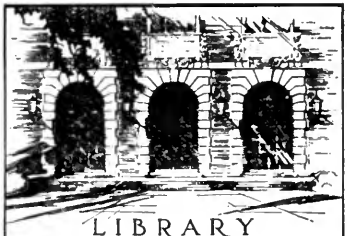

HIGH-PROTEIN CORN As a Source of Protein FOR DAIRY COWS

By W. B. Nevens
K. E. Harshbarger
G. H. Rollins
P. C. Burk
K. E. Gardner
K. A. Kendall

Bulletin 586

UNIVERSITY OF ILLINOIS · AGRICULTURAL EXPERIMENT STATION

CONTENTS

Urbana, Illinois March, 1955

Publications in the Bulletin series report the results of investigations made or sponsored by the Experiment Station.

High-Protein Corn as a Source of Protein for Dairy Cows

By W. B. Nevens, K. E. Harshbarger, G. H. Rollins, P. C. Burk, K. E. Gardner, and K. A. Kendall[1]

GROWING ON THE FARM as much as possible of the protein needed is one means of keeping down the costs of milk production. When the ration for the dairy herd consists of grass pastures, grass hays, corn silage, and cereal grains, all of which are low-protein feeds, the amounts of protein supplied may not meet the needs of high-producing cows.

This protein deficit has been overcome, in part, by making greater use of alfalfa, clovers, and other forage-type legumes and by enhancing the protein content of the forage through application of nitrogen to the pastures. Yet, even when forages grown on fertilized soil are part of the ration, it is still customary to include a high-protein supplement such as soybean meal. The expense of the supplement may be a considerable item in the cost of production and involves a direct cash outlay.

The purposes of this investigation were to determine (1) whether high-protein corn fed as silage or as grain might replace a part or all of the protein supplement usually included in the dairy ration, and (2) whether high-protein strains of corn produced yields of forage and yields of protein in the forage equal to those of corn hybrids commonly grown in central Illinois.

---

[1] W. B. Nevens, Professor of Dairy Cattle Feeding; K. E. Harshbarger, Assistant Professor of Dairy Production; G. H. Rollins, Assistant in Dairy Science; P. C. Burk, Assistant in Dairy Science; K. E. Gardner, Professor of Dairy Production; and K. A. Kendall, Associate Professor of Dairy Production.

The authors were assisted in the investigation by W. H. Jenner, student in Dairy Science. They are indebted to R. W. Touchberry, Assistant Professor of Dairy Cattle Genetics, for advice concerning plans for the experiment and statistical studies of the data, and to E. B. Earley, Associate Professor of Soil Fertility, Department of Agronomy, for aid in planning the investigations. They also acknowledge the courtesy of the Plant Breeding division of the Department of Agronomy, University of Illinois, Funk Brothers Seed Company of Bloomington, Illinois, and the Lowe Seed Company of Aroma Park, Illinois, in furnishing the special strains of corn used in this investigation.

PREVIOUS INVESTIGATIONS

A number of experiments have been undertaken with the purpose of producing high-protein corn and studying its chemical composition and feeding value.

Chemical Composition of Corn

In 1896 Hopkins (13)* began an experiment at the Illinois Station selecting corn for high and low content of protein and oil. He reported substantial increases and decreases in protein content after three generations of selection. Smith (20) in a later report on the same experiment found that ten generations of selection had raised the protein level of the strain named High Protein from the original 10.92 percent to 14.26 percent. After fifty generations of selection, according to Woodworth, Leng, and Jugenheimer (22), the mean protein content of High Protein reached 19.45 percent and that of Low Protein was reduced to 4.91 percent.

Earley, Carter, and Johnson (5) compared the protein, nicotinic acid, thiamine, and carotene content of kernels of medium-protein and Illinois High Protein corn grown at two different levels of soil nitrogen and phosphorus. The concentration of these substances decreased rapidly as the kernels approached maturity. At both levels of soil fertility Illinois High Protein contained more protein, phosphorus, nicotinic acid, and thiamine than mature kernels of the medium-protein corn. Illinois High Protein kernels, being white, contained very little carotene.

Frey, Hansen, Miller, and associates (7, 8, 9, 11, 15) in studies of the effects of selection upon protein quality in the corn kernel, found that the protein of low-protein corn was more nearly balanced nutritionally than that of high-protein corn. Zein, a protein which is low or lacking in some of the amino acids essential for nonruminant nutrition, formed a much larger percentage of the total protein of high-protein than of low-protein corn.

Hamilton *et al.* (10) reported that soil fertilization increased the weight of the corn kernel, and the content of protein, fat, and total phosphorus, but depressed the nicotinic acid content. It increased the percentage of total nitrogen present as zein nitrogen.

Showalter and Carr (19) found that a larger part of the protein was present as zein and globulins in high-protein than in low-protein

* See "Literature Cited," page 21.

corn and the diamino acids formed about twice as great a percentage of the total protein in the high-protein strains.

Hunt *et al.* (14) observed that the protein, niacin, and pantothenic acid contents of six corn hybrids declined rapidly as the corn approached maturity. During the period August 24 to October 20 declines ranged from 20 to nearly 50 percent.

Harshbarger *et al.* (12) reported that fertilization brought about an enhanced protein content in the leaf-stalk portion of corn forage when the crop was grown on soil low in fertility. Fertilization had little effect on the protein content of the grain portion.

