SINGLE GRAINS COMPARED TO GRAIN MIXTURES AS SUPPLEMENTS TO ROUGHAGE FOR MILK PRODUCTION

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A THESIS

Submitted to the School of Graduate Studies of
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AN ABSTRACT

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Approved W. W. Snyder

Single grains were compared to grain mixtures as supplements to roughage for milk production. Three separate experiments were conducted in this investigation. Oats, barley, and corn were compared individually to a grain mixture, equal parts by weight, of three cereal grains.

In each of three 84 day (four 21-day periods each) experiments the single grain was compared to the grain mixture as a supplement to hay and hay crop silage for winter feeding dairy cows.

Two cow groups of three registered Holstein cows each, comparable in age, body weight, milk production, and stage of lactation were used in each experiment.

Both groups of cows in each study were fed from the same supply of hay and hay crop silage. Rate of grain feeding was based upon the individual cows milk production and was adjusted on or before the seventh day of each 21 day feeding period.

The cows were confined in their stanchions during the three experiments, except while being lead to the scales to be weighed every third day. A mixture of sawdust and shavings was used as bedding. This prevented the cows from obtaining additional nutrients by eating their bedding. Water was available in drinking cups at all times. A daily supplemental mineral supply was provided each cow each day.

All hay, hay crop silage, and grain feedings were weighed and recorded for each cow each day. Feed not consumed was weighed back before each succeeding feeding.

Cows were weighed daily for three days prior to the start of each experiment. The mean weight was used as the base weight. The cows were weighed the second day of each three-day period at about the same time.

The cows were milked twice daily at 6:00 A.M. and 4:00 P.M.

The milk was weighed and samples for butterfat determinations were taken at each milking. Milk samples were preserved with corrosive sublimate, and butterfat tests were run every three days.

In each experiment one group of cows was fed the single grain, hay, and hay crop silage during the first and third periods. During the second and fourth periods this group was fed the grain mixture, hay, and hay crop silage.

The other group of cows was fed the grain mixture, hay, and hay crop silage during feeding periods one and three and were fed the single grain, hay, and hay crop silage during periods two and four, respectively.

The data for the last 15 days of each period in each experiment were used in calculating results.

Results of these experiments show that oats, corn, or barley fed alone as supplements to hay and hay crop silage were equal to grain mixtures, equal parts by weight, of three cereal grains, for milk production, maintaining body weight and general herd health.

It is concluded that for cows fed liberal amounts of quality roughage, the use of oats, barley, or corn will result in satisfactory milk production for at least three months of the winter barn-feeding season.

--C. J. Little

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INTRODUCTION

For years dairymen have favored a grain ration for dairy cows composed of a mixture of several kinds of grains.

These recommendations are based upon the belief that palatability and quality are less likely to be lacking if the ration contains a mixture of grains rather than a single grain.

In some dairy farming areas commercial feedstuffs are scarce and expensive as compared to cereal grains. In certain areas where the growing seasons are short and the nights cold, the efficient production of home grown cereal grains is often limited to one grain.

Northern sections of the United States bordering upon Canada are dairy farming regions in which corn does not regularly mature; thus, oats and barley are produced and used for dairy cattle feed. Oats and/or barley are most abundantly produced in these areas. This applies as well to similar areas in other parts of the world.

In Alaska barley is the most commonly grown cereal grain. According to Sweetman (139), Dairy Husbandman, Alaska Agricultural Experiment Station, University of Alaska,

they produce just enough oats to be sure to have whole oats to feed to their dairy calves.

Corn grain is acknowledged to be the number one feed grain in the United States and is often in surplus supply in corn growing areas.

There appears to be some hesitancy on the part of dairymen in the areas mentioned to take advantage of the opportunity presented by an over supply of a single cereal grain.

The purpose of this investigation was to determine whether milk production, during the winter barn-feeding season, could be sustained at a comparable level by feeding a single cereal as compared to a grain mixture of three cereal grains equal parts by weight. Each ration was fed as a supplement to hay and hay crop silage.

Three separate experiments were conducted as a part of this investigation:

Experiment one: A single grain, oats (ground), was compared to a grain mixture (ground) of equal parts by weight of oats, wheat, and corn as a supplement to hay and hay crop silage for milk production during the winter barn-season.

Experiment two: A single grain, corn (ground), was compared to a grain mixture (ground) of corn, oats, and barley equal parts by weight as a supplement to hay and hay crop silage for milk production during the winter barn-season.

Experiment three: A single grain, barley (ground), was compared to a grain mixture (ground) of barley, oats, and corn equal parts by weight as a supplement to hay and hay crop silage for milk production during the winter barn-season.

REVIEW OF LITERATURE

Experimental evidence has accumulated over the years to indicate that dairy cows can be fed successfully on a great number of grain rations. Different combinations of grains, protein supplements as well as single grains, have proved successful as supplements for quality roughage. Practical farm feeding experiences have aided research workers in developing their studies.

The soil bank program, acreage quotas, and the continued close spread between the price of dairy products and feed concentrates has stimulated greater interest in the use of home grown cereal grains.

It is sound dairy management, in making up a dairy ration, to use feeds that are available at the least cost and at the same time supply adequate nutrients.

Loosli and associates (92) of the subcommittee on dairy cattle research of the National Research Council in 1956 concluded: In practice the tendency is to overfeed protein and underfeed energy. A limited energy supply lowers milk production more than does a deficiency of any other nutrient.

Nutritive Characteristics of Cereal Grains

Morrison (110) states that cereal grains are all low or relatively low in fiber. They are therefore relatively

high in total digestible nutrients and net energy. In addition nearly all the cereal grains are highly palatable to cattle. Rye is the only one of the common grains not well liked by cattle. Corn is the lowest in the list of cereal grains in protein content, and the other grains are relatively low in protein. The proteins of the cereal grains are also of low quality, for they contain only small amounts of certain of the essential amino acids. Corn, wheat, barley, and oats rank in that order in amount of digestible nutrients each provides. Oats are higher in fiber and thus fall at the bottom of the list in total digestible nutrients.

Rasmussen (125) in 1942 stated, in general wheat is superior to the other grains in feeding value. It can be used to good advantage for milking cows.

Henderson and Reeves (60) in 1953 gave this evaluation: Barley is an excellent feed for dairy cows. It can be substituted pound for pound for corn. Corn should usually be included in the dairy ration. Not only is it highly palatable, but it supplies a large amount of digestible nutrients economically.

Fries et al. (44) studied the protein requirement for milk production and they concluded that oats were an excellent feed for dairy cattle and when not too high in price should be used in the dairy cow's ration. Oats are bulky,

palatable, and higher in protein than corn. They also found that wheat may be substituted for corn in the dairy ration pound for pound when the price permits.

Fitch and Gullickson (39) in 1938 evaluated cereal grains for dairy cattle feeding as follows:

Corn is especially palatable and is a splendid feed for the cow in milk. The protein content is low; likewise the mineral matter especially calcium. If corn is fed with timothy hay or corn silage, the protein content is entirely too low. Corn silage and ground corn, combined with legume hay, make a good ration for general feeding.

Oats are excellent feed for dairy cows and growing animals, having a feed value almost equal to bran. Oats contain a fair amount of protein but not enough to be effective in making up a deficiency in this constituent in the ration. The by-products from oats are mostly from oatmeal factories and consist of oat shorts, fine parts of the grain, and hulls, now called oat feed. The hulls are largely crude fiber and are about equal to oat straw in feed value. Sometimes oat hulls are used in cheap mixed feeds that are put on the market.

Barley is a valuable feed for dairy cows. Barley is practically equal to corn pound for pound. It contains considerably more protein than corn. Its use as a feed for dairy cows is increasing.

Wheat is generally fed to dairy cows in the form of one of its by-products. Its value lies not alone in its protein content, which is only medium, but it also is a rich source of phosphorus.

Henderson and coworkers (59) concluded that oats are an excellent feed for dairy cattle. They are bulky, palatable, and fairly high in protein and mineral matter and when cost permits should be fed. Oats vary greatly in composition and should be purchased on guaranteed analysis.

Role of the Rumen

Huffman (66) in 1948 stated, the rumen is often looked upon as a store-house for roughage or a place for digestion to take place. Actually, digestion and synthesis are taking place simultaneously. A few of the dietary factors synthesized in the rumen are vitamin K, thiamine, riboflavin, niacin, pantothenic acid, biotin, fat, carbohydrates (starch-like compounds), protein from nonprotein nitrogen and unknown dietary factors. The reason that cows milk is always a good source of most of the members of the vitamin B complex, regardless of the ration fed, is that they are synthesized in the rumen.

The results of Huffman and co-workers (70, 73) support the modern concept of a balanced ration and illustrate some

of the imperfections in both the calculated net-energy and starch equivalent concepts as scientific methods of feed evaluation. Their findings gave further support to the contention that grain supplies unidentified factor(s) needed by some hays for more efficient milk production. This was true also when corn replaced immature hay on an equal total digestible nutrient basis. (74, 69).

The work of Davis and associates (27) in 1953, at Cornell, reported four years of experimentation with 35 cows. They replaced part of the total digestible nutrients in roughage with corn or distillers grains. They concur with the findings of Huffman et al. (70, 73).

Corn as a Replacement Supplement to Alfalfa Hay

Huffman and Duncan (69) in 1949 reported the results of 15 trials, using 12 cows fed 11 hays from eight crop years, in replacement of a part of the alfalfa with corn on an equal total digestible nutrient basis. The replacement always resulted in an increase in 4 percent fat-corrected milk.

The possibility that this milk production increase caused by corn is a rumen phenomenon was suggested in 1931 by Forbes and his co-workers (42).

Loosli and associates (91) in 1955 found a consistant increase in milk production when concentrates were used to

replace part of the total digestible nutrients in hay. They felt that stored energy in the individual animals was not accurately considered in obtaining these results.

Huffman and Duncan (71) in 1954, while studying the nutritive value of corn silage for milk cows, showed conclusively again that corn (the grain in the corn silage) contributes the unidentified grain factor(s) needed to balance the total digestible nutrients in roughage.

Beach (10), Carroll (24), Fairchild and Wilbur (38), Hills (61), and Archibald and Parsons (1), and Teichman et al. (140) have reported experimental evidence in agreement with Huffman and Duncan (71).

