

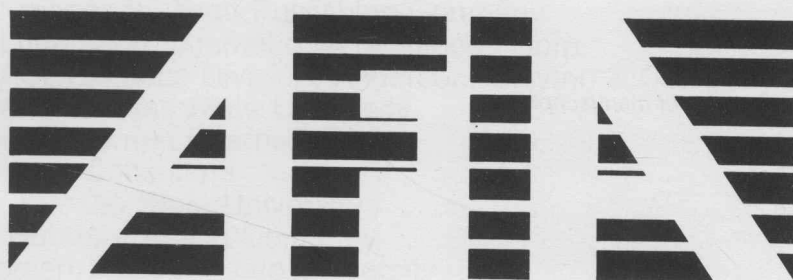
Feed Manufacturing Technology

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Feed Manufacturing Technology

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AMERICAN FEED INDUSTRY ASSOCIATION, INC.

1985

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Feed Manufacturing Technology

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We especially appreciate the thousands of hours Professor Robert R. McElhiney of Kansas State University gave as Technical Editor. Without his "labor of love" to the industry, this publication would not have been completed.

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Special Recognition

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"Feed Manufacturing Technology III" is, obviously, the third edition of what has become the handbook of feed manufacturing throughout the world. But, what may not be generally known is that the seeds for the FMT books were sown in 1961 when the Feed Production School, Inc. published the "Feed Production Handbook" with Dr. Harry B. Pfost, Professor in the Department of Grain Science and Industry at Kansas State University, as Editor-in-Chief.

Subsequently, when the American Feed Manufacturers Association published the 1970 and 1976 editions of "Feed Manufacturing Technology," Dr. Pfost served as Technical Editor and was a major chapter contributor to both editions.

No person has contributed more to the technology of feed manufacturing or has had more influence in moving the industry from the state-of-the-art to the state-of-the-science than Harry Pfost. His former students and colleagues at Kansas State University, the feed industry in general, and I join in recognizing the many accomplishments of our friend and mentor, Dr. Harry B. Pfost.

Robert R. McElhiney

Ray J. Lunemann was General Production Manager of Supersweet Feeds (International Multifoods Corp.) until his untimely death on August 19, 1985 just as this book was in its final publishing stage. His contributions to FMT III as an associate editor and his leadership in the U.S. feed industry were substantial, and he will be sorely missed by his many friends and colleagues in the industry. — RRM

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PROFILE OF THE FEED INDUSTRY

Charles Olentine
Watt Publishing

Next to the dog, cattle are believed to be the oldest domesticated animal. This probably occurred during the New Stone Age. Because the ancestors to today's cattle were by nature browsers, feeding did not pose many problems. As grass and forage became depleted, the animals were merely moved to areas where browse was in abundance. As more animals became domesticated and the pressure for animal products increased, it became necessary for the livestock tender to confine his animals and bring them feed.

Even though animals have been domesticated for thousands of years, the concept of commercial feed — that is, feed for sale — is a recent development. In fact, most of the information presently used in the formulation of feeds is less than 100 years old.

The feed industry got its start in the U.S. primarily as an outlet or dumping ground for milling by-products. The first feed mill built in the U.S. was built in 1875 in Waukegan, Illinois. Few people then could have dreamed of the strides taken in a little more than 100 years in feed processing and the scientific feeding of livestock and poultry.

Upon reflection, it seems hard for the feed man of today to believe that soybeans were grown primarily as a hay crop in the early part of this century or that the use of soybean meal in livestock rations did not begin until 1922 in this country. Vitamins were unknown at the turn of the century. Vitamin A was not discovered until 1912, and the functions of vitamin B₁₂ were not fully known until the 1940's.

Antibiotic incorporation in feed was begun in the early 1950's. With this practice eventually came more regulation of the feed manufacturer. Today, Good Manufacturing Practices Regulations are outlined and followed by mandate of the Food and Drug Administration.

As the feed industry grew, new processing methods were shown to produce improved responses in growth rate and feed efficiency in livestock and poultry. Simple grinding or feeding whole ingredients do not always work. Ingredients are now exposed to dehulling, extrusion, grinding, rolling, flaking, popping, roasting, microwaving, exploding, or pelleting. All affect nutrient utilization in one way or another.

The days of simple mixing are over. The feed manufacturer of today must monitor ingredient quality, keep an inventory of ingredients and medicinal products, coordinate delivery fleets, institute preventive maintenance programs for expensive equipment, become familiar with computer technology, and know how to manage people.

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- Evolution of the Industry
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- Scientific Research
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- Government Regulation of Feed

Chapter 2. **The U.S. Formula Feed Industry Today** — Wayne Anderson

- Defining the Industry
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Chapter 3. **Feed Manufacturing: An International Perspective** — Charles Olentine.

- Developed vs Developing Economies
- Factors Affecting the Feed Industry — Culture and Religion, Governmental Policies, Transportation, Handling, and Storage Problems
- Feed Mill Design

Not only must the feed manufacturer in the U.S. know his immediate market, he must familiarize himself with the international factors that are now affecting his business. Ingredient markets are now governed by world demand, not merely local demands. Also, new technological developments in feed manufacturing are arising outside of the U.S. The progressive feed manufacturer will have to be able to adapt the new technology to his operation, but only after evaluating the economic benefits versus increased capital expenditures.

