MINNESOTA

NUTRITION

CONFERENCE

FOR FEED MANUFACTURERS AND DEALERS

PETERS HALL

INSTITUTE OF AGRICULTURE

UNIVERSITY OF MINNESOTA

St. Paul 1, Minnesota

Monday and Tuesday

September 10 and 11, 1962

Agricultural Short Courses and
Departments of Agricultural Biochemistry,
Animal Husbandry, Dairy Husbandry, and
Poultry Husbandry, University of Minnesota;
The Northwest Feed Manufacturers Association, and
Northwest Retail Feed Association

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Program

Peters Hall Auditorium
Monday, September 10, 1962

Ogden P. Confer, Presiding
President, Northwest Feed Manufacturers Association

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9:30	Calcium and phosphorus requirements of breeding swine	L. E. Hanson
10:00	Intermission	
10:15	Nutrient intake concept in poultry nutrition	K. E. Dunkelgod
11:00	Controlling estrus in farm animals	E. F. Graham
11:30	Lunch	North Star Ballroom
	Fats in the human diet	W. O. Lundberg

Frank M. Crane, Presiding
Chairman, Northwest Feed Manufacturers
Nutrition Conference Committee

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Tuesday, September 11, 1962
Jack Conlee, Presiding
President, Northwest Retail Feed Association

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C. L. Cole, Presiding
Department of Dairy Husbandry

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3:00	Feeding replacement pullets	D. C. Snetsinger
3:30	Any further questions?	
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Next Conference - September 9-10, 1963

WHO'S WHO

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*W. O. Lundberg, Professor and Director, The Hormel Institute, University of Minnesota, Austin
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N. D. Magruder, Poultry Nutritionist, Cargill-Nutrena Research Farm, Elk River, Minnesota
*R. J. Meade, Professor, Department of Animal Husbandry
*M. O. Schultze, Professor, Department of Biochemistry
*H. J. Sloan, Director and Professor, Agricultural Experiment Station, Institute of Agriculture
*D. C. Snetsinger, Assistant Professor, Department of Poultry Science
*P. E. Waibel, Associate Professor, Department of Poultry Science

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CALCIUM AND PHOSPHORUS REQUIREMENTS OF BREEDING SWINE

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Department of Animal Husbandry
University of Minnesota, St. Paul

The importance of adequate calcium (Ca) and phosphorus (P) in swine rations has been recognized for many years. Less well recognized is the fact that the feedstuffs used in a ration, at least for young pigs, affect the level of Ca and P required in the ration. Much of the P found in cereals and high protein feeds of oil seed (e.g. soybean) origin is present as phytin. Under suitable conditions the enzyme, phytase, will split this compound making the P available for absorption.

Some phytase is found in the gut of the pig and some feedstuffs contain considerable phytase activity. However, corn, oats and the high protein feeds of plant origin, including soybean meal, have very little phytase activity. The presence of phytin in the ration increases the level of Ca needed because its presence decreases Ca absorption. Conversely, excessive Ca will decrease the utilization of phytin P. Recent studies at Iowa and Indiana have shown that pigs do not utilize phytin P as well as inorganic P.

Poultry nutritionists have recognized the rather poor availability of P found in plant seeds for many years. Whether the pig utilizes phytin P better than or as well as the chick has not been determined. Studies at Indiana and Missouri show rather clearly that phytic acid is responsible also for the apparently high requirement of the young pig for zinc, ,ut that is another story.

I believe that it is important that we consider the nature of the ration in prescribing Ca and P levels for swine. In line with this view, the recommendations made in this paper are based on the assumption that only limited amounts of milk and other animal products will be included in the pig starter. For older animals it is assumed that 50% or more of the supplemental protein will be supplied by soybean meal.

The production of well developed breeding stock with sound feet and legs starts with adequate nutrition of the baby pig, hence consideration is given to the Ca and P requirements of all ages. Because life-cycle studies have not been made recommendations must be based on studies of separate segments of the cycle. The sum of the segments may not be equal to the whole cycle. Only research which includes an entire generation or more will provide the answer.

In view of the many inadequately defined interrelationships between Ca and P with other elements I believe a conservative approach should be followed in recommendations. On the other hand, I do not believe that we should allow our recent experience with parakeratosis to deter us from feeding adequate levels of Ca and P.

Baby Pigs

Given the opportunity, the baby pig absorbs and stores Ca with remarkable efficiency. Danish workers (1) have reported that pigs 2 to 35 days of age utilized 70% of the Ca of a high-milk diet fed to them and Hansard et al (2) reported that 14 day old pigs utilized 91% of the Ca in fresh cow's milk. In the Danish study 50-55% of the P in the diet was utilized. Since sow's milk contains about twice as much Ca and 1.6 times as much P as cow's milk one might expect that the Ca and P requirements of baby pigs would be quite high. However, this does not appear to be the case when dry diets are fed.

Several studies of Ca and/or P requirements of young pigs have been reported recently by the Florida, Iowa, Michigan and Minnesota stations. Their findings are summarized in the following table.

Source of data	Age of pigs	Kind of diet	Indicated requirements Ca, %	P, %
Combs et al (3)	2-7 weeks	Corn-soy-sugar	0.4-0.5	0.44-0.48
Wallace (4) (Review)	---	----	0.6	0.5
Zimmerman et al (5)	2-6 weeks	25% milk products	0.7	---
Zimmerman et al (6)	3-7 weeks	" " "	---	0.4
Miller et al (7)	baby	Purified	0.8	---
Miller et al (8)	"	"	---	0.6
Rutledge (9)	3-9 weeks	Practical 13% milk products	0.8	---
Teter (10)	12-50 lbs.	Corn-starch-sugar soy-blood-8% milk	---	0.5-0.6

It is apparent from these data that there are differences in estimated requirements. Some of these differences are undoubtedly due to differences in the rations fed. Part of the difference also comes about due to the emphasis placed on each criterion used in evaluating the data. Wallace (4) in his review, stated "The overall information available on the calcium and phosphorus requirements of the baby pig is somewhat clouded. It does seem quite clear though that those levels which promote a high degree of calcification in the bone are not the levels which promote optimum gain and feed conversion. This writer would recommend

the minimum levels which consistently prevent bone abnormalities and permit maximum performance. These levels are no more, and possibly less, than 0.5 percent phosphorus and 0.6 percent calcium."

The Michigan workers (7) noted that 0.6% Ca supported maximum gains and feed efficiency when the ration contained 0.5% P but concluded that 0.8% Ca was the minimum for adequate bone development. They (8) also concluded that 0.6% P was optimum for growth and development when the ration contained 0.8% Ca. The Minnesota data (9, 10) support the Michigan conclusions. Using high-milk pig starters the Iowa workers (6) reported that Ca:P ratios greater than 1.6:1 suppressed growth and that 0.4%P was inadequate regardless of the Ca level fed. Their (5) previous report indicated that 0.52% Ca was inadequate, whereas 0.7% was adequate.

There is no question but that best live weight gains are obtained with Ca levels that are suboptimum as far as bone development is concerned. High P does not appear to have this adverse effect. The real question is - What is the optimum in bone development, especially if the pig is to become part of the breeding herd? In the Minnesota study of Ca bone calcification and strength was maximum when the highest level of Ca (1.0%) was fed. Similarly Illinois workers (11) found that 0.2% Ca permitted maximum rate and efficiency of gain although ash content of bone increased with all increments of Ca fed up to 2%. Their pigs were fed a purified 21% protein diet containing 0.8% P from 14 days to 7 or 8 weeks of age.

The Florida studies (3) show rather clearly that the Ca:P ratio is quite critical especially when minimal P levels are fed. On the other hand, as shown in their photographs, when the ration is deficient in P (0.4%) poor bone development occurs at Ca:P ratios of 0.9:1, 1.2:1 and 1.5:1. Since 0.4% P was clearly inadequate in the Florida and Iowa studies it would appear that rations for baby pigs should not contain less than 0.5% P.

The Ca level can be debated if one intends to market the pigs. However, for pigs which might become part of the breeding herd it is my opinion that the ration should contain about 0.8% Ca, if the ration being fed is such that it will promote rapid gains.

Growing Pigs

I have chosen to label pigs from 30-50 lb. to market weight as growing pigs. At one time they were usually referred to as growing or fattening or growing-fattening and more recently as growing-finishing pigs. I think we ought to completely discard these older adjectives because we do not or should not deliberately fatten pigs and the finishing process is also quite automatic when pigs are full fed. What we really need to do to hold our consumer market is to grow the pigs to market weight. Let's do this and stop using the word fat, fattening or finishing. Please pardon the detour from the subject.

Many studies have been made of the Ca and P requirements of growing pigs. The early studies at Kansas (12) indicated that 0.4% Ca and 0.3% P was adequate for pigs from 40 lb. to 230 lb. They fed basal rations that were very low in P while studying the P requirement. On the other hand, Indiana (13) workers fed a corn-soybean meal ration and their data suggested that the desirable Ca level was 0.6% when the ration contained about 0.4% P. In these studies feed intake was limited to that of the pigs with the poorest appetite and average daily gains varied from 1.1-1.3 lb. daily and feed required per 100 lb. gain varied from 366-420 lbs. In other studies at Ohio (14) and Indiana (13) in which corn and soybean meal rations were fed it was found that 0.4-0.45% P was required when the rations contained adequate Ca and vitamin D. Relatively slow growth was obtained in these studies because they were made before vitamin B_{12} was discovered and the rations were deficient in this vitamin.

Modern rations in the Corn Belt are based on corn and the major source of supplemental protein is soybean meal. When properly fortified with vitamins, minerals and antibacterial agents such rations produce much more rapid gains than obtained in the early studies referred to above. Furthermore, many pigs of today will require 300 lb. of feed or less per 100 lb. of gain. As ration efficiency increases it would be expected that the amount of Ca and P contained in it would need to be increased in order to provide the pig with the same amount of these elements as consumed when more feed was eaten per unit of gain. For example, 400 lb. feed with 0.4% Ca contains 1.6 lb. Ca whereas 300 lb. feed would need to contain 0.53% Ca to provide the same Ca intake.

In a recent Indiana (15) study with a corn-soy type ration which contained about 0.3% P the addition of 0.15% P in the form of dicalcium phosphate or of phosphoric acid produced a marked increase in daily gain and efficiency of feed conversion.

The most extensive recent study of Ca and P requirements of growing pigs fed a fortified corn-soy ration has been reported by Iowa workers (16). They concluded that the optimum Ca and P levels appeared to be 0.8% and 0.6% respectively, for pigs fed from weights of 25 lb. to 100 lb., and 0.7% and 0.5% respectively, for pigs fed from 25 lb. to 200 lb. They also reported that "at least 0.4% Ca and 0.4% P was necessary in the diet to assure freedom from skeletal abnormalities."

In a brief recent report workers at Michigan State (17) reported that 0.3 and 0.5% Ca supported maximum growth in pigs fed a fortified corn-soy type ration to market weight whereas 0.7% Ca depressed growth. However the breaking strength of the bone (11th rib) was significantly increased by the higher levels of Ca.

Since most growing rations today are relatively low in animal by-products I believe that it is wise to include 0.7% Ca and 0.5% P in the rations of growing pigs up to 100-125 lb. If the pigs are intended for market the Ca and P levels can be reduced to 0.5% Ca and 0.4% P for the period from 100-125 lb. to market weight.

It is my view that gilts intended for the breeding herd should be removed from the market pens, at a weight of about 125 lb. and placed on restricted rations. When this is done I believe the Ca and P levels should be maintained at 0.7% and 0.5%, respectively.

Gestation and Lactation

Strange as it may seem very little research attention has been given to Ca and P requirements for gestation and lactation. More than 30 years ago English workers showed that bred gilts could go through gestation successfully when fed rations very low in Ca, 0.04% in one series of studies (18). Gilts fed this low level of Ca farrowed normal first litters, but lactation was poor and some females produced no milk. They were continued on the deficient rations for 3 or 4 additional gestations and in the subsequent litters the number of pigs dead at birth increased and there was almost total lactation failure. The ration contained 0.31% P and it was shown that the lack of Ca did not interfere with P absorption nor with the digestibility of the organic nutrients in the ration.

A few years later Hogan (19) reported a series of studies of Ca requirements in which he suggested that the ration should contain not less than 0.4% Ca. On the basis of the literature available in 1947, Mitchell (20) estimated that the pregnant sow in the 8th week of gestation required 0.09% Ca and that the requirement increased to 0.43% during the 16th week. Similarly he estimated that the P requirement increased from 0.17% in the 8th to 0.29% in the 16th week of gestation. He suggested that in practice it would be wise to feed somewhat higher levels than these estimates as a safety factor, but he also cautioned against the use of large excesses.

The only recent study of Ca or P requirements for breeding females of which I am aware is a study by Teter (10) of P needs. He started with gilts weighing about 50 lbs. They were fed a ration of corn, cornstarch, blood flour, 50% protein soybean meal, minerals and vitamins. The rations, with one exception analyzed 0.52-0.54% Ca (calculated 0.6%) and the basal contained 0.22% P and 300 I.U. vitamin D/lb. feed. P levels of 0.35%. 0.45% and 0.55% were obtained by adding dicalcium phosphate or soft phosphate to the basal diet. Feed intake was controlled so that gains of approximately 1.0 lb. per day would be obtained.

During the first 140 days the average daily feed consumption for all lots was 4.27 lb. per gilt. On the average the controls gained slightly less than 1.0 lb. daily, those fed soft phosphate gained

1.1 lb. and those fed dicalcium phosphate gained 1.2 lb. Rickets developed in 4 of the 10 control gilts. At breeding time 5 contol gilts remained and 4 of these showed estrus and were bred. One of these farrowed 10 live pigs and nursed 7. During the 4th week of lactation she became paralyzed and autopsy revealed two fractured vertebrae. The remaining 3 gilts farrowed a total of 18 pigs, 11 of which were born alive. Six of these were killed for bone assays, 2 died and the remaining 3 were nursed by one gilt for 5 weeks. This gilt and one other negative control were rebred for second litters and farrowed 7 and 13 live pigs, respectively.

Not all of the supplemented gilts were breeders but on the whole their reproduction records were satisfactory through the first cycle. The gilts fed dicalcium phosphate also produced second litters successfully. However, 5 of the 12 gilts fed soft phosphate did not resume normal estrus within 30 days after weaning their first litters. These gilts lost significantly more weight during the first lactation than those fed dicalcium phosphate and it is probable that this was the reason for their failure to cycle normally. The soft phosphate supplemented rations were quite dusty and feed consumption was not adequate during lactation. An outbreak of TGE destroyed 12 of the 18 second litters produced, hence it was not possible to collect data for the second lactation.

It was concluded from this study that 0.22% P as supplied by the basal diet was inadequate for growth, gestation and lactation of gilts. Because of the problems encountered it was not possible to demonstrate any marked differences in results due to the different levels of supplemental P fed. The growth data indicated that 0.35% P is near the minimum when the gilts are fed to gain about 1.0 lb. daily. Total reproductive performance during two gestations and one lactation appeared to be slightly better when 0.45 or 0.55% P was fed, but the results were not conclusive.

In a recent study at North Carolina (21) littermate gilts were divided into two groups of 10 and fed rations containing 0.54% Ca and 0.43% P or 1.27% Ca and 0.45% P. After 8 weeks on test the Ca level was increased to 2.0% for the latter group. The gilts used in this study were hand-fed 4 lb. feed/head/day of a 15% protein mixture from a weight of 190 lb. until they were 8 months old. They were started on the test rations 2 weeks before breeding and fed 6 lb. feed daily. About 4 weeks after breeding and for the remainder of gestation they were fed 4 lb. feed/ head/ day. Four gilts were slaughtered from each group 25 days after breeding for a study of embryo survival and no differences were found. The other 6 in each group were allowed to farrow and the Ca levels did not appear to have affected the gestation or lactation performance, which was excellent in both groups.

The NRC subcommittee on swine nutrition states the requirements for gestation and lactation as 0.6% Ca and 0.4% P. The

latest Danish recommendations (22) are for approximately 0.8% Ca and 0.6% P during the last 4 weeks of gestation and during lactation. For the first 12 weeks of gestation the recommendation is for approximately 0.85% Ca and 0.65% P. Other European recommendations (23) (stated as % of dry matter in feed) vary from 0.5% Ca and 0.3% P (W. Germany) to 0.6-0.8% Ca and 0.55-0.60% P (Norway) during gestation and 0.6-0.8% Ca and 0.55-0.60% P (Norway) to 0.7-1.0% Ca and 0.5-0.7% P (W. Germany) during lactation.

My view after studying the data available, is that gestation and lactation rations of the usual kind fed in the U.S. should provide 0.7% Ca and 0.5% P for gilts and yearling sows and 0.6% Ca and 0.4% P for mature sows. I feel quite certain that these levels are adequate for continuous high production and they are not so high that they will be detrimental.

Summary

Until further data become available I recommend that rations for pigs weighing 10-40 lb. contain 0.8% Ca and 0.6% P; those for pigs weighing 40-100 or 125 lb., 0.7% Ca and 0.5% P. The latter levels are recommended also for growing gilts, for yearling sows and gilts during gestation and lactation, and for growing boars. For mature sows 0.6% Ca and 0.4% P; and for mature boars and for market pigs weighing 100 lbs. or more 0.5% Ca and 0.4% P is recommended. In areas where the rations contain more animal by-products high in Ca and P than is usual in the Corn Belt somewhat lower levels than those recommended can be fed with satisfactory results.

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This nutrient intake concept, as it is applied to the feeding of market poultry, is designed to include the required nutrients in the proper balance in that quantity of feed which it is estimated the turkey or broiler will consume in one day. Nutrient intake standards based upon this concept more adequately meet the growing bird's requirements at each specific physiological age throughout the entire growing period. Basic information pertaining to nutrient intake requirements and interrelationships for specific growth rates, factors affecting feed intake which are vital to the application of the nutrient intake concept, and the solving of certain formulation and mixing problems in connection with practical rations based upon nutrient intake standards, will require a great deal of study by research workers during the next few years.

The need to determine nutritional requirements on a daily intake basis was first encountered in human nutrition. Cowgill (1928) emphasized the importance of daily nutrient intake when he stated that "unwarranted conclusions were drawn when the energy level of the diet was ignored and no records of food intake were kept." Currently, nutritional requirements of man are generally expressed on a daily nutrient intake basis.

Although the factors that regulate feed intake are not fully understood, it is recognized that under ordinary physiological conditions the body adjusts intake with remarkable precision. The information available at present suggests that many variables are involved. These variables include: sex, environmental temperature, physiological age, stress, energy requirements and genetic influences. Hegsted and Haffenreffer (1949) suggested that food intake is controlled in such a manner that the total caloric intake is at a constant percentage above the caloric intake required to support basal metabolic rate. If the feed thus consumed contains adequate proportions of nutrients for growth, the animal increases in size, basal metabolism increases, and as a result feed intake is increased on succeeding days. Allison (1957) reported that an optimal energy intake is needed to establish an efficient balance between fat stores and lean body mass, and that this optimal energy intake varies with the age and physiological state of the animal. Johnston (1957) indicated that the growth pattern of adolescents of both sexes was correlated to physiological rather than to chronological age.

Relatively little consideration has been given to sex as a factor which influences feed intake. Brooks (1933) suggested that there is a need for specific data on the utilization of feed by each sex if the effects of different diets on growing turkeys are to be

measured more completely. Almquist (1951) recommended that turkey toms and hens be reared separately. Dunkelgod and Thayer (1961) reported a difference in the nutritional requirements of male and female poults grown to eight weeks of age. These observations emphasize the need for separate standards for the feeding of male and female turkeys to market weight.

Dunkelgod et al (1962) presented nutrient intake standards for growing male and female turkeys to market weight which are based upon nutrient intakes that produced a 12-pound market-weight hen in 16 weeks with a 1.85 feed conversion and a 24-pound tom in 21 weeks with a 2.2 feed conversion. These results indicate what can be done within the genetic potential inherent in present commercial strains of market turkeys. Economic limitations and the need for new ingredients with special characteristics make it impossible at present to utilize these data fully in the formulation of practical turkey starter and grower diets. However, these data have been applied in the formulation of practical diets which have been fed with outstanding results under commercial feeding conditions in a series of field tests completed during 1960.

The lack of adequate data in the area of amino acid balance for growing turkeys emphasizes the need for new research tools with which to determine more precisely the amino acid requirements for optimal growth throughout the entire growing period. In current research at the Oklahoma Agricultural Experiment Station, blood plasma levels of amino acids (Tonkinson et al, 1961) are being used as a measure of dietary amino acid adequacy and to study their interrelationships as they are related to body weight gain and body composition. Research workers are conscious of the fact that the body contains certain labile protein fractions which are lost during periods of low protein intake. Although they are known to exist, little is known of their significance insofar as protein requirements are concerned. More accurate estimates of optimal amino acid ratios and of protein intakes can be made only when more is known about these protein reserves and how they can be measured accurately.

Caloric intake per bird per day exerts the greatest influence in determining feed intake and has a direct effect upon the utilization of other nutrients. Turkeys eat primarily to satisfy their caloric needs. If insufficient energy as carbohydrate or fat is available, the protein will be diverted from its normal use in protein synthesis and will be utilized as a source of energy. When the caloric intake drops below the requirement level or when the Calorie:protein ratio is too narrow, rate of gain is depressed and efficiency with which nutrients are utilized is significantly decreased.

Current knowledge pertaining to daily nutrient intake does not include all of the answers to the problems involved in formulating practical rations on a nutrient intake basis. Sufficient data are available, however, which permit the effective application of the nutrient intake concept, by means of practical nutrient intake standards, to the formulation of rations for use under practical feeding conditions. As more essential data become available, it will be possible to continue to refine the practical nutrient intake standards. This will permit a progressive improvement in the efficiency with which nutrients are utilized in the production of broiler and turkey meat. In addition, through the control of nutrient intake, it will be possible to produce poultry meat of a pre-determined nutrient composition.

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CONTROLLING ESTRUS IN FARM ANIMALS

E. F. Graham
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University of Minnesota, St. Paul

The importance of controlling reproductive processes in mammals as increasing with applications of new control methods recently introduced. Techniques are being designed to prevent conception and to redate or initiate estrus in order that the conception date may be controlled. In artificial insemination of farm animals, control of breeding dates would increase the efficient use of time and semen as many animals could be bred during a short period of time. The adjustment of the estrous period could also be important in many types of experimentation to start all animals out at the same time and is especially important in research on ovum transplantation.

This discussion will center around the ovarian steroid hormone, progesterone, from the corpus luteum as it is a natural substance controlling estrual cycles. I would like to diverge just a moment at this point and review the factors and studies that led up to the discovery of progesterone.

This history of progesterone began in Holland with Regner de Graff, who published in 1672 the first book-length description of the female reproductive system. Most people today associate de Graaf's name with the follicles of the ovary or the Graafian follicle or corpura. De Graaf recognized and described the corpus luteum and its association with pregnancy. He also found that in species bearing more than one infant at a time there was a similar number of corpora lutea; and that the corpora lutea remain intact during pregnancy but disappear after parturition. De Graaf postulated that the corpus luteum was directly responsible for ovulation. It wasn't until 226 years later, in 1898, that Louis - Augusta Prenant suggested that the corpus luteum was an organ of internal secretion. Note that this suggestion was four years before Baylis and Starling enunciated the concept of specific hormonal action at the very dawn of modern endocrinology. Prenant's guess was that the function of the corpus luteum was to supress ovulation during pregnancy. Today we know that one of the actions of the corpus luteum is to do just that.

In 1903 Ludwig Fraenkel, a German, and in 1910 two Frenchmen, Paul Ancel and Paul Bouin, investigated other aspects of the role of the corpus luteum and demonstrated its action on the endometrium of the uterus in preparation for and maintenance of pregnancy.

The theory of the inhibition of estrus by the corpus luteum was first tested experimentally by Loeb (1911), who demonstrated that the removal of the luteal tissue accelerated the time of the next ovulation, whereas extirpation of other parts of the ovaries had no such effect. Later in 1921, Williams and Williams and Hammond (1927) reported that extirpation of the functional luteal tissue from the cow resulted in estrus and ovulation occurring within two to four days. McKenzie and Terrill (1937) reported similar observations in the ewe. It was therefore quite apparent that the corpus luteum had an action of inhibiting estrus.