Mitchell, Hamilton, and Beadles (16) reported that the protein content of Illinois High Protein corn grown on nitrogen-deficient soil was 13.5 percent while on nitrogen-fertilized soil the protein content was 20 to 21 percent. In nitrogen-balance studies with rats, they found that the digestibility of the protein of corn increased slightly as the protein content of corn increased, but the biological value decreased considerably. They concluded, however, that the supplementation of the protein of corn with lysine and tryptophan will raise the biological value to levels that may approximate the biological value of meat protein.

Feeding Experiments

Other experiments with high-protein corn tested its nutritive value in feeding trials with beef cattle, dairy cattle, sheep, and swine.

Snapp (21) found high-protein corn (13.2 percent protein on moisture-free basis) superior to standard hybrid corn for fattening yearling steers.

Bond (1) found high-protein corn silage superior to standard hybrid corn silage as a feed for the wintering of 400-pound beef calves. In another feeding trial, this time with yearling steers, he observed that a ration composed of high-protein corn and high-protein corn silage produced better general appearance and finish than a ration containing standard shelled corn, soybean meal, and corn silage.

Burk (2) concluded from the results of a feeding trial in which silages made from high-protein corn and standard hybrid corn were fed to high-producing dairy cows that the extra protein of high-protein corn silage may replace part or all of the protein usually furnished in high-protein supplements.

Ross (18) found that lambs fed high-protein corn grain (either 11 or 13 percent protein) made significantly greater gains than lambs fed low-protein corn (7 percent protein). He also found insignificant dif-

ferences in gains, and in feed required per unit of gain, in pigs fed either 8 percent or 14 percent protein corn at levels which provided equal amounts of corn protein, energy, and fiber. He pointed out that it is essential that high-protein corn, as well as low-protein corn, be supplemented with adequate vitamins, minerals, and amino acids if pigs are to make satisfactory growth.

Dobbins *et al.* (4) reported that no difference was found in the nutritive value of two rations for pigs when the rations contained 15 percent protein and included either 8.2 percent protein corn or 11.7 percent protein corn. When 12.8 percent protein corn was fed, however, the gains were significantly less than those made by pigs on lower-protein corn.

Eggert, Brinegar, and Anderson (6) obtained nitrogen-retention values in the feeding of weanling pigs which were 37.2 percent for corn containing 10.6 percent protein and only 27.9 percent for corn containing 14.9 percent protein. Supplementation of the diets with lysine and tryptophan apparently corrected the deficiency and gave nitrogen-retention values which were nearly alike for both diets.

PLAN OF FIELD WORK

The corn was grown on three fields of the Dairy Science farm — Field B, Field 17-20, and Field M. The chief soil types on Field B and Field 17-20 are Drummer silty clay loam, and Brenton, Catlin, and Flanagan silt loams. The soil types on Field M are Drummer silty clay loam, and Brooklyn, Thorp, and Flanagan silt loams.

For many years just before the beginning of the experiment, Field M had been a part of a tenant-operated farm on which a cash-grain system of farming had been followed, and the fertility level of the field was low. The fertility of Fields B and 17-20, however, had been maintained at a high level through frequent growing of grasses and legumes, together with liberal applications of barnyard manure. Limestone had also been applied as needed.

The tests were conducted during the years 1950-1953 inclusive. The corn was grown on Field B during three years of the tests, on Field M for two years, and on Field 17-20 for one. Most of the corn rows were 80 rods in length and the size of the plots ranged from 0.28 to 6.96 acres.

Selection of kinds of corn. U. S. Hybrid 13 was selected as a standard and Illinois High Protein and three commercial strains were

to be compared with it. U. S. Hybrid 13 is a yellow dent corn which is widely grown throughout the corn belt and is well adapted to central Illinois conditions. It has stiff stalks, a strong root system, and large, thick ears. It is early to midseason in maturity.

Illinois High Protein, which was developed at the Illinois Station, is an open-pollinated strain of white dent corn. Its characteristics, as reported by Woodworth, Leng, and Jugenheimer (22), are lower ear height, lower plant height, a smaller percentage of erect plants, and more tillers per hundred plants than U. S. Hybrid 13. Its yield of grain is about half that of U. S. Hybrid 13, and it matures earlier. When grown on productive soils, the protein content of Illinois High Protein usually ranges from 16 to 20 percent while that of U. S. Hybrid 13 varies from 8 to 9 percent.

The commercial strains, which are designated here as Corn C, Corn D, and Corn E, were characterized by larger and stronger plants than those of Illinois High Protein and had maturity dates about the same as that of U. S. Hybrid 13. The protein content of the grain of the commercial strains ranged from 11 to 15 percent.

The high-protein strains of corn employed in the experiments were assumed to be representative of the best high-protein corn available at the time. Because of the progress made by corn breeders in improving the vegetative and yield characteristics of dent corn, as well as their development of strains of corn with a high content of protein, it was assumed that the strains of corn selected for this test did not represent the ultimate goal in corn development and that further improvement was still possible.

Harvesting and storing silage. Yields were obtained at the time the plots were completely harvested for silage. The loads were weighed and random samples were taken for determination of dry matter and other nutrients.

One year, samples were taken of the standing crop. The samples were chosen by harvesting every one-hundredth plant in one or two rows, each 80 rods in length. Each sample was separated into ear and leaf-stalk portions. After chopping and subsampling, the subsamples were dried and saved for dry-matter and protein analysis.