The first section of FEED MANUFACTURING TECHNOLOGY provides an overview of the feed industry in the U.S. and abroad. A historical perspective is provided so that the reader can trace where the industry has been and can project where it is going.

History of the Formula Feed Industry

Robert W. Schoeff
Kansas State University

Water-powered grist mills were grinding grain for farmers more than 200 years ago. Most of the early mills were built for grinding wheat and corn for human consumption rather than for livestock feed. A lot of water has gone over the dam since those early pioneers brought in buhr stones by horseback and wagon and built dams and mills from the timber and rocks along swift-running streams.

Growing with America were the wheat and corn milling, meat packing, milk processing, and oilseed processing industries. The waste materials from those industries were dumped into the nearby rivers or streams until city officials, for obvious reasons, stopped the practice. Necessity is the mother of invention, and processing firms began to earnestly explore means of eliminating the cost of disposing of waste material.

Simple logic appears to have played a key role in helping men decide that, if cereal grains were good for human consumption, the leftovers might have some feed value for livestock and poultry. Chemical analyses confirmed the protein value of those waste materials. It was also found that those same materials often contained beneficial minerals and vitamins. During that same period, German and American scientists discovered that protein needs varied between animals and the functions they performed. This led to the realization that protein could be a limiting factor in the production of meat, milk, and eggs. With that realization, waste materials became by-products with a definite market value. The need to process and mix those by-products with feed grains provided a reason for founding new firms and a new industry.

Feeding Standards Developed

In 1810 a German scientist, Thaer, developed the first feeding standard comparing other feeds to meadow hay and assigning them hay values. German scientists continued to pioneer feeding standards with the Weende Experiment Station (Henneberg and Stohmann) devising the proximate analysis system over 100 years ago that broke feeds into six components: moisture, ash, crude protein, ether extract, crude fiber, and nitrogen-free extract. In 1864 Wolff published the first feeding standards based on digestible nutrients.

In the U.S. Atwater and Armsby developed standards in the latter part of the Nineteenth Century. Henry and Morrison evolved a feeding standard system that was used by many for the first 50 years of this century. In 1944 the National Research Council (NRC) of the National Academy of Sciences developed a series of feeding standards for livestock and poultry that are routinely updated and are the recognized benchmarks for feed formulation today.

Evolution of the Industry

The first opportunity for the formula feed industry to be of service arose in the late 1800's. Horses and mules supplied the main form of transportation, and livery stables were almost as common as service stations are now. Good horse and mule feed was in great demand. The nation's largest feed company made its start with such a feed. Early feed manufacturers were selling, mixing, warehousing, and providing delivery services just as the feed industry is

doing today; however, very little scientific formulation or manufacturing was involved.

Some of the original firms that entered the feed business are still in operation. There have been consolidations and mergers from which have arisen some of the present industry leaders. The following information is based on Wherry's (1947) fine research regarding early American feed firms. Additional information was obtained from trade papers and through personal contact with industry pioneers.

Blatchford's of Waukegan, Illinois, is credited with being the oldest feed manufacturing firm in the United States in continuous operation. John Barwell from Leicester, England, started that firm in 1875 to make a calf meal. The National Food Company of Fond du Lac, Wisconsin, was founded about the same time, also to make calf feed for Wisconsin dairymen.

Before 1875 a number of companies had been involved in the feed business in different ways. E. T. & H. K. Ide has been identified as the oldest feed firm operating in the U.S., offering ground grain in 1813 in Passumpsic, Vermont.

Eagle Milling Co., the predecessor of Arizona feeds, began selling grain in 1874.

H. K. Webster Company began selling horse feed in Lawrence, Massachusetts, in 1866.

Several other feed firms date their beginning back more than 100 years ago to 1875, Critic Mills; 1879, O. A. Cooper Company; and 1885, Moorman Manufacturing Company.

Ralston Purina Company was founded in 1894 as the Robinson-Danforth Commission Company to manufacture horse and mule feeds. The Checkerboard trademark was copyrighted in 1900; and by 1918 the company had five plants in operation.

John W. Eshelman and Sons established a feed store in 1895 in Lancaster, Pennsylvania, and built their first feed mixing plant in 1907. This firm was founded as a country grist mill in 1842. Albers Milling Co., Division of Carnation Co., purchased the firm in 1974.

Albers Bros. Milling Company was organized in 1895 as Albers and Schneider Company in Portland, Oregon. Thomas Schneider's interests were purchased by the Albers Brothers in 1899. The company was purchased by Carnation Company in 1929 and was renamed Albers Milling Company. Carnation was purchased by Nestle in 1985.

In 1898 the American Milling Company was formed through consolidation with another firm. American Milling merged with McMillen Companies in 1929 to form Allied Mills Inc. Allied Mills Inc. was merged into Continental Grain Co. in 1981 and became the Wayne Feeds Division.

In Texas Uncle Johnny Mills got its start in 1898 as South Texas Grain Company and changed names in 1943. It ceased operations in 1965. Aubrey and Company of Louisville, Kentucky, began manufacturing feeds in 1898, and their assets have since been sold to Hubbard Milling Company.