Burroughs et al. (21) in 1951 investigated the influence upon cellulose digestion by rumen microorganisms by concentrates. They found that corn and wheat bran were two of the feeds that influenced cellulose digestion favorably.

Gall and associates (46) in 1949 studied the rumen content of 21 cattle and 12 sheep on practical winter rations and 11 cattle and six sheep on pasture. Cultural results from both species on all rations presented a rather uniform pattern in many respects. There was a noticeable increase in fast-growing organisms correlated with an increase in the amount of grain in the ration.

Bortree and co-workers (16) in 1948 made estimates of the bacterial populations of the rumen contents of cattle on various types of rations. Four rumen fistula animals were used. Samples were taken from three of the animals while they were being fed hay alone, hay and dextrose and pasture alone. The fourth animal received two pounds of hay and six pounds of concentrate per day. When methionine was added to a ration made up of corn, starch, glucose, and minerals, there was a marked difference in the physical condition of the rumen contents and a change in type of iodine staining organisms present. The addition of grain or a readily fermentable carbohydrate to a hay ration decreased the time required to reach the peak in the bacterial populations in the rumen.

Powell (122) in 1938 of the Ralston Purina Company at St. Louis, concluded from research results that there is a definite correlation between rumen activities and the milk the cow produces.

Saarinen and co-workers (130) in 1951 in ten trials replaced part of an all hay ration with corn and found no changes in milk production on the basis of net energy intake. They indicated, however, the possibility that the hays used in the investigation were not deficient in the factor(s) reported by Huffman and associates (70, 73, 74).

Absorption from the Rumen

Rankin and Dukes (124) in 1942 found in ten experiments with two rumen fistula sheep when dextrose was placed in the posterior ventral sac of the rumen a marked rise in blood sugar level resulted. The increases over the level at the time of administration varied from 34 percent to more than 400 percent.

Other experiments revealed that potassium iodide, strychnine, and sodium cyanide can all pass through the mucosa of the rumen. These experiments indicate the rumen is an organ of absorption.

Morrison (110) concluded that recent studies show that some absorption of soluble nutrients, such as organic acids, can take place from the stomach of ruminants.

Schaefer (133) in 1947 found that adult ruminants are not as specific in their protein requirements as the single stomach or monogastric animals. The calf, in early life, is like the non-ruminants in that the rumen is undeveloped; hence it requires a better-quality protein.

Roughage Quality and Quantity in the Dairy Ration

The fundamental problem of ruminant nutrition is to enhance the ability of cattle to utilize coarse feed, Huffman (67) in 1953.

Meigs (102) in 1933 reported on 10 years of work to determine the effects of different kinds of hay on the performance of cows. They kept their cows entirely off pasture and found when cows were fed high quality hay they maintained their health, milk yield and reproductive capacity up to more than seven years. When the hay fed was of low quality, the milk yield was reduced, health and reproductive capacity was very seriously interfered with. The grain mixtures fed along with the hay was a mixture of corn, wheat, and soybean and/or linseed.

McIntyre and Ragsdale (98) in 1945 of Missouri reported the results of feeding cows roughage alone for milk production. Cows produced 85 percent as much milk and 80 percent as much fat as cows on a full grain ration.

Bowstead (19) in 1956 at the University of Alberta in reviewing the results of experimental work at their experiment station on care and feeding of dairy cattle from 1921 to 1956 concluded, when alfalfa is fed, high priced protein supplements are not required.

Logan (88) in 1954 compared alfalfa hay harvested at bud stage vs. alfalfa hay in full bloom for milk production. Significantly greater milk yields were obtained from cows fed the less mature roughage.

Monroe et al. (106) in 1939 conducted three feeding trials in which hay crop silage was compared with legume hay and corn silage. It was shown that hay crop silage may be satisfactorily fed to replace hay. Such feeding may be continued for the winter feeding period without ill effect to the cows.

Huffman (65) in 1939 stated that most cows will consume about three pounds of hay equivalent per 100 pounds of body weight which is a 50 percent in roughage consumption over the old thumb rule.

Protein - Carbohydrates - Fats

Proteins in the feed are organic compounds that contain nitrogen. Cows use the proteins of their feed to form the proteins in the milk, meat, blood, and other body tissues. Proteins make up 17 to 18 percent of the body of a mature cow and 27 percent of the solids of milk. Young pasture plants, legume hays, and feeds obtained from oil-bearing seeds, as cottonseed meal, are examples of feeds that are relatively rich in this constituent. Protein cannot be replaced by any other feed constituent to form animal proteins, but it can take the place of carbohydrates and fats for the formation of animal fat and as a source of energy.

The carbohydrates of feeds include starches and sugars and are included in the nitrogen-free extract in the analyses

of feeds for chemical composition--and crude fiber. Carbohydrates make up the greater part of feeds from plant sources.

Carbohydrates provide body energy. All of them can be converted into body fat, milk fat, and milk sugar. Starches and sugars as a rule are digested more readily and more completely than crude fiber. For that reason they are more valuable than crude fiber. A high content of crude fiber in a feed is usually associated with low feeding value.

All fats and fat-like substances are soluble in ether and certain other solvents. Therefore in analyzing feeding stuffs, the sample of feed is extracted with ether, and all the substances thus dissolved are included under the classification of fat, or ether extract. The term lipids is often used for the entire group of fats.

Fats are used much like carbohydrates in the cow's body, but they have an energy value 2.25 times as great as carbohydrates. The cow can build fats from carbohydrates in her body. Johnson and associates (77) in 1948 found that fats in ordinary farm grains were plentiful enough for the dairy cow's ration.

It is fortunate in dairy cattle nutrition that the protein in the legumes in hay and hay crop silage help to correct the deficiencies of the proteins of the cereal grains.

Hart and Humphrey (52) in 1919 showed that it is impossible to furnish dairy cows of high milk producing ability

with a sufficiently high protein level while feeding cereal grains as supplements to a clover-hay-corn silage roughage program. The protein needs of low producing cows were adequately supplied. One cow produced 22.2 pounds of milk daily for 16 weeks on such a ration. The cereal grain--clover, hay, and corn silage ration provided for this cow a sufficient supply of protein.

Hart and Humphrey (52) with the knowledge available in 1919 concluded that a safe procedure for maintaining high milk production was through the use of a high level of protein intake.

Monroe (105) in 1924 reported on a comparison of the metabolism of calcium, magnesium, phosphorus, and sulfur in dairy cows fed high and low protein rations. The magnesium, sulphur, and nitrogen balances of the high protein fed cows showed no marked difference from the corresponding balances of the low protein fed cows.

Forbes and Swift (41) conducted trials from 1916-1922 on the efficiency of the utilization of protein in milk production as indicated by nitrogen-balance experiments. The four series of balances demonstrated that when requirements were exceeded, if less nitrogen had been fed the efficiency of utilization would have been higher.

Bartlett *et al.* (8) in 1940 in England conducted a large scale experiment using 500 cows. They fed one half of the

cows 0.6 pounds of protein equivalent per 10 pounds of milk produced and the other half a production ration using the same feeds, ground nut cake, corn meal, wheat offals, and molasses, supplying only two-thirds this amount of protein. They found no difference in milk production during 20 weeks of winter feeding; however, during the pasture season that followed the cows on the low protein ration produced a significantly greater amount of milk.

This experiment was repeated the following winter and confirmatory results were obtained.

Perkins (120) in 1935 compared rations with nutritive ratios of 1:2 and 1:13 and others less extreme over extended periods and found:

In the 1:2 ration the amount of protein supplied was six times the protein content of the milk. The milk production was less than would normally be expected from these cows on ordinary feeding. There was no evidence that the ration was injurious to the cows.

On the ration with the nutritive ratio of 1:13 there occured over long periods practically 100 percent conversion of feed protein to milk protein. Production on this ration was on a lower plane and the cows were thinner in flesh but maintained their liveweight from year to year and remained in apparent health and produced normal well developed calves.

Clearly, the dairy cow has a remarkably wide degree of tolerance with respect to the protein content of her ration.

Perkins and Monroe (119) in 1925 continued an investigation previously reported (118). They conducted a metabolism experiment on four Holstein cows to determine the apparent digestibility of low protein rations by dairy cows and found:

No marked difference in the digestibility of a very low protein ration between cows long accustomed to the ration and others recently transferred from a ration containing a liberal supply of protein.

Krauss (84) in 1943 of Ohio reported trials involving 128 cows for 100-110 day periods. They found no difference in milk production at various fat levels in the ration ranging from 2.7 percent to 4.9 percent and concluded that no need exists for raising the fat percentage of the grain mixture making up the usual dairy feeds.

Fries et al. (44) in 1924 in an experiment set up to determine the results of just meeting the protein requirements as compared to feeding well over the requirement level concluded: There is, with the cow, a prominent inclination to produce milk at an individual rate which is determined by inheritance.

A number of investigators (23, 30, 50, 51, 56, 57, 78, 126, and 136) have shown that milk production on alfalfa hay alone varies from 50 to 85 percent of that on alfalfa hay supplemented with grain, with the actual production depending on the level of grain feeding and the ability of the cow.

Smith and co-workers (137) in 1945 found that the replacement of 13 to 25 percent of the total digestible nutrients in an all alfalfa hay ration with grain allowed cows to produce at a normal level.

There were indications that this increased milk flow with concentrate feeding was due to improved quality in the protein.

Ritzman and Colovus (128) in 1943 studied the physiological requirements and utilization of protein and energy by growing dairy cattle. They found the biological value of protein depends not only on the character of its nitrogenous constituents, or on the level of the protein intake, but also on the physiological adaptability of the individual animal to utilize it.

Vitamins

The term "vitamin" is a group name for certain substances other than proteins, fats, carbohydrates, and minerals which have been discovered to be necessary in animal nutrition.

These vitamins occur in minute quantities in natural food materials. Those studied have been named A, B, C, D, E, G, and K. Vitamin G is often called riboflavin or B_2. The vitamins were formerly recognized solely by their physiological effects. Now they are known to be definite feed constituents. They are essential to the life and health of animals. (77, 110).