In making the silage which was used in the feeding and digestion trials, the forage of each of the strains of corn tested was harvested at a proper silage stage and stored separately in an upright silo. No water or conditioners were added to the forage.

COMPARISON OF PROTEIN CONTENTS AND YIELDS

In this experiment the amount of protein produced per acre and the distribution of the protein between the ear and leaf-stalk fraction were matters of primary interest. Other criteria generally used in evaluating a particular strain of corn for its suitability as a silage crop were also considered. These include (1) yields of forage, (2) yields of dry matter in forage, (3) ability to reach harvest stage before frost, (4) ability to produce large yields of grain, (5) resistance to lodging and disease, and (6) feeding value of the silage.

Yields of fresh forage. Since a farmer expects the forage crop to supply sufficient silage to feed his livestock, he often bases his estimate of the worth of such a crop upon the acre yield of fresh forage. All of the strains of corn tested in this trial gave satisfactory yields of fresh forage when grown on highly productive land (Fields B and 17-20, Table 1). When grown on Field M, a field known to be low in productivity, some of the yields were considerably below the 10-ton average for the state.

Yields of dry matter. The yields of dry matter in the forage varied considerably (a) from year to year, (b) between fields, (c) between nonfertilized and fertilized plots, and (d) between strains of corn (Table 1).

Seasonal differences were noted in the yields from Field B. The yields obtained in 1951 were higher than those of the other two years in which this field was used. The yields of forage from Field M were considerably below those from Field B during 1950 and 1951, reflecting the difference in productivity between the two fields. In 1951 certain plots of Field M were fertilized and these plots furnished somewhat larger yields of forage than the nonfertilized plots.

In each of the four years Illinois High Protein, with a single exception, produced less dry matter per acre than any of the other strains of corn. On Fields B and 17-20 the dry-matter yields of Illinois High Protein in the different years were from 18 to 40 percent less than those of U. S. Hybrid 13. The yields of the other high-protein strains were variable but, except for one plot of Corn D in 1951, were higher than those of Illinois High Protein.

Delaying the harvest date resulted in higher percentages of dry matter in the forage and higher yields of dry matter. The effect of harvest date is illustrated in the yields of Fields B and M in 1950 (Table 1).

Table 1. — Yields of High-Protein and U. S. Hybrid 13 Corn Forage Grown for Silage

Kind of corn	Field	Acreage	Date of harvest	Dry-matter content	Acre yield of forage		Protein in dry matter	Acre yield of protein
					Fresh matter	Dry matter		
		acres		*perct.*	*tons*	*tons*	*perct.*	*lb.*
U. S. Hybrid 13	B	.75	9-13-50	23.4	19.90	4.67	9.28	867
U. S. Hybrid 13	B	.38	9-19-50	26.6	19.39	5.15	10.11	1,041
Illinois High Protein	B	6.00	9-14,15-50	24.9	13.78	3.43	12.59	813
Corn C	B	6.00	9-15,16,18-50	26.3	16.97	4.47	10.20	912
U. S. Hybrid 13	M	.99	9-7,8-50	26.0	10.48	2.75	6.58	362
Corn D	M	.99	9-8-50	25.4	9.59	2.44	5.92	289
U. S. Hybrid 13	M	6.96	9-19,25-50	32.8	10.31	3.38	6.78	458
Corn C	M	3.97	9-25,26-50	36.4	8.13	2.96	6.48	385
Corn D	M	.99	9-27,28-50	34.0	7.88	2.68	5.82	312
U. S. Hybrid 13	B	.75	9-19-51	29.4	18.98	5.59	9.07	1,014
U. S. Hybrid 13	B	.38	9-22-51	29.6	21.87	6.47	8.83	1,143
Illinois High Protein	B	3.75	9-20,21,22-51	28.2	15.44	4.35	11.61	1,010
Corn C	B	3.75	9-17,18,19-51	27.8	19.23	5.34	9.28	991
Illinois High Protein	M[a]	.59	9-22-51	36.0	6.93	2.50	9.98	499
Corn C	M[a]	.57	9-22-51	33.8	9.85	3.22	6.78	437
Corn D	M[a]	.38	9-22-51	36.8	5.60	2.06	7.33	302
Illinois High Protein	M[b]	.82	9-22-51	31.3	9.08	2.84	10.16	577
Corn C	M[b]	.52	9-11-51	27.7	12.98	3.59	8.19	588
Corn D	M[b]	.28	9-22-51	36.1	8.90	3.21	8.70	559
U. S. Hybrid 13	17-20	1.53	9-6-52	29.1	18.12	5.28	9.21	972
U. S. Hybrid 13	17-20	.76	9-8,15-52	34.7	16.89	5.87	9.56	1,121
Illinois High Protein	17-20	1.53	9-5,6-52	25.0	13.11	3.28	13.02	854
Corn C	17-20	1.53	9-8-52	29.5	18.06	5.33	9.74	1,037
Corn D	17-20	1.53	9-6-52	29.5	17.15	5.06	10.45	1,057
Corn E	17-20	1.53	9-6,8-52	27.2	15.50	4.21	11.69	985
U. S. Hybrid 13	B[a]	1.69	8-31-53	33.5	12.99	4.36	8.48	739
U. S. Hybrid 13	B[b]	1.50	8-31-53	35.3	14.98	5.28	9.66	1,020
Illinois High Protein	B[b]	1.50	8-29-53	35.1	11.22	3.94	11.81	931
Corn C	B[b]	1.50	8-31-53	31.5	13.49	4.25	9.83	835
Corn D	B[b]	5.25	8-28,29-53	38.6	10.48	4.04	10.25	828

[a] Nonfertilized. [b] Fertilized.

