quality of spreads for use by the Armed Forces produced specifications and much useful information on ingredients, average age of blend, special flavors, and methods to prolong keeping quality with high temperature short-time sterilization and aseptic canning of spreads (154, 156, 157). Studies of combinations of Cheddar and semisoft cheese in process cheese spreads showed that acidity, age, and ratios of solids-not-fat to fat affected the melting properties and firmness of the finished cheese (117, 168, 169, 239).

Slices

In the late 1930s the appeal of pre-sliced cheese for merchandising was recognized. Cheddar and Swiss cheese were being sliced and packed in gas-venting cans (249). Research workers at Marathon Paper Mills were wrapping and sealing slices of natural cheese in Parafilm.

In 1944 a new method was invented which formed hot processed cheese in a thin sheet on a cooling drum. This sheet was cut continuously into ribbons and removed from the drum. The ribbons were superimposed mechanically and then cut to form stacks of sliced cheese for packaging. The packages of slices were very well accepted (18, 134). The process was not licensed for use by other manufacturers.

By 1950 several other methods of making sliced cheese were being used or had been invented or proposed. Some operators cast cheese in blocks and sliced it for packaging. Placing hot cheese into compartments, sized to hold one slice, was followed with several variations (108, 235). Cheese was spread or extruded in thin layers and chilled on moving belts to form ribbons for cutting to the desired size (171). Spinning hot cheese in a bowl, while cooling it to the solidifying temperature, formed a ribbon of cheese as it crept up the sides of the bowl until it could be removed and sliced to the proper size (109).

Slices of cheese, with some exceptions (19, 134), tended to stick together. Some operators prevented this by interleaving slices with non-sticking films (108, 158). Heating the surfaces of slices prevented sticking. This was accomplished by passing slices or slabs between hot rollers and then cool rollers by one method (89) or exposing them to radiant heat to form a thin layer of oil on the surfaces. This free oil had the added advantage of inhibiting mold growth (92, 167).

Multi-ribbon formation of non-sticking slices was further improved by a machine which chills both sides of the cheese ribbons. The hot cheese is pumped through a manifold with 8 to 12 nozzles extruding ribbons of cheese on the upper of two stainless steel belts where it is partially cooled, then inverted onto the lower belt to complete the chilling operation. The cooled ribbons are superimposed to make 6, 8, or 12 layers. These are cut to form stacks of slices of the desired dimensions (24).

The most modern method of producing individually wrapped slices was developed by L. D. Schreiber Cheese Company, Inc. Highly sophisticated automatic equipment forms the wrapping material into a tube into which the hot cheese is extruded continuously. This tube is sealed transversely to form a chain of packets which is then cooled. Each packet is cut from the chain transversely through the center of the seal to form individually wrapped and sealed slices. This is done at a speed of 400 to 600 slices/min (50).

Making packages of sliced cheese involved preventing mold growth in the interstices of the packages where small volumes of air had been trapped...
in wrapping. Packaging with N₂ or CO₂, or mixtures of these gases, was a successful solution (181). Another method advocated spraying sides and bottom of the package with liquid wax and then applying a polyvinylidene film as a top cover (243).

Development of the antifungal, sorbic acid and potassium sorbate, proved to be effective and safe for protecting sliced cheese from mold growth in packages. The treatment was most effective with tight clinging wrappers which excluded air, because the antifungal itself was attacked by mold, if any were present, before the cheese itself was affected. Research showed that the sorbic acid was superior to the vacuum pack in prolonged storage. It was usually applied to the inner surface of the thermostatic-coated film used for wrapping (213). Machines were devised for applying the sorbic acid powder to all cheese surfaces in a stream of pressurized air (97).

Studies showed that molds isolated from moldy process and natural cheese which had been previously treated with potassium sorbate would grow on an artificial medium containing 1,500 to 5,400 ppm potassium sorbate. Penicillium roqueforti was most resistant (152).