Quaker Oats was founded as a holding company in 1901, then changed to an operating company in 1906. Quaker sold its feed business to Allied Mills in 1969, and the famous Full-O-Pep trade mark was retired.

The Ubiko Milling Company was founded in 1902 in St. Bernard, Ohio, under the name of J. W. Biles Company. Its present name was acquired in 1912.

In 1903 the Charles M. Cox Company started operations in Boston, Massachusetts. The firm later became Wirthmore Feeds, Inc. and ceased doing business in the late 1960's. Also in 1903, Hales & Hunter Company began making feed under the name of Edwards and Loomis Company in Chicago. They changed their name in 1920 and later sold out to the Nutrena Feed Division of Cargill Inc.

The Schreiber Hay & Grain Company of St. Joseph, Missouri, started making rations for horses in 1905. The name was later changed to Schreiber Mills, Inc.

In 1912 Larowe Milling Company (later a division of General Mills, Inc.) started in Cohocton, New York.

It was 1918 before the first cooperative, Eastern States Farmers Exchange, started operating a feed mill in Buffalo, New York. Some other older major feed companies were:

1918 — Doughboy Mills, Inc., New Richmond, Wisconsin, now Domain, Inc.

1920 — Nutrena Mills, Inc., Kansas City, Missouri, now a division of Cargill, Inc., Minneapolis, Minnesota.

1920 — Beacon Milling Company, Cayuga, New York.

1920 — Cosby-Hodges Milling Co., Birmingham, Alabama, now a subsidiary of the Federal Company.

1922 — Cooperative G. L. F. Exchange, Ithaca, New York, now Agway after merging with Eastern States Farmers Exchange and Pennsylvania Farm Bureau in 1964.

Hundreds of other firms entered the feed business as the agricultural revolution swept across the United States. Increased competition and declining profits in the flour milling industry led many of those companies to take up feed manufacturing. Trade publications carried numerous speeches and articles in which flour mill superintendents were warned they should not resist management's decision to add the new line of business.

In the 1930's and 1940's, most of the feed plant capacity in the U.S. was located near major flour milling centers such as Chicago, Kansas City, Buffalo, and Minneapolis where the feed plant served as an outlet for milling by-products. Those plants tended to be extremely large and used line mixing techniques. As the feed industry moved away from the urban areas and formulas became more complicated, feed plants became smaller and adopted batch mixing making the older plants obsolete.

New firms continued to enter the feed business until about 1950. Since that time, a decline in the number of farms coupled with integration and increased competition within the feed industry has brought about consolidations and a few business failures. In the 1970's and early 1980's, there was a notable increase in the number of premix manufacturers. Specialized livestock production, particularly poultry, began to take place in the 1940's. The poultry industry began to become extremely sophisticated during that period, especially in the Delmarva area then extended into the southeastern states and west into Arkansas and Texas. With integration, it became more economical to produce feed in the production area rather than ship feed from centralized locations such as Buffalo or Chicago. Intense competition caused most commercial feed manufacturers to withdraw from integrated egg, broiler, and turkey feed production.

In the late 1950's and early 1960's, there arose a trend for the construction of extremely large plants that provided impressive skylines, but were soon out of favor due to the expenses involved in shipping large quantities of raw materials and distributing finished products. In their place, small strategically located plants of 30,000 to 50,000 tons were built that provided for more efficient procurement and distribution. Starting in the 1950's, the growth of com-

mercial feedlots added more than 2,000 new feed plants. In the Midwest, hundreds of new custom feed plants were built to carry out the secondary manufacturing phase using commercial supplements/concentrates.

During the 1960's and 1970's, the South was experiencing rapid expansion in feed consumption. The broiler industry grew at a rapid rate, and many farmers were switching from the traditional cotton and tobacco crops to broilers and layers on a contract basis.

Computers are controlling more processes, requiring fewer workers, and providing better quality control and operating efficiency. Almost every function of feed manufacturing is being addressed: formulation, purchasing, process control, inventory, warehousing, billing, or payroll. Stafford and Snyder (1964) published the first papers and worked with Beacon Milling Co. in establishing one of the first commercial computer applications. Totally computerized feed manufacturing plants became a reality in 1975. T. E. Ibberson designed and constructed four plants: FCX Inc., Southern States Coop, Landmark Inc., and The Andersons. In the 1970's the pelleting process was being placed under the control of computers; and in the 1980's proven automated systems were being used world wide. Inflation and rising labor costs during the 1970's, along with new technology, encouraged automation.

History of New Ingredients

In the 1880's farmers relied almost entirely upon feed grains and roughages grown on the farm to feed their livestock and poultry. Wherry (1947) wrote, "Sixty years or more ago, the flour mills in Minneapolis dumped wheat bran into the river because nobody wanted it. Cottonseed meal was used as fertilizer, if used at all. Most of the linseed meal was shipped to Europe. Soybeans were known only in the Orient. Large milk companies did not permit the feeding of gluten feed to dairy cows, and tankage was almost unknown."

By accident and necessity, it was discovered that the by-products of the milling, meat packing, oilseed processing, and other processing industries had considerable feed value. Not only did those by-products contain substantial amounts of protein, but they also furnished minerals and vitamins lacking in feed grains and roughages. The commercial feed industry growth was, and still is, closely tied to the introduction of new by-products. By far the most important of the by-products is soybean meal. Soybeans have been called the keystone of modern animal agriculture. Soybean meal consumption nearly doubled between 1950 and 1960 and accounts for approximately 55 percent of all high protein feeds available for feeding.