Wegner et al. (149) in 1940 found that a rumen fistula heifer had the ability to synthesize significant amount of thiamin, riboflavin, nicotinic acid, pyridoxine, panothenic acid and biotin when fed a ration very low in these compounds.

Hunt (75) and co-workers in 1943 conducted experiments on riboflavin and thiamin in the rumen content of cattle and showed that riboflavin was synthesized in the rumen when a ration of corn, alfalfa hay, and a protein supplement were fed. When corn was omitted from this ration there was no apparent synthesis of riboflavin.

McElroy and Gross (94) in 1940 studied rumen action in sheep and cows and found conclusive evidence of riboflavin and vitamin K synthesis in the rumen. In a second study (95) they found evidence of the synthesis of vitamin B_6 (pyridoxine).

Rumen synthesis of thiamin in large amounts has been demonstrated by McElroy et al. (96) and Wegner et al. (149).

Yet there is no clear evidence to show this source of supply is adequate. It has been reported by Sure and Beach (138) that lactation increases the thiamin requirement of the rat enormously. In view of the role which thiamin plays in the metabolism of carbohydrates (2, 6), there is evidence that this vitamin also plays a role in the synthesis of fats from carbohydrates (89, 96, 97).

Loosli and Lucas (90) studied the effect of a low thiamin supplement upon milk and fat production in a double reversal trial using four cows of medium production on a low fat diet. No effect upon the production of milk or fat was observed.

In experiments to show the apparent vitamin A requirements of cows, Hilton (62), Wilbur (150), Hauge et al. (55) found that cows can utilize the carotene of alfalfa as isolated carotene (in oil).

Walsh and Haugh (147) found that the carotene in green forage was rapidly destroyed in the field curing of hay.

Summer sunshine was an effective source of vitamin D for dairy cows in a study by Wallis (145) at South Dakota. Cows were depleted of vitamin D by placing them on a vitamin D deficient ration. The physical condition and appetite

of the cows were improved within two weeks after sunshine exposure. The calcium and phosphorus balances shifted from negative to strongly positive within two weeks of exposure to sunlight.

Wallis (146) found that dairy cows are not dependent upon a food source of vitamin C. Cows maintained up to three and four years on an experimental ration low in vitamin C showed a concentration of this factor in the blood plasma and milk equal to or higher than cows receiving higher amounts on normal herd rations.

Lachat and Palmer (86) in 1935 compared the rachitogenic effect of cereal grains, especially oats. They concluded this effect to be due to the varying vitamin content. Rolled oats and yellow corn were found to be rachitogenic to both rats and chicks.

Minerals for Dairy Cows

Woodward and Nystrom (154) in 1940 with co-workers of the United States Department of Agriculture summarized the role of minerals in the dairy cows' rations.

Minerals make up about 4 percent of the weight of the cow (exclusive of the contents of the digestive tract), and 78 percent of these minerals occur in the bones. Minerals are also present in more or less abundance in all tissues of the animal body, in the digestive juices, and in excretions

and secretions. They exert an important influence on many of the physiological processes and are as necessary as the other constituents of the ration. In the milking cow they are used mostly to provide the minerals of milk, and to a lesser extent for the development of the fetus.

Mitchell (103) classifies the functions of mineral nutrients under four headings:

1. They contribute to the structure of the body. Calcium, magnesium, and phosphorus are important constituents of bone. This is a growth requirement.
2. They aid in maintaining the status quo of the tissues already formed against the constant erosion of life processes. This is a maintenance requirement.
3. They participate in the functional activities of the body, such as muscular activity. Reproduction and production will increase mineral requirements in proportion to the mineral content of the products formed.
4. As integral parts of the enzyme systems in the tissues, they aid materially in metabolizing the organic food nutrients making up the bulk of farm rations.

A large number of mineral feeding experiments with dairy cows have been conducted with results varying in different geographical areas.

Calcium

Calcium is the major mineral element in respect to quantity contained in the bodies of milk cows according to Bohstedt (15).

Reed and Huffman (127) in a five year experiment with different proportions of calcium in dairy rations found a ration having 0.28 percent calcium on the air dry basis, adequate for normal growth, good reproduction, and a liberal milk flow.

Hart et al. (54) in 1932 reported an experiment of five years duration involving 22 cattle in two lots. They found about 0.20 percent calcium in the ration on the dry basis between pasture seasons permitted good health, and in so far as the calcium question was uncomplicated by infection, permitted successful reproduction.

Fitch and co-workers (40) in 1932 were able to reduce the calcium to 18 percent of the entire ration on a dry matter basis while obtaining good results in respect to reproduction and milk production.

To further consider the question of vitamins and availability of minerals, Palmer and co-workers (117) in 1935 withheld the vitamin supplements and further reduced the calcium content of the ration to 0.12 percent on the air dry basis. They reported no abortions due to this low level of calcium

during one or two succeeding gestations; nor, did this ration appear to have any effect upon milk production.

According to Kellner (82) in 1926 the calcium content of milk seems to be independent of the calcium level of the ration. Milk secretion draws on the calcium reserves of the body and apparently ceases when the available material for it gives out.

Bohstedt's (15) work with the very low level of 0.12 percent calcium in the ration of mature cows reveals a surprising adaptability by cows to a calcium deficiency ration. A level of 0.18 percent nevertheless is reassuring. The margin of safety in commonly used rations may be adequate with average or better quality roughage.

Phosphorus

Deficiencies of phosphorus among ruminants out number deficiencies of calcium.

Theiler et al. (141) in 1924 solved in a rather dramatic way the cause of bovine botulism, by tracing this pathogenic disease to a deficiency of phosphorus in range feeding.

Subsequently, a number of phosphorus-deficient areas have been identified in the states of Florida (11), Texas (135), Wisconsin (53), Minnesota (34), Pennsylvania (43), and parts of other states.

Where cattle subsist mainly or entirely on roughages, a depraved appetite is often prevalent unless grain, particularly protein concentrates, raises the phosphorus level in the ration.

Huffman and associates (72) in 1933, after extensive feeding experiments with various dairy rations supplemented and unsupplemented with phosphorus compounds, recommended that milking cows be provided with 10 grams of phosphorus (the Kellner standard) in their ration for every 1000 pounds of body weight. For every pound of milk produced add 0.75 grams of phosphorus to their ration and that 17 grams of phosphorus should be fed during low production and during the dry period. This amount of phosphorus would be amply supplied by common rations that are recognized as satisfactory, such as the rations for milking cows which have 0.26 or 0.27 percent phosphorus on the air dry basis. Thus, a 1200 pound cow giving 30 pounds of milk daily would need about 0.24 percent of phosphorus in her ration. A 1200 pound cow producing 60 pounds of milk needs 0.30 percent of phosphorus in her ration on an air dry basis.

An uncomplicated phosphorus deficiency was brought on by Eckles and co-workers (35) in 1935 by feeding a ration of prairie hay which contained only 0.07 percent phosphorus.

A phosphorus and protein deficiency may be combined according to Kellner (82). Uncomplicated phosphorus deficiency

has delayed sexual maturity and repressed estrum but has not prevented ovulation and conception. The combined deficiency did not prevent normal vigor in new-born calves, though the dams were undersized and emaciated in appearance.

Calcium-Phosphorus Relationship in Dairy Cattle

Because they are normally exposed to sunlight and/or are fed some sun cured roughage, dairy cattle do not require a rigid calcium-phosphorus ratio in their rations. According to Kuhlman and Gallup (85) in 1942, it is necessary that either of the two minerals be present in at least minimum necessary amounts, then the body metabolism within rather wide limits takes care of the surplus amount of the other element. Nevertheless it has been suggested that from 1-2 parts of calcium to every one part of phosphorus is the desirable relationship. Ca:P ratios as extreme as 4:1 have been fed to both growing, Dutoit et al. (33), and mature cattle, Huffman and co-workers (72) with apparent success. Alfalfa hay thus has a ratio of about 7:1. Feeding alfalfa hay alone sets a rather low limit for milk production according to Headley (58), unless the cows are fed bonemeal or other sources of phosphorus (61, 62). The feeding of most any grain or concentrate with alfalfa would narrow the ratio. In mineral balance studies at Vermont by Ellenberger (36) one group of cows was fed large amounts of calcium; another

group was fed on a ration with a negative calcium balance. There was no interference in the utilization of phosphorus.

Mitchell and McClure (104) computed the percentages of calcium and phosphorus of the dry ration requirements for young Holstein cows. They found that a 1200 pound Holstein requires 5.4 grams per day of feed calcium with a necessary percentage of calcium of 0.08 percent. The feed phosphorus requirement was 10.9 grams with a necessary phosphorus percentage of 0.16 percent in the dry ration.

Colovus et al. (25) conducted experiments in 1952 and again in 1953. The results showed that the feeding of 100 grams of ground limestone daily reduced protein digestibility by 6-8 percent. Fifty grams showed no detrimental effect.

Other Minerals

Salt is used almost universally in dairy cattle rations, and its importance has been long recognized. The need for salt was emphasized by Babcock (4) over 50 years ago. Salt was withheld from one-half of a dairy herd with the result that in time these animals presented a striking adverse contrast to the remainder of the herd. Babcock's recommendation for feeding salt was to allow 0.75 ounce of salt daily per 1000 pounds of body weight and in addition 0.3 ounce for every 10 pounds of milk produced.

Records kept of salt consumption of individual cows have shown great differences according to Cooper (26), and he suggested that the need for salt varies with the individual cow. In areas where "big neck" calves have occasionally been born, iodine in some form should be fed (110).

Copper and iron deficiencies in cattle were discovered in Florida by Becker (12) in 1940 where cattle subsisted on forage grown on sandy soil which was low in organic matter. Such occurrences may be found elsewhere but need not prompt the adding of iron and copper to the rations of dairy cattle.

Cobalt-deficient areas were reported in Michigan (7) and identified as due to a low level of cobalt in roughages grown in some areas bordering Lake Michigan and Lake Huron. Cobalt-deficient regions were also identified along the coastal plains from Texas to the Carolinas including Florida (111), in Wisconsin (49), in Australia (87, 93, 144), in New Zealand (3), and in Scotland (32).