Papanicolaous (1926) showed that a lipoid extract of luteal tissue inhibited estrus and ovulation in the guinea pig. Gley (1928) was able to inhibit estrus in the rat by extracts of sow corpora lutea. Payne et al (1928) obtained an unsaponifiable, cholesterol-free, phosphatid-free fraction from the corpus luteum of the cow. This extract inhibited estrus while it was being administered and for a few days after its withdrawl. This observation led to the idea that estrus could be inhibited by secretion from the corpus luteum and estrus would follow shortly after the withdrawl of the administration. In 1931 Erick Fels and Karl Slotta and Allen (1932) obtained almost pure preparations. In 1933 Karl Butenandt of Berlin determined the structural formula and in 1934 made the hormone synthetically by conversion from an inert steroid of known composition. So during the period of 1936-1948, the action of progesterone on the estrous cycle was studied by a host of workers, Makepiece et al (1936) Dempsey (1937) Selye et al (1936) Phillips (1937) Astwood and Fevold (1939) Burrows (1939) Biddulph et al (1940) and others.

In applying this knowledge to studies with larger animals, Dutt and Casida (1948) and O'Mary, Pope and Casida (1950) were able to synchronize the estrual periods in ewes during their natural breeding season. By daily injections of 10 mg. of progesterone the time of onset of estrus could be controlled, if injections were started while a functional corpus luteum was present. Later Ulberg, Grummer and Casida (1951) using gilts and Ulberg, Christian and Casida (1951) using heifers, were also able to control time of heat and ovulation by injecting sufficient levels of progesterone, providing that injections were started before the progesterone level produced by the animal was not so low that follicular development had started. They found that 100 mg. given daily inhibited estrus while the requirement for heifers was only 50 mg. per day.

Results of experimental trials in cattle conducted by the Minnesota group are given in the following tables.

The results of administering varying amounts of progesterone subcutaneously in corn oil and in a saline suspension is listed in Table 1 (Donker 1952). The administrations began from the 13th to the 17th day of the cycle, and were continued for from 1 to 12 days. It will be noted that the interval between the last administration and the appearance of heat varied from 3 to 8 days. Although the data are limited, it appears that when 50 mg. were administered daily, the saline suspension resulted in a longer interval between the last treatment and the appearance of heat than when the corn oil solution was used. The administration of 30-70 mg. progesterone daily was sufficient to surpress estrus.

In Table II, Dziuk (1955), are presented the results of attempts to

recycle cows with progesterone dissolved in corn oil and administered subcutaneously. The beginning of treatment varied from the 13th to the 17th day of the cycle; the amount of progesterone from 40 to 60 mg/day; and the duration of treatment from 4 to 18 days. The interval between the last treatment to the onset of heat varied from 3 to 9 days.

In Table III, Nichols (1957), are listed the results of 17 trials in which the daily dosage was kept constant, but the beginning of treatment varied between the 15th and 18th days of the cycle and the duration of treatment from 4 to 12 days. The interval between the last day of treatment and onset of heat varied from 4 to 7 days and the time of beginning of treatment and duration of the treatment were not related to the differences in the time of appearance of heat.

In larger trials as shown in Table IV and V, Avery, Cole and Graham (1962), experiments were designed to test the effect of number of injections of 50 mg progesterone daily and the day of treatment initiation over wider ranges. The length of treatment had no significant effect on time required to exhibit estrus following cessation of treatment nor did the initiation of treatment from 1-18 days of the cycle affect the interval of estrus from the last treatment (Table V).

Due to the fact that the interval from last treatment with progesterone to estrus was over 3 days an experiment was designed to test the effect of administering progesterone in larger quantities at 3-day intervals. The results are shown in Table VI. In this case the interval from last treatment to estrus was extended, and had no detrimental effect.

Another progestogen has been used in recycling cattle at this station. The use of an orally active progestogen, 6- methyl -17-acetooxyprogesterone, "Provera", has been fed to cattle in limited quantities of grain. The optimal amount fed daily was found to be 300 mg per day. Thirty cows have been recycled with "Provera" without failure. Estrus occurred on the average of 3 days following last administration.

The point of greatest concern with recycled dairy and beef cattle is the possible effect on conception rate at first estrus. Willett (1950) reported 11 of 22 animals conceiving at first heat after treatment. Trimberger and Hansel (1955) had only 3 out of a group of 24 cows conceive at first service after cessation of progesterone treatment. The normal rate of conception for the herd at that time was 64%. Nellor and Cole (1956) in studies involving 179 animals observed a conception rate of only 17 per cent in beef heifers which were bred at the first heat following one large dose of progesterone. On the other hand, O'Mary et al (1950) treated sheep and Ulberg and Patterson (1954) and Johnson et al (1958) treated cattle and found no reduction in fertility when using progesterone.

Table VII, Avery, Cole and Graham (1962), shows the results of a small field trial to test the influence of synchronization of estrus on fertility. In this trial no difference was observed between recycled animals and the controls, however the overall fertility was low but normal for the herd.

A few studies have been conducted using purified progesterone on synchronization in swine.

Ulbert et al (1951) utilized 43 gilts in studying the effects of four different levels of progesterone upon ovarian function (12.5, 25.0, 50.0 and 100 mg/day). The three higher dosages were capable of inhibiting heat and ovulation during treatment when injections were started early enough in the cycle. The lower dose had no effect. However, it was found that only the group receiving 100 mg/day ovulated at the estrus immediately post treatment. A high percentage of the gilts receiving 50 mg/day developed cystic ovaries. These animals failed to show heat in a period of 7-26 days post treatment.

Baker et al (1954) working with 95 gilts of mixed breeding in three independent trials tested the levels of 25 and 100 mg/day started on day 10 or 15 of the cycle.

Heat was inhibited by both levels; however, no fertility was obtained in the 25 mg/day group and a low fertility rate was found in those treated with 100 mg/day started on day 15.

The progesterone treatment increased the ovulation rate over that of the controls 3.2 ova. Fertilization failure was significantly increased over all progesterone groups but was not affected by the cystic condition.

Foote et al (1958) split 49 animals into 5 groups. All animals were started on day 12 of the cycle. Group I received no injections, group II, III, IV, received .4 mg per lb. of body weight (subcutaneously) from day one through day 17 of the experiment; Group IV also received 20 mg estradiol and Group V 20 mg estradiol only on day 14. Group II was slaughtered on day 25 of the experiment while all other groups were killed on day 18.

The average number of follicles 3 mm or larger on the ovaries of gilts in the five treatment groups was 19.9, 7.6, 36.8, and 3.7, 9.2 respectively. Seven of 11 gilts in Group II had ovulated at the time of slaughter with an average of 14.1 ova. These differed from the averages of Groups I and V (11.3 and 11.7).

Studies conducted at this station by Gerrits and Graham (1962) with 109 gilts indicate that the subcutaneous injection of progesterone at the rate of 100 mg per day or 300 mg administered every third day was effective in inhibiting estrus when initiated between day 1 and 12 of the cycle. The frequency distribution of return to estrus after the last treatment is shown in Table VIII.

Fertility data on 59 gilts showed no difference in conception rate between animals synchronized with injectable progesterone and the controls. Also no difference was observed between the two groups in number of embryos recovered at 25 days post breeding (11.6 in both groups).

Oral progestational compounds also have been used on swine.

Neller (1960) reported that estrous activity was not inhibited in 3 of 11 gilts receiving from 0.9 to 2.0 mg of 17 alpha-acetoxyprogesterone per lb. of body weight per day. Estrus was controlled in mature gilts fed twice a day at levels ranging from .8 to 1.6 mg of the oral compound per 16 lb. of body weight.

First (1960) synchronized 68 crossbred gilts with "Provera" for 15 days. Sixty-six gilts exhibited standing estrus and 94% began estrus in the 43-hour period of 77-120 hours after the last feeding. After breeding, 25% were pregnant on slaughter at 25 days gestation. In another group receiving a similar treatment fifty gilts were used. Thirty-eight were bred post treatment, 21 animals farrowed, an average of 7 pigs/litter (42% conception). All were bred artificially.

Nellor (1961) demonstrated that .5 mg of 6 methyl-17-acetoxyprogesterone per lb. of body weight fed twice daily in a limited ration (3-4 lbs. of feed per gilt per day) controlled estrus and ovulation. Eighty-nine per cent of the gilts came into estrus 4-5 days after the end of treatment. The conception rate of animals bred at the controlled estrus was 77%. Ovulation rate as estimated when fetuses were recovered 35 days following controlled estrus were not different from controls.

Gerrits and Graham (1962) fed forty-two gilts varying quantities of "Provera" (from .496 to 1.7 mg per lb. body weight per day) and were unable to synchronize estrus to any acceptable degree. In these studies it was well demonstrated that feeding the material twice per day was more effective than once a day feeding and that starting the treatment from day 1-7 of the cycle was more effective than later in the cycle.

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FROM FEED BAG TO BLOOD CELLS VIA BACTERIA
A TRAIL OF RESEARCH

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The feed industry showed much concern 10 years ago when trichloroethylene-extracted soybean meal became implicated as the probable cause of a severe hemorrhage disease in calves and cattle, an aplastic anemia. This is a condition in which the bone marrow loses the capacity to form the blood platelets needed for clotting of blood, the white blood cells which are so vital for defense against bacterial infections and the red blood cells which are needed to carry oxygen from the lungs to the tissues. An animal (or man) afflicted with aplastic anemia therefore is likely to develop high fevers from infection, suffer from lack of oxygen and bleed to death internally and externally because the blood does not clot - not a pretty picture.

Realization that some specimens of trichloroethylene - extracted soybean meal contained apparently a substance which was very toxic for the bovine animal triggered two events: (1) the cessation of the production of this feed in Minnesota and elsewhere in the U.S. (2) the start of a long period of research on this toxic substance designed to find out (a) what it is, (b) what it does in bio**logical systems,** (c) how it does the damage, (d) why some species **are so resistant.**

Whenever one starts on a trail of research of this type, the end, at first, is only a hope, indistinct and blurred in outline, assuming **more concrete form** as one progresses on the road to points where the goal appears to come into focus, only to fade away into the unknown again. It is a long road frought with hazards and detours, offering a few short cuts for those who know their way, and dead end alleys for all. It is a road of hard labor and sacrifice which, for all its bleakness, is full of fascinating promise as it leads from one turn to another, unfolding new vistas, new realizations and knowledge never had before. It is a road on which one is joined by others, similarly attracted, whose help and guidance speed progress, widen the sense and acuity of perception and broaden the area covered. It is a road marked by definite stages of progress, which become charted, for all to follow, and each in turn serving as point of departure for a new stage of pursuit. Above all, however, it is a road full of intellectual rewards and fascination as it leads into new and unknown areas.

On the trail which started with the bloody remains of a cow and a bag of feed 10 years ago we have reached some points and opened new avenues which have led us from the first crude but so essential feeding tests to the sophisticated but equally essential methods of modern biochemistry. The major steps on our road to this point were:

1. Demonstration that aplastic anemia could be produced in cattle under controlled conditions, at will, by feeding the suspected feed.

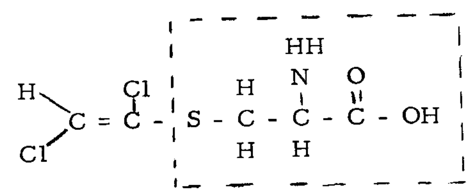
2. Development of a biological assay by which the relative amounts of the toxic factor could roughly be determined. Because common laboratory animals were resistant to the toxic factor, the calf was used for the bioassay.

3. Using the bioassay with the calf as a guide we demonstrated among other things that (a) residual trichloroethylene itself, i.e. the solvent, is not responsible for the condition, (b) the toxic factor is an organic compound, (c) it is associated with the proteins of the meal, (d) when the proteins are digested, the toxic factor is not destroyed, but it becomes water soluble.

4. Some proteins other than those of soybean can assume toxic properties after treatment with trichloroethylene (Picken, Iowa State University).

5. At this stage, in 1957, McKinney, Picken and their associates of the Northern Regional Laboratory, U.S.D.A., Peoria and Iowa State University, in cooperative work, who were searching for the toxic factor, synthesized an organic compound which when fed in small amounts to calves also produces aplastic anemia. This substance is S-(dichlorovinyl)-cysteine, called by us <u>DCVC</u>.

   Its chemical structure is



in which cysteine portion, delineated by the broken lines is the same as that found in the amino acid cysteine, a component of many proteins. In DCVC the dichlorovinyl group has replaced a hydrogen atom of cysteine. Although the toxic substances has never been isolated from soybeans in pure form, there is good reason to believe that DCVC or something very closely related to it is formed when soybeans are treated with trichloroethylene.

We have also synthesized this substance, DCVC, and amply confirmed that it is extremely toxic for the bovine animal. A single intravenous injection of 2 milligrams of DCVC per kg of body weight, while apparently well tolerated, initiates a chain of events which terminates in fatal aplastic anemia 3 - 4 weeks later. We would like to know what goes on and how, during that time in the calf. In what way are those primitive cells in the bone marrow which normally give rise to the various types of blood cells affected so that they lose their ability to do this job after having been exposed to DCVC or something formed from it?

To help answer this question we have enlisted the aid of a lowly microbe, Escherichia coli B which inhabits our intestine. Like the calf, this bacterium is highly susceptible to toxic effect of DCVC. Sublethal doses will produce bizarre, abnormal growth of these cells. Here we have then a biological system with which we can study what DCVC can do, and then apply this knowledge to our studies on blood formation. Perhaps similar or the same type of reactions with DCVC take place in E. coli and in the calf; perhaps they are different. In either case we ought to know.

To study the fate of DCVC in living organism we have built two radioactive tracers into the DCVC molecule, namely S^{35} or C^{14} in the position located as shown in these partial structures of DCVC:

$$C = C - S^{35} - C - C - \overset{\overset{O}{\|}}{C}OH \qquad (I)$$

and

$$C = C - S - C^{14} - C - \overset{\overset{O}{\|}}{C}OH \qquad (II)$$

With the sulfur-labeled DCVC shown in (I) above we have found that the rat and the calf handle this substance quite differently, the calf being able to break it down into various products, but not to excrete it in the urine unchanged. We now suspect that it is one of the fragments produced in the calf from DCVC which is responsible for the toxicity.

We are studying fate of DCVC in the test tube, using bovine

kidney tissue and the radioactive sulfur-labeled DCVC (I). As in the living animal, these kidney preparations can break down DCVC, much of the radioactivity becoming tied up with the proteins of the kidney.

10. Recently we have administered to our bacteria, E. coli B, each of the two types of radioactive forms of DCVC, (I) and (II) shown above, in parallel experiments, side by side. Much more of the radioactive sulfur was taken up by the cells and built into the proteins than of the radioactive carbon. This is decisive evidence that somehow E. coli splits DCVC:

$$C = C - \underset{\uparrow}{S - C} - C - \overset{\overset{O}{\|}}{C}OH$$

at the point of the arrow. The next move is to find out what the nature of the fragments is, if they are toxic, how they are formed, if they are also formed in the calf and if they prevent in this specie the normal formation of blood cells.

We have come a long way from the feed bag with the toxic meal and the bloody, dead cow. We've still got a long way to go! Where will it lead?

On this trail we have had financial support for this work from interested parties, first from the feed and chemical industry, then from the USDA, and later from the U.S. Atomic Energy Commission and the U.S. Public Health Service. Throughout this period, the research was a cooperative venture between the author and his students and Dr. J. Sautter from the Department of Pathology, College of Veterinary Medicine, and his associates. The sympathetic and helpful support of the administrative officers of the Institute of Agriculture, the College of Veterinary Medicine and the University is gladly acknowledged.

NUTRITION AND MANAGEMENT CONSIDERATIONS IN SPECIFIC PATHOGEN-FREE SWINE PROGRAMS

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Specific Pathogen-Free swine (SPF) are, by definition (Caldwell et al, 1961), animals that have been taken aseptically by hysterectomy on or about the 112th day of gestation, raised in isolation units for four weeks, then placed on premises that previously have not been populated with swine or have been cleared of non-SPF swine and cleaned. To continue to qualify as SPF, a herd must be certified free of atrophic rhinitis (AR), virus pig pneumonia (VPP), brucellosis and dysentary. SPF replaces the term "disease-free" which was earlier used to describe animals known to be free of certain diseases but not "germ-free."

One of the earlier efforts to bypass or eliminate persistent infections encountered with baby pigs raised in a laboratory environment was reported by Whitehair et al (1943). They used Caesarean section to secure clean pigs. Later, Thompson et al (1952) similarly secured 23 pigs, 17 of which were raised to maturity and maintained through normal reproduction cycles. The use of hysterectomy to secure baby pigs and then confining them to isolation units for the first few weeks of life was successfully accomplished, as reported by Young et al (1955), Hoerlein et al (1956) and Underdahl and Young (1957).

The swine repopulation program as an approach to elimination of certain swine diseases was discussed by Young and Underdahl (1956). Initial introduction of 39 SPF (then called disease-free) pigs to Nebraska farms was accomplished in the spring of 1957 (Caldwell et al, 1961). By the spring of 1961, SPF records of performance had been obtained on 1,345 litters (Welch, 1962). Repopulation programs have developed in many other states and also in areas outside the United States (Betts et al, 1960).

SPF swine are classified as (1) Primary - those pigs removed from the dam by hysterectomy, and (2) Secondary - the normally-farrowed offspring from Primary stock and succeeding generations.

Primary SPF pigs are extremely susceptible to infections since they have not nursed the dam and are deprived of the antibody protection associated with the ingestion of the sow's colostrum. They are, therefore, confined in isolation units for the first four weeks to allow time for the pig to develop some of his own disease-

combating mechanisms. Normally-farrowed pigs do not develop antibody-producing ability until at least three weeks of age (Miller et al, 1962).

Secondary SPF pigs, however, have the benefits from normal birth and nursing.

In February 1960, at the University of Illinois, the first of 21 litters from selected sows and gilts was taken by hysterectomy. These litters were the seed stock for a herd that is now used for research in breeding and genetics. They were confined to isolation units for the first four weeks, then moved to a farm that had no recent history of swine population (Woods et al, 1962). Additional litters were secured for investigations in management and nutrition.

Experiments with Primary SPF Pigs

Berry et al (1962) showed that performance of the hysterectomy-derived pig is markedly affected by management and feeding programs. From birth to 21 days of age pigs fed seven times a day gained significantly faster than littermates fed three times per day. This increase in performance reflected the greater total nutrient intake per day. It was also observed that feeding smaller amounts of diet at more frequent intervals essentially eliminated "overfeeding diarrhea" which occurred often when large quantities were fed infrequently. These results are not surprising since the newborn pig nurses frequently and for short periods of time (Barber et al, 1955; Gill and Thompson, 1956).

Antibiotic in the diet to provide 100 mg. per pig per day had no deleterious effect and it appeared to have a protective effect against the non-pathogenic organisms encountered in the brooders. This would be consistent with the report of Hill and Larson (1955).

A lactose-casein diet which previously had been shown to be adequate for pigs weaned at two and three days of age was inadequate for the hysterectomy-derived pigs.

Experiments with Secondary SPF Swine

Other things being equal, the Secondary SPF pig should be healthier than his non-SPF counterpart. He would thus be expected to more fully realize his genetic growth potential. This causes the question, "Do the SPF and non-SPF pigs differ in their nutritive requirements?" It could be argued that the SPF pig needs more of certain nutrients per pound of feed or per pound of body weight because of his rapid growth. Conversely, one could argue that therapy.

c. Variable litter size at farrowing.

Secondary Swine

A. Problems - primarily associated with management. Bacterial scours, outbreaks of TGE, overcrowding, insufficient water and feed, etc.

B. Performance

1. Marked improvement over Primary stock on the average.

2. Freedom from the sensitivity and high susceptibility to environment shown by Primary stock.

3. Antibiotics in well-balanced grower rations have stimulated growth.

Summary

The SPF swine program has become an important part of the swine industry, although time has not yet fully allowed final evaluation. Primary SPF pigs have been highly variable in **performance and in their ability to withstand the non-sterile farm environment.** The Secondary SPF pigs have been free **of many of these difficulties.**

Limited research would indicate that nutritive requirements of Secondary SPF swine are not significantly different from non-SPF swine. In general, the feeding program that does a good job for regular herds should do an excellent job for SPF herds.

Response to antibiotics in the feed will reflect the extent of contamination by various organisms. It will usually be less than would be realized with non-SPF animals.

The degree of success realized with the SPF program under the many and varied circumstances now being tried will determine its role in future swine production. As a program, its potential is only as great as the intelligence and know-how exercized in its application by the swine producer. Management will largely determine the results.

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Table 3. Summary of Results From Different Protein Levels In The Absence and Presence of Antibiotic.

Initial to 110 lb. / 110 lb. to 200 lb.	Protein level, % 18 / 14	16 / 12	16 / 16	Av.
Average daily gain, lb.a/				
Initial to 100 lb.				
No antibiotic	1.50	1.47	1.39	1.46
10 mg. antibiotic	1.62	1.61	1.55	1.59
Av.	1.56	1.54	1.47	
Initial to 200 lb.				
No antibiotic	1.80	1.75	1.76	1.77
10 mg. antibiotic	1.90	1.82	1.84	1.86
Av.	1.85	1.78	1.80	
Feed per lb. gain, lb.				
Initial to 100 lb.				
No antibiotic	2.35	2.35	2.38	2.38
10 mg. antibiotic	2.41	2.47	2.47	2.44
Av.	2.38	2.41	2.41	
Initial to 200 lb.				
No antibiotic	2.94	3.12	2.98	3.01
10 mg. antibiotic	3.03	3.04	3.04	3.03
Av.	2.98	3.08	3.01	

a/ Each figure represents average of 2 pens of 6 pigs each. Average initial weights were approximately 34 pounds.

Table 4. Results From Antibiotic Supplementation to Corn-Soybean Meal Rations For Secondary SPF Swine.

	Control	Antibiotic a/
Number of pigsb/		
Experiment 1	8	32
Experiment 2	6	24
Average daily gain, lb.		
Experiment 1	1.60	1.66
Experiment 2	1.63	1.72
Av.	1.61	1.69
Feed per lb. gain, lb.		
Experiment 1	2.94	3.06
Experiment 2	2.78	2.82
Av.	2.87	2.96

a/ Levels of antibiotics used were 10 and 20 mg. per pound of ration.
b/ Average initial and final weights for experiments 1 and 2 were 42, 180 and 38, 133, respectively.

MICROBES AND FEED QUALITY

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Numbers and kinds of microbes in grains and feeds. More than 160 species or kinds of molds have been found on barley grain, plus a fairly large number of species of yeasts and bacteria, and other grains probably bear an equally large assortment of microbes. It is not unusual to obtain thousands to tens of thousands of colonies of molds from a gram (about 25 kernels) of malting barley, plus tens to hundreds of thousands of colonies of yeasts, and hundreds of thousands to millions of colonies of bacteria. A gram is about 1/450 of a pound. Most feed grains bear a much heavier load of microbes than does malting barley or grain intended for human food.

Field molds and storage molds. In general, the molds that occur on grains can be divided into 2 groups: 1. Field molds. These, invade the kernels while the kernels are developing on the plants in the field. These field molds do not continue to grow on threshed grains or in feeds whose moisture content is below 20%, although they may grow on moist corn stored on the cob in cribs. The field molds may survive for months or years in dry grains. 2. Storage molds. These do not infect the grains to any significant degree before harvest, but may invade grains and feeds stored at moisture contents above about 13%. The extent to which these storage molds invade stored grains and feeds is determined by the moisture content of the stored materials, the temperature of the stored materials, the length of time the materials are stored, the amount of mold present at the beginning of any given storage period, and the activities of grain infesting insects and mites. The storage molds, if they grow rapidly enough, will cause grains and feeds to heat, but heating is not a good criterion of whether molds are or are not growing in grains and feeds--as it sometimes has been stated to be. Heating is likely to indicate the final stages of spoilage by molds, not the beginning stages. Some of the most common storage molds never grow fast enough to cause detectable heating, but still may cause extensive spoilage. In recent years several compounds have been advertised as effective controls of molds in feed grains and feeds; none of those tested by us has been of any real value in controlling the molds in grains stored under conditions that approximate those likely to be encountered in practice.