Packages of process cheese in slices are replacing the original 5-lb. loaf. Kraft announced in June 1973 that it had stopped making the 5-lb. loaf which changed the course of the cheese industry in the 1920s.

Cans and bars

Processed cheese was first placed in cans in the U.S. by J. L. Kraft in the summer of 1915; it was first marketed in 1916. In 1917 large orders were placed by the Federal Government for military use and by 1918 the cheese was being shipped worldwide. This cheese was prepared from cured Cheddar, shredded, blended, heated to a dough, and run to a filler. This filler lined 1/4-lb. cans with paper, filled and covered them at the rate of 18,000 units per hour. Then this canned cheese was heated under pressure at 250 F for 30 min, chilled and packed 24 per case (13). The J. L. Kraft and Bros. Cheese Company of Chicago became known as the producer of sterilized cheese in cans (5), although Phenix Cheese Company was also working with this product (13). After 1918 the commercial acceptance of the 5-lb. loaf quickly discouraged production of canned cheese for domestic use.

Research and development on the canning of process cheese again became important with the expansion of military forces in 1940. Canned cheese in 4-oz. tins was designated an important part of field rations for the troops. Larger 7-lb. cans were needed for field kitchens as well as military bases. The 7-lb. cans are still produced for institutional use.

These products were made for the military forces to conform to specifications of the Quartermaster Corps, Food and Container Institute. Information from commercial laboratories, civilian advisers, and experiments of the National Cheese Institute were all used to prepare specifications for manufacturing. Problems of canning cheese varied. Exteriors of tins were coated with non-reflecting, dark-colored lacquer. Interiors of cans were lacquered to prevent discoloration or corrosion, and were lined with parchment paper for easy emptying. Palatability was a prime concern. Special combinations of process cheese were submitted to taste panels. Successful combinations selected for production included such flavors as pimiento, smoke flavor, and cooked bits of bacon or ham. The optimum composition of the cheese was determined in the same way. It was found that products with higher moisture were preferred to the regular process cheese. These products also were better adapted to canning and sterilization when it was practiced eventually. High nutritive value was required in some of these rations so butter was added.

These products had to endure long periods of storage at temperatures of 100 F or sometimes higher. Maximum temperatures of heating during processing approximated 195 F at first, but eventually sterilization in the can was practiced before the Korean War.

Research and development on canned cheese spread for military use continued after 1945 at the Food and Container Institute of the Quartermaster Corps. These projects showed that process cheese in cans exposed to a heat treatment of 240 F for 75 min in a steam-pressure retort was not acceptable, whereas process cheese spreads with and without meat added, stood this treatment satisfactorily to give good keeping quality and palatability (155). The age of blends of Cheddar influenced the stability of spreads (157).

The durability of process Cheddar in tin cans was tested by storage for up to 7 years at 100, 70, 47, 32, 0, and -20 F. Effects were measured by changes in color, texture, flavor, vitamins, and container damage. Cheese at 100 F softened, oiled off, and swelled the tins within 6 months. At 70 F and below freezing, the product was relatively stable, but cheese stored at 32 F was best (56).

Swelling of cans of process cheese spreads after long storage at high temperatures indicated that anaerobic spore-forming, gas-forming organisms had survived the heating treatments. Studies with spores of such an organism, PA 3679, under test conditions, showed that heat resistance of the spores decreased with lower pH and higher brine concentration (127).
Further research disclosed that heating and cooling lags in thermal death time increased with the level of cheese in the can and when the can was in a flat position rather than on edge (124).

Related to the problem of preserving the food value of cheese in cans for the Armed Forces was the development of process cheese food bars. Military specifications for cheese-flavored bars had been proposed in December 1961. The bar consisted of Blue cheese, dehydrated potatoes, potato starch, shortening, uncreamed Cottage or Bakers cheese, starter distillate, color, and water. Bars made of this mixture and freeze-dried until crisp had a composition of 13-15% fat, 7.7-9% protein, 70-75% carbohydrate, 0.7-1.4% salt, and a maximum of 2% moisture. This bar was patented by the Secretary of the U. S. Army (125).