Yields of protein. In all four years, the percentage of protein in Illinois High Protein forage was higher than in the forage of any of the other strains of corn tested (Table 1). For this reason, the acre yields of protein by Illinois High Protein were only 9 to 18 percent below those of the other strains, even though the yields of dry matter of Illinois High Protein were considerably lower. In tests carried out in one field in 1951, the yields of protein in Illinois High Protein were approximately equal to those of the other strains.

A higher protein content was found in the forage grown on highly productive land (Fields B and 17-20) than in that produced on a field low in productivity (Field M). The fertilization of one group of plots on Field M brought about an increase in the protein content of the forage. In 1951 the three strains of corn grown on Field M produced one-fifth more dry matter and over one-third more protein when grown on fertilized soil than when grown on nonfertilized soil. The application of fertilizers containing nitrogen is an excellent means of increasing not only the yields of forage but also the quantity of protein in the crop. These findings are in agreement with earlier investigations at this Station (12).

It seems also true that the factor in the high-protein strains which is responsible for high percentage of protein content is not given full opportunity for expression when the crop is grown on soil low in productivity. In 1950 (Table 1) the protein percentage in the dry matter of the high-protein strains grown on Field M was not as high as that of U. S. Hybrid 13 grown on the same field. In 1951 the percentage of protein in the commercial strains grown on both nonfertilized and fertilized plots in Field M was not as high as that of U. S. Hybrid 13 grown on Field B in the same year. The protein percentage of Illinois High Protein grown on Field B, however, was considerably higher than that of U. S. Hybrid 13.

Protein of ear and leaf-stalk fractions. Determinations of dry matter in samples taken from the standing crop showed the ear fraction of the forage to be much higher in dry-matter content than the leaf-stalk fraction (Table 2). This is the usual condition at the silage-harvest stage, when the ears are nearing maturity.

The protein contents of the leaf-stalk fractions did not show any marked superiority of the high-protein strains over U. S. Hybrid 13, although Illinois High Protein was somewhat above the others. For the grain, however, there was a pronounced difference in the protein contents of the various strains of corn, the protein content of Illinois High Protein grain being approximately 50 percent higher than that of

Table 2. — Dry-Matter and Protein Contents of Leaf-Stalk and Ear Fractions of Corn Forage, 1950

Kind of corn	Field	Date of sampling	Dry-matter content		Protein content[a]	
			Leaf-stalk	Ear	Leaf-stalk	Grain
			perct.	*perct.*	*perct.*	*perct.*
U. S. Hybrid 13.....	B	9-7-50	18.0	40.0	10.0	11.2
Illinois High Protein....	B	9-7-50	23.2	35.5	11.4	17.4
Corn C.....	B	9-7-50	19.0	41.0	10.4	10.2
U. S. Hybrid 13.....	M	9-7-50	21.4	37.8	5.5	8.1
U. S. Hybrid 13.....	M	9-15-50	18.7	46.9	5.3	8.7
Corn D.....	M	9-7-50	23.3	41.0	5.1	7.7

[a] Dry-matter basis.

the grain of other strains of corn grown on the same field. In this phase of the trial, the grain of one of the commercial strains was not as high in protein as that of U. S. Hybrid 13.

The protein contents of both the leaf-stalk and grain of forage grown on Field M were far less than those of the forage produced on Field B. These results confirm the findings for the forage as a whole (Table 1).

Rate of development. All the strains of corn included in these trials reached a proper silage-harvest stage before frost. In fact, as judged by the dry-matter percentages shown in Table 1, they were nearly alike in rapidity of development for silage. All the strains of corn produced good yields of ears. Illinois High Protein was affected by leaf-firing to a greater extent than the other strains. This may have been due to a deficiency of available nitrogen.

FEEDING VALUE OF HIGH-PROTEIN CORN

The feeding value of high-protein corn was studied in several experiments: (a) digestion trials with rabbits and then with Holstein steers using corn silage, (b) feeding trials with dairy cattle using corn silage, and (c) feeding trials with dairy cattle using corn grain.

Digestibility of corn silage. In arriving at the feeding value of a new feed, it is necessary that the digestibility of the nutrients be known. In the case of the high-protein corn silage being studied, it was important to learn whether the protein of this silage is digested as fully as that of corns commonly used.

Two digestion trials were conducted. A preliminary study was carried out with rabbits to discover whether a difference between silages existed and whether a more laborious trial with cattle would be justified. Investigations with rabbits offer the advantages of the use of a relatively large number of animals in experiments designed especially for simplicity of statistical analysis, together with economy of feed and labor in caring for the animals. Because of the somewhat unsatisfactory results obtained with rabbits, a second study was undertaken in which cattle were employed.

Digestion Trial With Rabbits

Twelve New Zealand White rabbits were used in a trial to determine the apparent digestibility of the dry matter and protein of silage made from U. S. Hybrid 13, Corn C, and Illinois High Protein corn. A 3 X 3 Latin-square design as suggested by Cochran *et al.* (3), was followed, using three rabbits in each group.

The rations consisted of air-dried corn silage, 88.5 percent; sucrose (C.P.), 10 percent; trace-mineralized salt, 1 percent; and commercial vitamin A-D concentrate, 0.5 percent. The three rations were alike except for the kind of silage.