Toxicity of moldy grains and feeds. There is good evidence that barley invaded by certain species or strains of Fusarium, a common field mold that produces scab or blight in barley, wheat and corn, is toxic to swine when eaten (2, 4, 5). Other common field molds are suspected of being toxic when present in sufficient amounts, or when they have developed under conditions that may prevail at certain times but not at other times. One investigator stated (6) "It appears that certain samples of corn may be very moldy and not dangerous to use, while other samples of corn that do not seem to be of low quality may prove dangerous to use." And, "It is known that soft corn, when not moldy, may be fed to all classes of livestock with fair results; that moldy corn is especially dangerous to horses and sheep; but that cattle are not commonly injured by moldy corn, while hogs can usually be trusted to eat what they will." Yet in Georgia in 1952-53, eating of moldy corn was held to be responsible for the death of hundreds of swine (1). Samples of the corn collected in the fields where the swine had fed were fed to hogs by stomach tube and resulted in poisoning of the animals. Two of the molds cultured from this corn were grown on autoclaved corn, and either the mold-corn mixture or a water extract of it administered to experimental animals, and found to be toxic. Eight to 16 ounces of the corn on which Penicillium rubrum, the most toxic of the two molds, was grown, when administered via stomach tube to pigs weighing 30 - 60 pounds, killed them in 18 - 36 hours. Nine isolates of Aspergillus flavus from the moldy field corn were similarly tested, and only one of them was toxic.

Aspergillus flavus is a common storage mold on grains kept at moisture contents above 17%, and A. chevalieri is common on grains and feeds kept at a moisture content of 15 - 16%. Each of these was inoculated separately onto ground wheat, allowed to grow for 15 days, the moldy wheat mixed with complete feed in the ratio of about 1:14, and fed ad libitum to 10 day old chicks. The chicks developed extensive internal hemorrages and diarrhea. The investigator stated, "All symptoms were typical of classical 'hemorrhagic syndrome' (7)."

Calves which had eaten a pelleted feed in Wisconsin developed hyperkeratosis, an overgrowth of the horny layer of the skin. Aspergillus clavatus, another storage mold, was isolated from the pelleted feed, grown on sterile whole corn, and fed to 3 calves. Two of the calves died in 5 to 13 days, the 3rd developed "profuse lacrymation, and gross thickening of the skin on both sides of the cheeks and neck." (3). The writer stated, "On the basis of the data obtained so far, it is premature to establish at this time that the strain of Aspergillus clavatus isolated from toxic feed pellets is an etiological factor in cattle hyperkeratosis. However, corn on which this fungus had been cultured, when fed to calves, produced some of the symptoms observed in field cases of X disease."

Recently several samples of toxic peanut meal have been encountered in Africa, Brazil, and India, and the toxin has been proven to be a product of Aspergillus flavus.

In summary, it seems unquestionable that certain common molds growing in grains and feeds under certain conditions, produce materials that are toxic to animals. The exact conditions that result in production of toxins by certain microorganisms or certain combinations of them are not yet known. The problem evidently is rather complex, and much more research will be required to provide the answers we need.

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CONTROLLED LIGHTING FOR LAYERS

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When requested to present this talk many thoughts entered my mind. First, the subject is one of the more controversial when discussing the management of replacement pullets and layers. Second, everyone seems to have their own ideas about lighting, length of light, type and intensity of light, economies of restricted lighting, and many other intricacies and avenues of the effect of increased lighting on the pullet and eventually the laying hen. Third, the literature is so vast on the subject that to do credit to everyone concerned would require a paper the length of which would be difficult for the audience to long endure. During the search for literature, it was found that no less than 206 scientific publications have been published since 1954. This does not take into consideration the number of magazine articles and reviews of restricted lighting in many of the trade papers.

Introduction

Artificial light for laying hens has been used by commercial poultrymen in the United States and Canada for the last 43 years; and there are indications that the practice may have been tried by one or two on an experimental basis as long as 60 years ago. Since kerosene and gasoline lanterns or farm electric plants were the chief source of light on a great many farms prior to rural electrification, the majority of poultrymen were working under a severe handicap when trying to provide artificial light. The advent of fan-ventilated windowless houses greatly broadened the possibilities of growing pullets for market egg production under less than normal daylight. Callenbach and co-workers (1) indicated that sexual maturity was not advanced by a constant 24-hour lighting program during the growing period.

Investigators through the years have provided conclusive evidence demonstrating that the anterior pituitary gland plays a dominant role in the gonadal response to light (2, 3). The most widely supported theory regarding the manner in which light affects this gland is as follows:

$$\text{light} \longrightarrow \text{eye} \xrightarrow{\text{optic nerve}} \text{brain} \xrightarrow{\text{impulses}} \text{hypothalamus} \xrightarrow{\text{portal blood vessels}} \text{PITUITARY}$$

The Effect of Light Intensity of Egg Production

Brown and Smith (4) compared hens receiving a constant 15 hours of light with hens receiving natural daylight. The intensities of artificial light ranged from 1/2 to 15 foot-candles. The increase

in egg production and labor income from hens for a 60-week production period were highly significant for the lighted hens. There was no significant difference in production or income between pens with different light intensities of the supplemental lighting.

Other studies (5, 6) have demonstrated that varying intensities of light from 1 to 31.3 foot-candles had no significant effect on egg production. The minimum light requirement for egg production was established at 1 foot-candle from the results of these tests.

Cornell scientists (7) tested 60 and 100-watt incandescent bulbs, fluorescent lights, photo-cell automatic light controls and incandescent red lamps. The 147-day test yielded 93 eggs per bird under 60-watt lights. There was no increase in production when 100-watt bulbs were used. Egg production was 81 eggs per bird in pens using fluorescent lighting, 8% below the eggs produced under 60-watt incandescent bulbs. The investigators stated that fluorescent lights would be more efficient if the temperature in the house stayed at a constant of 80°F. all year. The temperature in houses, however, fluctuates between 40° and 90°F., as the temperature decreases, the fluorescent lights become more inefficient. At 40°F., fluorescent lights give no more light than incandescent lamps and cost 10 times as much to install. The predominately blue light in fluorescent lights may reduce egg production, the Cornell workers stated.

Using a photo-cell to "click" on lights on a cloudy day only slightly increased production. It was decided that the cost of the photo-cell is not justified. Red incandescent (60-watt) lamps gave the same amount of stimulation as regular 60-watt white bulbs.

Weber (8) used the new technique of "flash-lighting" and received encouraging results. Two 20-second flashes of high intensity light (1500-watts) in addition to natural day light were administered at 4:00 A.M. and 4:45 A.M. daily. Several other investigators supported this previous experiment (9, 10, 11).

Effect of the Total Length of Light and Dark Periods in Egg Production

Though the literature is scant in work reporting the effect of the total length of the light and dark period on egg production, several excellent papers deserve to be cited. Byerly and Moore (12) subjected birds to alternate light and dark periods totaling 26 hours in an attempt to increase clutch-length. Five hens, which received 14 hours of light and 12 hours of darkness during a previous experiment were placed on a 24-hour day (14 hours light, 10 hours darkness). Nine other hens of the same breed were placed on a 26-hour day (14 hours light, 12 hours darkness). The 26-hour day hens increased the average clutch-length and hen-day production when calculated on a 24-hour basis. A test period of 8 weeks gave the following results:

Yearling Hens:	Average Clutch-Length*	% Egg Production 24-hour Basis
Natural day light	2.10	44.6
14 hours light, 10 hours darkness	1.83	43.5
14 hours light, 12 hours darkness	5.14	63.6
Pullets:		
14 hours light, 10 hours darkness	2.04	64.8
14 hours light, 12 hours darkness	5.42	83.6

* Number of eggs laid on successive treatment-days, separated from other clutches by one or more days during which no egg was laid.

They suggested that the increase was due to the birds receiving adequate rest periods with the use of the 26-hour day.

In a thorough study, Biellier and Ostmann (13) stated that layers placed on a 23-hour day (laying at peak production and producing an egg, in an interval less than 24 hours) could be identified and therefore used in genetic selection to decrease the interval in egg formation or increase the rate of lay.

Caged hens (14) were subjected to day periods ranging from 21 to 42 hours. Each day period consisted of one-half artificial light and one-half total darkness for the two-week intervals. The most desirable day length for maintaining top egg production was somewhere between 24 and 27 hours, at least, for the breeding and laying ability of hens used in the trial. Day lengths of less than 24 hours had the effect of shortening the egg clutch and increasing the number of days skipped in egg production between clutches. Day lengths from 26 to 32 hours caused the oviposition to occur in the period of darkness.

Effect of Hours of Light Per Day on Egg Production

A period of 12 to 14 hours of light per day was recommended as early as 1920 for maximum egg production (15).

Kennard and Chamberlin (16) observed that continuous light was more effective than either natural light or natural light plus morning lights beginning at 4:00 A.M. One 10 to 15-watt lamp per 400 square feet of floor space proved to be satisfactory.

Dobie et al (17) performed extensive studies on the optimum amount of light for layers. They concluded that 13 hours of incandescent light were required to attain maximum production from high-producing hens. When they varied the light from 13 to 19 hours per day, egg production was not increased enough to warrant recommendations.

In experiments with quail (18) 9 hours of light with a 1-hour interruption during the dark period resulted in full sexual activity.

When the light was given continuously, there was no response.

In an experiment using intermittent lighting, Wilson and Abplanalp (19) gave one group of hens 1 minute of light, and 3 hours and 59 minutes of darkness 6 times daily: thus the pullets received 6 minutes of light evenly spaced throughout the 24 hours. A control group of pullets on 14 hours of light and 10 hours of darkness produced slightly more eggs (70.0%) than the intermittent-lighted birds (69.8). Pullets receiving 24 hours of continuous light attained a production of 66.9 per cent.

An interesting paper from the same institution (20) tested the production of hens remaining in continuous darkness for 5 weeks. Some hens did cease egg production, while others previously pausing, started to lay. In fact, some individual birds laid from 60.2 per cent and 77.1 per cent, respectively, in two different tests. The investigators concluded that the hen does not need light for either ovulation or oviposition.

All night lights increased average lay per hen by 4.4 eggs during a year-long Connecticut egg laying test (21). The most significant result was that slightly more than three-quarters of the production increase came during the first 12 weeks, when each hen averaged 3.8 more eggs than did her sisters on a 14-hour light schedule. After the first 12 weeks, production under the two systems became more or less equal.

The term "Stimulighting" was given birth by King (22) in 1958. In this system the chicks were restricted to 6 hours of artificial light each day from 0-20 weeks of age. After the birds entered the laying house the light was increased by 18 minutes per week. At the end of King's experiment the hens were receiving 21 hours and 36 minutes of light each 24 hours. The "stimulighted" pullets laid 270 eggs per pullet, compared with 215 eggs per pullet raised on 12 hours of light for the first 5 months and 14 hours of light per 24 hours during the remainder of the laying year.

Month	Pen Receiving "Normal" Light, %	Two Pens On "Stimulight" Program, %	
July	48	53	65
August	75	75	75
September	77	71	61
October	68	79	87
November	61	80	88
December	59	79	74
January	59	78	83
February	57	72	80
March	57	75	75
April	54	77	74
May	47	65	71
June	43	64	72
Total Eggs per Hen	215	264	275

Under farm conditions (23) "stimulighted" pullets produced 236 eggs while 209 eggs were produced by control birds.

Since King initiated his system, several other modifications have been developed. Some examples are presented as follows:

1. King's: Six hours of light from 0-20 weeks, then increase light 18 minutes per week.

2. Short day growing: Six hours of light from 0-20 weeks, then 14 hours light for laying period.

3. Step-down, step-up: Start chicks on 17 to 23 hours of light; reduce 20 minutes per week for 22 weeks; then increase 15 minutes per week during laying period.

All of these lighting systems have merit. Dale King's is ideal for windowless houses, or window-covered houses. The step-down, step-up system is most adaptable for open poultry houses.

Lawatsch and co-workers (24) conducted two experiments on successive years using caged layers on the "stimulight" program. One group received 6 hours of light until 20 weeks of age while the other group remained on 14 hours of light and 10 hours of darkness. The results indicated:

1. When light is restricted to 6 hours per day the pullets were 5.28% lighter in body weight at 20 weeks of age. However, when the light was increased weekly in the laying house, the pullets that were restricted gained 5% more weight during the laying year than the conventionally-lighted birds.

2. Feed consumption on a per bird basis was the same for both groups.

3. Average egg weight on any given day for the two groups was the same.

4. There was no difference in egg quality between the two groups.

5. Hours of light provided on the "stimulighting" plan for a 12 month period amounted to 99.3% of the total needed to supply a straight 14 hour day.

6. Stimulighted birds, Experiment 1, laid 6.5% more eggs and consumed 0.32 pounds less feed per dozen eggs than the "normal" lighted birds. Pounds of feed consumed per bird laying per year amounted to 90.59 for the birds receiving 14 hours of light and 93.57 for the stimulighted birds.

7. On a 1000-bird basis the stimulighted birds provided greater income over feed cost, electricity and cost of chicks.

This experimental work is presented in Tables 1, 2 and 3.

In more recent work (25) 10,000 pullets were restricted in their feed to 80% of the normal amount daily consumed by pullets during the growing period (8-20 weeks of age). These pullets were also restricted to 6 hours of light and 18 hours of darkness per day. The double restriction (light and feed) retarded maturity at such a rate that the pullets did not reach 50% production until their 33rd week of life. A period of 12 weeks without appreciable production is not desirable, therefore, double restriction can not be recommended. The results of a paper by Berg (26) demonstrates that restricted light exerted more influence on sexual maturity than restricted feed.

Modification of Stimulighting With High Density Poultry Houses

High density windowless housing (hens in layer house at 3/4 square foot per bird) has embraced the stimulighting system. The King stimulighting schedule was adhered to at the Cargill-Nutrena Research Farm until it became obvious that some modifications had to be made. Birds placed in the all-slatted floor layer house at 21 weeks of age formerly received 6 hours and 18 minutes of light for the first week with an increase of 18 minutes per week for the entire laying year. Due to the presence of a vast society (520 birds per pen), many birds were found to be timid and this with a lack of maturity presented a problem of unevenness in size that lasted for many weeks after housing. The present lighting program finds that the period of light is increased 1/2 hour per week beginning with the 17th week of life making a total of 8 hours of light by the 20th week.

Once the layers are in the laying house, their light is again increased by 1/2 hour per week until a 14-hour day of light is reached. The birds are allowed to peak in production and decline approximately 10% before increasing the period of light further. This is accomplished by increasing the light by 1/2 hour periods for 4 weeks until a light period of 16 hours is attained. At 16 hours the birds remain until the completion of the laying year. The reasoning behing this schedule is as follows: The "Hi-Density" system is practically automatic consisting of feeders, waterers, nests, egg belt, collection table, etc. Not least among these automatic gadgets is a nest "close-out" device which by the pressure of air (regulated by a time clock) gently pushes the birds out of the nests about 30 minutes before the lights are turned off for the night. It was diagnosed that as the period of light was increased above 17-18 hours, the more the birds laid toward evening, eventually requiring the night man to collect many eggs. As the birds laid more toward evening and the hours of darkness decreased the floor egg rate was increased, as many eggs were laid during the 30 minutes that the nests were closed before complete darkness. The birds also were found to lay some eggs during the period of darkness, particularly when the hours of light approached 19. Stopping at 16 hours of light has helped to prevent this from occurring.

There are many conflicting reports to stimulighting and/or controlled lighting of layers. There are many questions as yet to be answered under various conditions of density, type of floor, nest-proximity, nutrition, environment and temperature. I have tried to present some of the existing literature and hope that it has encouraged some ideas for future investigations.

Table 1. Egg and Body Weights - Egg Quality

Item	Conventional Lights	Stimulighting
Date of First Egg	July 28, 1958	August 8, 1958
Age of Pullet at First Egg	20 wks. 5 days	22 wks. 2 days
Date of 10% Production	August 11, 1958	August 19, 1958
Average Egg Weight Aug. 30, 1958 (Pullets 25 weeks of age)	50 grams	50 grams
Average Haugh Units (at end of test)	81.6	82.0
Initial Body Weight, July 23, 1958 (20 weeks of age)	3.22 lbs	3.05 lbs.
Final Body Weight, July 22, 1959 (72 weeks of age)	4.91 lbs.	5.05 lbs.
Average Body Weight Gain	1.69 lbs.	2.00 lbs.

Table 2. Lighting (12 months of lay)

	Conventional	Stimulighting
No. of bulbs/1000 hens	24	24
No. of watts/bulb	40	40
No. of watts/1000 hens	960	960
Total hours of light/year	5,110.0	5,077.8
Total No. of kilowatt hours	4,905.6	4,874.7
Cost of light/yr. @ 2 1/2 ¢/kwt.	$110.38	$109.68

Table 3. Mortality, Egg Production and Feed Consumption

	Conventional	Stimulighting
No. of birds started	185	206
No. of birds completing test	168	181
Per cent mortality	9.19	12.14
No. of small eggs per cent of total eggs	3.20	0.47
No. of medium eggs per cent of total eggs	12.06	6.62
Per cent production (Hen-day)	62.5	69.0
No. eggs per bird (Hen-day)	228.	251.
No. eggs per bird (Hen-Housed)	218.	240.
Pounds feed per dozen eggs	4.98	4.66
Pounds feed per bird (Hen-day)	94.5	97.6
Pounds feed per bird (Hen-housed)	90.6	93.6

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PROTEIN-ENERGY RELATIONSHIPS IN RATIONS OF GROWING SWINE

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The addition of fat to animal diets to increase caloric density has been investigated periodically and practiced to some extent for at least a quarter of a century. In an early work, Robison (1943) reported that additions of corn oil or coconut oil to provide rations containing 8.7% of fat resulted in more rapid and efficient gains of growing swine. It was cautioned, however, that not much more softening fat than was present in corn could be fed without deleterious effects upon the carcass.

At least two developments since World War II have contributed to an increase in our interest in the use of fats to increase the caloric density of rations for swine as well as poultry: (1) the relatively low cost of fats per unit of energy, and (2) the successful development of antioxidants so that rations containing added fat can be stored at room temperature without becoming rancid. Several questions arise regarding the use of fats in rations of growing swine: (1) if pigs eat to satisfy energy requirements and not within anatomical limits must the protein content of the ration be increased, (2) will the feeding of fats, particularly those high in unsaturated fatty acids, result in deleterious effects upon the carcass, (3) will swine fed high energy rations simply become overfat and yield undesirable carcasses, and (4) if the proper amount and ratio of essential amino acids is maintained at all stages of the growing period will swine fed high energy diets simply develop more rapidly without becoming overfat? Williams et al (1954) as a result of their studies on amino acid analysis of tissues of pigs of various ages suggested that for optimum protein utilization a similar ratio of amino acids may be necessary throughout the growing period.

Several investigations have been conducted in which the energy content of diets fed to growing swine was increased by addition of fats but where no attempt was made to maintain a constant ratio of amino acids (protein quality) in all diets. Hillier (1950) reported a series of experiments in which rations containing 2, 4, 8 or 12% lard or 2 or 12% tallow and containing 18% protein were fed until the pigs weighed 160 lbs. and 14% thereafter and until the pigs weighed 225 lbs. Average daily gains increased from 1.73 to 1.90 lb. and therms of gross energy required per pound of gain decreased from 5.58 to 5.38 as the lard content of the rations increased from 2 to 12% Average backfat thickness and percentage lean cuts of carcass did not appear to be closely related to level of dietary lard. However, carcasses from pigs fed rations containing 12% lard had 0.19 in. more backfat and yielded 2.35% less lean cuts of carcass than did carcasses from pigs fed rations containing 2% of lard. Similar differences in carcass measurements resulted due to the two different levels of tallow and the pigs fed the rations containing the higher level of tallow gained 5.8% more rapidly on 9.5% less gross energy than did those fed rations containing 2% of tallow. Perry et al (1954) substituted 1 to 10% of lard for corn in rations for growing-fattening swine and reported no beneficial effect upon rate of gain but an improvement in efficiency of conversion of feed to gain. Kropf et al (1954) reported similar findings when 0, 10 or 15% of raw ground waste beef fat was included in rations containing 16% of protein. They found little effect of fat additions on backfat thickness or carcass grades. Barrick et al (1954) included 10% of beef fat or 10% of brown grease in rations containing 16% of protein and found an improvement in rate of gain, a reduction in feed required per unit of gain and a tendency toward greater backfat thickness due to fat inclusions. Anderson et al (1957) replaced corn in a corn-soybean meal basal ration with either 2.5, 5.0, 8.0 or 10% of tallow or 10% of lard. They reported that with the exception of the lowest level each level of supplemental fat consistently increased liveweight gains and decreased feed required per unit of gain. Both rations containing 10% of added fat resulted in increased backfat thickness while the other levels of supplemental tallow had little effect on thickness of backfat. Heitman (1956) reported the results of three trials in which rations containing 5 or 10% stabilized renderers tallow or 10% stabilized lard were used. Additions of tallow resulted in significant increases in weight gain while the addition of 10% of lard was without effect. The use of high-fat rations resulted in significant increases in backfat thickness but the author indicated that the increases were no greater than would have been expected due to increases in weight. The pigs in each test were on test for the same number of days. In two of the three trials efficiency of feed utilization was improved as a result of tallow and lard additions but the improvement was no greater than would have been anticipated because of the increased T. D. N. content of the diets.

Sewell et al (1958) reported that the addition of 0, 5 or 10% of tallow to 18% protein rations fed to pigs during the period from 40 to 180 lbs. resulted in increased efficiency of gain and significant increases in gain. Thrasher et al (1959) added 5 and 10% of a grease, tallow or lard to isonitrogenous rations for growing swine. Significant increases in gain were reported due to each addition of fat and improvements of 11 and 21%, respectively, in

efficiency of feed utilization resulted from additions of 5 and 10% of fat. Although backfat thickness and fat trim tended to increase with level of supplemental fat they found no significant effect of level of source of fat on these measurements. In a subsequent study, Thrasher et al (1960) used rations containing 18, 15 or 12% of protein, reduced by 2% when pigs weighed 100 lbs., and containing 0 or 10% of tallow. Tallow additions were reported to produce highly significant increases in rate of gain of gilts but not of barrows, resulted in 15 to 23% improvement in efficiency of feed utilization and increased backfat thickness without having a significant effect on other measurements of carcass leanness. They found that feeding of rations containing 12% of protein initially resulted in 22% slower gains, a highly significant increase in backfat thickness and highly significant reductions in loin eye area and percentage of the lean cuts. There were no significant differences in carcass measurements of pigs fed rations containing 18 and 15% of protein initially Noland and Scott (1960) used corn-soybean meal type rations containing 12, 16 and 20% of protein and 950, 1050 and 1200 Kcal. of productive energy per pound. Energy levels of rations were adjusted by use of ground rice hulls and stabilized animal fat. Increases in energy content of the ration containing 12% of protein resulted in depressions of gain during the period from weaning to 75 lbs However, pigs fed rations containing 12% of protein and 1200 Kcal. of productive energy gained most rapidly from 125 to 200 lbs. These workers concluded that the relationship between rate of gain and calorie-protein ratio varied with weight. The highest level of energy resulted in the greatest backfat thickness regardless of protein content of the diet but a positive relationship between energy level and backfat thickness resulted only with rations containing 12% of protein. These results and those of Thrasher et al (1960) may indicate that high energy rations containing inadequate protein, perhaps an improper ratio of the essential amino acids, result in depressed rate of gain particularly during the early stages of development and carcasses that are overfat because the pigs gain very rapidly after they reach weights of 100 to 125 lbs. Boenker (1960) reported that increases in energy content of the diet without increases in protein content of the diet resulted in significant increases in backfat thickness. Mitchell and Hamilton (1935) working with rats demonstrated the necessity for an upward adjustment in protein content of the diet in relation to total energy to realize full benefit from the increased energy in the diet.

