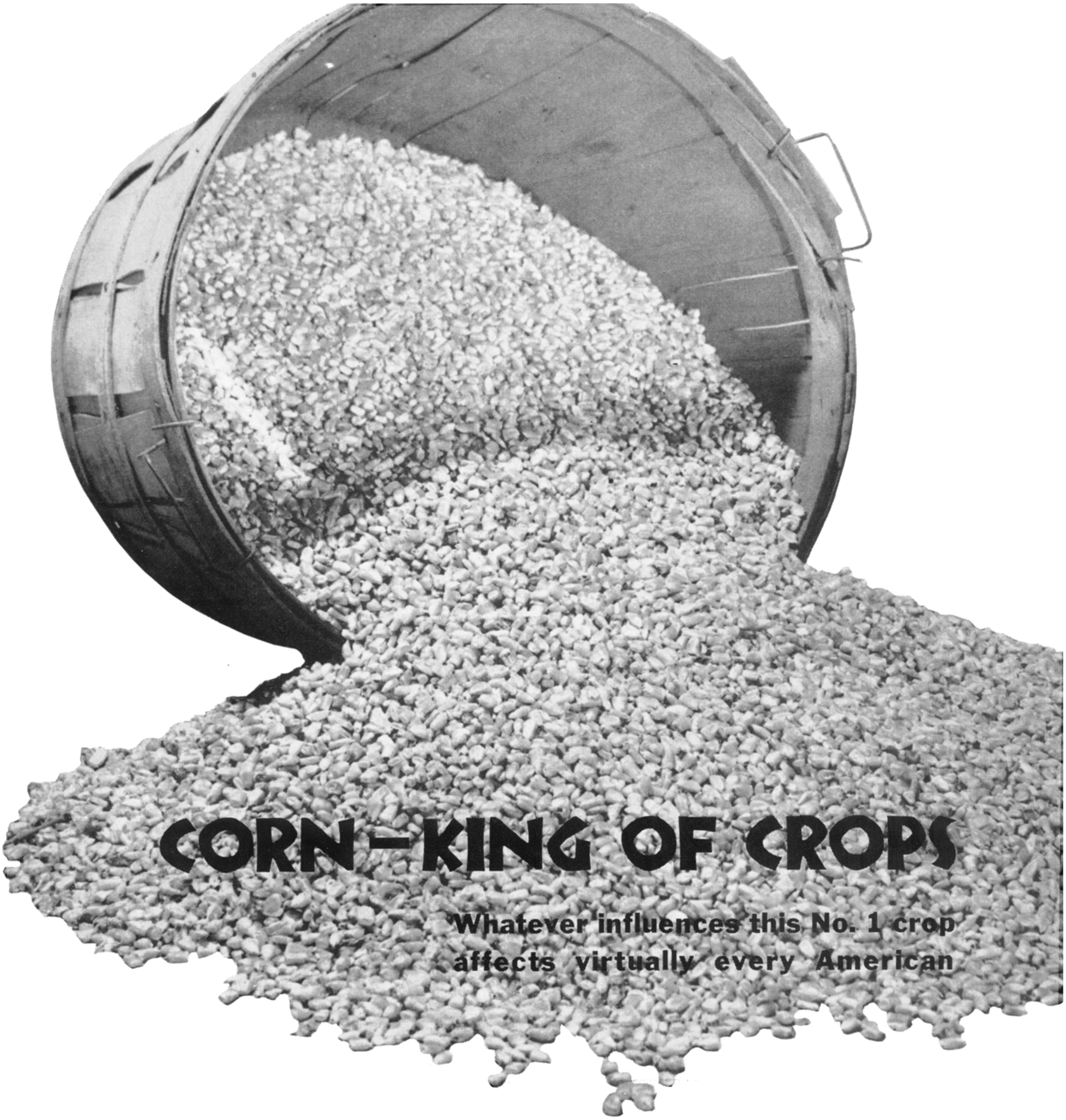


CORN—KING OF CROPS

Whatever influences this No. 1 crop affects virtually every American

In a nation recognized everywhere as the most highly industrialized in the world, it would doubtless come as a surprise to many that the commodity representing highest dollar value each year is not iron or steel, or coal, or petroleum, but a prosaic product of the farm—corn. Total annual production of this one grain, in fact, exceeds the nation's combined output of steel and coal.

It is small wonder that much attention is given today to every facet of corn production and use. It was not always so. For many years—up until relatively recently, in fact—the corn economy demanded and received only a modicum of attention, since production was adequate to satisfy existing requirements, and there were still sizable reserves of tillable land which could be pressed into service to provide for moderate increases in demand.

Within the past few decades, however, accelerating population growth, coupled with rising living standards, has led to fairly rapid cultivation of most of our high-to-medium grade land reserves. Improvement of productivity has emerged as the great need of our era, and the notable progress of the past two decades probably presages even greater improvement to come.

Most of the improvement in average corn yields has been made within the past two decades. While the most important single factor contributing to larger yields is the greater yielding potential of hybrid corn, numerous agronomic improvements also have contributed substantially to the increased production. The combination of good hybrids plus improved cultural practices and increased fertilization has been more effective in increasing production than either would have been alone.