Unthriftiness and emaciation were reported as common symptoms of cobalt-deficient herds. Throughout the United States cobalt therapy patterned after that followed in Michigan (7) was generally recommended, that is one ounce of cobalt sulfate or chloride per 100 pounds of salt or its equivalent with the use of salt-cobalt mixture constituting one percent of the grain ration.

Ely and co-workers (37) studied the approximate level of cobalt that will produce toxic symptoms in dairy calves. They found equivalent amounts of cobalt fed as the sulfate, chloride, or carbonate were equally toxic. Cobalt fed in excess of 40 mg. daily per 100 pounds of body weight produced toxic effects in calves.

The results of Keener and associates (81) in their study of cobalt tolerance in young cattle are in agreement with the findings of Ely and his co-workers.

According to Garner (47) magnesium is not made available by the action of the gastric juice of ruminants but is liberated from vegetable cells by the ruminal organisms. Free magnesium does not exist in the alkaline rumen but becomes available by the action of the abomasal hydrochloric acid.

Magnesium in sub-normal amount in relation to other mineral elements seems to play a part in grass tetany according to Bohstedt (15).

Great variation in the manganese content of feeds in Michigan was noted by Schaible and co-workers (134) working on poultry nutrition. It has been appreciated that manganese plays a role in reproduction.

General Consideration

The widespread acceptance of the use of mineral supplements in dairy cattle feeding has provided insurance against mineral deficiencies.

The ability of the dairy cow to store calcium and phosphorus in her skeleton against the day of need for milk production is equally reassuring to patrons of dairy cattle nutrition.

Free choice to a supplemental mineral supply for dairy cows is advisable in a box protected from the weather either in the yard or pasture.

Bentley and Phillips (13) studying the effect of low manganese rations upon dairy cattle found that low dietary manganese caused abnormal structural changes in the livers of the cattle subsisting thereon. They concluded under practical conditions it would seem the addition of supplemental manganese to cattle rations would be indicated where the manganese was below 20 ppm. in the ration.

Gessert and co-workers (48) in 1952 found that a practical dairy ration had lower concentrations of trace minerals in their tissues and organs than cattle which received a similar ration supplemented with trace minerals (copper, zinc, cobalt, and manganese) in abundant amounts.

Simple vs. Complex Rations

Oats vs. oats and barley were compared in 1909 at Ontario Agricultural College (113). Two experiments were conducted. In experiment No. 1, cows were fed oats alone vs. a mixture of two parts oats and one part barley. In experiment No. 2, the cows were fed oats vs. a mixture of equal parts of oats and barley. Results indicated that oats alone produced equal results when compared to the two grain mixtures.

Oats were compared to wheat bran, by research workers at Ontario Agricultural College (114) as a supplement to roughage for dairy cows. The cows on the oats ration produced five percent more milk than cows fed wheat bran.

At the Indian Head, Saskatchewan experiment station, research workers in 1936 (76) compared oats, wheat, and barley as supplements to roughage over a five-year period (1931 to 1936). Barley, oats, and wheat were found to be equal for milk and butterfat production.

McQueen (101) in 1915 compared wheat, barley, and oats for milk production. In four of the six instances cows fed barley and two instances cows fed oats produced milk at the lowest cost.

McCollum (99) in 1922 after studying the supplementary value of various cereal grains along with alfalfa leaves made

the following observations. Among the grains studied, the oat kernel is the best supplement to the alfalfa leaf. A simple mixture, 60 percent rolled oats and 40 percent alfalfa leaf, induces in the rat nearly normal growth to the full adult size. Animals grown on this diet have shown moderate fertility and fair success in the rearing of young. However, they were not nourished in the optimal manner, for they fell considerably below the maximum capacity of well-nourished animals in respect to fertility and successful rearing of young.

McCollum et al. (100) in 1917 found that some females would not reproduce when fed on a ration made up of 80 percent oat meal and 20 percent alfalfa. They also found that in every case where the young could be reared to weaning, or to the point where they could eat food, they made much more rapid growth than they did when taking the mother rats milk. At the time this work was carried on, results would indicate the corn plant to be more efficient in non-ruminant nutrition as compared to oats.

In a study of simple home-grown cereal grain rations for dairy cows Bowling (17) in 1930 found ground oats, alfalfa leaf meal, alfalfa hay, and corn silage as efficient in supplying protein to three high producing cows as a more complex ration made up of alfalfa hay, corn silage, corn, oats, wheat, bran, linseed oil meal and cottonseed meal.

Davis (28) and associates in 1953 investigated the effect of the texture of crimped vs. ground oats on digestibility. Although the course texture gave slightly higher digestion coefficients, the difference was not significant.

Home grown cereal grains were compared to supplementary concentrates such as bran and oilcake by Canadian workers (79, 80, 131, 132) as supplements to roughage. No differences in milk production nor in maintaining body weight were noted.

Byers et al. (22) in 1955 found that cows fed on an all corn diet of shelled corn and corn silage produced more milk when this ration was supplemented with alfalfa hay or 3.5 percent urea.

Dowe et al. (31) in 1955 conducted 28 digestion trials to study the apparent digestibility of the dry matter, crude protein, crude fiber, ether extract, and nitrogen-free extract of rations containing the following ratios of corn to alfalfa hay: 1:1, 2:1, 3:1, 4:1, and 5:1. The differences in apparent digestibility of the nutrients between ratios were not significant.

Rupel et al. (129) in 1941 showed the adequacy of corn and oats for growth in dairy heifers. The rate of growth was not improved by the addition of bonemeal or wheat bran.

Huffman and Duncan (68, 69) reported the nutritive value of an alfalfa hay ration when corn and wheat were fed as

supplements. The results of their experiments indicated that digestible calories are not the limiting factors in alfalfa hay for optimum milk production but that an unknown milk-stimulating factor or factors are supplied by corn or wheat.

Turk and co-workers (143) in 1915 observed that the biological value of the protein in alfalfa hay was 50 when the hay was fed to lambs whereas the biological value increased to 72 when the hay was supplemented with corn.

Dawson and co-workers (29) in 1944 conducted experiments comparing single grains and grain mixtures as supplements to alfalfa hay and silage for milk production. The results obtained over lactation periods of 365 days were in agreement with those found in the three experiments, a part of this thesis.

The cows (29) receiving the single-grain ration had somewhat better breeding records during the experiment, gained more weight, and produced 95 percent as much butterfat as the cows on mixed-grain rations. The differences were not significant.

This experiment also shows that where cows have an opportunity to consume as much good hay and silage as they like, it makes little difference whether the additional nutrients they require are obtained from a single grain or a mixture of several grains and/or grain by-products.

Canadian researchers (20) at the Brandon-Manitoba experiment station in 1930 studied the value of barley in the grain ration for dairy cows and found that ground barley was equal to oats for milk production.

Workers at Ontario Agricultural College in 1933 (116) found that grain rations containing two and three parts by weight of barley produced more milk than a grain ration containing seven parts by weight of barley. The cows on the seven parts by weight of barley were easily thrown off feed.

Graves et al. (51) in 1940, using 12 Holstein cows, fed them on four different rations in four lactation periods on four different planes of feeding. The four rations were: number one--a mixture of two parts of barley, one part oats, one part bran, and alfalfa hay, corn silage, and pasture in season; number two--alfalfa hay alone or pasture in season; number three--ground barley, one pound to 6.03 pounds of milk, and alfalfa hay alone or pasture; and number four--alfalfa hay and pasture with corn silage. The barley rations produced 86.03 percent and 80.24 percent as much milk as number one, the full-grain ration.

Willard (153) in 1940 compared barley as a supplement to alfalfa hay and pasture, to alfalfa and pasture only for milking cows. From two to 12 pounds of barley per head was found to have little effect upon lowering the hay consumption.

When Holstein cows had a daily capacity of 30 to 40 pounds of milk at their peak, there was little increase in production when barley was fed with good hay and pasture. Cows with greater capacities at peak production benefitted proportionally from the barley feeding.

True and co-workers (142) concluded that the practice of feeding barley to cows to supplement alfalfa hay was economically sound and should be recommended.

Watson et al. (148) in 1949 reported the effect of the plane of nutrition on the digestibility of barley as the result of their studies with ruminants. Digestive trials were carried out with six grade Shorthorn steers. They were 1½-2 years old and weighed an average of 430 kilograms throughout the experiment. Various rations were made up by feeding barley at 1, 2, 3, 4, and 5 kg. per day along with an average of 7 kg. of hay per day. The hay was fed at approximately maintenance level. It was found that as the plane of nutrition increased, the digestibility of the barley decreased.

In experimental work conducted in 1923 Berg (14) found that barley as the sole protein was incapable of maintaining growth in chickens and rats. Normal growth on a 16 to 17 percent protein ration was secured.

Monroe and associates (107, 108, 109) compared simple and complex grain mixtures in dairy rations that were fed

continuously for 4½ years. The two grain rations were designed to be theoretically equal in feeding value. Both mixtures contained corn, oats, and soybean meal. In addition, the complex mixture also contained wheat bran and linseed meal which reduced the amount of corn. The roughage consisted of legume-mixed hay and corn silage. During the pasture season the cows were pastured on improved bluegrass and legume meadows. The rate of grain feeding was one pound of grain for every three pounds of milk produced in excess of 20 pounds.

Over a period of years they concluded, a simple grain mixture containing corn, oats, and soybean oil meal may be fed to dairy cows as satisfactorily as a more complex mixture provided a program of feeding liberal amounts of high quality roughage is followed.

Supplemental salt and phosphorus must be supplied to the cows under this system.

Horwood (63) in 1931 and Horwood and Wells (64) in 1936 reported the results of two trials with high-producing cows where simple home grown rations were compared with complex rations.

In the first trial, conducted during the winter of 1933-34, a simple ration consisting of mixed hay (50 percent alfalfa and 50 percent grass) and ground corn was compared

with a complex ration consisting of mixed hay, sunflower silage, roots, and a grain mixture consisting of 500 pounds of ground corn and 100 pounds of cottonseed meal.

In the second trial, conducted during the winter of 1934-35, a simple ration consisting of alfalfa hay and ground barley was compared with a complex ration consisting of alfalfa hay, roots, and a grain mixture consisting of 1,000 pounds ground barley and 100 pounds cottonseed meal.