Brooks and Thomas (1959) fed 15% protein rations containing 0, 4, 8 or 12% of lard and reported slightly increased T. D. N. requirement per unit of gain and no significant effect on liveweight gains. In another trial they fed rations containing 14 or 16% of protein and 0 or 10% of fat and found a slight improvement in efficiency of utilization of T. D. N. for gain and significant increases in rate of gain due to added fat but no effect of protein level on either measure of performance. They also fed rations providing protein sequences of 18-15-12, 16-13-10 and 14-11-9% of protein with changes being made to the intermediate and lowest levels of protein when the pigs reached weights of 75 and 125 lbs., respectively. These rations were fed with 0 or 6% of lard. Their findings were that addition of lard resulted in an improvement in efficiency of utilization of T. D. N. as well as increased gains. However, the differences were significant only within the lowest protein level sequence Protein level was without significant effect on liveweight gains or efficiency of T. D. N. utilization. Their conclusions differ somewhat from those implied or drawn immediately above in that they indicated protein need, expressed as a per cent of the diet, to be constant and independent of dietary energy.

Abernathy et al (1958) fed 14 and 18% protein rations containing 0, 5 or 10% of tallow to pigs during the period from 40 to 190 lbs. They found that increasing the tallow content of the rations resulted in a highly significant linear increase in liveweight gains throughout the test. Neither protein level nor energy content of the diet had a significant effect on live-probe backfat measurements, but there appeared to be a trend toward increased backfat thickness with increasing level of dietary tallow. Kennington et al (1958) fed rations containing 14 to 20% of protein and 0 to 20% of lard to pigs during the period from 30 to 135 lbs. Significant linear increases in daily gains and backfat thickness resulted with increasing levels of lard, and efficiency of feed utilization was improved due to lard additions. Calorie-protein ratios and protein contents of the diets were without significant effect upon any of these measurements. Pond et al (1960) used 12 and 20% protein rations containing 0 and 10% tallow. Feeding the higher protein rations to growing pigs during the period from weaning to 200 lbs. resulted in highly significant increases in rate of gain, protein required per unit of gain and in efficiency of utilization of T. D. N. for gain. Only with the high protein ration did the use of tallow result in a highly significant increase in rate of gain. Backfat thickness increased slightly as a result of the inclusion of tallow in the ration but efficiency of utilization of protein for gain was improved significantly. These workers used rations containing 16% protein until the pigs reached weights of 150 lbs., and 12% thereafter in a second test for comparison with the high protein ration containing 0 or 10% of tallow. The only significant difference found between rations was that of increased daily gain due to the addition of tallow. Rupnow and Ensminger (1961) reported that the addition of 10% fat to rations for growing swine resulted in a reduction in amount of feed required per unit of gain but was without significant effect upon percentage lean

cuts of carcass, loin eye area, backfat thickness, fat trim and tenderness of the lean.

Clark et al (1961) reported the results of 3 experiments in which they increased the productive energy level from 950 to 1170 Kcal./lb. and used rations containing 13, 19 or 25% of protein; increased the metabolizable energy level from 1310 to 1640 Kcal./lb. and used 13, 19 and 25% protein rations; and, increased the metabolizable energy level from 1290 to 1730 Kcal./lb. using rations containing 18, 15 and 12% of protein. Generally, they found that increasing the energy level in rations increased backfat thickness, increased intramuscular fat and decreased the yield of lean cuts. Increasing level of)protein decreased backfat thickness and increased yield of lean cuts, and in two of the studies decreased intramuscular fat. They also reported that supplementation with 0.1% of DL-methionine and 0.1% of L-lysine did not appreciably affect backfat thickness or percentage of lean cuts although there was a significant interaction of protein, energy and amino acids on backfat and percentage lean cuts. It appears that the wide range of protein levels used in these studies must be recognized and that improvements resulting due to wide differences in protein level may not reflect themselves in sufficiently improved carcass quality that the feeding of more protein than is generally recommended will improve economics of production. Nickelson et al (1961) studied the effect of varying the dietary calorie-protein ratio for pigs during the period from 100 to 200 lbs. Increasing the caloric density of the rations by the addition of lard had little effect upon daily caloric intake but did reduce caloric requirement per unit of gain and adversely affected carcass merit. Carcass quality as measured by specific gravity and backfat thickness was improved as a result of narrowing the calorie-protein ratio by increasing the protein content of the rations from 12 to 18% in the presence and absence of 15% added lard. Diets containing no more than 125 Kcal. per per cent of protein were reported to produce the most satisfactory carcasses, and rate and efficiency of gain.

Clawson et al (1962) reported a comprehensive study in which they studied the effects of fat level and calorie-protein ratio on rate and efficiency of gain of growing swine as well as upon carcass characteristics. They fed rations containing 0, 5 or 10% of stabilized yellow grease, substituting the fat for cerelose and also varying cerelose levels in the rations so that each diet contained amino acids in the same ratio as that of the 18% protein diet. Diets containing 10 to 18% of protein were utilized. Substitution of animal fat for cerelose resulted in a significant reduction in daily feed intake without significantly affecting the gross energy intake of pigs fed diets of higher energy intake. It is interesting that even those pigs fed diets containing as low as 10, 11 and 12%

of protein made satisfactory gains (1.85 lb. daily) although they did gain approximately 3 to 5% more slowly than did pigs fed rations containing more protein. Efficiency of feed utilization was not markedly affected even at these low protein levels perhaps indicating that balance and supply of essential amino acids were nearly optimum. In this experiment approximately 70% of the total protein was supplied by soybean meal (50%). Energy-protein ratio also influenced daily feed consumption, but not gross energy intake. Those pigs fed rations of the intermediate calorie-protein ratio, i.e., 31 vs. 26 or 38 and containing 13, 14 and 15% of protein, consistently consumed the largest amount of total feed. Rate of gain was significantly increased for the entire growing period (38 to 200 lbs.) and a significant interaction existed between fat level and energy-protein ratio. A greater stimulation in gain resulted from fat additions at narrow energy-protein ratios (protein levels of 16, 17 and 18%) than at the widest energy-protein ratio. The authors suggest that the addition of fat aggravates a protein deficiency in pigs fed low protein rations by causing a reduction in feed intake. Several workers (Barnes et al, 1959; Clawson, 1960; Lowrey et al, 1958) have reported that the addition of 10% of animal fat to 10% protein rations but not to 16 or 18% protein rations caused a depression in growth rate. Clawson (1960) overcame this depression by increasing the proportion of protein supplied by soybean meal from 25 to 50% which would have materially altered the essential amino acid content of the rations.

Clawson et al (1962) also obtained information on the influence of fat content of the diet, percentage of dietary protein and energy-protein ratio on digestibility of ration components. They reported that apparent digestibility of protein was not significantly affected by either energy-protein ratio or level of added fat. Digestibility of ether extract was not affected by energy-protein ratio but increased significantly with additions of fat to the ration. Digestibility of dry matter and nitrogen free extract increased significantly with increases in the energy-protein ratio and decreased as a result of adding fat to the ration. This may have been the result of the nature of the ration as rations with higher energy-protein ratios contained increased amounts of corn suger which may have been more highly digestible than other ration components. In contrast to these findings concerning effects of fat additions on digestibility of protein, Lowrey et al (1958) and Clawson et al (1959) reported that protein digestibility was improved as a result of the addition of fat to swine diets.

It is of interest to know the influence upon carcass characteristics of fat additions to the ration when different calorie-protein ratios are used. Clawson et al (1962) also obtained carcass data on

pigs used in their investigations. Average backfat thickness, loin eye area (cross sectional area of the longissimus dorsi muscle at the 10th rib), percentage 4 lean cuts of carcass and chemical characteristics were not influenced significantly by energy-protein ratio or by fat additions to the rations. The authors suggest "this might be the expected result if total protein intake was adequate because of the relative ratio of amino acids available from protein synthesis in the body was held constant." It is again emphasized that these workers accomplished a constant ratio of amino acids regardless of protein content of the diet by using a fixed ratio of yellow corn to soybean meal (50%), and that their having provided approximately 70% of the total protein in all rations from soybean meal provided substantial amounts of the critical amino acids (lysine, methioning + cystine and tryptophan) even in the low protein rations.

Greeley (1961) fed 16% protein rations containing 0, 5, 10 or 15% of stabilized lard, stabilized animal tallow or crude corn oil to growing pigs. Daily gains were depressed significantly due to the addition of corn oil, but were not significantly increased by either of the other sources of supplemental fat or by increasing levels of fat. This is in contrast to the findings of Kennington et al (1958), Gesler et al (1957) and other workers who have reported that the addition of 5 or 15% of animal fat promoted more rapid gains of growing swine during the period from 50 to 120 lbs. In this study, daily dry matter consumption was not affected significantly by source or level of supplemental fat which result is in disagreement with those of Boenker (1960) and Kennington et al (1958). However, this initial study of Greeley (1961) was conducted over only a short period which may have obviated the opportunity to obtain a true expression of treatment effects upon the various measures of performance. Subsequently, he individually fed rations containing approximately 13, 15, 17 and 19% of protein and 0, 4, 8 and 12% of stabilized animal tallow to 16 groups of 3 pigs each over an 8 week period. Within each level of protein the digestible energy values (Kcal./lb.) ranged as follows: 1209-1284, 1342-1432, 1494-1588, and 1657-1744. The ratio of amino acids was held constant in all rations by using fixed proportions of ground yellow corn and soybean meal (44%). Quantities of corn starch and/or ground oat hulls were adjusted as different increments of tallow were included in the ration in an attempt to maintain the energy contents of rations within narrow ranges. Pigs were kept on the assigned experimental rations for the duration of the study and were fed to limit of appetite. Highly significant increases in adjusted final weights, daily digestible energy intake, gain per lb. of dry matter consumed and gain per lb. of digestible protein consumed resulted with increasing levels of tallow in the rations. Level of dietary protein was without significant effect upon any of these performance criteria with exception of a highly significant increase in gain per lb. of digestible protein consumed resulting with decreasing protein content of the diet. It is interesting that the growing pigs used in this study (initial wt., 41.5 lbs.) gained as rapidly on the lowest as on the higher protein levels. As pointed out by Clawson et al (1962) this may have been the result of the lowest protein diet still furnishing adequate amounts of the essential amino acids in the proper proportion to meet the needs of the young rapidly growing pig. Approximately 60% of the total protein in all rations was supplied by soybean meal (44%) thus assuring substantial quantities of the essential amino acids, particularly lysine. The inability of low protein rations possibly not containing adequate amounts of amino acids, or not having the amino acids, or not having the amino acids in the proper proportion to support rapid gains, has been demonstrated by Lowrey et al (1958) who added 10% of fat to 13% protein rations, Clawson et al (1959) who added 10% of animal fat to 12% protein rations, and Noland and Scott (1960) using increasing energy levels in rations containing 13% of protein. All of these workers reported decreases in gain with increases in energy content of the ration. Greeley (1961), like Kennington et al (1958), Boenker et al (1960) and Clawson et al (1959) was unable to demonstrate a significant effect of calorie-protein ratio upon pig gains.

Greeley (1961) also determined digestibility coefficients for some ration components by use of the chromic oxide indicator technique. Slight, but statistically significant, increases in apparent digestibility of protein and of energy resulted due to increasing protein content of the diet. Likewise, increasing the level of supplemental fat resulted in significant increases in digestion coefficients for protein, ether extract and energy. With exception of the digestion coefficients for ether extract which increased from 51.5% when the ration contained no added tallow to 82.0 when the ration contained 12% of tallow, the increases in digestibility of protein and energy due either to increasing protein content of the diet or increasing increments of tallow were so small as to be of minor economic significance.

In a subsequent study Greeley (1961) self-fed rations of the composition previously outlined to 16 groups of 5 pigs each, with all lots of pigs being fed the 13% protein ration after the initial 42 days of the study. The pigs averaged approximately 45 lbs. initially and were fed to final weights of approximately 200 lbs. Average daily gains during the entire trial were not improved as a result of feeding more than 13% of protein in the ration during the first 42 days of the trial. Those pigs fed the 13% protein ration during the entire trial consumed slightly, but significantly, more dry matter daily than did pigs fed rations containing the higher levels of protein during the initial 42 days. As would have been expected significantly greater daily gains per lb. of protein consumed resulted with the use of the lowest level of protein. The inclusion of increasing increments of tallow resulted in significant reductions in daily dry matter intake, and increases in gain per lb. dry matter consumed, per therm digestible energy consumed and per lb. of digestible protein consumed. Daily intake of digestible energy was approximately equal regardless of level of dietary tallow perhaps indicating that within anatomical limits pigs eat to satisfy energy need, which is in agreement with the suggestion of Boenker (1960).

Four pigs (2 barrows and 2 gilts) were slaughtered from each of the 16 lots used in this study. Increasing the amount of dietary protein did not result in significant changes in carcass length, backfat thickness, loin eye area, or per cent trimmed ham and loin, or four lean cuts (ham, loin, picnic and boston butt), of slaughter weight of the pigs. Similarly, the use of increasing increments of tallow did not result in significant differences in these carcass characteristics between levels of tallow. However, there was a significant linear increase in backfat thickness with increasing increments of tallow. It appears that all rations contained adequate protein, essential amino acids, to promote maximum lean tissue, muscular development at all stages of growth even when rations containing more fat were causing slight increases in backfat thickness. A significant protein level x supplemental fat level interaction upon any of the carcass characteristics studied was not obtained.

In a recent study, Meade (1962) fed growing pigs corn-soybean meal type rations containing approximately 15% protein until the pigs reached weights of 100 lbs., and 12% protein thereafter. One group of the pigs was self-fed the rations continuously, the self-feeder of the second group was blocked every 10th day, the feeder of the third group was blocked every 5th day, and the ration of the fourth group was diluted by the addition of 15% of ground oat hulls which would have resulted in a lower digestible energy content of the mixture as consumed but maintained approximately the same protein-digestible energy ratio. Average daily gains and lb. of feed required per hundred lb. of gain listed in the same order as treatments were, respectively: 1.81, 351; 1.75, 358; 1.68, 360; and 1.69, 420 (356 when oat hulls subtracted). Although daily gains tended to decrease as a result of blocking the feeders and bulking the ration, the differences were not significant, and differences in feed requirement per unit of gain were of small magnitude. It is interesting to note that pigs in lots for which feeders were blocked tended to "stuff" themselves on the day following opening of the feeders and that those pigs fed rations containing 15% of ground oat hulls consistently consumed more feed daily, apparently in an effort to satisfy their energy need. The averages for backfat thickness (in.), loin eye area (sq. in.), and per cent ham and loin of slaughter weight again listed in order of treatments were, respectively: 1.68, 3.96, 26.4; 1.70, 3.80, 25.3; 1.80, 3.66, 24.8; and 1.63, 3.88, 25.8. Although backfat thickness tended to increase and loin eye area to decrease with shortness of interval for blocking the self-feeder the differences were not statistically significant. Blocking of the feeder every fifth day resulted in a highly significant decrease in percentage of trimmed ham and loin compared to all other treatments; blocking of the feeder every tenth day resulted in a significantly lower percentage of trimmed ham and loin than resulted with continuous feeding of either the corn-soybean meal type ration or the same ration diluted with 15% of ground oat hulls. Perhaps the tendency of the pigs to which feed intake was restricted periodically to "stuff" resulted in their having a gross oversupply of energy following increased consumption of feed to the extent that they simply developed a higher ratio of fat to lean. Apparently including 15% of ground oats in the ration did not sufficiently restrict digestible energy intake to result in substantial improvement in the carcass.

Summary

The following statements appear to be justified on the basis of the above review:

1. The addition of fat (lard, stabilized animal tallow, etc.) to rations adequate in protein, essential amino acids, does not consistently result in more rapid and efficient gains.

2. The addition of fat to rations that contain inadequate protein, or an improper balance of amino acids, results in depressed gains as well as an increase in backfat thickness and trimmable fat.

3. When 4 to 12% of fat is included in rations that are adequate in total protein, and contain the proper proportion of the essential amino acids:

   a. daily gain is increased or is not affected.

   b. less dry matter is required per unit of gain.

   c. digestible energy required per unit of gain is decreased or not affected.

   d. differences in loin eye area and percentage ham, or lean cuts, of carcass or slaughter weight will be small if encountered.

   e. backfat thickness may tend to increase with increasing levels of fat, but without accompanying deleterious changes in loin eye area, or yield of trimmed lean cuts.

   f. daily feed intake will decrease and within anatomical limits pigs will consume feed to satisfy energy need.

4. The total supply, and proportion, of essential amino acids is a more important consideration than is the percentage of protein in the diet. When rations contained adequate amino acids in the proper proportion pigs weighing 38 to 45 lbs. gained rapidly and efficiently when the total supply of protein ranged from 10 to 13%, but when attention was not given to the ratio of amino acids (protein quality) gains were depressed and hogs were fatter at slaughter weight.

5. The use of fats in swine rations appears to be a questionable practice, particularly in rations that are not properly balanced with respect to amino acids, in that more rapid and efficient gains if obtained can in many instances be more than offset by the deleterious effects of the added energy upon carcass characteristics. The addition of small amounts of fats may be justified from the standpoint of improving appearance of the feed, improving pelleting characteristics and in reducing wear and tear on milling machinery.

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PASTURE AND FEED-LOT BLOAT -- A BRIEF REVIEW

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Bloat is sometimes classified as an insidious disease, though today much is known about causative factors and prophylactic measures. Bloat is a digestive disorder of ruminants characterized by an inability to dispel or eructate gas from the rumen as fast as it forms. It is becoming clear that animal factors and dietary factors are both concerned when an animal bloats. Cole and Boda (1) have recently reviewed the work leading to a fuller understanding of attempts to control this disease that is estimated to cost the U. S. livestock industry 40-50 million dollars annually.

In the main, two specific types of rations most often are involved in bringing on bloat: lush legume pasture and prolonged heavy concentrate feeding in dry lots. Not every legume pasture or every heavy concentrate feeding regime causes bloat, however. Let us first consider pasture bloat.

The formation of a stable foam or froth in the rumen-reticulum is what causes trouble. In ordinary circumstances the fermentation gases formed in the rumen-reticulum are easily gotten rid of by belching. However, when the gas is caught up in a foam the reflex belching mechanism becomes relatively ineffective. One then might ask, what causes the foam to form? There is always a large quantity of gas being formed in the mass of feed and fluid in the rumen. It even appears that bloat-producing rations cause the release of greater quantities of gas over shorter periods of time than non-bloat rations, although it is a fact that the cow or sheep can eructate much larger quantities of gas than are normally formed if the belching mechanism is functioning normally. There are apparently several plant factors contributing to foam formation. It is felt that the protein from the cells of the growing legume plant contribute. It has been found by Boda, et al. (2) that fresh egg white can cause bloat. Further, the dehydration of bloat-producing alfalfa tops greatly reduces the incidence and severity of bloat compared to the fresh material (Boda, 3). It was hypothesized that the dehydration process denatured the cytoplasmic proteins. Bartley and Bassette (4) have strengthened this contention by finding that materials isolated from the foam from bloating cattle were protein in nature.

There have been several alfalfa saponins isolated and these are effective foam producing agents. Kansas State workers (5, 6, 7, 8) have investigated the effect of saliva, animal mucins and plant mucilages upon foam from isolated alfalfa saponin and upon animals made to bloat and found that each source of material was effective in reducing foaming, although saliva was most effective. This same group (9, 10, 11) has implicated rumen bacteria in the

bloat syndrome in that several strains of bacteria have been isolated from the rumen that break down salivary mucin. Furthermore, they showed that if the rumen was emptied and washed out, bloat was first seen in those cases inoculated with ingesta from bloated animals.

Recent work from Ohio (12, 13) indicated that plant pectin content in alfalfa was associated with bloat incidence. Alfalfa was also high in uronic acid which decarboxylated rapidly to release large quantities of carbon dioxide gas. There is good possibility that several other plant factors may be involved in causing bloat. Alfalfa juice when administered to animals at 10 per cent of their weight caused bloat but it was atypical (14). It was found that incidence of bloat from Ladino clover was not associated with a substance isolated from the clover (15) and which caused a decreased uptake of oxygen in certain tissues. This same study found no relation of bloat to saponin content of forage or to level of N, P, K, or Ca in clover.

Animals which bloat most often when put to pasture are different from those that do not bloat very often. The California group (16, 17) has found that bloaters produced less saliva with a higher concentration of bicarbonate ions. The rumen contents of such animals were higher in dry matter content and were less dense.

Pasture bloat can be controlled to a large extent by several means. Feeding of grass hay before turning out to pasture is effective, providing enough is consumed. The only carefully controlled work using grass hay has been from California. Work from that station indicated that Sudan (18) or oat hay (19) were effective against bloat from alfalfa pasture. Cole and Boda (1) outline several other means to control pasture bloat. Among these means are: planting grasses with legumes; spraying the pastures with one of several kinds of oil or fat; use of antibiotics or antifoaming agents in feed, water or salt; restrictive grazing such as strip grazing has also been effective. While all of the above are somewhat effective under specific conditions, they have not been effective enough to indicate that bloat is becoming a minor problem. Antibiotics lose their effectiveness after a period of days. Schemes of rotating and combining several antibiotics to prevent pasture bloat have been worked out by the Iowa workers (20). Use of oil or antifoaming agents to prevent bloat is limited to a few hours after they are ingested (21, 22, 23). Among the antibiotics used are penicillin, erythromycin, tylosin, chloramphenicol, oxytetracycline and streptomycin. It has been hypothesized that antibiotics are effective because they inhibit bacteria which attack plant chloroplasts which act as a defoaming agent in some manner.

Treatment of affected animals is by some of the same agents used prophylactically. Oils and other defoaming agents are effective if administered early enough (24). Such substances may be given via the mouth or if bloat is already quite serious by injecting directly into the rumen in the area of the paralumbar fossa. Often times it becomes necessary to perform a rumenotomy to save the animal.

Feed-lot bloat is in many ways similar to pasture bloat. Apparently foaminess is the main problem. In feed-lot bloat, however, many of the preventatives and treatments used for pasture bloat are not effective, e. g. soybean oil (24, 25). While it takes but a day or two to have pasture bloat, feed-lot bloat takes considerable time to become established as a problem and it then becomes progressively worse. Certain cattle have bloated 100 times or more before finally dying. Usually feed-lot bloat can be controlled by use of coarse fibrous feeds as hay or corn cobs. The literature indicates that beet pulp might also be effective in this regard.

Once feed-lot bloat has been established by a particular high-grain regime, it will be maintained even though considerably more roughage is added (27, 28). It was found that such bloat was brought on equally as well with corn or barley or long alfalfa hay or alfalfa meal. The Maryland Station has done considerable work on feed-lot bloat. A ration often used to induce bloat is as follows: 61 per cent ground barley, 22 per cent dehydrated alfalfa meal, 16 per cent soybean meal and 1 per cent salt (27). It was suggested that if means could be devised to induce the ruminant to drink more water, perhaps bloat might be overcome. Even though the Maryland group accomplished this by feeding various salt mixtures, the incidence or severity of bloat was not affected (29). It is thought that there may be a fundamental difference in the foaming agent(s) between feed-lot and pasture bloat. Evidence is accumulating that the causative agent in feed-lot bloat is a bacterial polysaccharide slime.

Though research in this area has become much more sophisticated by use of electronic gadgetry, there remains much to be learned about what causes foam formation at certain times with certain ruminants which in turn then bloat. Bloat is still a most serious problem and deserves continued effort on the part of workers in the animal sciences.

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A POSITIVE APPROACH TO FEEDING GRAIN FOR MILK PRODUCTION

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The heavier grain feeding concept as recommended in Michigan grew out of on-farm observations that many potentially high-producing dairy cows were underfed. (14)

Underfeeding Takes Many Forms, Sometimes Obscure.

Rarely does a man deliberately underfeed. It usually happens unwittingly through a variety of reasons that are not commonly recognized. Cattle voluntarily underfeed themselves when hay quality is not up to par (18) or when they must depend on high-moisture grass silage as a major source of nutrients (15). Very few dairymen adjust the level of grain feeding when forage quality changes. The forage-quality research indicates that 10 to 12 pounds of extra grain might be required just to cover up the differences in forage consumption and digestibility when different lots of forage are fed.

Milking parlors limit grain feeding according to the amount of time the cow is in the parlor. Most parlors have been designed for rapid and efficient milking but do not allow time for high-producing cows to eat sufficient grain (concentrates).