Some of the more important agronomic improvements put into use over the past 40 years are:

Cultivation for weed control rather than for moisture conservation.

Row placement of fertilizer for maximum effectiveness.

Heavy fertilization and denser planting rates.

Improved rotation and conservation practices.

Increased mechanization of corn culture.

Introduction of chemical weed control.

Development of improved pesticides.

Extensive experiments on fertilizer placement during the late 1920's and early 1930's indicated that for corn the most efficient method of applying fertilizer at planting time is in bands about an inch below and two inches to the side of the seed. Fertilizer attachments designed to deposit the fertilizer in this position rapidly became common equipment on corn planters.

Heavy Nitrogen Use

The increased availability of nitrogen fertilizers following World War II developed interest in supplemental and in much heavier applications of this element than were previously used. Experiments with heavy fertilization along with increased plant populations demonstrated that much of the damage formerly attributed to drought in some areas was in reality due to nitrogen shortage. As a result of this work, the use of fertilizers on corn has increased greatly. In addition, the difference between success and failure of corn production on some soils has been found to depend on the application of small amounts of such minor elements as zinc, magnesium, and copper.

Population studies covering a wide range of conditions have led to thicker planting on adequately watered, fertile soils, and to a gradual reduction of the distance between rows. The 44-inch row spacing is now seldom used, having generally given way to 40-inch rows.

Increased yields have permitted a material reduction in acreage, so that some of the land least adapted to it has been taken out of corn production. Lower acreage also has permitted better rotation, with more corn following legume crops than formerly. In addition, the increased use of contour farming, strip cropping, and water conservation procedures contributes to higher yields.

The great expansion of mechanized corn culture has occurred since 1930 and particularly since World War II. Iowa corn production for instance, now is so mechanized that it requires only 6 man hours per acre, whereas the national average 40 years ago was 35. The mechanization of corn culture has tended both to increase yields and to reduce cost of production. That mechanical equipment contributes to higher yields by making it possible to plant and cultivate the crop promptly at the most timely periods was strikingly dramatized in Iowa in 1950, when practically the entire 10 million acres of corn in the state was planted in one week of favorable weather following a late, rainy spring. Mechanization of harvesting was hastened by both labor shortage and the advent of stormproof hybrid corn, which remains erect until harvest.

Herbicides Can Cut Costs Still More

Chemical weed control, one of the newest agronomic developments, offers to cut the cost of corn production still further. Chemical weed control cannot be expected to increase corn yields over those obtained by other good methods of weed control, but it is more efficient under many conditions. Of the various weed sprays tried on corn, 2,4-D is most widely used at present, with nonvolatile esters used mainly for pre-emergence sprays, and amino salts used mainly for post-emergence treatment.

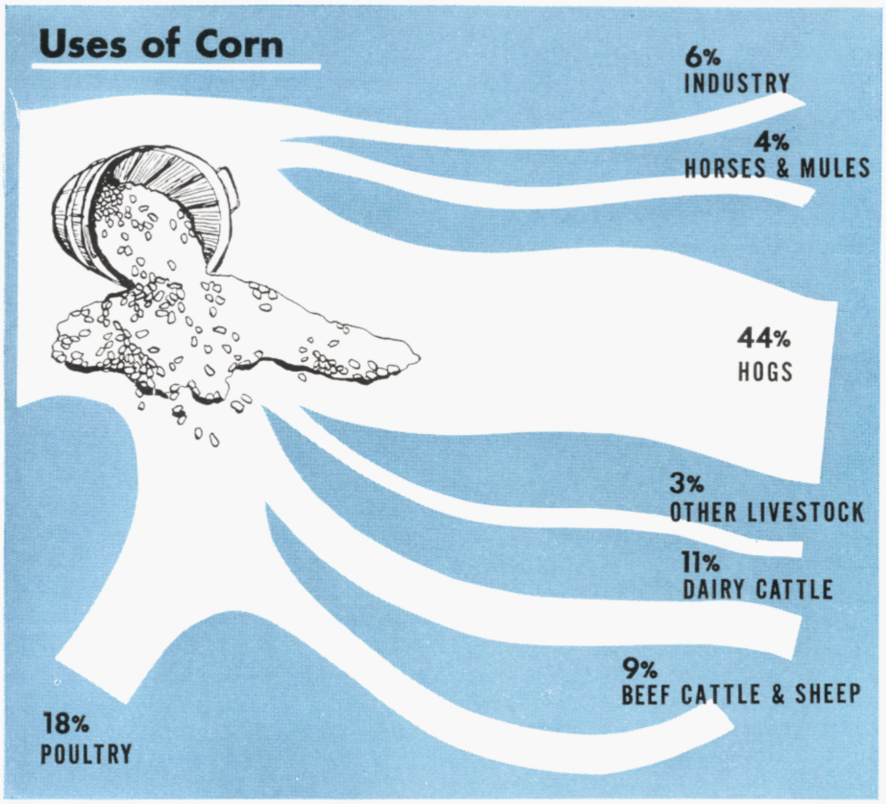
Among the insecticides, aldrin, heptachlor, chlordan, dieldrin, and DDT deserve special mention as controls for wire worms, root worms, and other soil insects that have been extremely difficult to control in the past. Under heavy insect infestations these chemicals have given spectacular increases in both yield and resistance to lodging. Mixtures of fertilizers and pesticides are becoming increasingly popular with farmers; in the North Central region, for example, 10 pounds of aldrin per ton of corn fertilizer is used to control wire worms and northern corn root worms.