**Dried process cheese**

Drying of natural cheese has been practiced for an unknown length of time; for military use it seemed especially attractive during World War II. It was tried, but not generally used (60). Spray drying a cheese emulsion was studied in the 1960s.

Spray drying of cheese began with selection of cured cheese with the desired flavor. Cheddar and Blue were commonly used. The cheese was dispersed to make a slurry in water and heated with sodium citrate or disodium phosphate to 100-180 F. It was then homogenized and spray dried at temperatures approximating 160 F. Foam spray drying of cheese was accomplished by dispersing cheese in water at 180 F with sodium citrate, homogenizing, injecting Ns between a high pressure pump and the atomizing nozzle, and then spray drying the foamed mixture. The resulting product, when canned under N2, was better in quality than non-foamed spray-dried cheese. Adding the antioxidant, Nordihydroguaiaretic acid, improved shelf-life but sometimes off-flavors appeared (51, 116, 193).

Agglomeration of particles of dried cheese was accomplished by suspending them in a fluidized bed with hot air or gas. A suitable agglomerating agent was then sprayed directly on the cheese so it was agglomerated and dried at the same time (25). Using different spraying nozzles produced desired control of particle size in usual spray-drying operations (166).

Gas chromatographic studies showed volatile flavors were lost to some extent in spray-drying cheese and new flavors formed when slurries were heated above 180 F. Foam spray-dried cheese retained flavor better (52).

Preparation of a process cheese-like mixture for coating popcorn involved adding vegetable fat. It met regulatory objections as a filled cheese. The manufacturer claimed it was not sold as cheese but merely to coat popcorn and thus manufacture of the product was permitted. A process for making a similar coating was described in 1970. The ingredients were spray-dried Cheddar, blended hydrogenated vegetable oils, dry buttermilk and sweet whey, glycerides, lecithin, and salt. The mixture could be sprayed when heated (220).

**Trends**

This consideration of the future of the process cheese industry will be limited to aspects of production, research and development, and manpower during the next 25 years.

**Production**

**Trends.** Data in Table 1 show 4-year averages of the number of manufacturing plants and production of pasteurized process cheese, cheese foods, and cold pack cheese reported annually by the U. S. Department of Agriculture since 1956. The number of plants since 1956 has been fairly steady although a downward trend is suggested by the 4-year period ending in 1971. Production of processed cheese of all types shows an upward trend. Production per plant is increasing. The trend should continue with expected improvements in buildings, equipment, and markets.

Values in Table 2 show that combined production of processed cheese, cheese foods, spreads, and cold pack is equivalent to half the total cheese (excluding Cottage types) produced in the United States. Production of processed cheese, which is the processed equivalent of Cheddar cheese, equals about 60% of Cheddar production. It is interesting that this relationship is the same as the consumer preference for this product indicated almost 40 years ago by the studies of Hobson and Schaars (112). The relationship seems likely to endure.

Trend of production has exceeded the growth in population as per capita consumption of all kinds of cheese has increased from 7.9 lb, in 1954 to 13.2 lb in 1972. It is probable that this increased consumption of processed cheese products should continue with the greater demand for economical, high-quality, protein foods in convenient packages.

**Cheese procurement.** Processed cheese operations have been located traditionally in or near the areas of maximum production. Many other factors affect choice of location such as proximity to markets, costs of transportation, and availability of skilled labor. Now there is a change taking place in areas of production which will affect the procurement policies if not the location of manufacturing operations. Data in Table 3 show total cheese production in the United States in 1956 and 1971. Percentage changes in production in five general areas of the country are shown.
In this 25-year interval all divisions of the U. S. increased cheese production except the South Central division. Production of whole milk Cheddar in this area actually declined.

The significant increase in importance of West North Central U. S. as a cheese producing area is evident from data in Table 3. In 1956 this section made only 35% as much cheese as the leading division, the East North Central; in 1971 it made 62% as much cheese as the leader. The leading area increased production $84 \times 10^6$ lb. in the 25-year interval, whereas the West North Central division raised production $193 \times 10^6$ lb.