The source and quantity of raw materials available, as well as transportation costs, restrict the use of many by-products to certain areas of the country. Soybean meal is produced in greatest quantity in the Midwest. Most of the citrus pulp is produced and consumed in Florida and California. Fish meal is used most heavily on the east and west coasts. Since the supply of most by-products is rather fixed and not influenced greatly by demand, price fluctuations are large in many instances. Feed companies must vary the quantity used, or substitute other ingredients where possible, to keep costs down.

New equipment and manufacturing techniques are often required to make efficient use of a new by-product in a commercial feed. For this reason, a chronological history of new ingredients is shown.

1850 — Molasses was used in feeds in Europe.

1885 — Cottonseed meal was first successfully manufactured in New Orleans by Paul Aldige about 1885, although earlier attempts had been made to extract the oil from cottonseed. This meal was not readily accepted for feeding until about

- 1900 because early feeders used 10 to 15 pounds per head daily and claimed it poisoned their stock.
- 1888 — Corn gluten feed was first marketed in Buffalo.
- 1888 — Corn gluten meal was manufactured extensively in Chicago and offered considerable competition to corn gluten feed.
- 1890 — Tankage and meat scraps began to be used for feeding. As early as 1870, the material was dried for use as a fertilizer. Records show that tankage was used in both poultry and swine rations in 1900 after experiments demonstrated the value of this protein supplement.
- 1898 — Blackstrap molasses was recognized as an excellent feed for livestock. Earlier it was fed "free choice" in the southern states to livestock. Molasses was first used in commercial feed when it was added to linseed meal and standard midds by the Cleveland Linseed Company at their Chicago plant, for sale to dairy farmers. The name "Sucrene" was given the product and is still being used by Wayne Feeds.
- 1900 — Linseed meal was used extensively in Europe prior to 1900 but was slow to catch on in the U.S. Many tons were exported because of lack of demand by local feeders.
- 1900 — Alfalfa meal was recognized as having excellent feed value and was used first in horse feeds and then in poultry, dairy, and hog rations.
- 1900 — Bonemeal was used in feeding prior to 1900 and was included in prepared poultry feeds as early as 1904.
- 1900 — Distillers' and brewers' grains were fed as wet slop near distilleries for years prior to 1900. Only when efficient drying methods were developed did the dried product gain acceptance and a market, particularly in dairy feeds.
- 1903 — Dried beet pulp was introduced to the U.S. by James E. Larowe, founder of the Larowe Milling Company. It was widely accepted in Europe; but American dairymen were slow to accept the product and, as a result, it was 1910 before feed companies began using it in large quantities.
- 1910 — Dried buttermilk became available when the drying process was perfected. Dried buttermilk was first used in commercial poultry mashes by Sherman Edwards of Chicago in 1915.
- 1910 — Fish meal probably originated on the West Coast at about this time, although it was not extensively offered for sale until about 1915. Professor George Cavanaugh began testing fish meal in poultry rations at Cornell University in 1915. Shortly after those tests began, Philip R. Park used it in commercial poultry mashes.
- 1915 — Albers Bros. were reported to have imported soybean cake from the Orient before 1915.
- 1920 — Dried skim milk became available and was used in formula feeds in increasing quantities.
- 1922 — Soybean meal was first produced in the U.S.
- 1931 — Citrus pulp was discovered to be a good livestock feed, as the Florida citrus industry started canning grapefruit and oranges. Tonnage was small until 1946 when frozen concentrated orange juice reached the U.S. market in volume.
- 1943 — Urea was developed as a synthetic source of protein for ruminants in 1939. It was first used commercially in 1943 as the wartime shortage of animal and vegetable protein created a strong demand for this substitute.
- 1952 — 50% soybean meal was produced for use in broiler and poultry feeds. The introduction of high energy, low fiber broiler and layer rations in 1955 and 1956 created a strong demand for this substitute.
- 1954 — Animal fats were added to poultry rations. Tallow was the principal fat used, due to its low price. Fats were used for added energy and to improve feed texture by eliminating dustiness in mash form. Other animal, vegetable, and poultry fats are now being used.
- 1966 — Poultry feather meal became available after many years of research on the utilization of the large tonnage of feathers that were a waste product of the broiler processing industry.
- 1958 — Soybean hulls, a by-product of the manufacture of 50% soybean meal, were processed into flakes and provided a new bulky ingredient, high in digestibility and liquid absorption and ideally suited for use in dairy rations.
- 1960 — Wood molasses was first marketed by Masonite Corporation. It is a by-product of the production of pressed wood fiber panels.
- 1960 — Poultry waste became recognized as a useful livestock feed. It can be used officially within a few states but has not been approved by FDA for interstate shipments.
- 1977 — Liquid methionine hydroxy analogue was first marketed, opening the way for liquid methionine products.

The AAFCO official publication lists more than 540 feed ingredients that are approved or have tentative approval for sale as animal feed, compared to 440 in 1969 and 38 in 1911.