Studies (10, 28) indicate that an average cow can eat about 0.6 pounds of grain per minute in milking parlors (rate varies slightly with physical form of the feed), somewhat slower in a stanchion barn.

In practice, the daily intake is limited to approximately the amounts indicated in Table 1.

Table 1. Feed Consumption in Milking Parlors

Parlor Type	Eating Time in Minutes Per Milking	Grain Per Day Average Cow
Double 5 herringbone	14	16 lbs.
Double 3 walk-through	10	11 lbs.
3 U side-opening	7	8 lbs.
3-in-line side opening	8	9 lbs.

The better cows in the herd are most frequently underfed. Herds are constantly being upgraded by culling and using improved breeding stock. Currently some 50% of the dairy cattle in Michigan are bred artificially. This means that the production potential of the average dairy cow is considerably better than it was ten or twenty years ago. Today's better bred cattle require more energy to reach their full production potential, and maintain high levels of milk production, than most dairymen have been accustomed to feeding. When the level of feeding is limited, high-producing cows soon lose considerable body weight and then decline rapidly within six weeks or two months to a lower level of production that can be maintained by the level of feeding offered. It is during this early lactation period that liberal grain feeding is most essential.

Fear of causing udder congestion, mastitis, sterility, or "burning up" the cow caused some dairymen to limit grain feeding. Interestingly, these opinions are most apparent among dairymen who have not fed heavily. The availability of a thorough review of research (16, 17) on the subject helps to overcome these notions.

Grain prices are favorable for heavier grain feeding where grain is plentiful. The cost of 100 pounds of nutrients from grain (T. D. N.) is frequently as cheap as hay in the better grain-producing areas and may be nearly as cheap in grain deficient areas. Typical costs of T. D. N. from various sources in Michigan are shown in Table 2.

Table 2. Cost of Nutrients from Various Feeds in Michigan

	Yield/Acre Total	Yield/Acre T. D. N.	Cost/100 # T. D. N.
Alfalfa brome hay	3.6 T.	3,600	2.00
Hay crop silage	12.0 T.	4,000	1.92
Corn silage*	15.0 T.	6,000	1.25
Shelled Corn	75.0 bu.	3,360	2.08
Ear Corn	75.0 bu.	3,830	1.85
Oats	60.0 bu.	1,344	2.57

* Corn silage estimated at $75 per acre production and storage cost.

Recognizing that the above-mentioned problems do exist on farms is the first step toward accepting the concept of heavier concentrate feeding. In practice very few dairymen follow established feeding standards and these have only limited practical value. The move toward heavier concentrate feeding was simply an attempt to get Michigan's dairy cattle adequately fed to obtain the levels of production that improved breeding has made possible.

The significance of feeding heavier levels of concentrates under modern farm conditions was best demonstrated by the work of Charron (8). In this study of 442 paired cows on 48 farms, milk production was increased at the average rate of 2,031 lbs. per lactation when concentrates were increased to 2 lbs. per 100 lbs. of body weight. In a second study Charron (9) reported that 226 cows on 54 farms, fed all the grain they would consume when offered the regular roughage ration, increased milk production at the rate of 2462 lbs. per lactation. Milk production was increased at the rate of 2,000 lbs. or more on 64 per cent of the cows and 4,000 lbs. or more on 24 per cent of the cows. "In this study, the rate of response to higher grain was influenced by the stage of lactation when such feeding occurred. For each week after the first week fresh that added feeding was delayed, there was a seven per cent reduction in rate of response. This implies that the production challenge from feeding decreases as lactation progresses, and to be most effective, the challenge should occur early in the lactation" according to Charron (9).

Relationship of Level of Feeding to Level of Production and Return Above Feed Costs

Examination of Michigan Dairy Herd Improvement Association summaries for several recent years reveals a close relationship between the level of production, amount of concentrates fed, and return above feed cost. Selected levels of production from the 1961 summary are presented in Table 3 (20).

Table 3. Annual Summary of Holstein DHIA - IBM Herds - 1961 - Based on Average Milk Production (20)

Production Grouping (Milk)	Averages Per Cow					
	Pounds -Milk	Pounds B'Fat	Pounds Grain	Feed Cost $	Returns Over F. C. $	Feed Cost CWT. Milk $
16000 - Over	16630	598	4850	213	495	1.28
14000 - 14999	14424	523	4510	201	424	1.39
12000 - 12999	12462	452	3740	182	353	1.46
10000 - 10999	10544	384	3410	171	279	1.62
8000 - 8999	8589	316	2950	160	207	1.86
8000 - Under	7272	270	2200	143	160	1.97
ALL	11635	423	3610	177	322	1.52

These data strongly suggest that the amount of grain feed was an important factor in arriving at a given level of production. However, the influence of better breeding at the higher levels of production confounds the independent effects of higher levels of feeding. The influence of grain feeding on level of production is somewhat more clear when herds are grouped according to the amount of grain fed as in Table 4, but these data are also confounded by the effects of inheritance. In any system where groups are averaged, there is a tendency to hide the true differences due to the influence of overfeeding some poor individuals and underfeeding of others, as might be expected to occur under farm conditions. Thus, these tables demonstrate a tendency that could well be more pronounced with better refinement of the data.

Table 4. Relationship of Amount of Grain Fed Per Cow to Other Factors. Holstein Herds 1961 - Michigan DHIA (20)

Amount of Grain Fed Per Cow (lbs.)	Av. Production Milk (lbs.)	Av. Production B'Fat (lbs.)	Feed Cost Grain $	Feed Cost Total $	Returns Over Feed $	Returns Per $1.00 For Feed $
Under 2000	9887	358	41	148	269	2.82
2000 - 2499	9992	368	51	145	277	2.91
2500 - 2999	10802	393	61	158	305	2.93
3000 - 3499	11433	414	69	170	318	2.87
3500 - 3999	11955	415	78	178	335	2.88
4000 - 4499	12162	443	88	190	333	2.75
4500 - 4999	12506	455	99	202	337	2.67
Over 5000	12878	474	109	216	347	2.60

These tables also suggest that the "true" potential production of the lower producing herds is not known since these herds were not fed as heavily as the high-producing herds. From this kind of deduction one concludes that the only way to determine the potential production of a cow (or herd) is to challenge the cow by heavy feeding and measure the response in milk production. Thumb rules that feed "according to production" are unsatisfactory for establishing potential production since the level of feeding lags behind production and is dependent upon production rather than leading production as is done with challenge feeding. Thus, in a modern feeding program, cattle should be fed "for production" rather than "according to production." Then the level of feeding sets the pace for production to follow. Once the potential rate of production is established, grain feeding can be gradually adjusted accordingly to production to conform to economic considerations.

To illustrate the effect of level of feeding on the lactation record of the potentially good individual, consider the case of Cow A-14 in Table 5. This cow averaged nearly 17,000 lbs. of milk for the first three lactations listed when fed liberal amounts of grain averaging 4,960 lbs. per lactation. During the next lactation she was fed practically no grain and produced only 8,600 lbs. of milk. Should this be called a good cow or a poor cow? It would seem that the level of feeding had a lot of influence on the kind of cow she turned out to be. Apparently, the 4,800 lbs. extra grain produced about 8,300 lbs. more milk. If it could be agreed that the extra milk was worth $4.00 per Cwt. then the extra grain was worth $6.91 (gross return per Cwt. of grain) when marketed through this cow. Comparison of lactations 5 and 6 reveals similar returns for Cow A-5 (Table 5). Note that these records include the 305-day lactation actual milk and feed weights while Huffman included feed for the dry period in his report (16).

Table 5. Influence of Levels of Concentrate Feeding on Individual Cow Lactations. M.S.U. Research Herd. Unpublished data of C. F. Huffman.

Cow A-5

Lactation No.	Actual Milk	Alf. Hay	Concentrate	Total TDN	Lbs. Milk per lb. TDN	Feed Cost	Value of Milk	Return Above Feed Cost	Return per $1 Feed Cost
3	14,100	9,766	4,626*	8,165	1.73	$212	$564	$352	$2.66
4	11,461	11,530	1,815	7,295	1.57	160	458	298	2.86
5	18,997	9,179	6,058	8,692	2.18	243	760	517	3.13
6	8,904	12,357	50	6,266	1.42	125	356	231	2.85

* Oats - only grain fed in this lactation.

Cow A-14

Lactation No.	Actual Milk	Alf. Hay	Concentrate	Total TDN	Lbs. Milk Per lb. TDN	Feed Cost	Value of Milk	Return Above Feed Cost	Return Per $1 Feed Cost
2	17,096	9,954	4,987	9,084	1.88	$224	$684	$460	$3.05
3	17,516	10,262	5,274	9,414	1.86	234	701	467	3.00
4	16,137	10,499	4,620	8,868	1.82	220	645	425	2.93
5	8,601	12,712	144	6,521	1.32	130	344	214	2.65
6	13,167	8,771	3,573	7,066	1.86	177	527	350	2.98

Prices used: Hay $20 T., Concentrate $50 T., Milk $4.00 cwt.

From DHIA information such as Table 3 it is obvious that heavy concentrate feeding is not new to those dairymen whose herds are consistently among the top producers. Ross et al (26) demonstrated the relationship between level of feeding and level of production with data from 15 DHIA associations in 1923 as shown in Table 6. In comparing with Table 3, one concludes that it takes about as much concentrate to reach a given level of production today as it did 40 years ago, allowing for some variation due to the limitations of the data.

Table 6. Relationship of Level of Production to Cencentrates Fed and Other Factors. Ross et al. 1923.

Group No.	No. of Cows	Class	FCM	Total Grain	Total Hay	TDN in Hay	TDN in Hay + lb. gr.	FCM lb. Feed	Feed Cost	Value of Milk	Value of Milk Above Feed Cost
			lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	$	$	$
1	21	2,500 - 3,500	2,896	1,437	2,564	1282	2719	1.07	61.57	115.84	54.27
2	79	3,500 - 4,500	3,848	1,809	2,651	1326	3,135	1.23	71.74	153.92	82.18
3	183	4,500 - 5,500	4,761	2,122	2,968	1484	3,606	1.32	82.73	190.44	107.71
4	254	5,500 - 6,500	5,670	2,378	3,253	1627	4,005	1.42	91.98	226.00	134.82
5	309	6,500 - 7,500	6,592	2,611	3,397	1699	4,310	1.53	99.25	263.68	164.43
6	266	7,500 - 8,500	7,374	2,870	3,629	1815	4,685	1.57	108.04	294.96	186.92
7	221	8,500 - 9,500	8,284	3,109	3,663	1832	4,941	1.68	114.36	331.36	217.00*
8	137	9,500 -10,500	9,044	3,441	3,715	1858	5,299	1.71	123.18	361.76	238.58
9	76	10,500-11,500	9,938	3,698	3,521	1761	5,459	1.82	127.66	397.52	269.86
10	33	11,500-12,500	10,689	3,915	3,332	1666	5,581	1.92	131.20	427.56	296.36
11	19	12,500-13,500	11,514	4,627	3,842	1921	6,584	1.76	154.10	460.56	306.46
12	4	13,500-14,500	12,270	3,568	3,285	1643	5,211	2.35	122.05	490.80	368.75
13	1	14,500-15,500	14,000	5,486	3,617	1809	7,295	1.92	173.32	560.00	386.68

Table prepared from the data of Ross et al (26).

Turner (30) showed a close relationship between level of production and level of feeding with data from high-producing cows supplied from the Illinois cow testing plan at Dixon, Illinois, in 1924. (Table 7) Turner pointed out that the economic law of diminishing returns may operate with average or poor cows that are fed above their requirements but it did not operate with good cows. He found that the milk production per pound of grain increased as the yearly milk production increased.

Table 7. Relation Between Milk Production and Feed Intake

Cows No.	FCM	Total Hay	Total Grain	TDN in forage + lb. grain	FCM lb. Feed	Feed Cost	Value of Milk	Value of Milk Above Feed Cost
	lb.	lb.	lb.	lb.	lb.	$	$	$
4	14,116	5,877	2,939	11,333	1.25	268.62	564.64	296.02
10	15,466	5,818	2,909	11,453	1.35	271.78	618.64	346.86
7	17,283	6,204	3,102	12,687	1.36	301.67	691.32	389.65
7	18,658	6,072	3,036	12,751	1.46	303.60	746.32	442.72
10	20,098	6,033	3,017	12,811	1.57	305.18	803.92	498.74
4	21,459	5,898	2,949	12,493	1.72	297.58	858.36	560.78
4	23,013	6,245	3,123	13,742	1.68	327.93	920.52	592.59

Since the subject was recently comprehensively reviewed by Huffman (16), it seems unnecessary to present all of the data here.

The most significant recent contribution to an understanding of the opportunities and limitations of heavy concentrate feeding is the work of Brown (6) at Michigan State University.

In this experiment cows were assigned to one of three rations according to their production during the first 30 days of lactation. The rations were: (1) Alfalfa Hay ad. lib., 40 lbs. corn silage and concentrates 1:3.5 lbs. milk. This ration is fairly typical of Michigan feeding programs. (2) Alfalfa hay 15 lbs., 40 lbs. corn silage and concentrates 1:2.5. (3) Alfalfa hay 5 lbs., 40 lbs. corn silage (offered) and concentrates ad. lib.

Extension factors were used to predict the 260-day lactation of all cows, based on pre-experimental production, as they were assigned to the various feeding regimens. Comparisons of actual production and predicted production are shown in Table 8.

Table 8. Milk Production Response of Cows Fed Different Levels of Grain and Hay*

Cow	Group	Hay (lb/day)	Grain	260 Day Production Estimated (lb.)	260 Day Production Actual (lb.)	Difference Actual - Estimated (lb.)
598	1	free choice	1:3.5	12,042	13,453	+ 1411
635				8,862	7,448	- 1414
A78				8,445	6,963	- 1482
644				9,841	9,144	- 697
626				11,789	10,697	- 1092
645				12,053	12,764	+ 711
Av.				10,505	10,078	- 427
685	2	15	1:2.5	9,942	11,510	+ 1568
630				10,562	11,274	+ 712
638				8,429	11,414	+ 2985
627				7,880	9,901	+ 2021
641				11,186	12,212	+ 1026
572				9,252	7,766	- 1486
Av.				9,542	10,680	+ 1138
643	3	5	Free Choice	9,012	11,740	+ 2728
302				9,698	13,353	+ 3655
645				7,822	7,440	- 382
612				14,304	19,454	+ 5150
642				8,854	13,987	+ 5133
686				9,863	10,058	+ 195
Av.				9,926	12,672	+ 2746

*From: Brown, L. D. Effect of High Level Grain Feeding on Milk Production - Michigan State University, Dairy Department (Mimeo) E. Lansing, Michigan

From the data in Table 8, it should be noted that four of the six cows in group 3 responded remarkably to heavy concentrate feeding. However, it is just as important to recognize that two cows in this group (645 and 686) did not respond to heavy feeding. It is apparent that heavy concentrate feeding is primarily for cows with inherently high milk production potential.

Average daily feed consumption for the 260-day experimental period is presented in Table 9.

Table 9. Average Daily Feed Consumption for the 260-Day Experimental Period

Feed	Group 1	2	3
	lb/day	lb/day	lb/day
Grain	11.9	17.0	36.0
Hay	24.4	13.9	4.9
Corn Silage	38.2	37.7	34.2

In drawing conclusions from these data for farm application one should recognize that concentrates were fed ad. lib. continuously throughout the lactation whether or not the cow responded in milk production and regardless of the level of production in late lactation. Since this resulted in considerably more concentrate consumption than would normally be required to achieve these levels of production, the economic importance of liberal feeding of good cows is somewhat distorted and is definitely under-evaluated when group averages are used. In actual practice, where dairymen can control the level of concentrate feeding for individual cows there would be little reason to feed all cows ad. lib. regardless of production and stage of lactation. However, Olson et al (22) and Olson and Benson (23) recently demonstrated that where the nutrients from concentrates are approximately as cheap as the nutrients from forage, concentrates can be used economically at high levels of feeding. In these trials when hay and concentrates were fed free choice in a loose housing arrangement, a group of Guernsey and Jersey cows consumed 3.5 lbs. of hay and 32.6 lbs. of concentrates (ground ear-corn and soybean meal). Holsteins averaged 4.0 lbs. of hay 42.7 lbs. of concentrates per day under the free-choice feeding conditions.

Average daily milk production, persistency, and body weight change for the 260-day period of Brown's experiment are shown in Table 10.

Table 10. Average Daily Milk Production, Persistency, and Body Weight Change for the 260-Day Experimental Period (6).

Milk Production (lb/day)	Group 1	2	3
Actual	37.9	41.0	48.2
4% FCM	36.6	39.9	46.0
Persistency (%)	85.0	92.7	94.0
Body Weight Change (lb/day)	+0.6	+0.9	+0.9

Heavy concentrate feeding had no observable effect on butterfat, protein, or solids-not-fat in the Michigan trials (6).

However, Boyd (5) reported that milk fat tests averaged 3.48%, 3.38% and 3.11% when cows were fed no grain, normal, and ad. lib. grain. Shelled corn rather than ear corn was used in these rations. Lowered butterfat test was observed on a number of Michigan farms where shelled corn was fed at a heavy rate. Protein (5, 21) and solids-not-fat (5) were higher in milk of cows fed heavily on concentrates.

Effect of Level of Feeding on Efficiency of Production

Jensen et al (19) demonstrated the principle of diminishing returns under the conditions of their experiment. Cows were assigned to the experiment to form equalized groups based on production in previous lactations, and groups of cows were fed at various grain to milk ratios. There is reason to doubt whether the methods employed in this experiment adequately evaluate the effects of grain feeding over a wide range of conditions. It is apparent from the data that there was considerable variation in production potential among cows within groups despite efforts to eliminate this variable.

These experiments suffered from a serious flaw in construction which predetermined their outcome. All groups were fed to a percentage of the theoretical requirement for their current production ranging from 90 per cent to 130 per cent of the feeding standards for that milk yield. If there was any response to heavier feeding, the level was raised continuously until a limit was reached--since it is unlikely that any cow has an infinite capacity for feed. Thus, the experiment proved the obvious, that any cow whose feed is constantly adjusted above its production must eventually give a lower return per unit of feed than a cow fed at the standard rate.

The law of diminishing returns undoubtedly operated for low-producing individuals and might have appeared to operate for the group as a whole without in fact operating for high-producing individuals that responded to heavy levels of feeding. The expected average production of groups used on the experiment was 8,817 to 9,017 pounds of milk per lactation. This level of production was undoubtedly reasonable for the times but the conclusions are not necessarily valid for cows capable of twice this production. Huffman (16) summarized the results of a number of other studies and concluded, "In the investigation of the effects of heavy grain feeding upon the efficiency of milk production it is necessary to use inherently good cows."

Gardner (12) studied the feed input-milk output relations using results of heifers from five bull progeny tests in England. Feeding was liberalized to induce potential production and later adjusted to a standard rate. Regression analysis of these data indicates an increasing marginal return of milk to extra feed in four tests. Only in one test was a diminishing marginal return indicated. Similarly, Orton (24) could find no visible sign of diminishing returns to feed when the yield of milk was plotted against the nutrients fed using data from England and Wales. "The simple regression equations showed highly significant responses to nutrient inputs," according to the author. Orton (24) got the same results by using data from Denmark.

Reid (25), on the other hand, contends that the TDN value of mixed rations comprised of concentrates and forages declines at an ever increasing rate as the amount of ration ingested per unit of time is increased; and therefore, a higher rate of feeding per pound of milk is required at higher levels of production. It was not clear from the evidence presented that this phenomena holds true when high energy feeds (concentrates) become a relatively large proportion of the total ration as the amount of ration ingested per unit of time is increased. In light of the conflict of opinion among several investigators, these concepts deserve further study.

Huffman (16) presented considerable data indicating that with cows capable of producing 15,000 to 20,000 lbs. of milk per lactation there was a tendency for efficiency of production (FCM per lb. of feed or TDN) to increase, at least no decrease, with higher levels of feeding. With such cows it appeared that appetite to consume larger amounts of feed could be the first factor limiting production and that the law of diminishing returns did not apply in these cases. Likewise, it would appear that experiments designed to measure the influence of feeding on milk production should start early in the lactation or prior to freshening in order to express their full significance. Data obtained from heavier feeding trials that began mid-way through the lactation are often misleading since the extra feed is not supplied at the time high-producing cows need it most.

Input-output relations are likely to have very limited application in the practice of feeding cattle, particularly over short periods of time, since it is unrealistic to assume that milk production can be "shut off" during periods of unfavorable prices and then "turned

on" again to full flow when prices become more favorable during the same lactation period.

Effect of Feeding Concentrates Prior to Calving

The concept of feeding liberal amounts of grain ration before freshening (pre-partum) was introduced by Boutflour (4) of England 35 years ago. He called the practice "steaming up" and claimed that the process helped to build up body reserves, and to accustom the cow to the heavy grain ration she should receive in early lactation. Boutflour claimed that milk production in the subsequent lactation is increased by this technique. There is considerable evidence that Boutflour was at least partially right in his contentions, although not all research agrees, as reported here.

The idea was essentially ignored by research workers until 1944 when Blaxter (2) compared the effects of "steaming up" with additional concentrates or additional roughage in the last six weeks before calving. Concentrate feeding began at two pounds per day and was increased to 4 and then 6 pounds per day at two-week intervals of the dry period. Another group was fed additional roughage to equal the nutritive value of those fed concentrates. Controls were fed roughage adequate for maintenance and the production of half a gallon of milk per day. The additional concentrates increased live weight gain before parturition and live weight loss thereafter. A statistically significant increase in production of 7 pounds of milk per day was obtained during the first 10 weeks of lactation from the cows which had received the additional concentrates before calving. Concentrates were fed at a standard rate per gallon to all animals after calving. Additional roughage had a slight but non-significant effect on milk production but these cattle lost very little weight after freshening. The controls gained weight after freshening.

Swanson and Hinton (29), using 75 pairs of cows in two experiments, recently confirmed the work of Blaxter (2). Feeding 8 lbs. of concentrates per day in the six weeks prior to calving resulted in 302 lbs. more milk (FCM) in the first 15 weeks of the next lactation. The cows fed concentrates prepartum gained 30.5 lbs. more in 35 days than pair-mates not fed grain. They also lost 20.3 lbs. more in 35 days after calving. These differences were statistically significant. It was noted that the groups fed only roughage while dry began to gain weight consistently at 5 to 6 weeks of lactation, but those fed grain in the dry period lost weight or failed to gain for about 10 weeks. However, feeding of an extra 330 lbs. of concentrates for the last 110 days of the previous lactation, but none during the dry period, failed to produce a response in milk production in the next lactation.

Bayley et al (1) in using partial regression analysis of farm records estimated the effects of condition of heifers at calving on milk production during the subsequent lactation as follows: 46 lbs. of milk increase from "fair" to "good" condition grades and an increase of 850 lbs. from "good" to "excellent". The effect of the condition of the dry cows was an increase in milk of 600 lbs. per lactation between the grades "fair" and "good".

Flux (11) used six pairs of 2-year-old monozygous twin heifers to determine the effect of underfeeding for ten weeks prior to calving. Those which had been well fed before calving produced an average of 1057 lbs. more milk per 270 days than their twin mates which had been poorly fed.

Castle and Watson (7) could find no advantage of feeding 330 lbs. of concentrates compared to 160 lbs. before calving. The authors speculate that the superior quality of forage used in this trial might have been responsible for failure to show a benefit from steaming-up. However, in comparing high post-calving feeding (25.8 cwt. of concentrates) with low post-calving feeding (12.1 cwt. per cow) it was noted that one pound of additional starch equivalent resulted in an additional 1.05 lb. of milk.

Greenhalgh and Gardner (13) reported no increase in milk production during the subsequent lactation although cattle gained weight from feeding concentrates prior to calving. Heifers were gradually increased up to 9 lbs. and cows up to 12 lbs. of concentrates per day. In this experiment two pounds of corn silage and 1 1/2 lbs. of hay was feed per 100 lbs. of body weight as the roughage. It is possible that the nutrient value of this ration was sufficient to stimulate production of the controls since cattle would be getting 3 to 4 lbs. of grain from the corn silage.