Procurement of cheese for processing may be affected by the recent large scale amalgamations of farmer cooperative associations. Historically, cooperatives market fluid milk in the highest price classification. They have established their own manufacturing plants to handle surplus milk or have sold it instead to independent manufacturers. It seems unlikely at this time that processors will undertake the conversion of variable surplus supplies into cheese in their own factories although the possibility may be highly desirable as demands for fluid milk change.

Milk substitutes. Production of processed cheese-like foods from vegetable fats and proteins, or with such fats and proteins in combination with milk fat and milk proteins, seems probable. This trend will be encouraged by consumers who want to meet special dietary requirements. The making of low-fat, low-cost, cheese-like food can be expected for domestic and foreign markets that are demanding these low-cost protein-rich foods where shortages exist. Research is needed to make these products of acceptable quality. Industry is now studying possibilities and has demonstrated its ability to produce these products.

Manufacturing. Production data indicate the trend toward greater production per plant. Expanded and improved operations will require closed systems and mechanized operations to eliminate hand contacts and to reduce labor requirements at all stages of manufacturing. There will be less reliance on manual controls. Manpower will be used only for machine activation, inspection, engineering functions, and mechanical maintenance. Such changes depend in large part on the improvements in grinders, cookers, and packaging machines. Closed systems will retain more of the volatile odors now lost in steam cooking operations. Consideration is now being given to achieving emulsification of the fat and protein of cheese with less dependence on chemical emulsifiers by using systems related to those described by Parsons in which cheese is emulsified under pressure at temperatures below that of pasteurization (173-176) or by application of colloid mill mixing and dispersing principles.

Analytical procedures using ultrasonic sound and electrometric methods of analysis are coming into use. These procedures can be adapted to in-line analysis of product flow. They offer methods for continuous standardizing and composition control of blends.

Uniformity of composition facilitates mechanization and automation of product movement during processing, packaging, and casing. The mechanical handling of the cased goods with computer controls is now practiced in modern plants and warehouses; such controls will be used extensively in advanced processing plants to simplify handling the diversity of products which are directed to many different destinations for storage and shipping.

Packaging. Although methods and materials for packaging have been greatly improved in recent years, they are still being changed. Wrapping materials now provide good protection, but experts are searching for methods and materials which will make antimycotics unnecessary. Mold-free units must be made.

### Table 1. Processed Cheese, Cheese Foods, Cheese Spreads and Cold Pack Cheese: Four-Year Averages of Production in the United States from 1956 to 1971 (237)

<table>
<thead>
<tr>
<th>Years</th>
<th>Processed cheese</th>
<th>Processed cheese foods, spreads and cold pack</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant Production</td>
<td>Plant Production</td>
<td>Plant Production</td>
</tr>
<tr>
<td></td>
<td>(Number)</td>
<td>(Number)</td>
<td>(Number)</td>
</tr>
<tr>
<td>1956-'59</td>
<td>48</td>
<td>1,000 lb.</td>
<td>732,067</td>
</tr>
<tr>
<td>1960-'63</td>
<td>571,478</td>
<td>221,475</td>
<td>729,963</td>
</tr>
<tr>
<td>1964-'67</td>
<td>509,267</td>
<td>246,207</td>
<td>950,474</td>
</tr>
<tr>
<td>1968-'71</td>
<td>462,760</td>
<td>406,477</td>
<td>869,237</td>
</tr>
</tbody>
</table>

Excluding spreads made from Neufchatel and Cream cheese.