Wide Row Spacing

Another innovation currently receiving attention is the use of extra widely spaced rows, 60 to 80 inches apart, to permit the planting of wheat or other crops between corn rows. The corn plants are closely spaced within the widely spaced rows so as to maintain approximately the same total number of plants per acre.

The use of wide row spacings with the interplanting of winter wheat has resulted in reductions in corn yields

USDA agronomist applies pollen from a selected parent corn plant to the silks of another selection in part of the department's hybrid corn breeding program



of 10 to 25%, and roughly corresponding increases in wheat yields over those obtained from wheat planted after corn harvest. Under suitable rainfall conditions the wide corn rows also have permitted the successful establishment of interplanted legume and meadow seedings. This practice offers considerable promise in the eastern part of the Corn Belt, but results have been rather erratic in drier western areas.

As for the future, the general lines of research that seem to offer greatest promise of contributing to agronomic improvements are on: (1) the mineral nutrition of corn; (2) the consumptive use of water; (3) chemical aids to corn production; and (4) further mechanization of production, and artificial drying of the harvested crop.

Although a great deal is known about mineral nutrition of corn, we fall short of having corn nutrition on the efficient assembly-line basis of the broiler chicken industry, for example. To maximize yields and minimize production costs, research dealing with the plant food requirements and general nutrition of the corn plant is essential.

By far the most comprehensive experiments on mineral accumulation in the corn plant have been conducted by J. D. Sayre at Wooster, Ohio. Sayre grew Ohio hybrid K35 and harvested plants every three days beginning June 20, a month after planting, and ending on Sept. 18. The harvested plants were separated into their different parts such as leaves, stalks, and ears, which were then weighed and analyzed chemically. The maximum requirement for nitrogen was found to occur during the last few days of July, when the daily intake amounted to 4.0 pounds per acre. From July 11 to Aug. 4 the daily nitrogen accumulation averaged 2.7 pounds per acre. Much less phosphorus was accumulated than nitrogen, although maximum accumulation occurred during the period from July 5 to July 17, when an average of 3.2 pounds was absorbed daily by the plants. Computed on an acre basis Sayre's plants yielded at the rate of 118 bushels an acre and accumulated nitrogen at the rate of 144.1 pounds per acre, phosphorus at the rate of 30.2 pounds per acre, and potassium at the rate of 98.4 pounds per acre.

Another profitable line of investigation is use of radioisotopes to determine the amount of an absorbed mineral element that comes from the fertilizer and the amount that comes from the residual supply in the soil at any stage of plant development. This kind of information may lead to reevaluation of some of our fertilization concepts.

In the past, much research, directed toward the most effective use of a given amount of fertilizer, has led to a great increase in fertilizer use and a large increase in crop yields. However, when the best information available has been used in attempts to produce 300 bushels of corn per acre, results have been disappointing in many cases. Present information on fertilizer use appears adequate to provide for 100- to 150-bushel yields, but may be quite inadequate for 200- to 300-bushel yields. Such yields may not be economical at present but might become economical if more basic information were available on the factors limiting attainment of these large yields.

In many areas the main factor now limiting corn production is the available supply of water. As fertilizer applications and plant populations are stepped up, water will become the limiting factor in many additional areas.

Corn now is grown under irrigation in many of the drier areas of the West. Research is in progress, chiefly in these drier areas, on the consumptive use of water by several crops including corn. With increased information on the most efficient procedures for using water, and increasing use of portable irrigation equipment, a marked expansion in the use of supplemental irrigation for corn can be expected in more humid areas as well. Information on mulches indicates that they may help appreciably in retaining soil moisture.

Pest Control Essential

As maximum production is approached, better control of diseases and insects becomes essential. The development of special sprays or biotics suitable for airplane application, and the development of granular and systemic insecticides could be of great importance in insect control. Hormones, already widely used in the feeding of some kinds of livestock but not yet an important factor in plant nutrition, may become so within the next 25 to 30 years.

Perhaps chemists will never develop a material that when applied to a corn field will kill all plants in the field except corn, and then will act as a fertilizer or growth promotor for the corn. But chemists and plant scientists already have developed chemicals which may be applied to corn as preemergence sprays to control most of the annual weeds. Some of the benzoic acid compounds, particularly 2,3,6-trichlorobenzoic acid, seem to be extremely promising in this respect. A larger proportion of the species of weeds occurring in corn fields may be controlled by mixtures of chemicals. The most promising at the present time is 2,3,6-trichlorobenzoic acid with 2-chloro-*N*, *N*-diallylacetamide.