The rabbits did not like the feed and failed to eat enough of it to maintain their body weights. Satisfactory results were obtained with only two groups of animals.

The values found for the apparent digestibility of the protein of the three silages were: U. S. Hybrid 13, 47 percent; Corn C, 49 percent; and Illinois High Protein, 55 percent. An analysis of variance showed that these differences were not significant. The lack of significance was attributed to wide differences in results obtained with rabbits fed the same ration and to the small number of animals which completed the tests. The results were sufficiently encouraging, however, to warrant further study.

Digestion Trial With Cattle

In this trial, two Holstein steers, approximately 18 months old, were confined in metabolism stalls equipped for the collection of urine and feces. The total collection method was followed.

The experimental periods were 10 days in length. An adjustment period preceded the first experimental period to permit the animals to become adjusted to their stalls and to determine the amount of silage which they would consume without waste.

Enough silage for a 10-day supply was removed from the silo, thoroughly mixed, sampled for analysis, and then refrigerated until fed. The ration consisted only of silage except for the addition of suitable amounts of trace-mineralized salt, dicalcium phosphate, a vitamin A-D concentrate, and 15 milliliters of cod-liver oil.

The silages fed were nearly alike in their contents of dry matter, ether extract, and fiber. They differed materially, however, in protein content, the Illinois High Protein silage having more than one and one-half times as much protein as the U. S. Hybrid 13 silage. The carotene content of the Illinois High Protein silage was much lower than that of the other silage because of the leaves being riper at the time of ensiling the forage and also because of the grain being white (Table 3).

The apparent digestibility of the dry matter and nitrogen-free extract of the U. S. Hybrid 13 silage was slightly higher than that of the Illinois High Protein silage, while the digestibility of the other nutrients of the U. S. Hybrid 13 silage was lower. The primary interest in this study was the digestibility of the protein of the two silages. A striking difference between them was found. The coefficient of apparent digestibility of the protein of U. S. Hybrid 13 silage was found to be 48 while for the Illinois High Protein silage it was 60. This is a difference of 25 percent. The digestibility study confirms the results obtained in the preliminary study conducted with rabbits in which a difference in apparent digestibility of protein in favor of Illinois High Protein was found.

Table 3. — Chemical Composition, Apparent Digestibility, and Digestible-Nutrient Content of U. S. Hybrid 13 Silage and Illinois High Protein Silage

Kind of silage	Dry matter	Protein (N × 6.25)	Ether extract	Fiber	N-free extract	Ash	Carotene
	perct.	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*	*mg./lb.*
Chemical composition of the dry matter							
U. S. Hybrid 13.....	30.4	7.8	2.6	23.6	60.6	5.4	21.8
Illinois High Protein..	30.0	11.8	2.8	23.8	55.0	6.6	4.1
Apparent digestibility of the nutrients							
U. S. Hybrid 13.....	67	48	75	62	74	...	....
Illinois High Protein..	65	60	77	65	71	...	....
Digestible nutrient content							
U. S. Hybrid 13.....	20.3	1.1	.6	4.4	13.7	...	....
Illinois High Protein..	19.5	2.1	.6	4.7	11.7	...	....

The digestible nutrient contents of the silages may be computed by using the chemical composition and digestibility figures. The results of this calculation expressed in terms of fresh silage are shown in Table 3. It will be noted from these figures that the two silages are similar in feeding value except for their digestible protein content. The U. S. Hybrid 13 silage provided only 1.1 pounds of digestible protein in 100 pounds of fresh silage, while Illinois High Protein furnished 2.1 pounds. The total digestible nutrient content as calculated by the usual formula[1] was found to be 20.5 for the U. S. Hybrid 13 silage and 19.8 for the Illinois High Protein silage. These figures are close to the digestible dry-matter contents of the silages.

This information is useful in formulating rations for dairy cattle. Assuming that a dairy cow is fed 30 pounds of silage daily, the feeding of 30 pounds of silage containing 2.1 percent digestible protein would supply 0.3 pounds more digestible protein than would be furnished in the same quantity of silage having only 1.1 percent digestible protein. To supply 0.3 pound digestible protein in protein concentrates would require the use of 0.8 pound soybean meal, 43 percent protein grade; or 0.9 pound linseed meal, 37 percent protein grade; or more than 2 pounds of wheat bran, 16 percent protein grade.

The cause of the greater digestibility of the protein of the Illinois High Protein silage is not apparent from the figures presented here. Presumably the difference is accounted for by a dissimilarity in the amino acid make-up of the proteins of the two silages. Because of the ability of cattle to make use of various protein feed materials, including several simple nitrogenous compounds, it is likely that the extra amount of protein digested from one of the silages was not wasted but was available for use by the body tissues. Metabolism data obtained in connection with the digestion trial may throw further light on this problem.

HIGH-PROTEIN SILAGE TESTED FOR MILK PRODUCTION

A fifteen-week feeding trial was conducted to compare the milk-producing values of Illinois High Protein silage and Corn C silage with that of standard corn silage.

[1] Total digestible nutrient content = digestible protein + digestible fiber + digestible nitrogen-free extract + (digestible ether extract × 2.25).

Eighteen registered cows of the Ayrshire, Brown Swiss, and Holstein breeds were fed rations containing one of the various silages.