### Table 2. Relation Between Production of Natural Cheese and Production of Processed Cheese, Cheese Foods, Cheese Spreads and Cold Pack in the United States (237)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total cheese</th>
<th>Cheddar</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(millions pounds)</td>
<td>(millions pounds)</td>
<td>(millions pounds)</td>
</tr>
<tr>
<td>1971</td>
<td>2,373</td>
<td>1,230</td>
<td>52</td>
</tr>
<tr>
<td>1970</td>
<td>2,201</td>
<td>1,138</td>
<td>52</td>
</tr>
<tr>
<td>1969</td>
<td>1,990</td>
<td>1,017</td>
<td>51</td>
</tr>
<tr>
<td>1968</td>
<td>1,938</td>
<td>971</td>
<td>50</td>
</tr>
<tr>
<td>1967</td>
<td>1,913</td>
<td>1,010</td>
<td>53</td>
</tr>
</tbody>
</table>

1 Total of all types excluding Cottage and full skim American.
2 Production of pasteurized process cheese, cheese foods, cheese spreads and cold pack cheese.
3 Production of pasteurized process cheese.
to open easily and to reseal hermetically to prevent dehydration, odor absorption, and mold contamination in the household refrigerator. Packaging operations will be speeded to deliver more than 200 packages and over 1,000 slices in packages per minute.

Expansion. Process cheese manufacturers expect greater production in more complex manufacturing units, some of which will have capacities exceeding 100 million lb./year. Such growth will be accomplished by development of the engineering accomplishments and technical expertise now used in modern plants. There are other methods of corporate development now evident in this industry. Some processors are expanding by increasing production of processed cheese, cheese foods, cheese spreads, and packaged natural cheese. These operations have succeeded and will continue to expand because they specialize in efficient procurement, curing, processing, quality control, and merchandising.

A second type of growth is attracting attention. It is production and merchandising of closely related food products. These are products which need similar facilities, sanitation techniques, skilled labor, and technological control. They are products which can use the same or similar equipment for heating, sterilizing, cooling, packaging, warehousing, and distribution. Outlets for these related products can be served by the same sales force and methods. These products, for example, can be cheese-like foods made with vegetable fats and proteins alone or combined with cheese; they may be convenience foods using cheese as a chief ingredient. This type of expansion attracts more attention as the dairy industry becomes more aware of opportunities in other phases of food production and distribution in this country and abroad.

And then there are organizations which are growing by absorbing or combining with other enterprises. The complementary enterprises may not even be closely related to processing in either procedures or location, but are attractive as outlets for capital and management ability. Examples of such organizations are conglomerates which are processing cheese, handling dairy products, groceries, meats, confections, chemicals, and engaged in warehousing and agricultural business enterprises. In such organizations the identity of the processor may be obscured.

Research

It would seem highly desirable if technical, industrial, and economic problems could be studied in a Cheese Research Institute supported by industry through the National Cheese Institute. Such an institute could provide postgraduate training for top echelon technical management directors and provide a place to train laboratory technicians and quality control personnel.

Such an institute would attract staff members of high caliber to work on problems of processes, products, packaging, equipment, analytical procedures, and quality control. The institute might centralize and classify scientific publications, statistical information, and other knowledge related to the industry's labor relations, regulatory edicts and proposals, and commerce. Such information would be compiled for the direct support of public relations and service work of the National Cheese Institute.

A few objectives of research and development important at this time are listed here; they may serve to suggest the nature of other information needed to assist the development of this growing industry: (a) engineering to achieve better use of heat, more mechanization and automation in manufacturing, storage, and transportation; (b) simplification and mechanization for rapid, accurate, laboratory procedures to determine chemical composition, rheological properties, and to identify and quantify certain microorganisms, enzymes, antibiotics, toxins, and vitamins in natural cheese and the finished products; such information must be the basis of informative labeling to show composition and nutritive values; (c) improvement of emulsifiers and stabilizers and mechanical methods of dispersing, solubilizing and making blends of cheese homogeneous; (d) preservation of cheese flavors and development of new combinations of flavors and ingredients to make meat-like foods with a cheese base; (e) improvements of sanitary controls and quality to enhance keeping properties without mold inhibitors or preservatives; (f) improve-

TABLE 3. COMPARISON OF CHEESE PRODUCTION IN THE UNITED STATES IN FIVE DIVISIONS IN 1956 AND 1971 (237)