Scientific Research

Much has been written about the contribution of nutritional research and new discoveries to the growth of the formula feed industry. It is well documented that scientific rations for livestock and poultry have contributed greatly to the variety, abundance, and quality of food available in the United States.

An amazing number of new discoveries have come from years of effort at agricultural universities and land grant colleges, by USDA, and by industry research farms. It is often said that more progress has been made in improving the production of meat, milk, and eggs in the past three quarters century than in the previous twenty-five centuries.

Some of the important milestones of animal and poultry nutritional research are:

- 1810 — First feeding standard developed by Thaer.
- 1828 — Urea first synthesized by Wohler.
- 1864 — First feeding standards based on digestibility were brought out by the German chemist, Emil Wolff.
- 1872 — Discovery was made of the difference in nutritional value of proteins from different sources.
- 1896 — Wolff-Lehman Feeding Standards were made available.
- 1896 — First patent granted describing molasses-phosphoric acid mixture.
- 1898 — First edition of *Feeds and Feeding* was written by Dean William A. Henry of the University of Wisconsin.
- 1912 — Vitamins were first discovered.
- 1913 — Fat soluble Vitamin A was recognized.
- 1922 — The role of Vitamin D in the prevention of rickets was discovered, making confinement rearing of poultry possible.
- 1920-1925 — The importance of calcium and phosphorus was recognized.
- 1925 — Essential trace minerals were recognized. It was found that nutritional anemia was prevented by iron and copper.
- 1928 — The multiple nature of Vitamin B was discovered.
- 1929 — Discovery was made of the effect of hens' diets on egg hatchability.
- 1931 — Alfalfa was dehydrated to supply an economical source of forage nutrients.
- 1932 — The first vitamin (ascorbic acid) was produced in chemically pure form.
- 1933 — Vitamin A and carotene were identified.
- 1933 — Vitamin K was demonstrated as an essential for blood clotting.
- 1933 — Riboflavin (B₂) was isolated but did not become commercially available until 1939.
- 1934 — The importance of the ratio of one mineral to another was established; i.e. ratio of calcium to phosphorus.

- 1935 — Cobalt was found to be essential for rumen activity.
- 1936 — Vitamin D₂ was found to be the most efficient form of Vitamin D for poultry.
- 1936 — Thiamine was first isolated.
- 1937 — Manganese was found to prevent slipped tendons (perosis) of poultry.
- 1938 — Choline was recognized as an essential nutrient.
- 1939 — Vitamin B₆ was first synthesized.
- 1939 — Vitamin E was identified.
- 1939 — Riboflavin and niacin were marketed commercially.
- 1940 — Vitamin E was offered commercially.
- 1941 — Fermentation products were identified as sources of the Vitamin B-complex and unknown factors.
- 1944 — Animal protein factor was demonstrated.
- 1946 — Folic acid was discovered.
- 1947 — High energy feeds became practical rations for broilers.
- 1948 — Vitamin B₁₂ was isolated in pure form (animal protein factor).
- 1949 — Vitamin B₁₂ was offered commercially.
- 1950 — Antibiotics, nonnutrient growth stimulants, were found to increase growth of young animals.
- 1950 — Amino acid methionine was produced commercially.
- 1951 — Introduction of commercial liquid supplements in the U.S.
- 1952 — Animal fats were used in feeds for energy.
- 1953 — Antioxidants were first used in fats to control rancidity.
- 1955 — Diethylstilbestrol, a synthetic hormone, was added to cattle rations to stimulate gains.
- 1955 — Whey and fish meal became practical sources of unidentified growth factors.
- 1956 — Demonstrated the importance of calorie-to-protein ratio.
- 1956 — First U.S. patent granted on liquid supplements with Ethanol.
- 1957 — The importance of zinc and selenium in nutrition was discovered.
- 1957 — U.S. patent on liquid supplements containing molasses, urea and phosphoric acid was granted.
- 1967 — A new bloat preventive for ruminants called Bloat Guard was patented by Bartley at Kansas State University.
- 1968 — Net energy system developed for ruminants.
- 1969 — Starea was produced by combining the starch in feed grains with urea by the extrusion process at Kansas State University.
- 1969 — Buffers first shown to alleviate milk fat depression in dairy cattle.
- 1971 — New anticoccidial drugs containing ionophores were introduced.
- 1972 — Metabolizable protein for ruminant concept was introduced leading to research on protein bypass in ruminants.
- 1973 — FDA first banned further use of Diethylstilbestrol.
- 1975 — First ionophore (sodium monensin) cleared for growth promotion in beef cattle.
- 1976 — True metabolizable energy assay for poultry first published.
- 1978 — Agway granted a patent for a process to regulate protein solubility in dairy feeds.

Animal feeds are formulated far more scientifically and accurately than they can be manufactured. The feed industry is closing the gap in production know-how that requires coordination and support of research by equipment manufacturers, formula feed manufacturers, universities, and other public agencies.