The standard corn silage consisted of a mixture of the forage of U. S. Hybrid 13 and four other hybrids — Illinois 206, 784, 972A-1, and 2119(W) — having about the same maturity date as U. S. Hybrid 13. Previous trials had shown that all of the hybrids were well-adapted to central Illinois conditions and were high-yielding both for forage and grain (17).

The cows were divided into trios, each trio consisting of three cows as nearly alike as possible with respect to breed, age, stage of gestation, stage of lactation, weight, and productive ability. One cow from each trio was assigned to one of the three experimental rations.

Each of the rations was designed to furnish the same amount of protein and total digestible nutrients. The average protein contents of the silages were: Illinois High Protein, 3.1 percent; Corn C, 2.8 percent; and the standard silage, 1.8 percent. A cow fed 42 pounds of Illinois High Protein silage daily received about ½ pound more protein in her silage than a cow fed the same quantity of standard silage. A cow fed 42 pounds of Corn C silage daily received 0.4 pound more protein. Because of these differences, the protein content of the rations was adjusted to the proper level by increasing the proportion of protein supplement (soybean meal) in the grain mixtures fed with the

Table 4. — Composition of Rations Used in Feeding Trial With Dairy Cows

Kind of feed	Ration		
	Standard corn silage	Illinois High Protein silage	Corn C silage
Grain mixture			
Ground ear corn, lb.	725	725	725
Ground oats, lb.	125	250	165
Soybean meal, lb.	125	...	85
Salt, lb.	15	15	15
Steamed bonemeal, lb.	10	10	10
Total weight, lb.	1,000	1,000	1,000
Total protein, perct.	12.9	8.7	11.6
TDN content (calculated),[a] perct.	71.7	70.6	71.3
Corn silage, protein content, perct.	1.8	3.1	2.8
Alfalfa hay, protein content, perct.	13.6	13.6	13.6

[a] See footnote, page 14.

silages of lower protein content (Table 4). Cows producing equal quantities of milk had approximately equal protein intakes throughout the trial. All cows were fed from the same lot of alfalfa hay.

Each cow within a trio received the same amount of silage, grain mixture, and hay daily. Each cow was fed the same ration throughout the trial, except that the amounts of the feeds supplied were changed periodically according to changes in milk yield. This decrease affected all components of the ration so that the relationship of one to the other was not changed. (The protein contents of the grain mixtures, silages, and alfalfa hay, as determined from analyses of samples of feeds, are shown in Table 5.)

The average amounts of each feed consumed daily per cow were nearly alike for the three rations (Table 6). The cows fed Illinois High Protein silage had a lower dry-matter intake than the other groups chiefly because of the lower dry-matter content of the silage (24.1 percent as compared with 27 percent in the standard and 28.3 percent in Corn C, as shown in Table 5).

The cows were weighed on three consecutive days at the beginning and the end of the trial and once weekly throughout the trial. Milk yields were calculated in terms of fat-corrected milk (FCM) for each cow. The three groups were compared with respect to their FCM production and net changes in weight.

The yields of fat-corrected milk of cows fed the three silages were good, the average daily yield per cow ranging from 28.3 pounds to

Table 5. — Dry-Matter and Protein Contents of Experimental Feeds

Kind of feed	Number of samples analyzed	Average dry-matter content	Average protein content	
			Fresh-matter basis	Dry-matter basis
		perct.	*perct.*	*perct.*
Standard corn hybrid silage	12	27.0	1.8	6.8
Corn C silage	12	28.3	2.8	9.9
Illinois High Protein corn silage	12	24.1	3.1	12.8
Alfalfa hay	10	82.2	13.6	16.5
Grain mixture fed with Illinois High Protein silage	12	82.5	8.7	10.6
Grain mixture fed with standard silage	12	82.2	12.9	15.7
Grain mixture fed with Corn C silage	10	82.0	11.6	14.1

29.7 pounds (Table 6). The cows fed Corn C silage gained slightly in weight while the other groups lost weight. The greater losses of the cows fed Illinois High Protein silage were presumably caused by the lower dry-matter intake. An analysis of variance of the data showed that the differences between the groups in both FCM production and increase in weight were not significant.

Judging from the results of the silage-feeding trial, the protein of silage made from high-protein strains of corn may replace some of the protein generally supplied by concentrates. This study did not take into account the comparative costs of protein in homegrown feeds and in commercial supplements, but the cost should be considered before introducing any change in herd management.

Table 6. — Feed Consumption, Milk Yield, and Live-Weight Change of Dairy Cows Fed Three Kinds of Silage

(Expressed as pounds per cow daily)

Kind of silage	Feed intake			Dry-matter intake	Yield of FCM	Live-weight change
	Silage	Hay	Grain mixture			
Standard corn hybrid.....	42.8	10.6	9.6	28.1	29.7	−.11
Corn C.....	43.1	10.6	9.9	29.0	28.7	+.29
Illinois High Protein.....	42.0	10.6	10.0	27.1	28.3	−.66

HIGH-PROTEIN CORN GRAIN TESTED FOR MILK PRODUCTION

Another feeding trial was conducted with dairy cows to see if the grain instead of the silage of high-protein corn could replace protein concentrates in the ration.

Twelve cows were assigned to two groups, each group containing five Holsteins and one Ayrshire. The cows were fed continuously on the same rations for 13 weeks, including a 3-week preliminary and a 10-week experimental period.

All cows were fed from the same lots of good-quality roughage, including alfalfa hay and corn silage. The grain mixture fed the control group was one commonly used for the herd; the grain mixture fed to the experimental group contained the high-protein corn grain.