During the first trial, the cows while receiving the complex ration produced 5.6 percent more 4 percent fat corrected milk than while receiving the simple ration. The cows, however, lost 206 pounds in weight while on the complex ration and gained 389 pounds while receiving the simple ration.

During the second trial the cows produced 12 percent more 4 percent fat corrected milk while receiving the complex ration. However, the cows gained 335 pounds in body weight while on the simple ration compared to a gain of 56 pounds while on the complex ration.

A summary of both trials shows that the cows consumed 414.5 pounds more digestible protein and 298.5 pounds less total digestible nutrients while receiving the complex ration. They produced 8.9 percent more 4 percent fat corrected milk while on the complex ration. The cows while on the

complex ration lost 150 pounds in body weight and gained 724 pounds while on the simple ration.

Norton and Savage (112) in 1944 reported eight investigations in which the value of ground whole grains were compared to concentrate mixtures for dairy cows. The results indicated that simple mixtures are practically equal to the more complex mixtures. Abrupt changes from one grain ration to another had no unfavorable effect on feed consumption. The rations proved equally palatable. Body weight essentially was unaffected by the different grain rations.

Bowstead (18) of the University of Alberta and researchers at Ontario Agricultural College (115) conducted experimental studies with wheat as a concentrate for dairy cows. They found that milk and butterfat production were maintained as well with wheat as with oats and barley. Their results were in agreement.

Wheat in surplus supply or when the price is favorable can be fed to dairy cattle with profit to the dairyman, states Bateman (9) in a report of the results of work carried on at the Utah Agricultural Experiment Station during the winter of 1933.

Four cows were fed chopped wheat according to production as the only grain in combination with alfalfa hay for one complete lactation period. Three of the cows were only

average producers, so at no time did they receive a large amount of grain. The other cow, E-47, produced 14,031 pounds of milk containing 430 pounds of butterfat during the lactation period of 343 days. During this period the total wheat consumption was 2,892 pounds. During the month of highest butterfat production E-47 consumed an average of 14 pounds of chopped wheat per day. At no time during the wheat feeding period did the cows refuse a significant amount of the chopped wheat offered. The condition of the cows was normal as far as could be determined and they showed excellent condition throughout their lactation periods.

Baker and Tomhave (5) in 1944 studied the intensity of feeding as related to milk production. They found the amount of milk produced for each pound of total digestible nutrients fed was greatest at the lowest feeding level. Five groups of Holstein cows were fed maintenance rations plus an allowance of total digestible nutrients for milk production at 82.2, 105.3, 122.4, and 131 percent of the Haecker standard, respectively.

Wiley and Neal (151, 152) in 1936-37 compared limited (1:6) and heavy (1:3) grain feeding with two groups of 7 Jersey cows each for 1048 days.

The light grain fed group consumed less grain and less roughage. The heavy grain fed (1:3) group produced more

milk and butterfat. The feed cost, on the limited fed group, per pound of butterfat and per hundred pounds of milk, was lower. The income over feed cost was slightly higher for the limited fed group.

Kitchen (83) at the New Jersey Experiment Station in 1950 using three groups of 10 cows each were fed as follows: Group one was fed on all roughage ration of U.S. No. 1 extra green leafy alfalfa hay and corn silage. Group two was fed from the same roughage and one pound of grain for each six pounds of four percent fat corrected milk produced. Group three was fed the roughage and one pound of grain for each three pounds of four percent milk. Using group three as 100 percent, the cows in group two produced 95 percent as much milk and those on roughage alone produced 85 percent as much milk as group three.

Peterson (121) in 1927 found that different cows respond in different ways to the same ration insofar as the influence of individual feeds upon the quantity and quality of milk. The response, whether an increase or decrease, was immediate with most cows, appearing in most cases within eight hours after the first feeding or change over to a particular feed.

Ragsdale and Turner (123) reported in 1923 that the effect of underfeeding should be taken into consideration in interpreting data on feeding trials of short duration.

The quantity of milk produced is reduced as a result of underfeeding, the amount of reduction depending on the length of the feeding period and the stage of lactation.

Summary and Discussion of Review of Literature

Research workers generally give support to the contention that grain supplies unidentified factor(s) needed by some hays for more efficient milk production.

The results of work reviewed show that there is a relationship between rumen activities and the amount of milk a cow produces.

Cows fed roughage alone produce up to 85 percent as much milk as cows on full grain feeding.

It is apparent that for milking cows receiving liberal amounts of high quality roughage, the use of simple grain rations can be expected to result in satisfactory milk production. This should allow for considerable flexibility in the composition of dairy cattle rations. More efficient use of the supply of grain available on the individual dairy farm can be made.

The dairyman that must purchase concentrates for dairy cattle feeding has a choice of ingredients according to the cost and the available supply.

OATS COMPARED TO A THREE CEREAL GRAIN MIXTURE

A single grain, oats (ground) was compared to a grain mixture of equal parts by weight of oats, wheat, and corn (ground) as a supplement to hay and hay crop silage for milk production in this experiment.

Experimental Procedure

The Cows

Two cow groups (I and II) of three registered Holstein cows each, comparable in age, body weight, milk production, and stage of lactation were used in this experiment.

Feeding

Both groups of cows were fed from the same supply of hay and hay crop silage. The daily roughage ration for each cow was 50 pounds of hay crop silage and 10 pounds barn-dried hay.

The rate of grain feeding was based upon production as shown in table 1.

Table 1--The Rate of Grain Feeding Was Based Upon Production as Follows:

Milk per milking in lbs.	Feed pounds grain--per feeding
5	-
10	½
15	2+
20	4+
25	6+
30	8+

Adjustments in amount of grain fed were made on or before the seventh day of each feeding period.

The rate of grain feeding presented in table 1 was based upon pre-trial calculations. Using the body weights and production recorded in table 2 and an analysis of roughage of similar botanical composition and maturity at harvest, the amount of grain fed was designed to supplement the daily roughage ration of 50 pounds of hay crop silage and 10 pounds of hay. The rate of grain feeding in table 1 was a minimum of one pound per day less than Morrison's recommendations table VIII at the 20, 30, 40, and 50 pound levels of daily milk.

A twice-a-day feeding schedule was followed, feeding all of the grain upon the silage in the morning and the hay

was fed alone in the evening. The silage and grain were fed at 8:00 A.M. and the hay at 3:30 P.M. daily. The unconsumed roughage was weighed back and recorded before each succeeding feeding. Special mangers were used to prevent feed loss.

Supplemental minerals were provided by adding two pounds of a mineral mixture to 98 pounds of the grain ration. The supplemental mineral mixture used contained three parts by weight of trace mineral salt, and one part by weight of steamed bonemeal with one-half ounce of cobalt carbonate added to each 100 pounds of this mineral mixture.

All hay, hay crop silage, and grain feedings were weighed and recorded for each cow. Feed not consumed was weighed back before each succeeding feeding.

Representative samples were taken of grain, hay, and hay crop silage once every three days. Individual samples for each period made up the composite sample used for chemical analysis and reported in table 3.

Exercise

The cows were kept in their stanchions for the duration of the trial except while being lead to the scales to be weighed every third day.

Bedding

A mixture of sawdust and shavings was used as bedding. This prevented the possibility of cows obtaining additional nutrients by eating their bedding.

Water

Water was available in drinking cups at all times.

Milking

The cows were milked twice each day at 6:00 A.M. and 4:00 P.M. The milk was weighed and samples for butterfat determinations were taken at each milking. Milk samples were preserved with corrosive sublimate, and butterfat tests were run every three days on three-day composite samples.

Cow Weights

Cows were weighed daily for three days prior to the beginning of the experiment. The mean weight was used as the base weight. The cows were weighed the second day of each three-day period at about the same time, 1:30 P.M.

Group Treatment

Two groups of cows were used in a four-period experiment with 21 days constituting each period. Group I cows were fed oats, hay, and hay crop silage during the first

and third periods. During the second and fourth periods, group I cows were fed the grain mixture (oats, wheat, and corn--equal parts by weight), hay crop silage, and hay.

Group II cows were fed the grain mixture (oats, wheat, and corn--equal parts by weight), hay, and hay crop silage during feeding periods one and three and were fed oats, hay, and hay crop silage during periods two and four, respectively. The data for the last 15 days in each period were used in calculating results.

This experiment was conducted at Michigan State University's Upper Peninsula Experiment Station, Chatham, Michigan, during the winter-barn season of 1954. The experiment started January 15 and continued for four 21-day periods through April 8.

Results and Discussion

Age, stage of lactation, milk production, and body weight for the two groups are presented in table 2. The two groups were balanced as comparable as possible.

Table 2--Age, Stage of Lactation, Milk Production and Body Weight of the Cows at the Start of the Experiment

Group No.	Cow (No.)	Age (Yrs.-Mos.)	In milk (Days)	Average daily milk production[1] (Lbs.)	Average base weight[2] (Lbs.)
I.....	24	7-10	53	44.2	1273
	86	3-10	273	28.7	1322
	109	2-4	34	40.3	1203
Average.....		4-8	120	37.7	1266
II.....	51	5-10	200	42.1	1401
	69	4-8	84	47.2	1363
	108	2-6	78	31.6	1039
Average.....		4-4	120	40.3	1267

(1) Average daily milk production Jan. 12, 13, 14, 1954.
(2) Average base weight Jan. 12-14, inclusive.

The chemical composition of the oats, grain mixture (oats, wheat, and corn--equal parts by weight), hay, and hay crop silage is presented in table 3.