Linear programming and least cost formulation was a major scientific development introduced to the feed industry. W. V. Waugh of the U.S. Department of Agriculture was the first to see the potential of the mathematical procedure developed by George B. Dantzig in 1947. Waugh developed a minimum cost dairy feed in 1951 that challenged many long-held feeding concepts. Dr. Robert F. Hutton of Pennsylvania State University, played a

leading role in introducing linear programming to the formula feed industry. By 1957 several firms were experimenting with this technique; among the leaders were G. L. F., McMillen Feed Mills, and Nutrena Mills. In 1958 Dr. Hutton published a series of articles on "The Use of Linear Programming in Feed Manufacturing." The use of linear programming in formulating least cost feeds expanded rapidly among feed manufacturers with sufficient volume to justify the added expense and, in many cases, had electronic accounting systems, computers, and trained personnel available within their own company.

Today, least cost formulation is used by nearly all feed manufacturers, integrated poultry and livestock operations, and large farmers. The use of computers has been expanded to provide least cost production in integrated poultry and livestock operations.

A valuable by-product of linear programming has been the stimulation of new research. The electronic computer has challenged research nutritionists to explore the feasibility of many new combinations of ingredients.

Manufacturing

Early feed manufacturing equipment was simple. In fact, the hand scoop shovel was the basic mixing tool used by feed manufacturers prior to 1900. As those early feed companies expanded their operations, the need for new and improved equipment became real. Through close cooperation of equipment manufacturers and suppliers with the feed industry have come the many new machines and systems that make up today's modern feed plant. This impressive road of progress has not been well documented due, in part, to the fact that many machines now in use were first designed and built by individual feed companies for their own use. From the initial efforts of those pioneers, equipment manufacturing firms modified and improved the basic designs and then offered the machines for general industry use.

The following provides a chronological history of feed manufacturing, based on the best information available.

- 1848 — Cotton bags were first manufactured by Chase Bag Company to replace wooden barrels.
- 1870's — Both porcelain and cast steel rolls for roller mills were developed in Europe and imported by U.S. firms for flour milling and grain processing.
- 1886 — Jute was first imported from India for making bags.
- 1895 — A patent was issued for improvements on hammermills in use, indicating they were being manufactured prior to this date.
- 1900 — The first attrition mill was designed and patented by Sprout-Waldron Company.
- 1905 — Commercial electromagnets became available.
- 1909 — A horizontal batch mixer was built by S. Howes Company.
- 1910 — Volumetric feeders for line mixing were available from B. F. Gump Company.
- 1910 — Automatic hopper scales were available from Richardson Scale Company.
- 1911 — The first commercial pellet mill was made by Sizer Ltd. in England.
- 1913 — A molasses feed mixer was built by S. Howes Company.
- 1914 — Sprout-Waldron Company built a horizontal batch mixer.
- 1916 — Molasses regulating and proportioning equipment was built by S. Howes Company.
- 1918 — The first commercial vertical mixer was manufactured by Sprout-Waldron Company.
- 1919 — A patent was issued for making cotton bags from material with dressprint design.
- 1924 — A machine for pelleting high molasses feeds was built and patented by Schreiber Mills, Inc.

- 1927 — Beacon Milling Company built batch mixing systems in a new feed plant that was the forerunner of present "push button" plants.
- 1928-1929 — Sizer pellet machines were imported into the United States. Among the early users were Schreiber Mills, Inc., Nutrena Mills, Inc., Albers Milling Company, Tarkio Molasses Feed Company, Quaker Oats, Beacon Milling Company, Ralston Purina Company, and S. Howes Company who became the U.S. distributor.
- 1930 — S. Howes Company built a pellet machine and cuber for sale in the U.S.
- 1931 — A new type pellet mill using a steel die was introduced by California Pellet Mill Company.
- 1931 — B. F. Gump Company was marketing a molasses feed mixing machine.
- 1933 — Wenger Mixer Manufacturing Company sold their first high speed molasses feed mixer.
- 1933 — Beacon Milling Company produced the first pelleted duck feed.
- 1936 — The patent expired on cotton dressprint bags. Conflicting claims are made as to who was first to use this type of bag. Dressprint bags were widely used in the late 1930's and early 1940's.
- 1939 — The first packaged model of high speed molasses mixer that included a percentage feeder, molasses conditioning tank, and metering pump was sold by Wenger Mixer Manufacturing Company.
- 1940 — Pneumatic equipment for handling materials in a feed plant was introduced by Sprout-Waldron Company.
- 1941 — Permanent plate magnets were offered on a commercial basis by Eriez Company.
- 1941 — California Pellet Mill Company introduced a vertical pellet cooler for commercial sale. At least one feed company is reported to have built its own vertical cooler prior to this time.
- 1942 — The first bulk truck was built for delivery of feed in bulk form by Triangle Grain Company, Bellflower, California.
- 1945 — Tote bins for bulk feed handling were first developed by Frank White for Fisher Flour Mills, Seattle, Washington.
- 1946 — The first high molasses pellet extruder for making pellets with 30 to 50% molasses was developed by Wenger Mixer Manufacturing Company.
- 1947 — Formula feeds in crumble form were introduced for poultry.
- 1948-1950 — Paper bags were introduced for general industry use by St. Regis Paper Company and Bemis Bros. Bag Company.
- 1949 — The weigh buggy was developed by Allied Industries, Inc.
- 1949 — The term "push button mill" began to appear in feed trade publications as controls were automated.
- 1950 — The first commercial horizontal pellet cooler was offered by Wenger Mixer Manufacturing Company.
- 1950 — Liquid metering pumps and equipment for handling animal fats were developed by Wenger Mixer Manufacturing Company.
- 1955 — A multiblender machine for conditioning, feeding, and applying molasses, fats, and fish solubles individually or in combination was made available by Wenger Mixer Manufacturing Company.
- 1955 — The Attala Company of Kosciusko, Mississippi, built the first feed plant to utilize a punch card mixing control system. The electronic feed panel for proportioning and mixer control was designed by Richardson Scale Company.
- 1957 — A multiduty machine capable of producing hard pellets, high molasses pellets, and molasses feeds in meal form, was introduced by Wenger Mixer Manufacturing Company.
- 1957 — The first commercial expansion pellet mill was sold by Wenger Mixer Manufacturing Company. Ralston Purina Company had developed their own machine for making expanded dog food prior to this date.
- 1957 — A full drop-bottom horizontal mixer was developed by Hayes & Stolz Company.
- 1960 — A square vertical mixer was imported from Holland and distributed by Ross Machine and Mill Supply Company.
- 1961 — A unique cone-shaped vertical mixer with rotating screw was imported from Holland and distributed by J. H. Day Company.
- 1962 — A pellet durability tester was developed by Pfost at Kansas State University, Department of Flour and Feed Milling Industries.
- 1965 — The tip-tub mixer was first introduced by Wenger Company.
- 1974 — The first feed plant designed exclusively for manufacturing catfish rations in the U.S. was built near Belzoni, Mississippi.
- 1975 — Totally computerized feed manufacturing plants became a reality. T. E. Ibberson designed and constructed four plants: FCX Inc., Southern States Coop, Landmark, Inc., and The Andersons.
- 1976 — A fully automated pigeon feed processing plant was started at Cressona, Pennsylvania.
- 1979 — Holly Farms installed the first bulk facilities for receiving microingredients and liquid methoinine in bulk.
- 1979 — A rotary mill was developed in Australia by CSIRO in 1979. The ripple mill was introduced in the U.S. by California Pellet Mill Co. in 1982.
- 1983 — Equipment for the continuous testing for pellet durability was offered by several European firms including Buhler-Miag.