Mechanization of corn production has proceeded to the point where in 1950 Iowa's 10 million acres of corn could be planted in a week of favorable weather following a rainy spring

Undoubtedly the mechanization of corn culture will continue at a rapid pace. The trend seems to be toward development of high-speed planting and cultivating equipment, and of picker-shellers and corn combines for harvesting. The use of picker-shellers will require facilities for drying shelled grain, as the tendency is to harvest as early as possible in order to avoid disease and insect damage. Expansion of facilities for farm drying will call for tight storage bins to replace the present open cribs for ear storage. As a genetic sidelight, increased use of picker-shellers also will result in demands for hybrids that mature uniformly. Irregular maturity with some soft ears in the crop could seriously interfere with early harvest.

Genetic Improvement

While continued progress through agronomic improvements is assured, the possibilities of improving corn yields and corn quality through genetic research certainly have not been exhausted. Following the early reports of Mendel in 1865, and corroborating studies by Correns, De Vries, and Tshermak about 1900, corn became a favorite subject for genetic studies.

In 1904 G. H. Shull began his experiments on the effects of self and cross fertilization on kernel row number in maize. Little that was new or important came from this work as far as information on kernel row number was concerned, but from these studies did come the first clear picture of inbreeding depression and the restoration of vigor upon the crossing of inbred lines. In a very real sense the present-day hybrid corn industry was a direct outgrowth of these studies.

By 1918, the genetics of corn had made tremendous progress. A number of simply inherited characteristics had been studied; linkage of some of these characteristics had been reported. In contrast to the simply inherited attributes, some work had also been done on quantitative attributes, of which kernel row number and plant height might be taken as typical examples. Originally these attributes were assumed not to follow the Mendelian pattern of inheritance. The work of East and of Emerson and East provided strong presumptive evidence that, while quantitative attributes were much more difficult to study, they followed the same Mendelian principles as the more readily classifiable variation exhibited by discontinuous attributes.

Prior to 1920, corn breeding had consisted largely of mass selection, and corn shows had achieved considerable prominence. The acceptance and distribution of a variety was in large part dependent upon its winnings in corn shows. However, feeling grew that the qualities emphasized by show card standards were not closely associated with performance, and that winning samples were not necessarily a measure of the productive worth of a strain of corn but were rather a measure of the judgment and patience of the sample selector.

For these reasons sentiment was favorable for exploring the new approach: inbreeding and hybridization. Breeding programs aimed at these objectives were started in many of the Corn Belt and southern states in the early 1920's. By the early 1930's tested hybrids were being grown on a limited commercial scale.

The spread of hybrid corn following this initial introduction was very rapid and has been referred to by some as the most important development in agricultural technology in the last 100 years. It has been conservatively estimated that the hybrids which replaced the open-pollinated varieties increased yields by at least 25%. These first hybrids have long since been replaced by new and better combinations, which outyield the first commercially acceptable hybrids by at least 15%.

Mechanization Became Possible

Besides their increased yields, the hybrids are superior in other characteristics, particularly resistance to lodging. The mechanization of corn harvesting became possible largely because of the improved stalk and root qualities of hybrids.

A satisfactory explanation for hybrid vigor, or heterosis, remains one of the most important problems in corn breeding and genetics. Tremendous progress has been made in corn breeding without this information, of course, but progress and efficient progress are not necessarily synonymous.

Corn diseases and insect pests of corn regularly cause average losses ranging from 5 to 10%, much of which undoubtedly can be avoided by breeding. Sources of resistance are now known for most of the major pests; it remains to introduce this resistance into agronomically useful lines. Work of this sort is already far advanced with leaf blight, *Helminthosporium turcicum*, Diploida stalk rot, the European corn borer, and the corn ear worm.

The Chemical Make-Up of Corn

Corn is probably as diverse chemically as it has been shown to be in other ways. The modification of chemical composition to fit industrial or nutritional needs will undoubtedly receive further attention. Waxy hybrids have been developed and approximately 1 million bushels of this type of corn is milled annually for its special type of starch. Several genetic systems are known to produce material increases in the amylose fraction of the endosperm starch. At least one of these could be used commercially if and when demand warrants.

Relatively little is known about carbohydrate synthesis. A large number of recessive genes have been found to affect carbohydrate synthesis in some as yet unknown fashion. The use of analogous material in *Neurospora* has shed much light on both gene action and types of chemical synthesis involved. It appears probable that a combined genetic and chemical approach to starch synthesis would be equally productive.

High oil types have been developed. Studies have indicated a considerable variation in composition with respect to the essential amino acids, lysine and tryptophan, which are deficient in the corn endosperm. It appears that corn having improved nutritional characteristics is entirely feasible if sufficient analytical and breeding efforts are expended. Whether it is possible to develop types having an adequate amino acid balance is still problematical. The value of such corn would vary with the class of livestock to which it was fed. For feeding swine, a corn type which did not require protein supplementation would be worth approximately one third more per bushel than the corn varieties now being grown.

It has been argued by some that breeding to increase corn yields is no longer effective. Certainly it is true that each added increment of yield attained by breeding is more costly in both time and effort, but there is no convincing evidence that yield variability has been exhausted. The cooperative breeding program in Iowa, for instance, includes experimental hybrids which appear superior to hybrids now in extensive commercial production. It seems a safe bet that corn hybrids with even greater yield potential will be developed.

Corn in Animal Nutrition

Where will it all go? How will the tremendous corn crops projected for future years be utilized for the greatest over-all benefit to mankind?