	Control group mixture *lb.*	*Experimental mixture* *lb.*
Corn	40, ground, No. 2 shelled	77, ground, shelled, high-protein
Ground oats	35	20
Wheat bran	10	....
Soybean meal	5	....
Linseed meal	7.5	....
Bonemeal	1.5	1.5
Salt	1.5	1.5

The control grain mixture contained 15.1 percent protein; the high-protein corn contained 11.6 percent protein and the experimental mixture of which it was a part contained 11.7 percent protein.

Both groups of cows consumed more digestible protein and total digestible nutrients (TDN) than the estimated requirements (Table 7). It may be calculated that 11.7 pounds of high-protein grain mixture containing 9 pounds of high-protein corn provided about ⅓ pound more protein than an equal amount of a mixture of the same formula containing standard corn.

Table 7. — Daily Feed and Nutrient Consumption and Milk Yield of Cows Fed High-Protein Corn

(Expressed as pounds daily per cow)

Ration	Feed consumed			Digestible protein		TDN		Yield of FCM	
	Silage	Hay	Grain mixture	Req.[a]	Con.[b]	Req.[a]	Con.[b]	Prelimi-nary[c]	10 weeks[d]
Control	40.8	15.9	11.5	2.49	3.52	21.8	23.5	47.3	44.3
High protein	36.0	14.1	11.7	2.40	2.85	20.7	22.7	46.8	44.2

[a] Estimated requirement. [b] Calculated amount consumed. [c] 3-week preliminary period. [d] 10-week experimental period.

As shown in Table 7, the yield of milk (FCM) was practically the same for both groups. A criterion of the effectiveness of the ration in maintaining normal milk production is the rate of decline in milk yield, a decline of 2 percent weekly being considered normal. In this trial, the production of both groups was sustained in a normal manner. The total decline from the midpoint of the preliminary period (average of three weeks' records) to the end of the experimental period, a total of 11 weeks, was 25 percent for the control group and 22 percent for the high-protein group.

The body weights of the cows of the control group showed a loss of 0.14 pound daily during the 10-week experimental period while the high-protein group gained 0.24 pound daily per cow.

The results of the trial indicate that a ration containing no protein supplement but instead corn known as a high-protein strain can be satisfactory for dairy cows over a portion of the lactation period. A more dependable basis for determining whether protein supplements can be completely eliminated from rations for milk production would be a carefully conducted trial during not less than two successive lactation periods.

SUMMARY AND CONCLUSIONS

Illinois High Protein and three commercial strains of high-protein corn were compared with U. S. Hybrid 13. When grown on highly productive land, all of the strains gave satisfactory yields of both fresh forage and dry matter in forage. The yields of the commercial high-protein strains did not differ widely from those of U. S. Hybrid 13 but the dry-matter yields of Illinois High Protein were considerably less than those of U. S. Hybrid 13.

When grown on highly productive soil, the percentages of protein in the forage of the high-protein strains were considerably above those of U. S. Hybrid 13 forage, but when grown on poor, unfertilized soil only small differences in protein content were found. Illinois High Protein forage was highest in protein percentage and, despite lower dry-matter yields, furnished nearly as many pounds of protein to the acre as forage of the other strains harvested on approximately the same date.

When grown on highly productive soil, the grain of Illinois High Protein was nearly 50 percent higher in protein content than the grain of the other strains, but there was little difference between strains in the percentage of protein found in the leaf-stalk part of the forage. On poor soil there was little difference between strains in the protein content of either the ear or the leaf-stalk fractions of the forage. An ample supply of plant food, particularly nitrogen, evidently must be available to the crop to enable it to express its full potential yield of dry matter and of protein.

A digestion trial with rabbits in which silages from Illinois High Protein, a commercial high-protein strain, and U. S. Hybrid 13 corn were studied showed differences in the apparent digestibility of the protein, that of Illinois High Protein showing the highest value. The differences, however, were found not to be significant.

In digestion trials with Holstein steers, a coefficient of apparent digestibility of 60 was found for the protein of Illinois High Protein

silage and only 48 for the protein of U. S. Hybrid 13 silage. This is an important difference. The total-digestible nutrient content of U. S. Hybrid 13 silage was calculated to be 20.5 and that of Illinois High Protein silage 19.8.

The yields of three groups of high-producing cows fed three different rations containing (1) standard silage made from U. S. Hybrid 13 and similar corn hybrids, (2) silage made from Illinois High Protein, and (3) silage made from commercial high-protein corn did not differ significantly. All silages proved satisfactory as feeds for milk production. Since a smaller amount of protein supplement was used in the ration which included the commercial high-protein silage and none at all when Illinois High Protein silage was fed, it is concluded that the use of silage made from high-protein strains of corn makes possible a reduction in the amounts of protein concentrates commonly fed for milk production.

The production of dairy cows fed a grain mixture containing no protein supplement but including corn having a protein content of 11.6 percent was as well maintained over a 10-weeks' period as that of cows fed standard corn and a protein supplement. The production of both groups was unusually high. Both rations supplied protein in excess of the estimated requirements.

The findings of these experiments point to high-protein corn as a satisfactory means of supplying protein in rations for dairy cows. When the crop is homegrown, direct cash outlays for protein supplements may be reduced. Whether farmers will grow special strains of high-protein corn for feed will largely depend on how favorably these strains compare in yields of grain and forage with the yields of other corn. The results of the experiments reported in this publication indicate that high-protein corn has a promising future.