Table 3--Chemical Compositon of Hay Crop Silage, Hay, Oats, and Grain Mixture as Fed(1)

Sample Number(2)	Ash	Crude fiber	Ether extract	H_2O	Protein	N-Free extract
	%	%	%	%	%	%
Silage No. 1	1.79	9.35	1.12	73.74	3.90	10.10
" " 2	1.62	8.17	1.12	75.36	3.61	10.12
" " 3	1.90	8.60	0.99	76.05	3.48	9.98
" " 4	1.67	7.78	1.05	76.42	3.56	9.52
Hay No. 1	4.41	32.56	1.68	7.32	7.13	46.90
" " 2	4.73	30.05	1.90	7.22	8.50	47.60
" " 3	4.33	32.09	2.27	6.29	8.25	46.77
" " 4	5.47	30.61	2.43	6.73	9.50	45.26
Oat grain No. 1	3.89	10.19	4.39	10.90	11.81	58.82
" " " 2	4.17	10.18	3.76	10.01	11.88	60.00
" " " 3	4.04	10.26	4.55	10.03	11.69	59.43
" " " 4	3.85	10.19	3.63	9.83	12.00	60.50
Mixed grain No. 1	3.59	4.50	2.95	11.05	10.44	60.47
" " " 2	3.90	4.09	3.02	10.56	10.38	68.05
" " " 3	4.08	4.41	3.01	9.55	10.94	68.01
" " " 4	3.81	5.11	3.06	10.45	10.81	66.76

(1) Chemical analyses of feeds were made by members of the Michigan State University Department of Agricultural Chemistry.

(2) Sample number also indicates period fed.

Fat-Corrected Milk

The total milk production on each ration and the total milk production for each cow for the four periods was corrected to a four percent butterfat basis by the following formula developed by Gaines and Davidson (45) in 1923:

0.4 x pounds of milk produced + 15 x the pounds of butterfat produced = pounds of 4 percent fat-corrected milk.

Hereafter 4 percent fat-corrected milk will be listed as 4 percent F.C.M.

Feed consumption, body weight at the start and end of the last 15 days of each feeding period for each group, and the production in 4 percent F.C.M. by feeding periods are listed in table 4.

Table 4--Feed Consumption, Body Weight,(1) and 4 Percent F.C.M. by Periods for the Two Groups of Cows.(2)

Group	Period	Grain Fed	Grain	Hay	Silage	Average Body Weight			4% F.C.M.
						Start	End	Diff.	
			(Lbs.)	(Lbs.)	(Lbs.)	(Lbs.)	(Lbs.)		(Lbs.)
I	1	Oats	502.5	421	2240	1246	1238	- 8	1686.5
	2	Mix	510.0	450	2250	1230	1231	+ 1	1469.9
	3	Oats	450.0	450	2250	1241	1237	- 4	1425.7
	4	Mix	420.0	450	2250	1225	1241	+16	1332.6
II	1	Mix	539.1	420	2242	1245	1238	- 7	1522.1
	2	Oats	510.0	450	2250	1263	1268	+ 5	1543.0
	3	Mix	495.0	450	2250	1267	1264	- 3	1470.0
	4	Oats	480.0	450	2250	1269	1270	+ 1	1438.0

Total Milk Production for 4 periods on Oats Ration	6093.2
Total Milk Production for 4 periods on Grain Mixture (Oats, Corn, and Wheat--Equal Parts by Weight	5794.6
Difference in favor of oats ration	298.6

(1) Average body weight at the start and end of the last 15 days of each feeding period.

(2) Data for the last 15 days were used in each period in the calculation of results.

During the first feeding period, Group I consumed 421 pounds of hay and 2,240 pounds of hay crop silage, while Group II cows consumed 420 pounds of hay and 2,242 pounds of hay crop silage.

During periods 2, 3, and 4, the hay and silage intake for Groups I and II were the same: 450 pounds of hay and 2,250 pounds of hay crop silage.

Except for the first feeding period, identical amounts of hay crop silage and hay were consumed by each group during each period.

Group I consumed 502.5 pounds of oats during the first feeding period, 510 pounds of grain mixture during the second feeding period, 450 pounds of oats in the third feeding period and 420 pounds of grain mixture during the fourth period.

Group II consumed 539.1 pounds of grain mixture during the first feeding period, 510 pounds of oats during the second feeding period, 495 pounds of grain mixture in the third period and 480 pounds of oats during the fourth period.

Integrated results for the two groups of cows reveal that during the four periods oats were fed, the cows consumed 1942.5 pounds of oats, 1771 pounds of hay and 8990 pounds of hay crop silage. During the four oats feeding periods, 6093.2 pounds of 4 percent F.C.M. were produced.

Integrated results for the two groups of cows show that during the four periods the grain mixture (oats, wheat, and corn--equal parts by weight) was fed, the cows consumed 1964.1 pounds of grain mixture, 1800 pounds of hay, and 8992 pounds of hay crop silage. During the four periods the cows were fed the grain mixture, 5794.6 pounds of 4 percent F.C.M. were produced.

Table 5 shows the average amount of digestible crude protein and total digestible nutrients required by each group of cows according to calculations, and also the amounts of protein and total nutrients in the feed consumed.

Table 5--Nutrients Required by the Cows on Each Ration and the Amount They Obtained from Their Feeds During the Last 15 Days of Each Feeding Period

Feeding Period(1)	DIGESTIBLE CRUDE PROTEIN		TOTAL DIGESTIBLE NUTRIENTS	
	Single Grain Oats	Mixture Oats-Wheat-Corn	Single Grain Oats	Mixture Oats-Wheat-Corn
Requirement(2)	(lbs.)	(lbs.)	(lbs.)	(lbs.)
Maintenance(3)	131.4	131.4	1674.0	1674.0
Production	249.8	237.6	1949.8	1854.3
Total	381.2	369.0	3623.8	3528.3
INTAKE FROM				
Hay	78.7	81.0	850.1	864.0
Hay Crop Silage	179.8	179.8	1438.4	1438.7
Grain	182.6	178.7	1361.7	1505.5
Total	441.1	438.9	3650.2	3808.2
Nutrient Intake in Excess of Requirements	+59.9	+69.9	+ 26.4	+279.9

(1) Data for the last 15 days were used in each period in the calculation of results.

(2) High level Morrison's T.D.N. requirements used; low protein requirement level, Morrison's used.

(3) Maintenance was figured at 1250 pound cow level.

(4) Feed analysis F.B. Morrison's, Feeds and Feeding, 22nd Edition, 1956, used as follows:

Oats (9.4% D.P. - 70.1% T.D.N.)
Corn (7% D.P. - 80% T.D.N.)
Wheat (11% D.P. - 77% T.D.N.)
Mixture (9.1% D.P. - 77% T.D.N.)
Hay (4.5% D.P. - 48% T.D.N.)
Hay Crop Silage (2% D.P. - 16% T.D.N.)

The results in table 5 show that in every feeding period the nutrients consumed were in excess of requirements.

Cows fed oats for the four periods produced 298.6 pounds more 4 percent F.C.M, that is five percent more milk than cows fed the grain mixture.

A general decline in milk production was noted during the experiment. It is likely that the decline was increased due to each cow group containing one cow well along in her lactation period. One cow in group 1 started the trial with 273 days in milk. One cow in group 2 started the trial with 200 days in milk.

No consistently significant difference in body weight changes or general health were noted within the groups or between the groups at any time.

Summary

A single grain, oats, was compared to a grain mixture of equal parts by weight of oats, wheat, and corn as a supplement to hay and hay crop silage for milk production. Two comparable groups of cows were used in an experiment of four 21-day periods.

Cows fed oats for the four periods produced 298.6 pounds more 4 percent F.C.M. for the 180 cow-days reported in this experiment. This represents five percent more milk

than was produced by the cows during the four periods the grain mixture was fed. An analysis of variance showed no significant difference in milk production.

No significant difference between oats and the grain mixture as affecting body weight, butterfat test, and general health was observed under the conditions of this experiment.

CORN COMPARED TO A THREE CEREAL GRAIN MIXTURE

A single grain, corn (ground), was compared to a grain mixture of equal parts by weight of oats, barley, and corn (ground) as a supplement to hay and hay crop silage for milk production in this experiment.

Experimental Procedure

The Cows

Two cow groups (I and II) of three registered Holstein cows each, comparable in age, body weight, milk production, and stage of lactation, were used in this experiment.

Feeding

Both groups of cows were fed from the same supply of hay and hay crop silage. The daily roughage ration for each cow was 50 pounds of hay crop silage and 10 pounds of chopped barn-dried hay.

The rate of grain feeding was based upon production as shown in table 1.

Adjustments in the amount of grain fed per cow were made at the end of the first week of each period. The rate of grain feeding was based upon cow body weights and milk production listed in table 6 and analyses of roughage comparable to the haycrop silage and hay supply fed. This rate of grain

feeding was planned to supplement the daily roughage ration of 50 pounds of hay crop silage and 10 pounds of hay. It was a minimum of one pound of grain per day less than Morrison's table VIIIa recommendation at the 20, 30, 40, and 50 pound levels of daily milk production.

Cows were fed twice daily. The grain was fed on the silage at 8:00 A.M. and the hay was fed at 3:00 P.M.

Unconsumed roughage was weighed back and recorded prior to each succeeding feeding. Special mangers were used to prevent feed loss.

A supplemental mineral mixture containing three parts of trace mineral salt and one part of steamed bonemeal to which one-half ounce of cobalt carbonate was added per 100 pounds was available in an individual box for each cow during the daytime.

All hay, hay crop silage, and grain feedings were weighed and recorded for each cow. Feed not consumed was weighed back and recorded.

Representative samples were taken of grain, hay, and hay crop silage once every three days. Individual samples for each period made up the composite sample used for chemical analysis and reported in table 7.

Exercise

The cows were kept in their stanchions for the duration of the trial except while being lead to the scales to be weighed every third day.

Bedding

A mixture of sawdust and shavings was used as bedding. This prevented the possibility of the cows obtaining additional nutrients by eating bedding.

Water

Water was available from individual drinking cups at all times.

Milking

Cows were milked twice each day, at 6:00 A.M. and 4:00 P.M.

The milk was weighed and samples for butterfat determinations were taken at each milking. Milk samples were preserved with corrosive sublimate, and butterfat tests were run every three days on the three-day composite samples.

Cow Weights

Cows were weighed daily for three days prior to the beginning of the experiment. The mean weight was used as the base weight. The cows were weighed the second day of each

three-day period during the experiment at about the same time, 1:30 P.M.

Group Treatment

Two groups of cows were used in a four-period experiment with 21 days constituting each period. Group I cows were fed corn, hay, and hay crop silage during the first and third periods. During the second and fourth periods, group I cows were fed the grain mixture (corn, oats, and barley--equal parts by weight), hay, and hay crop silage.