The major portion doubtless will be used right on the farm as it is today, to feed ever mounting numbers of livestock. As shown by Figure 1, hogs and poultry consume over 60% of the corn grain. Less is fed to dairy and beef cattle, which together consume only a third as much as swine and poultry. Nonfood industry uses only 6% of the total corn grain crop.

A look at the trends in our eating habits shows that the consumption of eggs, fruits and vegetables, and dairy products is going up at a rather rapid rate. The use of meats, fish, and poultry is also increasing. However, there is a definite downward trend in the use of cereal products and potatoes. The trends of future eating habits will largely determine what is done with the corn crop in terms of both the grain and the plant portions.

Trends in the numbers of the different classes of livestock and poultry have a great effect on the demand for corn and the relative use of various parts of the corn crop plant. Poultry, swine, and beef cattle numbers are all taking a definite swing upward; dairy cattle are increasing gradually; the sharp drop in sheep and lamb numbers has been stopped and apparently stabilized, whereas the numbers of horses and mules continue to decline with power mechanization.

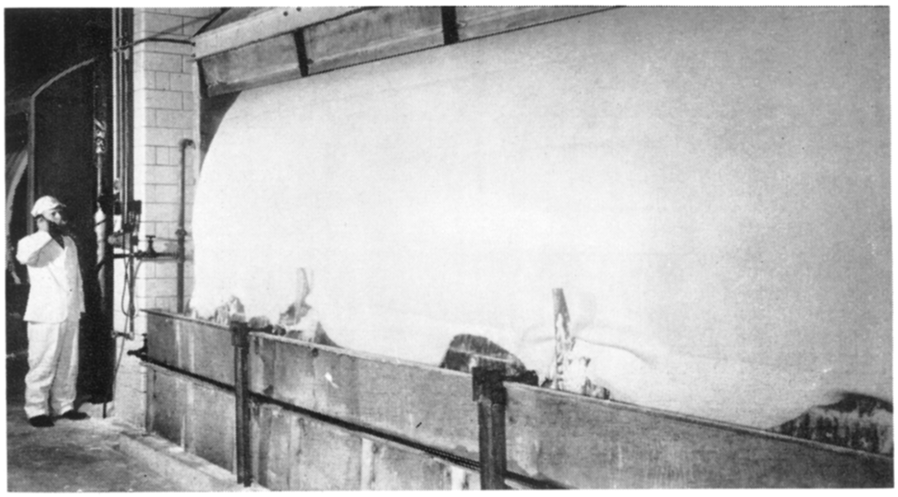
According to calculations from L. A. Maynard of the gross calories and protein recovered from feedstuffs when fed to livestock, pork yields the greatest amount of calories and protein combined, with milk next, followed by poultry meat, eggs, beef, and lamb.

Livestock numbers have kept pace with human population. Although the index of meat animal numbers increased more rapidly during World War II than did the U. S. human population, it later declined and is now paralleling the human population growth. It is expected, if incomes and purchasing power stay up, that the meat animal index in numbers will continue to parallel increases in human population. If this relationship should continue to hold, we can expect a continued increase in the use of corn for meat-animal feeding.

Over 68% of the ration of hogs comes from corn grain, and from the nutritional standpoint all of the 14.2% of other grains consumed by hogs could come from corn as well. Poultry are the next greatest consumers of corn (grain), and here again a large portion of the other grains could be corn. Only about 10% of the rations of beef and dairy cattle is made up of corn (grain). However, corn silage can make up a large portion of the rations of these two kinds of cattle. Corn makes up a relatively small portion of the total ration of sheep and goats.

As the agronomist is able to push corn yields upward, the proportion of stalks remains relatively constant, but there is a great decrease in the proportion of leaves. As would be expected, the proportion of cobs increases as the proportion of shelled corn increases. In the future, the animal nutritionist is faced with the utilization of more shelled corn, more cobs, less leaves, and about the same proportion of stalks. Wise Burroughs, who is in charge of ruminant nutrition research at Iowa State College, stated at a recent meeting that he had chosen Iowa principally because he was interested in utilization of corn stalks by beef cattle. This comment typifies the thinking of ruminant nutritionists concerning the future of beef cattle feeding.

Present research indicates a great increase in the use of corn silage for sows as the swine business becomes more specialized and a bigger volume is handled on each farm. There will be increases in the use of better balanced rations, which include proteins, vitamins, minerals, antibiotics, arsenicals, and unidentified growth factors. Accompanying these changes will be a decrease in the feed required per pound of gain. Corn will make up somewhere between 70 and 90% of the total ration. However, corn as a percentage of the total carbohydrate in the ration will go up. Research is showing us how to use more and more corn in the total ration for swine, especially from farrowing to market. The use of both corn grain and corn silage will see an over-all increase in the future rations of swine.