Distribution Patterns

Pioneer companies of the feed industry had to do considerable missionary work to get their product accepted by farmers. After sufficient orders for the feed were secured, the salesman often rushed back to the plant to help mix and load the feed for delivery. The bagged feed moved from the plant to the customer by wagon, train, and riverboat (Philpott, 1960). As sales areas were extended, brokers and dealers were established to assure that feed would be readily available for regular and prospective customers. Many of the early feed dealers handled both flour and feed.

From the very start, feed companies were shipping their products long distances. Ralston Purina was selling horse and mule feed all along the Mississippi River and found a ready market on the cotton and sugar plantations and lumber camps in the South where large numbers of horses and mules were used. The Cleveland Linseed Oil Company of Chicago sold its "Sucrene" oil meal to dairymen as far away as Philadelphia.

The shipment of bagged feeds by rail from the manufacturing plant located in a major trading center to the broker, wholesaler, or dealer became the common distribution method. In the late 1920's and early 1930's, a few trucks were used to move feed from the plant to nearby dealers. Truck shipments increased slowly due to the capital investment required and higher rail freight costs. Nearly all feed plants were located on a railroad and used intransit milling privileges. Special zoning in the East and New England by eastern trunk line railroads made the shipment of feed from Eastern, Cornbelt, and Great Lakes cities very economical.

As the feed industry decentralized, smaller plants were built closer to the customer. Ingredients and finished feed moved shorter distances and trucks offered the convenience, timeliness, and flexibility needed for moving those items at costs comparable to rail rates. Improved major and secondary roads, along with better trucks, contributed to the switch from rail transportation.

Dealer distribution became the accepted way to do business in the early 1900's. Company-owned stores were often used to obtain distribution into new market areas. Nearly every major feed company has owned or controlled some of its retail feed outlets at some time. Except in the New England states and far western states, the trend in recent years has been away from company-controlled retail feed stores by private firms. Several regional cooperatives own or control all or part of the local cooperative farm service centers in their market area.

Many dealers in the 1940's and 1950's sold more than one brand of commercial formula feed. Differences in price, quality, number of available feeds, sales assistance, and competition were factors that influenced a dealer's decision to handle several brands. To meet that competition, major feed companies developed a complete line of feeds that enabled their dealers to meet nearly every customer's need. In the late 1950's, the distribution of formula feeds shifted towards a single brand marketed through a retail dealer who devoted all of his time and energy to merchandising the products and services that he and the manufacturer had to offer. In the 1970's the trend to single brand dealers was reversed and more split dealers were observed throughout the midwestern states.

Direct selling to feeders increased as part of the trend to decentralization of feed manufacturing facilities and to increased use of premises by farmers.

Government Regulation of Feed

Government regulation of feed began prior to 1900; however, the exact date is in doubt. In 1895 Connecticut passed a general food law containing provisions for the regulation of food sales for man and animals. Massachusetts passed the first specific feed law in 1896. Other New England and eastern states followed in passing similar laws; and, by 1920 thirty-eight states had some form of regulation in effect. Today, all states except Nevada have laws regulating the sale of feedstuffs.