Group II cows were fed the grain mixture (corn, oats, and barley--equal parts by weight), hay, and hay crop silage during feeding periods one and three and were fed corn, hay, and hay crop silage during periods two and four, respectively. The data for the last 15 days in each feeding period were used in calculating results.

This experiment was conducted at Michigan State University's Upper Peninsula Experiment Station, Chatham, Michigan, during the winter-barn season of 1956. The experiment started January 16 and continued for four 21-day feeding periods through April 8, 1956.

Results and Discussion

Age, stage of lactation, milk production, and body weight for the two cow groups are presented in table 6. The two groups were balanced as comparable as possible.

Table 6--Age, Stage of Lactation, Milk Production, and Body Weight of the Cows at the Start of the Experiment

Group No.	Cow (No.)	Age (Yrs.-Mos.)	In milk (Days)	Average daily milk production(1) (Lbs.)	Average base weight(2) (Lbs.)
I.....	35	8-11	92	52.5	1198
	107	4-5	167	36.7	1306
	121	3-8	193	36.3	1187
Average.....		5-8	150	41.8	1230
II.....	71	6-6	199	28.8	1390
	118	4-0	179	37.0	1268
	119	3-9	120	46.3	1081
Average.....		5-4	166	37.4	1246

(1) Average daily milk production January 14, 15, 16, 1956.
(2) Base Weight (Average 3-day weight, January 14, 15, 16, 1956.

The chemical composition of the corn, grain mixture (corn, oats, and barley--equal parts by weight), hay, and hay crop silage is presented in table 7.

Table 7--Chemical Composition[1] of Hay Crop Silage, Hay, Corn, and Grain Mixture as Fed

Sample Number[2]		Ash	Crude fiber	Ether extract	H_2O	Protein	N-Free extract	Carotene	pH
		%	%	%	%	%	%	ppm	
Silage	IS	1.58	8.04	1.14	72.98	3.41	12.85	55.2	4.16
	IIS	1.85	8.42	1.10	71.60	3.54	13.49	59.0	4.09
	IIIS	1.70	7.86	1.17	72.99	3.61	12.67	53.3	4.06
	IVS	1.59	7.93	1.26	72.69	3.66	12.87	61.3	4.00
Hay	IH	3.95	30.30	1.68	13.57	7.02	43.48	--	--
	IIH	3.36	30.59	1.77	12.92	7.07	44.29	--	--
	IIIH	3.32	32.01	1.70	12.06	7.13	43.78	--	--
	IVH	3.78	30.90	1.45	13.14	6.59	44.14	--	--
Corn	IC	1.31	2.77	3.67	12.70	9.31	70.24	--	--
	IIC	1.34	3.01	3.77	11.66	9.88	70.34	--	--
	IIIC	1.34	2.98	3.76	12.46	9.56	69.90	--	--
	IVC	1.40	2.99	4.00	11.54	9.81	70.26	--	--
Mixture[3]	IM	1.77	6.37	3.01	11.95	11.13	65.77	--	--
	IIM	1.77	5.44	2.90	11.88	11.56	66.45	--	--
	IIIM	1.71	5.70	2.89	11.22	11.25	67.23	--	--
	IVM	1.77	5.91	3.21	12.61	11.19	65.31	--	--

(1) Chemical analyses of feeds were made by members of the Michigan State University Department of Agricultural Chemistry.
(2) Sample number indicates period fed.
(3) Corn, oats, and barley mixture.

Fat-Corrected Milk

The total milk production on each ration and the total milk production for each cow for the four periods was corrected to a four percent butterfat basis by following the formula developed by Gaines and Davidson (45) in 1923:

0.4 x pounds of milk produced + 15 x the pounds of butterfat produced = the pounds of 4 percent fat-corrected milk.

Hereafter 4 percent fat-corrected milk will be listed as 4 percent F.C.M.

Feed consumption, body weight at the start and end of the last 15 days of each period for each group and the production of 4 percent F.C.M. by feeding periods are listed in table 8.

Table 8--Feed Consumption, Body Weight, and 4 Percent F.C.M. by Periods for the Two Groups of Cows

Group	Period	Grain Fed	Grain	Hay	Silage	Average Body Weight			4% F.C.M.
						Start	End	Diff.	
			(Lbs.)	(Lbs.)	(Lbs.)	(Lbs.)	(Lbs.)	(Lbs.)	(Lbs.)
I	1	Corn	579.0	451.0	2250	1283	1231	-52	1655.3
	2	Mix	540.3	450.0	2250	1245	1247	+ 2	1597.0
	3	Corn	484.0	450.0	2250	1271	1276	+ 5	1466.5
	4	Mix	434.5	450.0	2250	1272	1293	+21	1338.1
II	1	Mix	495.0	453.5	2250	1307	1233	-74	1410.4
	2	Corn	443.0	450.0	2250	1281	1269	-12	1309.2
	3	Mix	351.5	450.0	2250	1287	1275	-12	1163.7
	4	Corn	301.0	450.0	2250	1287	1315	+28	1028.6
Total milk production for 4 periods on corn ration									5459.6
Total milk production for 4 periods on grain mixture ration (Corn-oats-barley, equal parts by weight)									5509.2
Difference in favor of mixed ration									49.6

During the four periods corn was fed, the cows consumed 1807 pounds of corn, 1801 pounds of hay and 9000 pounds of hay crop silage.

During the four corn ration periods the cows produced 5459.6 pounds of 4 percent F.C.M.

During the four periods the grain mixture (corn, oats, and barley--equal parts by weight) was fed, the cows consumed

1821.3 pounds of the grain mixture, 1803.5 pounds of hay, and 9000 pounds of hay crop silage.

For the four periods of this experiment in which the grain mixture was fed the cows produced 5509.2 pounds of 4 percent F.C.M.

Table 9 shows the average amount of digestible crude protein and total digestible nutrients required by the cows on both grain rations for four periods, according to calculations, and also the amount of protein and total digestible nutrients in the feed consumed.

Table 9--Nutrients Required by the Cows on Each Ration, and the Amount They Obtained from Their Feeds(1)

Feeding Period(2)	DIGESTIBLE CRUDE PROTEIN		TOTAL DIGESTIBLE NUTRIENTS	
	Single Grain Corn	Oats-Barley-Corn	Single Grain Corn	Oats-Barley-Corn
Requirement(3)	(Lbs.)	(Lbs.)	(Lbs.)	(Lbs.)
Maintenance(4)	135.0	135.0	1800.0	1800.0
Production	223.8	225.9	1747.1	1763.1
Total	358.8	360.9	3547.1	3563.1
INTAKE FROM				
Hay	81.0	81.2	864.5	865.7
Hay Crop Silage	180.0	180.0	1440.0	1440.0
Grain	126.5	160.3	1445.6	1382.4
Total	387.5	421.5	3750.1	3688.1
Nutrient Intake in Excess of Requirements	+28.7	+60.6	+203.1	+125.0

(1) Feed analyses, F. B. Morrison's, Feeds and Feeding, 22nd Edition, 1956, used as follows:
Oats (9.4% D. P. - 70.1% T. D. N.)
Corn (7% D. P. - 80% T. D. N.)
Barley (10% D. P. - 77.7% T. D. N.)
Mixture (8.8% D. P. - 75.9% T. D. N.)
Hay Crop Silage (2% D. P. - 16% T. D. N.)
Hay (4.5% D. P. - 48% T. D. N.)

(2) Data for the last 15 days in each period used in the calculation of results.

(3) High level T.D.N. and low level protein requirements from F. B. Morrison's, Feeds and Feeding, 22nd edition used.

(4) Maintenance was figured at the 1300 pound cow level.

Table 9 shows the nutrients consumed were in excess of requirements thus preventing a depressing effect upon milk production, due to under feeding protein and/or total digestible nutrients.

Cows fed the grain mixture produced 49.6 pounds more 4 percent F.C.M.--a difference of eight hundredths of one percent.

No consistently significant difference in body weight changes or general health were observed within groups or between groups during this experiment.

Summary

A single grain, corn, was compared to a grain mixture of equal parts by weight of corn, oats, and barley as a supplement to hay and hay crop silage for milk production. Two comparable groups of cows were used in an experiment of four 21-day periods duration.

No significant difference between corn and the grain mixture (corn, oats, and barley--equal parts by weight) as to influence on milk production, butterfat test, general health and body weight was observed under the conditions of this experiment.

BARLEY COMPARED TO A THREE CEREAL GRAIN MIXTURE

A single grain, barley (ground), was compared to a grain mixture of oats, barley, and corn (ground), equal parts by weight, as a supplement to hay and hay crop silage for milk production in this experiment.

Experimental Procedure

The Cows

Two groups of registered Holstein cows (groups I and II) comparable in age, body weight, milk production, and stage of lactation were used in this experiment.

Feeding

Both groups of cows were fed from the same supply of hay and hay crop silage. The daily roughage ration for each cow was 50 pounds of hay crop silage and 12 pounds of chopped barn-dried hay at the start of the experiment. The hay allotment was raised to 15 pounds per cow per day at the start of the third feeding period.

The rate of grain feeding was based upon production as shown in table 1.

Adjustments in amount of grain fed per cow were made at the end of the first week of each feeding period.

The rate of grain feeding was based upon cow body weights and milk production presented in table 10 and the analyses

of roughage comparable to the hay crop silage and hay supply fed. This rate of grain feeding was planned to supplement the daily roughage ration of 50 pounds of hay crop silage and 12 pounds of hay--15 pounds during the third and fourth periods. It was a minimum of one pound of grain per day less than Morrison's table of recommendations VIIIa at the 20, 30, 40, and 50 pound levels of daily milk production.

Cows were fed twice daily. The grain was fed on the silage at 8:00 A.M. and the hay was fed at 3:30 P.M.

Unconsumed roughage was weighed back and recorded prior to each succeeding feeding. Special mangers were used to prevent feed loss.

A supplemental mineral mixture containing three parts of trace mineral salt and one part of steamed bonemeal to which one-half ounce of cobalt carbonate was added per 100 pounds of the mineral mixture was available to each cow in an individual box during the daytime.

All hay, hay crop silage, and grain feedings were weighed and recorded for each cow. Feed not consumed was weighed back and recorded.