Similarly, Schmidt and Schultz (27) using trios of cows fed 0, 6 lbs., and 15 lbs. of concentrates per day could find no increase in production due to prepartum feeding. Likewise, they concluded that the amount of concentrate fed either before or after calving did not significantly affect the amount of udder edema or mastitis although high-producing cows and first calf heifers tended to have more edema (13, 27).

It is possible that differences in control of variation by carefully pairing cows and the numbers involved could account for the difference in statistical results arrived at by various investigators. Likewise, the amount and quality of roughages

fed could account for some of these differences.

The feeding of heifers is frequently neglected under farm conditions and it is entirely possible that prepartum feeding of concentrates under these conditions could produce an even greater response than has been reported in the literature. Also, the effect of feeding even higher levels of concentrates (such as ad. lib. feeding) has not been reported in the literature. It seems possible that the levels fed prepartum (6 to 15 lbs. per day) in other experiments were inadequate to fully "steam-up" for the ensuing lactation, particularly when the roughage fed is of questionable quality.

An adaptation of this practice is in use by a number of Michigan dairymen. These dairymen usually start feeding extra concentrates two to three weeks before calving and gradually increase up to 20-25 lbs. per day by freshening time. In a few cases grain is offered ad. lib. and even heavier levels are fed.

In this author's opinion the practice has particular merit on farms where dairymen have not been accustomed to heavy feeding. It is logical that pre-partum feeding will help to get the rumen, the cow's eating habits, and appetite adjusted before calving occurs and will, therefore, get the cow on a higher level of feeding early in the lactation. This, in itself, results in reaching the peak of production earlier in the lactation and in obtaining a higher peak than when liberal concentrate feeding is delayed. This advantage appears to be sound whether or not there is a carry-over effect from pre-partum feeding.

Economic Situation Demand High Production Per Cow

Prices for farm commodities are low relative to the cost of machinery and other items that farmers must purchase. In this kind of economy, profit margins are very small and it is necessary for the dairyman to produce as efficiently as possible. Increasing the rate of production per cow is one means of increasing the gross efficiency of use of land, labor, capital, and management. The importance of achieving high levels of production per cow is pointed out in a study of DHIA and farm management records (Table 11). This study indicates that two cows producing at the rate of 13,700 lbs. of milk (520 lbs. of butterfat) can net as much "return for labor and management as five cows producing 8,500 lbs. of milk (330 lbs. of butterfat)".

Table 11. Number of Cows and Total Milk Production Required to Return $5,000 for "Labor and Management".

Production Per Cow		Number	Total Milk
Milk	Butterfat	of	Produced
lb.	lb.	Cows	lb.
8,500	328	46	391,000
9,700	375	33	320,000
12,300	450	22	270,600
13,700	520	18	252,000

Adapted from DHIA and Farm Management Records, Michigan State University DairyDepartment, Miscellaneous Circular E-19, 1961.

It is also interesting to note that if a dairyman wants $5,000 return for his labor and management he must milk about 46 cows if the level of production is 8,500 lbs. per cow per year. These 46 cows produce a total of 392,000 lbs. of milk per year. Eighteen cows producing 13,700 lbs. of milk per year will net the same return for labor and management, but the total production for the year is only 252,000 lbs.

Since the low producing herd must sell 139,000 lbs. more milk to net the same return, it would appear that low producing cows contribute much to the surplus milk problem but contribute very little to net farm income.

Low production per cow is a poor solution to either the milk surplus problem or the economic problem of dairy farmers with investments of $1,700 to $2,500 per cow (average $2,000). For a certain group of dairymen producing at the rate of 10,900 lbs. of 3.5% milk per year the total cost for producing milk was estimated at $439 per cow. Of this, non-feed costs (overhead) accounted for $242 per cow, and feed cost was another $197 per cow. The cost per cwt. of milk was estimated as follows: non-feed cost $2.22 plus feed cost $1.81 for a total of $4.03 per cwt. of milk. If the production can be raised to 14,000 lbs. and assume that overhead per cow is the same but feed cost increases $43 per cow, then the cost is reduced to $3.44 per cwt. of milk. Overhead includes interest on investment and depreciation, part of which the dairyman might be able to keep if he doesn't have to pay it all against indebtedness. Thus, he may or may not be going broke if milk happens to be that price or lower. The point is that the greater the indebtedness and investment per cow, the greater must be the return per cow. These dairymen cannot be contented with mediocre production and remain competitive with farms that have low credit expense.

A positive program of (1) using the best breeding available, which is usually artificial insemination; (2) keeping and using dairy herd improvement records; (3) feeding concentrates liberally prior to calving and early in the lactation; and (4) culling those cows that produce 70 lbs. of butter or 2,000 lbs. of 3.5% milk below the herd average on a 305-day mature equivalent basis, can rapidly move the average production of any dairyman above the 500 lbs. of butterfat class in three to five years if he does a reasonable job with the other management. In view of the current milk surplus situation, any program designed to increase production per cow must necessarily emphasize culling the less profitable cows.

Summary and Conclusions

Feeding programs on a majority of dairy farms are not adequate to achieve the potential economical production for which the cattle have been bred. Therefore, more liberal use of concentrates can substantially increase milk production per cow and improve overall dairy farm efficiency. Thumb rules for grain feeding and feed standards fail to maximize production of the cow since the level of feeding lags behind the level of production. The potential production of a cow can best be established by: (1) offering liberal amounts of concentrates (1 to 2 lbs. per 100 lbs. of body weight), starting about three weeks before calving and continuing to increase concentrates after calving until either peak of production is reached or the peak of appetite is reached, depending on which occurs first. If after about 60 days post-partum the level of feeding appears uneconomical for the level of production, adjustments can be made.

Where cattle are fed concentrates in milking parlors it is generally necessary to feed additional grain in feed-lot bunks. In such cases, best use will be made of the concentrates if cattle are handled as two or more groups. A suggested method is to feed additional concentrate to (1) dry cows for about three weeks before due date; (2) all fresh cows for a period of 90-120 days post-partum or until they drop below 50 lbs. (3.5% milk equivalent) of milk per day. All other cows would get only the concentrates allowed in the milking parlor.

Feeding concentrates more liberally has resulted in substantial gains in milk production in numerous dairy herds in Michigan and is rapidly becoming a standard practice among dairymen.

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HIGH-ENERGY RATIONS FOR BEEF CATTLE

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Early attempts (Davenport, 1897; Huffman, 1928) to feed ruminants high-energy rations were unsuccessful. The early workers concluded that fibrous materials were necessary for the normal function of the rumen. Mead et al., in 1931, fed calves a basal ration of barley, oats, wheat bran and linseed meal for 19 months. The addition of cod liver oil and alfalfa ash to the basal ration resulted in normal growth. They concluded that roughage was not necessary in the diet of calves and that minerals and vitamin A were limiting in explaining the results of earlier studies.

Recent interest in high-energy rations for beef cattle was stimulated by the report of Geurin et al. (1959) that rolled barley serves as both grain and roughage for fattening cattle. Numerous recent experiments have confirmed these findings and have indicated that the amount of roughage in cattle rations may be decreased from the usual recommended levels.

Actually, the practice of feeding high amounts of ground shelled corn with a minimum amount of hay to cattle is not new. Feeders in the corn belt states for years have successfully fed minimum amounts of hay during the terminal phases of feeding. Also it has been a common feedlot observation that cattle fed extremely high energy, or "hot", rations during a long feeding period often were subject to certain feedlot problems, such as going off feed, stiffness, founder and scours.

Opinions vary regarding the length of time cattle should be fed all-concentrate rations. Church (1961) indicated that most cattle fed all-concentrate rations have been yearling cattle fed for short periods of time. He suggested that such cattle are better suited to this type of feeding regime than calves. However, he suggested that probably all-concentrate rations were suited to feeding periods shorter than 150-180 days. Dinusson (1962, personal communication) estimated that cattle should not be fed rolled barley (no hay) rations for longer than 180-200 days. On the other hand, Keith (1962, personal communication) suggested, as a result of their studies, that it is not economical to feed all-concentrate rations longer than 90 days. He indicated that cattle fed all-concentrate rations had a high incidence of founder.

High-energy rations are usually supplemented with 1 or 2 lb. of a supplement. These supplements may contain soybean meal (about 5% fiber), linseed oil meal (8-9% fiber), cottonseed meal (10-11% fiber), dehydrated alfalfa meal (19-28% fiber), in addition to such feedstuffs as molasses, beet pulp, minerals, salt, vitamins and various feed additives. Thus, the supplement may contribute appreciable amounts of fiber, or roughage, to the ration. High-energy rations based on ground shelled corn, urea, a protein supplement, minerals, feed additives and vitamins may contain as little as 2.3% fiber. By comparison, a standard feed-lot ration made up of about 18 lb. of ground ear corn, 3 lb. hay and 1 lb. of protein supplement may contain 10.5% fiber. The precise minimum amount of fiber necessary for cattle rations to provide the roughage factor is not known, although it appears likely it is below the amount contained in barley (6%).

The amount of ash or minerals in a high-energy, or all concentrate ration, may be as low as 2-3%. Feed-lot rations containing normal amounts of hay may contain over 3% ash. Minerals normally enter the rumen from the saliva, feed and from mineral supplements. Extremely high energy rations with inadequate mineral levels may be expected to influence the resulting rumen pH. It has been demonstrated that sheep fed high carbohydrate rations develop rumen pH values below 5 (Bullen, 1957). The sheep in this trial remained normal provided rumen pH stayed above 5. Below a rumen pH of 5, a mild acidosis was observed and below 4.5, more severe symptoms were noted, such as dullness, inappetance, hyperventilation, salivation, grunting and grinding of teeth. In fatal cases of acidosis he reported a blood pH of 6.6 and a blood lactic acid level of 200 mg. per 100 ml. blood.

The effect of various ratios of rolled shelled corn to alfalfa-brome hay upon rumen pH was studied extensively at the Minnesota station (Kolari, unpublished data). Rumen fluid samples were aspirated from a rumen fistulated steer, weighing about 900 lb., prior to feeding ("O" hour) and 1, 2, 3, 4, 6, and 8 hours after the morning feeding. The steer was fed 16 lb. of feed daily. Rumen fluid samples were taken from the top, middle and bottom of the rumen for 3 consecutive days for each ration treatment (table 1).

Table 1. The Effect of Ratio of Rolled Shelled Corn to Alfalfa Hay upon Rumen Fluid pH.

Ratio	Sampling site within the rumen[a] Top	Middle	Bottom	Average
Hay, 100; corn, 0	7.08	6.94	7.16	7.06
Hay, 80; corn, 20	7.02	6.98	7.29	7.10
Hay, 60; corn, 40	6.33	6.53	6.79	6.55
Hay, 40; corn, 60	6.05	6.29	6.81	6.38
Hay, 20; corn, 80	6.02	6.43	6.72	6.39
Hay, 10; corn, 90	5.95	6.18	6.45	6.19
Hay, 5; corn, 95	5.33	5.41	5.62	5.46
Average	6.25	6.39	6.69	

[a]Average of "O", 1, 2, 3, 4, 6 and 8-hour rumen fluid samples.

Rumen pH values consistently dropped to their lowest values 3-4 hours after feeding and then gradually rose to the 8-hour values,

which were usually similar to the "O" hour values. The lowe pH value recorded was 4.90 during the 3rd hour after feeding 95% corn-5% hay diet. At this point the steer "went off feed" the rumen had a strong odor of lactic acid. The consistency o the rumen fluid was somewhat similar to cream. Urine pH ranged from slightly over 7 to 8.3 when the steer was fed rati containing less than 60% corn. When the ration contained 95% corn and 5% hay, urine pH averaged 5.46 during an 8-hour col lection period. Urine pH values tended to follow the trend esta lished by rumen pH values, i.e. decreased during the first 3- hours post feeding and then gradually climbed to their normal "O" and 8 hour values.

The amount of saliva secreted daily by a mature cow varies fr 50-80 liters; for sheep, the output is 6-10 liters. McDougall (1948) studied the output and concentration of the various ions i ruminant saliva and as a result of these studies suggested a co position for synthetic saliva which has been used in various *in vitro* studies. Emery (1960) studied the physical and chemica changes in saliva due to feeding various ratios of hay to grain cow diets. Saliva, in addition to aiding in increasing the buffe ing capacity of the rumen, aids in the control of both feed-lot pasture bloat and functions in the so-called nitrogen cycle.

A common observation in ruminants fed rations containing littl or no roughage or pelleted feeds is that the rumen wall is coat with a layer of dark material. Jensen *et al.* (1958) introduced the term ruminal parakeratosis to describe lesions in feed lot lambs fed pelleted rations. Rumen parakeratosis may be defi as an increase in the thickness of the cornified portion of the rumen epithelium with a persistence of nuclei in the cornified cells. In addition, other ruminal mucosal changes that may o cur as a result of various rations include: hyperemia, edema, atrophy, necrosis, inflammation and excessive pigmentation (Ward, 1962). A greater frequency of ruminal parakeratosis h been reported during the last few years and this may be relate to recent trends in feeding ruminants, i.e. feeding pelleted or high-energy rations. Rumen parakeratosis is often observed i stock fed rations containing pelleted dehydrated alfalfa or beet pulp and grain. A decreased absorption of rumen metabolites may be expected as a result of rumen parakeratosis. Howeve the relationship of rumen parakeratosis to weight gain needs additional study.

Numerous researchers have studied the effect of energy levels feed preparation and the feeding of various minerals upon the relative concentrations of acetic, propionic, butyric and other volatile fatty acids (VFA) in the rumen. Rumen VFA may acc for over 50% of the energy obtained from feed. Studies have demonstrated that the molar percentages of the VFA, such as acetic and propionic acids, can be controlled by the diet. In view of the findings of Armstrong and Blaxter (1957-58) that th heat increment of acetic acid when fed to fasting sheep was co siderably greater than when either propionic or butyric acids were fed, then the control of rumen metabolites is extremely important in formulating efficient rations. Shaw (1957) observed that cooked diets composed largely of bread or of cooked rice, cooked potato meal, bread and molasses resulted in a marked decrease in the molar percentage of acetate and a marked increase in propionic acid in the rumen. Similar results were obtained by Eusebio et al. (1959) who fed heifers a corn meal diet in comparison to an alfalfa hay-corn meal diet, and by Shaw et al. (1960) when calves were fed pelleted alfalfa, flaked corn and linseed oil meal in comparison with a ration of chopped alfalfa, ground corn and linseed oil meal. Numerous studies have also been conducted upon the effect of protein upon rumen VFA; these studies indicate that under certain conditions protein stimulates VFA production and that the amount of 4-carbon or branched chain VFA are increased due to such treatment.

Balch et al. (1957) fed milking rumen-fistulated dairy cows diets containing various ratios of hay and concentrates. His data demonstrated that total VFA production as a result of feeding a high-energy ration was greater than when a higher roughage ration was fed. The total VFA concentration in the rumen tended to increase and decline more rapidly when the higher grain rations were fed. VFA production was directly related to rumen pH values. However, the data of Eusebio et al. (1959) do not indicate that total VFA concentration was higher when an all-grain ration was fed in comparison to one containing hay and grain.

Flatt et al. (1959) has extensively studied the development of the rumen in relationship to diet. His studies demonstrated that solid diets stimulated rumen growth and milk diets retarded growth of the rumen in addition to causing little or no papillary development. He suggested that chemical entities, rather than coarse material, stimulated rumen papillae development. Their data suggested that hay-fed cattle had slightly larger rumen volumes than those fed grain. The data of Wing and Ammerman (1960) suggested that the growth of the other three compartments of the stomach are a function of age and therefore independent of type of feed fed.

Considerable research has been devoted to determine the effect of the amount of energy, or roughage-concentrate ratio, upon feed lot performance and carcass characteristics of fattening cattle. These studies have demonstrated that a somewhat wide range of roughage to concentrate may be fed without greatly influencing these parameters. The effect of feeding various concentrate to roughage ratios to cattle upon carcass characteristics has been reviewed (Kolari, 1960). However, cattle fed low levels of roughage tend to crave some fibrous feeds and tend to consume more bedding than usual or chew on fences, boards, etc.

The practice of feeding high-energy or all-concentrate rations to cattle has certain advantages: (1) ease of automation of feeding operations; (2) less feed is usually required per unit weight gain; (3) may be more economical when roughage or hay costs are

high; (4) aid in reducing heat stress, due to less heat production, during summer, or during periods when temperatures are relatively high.

HIGH ENERGY RATIONS FORMULATED WITH CORN

Sand in high-energy rations. It has previously been indicated that rations limited in fiber content predispose to rumen parakeratosis and other rumen problems. Adequate fiber in the diet wears off epithelial cells from the rumen wall and maintains a "healthy" appearing rumen. The Iowa station (Woods et al., 1961) conducted experiments to determine the value of feeding 1 or 2% high-grade white silica sand to substitute for the "roughage factor" in cattle rations (table 2). They fed a high-concentrate ration, for 105 days to 17 steers weighing slightly over 800 lb., that consisted of: rolled shelled corn, 74.5; corn cobs, 10; molasses, 5; urea, 0.5; soybean meal, 3.8; ground alfalfa hay, 5; and minerals and vitamins, 0.2%. The basal ration supplied 11% protein, 0.3% calcium and phosphorous and 10 mg. stilbestrol per head daily.

Table 2. The effect of adding sand to high concentrate rations.

	Basal	Basal and 1% sand	Basal and 2% sand
Av. Daily gain, lb.	3.43	3.69	3.96
Daily feed, lb.	26.6	27.5	27.9
Feed/cwt. gain, lb.	776	745	704
Carcass grade[a]	5.5	6.2	5.7

a Carcass grades: 5, av. good; 6, high good.

Results of this experiment indicated that the addition of sand to the basal ration improved weight gain and efficiency of feed use. Carcass grades were similar between treatments.

Woods et al (1961) repeated the above experiment with the same basal ration. In addition they fed 2 lots of steers for 70 days a conventional ration of cracked corn, protein supplement and a limited amount of hay to determine the effect of feeding sand with a conventional ration (table 3). The cattle fed the conventional ration received 5 lbs. hay per head daily and either 1 lb. of a protein supplement (no sand) or 1.5 lb. of protein supplement (2% sand).

Table 3. The effect of feeding sand to fattening yearling cattle fed convention or high-concentrate rations (progress report).[a]

	Conventional ration		High concentrate ration	
	No sand	2% sand	No sand	2% sand
Av. Daily gain, lb.	3.15	3.20	3.10	3.27
Daily feed, lb.	21.7	21.8	20.2	20.5
Feed/cwt. gain, lb.	688	685	651	621

a Ten steers per treatment.

Cattle fed the conventional ration were fed twice daily. Cattle fed the high concentrate ration were fed either twice or six times daily. Results of this trial indicated small differences in the rate of gain between the conventional and high-concentrate rations, but efficiency of feed use favored the high-energy ration. Seventy-day results indicated that cattle fed six times daily (3.60 lbs.) gained more rapidly than those fed twice daily (2.77 lbs.). Daily feed consumption was similar for those fed twice daily (20.5 lbs.) and six times daily (20.1 lbs.). Feeding high energy rations many times a day may aid in the control of rumen pH by: (1) not exceeding buffering capacity of the rumen; and (2) reducing the sharp decline in rumen pH subsequent to the ingestion of large quantities of readily fermentable carbohydrates.

In another experiment, the Iowa workers added 2% sand to a basal ration of 20% coarsely ground corn cobs and 80% concentrates (ground shelled corn and protein supplement). The control cattle were fed the basal ration. Results of this trial with yearling steers fed 110 days indicated that average daily gains were similar for those fed and not fed sand (3.40 vs. 3.39 lbs.) and that differences in daily intake of feed and feed required per unit weight gain were small.

Roughage in corn rations. The effect of feeding an all-concentrate ration was studied in a Minnesota trial (still in progress). Thirty-six yearling steers were divided into 3 groups and fed 3 levels of hay: (1) none; (2) 4 lb. (3) 8 lb. per head daily. Ground shelled corn was fed to appetite. Steers fed no hay received 2 lbs. per head daily of a protein supplement (calculated, 52% protein) made up of: soybean meal, 46; dehydrated alfalfa, 25; ground shelled corn, 10; urea, 10; steamed bonemeal, 2; limestone, 5; and trace mineralized salt, 2%. After 84 days steers fed no-hay had gained 2.80, those fed 4 lbs. hay gained 2.88 and those fed 8 lbs. hay gained 3.01 lbs. per head daily. The total daily protein intake of the steers fed 4 or 8 lbs. hay was equalized with those fed no-hay by the use of soybean meal. Efficiency of feed use data are not available, but it appears that steers fed the all-concentrate ration have consumed less ground shelled corn per head daily. Some scouring has been observed in the all-concentrate group.

Anthony et al (1960, 1961) conducted two studies to determine the value of adding roughage to high-energy rations. In one experiment yearling steers were fed the following treatments for 180 days: (1) a high-energy diet of ground corn, protein supplement, molasses and minerals; (2) a high-roughage ration of 30% hay, cottonseed hulls or peanut hulls, with the balance made up of ground corn, protein supplement, molasses and minerals. Average daily gains and feed required per 100 lbs. gain for treatment (1) were 2.11 and 775 lbs., and for treatment (2) were 2.45 and 1005 lbs., respectively. Differences in average daily gains and feed required per unit weight gain were statistically significant. In the other experiment, 8 steer calves per lot were fed as follows, in addition to grain, for 200 days: (1) 30% hay; (2) 10% hay; and (3) no hay and a supplemental protein mixture of cottonseed and soybean meal. Average daily gains and feed required per 100 lbs. gain

for the treatments, in the order given above, were, respectively: (1) 2.04, 988; (2) 2.14, 964; and (3) 1.96 lb. and 966 lbs. Differences in feed lot performance and carcass grades due to treatments were not statistically significant.

Sixty-four heifers were fed ground shelled corn to appetite, a protein supplement and (1) 2; (2) 4; (3) 6; or (4) 8 lbs. alfalfa-brome hay in Minnesota trials (1962, data not published). Average daily gains and carcass grades for the hay treatments, in the order given, were, respectively: (1) 2.28 and 9.00; (2) 2.29 and 9.13; (3) 2.13 and 8.25; (4) 2.09 lbs. and 8.33 (carcass grades - 8, average good and 9, high good). Differences in feed lot gain and carcass grades were not large. In an earlier trial (Kolari et al, 1961) 45 fattening heifers were fed 4, 6 or 8 lbs. hay per head daily with rations similar to that indicated above. Weight gains of the cattle fed the various hay levels were similar. Carcass grades for the 4, 6 and 8 lb. hay levels were, respectively: 10.2, 9.6 and 8.9. Carcass grades tended to be slightly lower for each successive hay level above 4 lbs. per head daily and agree with the results of the 1962 trial. Differences in fat cover over the 12th rib and marbling scores were small.

Pelleting high energy rations. The effect of pelleting high-energy, or all-concentrate, rations upon feed lot performance of fattening calves was studied by Perry et al (1958). Thirty-six steer and heifer calves, averaging 560 lbs. at the start of the trial, were fed complete mixed rations composed of ground ear corn, 84, Purdue supplement A, 11 and molasses, 5% for 84 days. Calves fed the meal ration gained 11% more rapidly than those fed the same ration in pelleted form. Calves fed the pelleted ration required 13.7% less feed per unit weight gain. The feeding of a pelleted ration also resulted in a 24% decrease in daily feed intake.

The addition of buffering agents. North Carolina workers (Wise et al, 1962) conducted a series of experiments with low-fiber high-energy rations to which various alkalizing, or buffering agents were added with the hope that these additives would aid in the control of rumen pH and therefore improve the performance of cattle fed these rations. In the first experiment 10 steer calves, weighing 530 lbs. at the start of the trial, were fed rations containing 11% sodium and potassium bicarbonate for 91 days (table 4).

Table 4. Composition of all-concentrate rations.