LITERATURE CITED

1. BOND, JAMES. The value of high-protein corn for beef cattle. Twenty-fifth Ann. Illinois Cattle Feeders' Meeting. p. 11-12. 1953.
2. BURK, P. C. High-protein corn silage as a feed for milk production. Ill. Agr. Exp. Sta. Bien. Rpt. 1950-1952. p. 74. 1953.
3. COCHRAN, W. G., AUTREY, K. M., and CANNON, C. Y. A double change-over design for dairy cattle feeding experiments. Jour. Dairy Sci. **24**, 937-951. 1941.
4. DOBBINS, F. A., KRIDER, J. L., HAMILTON, T. S., EARLEY, E. B., and TERRILL, S. W. Comparison of high and low protein corn for growing-fattening pigs in drylot. Jour. Anim. Sci. **9**, 625-633. 1950.
5. EARLEY, E. B., CARTER, J. N., and JOHNSON, B. C. Nicotinic acid, thiamine, and carotene content of kernels of medium- and high-protein corn. Agron. Jour. **44**, 326-328. 1952.
6. EGGERT, R. G., BRINEGAR, M. J., and ANDERSON, C. R. The quality of protein of normal and high protein corn for growing swine. Jour. Anim. Sci. **12**, 282-290. 1953.
7. FREY, K. J. The inheritance of protein and certain of its components in maize. Agron. Jour. **41**, 113-117. 1949.
8. FREY, K. J. The interrelationships of proteins and amino acids in corn. Cereal Chem. **28**, 123-132. 1951.
9. FREY, K. J., BRIMHALL, B., and SPRAGUE, G. F. The effects of selection upon protein quality in the corn kernel. Agron. Jour. **41**, 399-403. 1949.
10. HAMILTON, T. S., HAMILTON, B. C., JOHNSON, B. C., and MITCHELL, H. H. The dependence of the physical and chemical composition of the corn kernel on soil fertility and cropping system. Cereal. Chem. **28**, 163-176. 1951.
11. HANSEN, D. W., BRIMHALL, B., and SPRAGUE, G. F. Relationship of zein to the total protein in corn. Cereal Chem. **23**, 329-335. 1946.
12. HARSHBARGER, K. E., NEVENS, W. B., TOUCHBERRY, R. W., LANG, A. L., and DUNGAN, G. H. Yield and composition of corn forage as influenced by soil fertilization. Ill. Agr. Exp. Sta. Bul. 577. 1954.
13. HOPKINS, C. G. Improvement in the chemical composition of the corn kernel. Ill. Agr. Exp. Sta. Bul. 55. 1899.
14. HUNT, C. H., RODERIGUEZ, LORRAINE D., TAYLOR, SYLVIA, and BETHKE, R. M. The effect of maturity on the variation in protein, niacin, and pantothenic acid content of corn hybrids. Cereal Chem. **29**, 142-147. 1952.
15. MILLER, P. A., HURST, T. L., and BRIMHALL, B. Relationships of lysine and niacin with crude protein and certain protein components in corn grain. Agron. Jour. **44**, 342-345. 1952.
16. MITCHELL, H. H., HAMILTON, T. S., and BEADLES, JESSIE R. The relationship between the protein content of corn and the nutritional value of the protein. Jour. Nutr. **48**, 461-476. 1952.
17. NEVENS, W. B. and DUNGAN, G. H. Yields of corn hybrids harvested for silage. Ill. Agr. Exp. Sta. Bul. 533. 1949.
18. ROSS, C. V. Studies of the nutritive value of high-protein corn for livestock. Ill. Agr. Exp. Sta. Bien. Rept. for 1950-1952. p. 65. 1953.
19. SHOWALTER, M. F., and CARR, R. H. Characteristic proteins in high and low protein corn. Jour. Amer. Chem. Soc. **44**, 2019. 1922.
20. SMITH, L. H. Ten generations of corn breeding. Ill. Agr. Exp. Sta. Bul. 128. 1908.
21. SNAPP, R. R. The value of high-protein corn for fattening cattle. Twenty-fourth Ann. Illinois Cattle Feeders' Meeting. p. 2-5. 1952.
22. WOODWORTH, C. M., LENG, E. R., and JUGENHEIMER, R. W. Fifty generations of selection for protein and oil in corn. Agron. Jour. **44**, 60-65. 1952.

OTHER ILLINOIS PUBLICATIONS ON SILAGE

The following Illinois publications give information about silage crops, methods of making and handling silage, feeding value of silage, and money value of the silage. They can be obtained on request from the Information Office, College of Agriculture, Urbana, Illinois.

Grass and Legume Silages for Dairy Cattle. Circular 605. 20 pages.

Feeding the Dairy Herd. Circular 677. 36 pages.

Making High Quality Silage for Dairy Cattle. Circular 686. 24 pages.

Handling Silage and Concentrates for Beef Cattle in Dry-lot. Circular 714. 16 pages.

Yields of Corn Hybrids Harvested for Silage. Bulletin 533. 20 pages.

A Method for Estimating the Money Value of Corn Silage. Bulletin 576. 16 pages.

Yield and Composition of Corn Forage as Influenced by Soil Fertilization. Bulletin 577. 20 pages.

Sorghums and Soybeans as Silage Crops for Milk Production. Bulletin 578. 64 pages.

6000—3-55—56650