Representative samples were taken of grain, hay, and hay crop silage once every three days. Individual samples for each period mixed together made up the composite sample used for chemical analysis and reported in table 11.

Exercise

The cows were kept in their stanchions for the duration of the trial except while being lead to the scales to be weighed every third day.

Bedding

A mixture of sawdust and shavings was used as bedding. This prevented the possibility of cows obtaining additional nutrients by eating their bedding.

Water

Water was available for each cow from individual drinking cups at all times.

Milking

Cows were milked twice each day, at 6:00 A.M. and 4:00 P.M.

The milk was weighed and samples for butterfat determinations were taken at each milking. Milk samples were preserved with corrosive sublimate, and butterfat tests were run every three days on the three-day composite samples.

Cow Weights

Cows were weighed daily for three days prior to the beginning of the experiment. The mean weight was used as the base weight. The cows were weighed the second day of each

three-day period during the experiment at about the same time of day, 1:30 P.M.

Group Treatment

Two groups of cows were used in a four-period experiment with 21 days constituting each period. Group I cows were fed barley, hay, and hay crop silage during the first and third periods. During the second and fourth periods, group I cows were fed the grain mixture (barley, corn, and oats--equal parts by weight), hay, and hay crop silage.

Group II cows were fed the grain mixture, hay, and hay crop silage during feeding periods one and three and were fed corn, hay, and hay crop silage during periods two and four, respectively. The data for the last 15 days in each feeding period were used in calculating results.

This experiment was conducted at Michigan State University's Upper Peninsula Experiment Station, Chatham, Michigan, during the winter-barn season of 1956-57. The experiment was started October 11, 1956, and continued for four 21-day feeding periods through January 2, 1957.

Results and Discussion

Age, stage of lactation, milk production, and body weight for the two cow groups are presented in table 10. The two groups were balanced as comparable as possible.

Table 10--Age, Stage of Lactation, Milk Production, and Body Weight of the Cows at the Start of the Experiment

Group No.			In milk	Average daily milk production(1)	Average base weight(2)
	(No.)	(Yrs.-Mos.)	(Days)	(Lbs.)	(Lbs.)
I.....	84	6-8	204	42.3	1403
	24	10-7	113	47.6	1277
	118	4-9	125	47.0	1354
Average.....		7-4	147	45.6	1345
II.....	80	6-11	204	30.4	1505
	49	9-8	73	53.4	1299
	121	4-5	107	48.9	1221
Average.....		7-0	128	44.2	1342

(1) Average daily milk production October 8, 9, 10.
(2) Average base weight October 8, 9, 10.

The chemical composition of the corn, grain mixture (barley, oats, and corn--equal parts by weight), hay, and hay crop silage is presented in table 11.

Table 11--Chemical Composition of Hay Crop Silage, Hay, Barley, and the Grain Mixture as Fed(1)

Sample No.(2)		Ash	Crude fiber	Ether extract	H_2O	Protein	N-Free extract	Carotene	pH
		%	%	%	%	%	%	ppm	
Silage	IS	2.05	10.02	1.45	68.55	4.38	13.55	81.9	4.22
	IIS	1.91	10.82	1.41	67.75	4.50	13.61	94.0	4.12
	IIIS	1.80	8.94	1.25	72.74	3.75	11.52	59.0	4.49
	IVS	1.74	8.20	1.05	75.22	3.17	10.62	52.3	4.59
Hay	IH	4.64	35.71	1.77	5.50	8.56	43.82	31.6	--
	IIH	4.34	34.54	1.77	5.66	7.94	45.75	26.0	--
	IIIH	4.00	34.02	1.74	5.40	7.56	47.28	12.9	--
	IVH	4.09	34.96	1.59	5.44	8.31	45.61	12.9	--
Barley	IB	1.89	4.58	1.59	13.31	11.56	67.07	--	--
	IIB	2.14	6.19	1.48	12.88	12.00	65.31	--	--
	IIIB	2.04	5.86	1.60	13.01	12.06	65.43	--	--
	IVB	2.34	5.78	1.29	13.49	12.13	64.97	--	--
Mixture(3)	IM	2.01	5.85	3.04	12.97	10.13	66.00	--	--
	IIM	1.84	5.40	2.98	13.16	10.31	66.31	--	--
	IIIM	1.66	5.55	3.20	12.65	10.25	66.69	--	--
	IVM	1.75	5.80	3.25	12.90	10.31	65.99	--	--

(1) Chemical Analyses of feeds were made by members of the Michigan State University Department of Agricultural Chemistry.
(2) Sample number indicates period fed.
(3) Corn, oats, and barley mixture.

Fat-Corrected Milk

The total milk production on each ration and the total milk production for each cow for the four periods was corrected to a four percent butterfat basis by the following formula developed by Gaines and Davidson (45 in 1923:

> 0.4 pounds of milk produced + 15 x pounds of butterfat produced = pounds of 4 percent fat-corrected milk.

Hereafter in this experiment 4 percent fat-corrected milk will be listed as 4 percent F.C.M.

Feed consumption, body weight at the start and end of the last 15 days of each feeding period for each group and the production of 4 percent F.C.M. by feeding periods are listed in table 12.

Table 12--Feed Consumption, Body Weight, and 4 Percent F.C.M. by Periods for the Two Groups of Cows

Group	Period	Grain Fed	Grain (Lbs.)	Hay (Lbs.)	Silage (Lbs.)	Average Body Weight Start (Lbs.)	Average Body Weight End (Lbs.)	Average Body Weight Diff.	4% F.C.M. (Lbs.)
I	1	Mix	622.5	558	2250	1375	1328	-47	1741.3
	2	Barley	562.5	540	2250	1305	1293	-12	1592.8
	3	Mix	517.5	675	2250	1304	1301	- 3	1528.4
	4	Barley	480.0	675	2250	1323	1291	-32	1370.3
II	1	Barley	612.0	558	2250	1371	1366	- 5	1743.0
	2	Mix	551.25	540	2250	1329	1323	- 6	1505.2
	3	Barley	495.0	675	2250	1360	1352	- 8	1444.8
	4	Mix	405.0	675	2250	1353	1345	- 8	1296.3

Total milk production for 4 periods on barley ration	6150.9
Total milk production for 4 periods on grain mixture ration (Barley, oats, and corn--equal parts by weight)	6071.2
Difference in favor of barley ration	79.7

(1) Average body weight at the start and end of the last 15 days of each feeding period.
(2) Data for the last 15 days were used in each period in the calculation of results.

During the four periods barley was fed, the cows consumed 2149.5 pounds of barley, 2448 pounds of hay, and 9000 pounds of hay crop silage and produced 6150.9 pounds of 4 percent F.C.M.

During the four periods the grain mixture (equal parts by weight of barley, oats, and corn) was fed, the cows consumed 2095.8 pounds of the grain mixture, 2448 pounds of hay, and 9000 pounds of hay crop silage and produced 6071.2 pounds of 4 percent F.C.M.

Table 13 presents the average amount of digestible crude protein and total digestible nutrients required by the cows on both grain rations for four periods according to calculations and also the amount of protein and total digestible nutrients in the feed consumed.

Table 13--Nutrients Required by the Cows on Each Ration and the Amount They Obtained from Their Feeds During the Last 15 days of Each Feeding Period

Feeding Period(1)	DIGESTIBLE CRUDE PROTEIN		TOTAL DIGESTIBLE NUTRIENTS	
	Single Grain	Mixture	Single Grain	Mixture
	Barley	Oats-Barley-Corn	Barley	Oats-Barley-Corn
Requirement(2)	(Lbs.)	(Lbs.)	(Lbs.)	(Lbs.)
Maintenance(3)	140.4	140.4	1854.0	1854.0
Production	252.2	250.9	1968.3	1942.8
Total	392.6	391.3	3822.3	3796.8
INTAKE FROM				
Hay	110.2	110.2	1175.0	1175.0
Hay Crop Silage	180.0	180.0	1440.0	1440.0
Grain	215.0	209.6	1670.2	1628.4
Total	505.2	499.8	4285.2	4243.4
Nutrient Intake in Excess of Requirements	+112.6	+108.5	+462.9	+446.6

(1) Data for the last 15 days were used in each period in the calculation of results.

(2) High level T.D.N. and low level protein requirement recommendations from Morrison used.

(3) Maintenance was figured at 1350 pound cow level.

(4) Feed Analysis, F. B. Morrison's, Feeds and Feeding, 22nd Edition, 1956, used as follows:

Oats (9.4% D.P. - 70.1% T.D.N.)
Corn (7% D.P. - 80% T.D.N.)
Barley (10% D.P. - 77.7% T.D.N.)
Mixture (8.8% D.P. - 75.9% T.D.N.)
Hay (4.5% D.P. - 48% T.D.N.)
Hay Crop Silage (2% D.P. - 16% T.D.N.)

Table 13 shows the total nutrient intake for the single grain feeding periods and the total nutrient intake of the grain mixture feeding periods to be in excess of requirements. This removed the possibility of milk production depression due to under feeding protein and/or total digestible nutrients.

Cows fed barley for four feeding periods produced 79.7 pounds more 4 percent F.C.M.--a difference of one-tenth of one percent more milk for the duration of the experiment.

No consistently significant difference in body weight changes or general health were observed between groups in this experiment.

Summary

A single grain, barley, was compared to a grain mixture of equal parts by weight of corn, oats, and barley as a supplement to hay and hay crop silage for milk production. Two groups of cows were used in an experiment of four 21-day periods duration.

No significant difference between barley and the grain mixture as to influence on milk production, butterfat test general health, and body weight was observed under the conditions of this experiment.

GENERAL SUMMARY

Three 84-day experiments were conducted in which single cereal grains were compared to grain mixtures. Oats, barley, and corn were compared individually to a grain mixture, equal parts by weight of three cereal grains.

Results showed that oats, corn, and barley fed alone as supplements to hay and hay crop silage were equal to grain mixtures, equal parts by weight, of three cereal grains, for milk production, maintaining body weight, and general herd health.

Conclusion

It is concluded that for cows fed liberal amounts of quality roughage, the use of single cereal grains--oats, barley, or corn--will result in satisfactory milk production for at least three months of the winter barn-feeding season.

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