	Basal, %	Basal plus Na and K bicarbonate, %
Ground shelled corn	95.1	84.6
Urea	1.0	1.0
Cottonseed meal	2.0	2.0
NaCl	0.5	-
$CaCO_3$	0.7	0.7
Defluorinated phosphate	0.2	0.2
Trace minerals	0.4	0.4
Vitamins A & D	0.1	0.1
$NaHCO_3$	-	4.0
$KHCO_3$	-	7.0

Calves fed the basal ration gained 1.9 lb. per head daily, required 5.8 lbs. feed per pound of gain and consumed 11 lbs. feed per head daily. Calves fed the ration containing sodium and potassium bicarbonate to increase the buffering capacity of the rumen gained 0.7 lb. per head daily, required 12.7 lbs. feed per pound of gain and consumed an average of 9.2 lbs. feed per head daily. The researchers pointed out that the feed intake of calves fed the bicarbonate was depressed and that diarrhea was frequently observed.

Further research was continued by this group to determine the effect of feeding the basal diet with minor modifications. The NaCl and trace minerals were replaced with trace mineralized salt; sodium acetate substituted for 5% of the shelled corn in treatment 2; treatments 3 and 4 consisted of the basal ration plus 2.5 lbs. per head daily of ground or long hay, respectively. The 24 steer calves fed in this 119-day experiment averaged 425 lbs. at the start of the trial (table 5).

Table 5. Feed lot performance and carcass characteristics of calves fed an all-concentrate ration alone or supplemented with Na and K acetate or hay.

	Basal	Na & K acetate	Ground hay	Long hay
Av. daily gain, lb.	2.5	2.2	2.6	2.5
Daily feed, lb.				
Basal	12.5	12.5	12.8	13.1
Hay	-	-	2.5	2.5
Feed/lb. gain, lb.	5.0	5.6	6.0	6.2
Carcass weight, lb.	407	382	406	401
Carcass grade[a]	11.3	9.7	10.3	10.8
9-11th rib separation				
Fat, %	37.9	28.4	35.5	34.6
Rind thickness, mm.	21	10.6	16.6	21.5

[a] Carcass grades: 9, low good; 10, average good; 11, high good.

Differences in weight gains were not statistically significant, although calves fed the acetate gained a quarter of a pound less per head daily than those fed the basal ration. One pound of hay was required per pound of gain by the calves fed hay. However, the amount of corn required per pound of gain was similar for calves fed the basal and those fed ground hay (5 lbs.); those fed the long hay required slightly more of the basal ration (5.2 lbs.). Calves fed acetate had the least amount of fat deposited in the 9-11th rib separation and the lowest carcass grade.

A third experiment was conducted in which the value of urea as a buffering agent was tested in addition to a lower level of bicarbonate and a high level of calcium carbonate (table 6).

Table 6. Composition of rations.

	Urea basal	SM[a]	SM & Na & K bicarbonate	SM & $CaCO_3$
Ground shelled corn	95.1	90.2	84.1	84.1
Urea (262)	1.0	-	-	-
Soybean meal (50%)	-	6.1	7.2	7.2
Cottonseed oil	2.0	2.0	2.0	2.0
$CaCO_3$	0.7	0.7	0.7	5.7
Defluorinated phosphate	0.2	-	-	-
Vitamin A & D[b]	0.1	0.1	0.1	0.1
Trace mineralized salt	0.9	0.9	0.9	0.9
Na & K bicarbonate[c]	-	-	5.0	-

[a] SM is soybean meal
[b] Vitamin concentrate: 600 gm./ton containing 5,000 I. U. A per gm. and 3 gm. D containing 165,300 I. U. per gm.
[c] Six parts K bicarbonate to 4 parts Na bicarbonate.

Three steers and 3 heifers were fed each of the ration treatments for 224 days. Feed lot performance and carcass data for the cattle are in table 7.

Table 7. The effect of feeding urea, bicarbonate and limestone on the feed lot performance and carcass characteristics of calves fed all-concentrate rations

	Urea	SM	SM & bicarbonate	SM & $CaCO_3$
Av. daily gain, lb.	1.54	1.60	1.66	1.78
Daily feed intake, lb.	9.65	11.04	12.32	11.85
Fed/lb. gain, lb.	6.27	6.90	7.42	6.66
Carcass weight, lb.	429	451	454	472
Carcass grade[a]	11.8	11.8	11.4	11.3

[a] Carcass grades: 11, high good; 12, low choice; 13, average choice.

Differences in average daily gains of cattle fed the various test diets were not statistically significant. However, calves fed the urea-basal consumed significantly less feed daily than the 3 groups of cattle fed soybean meal. These results indicated that 11% bicarbonate used in the first experiment was excessive and that calcium carbonate appeared promising as a supplemental buffer in high energy rations.

A fourth experiment was conducted to continue studies relative to all-concentrate rations. Forty steers, averaging 677 lbs. at the start of a 149-day experiment, were fed a basal ration of: ground shelled corn, 90; soybean meal (50%), 6; animal fat (yellow grease), 2; limestone, 1; trace mineralized salt, 1 lb. and 300 gm. vitamin A (10,000 I.U. per gm.) and 3 gm. vitamin A (165,300 I.U. per gm.). Ration treatments consisted of: (1) basal, and in addition to the basal (2) 0.8 lb. $CaCO_3$ per head daily; (3) 3 lbs. orchard grass per head daily; and (4) hay fed ad libitum (table 8).

Table 8. The effect of feeding limestone and hay with high-concentrate rations.

	Basal	$CaCO_3$	Hay. 3 lbs.	Hay, ad libitum
Av. daily gain, lb.	2.75	2.49	2.83	2.89
Daily feed, lb.				
Basal	18.4	16.8	19.3	19.5
Hay	-	-	3.0	6.0
Feed/lb. gain, lb.	6.69	6.74	7.93	8.82
TDN/lb. gain, lb.	5.33	5.39	6.02	6.46
Carcass weight, lb.	641	619	636	649
Carcass grade[a]	10.6	10.4	10.2	10.4
Fat, 9-11th rib, %	36.6	33.6	37.6	37.4

[a] Carcass grades: 10, average good; 11, high good.

Average daily gains were significantly lower for cattle fed the 5% limestone ration than those fed the other 3 treatments; their daily intake of feed, likewise was the lowest of the 4 groups. The cattle fed the hay rations consumed more of the basal ration and required more feed per unit weight gain than those fed rations containing no hay. Differences in carcass grades due to treatments were small, although cattle fed limestone had the lowest carcass weights and the least amount of fat in the 9-11th rib sample. Wise et al (1962) suggested that the inclusion of 2% animal fat in the all-concentrate rations may aid in the control of feedlot bloat, although these workers used fat in these rations to prevent dustiness of the feed.

Woods et al (1961) reported adding 1.5 and 3% sodium bicarbonate to fattening rations for heifers. Thirty-four heifers were fed a basal ration for 155 days that consisted of: rolled shelled corn, 74.5; corn cob, 10; molasses, 5; urea, 0.5; soybean meal, 3.8; ground alfalfa hay, 5; and, minerals and vitamins, 0.2% (table 9).

Table 9. The feed lot performance of fattening heifers fed two levels of sodium bicarbonate.

	Basal	Sodium bicarbonate, 1.5%	Sodium bicarbonate, 3%
Average daily gain, lb.	2.80	2.75	2.83
Daily feed intake, lb.	20.8	21.8	23.3
Feed/cwt. gain, lb.	744	791	822

The effect of buffers on rumen pH and VFA. Emery et al (1961) fed 3 Holstein cows that were rumen fistulated: (1) 12 lbs. alfalfa hay and 8 lbs. of grain mixture; (2) 14 lbs. grain and 1 lb. dehydrated alfalfa pellets; (3) treatment (2) plus 1 lb. sodium bicarbonate per head daily. Feeding sodium bicarbonate increased rumen pH from 5.8 to 6.4. Total VFA concentration in the rumen was highest for cattle fed the high-grain ration (112.7 uM/ml.) and the lowest for those fed the high-hay, or normal, ration (106.4 uM/ml.). Cattle fed the high-grain or high-grain plus sodium bicarbonate rations had slightly higher molar percentages of propionic and butyric acids than those fed the normal ration. The molar percentage of acetic acid was the highest in the rumen of cattle fed the normal ration (72.4); the high grain (68.4) and high-grain plus bicarbonate (67.4%) were quite similar.

More recent studies by Emery (1962) indicated that feeding sodium bicarbonate or calcium carbonate likewise resulted in higher rumen pH values when rations fed consisted of 2 lbs. alfalfa hay daily and grain was fed ad libitum. The feeding of supplemental bicarbonate increased the rumen concentration of acetic and butyric acids and decreased the concentration of propionic acid when compared to cattle fed no buffering agents.

HIGH ENERGY RATIONS FORMULATED WITH BARLEY

Corn vs. barley. Interest in all-concentrate rations was stimulated by the report of Geurin et al (1959) who reported a series of 3 experiments. They reported that when properly supplemented barley is fed as both grain and roughage cattle gain rapidly, finish quickly and ruminate normally (table 10).

Table 10. Rolled barley vs. ground ear corn for fattening steers.

	Ground ear corn	Rolled barley
Av. daily gain, lb.	2.63	2.95**
Feed/cwt. gain, lb.	865	708**
Carcass grade[a]	10	10

[a] Carcass grade; 10, low choice.
**P. 0.01

Earlier, Geurin et al (1955) demonstrated that the cob portion of ground ear corn can serve as the only roughage for fattening cattle.

Two-year-old steers were fed: (1) shelled corn, hay, protein supplement; (2) ground ear corn and a protein supplement. Average daily gains and feed required per 100 lb. gain for the cattle fed the two treatments in the order given were, respectively: (1) 2.55 and 939; and (2) 2.53 lbs. and 850 lbs.

Dinusson et al, (1960a) studied the comparative value of cracked shelled corn and dry-rolled barley for fattening heifers (6 lots of 6 heifers each). The heifers weighed approximately 440 lbs. at the start of the trial and were fed for 215 days. The average daily gains of the lots of cattle fed corn (1.88 lb.) were similar to those fed barley (1.90 lb.). Heifers fed the corn ration required about 6% more feed per unit weight gain than the barley-fed cattle (7.94 vs. 7.48 lbs. feed/lb. gain). The heifers fed corn consumed an average of 2.59 lbs. hay, 11.3 lbs. corn and 1.0 lb. supplement per head daily. The barley fed cattle consumed an average of 2.47 lbs. hay, 10.73 lbs. barley and 1.0 lb. supplement per head daily. Oats was included in the rations at 2 lb. per head daily during the first 68 days of the trial.

The data of Embry et al (1962) indicated that the rate of gain of cattle fed either rolled barley or ground ear corn were similar. They fed 63 yearling steers, weighing 798 lbs. at the start of the trial, for 153-155 days. The barley-fed cattle received 15.5 lbs. rolled barley, 2 lbs. of a pelleted 12% protein supplement and 0.2 lb. hay (hay fed until cattle were on a full-feed of barley) per head daily. The ground ear corn-fed cattle were fed an average of 19.1 lbs. corn and 3 lbs. of a pelleted 40% protein supplement per head daily. The barley ration contained 7.8% fiber compared to 9.7% fiber for the corn ration. The average daily gains and feed required per 100 lb. gain for the two rations were, respectively: barley ration, 1.97 and 897; ear corn ration, 1.98 lb. and 1110 lbs. Carcass grades and marbling scores were similar between treatments.

Barley with various levels of roughage. Embry et al (1962) tested the value of the addition of hay and/or molasses to dry-rolled barley rations for fattening steers. Forty calves, weighing about 517 lbs. at the start of the trial, were fed for 209 days (table 11). Hay fed in this trial was ground through a hammer mill with a 1-inch screen.

able 11. Feedlot performance and carcass characteristics of steer calves fed various barley rations.

	Barley	Barley & 5% molasses	Barley & 15% hay[a]	Barley, 5% molasses & 15% hay[b]
v. daily gain, lb.	2.46	2.51	2.64	2.75
aily feed, lb.				
Barley mix	16.56	16.87	19.37	21.28
Protein supplement[c]	1.00	1.00	1.00	1.00
Hay[d]	0.63	0.63	0.63	0.63
eed/cwt. gain, lb.	740	738	796	833
old carcass wt., lb.	609	626	645	656
arcass grade[e]	17.5	18.1	18.0	18.8
arbling score[f]	4.3	4.5	4.5	5.3

Two steers died from bloat.
One chronic bloater removed from trial.
Soybean meal, 38.7; ground barley, 39; beet molasses, 5; ground limestone, 10; trace mineralized salt, 6 lb.; and vitamin A (30,000 I.U. per lb. of supplement) supplement, 1.3%.
Hay fed at start of trial until cattle were on feed.
Carcass grades: 14, standard; 17, good; 20, choice.
Marbling scores: 3, traces; 4, slight; 5, small; 6, modest.

Feedlot bloat was a problem during the experiment when alfalfa hay was fed; later, prairie hay was substituted for alfalfa hay. Bloat was not a problem in the all-barley rations. Five per cent molasses added to the barley-hay ration reduced the dustiness of the ration. Results of this trial suggested that the addition of molasses to an all-barley or barley-hay ration had little if any effect on the feedlot performance and carcass traits of fattening cattle. Hay-fed cattle had the highest average daily gains and heaviest carcass weights. However, they required more feed per unit weight gain.

The Idaho station (1962) reported feeding an all-concentrate (barley) ration to steers for 167 days in comparison with supplemental hay and/or silage and 2 methods of handling cattle feeding programs. Average daily gains and efficiency of feed use (feed data for 140 days) for the various ration treatments were as follows, respectively: (1) all-concentrate ration, 2.59 and 740; (2) all-concentrate ration plus 2 lbs. alfalfa hay per head daily, 2.67 and 781; (3) all-concentrate ration plus 7 lbs. corn silage per steer daily, 2.78 and 893; (4) all-concentrate ration plus 0.7 lb. alfalfa hay and 6 lbs. corn silage per head daily, 2.77 and 851; (5) all-concentrate ration plus 0.7 lb. alfalfa hay per head daily and a gradually decreasing amount of corn silage, 2.61 and 1293; (6) 6 lbs. concentrate the first 84 days on trial and corn silage fed to appetite and then all-concentrate ration the last 84 days on feed, 2.91 lbs. and 1327 lbs.

The Idaho station (1962) examined the effect of feeding straw to steers fed an all-concentrate mixture composed of 65% dry-rolled barley, 30% dried molasses beet pulp, 2.5% soybean meal, 1% salt, 1.5% steamed bone meal and vitamin A. Average daily gains for a 217-day feeding period for cattle fed the all-concentrate ration (2.46 lbs.) were similar to the all-concentrate ration plus straw (2.41 lbs.). Differences in efficiency of feed use due to ration treatments were small.

McElroy (1961) fed a mixture of 3 parts rolled barley to 1 part rolled oats to fattening steers weighing 755 lbs. at the start of a 141-day trial. Another group of steers were fed the same mixture but in addition were fed an average of 7.7 lbs. alfalfa hay per head daily. Average daily gain for the all-grain ration was 1.90 lbs. per head daily. The steers fed hay gained 2.51 lbs. per head daily. The all-grain-fed cattle required 894 lbs. feed per 100 lb. gain while the hay-fed cattle required 918 lbs. feed. Differences in carcass grades due to treatments were small. The Canadian workers (McElroy, 1962) reported essentially similar results in a later study. They reported evidence of some stiffness and founder in cattle fed no-hay rations in the 1961 trial. Likewise, the rumen epithelium of no-hay cattle evidenced a certain degree of inflammation.

Protein supplementation of barley rations. Barley contains approximately 12% protein. Ten to 11% protein is usually considered adequate for beef cattle rations. Whetzall and Embry (1962) conducted an experiment with steers averaging 904 lbs. at the start of a 110-day trial to determine the value of supplementing barley rations with protein (table 12). The supplement fed the control steers consisted of: ground barley, 80.2; trace mineral salt, 6; ground limestone, 13.2%; and vitamins A and D to supply 10,000 and 1,000 I.U., respectively, per pound of supplement. Five mg. of stilbestrol were included per pound of supplement. Soybean meal was fed as the test protein supplement. The composition of the soybean supplement was similar to the control supplement except soybean meal replaced 48.2 parts of barley.

Table 12. The effect of feeding rolled barley with or without a protein supplement.

	Control supplement	Soybean meal supplement
Av. daily gain, lb.	2.64	2.76
Daily feed, lb.		
Rolled barley	18.2	19.2
Supplement	2.0	2.0
Feed/cwt. gain, lb.	766	768
Carcass grade[a]	19.1	19.1

[a]Carcass grades: 19, low choice; 20, average choice.

As a result of this experiment, the South Dakota workers concluded that a protein supplement is not needed with an all-barley ration that is properly supplemented with vitamins and minerals (e.g., control ration).

Somewhat different results were obtained by McElroy (1961, 1962). In the first trial yearling steers were fed a mixture of 3 parts rolled

barley and 1 part rolled oats as the basal ration. The basal ration contained 10.7% protein. The feeding of about 1 lb. linseed oil meal per head daily increased average daily gains from 1.90 lbs. for the basal ration to 2.16 lbs. for the linseed oil meal supplemented basal. Efficiency of feed use favored the protein supplemented cattle (831 vs. 894 lbs. feed per 100 lb. gain) and the cattle fed the protein supplement produced higher grading carcasses. In a later trial (McElroy, 1962), the feeding of 1 lb. linseed oil meal per head daily increased the rate of daily gain from 1.69 lb. to 1.82 lb. Dinusson et al (1962) studied the value of feeding 1/2 lb. per head daily of mixture of soybean and linseed oil meal to cattle fed dry-rolled barley in addition to feeding 1 lb. per head daily of 3 different supplements containing 15-17% protein. They suggested that supplements with protein levels above 17% were of no value when dry-rolled barley rations containing 12% protein are fed to fattening cattle.

Preparation of barley prior to feeding. North Dakota workers (Dinusson et al, 1961) compared 2 methods of preparing barley for cattle: dry-rolled vs. steam-rolled. Thirty-six steers averaging about 567 lbs. at the start of a 168-day feeding trial were fed (table 13).

Table 13. Steam-rolled vs. dry-rolled barley for fattening steers.

	Steam-rolled barley	Dry-rolled barley
Av. daily gain, lb.	2.31	2.20[a] (2.28)
Daily feed, lb.		
Hay	0.37	0.32
Grain	15.66	14.75
Supplement[b]	1.00	1.00
Feed/lb. gain, lb.	7.37	7.29

[a]One steer gained only 1.38 lb. per head daily. The figure in brackets is for the average of the other 11 steers.
[b]Supplement contained 22.3% protein.

Results of this experiment indicated no real differences in the feedlot performance of cattle fed either steam-rolled or dry-rolled barley. In another experiment (Dinusson et al, 1962), the North Dakota workers also concluded that there were no differences in the performance of fattening cattle fed either dry or steam-rolled barley.

Dinusson et al (1960b) examined three methods of preparing barley for cattle feeding; meal, pellet or dry-rolled. This study indicated that the method of preparation of barley did not greatly affect the feedlot performance of cattle. However, the authors did point out that steers fed rolled barley were the easiest to keep on feed.

Dried molasses beet pulp in barley rations. Keith et al (1961) designed an experiment to measure the effect of feeding steers 3 levels of dried molasses beet pulp (DMBP) in all-concentrate (steam-rolled barley) rations (table 14). Complete mixed rations were fed in which cottonseed meal was used to equalize the protein intake of the cattle. The concentrate mixture averaged slightly over 12% protein and contained the necessary minerals, stilbestrol and vitamin A.

Table 14. The effect of feeding various levels of dried molasses beet pulp with steam-rolled barley rations to fattening cattle.

Ration	Av. daily gain, lb.[a]	Feed/cwt. gain, lb.	Av. daily ration, lb.	Carcass grade[b]	Marbling score[c]
Barley	2.55	798	20.3	9.8	5.7
Barley & 15% DMBP[d]	2.76	760	21.0	9.8	5.7
Barley & 30% DMBP	2.69	806	21.7	10.7	6.4
Barley & 43% DMBP	2.78	816	22.7	10.4	6.0

[a]LSD at the 5% level is 0.19 lb. average daily gain.
[b]Carcass grades: 9, high good; 10, low choice; 11, average choice.
[c]Marbling scores: 1 is devoid and 11 is extremely abundant.
[d]DMBP is dried molasses beet pulp.

The average daily gains of the cattle fed DMBP were superior to those fed only steam-rolled barley. However, differences in the efficiency of feed use and carcass characteristics were small.

Supplementing barley rations with buffers. McElroy (1962) investigated the effect of supplementing an all-concentrate ration consisting of 3 parts coarsely rolled barley and 1 part coarsely rolled oats with buffers. One pound linseed oil meal was fed per head daily. The buffer mixture contained 70% sodium bicarbonate, 15% potassium bicarbonate and 15% disodium phosphate. The yearling steers in this experiment averaged about 735 lbs. at the start of the 133-day trial. Steers fed the all-concentrate ration (10 per treatment) gained 1.82 lb. per head daily and required 925 lbs. feed per 100 lb. gain. The feeding of 2% buffer salts with the all-concentrate ration resulted in average daily gains (1.78 lb.) that were essentially similar to the control (1.82) and the feed required per 100 lb. gain, likewise, was similar to the control (954 lbs.).

Rolled barley vs. rolled sorghum grain. Brethour and Duitsman (1962) compared the feedlot performance and carcass characteristics of two-year-old steers fed rolled-sorghum grain or rolled-barley rations. They suggested as a result of previous studies that all-barley rations had resulted in several foundered cattle. In this experiment they made a greater effort to bring the cattle on a full-feed of grain more slowly and once the cattle were on feed, provided feed free-choice for the cattle at all times. Twenty steers, averaging about 1132 lbs. at the start of the trial, were fed for 129 days. The sorghum grain ration consisted of Ellis sorgo silage, 5, milo, 21.9, alfalfa, 3 and special protein supplement, 1.5 lb. The barley ration consisted of barley, 18.9 and

ecial protein supplement, 2 lbs. Results of the trial indicated at barley-fed cattle gained significantly less (2.27 lbs.) per ad daily than those fed milo (2.59 lbs.). Differences in carcass ades and marbling scores were small. In a second experiment e Kansas workers fed rations similar to those outlined above steers averaging 833 lbs. at the start of the trial for 178 days. esults of this trial also indicated that barley-fed cattle gained gnificantly less (2.03 lbs.) per head daily than steers fed sorgum grain (2.30 lbs.).

gh-moisture ensiled barley. A study was conducted at the rookston Station (Frederick et al, 1961) to evaluate (1) feeding y-rolled vs. rolled high-moisture (30% moisture) ensiled barley and (2) the value of a special barley supplement vs. 4 lbs. falfa hay as supplements to the 2 kinds of barley. The barley pplement consisted of 60% dehydrated alfalfa meal, 30% dried et pulp and 10% ground limestone. Forty yearling steers were d for 170 days. A mineral mixture and trace mineralized salt ere offered free-choice. Results of this experiment are in table .

able 15. High-moisture ensiled barley vs. dry barley and a special protein supplement vs. alfalfa hay for fattening steers.

	Rolled dry barley		Rolled wet barley	
	Supplement	Hay	Supplement	Hay
Av. daily gain, lb.	2.12	2.25	2.40	2.22
Daily feed, lb.				
Barley	17.15	17.37	23.48	22.52
Hay	1.80	4.80	1.81	4.91
Supplement	0.78	-	0.78	4.01
Feed/cwt. gain, lb.[a]	932(831)	988(879)	1088(797)	1237(923)
Carcass grade[b]	9.3	9.6	7.8	8.4
Marbling score[c]	5.4	5.6	4.2	4.9

[a]Figures in brackets are on dry matter basis.
[b]Carcass grades: 7, low good; 8, average good; 9, high good; 10, low choice.
[c]Marbling scores: 4, slight; 5, small; 6, modest.

Results of this experiment indicate that differences in the feedlot performance of cattle fed ensiled high-moisture or dry-rolled barley were small. However, feed required per unit weight gain was consistently higher for the cattle fed alfalfa hay when compared to those fed the all-concentrate ration.

Summary

Current information on high-energy rations warrants the following conclusions:

1. In addition to good feedlot management, certain precautions should be observed when feeding all-concentrate rations:

(1) the change to all-concentrate rations should be gradual; (2) feed should be available at all times to prevent cattle from consuming large amounts of feed at one time; (3) the rations should contain adequate minerals and vitamins.

2. Average daily gains of cattle fed all-concentrate rations are not necessarily greater than cattle fed nominal amounts of roughage. However, efficiency of feed use favors high energy rations.