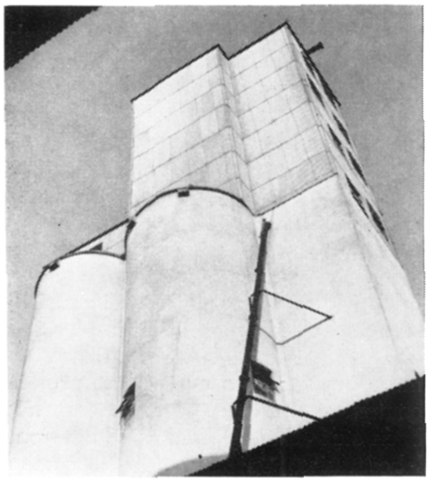


Battery of starch filters typical of those which all together turn out huge quantities of corn starch annually for many industrial and consumer uses

Trends in beef cattle feeding indicate that the use of green-cut forage for steers will increase. This forage may be the corn plant, or it may be legumes. The amount of corn silage used will increase gradually. Especially with respect to minerals, hormones, and unidentified growth factors, there will be a decrease in the feed per pound of gain, with an accompanying decrease in the corn per pound of gain. Prominent ruminant nutritionists believe that corn (grain) as a percentage of the carbohydrate in the total ration will decrease somewhat. The field of ruminant nutrition is just now coming into its own.

The dairy cattle business is built on a better quality roughage program than is beef cattle feeding. Dairy research workers feel that the use of both roughages and silages, both corn and grass, will increase. Better balanced rations are on the increase, with subsequent reduction of the feed and corn per pound of milk produced. Corn grain as a percentage of carbohydrate in the ration will increase, however, according to some leading dairy nutritionists. They say it is not a matter of cutting back on one (like corn grain) and increasing the other (like roughages and silages), but it is rather a matter of getting more over-all nutrients into the animal. It would appear, therefore, that the entire corn plant will find even greater usage in dairy cattle feeding in the future.

The poultry business, including egg, broiler, and turkey production, is the most highly specialized and most efficient of all those concerned with farm animals that convert feed to food. There has been a tremendous increase in the development and use of better balanced rations in poultry production, accompanied by a dramatic decrease in the feed per pound of gain or per dozen eggs. Hence, corn use decreases as feed efficiency increases. However, the use of corn as a percentage of the total carbohydrate in the ration has seen a big increase with development of high-energy rations, first for broilers, and then for caged layers. Corn as a grain will no doubt find greater use in poultry rations in the future.



Grain elevators hold a big part of the nation's 3 billion bushel corn crop

What will be the relative technological advances in the field of nutrition of swine, beef cattle, dairy cattle, and poultry, and what effects will these advances have on the widely varying relative efficiencies of these different classes of animals in converting feed to food? There will no doubt be a definite trend to improve feed efficiency through improved breeding, improved balanced rations, improved disease and parasite control, and improved control over environmental conditions such as housing, equipment, and management.

Technological advances in the production of different grain and forage crops, and changes in the relative efficiency with which they are produced, will no doubt affect the future of the corn plant in animal feeding. High yielding, easily harvested sorghum grains may find their way into livestock and poultry rations, replacing part or all of our present corn grain. Technological developments in the fertilizer and feed industries may have their impact. Development of the use of complete feeds and bulk feed delivery may affect the relative amounts of corn grain and other carbohydrate ingredients, such as mill feeds, used in the total ration.

It is conceivable that the over-all feed efficiency of the swine industry in this country could be increased by from one fourth to one third by taking all the corn to one central point, grinding it and mixing it into complete, well balanced rations, and then sending it back to the farm. We already know that we can get faster gains on less feed with pigs on a ground, mixed, well balanced ration, than we can by letting the pig walk up to the self-feeder and make his own free choice of grain and supplement. However, the cost of transportation and processing must be considered.

Corn in Human Nutrition

Of considerably less significance than livestock feeding on a tonnage basis, but certainly no less important from the standpoint of nutrition knowledge, is the direct use of corn as a food for humans. Corn products, like many other interesting food products, have a real place in the diet unless the individual preparations are used in excess.

We have had long experience in the association of a definite disease with the consumption of high amounts of maize or corn as a staple cereal in the diet. The early work of Goldberger and his colleagues showed that pellagra, which was prevalent in the South, could be prevented or cured by adding to the corn diet foods high in animal protein—for example, milk or meat.

The protein-deficiency theory seemed no longer tenable when it was shown that pellagra could be cured with protein-free extracts made from liver and yeast. It appeared that the final explanation was available when nicotinic acid or its derivatives was found to cure black tongue in dogs and, later, human pellagra. As assay methods were perfected, further proof of the relationship between corn and pellagra seemed to be added. The assays showed that whole corn or corn grits contained about 1 milligram of niacin per 100 grams. In comparison, whole wheat contained 4 to 6 milligrams per 100 grams. There is some loss of niacin when the corn is degermed, but the loss is not as great as that observed for thiamine and riboflavin.

One approach to correction has been enrichment programs in which thiamine, niacin, and iron are added to cornflakes, corn grits, and degermed corn meal. The enrichment process has increased niacin content to about 3.5 milligrams per 100 grams.