Justification for such laws was the inability of the buyer to judge the quality of ground ingredients, byproducts, or mixtures by visual inspection alone. The buyer, therefore, needed assistance in determining feed values and needed protection from those who sold material of poor or varying quality.

Those who sold by-products and feeds of poor or varying quality got the industry off to a bad start. The fact that laws were passed to control the sale of ingredients and formula feeds implied that everything was not on the up-and-up and created an unfavorable image of the industry, which has been nearly overcome. State and U.S. government publications continue to advise the farmer to beware of feeds containing low grade ingredients, since the quantities are not declared and prices appear to be high. For many years one feed manufacturer advertised its feed as one without a filler.

Federal control of feeds shipped in interstate commerce has been in effect since 1906 when the Food and Drug Act was passed. In 1938 the Federal Food, Drug and Cosmetic Act added certain requirements for labeling of feeds. On September 6, 1958, the Delaney Clause of the Food Additives Amendment became effective. That clause restricted the use of estrogenic compounds and arsenicals that were not proven safe under the conditions of their intended use. Considerable confusion and difficulty arose in the feed industry regarding compliance procedures. For the first time since the original Food and Drug Act of 1906, the manufacturing of feeds was brought under federal government scrutiny.

In 1965 actual inspection of feed plants (practically unheard of before) and suggested methods for storing and handling additives provided a new experience for feed manufacturers. Better house-

keeping and production methods had to be followed to comply with FDA recommendations. The design and engineering of new equipment and the layout of new feed plants was influenced as a direct result of the Delaney Amendment. Further changes in FDA Good Manufacturing Practices Regulations were made in 1976 and 1977.

In November 1909, the Association of American Feed Control Officials was organized to deal with the many problems found in working with a new industry. Their objective as stated in the constitution is as follows:

"The object of the Association shall be to promote uniformity in legislation, definitions, and rulings, and the enforcement of laws relating to the manufacture, sale, and distribution of feeds and livestock remedies in the continent of North America."

The Southern Association of Feed Control Officials was organized in 1938 and adopted uniform standards of feed analysis. That association has remained active through the intervening years to deal with control problems peculiar to the feed industry in the southeast.

Over the years trade papers have noted the continual need for uniform legislation and closer working relations with the feed industry, and have recognized the slow but positive improvement that has been taking place in working relations between industry and state authorities.

In 1937 the Association of American Feed Control Officials (AAFCO) collaborated with the American Feed Manufacturers Association in preparing a uniform feed law for use by the individual states. Acceptance of the model law by states was slow, and it was refined in October 1957; but all 50 states have now adopted the AAFCO model. Further modernizing of the uniform feed law took place in 1966 and 1968. In August 1969, the model feed law was revised to incorporate federal GMP's by reference. Uniform laws throughout all states have made the manufacture and marketing of feed much easier for firms selling in two or more states.

Starting in 1964, nine states have exempted integrated feeds and/or integrators from paying feed inspection fees. Conditions for exemption vary by state in Texas, South Carolina, North Carolina, Georgia, Arkansas, Florida, Tennessee, Mississippi, and Alabama. More states are requiring a licence to be obtained by firms to manufacture animal feeds. Six states have dropped registration of individual feeds.

Much has been accomplished through the joint efforts of industry and state control officials to provide the farmer with the information and product he desires. The goal of uniform feed laws and tonnage reporting systems is desirable and can be achieved.

In 1963 Miller Publishing Company developed a Feed Additive Compendium in cooperation with the Animal Health Institute. That publication is revised annually and has become the authoritative reference source on the use of feed additives.

Collective terms were approved in August 1969, effective January 1, 1970. This allowed for the grouping of ingredients into seven categories: animal protein, forage, grain, plant protein, processed grain by-products, roughage, and molasses products, which in turn allowed feed manufacturers to more fully utilize least cost formulations by substituting ingredients of equal value without the delay and expense of changing registrations and printing new tags.

Here is a summary history of the regulations of manufacturing and sale of commercial feeds:

1909 — The American Association of Feed Control Officials established.

1957 — A uniform state feed bill was approved by AAFCO in October 1957.

- 1958 — The Delaney Amendment to the Pure Food, Drug and Cosmetic Act was passed by Federal Government. It sets a zero tolerance for any feed additive that is known to produce cancer in man or animal.
- 1962 — The Kefauve-Harris amendment to the Federal Food, Drug and Cosmetic act required all firms manufacturing or mixing medicated feeds to register each plant.
- 1963 — The FDA issued regulations that became effective April 2, 1963.
- 1963 — Feedstuffs issued the first feed additive compendium.
- 1964 — AAFCO (American Association of Feed Control Officials) approved the use of a uniform feed tonnage report as a part of the inspection fee collection system.
- 1965 — May 11, 1965, FDA issued first GMP's for medicated feeds and started inspecting feed mills.
- 1966-1968 — AAFCO modernized and proposed a new model feed law.
- 1969 — AAFCO approved the use of collective terms effective January 1, 1970.
- June 21, 1973 — FDA banned further use of DES.
- February 19, 1975 — FDA reinstated regulations on use of DES.
- November 30, 1976 — The Federal Register carried revised GMP's by FDA effective December 29, 1976.
- 1977 — FDA revised GMP's that reduced analytical requirements.

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