<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>million pounds</td>
<td>%</td>
<td>million pounds</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New England and Mid Atlantic</td>
<td>131</td>
<td>260</td>
<td>+98</td>
<td>36</td>
<td>63</td>
<td>+75</td>
</tr>
<tr>
<td>E. North Central</td>
<td>809</td>
<td>1,181</td>
<td>+46</td>
<td>512</td>
<td>596</td>
<td>+18</td>
</tr>
<tr>
<td>W. North Central</td>
<td>214</td>
<td>594</td>
<td>+178</td>
<td>180</td>
<td>373</td>
<td>+107</td>
</tr>
<tr>
<td>South Central</td>
<td>144</td>
<td>147</td>
<td>+2</td>
<td>118</td>
<td>87</td>
<td>-26</td>
</tr>
<tr>
<td>Mt. and Pacific</td>
<td>84</td>
<td>159</td>
<td>+89</td>
<td>41</td>
<td>65</td>
<td>+38</td>
</tr>
<tr>
<td>Total</td>
<td>1,587</td>
<td>2,373</td>
<td>+71</td>
<td>888</td>
<td>1,225</td>
<td>+38</td>
</tr>
</tbody>
</table>

*Total of all types excluding Cottage and full skim American.
ments of wrappers and packaging methods and equipment to increase efficiency and extend keeping quality; (g) development of precooked and packaged cheese-base foods or food combinations for convenience meals, (h) improvements in methods of controlling and stabilizing rheological properties ranging from meat-like consistency to free-flowing sauces and blends for industrial use in other foods and for dispensing mechanically in serving in fast-food establishments, (i) improved products for "instant" meals in homes and in hospitals and institutions with minimum facilities for preparing meals, (j) improvement and development of new types of low-fat cheese products, and (k) development of low-cost non-dairy foods or combinations of them with cheese to approximate composition, nutritive value, and usefulness of cheese.

Manpower

Manpower to operate the complex processing plants in the future will need special training. It is probable that technical schools can teach a basic understanding of sanitary control, simple analytical procedures, and quality evaluation. In-plant training, however, will be essential to develop the proficiency necessary to perform assigned duties.

The technical directors, research workers, and management personnel can be expected to have university training or its equivalent. But these men and women will require exposure to industrial procedures and conditions to achieve maximum efficiency. To maintain and develop skill, knowledge and judgment, we foresee more reliance on seminars with their peers. Such seminars may be conducted by industrial associations, business institutions, universities, and regulatory and governmental agencies. These seminars should discuss pertinent technical advances in chemistry, bacteriology, food science, environmental health and sanitation, as well as public relations, labor management, business law, banking, business cycles, foreign and domestic trade, and the like.

Conclusion

What began as a simple cooking, package-filling, and merchandising business has developed into a consumer-conscious, complex, and diversified industry. We expect its amazing progress of the past 50 years will be surpassed by future progress.

People are intensely aware of the problems and hazards of population explosions and food shortages in all parts of the world. The process cheese industry with greater resources than ever of scientific information and technological capabilities can contribute efficiently and effectively to provide the people of this country with convenient, healthful and nutritious foods.

Acknowledgments

We are grateful to the many friends who have answered our questions, given us valuable facts, historical records, and more pictures than we can use. We especially thank Robert Anderson, National Cheese Institute; Phyllis Doan, Kraftco, Inc.; A. B. Erickson, The Borden Co., (retired); F. M. Frederiksen, (formerly) Pabst Cheese Co., Inc.; Carl Marty Jr., (formerly) Wisconsin Cheese Corp.; and Harold Steinkle, Borden Foods, Cheese Division, The Borden Co. We deeply appreciate criticisms, suggestions, and advice of David D. Nuusbaum, L. D. Schreiber Cheese Co., Inc., and Elmer H. Martel and Norman F. Olson, Department of Food Science, University of Wisconsin.

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The Process Cheese Industry

195


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