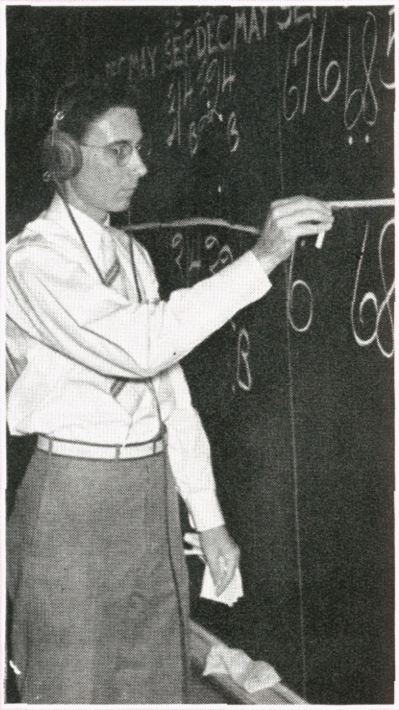
The work on niacin did not completely explain the observations made in the field. Goldberger found milk to be a good antipellagra food, but milk was soon found to be relatively low in niacin. Furthermore, pellagra was prevalent among the corn-eating peoples and rather rare among rice-eating people, even though rice products do not contain appreciably more niacin than many corn products.

The key to this problem was discovered when it was shown that there is a relationship between nicotinic acid and tryptophan. This was first shown with rats by adding corn to a synthetic diet containing 15% of casein. As corn was added growth of the rats decreased, but the growth inhibition could be counteracted with niacin. Furthermore, it was found that the addition of casein produced quite a growth response, and this casein was free of additional quantities of niacin. By using different mixtures of amino acids it was found that tryptophan would give a significant response. This finding provided a complete explanation for the observed tendency to pellagra in individuals eating large quantities of corn. Zein, the corn protein, is very low in tryptophan, and further work showed that the presence of other amino acids, especially threonine, increased the tryptophan requirement. The beneficial effects of milk were due, therefore, to the addition of a protein rich in tryptophan, while the beneficial effect of meat was due to the presence of both tryptophan and significant quantities of niacin in the meat protein.

Vegetable Protein Diets

The problem of using corn in diets where the other food material is largely of vegetable origin brings further complications. Modern research has shown that not only is there a problem of supplying minimum amounts of essential amino acids, but the presence of certain amino acids may increase requirements for others. The best example is found in recent work on the leucine-isoleucine relationships. High levels of leucine have a definite retarding effect on the growth of rats, but the effect can be overcome by

Our Corn Economy



Tabulating fluctuations at the Minneapolis Grain Exchange

CORN, OUR LARGEST CROP, is of unique importance in the food supply of animals and man, and holds an important place in industry as well. Whatever influences this No. 1 crop affects virtually every American.

The past 25 years have seen striking changes in the "corn economy" and the next 25 are likely to see more. In the spring of 1930, 104 million acres of corn were planted—essentially none of it with hybrid seed—and that autumn a little over 2 million bushels were harvested. Widespread drought had reduced yields from the then normal level of about 25 bushels per acre to 20.5 bushels; the season's average farm price was not quite 60 cents per bushel.

Conditions became even worse during the depression of the 30's and in some areas corn was even used as fuel. But the general recovery which began in the late 30's was paralleled by revolutionary changes in the corn economy:

Total corn acreage was reduced by nearly one fourth, to about 80 million acres;

Higher-yielding hybrid seed almost completely replaced the older types, and productivity was further augmented by greater use of commercial fertilizers, better land management, and the adoption of power machinery;

Because percentage increases in yields exceeded percentage decreases in acreage, 3-billion-bushel crops became the rule rather than the exception;

The number of man-hours expended per acre of corn harvested dropped from about 30 in 1930 to about 15 in the 1950's;

Increased efficiency in livestock, poultry, and milk production lowered the per-animal need for corn;

The population of the U. S. increased about one third and food consumption per person about one eighth, with a pronounced shift from carbohydrate foods toward more expensive types, especially meats.

In the next 25 years, the major contributor to the basic demand for corn and its products will be the continuing growth of the country's population. The increase may be conservatively estimated at one third, placing the 1980 population at about 222 million.

Food requirements of this larger population will be nearly half again greater than current consumption, assuming that the American diet will continue to be rich in animal products, and that a 10% greater consumption of foods per capita will develop. In line with past long-time trends it would be reasonable to look for an increase in the consumption per person of poultry and fruits of about a sixth; of meats, eggs, and vegetables a tenth; of fluid milk and cream a twentieth.

In sharp contrast to the increased number of mouths to feed in 1980, the total crop-land area suitable for agricultural production may not increase significantly (probably not over 5%). In order to meet the 1980 requirements for meat, milk, and eggs, then, greater yields of feed grains or their equivalent will have to be obtained. Considering the inelastic limits on the arable land area, the answer is increased yields per acre of each feed grain through better seed, greater use of fertilizers and insecticides, and more efficient livestock feeding.

higher levels of isoleucine. This observation is of particular importance in connection with corn, since zein is very rich in leucine—about 23%—and low in isoleucine. Feeding experiments with rats have shown that a zein diet supplemented with the deficient amino acids fails to support satisfactory growth and that a normal rate of growth is obtained only when the diet is supplemented with additional amounts of isoleucine. It appears also that the isoleucine in zein has a low degree of availability.

What, then are the future problems as they relate to the use of corn in the human diet? Certainly there is a need for more facts regarding the corn proteins and perhaps many other nutrients in corn cereals. From a practical point of view, these facts should be put to use as rapidly as possible in preparing adequate and properly balanced diets for the human. This is by no means impossible even when corn forms an appreciable part of the diet; it merely takes a little ingenuity. Certainly long-term programs should be focused on breeding types of corn which could contribute more adequately to nutrition and fit more closely into nutritional programs in different areas of the world.

An attempt has been made to develop corn with a high niacin content, but with the low cost of niacin enrichment, the latter may be a simpler and cheaper process. Perhaps it may be more important to modify the protein content of corn, a problem that has been studied in a number of different laboratories. Protein content has been increased to as high as 19.45% and reduced to as low as 4.9%.

A mere increase in the protein content of corn is not necessarily an improvement, since the more significant amino acids may be decreased while others may be increased. There is actually preliminary evidence that a protein increase is accompanied by a decrease in lysine and an increase in leucine. These changes are in the wrong direction. The question of balance depends entirely upon the amount of each available amino acid. Obviously there is much work left to do.

Corn in Nonfood Industry

After the voracious appetites of livestock and poultry have been satisfied, and man has taken some corn for direct food use, there is still enough left over to satisfy the needs of American industry. The wet milling industry is the largest user; dry millers and distillers in total constitute a poor second, while the remaining industrial users are minor in terms of grain disappear-

"Corn—King of Crops" is an Ag and Food staff condensation of material from a symposium sponsored by the Agricultural Research Institute on research and progress in corn. Those parts of particular interest to Ag and Food readers are emphasized here. The complete symposium, organized under the chairmanship of Norman F. Kennedy of Corn Industries Research Foundation, will be published by the National Research Council. Participants in the symposium and their topics were:

Floyd Hosking, Corn Industries Research Foundation. Corn in the American Economy.

G. F. Sprague, Iowa State Agricultural Experiment Station. Corn Genetics.

Merle T. Jenkins, Agricultural Research Service, USDA. Corn Agronomy.

Damon Catron, Iowa State College. Corn in Animal Nutrition.

C. A. Elvehjem, University of Wisconsin. Corn in Human Nutrition.

Robert Ruark, Corn Products Refining Co. Corn in Nonfood Industry.

Marvin L. McLain, Commodity Stabilization Service, USDA. The Role of Government and of Free Enterprise in Corn Storage and Marketing.

ance. If it is considered that the principal products of the dry miller are used in human and animal nutrition, and if alcohol is classed as a food, then the only significant manufacturer of corn products for industrial use is the wet miller.

In 1954, the wet milling industry used about 125 million bushels of shelled corn. About 4.3 billion pounds of starch was produced by this grind, and over 2 billion pounds of this starch went to industrial users as such or in the form of modified starch, derivatized starch, or dextrines, exclusive of the amounts reaching industrial end points through conversion to corn sirup or dextrose.

The principal industrial user of starch is the wet miller himself, since he also operates the plants involved in the manufacture of corn sirup, dextrose, crude sugar, dextrine, and starch-containing food products. The manufacture of dextrine for industrial purposes requires nearly 200 million pounds of starch yearly. Over 50 million pounds of crude sugar is used industrially. Dextrose and corn sirup go principally to the food industry, but significant tonnages of the former find chemical use.

After the wet miller's needs are provided, the largest industrial user of starch by far is the paper and paper products industry, consuming in excess of 700 million pounds of starch per year for clay coating, beater sizing, corrugating and laminating, and for adhesive uses.

Second is the textile industry, consuming about 300 million pounds per year for warp sizing, finishing, carpet back sizing, and printing. The next nonfood use is partially a use in industry and partially a home use, taking about 150 million pounds of corn starch per year in the power laundry and in the home.

These are the principal uses of starch, but others take substantial volumes. For example, starch is used in foundries as a core binder, in the mining industry as a depressant in the flotation process, and very recently in iron ore separation and aggregation. The oil industry uses large tonnages in well-drilling muds, and the asbestos and plaster board industries find starch valuable for fiber binding and for applying the paper board sheets used as the outside covering.

Add to these uses hundreds more requiring lesser quantities, and it becomes obvious that the future of starch is assured by the broad character of the product. Furthermore, the starch industry has now entered an age of starch derivatives.

The chemical derivatization practiced in starch production today is merely the beginning. The user in the future can expect starches that are snow white and that will produce water-clear solutions, starches that give films far stronger than those of today, and in fact starches that will produce self-supporting films suitable for industrial packaging.

The starch industry has lived through an era during which artisans produced a product that was used by industry in a classic fashion because it was cheap or because there was no easily available substitute. The industry is now producing materials that are of high quality and are used through choice because of their economic and physical values. In the future, the industry can expect its markets to increase, provided it realistically pursues its present course of quality improvement, understanding that its products are true chemical commodities.

The Future of Corn

The future of corn for all uses, of course, is likely to be influenced by the interplay between the forces of free enterprise and efforts on the part of Government to control supply-demand relationships. The extent of government involvement in the business of buying, storing, and marketing of corn and other farm commodities under price support has assumed such great proportions as to challenge the fundamental principle of reliance on private enterprise.