3. The place of buffers in cattle feeding needs further research. Results to date have not indicated much benefit from such ration treatment.

4. Although research results have been variable, it appears reasonable that cattle fed properly supplemented all-barley or all-ground ear corn rations will have weight gains that are quite similar. However, cattle fed ear corn rations have consistently had a higher feed requirement per unit weight gain.

5. The feeding of low levels of hay with barley rations does not necessarily reduce weight gains of cattle. Efficiency of feed use favors the all-barley ration.

6. The feeding of high-energy rations has not produced carcasses superior to cattle fed nominal amounts of roughage in the ration.

7. Rumen pH and volatile fatty acid production are affected by ration treatments.

8. Rumen parakeratosis, and other rumen problems, have been observed in cattle fed high-energy rations.

9. Feeding high-energy or all-concentrate rations provides for ease in automation of feeding operations.

10. Steam-rolled has not been superior to dry-rolled barley. Pelleting all-concentrate rations does not improve feedlot gains, although efficiency of feed use has often favored the pelleted feed.

11. High-moisture ensiled barley is equal to dry-rolled barley (on a moisture equivalent basis) for beef cattle.

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PRACTICAL NUTRIENT INTAKE STANDARDS FOR GROWING TURKEYS

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Feeding standards which are used as a basis for formulating turkey starter and grower diets specify that nutrients be provided as percentage of the total diet or in terms of a specific number of units of nutrient per pound of diet. These feeding standards do not take into consideration feed intake per bird per day or the nutrient requirements as determined by different rates of growth.

Feeding standards expressed in terms of daily nutrient intake make it possible to provide each nutrient at the level required for the growth rate inherent in the particular strain of turkeys being fed and to supply these nutrients in the quantity of feed which it is anticipated that each bird will consume during any given day of the growing period.

Dunkelgod et al. (1960) produced 12-pound hens in 16 weeks with a 2.85 feed conversion and 24-pound toms in 21 weeks with a 2.2 feed conversion. The diets fed in this experiment were based upon daily nutrient intake, with three different levels of nutrient intake being studied. Nutrient intake standards based upon these data have been described and presented by Dunkelgod et al. (1962). It is neither economically feasible nor physically possible to formulate practical rations to meet this nutrient intake standard (Dunkelgod et al., 1962), using feed ingredients which are presently available commercially. As economic and physical limitations are overcome, however, through the commercial development of improved feed ingredients, practical nutrient intake standards will be formulated which are closer in nutrient composition to this "benchmark" standard.

Nevertheless, economically feasible series of rations based upon nutrient intake standards derived from this "benchmark" standard were formulated and fed in commercial field tests during 1960. These economically feasible rations met daily nutrient intake standards with lower nutrient densities (units of nutrient per unit of ration) than did the standards which were originally described by Dunkelgod et al. (1962). As a result, the daily nutrient intake of the growing turkeys fed these lower nutrient density rations was reduced, thereby increasing the length of time required to reach market weight and the amount of feed required to produce a pound of gain.

Dunkelgod et al. (1961) described and presented three economically feasible nutrient intake standards for growing toms (see Standards 1, 2 and 3, Table I, Processed Series P-391). The three nutrient intake standards for growing hens (Standards 4, 5 and 6) are presented in Table II of Processed Series P-391. The data which were utilized in calculating each of these six standards were observed either under experimental feeding conditions at the Oklahoma Agricultural Experiment Station or under commercial field conditions. Data for Standards 1 and 3 for toms and Standards 4 and 6 for hens were obtained under experimental feeding conditions. Data for Standard 2 for toms and Standard 5 for hens were obtained under commercial field conditions.

As shown in Tables I and II in Processed Series P-391, each of the three nutrient intake standards for both toms and hens supports a different rate of growth. As nutrient intake is reduced, rate of growth becomes progressively slower (Standards 1, 2 and 3 for toms and Standards 4, 5 and 6 for hens), more time is required to reach a desired market weight and more feed is required per pound of market turkey produced. Feed consumption values become a major consideration if nutrient intake standards are to be utilized effectively. However, the multiplicity of factors which influence feed intake has not been clearly identified through research work and very little is known about the factors involved, or how they exert their effects. Thus, it is difficult to obtain an accurate estimate of feed intake for a given feeding situation unless a specific ration which contains the desired nutrient density and balance is fed to a selected strain of turkeys within a given feeding situation so that feed intake values can actually be measured. For this reason, it is suggested that the following procedure be followed to obtain an accurate estimate of daily feed intake for any given feeding situation.

The nutritionist, turkey producer or feed manufacturer must select the daily nutrient intake standard which is best for a given feeding situation. A series of starter and grower rations, based upon this selected daily nutrient intake standard, must then be obtained. This can be accomplished in one of two ways. Practical rations such as Series 1 can be used, or a new series can be formulated based upon the daily nutrient intake standards which have been selected.

Considerations necessary for use of Nutrient Intake Standards

1. Adequacy of present rations from a "nutrient efficiency" standpoint.

2. Are nutrient intake standards available which will provide the greatest profit margin with the particular strain of birds?

   a. Nutrient intake standards in P-391 were calculated from data obtained under experimental and field conditions. These standards, three for males and three for females, can only be used for specific growth rates.

   b. Standards established for one growth rate can be used only as an estimate in establishing other feeding standards.

   c. Research must provide more complete standards for a wider range of specific growth rates.

   Data required to formulate these standards:

   (1) Feed consumption values
   (2) Nutrient consumption values
   (3) Efficiency of nutrient utilization
   (4) Growth rate data on a number of strains

3. Size of market turkey and length of time desired to produce this particular weight.

   Factors involved in these considerations:

   a. Protein intake required
   b. Caloric intake required
   c. Vitamin intake required
   d. Mineral intake required
   e. Economic ceiling

4. In order to obtain the most efficient growth rate, regardless of the nutrient density, all nutrients should be as near to the proper balance as possible THROUGHOUT THE ENTIRE GROWING PERIOD.

5. The amount of feed consumed per poult per day must be balance with respect to all nutrients.

6. The consideration of nutrient balance should begin with the individual ingredients before they are combined to form a diet. Each ingredient should make a definite contribution to the nutrient balance.

7. Hens require a higher daily caloric intake than toms, whereas toms require a higher daily protein intake than hens.

8. In order to obtain the most efficient nutrient utilization "All" nutrients must be in proper balance.

Procedure that can be used in the formulation of diets based upon the nutrient intake concept

1. Available feed intake values for a specific rate of growth
   Example: P-391, page 4, column 9

2. Available nutrient intake values for a specific rate of growth
   Example: P-391, page 4, column 10--protein intake values for a specific rate of growth in column 4.

   column 11--Caloric intake values for a specific rate of growth and nutrient utilization.

3. Calculations necessary for the conversion of daily nutrient intake values to a percentage basis

		P-391, page 4
Feed intake	14 grams	column 9
Protein intake	4.4 grams	column 10
Protein (per cent)	4.4 ÷ 14 = 31.52	
Caloric intake	46.49 Calories	column 11
Calories/gram	= 46.49 ÷ 14 = 3.316	
Calories/lb.	= 3.316 X 454 = 1505.46	
	= 1505	

4. The standard for the 18 amino acids is given on page 13 of P-391. The protein block must be balanced with respect to the 18 amino acids.

5. Compare the individual ingredients with the standard for the 18 amino acids. Choose a group of ingredients that when combined will give amino acid ratios that agree with the standard.

6. When formulating practical turkey starter and grower rations, it is not possible in every instance to meet these amino acid ratios in all respects. Experience has shown that satisfactory results can be obtained when the level of any given amino acid is within the range of 20 per cent below or 20 per cent above the value as listed in the amino acid standard.

7. Vitamin-mineral-concentrate 60 and Vitamin-concentrate 60-A were formulated considering the approximate levels of vitamins and trace minerals contributed by most practical feed ingredients. Consequently, we simply add the Vitamin-mineral concentrate, VMC-60, and Vitamin-concentrate, VC-60A, at levels of 0.5 per cent and 0.25 per cent, respectively. The specific amounts of each vitamin and trace mineral added per pound of finished diet are given on page 31 of P-391.

8. Energy-protein ratios are extremely critical for the growing birds and are established by the specific standard chosen. (Table 1, P-391, page 4, column 14)

9. The finished diet and tables of complete calculated analyses are shown in P-391 on page 14.

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CALCIUM AND PHOSPHORUS NEEDS OF TURKEY

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The turkey has been thought peculiar among poultry in having an apparently high requirement for calcium and phosphorus. The National Research Council (NRC) indicated in 1954 that the turkey required 2% calcium and 1% phosphorus (0.50% inorganic from 0-16 weeks of age). The more recent 1960 edition of the NRC publication lists the same starting requirements, but during 8-16 weeks the requirements are reduced to 1.70% and 0.85%, respectively, These higher requirements are in comparison to calcium and phosphorus needs in the chick of 1.0% and 0.6%, respectively.

The high requirements suggested for turkeys were based on results which appeared in the 1940's. Most of the conclusions in these papers indicated a need for 2.0% calcium and 1.0% phosphorus. In examining the data, one can observe that considerably less calcium and somewhat less phosphorus were probably acceptable, especially when the levels of these elements were decreased simultaneously.

Crookston Studies

In studies conducted at the Northwest Experiment Station, Crookston, Minnesota, it was apparent that satisfactory market turkeys were produced with considerably less calcium and phosphorus than suggested by NRC, especially during the growing period. During 0-8 weeks of age, these turkeys were fed a mash containing 1.91% calcium and 0.98% phosphorus. At eight weeks of age, in the Minnesota standard program, it is customary to feed this starting mash as a supplement with free choice of corn and oats. Based upon the consumption of the mash, corn, and oats it was possible to calculate the greatly reduced calcium and phosphorus levels consumed by the turkeys.

Therefore, an experiment was established where the above calculated calcium and phosphorus levels were fed to the turkeys in a complete feeding program. The results were reported in a paper by Waibel, Johnson and Pilkey (1961).

The calcium and phosphorus levels fed the turkeys during various phases of their growth are listed in table I. The calcium and

osphorus levels were quite low in comparison to the suggested RC levels.

y inspecting the data from this experiment (Table 2), it is seen at turkeys which received the modified low calcium-low phosorus ration actually gained somewhat more weight during the periment, regardless of whether they were on range or in conement. There were no apparent leg weakness problems in any the treatments. Tibia ash was just as high with the modified tion as with the regular control ration.

is evident from these results that excellent turkeys were proced on the low calcium and phosphorus levels. It should, hower be pointed out that there were also some other nutrient anges in the modified ration. These data show, however, that od turkeys can be produced on reduced calcium and phosphorus vels during the growing period.

her Recent Studies

elson et al (1961), of Washington State University, reported that ey were able to produce satisfactory turkeys from 8-24 weeks f age on a ration containing 0.6% calcium and 0.6% total phoshorus.

Another early report in this area was that of Sullivan of Nebraska. He reported that male and female Broad Bronze turkeys between -20 weeks required 0.85% and 0.75% phosphorus, respecticely. He was using an assay diet containing 1.55% calcium. It is possile that the phosphorus requirement in this work was somewhat igher due to the 1.55% calcium level. Another important piece f work was that of Blaylock and associates, of International Milling Co., in 1961. They found that .80% calcium and .80% phosphorus produced growth and feed utilization during the 0-24 week age period. In addition, they reported that the calcium:phosphorus ration was quite critical, especially at marginal levels of phosphorus. In these cases, better performance could be achieved by keeping the calcium level quite low.

A brief table summarizing recent work is presented in Table 3. This covers various age periods during the 0-24 week period. From these results it is possible to form suggestive calcium and phosphorus allowances (requirement plus a conservative safety factor), and these are shown in Table 4.

Turkey Breeders

Virtually no work has been done on the calcium and phosphorus requirement of turkey breeders. As is true with many of the nutritional requirements of turkey breeders, considerable research is required to define the calcium and phosphorus requirements.

It is of interest to inspect the voluntary calcium consumption of turkey breeder hens receiving complete feeds (except calcium) containing approximately 1.3% calcium and free choice of oyster shell. Breeders receiving a corn-soybean meal diet consumed 2.47% calcium. Breeders receiving a diet of higher energy containing 5% fat consumed 2.63% calcium and breeders receiving a low energy diet containing 25% oats, 15% wheat standard middlings, and 10% wheat bran consumed 3.08% calcium. These birds were housed in triplicate pens, and it is of interest to observe that the calcium intake with the low energy diet was significantly higher than that of the corn-soybean meal diet. This is notwithstanding the fact that considerably more feed was also eaten by birds receiving the low energy diet.

There is little information on the phosphorus requirement of breeder hens. Wilcox et al (1957, 1961), of South Dakota reported that responses were obtained in egg production, hatchability, and egg size by the addition of inorganic phosphorus to a purified diet containing 0.06-0.08% phosphorus. With a practical diet containing 0.34% total phosphorus, apparently satisfactory egg production, fertility, and hatchability resulted. From these studies it was estimated that the phosphorus requirement of a laying turkey hen was between 0.25 and 0.43% total phosphorus.

The calcium level in our departmental publication entitled "Turkey Rations" is 2.27% calcium in a complete ration. The total phosphorus level in this ration is 0.66% and the inorganic phosphorus level is 0.46%.

Related Nutritional Requirements

Vitamin D. Work conducted decades ago indicated that the calcium levels could be reduced if sufficient vitamin D was present in the diet: that is, the calcium requirement increases in vitamin D deficiency. There is a possibility that some of the earlier high calcium requirements were caused by vitamin D stability problems in the assay diets. It is suggested that with the more recent lower levels of calcium, it is very important that vitamin D be present in adequate amounts. Turkey rations should be formulated to contain approximately 800 I.C.U. of vitamin D per pound, although the large safety margin contained therein may be reduced somewhat if the newer highly stable forms of vitamin D are supplied.

etary energy. The requirements listed for calcium and osphorus should be satisfactory for corn-soybean meal type ets. However, if energy level is increased it would also be se to increase the levels of calcium and phosphorus proponally.

ietary fat. One of the advantages of using the lower calcium vels with turkeys is that added saturated fats will yield a eater amount of their gross energy. This was shown by edde et al (1960) in studies conducted in our department. By milar reasoning, if high levels of saturated fats were fed, ove 5% of the diet, one should probably raise the calcium vel somewhat, due to formation of indigestible calcium soaps.

her minerals. The increased requirement for zinc and other trients with high calcium diets is well documented in a number species. Excessive calcium will also increase the phosphorus d manganese requirements. Thus is indicated the necessity keep dietary calcium in proper balance with other nutrients.

otentiation. A further advantage of using the reduced calcium evels in formulation is more efficient use of the tetracycline-ype antibiotics, such as Aureomycin and Terramycin. If a otentiated feeding program is required, it would appear feaible and safe, for short periods of time (such as one week), to educe the calcium levels shown in Table 3 to the same level as phosphorus. Thus a 1 to 1 ratio would be employed during the potentiation program.

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able I. Calcium and Phosphorus Levels in Crookston Study

ge of Turkey	Calcium	Phosphorus	
		Total	Inorganic
Weeks	%	%	%
8-14	1.24	0.75	0.50
14-20	0.89	0.58	0.35
20-24	0.62	0.48	0.25

able 2. Growth and Bone Ash of Growing Turkeys From 8-24 Weeks of Age

reatment	Body weight--weeks					Feed	Tibia ash[1]
	14♂♀	20♂♀	24♂	24♀	24♂♀	Gain	
	lb.	lb.	lb.	lb.	lb.		%±s
onfinement:[2]							
egular	9.6	15.2	22.6	15.0	18.8	4.78	63.92±.71
odified	10.2	15.6	23.2	15.8	19.5	4.54	64.80±.61
ange:[3]							
egular	10.6	17.5	25.3	16.4	20.8	4.25	—
odified	10.7	17.3	25.9	16.8	21.4	4.21	—

1. Bone ash was performed on distal half of left tibia, 5 birds per group, by Association of Official Agricultural Chemists (1950) method. s is standard deviation.
2. Each 15'X 17' pen contained 25♂ and 25♀ turkeys.
3. Each 1 acre brome pasture lot contained 50♂ and 50♀ turkeys.

Table 3. Calcium and Phosphorus Requirements of Turkeys as Indicated by Recent Research.*

Investigator	Variety**	Age	Calcium	Phosphorus Total	Phosphorus Inorganic
		Weeks	%	%	%
Pensack and Stokstad (1961)	BBB	0-4	1.20	0.80	0.55
	BSW	0-4	0.80	0.80	0.55
Formica et al. (1961)	BBB	0-8	0.81	0.65	—
	BBB	8-25	0.83	0.56	—
Blaylock et al. (1961)	BBB, MW BBW	0-24	0.80	0.80	0.52
Nelson et al. (1961)	BBB	8-24	0.60	0.60	0.34
Sullivan (1960)	BBB	8-20(♂)	(1.55)	0.85	0.50
	BBB	8-20(♀)	(1.55)	0.75	0.40
Wilcox et al. (1961)	BBB	8-16(♂)	(1.51)	0.80	0.55
	BBB	16-20(♂)	(1.09)	0.80	0.58
	BBB	20-24(♂)	(0.82)	0.60	0.38
	BBB	8-16(♀)	(1.24)	0.60	0.35
	BBB	16-24(♀)	(0.82)	0.60	0.38
Waibel et al. (1961)	BBB	8-14	(1.24)	(0.75)	(0.50)
	BBB	14-20	(0.89)	(0.58)	(0.35)
	BBB	20-24	(0.62)	(0.48)	(0.25)

* Values listed in parentheses cannot be considered as precise requirement estimates, since sufficient graded levels were not employed.

** BBB is Broad Breasted Bronze. BBW is Broad Breasted White. BSW is Beltsville Small White. MW is Medium White.

Table 4. Suggested Calcium and Phosphorus Allowances for Growing Turkeys

Age of Turkey	Calcium	Phosphorus Total	Phosphorus Inorganic
Weeks	%	%	%
0-8	1.2	0.85	0.55
8-14	1.0	0.75	0.50
14-20	0.80	0.70	0.45
20-24	0.60	0.60	0.35

FLOORS AND SPACE FOR GROWING PIGS

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Confinement raising of swine has stimulated application of automation and mechanization in the production facilities. Of the many factors causing increased consideration of confinement systems, the potentially greater unit of production per man hour of labor expended has been of prime importance. One of the most troublesome aspects, however, has been the handling and disposal of the waste material resulting from concentration of large numbers of animals in small areas. Many methods of cleaning concrete floors have been used to varying degrees of satisfaction--scraping (by hand or tractor scrapers), water pressure, mechanical gutter-cleaner equipment, and various combinations of these. Of very recent development is the incorporation of "self-cleaning" floors in confinement units. "Self-cleaning" is not strictly correct since the floors themselves are incapable of action, but it implies a structural concept which allows for the movement and behavior of animals to force manure through openings in the floor and eliminates labor of regular cleaning. The term slotted is now commonly used to describe such floor design.

For simplicity and clarity, the term slotted floor designates a hog house floor or any portion thereof having openings through which manure will drop or be forced through by animal movement. It includes expanded steel, concrete or steel grates, concrete or wood slats and any other material that may be used for the same purpose. The term slats describes materials fabricated in relatively long, narrow strips and spaced at uniform distances to provide a slotted floor.

In view of current interest, it is interesting and somewhat surprising that, according to Hammer (1960), the slotted floor principle has been used in livestock housing for at least 200 years. Loose-housing systems involving an enclosed, insulated loafing barn with a slotted floor originated in Iceland for housing sheep. And for the past 30 years Norwegian farmers have used similar plans for sheep and goat barns. It has been only within the past 10 years, however, that specific research has been carried out in European countries to evaluate the slotted-floor principle in housing for different species of livestock and poultry. Sheep, goats, calves, feeder cattle, dairy cattle, swine, unshod horses, and poultry have been kept on slotted floors. In the United States increased use of confinement facilities in swine has stimulated interest in floor designs and materials as means of improving sanitation and reducing manure-handling problems and labor.

General Management Considerations

Slotted flooring material must meet certain minimum qualifications

fore it can satisfactorily replace solid floors now commonly ed for swine of all ages. As it could affect total performance, w would slotted flooring affect:

1. Feet and legs? Bruising or other injury to feet and legs would probably adversely affect feed consumption because of the animal's reluctance to move around. Broken skin and tissues would invite infection and resulting complications.

2. Feed wastage? With slotted floors spilled feed would be less noticeable and not accessible to the pigs since it would be under them and mixed with the manure. Strict control and adjustment of feeders would be essential.

3. Sanitation and disease? The flooring material should not contribute to or be the cause of neglect of good management practices. Slotted floors can markedly reduce contamination from excreta and other materials.

4. Environment? Control of drafts is essential with slotted flooring, and temperature control becomes especially important with young pigs. Ventilation requirements may vary with method of manure handling or storage used.

5. Manure disposal? Properly installed slotted-floor units should materially reduce manure disposal problems.

6. Labor? Ill-planned and inadequately arranged units could increase total labor requirements, while well-planned units would reduce labor.

7. Cost, initial and maintenance? The usually higher initial cost of slotted flooring must be justified by other advantages. Information on maintenance costs of different materials is too fragmentary for definite conclusions.

8. Space requirements? Research suggests less space allowance per pig than generally recommended on solid floors is satisfactory, particularly as this results in floors and pigs being clean.

9. Total pig performance? Other things being equal, proper use of slotted floor arrangements should not prove deleterious to pig performance.

Research at the University of Illinois

Although various kinds of expanded metals and wire mesh products have been used for a number of years in cage units designed for nutritional research with individual pigs, the first evaluation of the slotted-floor principle in pens for groups of pigs was started in 1955. Table 1 summarizes 14 comparisons made over a two year period and shows that the pigs on the expanded metal gained approximately 19 per cent faster than those on concrete floor.

One series of the 4' x 8' pens was raised 10" above the concrete, with flooring of 3/4" 9-gauge flattened expanded metal having diamond-shaped openings. Each pen had a 250-watt brooder lamp for supplemental heat, a wooden overlay in one end to provide minimum sleeping space, a 4-hole pig self-feeder, and an automatic waterer. The data include only those comparisons in which ration and other experimental treatments were identical between similar animals on concrete and expanded metal floors.

The pigs showed no adverse effects from being on the expanded metal floor. They used the wooden overlay for sleeping except in very warm weather, when they slept on the metal. Pigs on the expanded metal kept much cleaner than those on concrete.

The concrete floor pens were cleaned daily. The concrete under the expanded metal was cleaned daily during hot weather but only monthly during the winter.

Table 1.--Summary of Performance of Young Pigs on Concrete and Expanded Metal Floors[a]/

Date	Expt. No.	Pigs[b]/ No.	Pigs Age	Pigs Wt.	Days on test	Av. daily gains, lb. Concrete	Av. daily gains, lb. Mesh	Feed/lb. gain Concrete	Feed/lb. gain Mesh
May '56	85a	16	15	7.5	21	.31	.37	2.19	2.06
Aug. '56	104	64	14	6.8	35	.28	.36	1.94	1.89
Oct. '56	113	64	16	8.0	35	.53	.67	1.81	1.99
Feb. '57	132	96	14	9.0	28	.30	.37	1.99	1.75
Aug. '57	163a	32	18	8.5	28	.56	.63	1.53	1.47
Aug. '57	163b	32	17	8.0	28	.44	.53	1.61	1.56
Aug. '57	163c	32	16	7.5	28	.37	.44	1.66	1.50
Oct. '57	169	40	18	9.5	28	.40	.44	1.86	1.82
Nov. '57	178	56	19	11.0	28	.36	.60	2.09	1.81
Jan. '58	187	32	16	9.6	42	.63	.64	1.70	1.74
Feb. '58	197	64	20	13.5	21	.65	.72	1.51	1.51
Mar. '58	198	32	17	9.2	35	.51	.61	1.58	1.57
May '58	208	96	18	12.0	28	.52	.62	1.70	1.72
July '58	221	72	17	11.0	36	.57	.62	1.83	1.86
Average		52	16.7	9.8	30	.46	.55	1.78	1.73

a/ These data were taken from experiments in which pigs of comparable ancestry, weight and condition were randomly assigned to concrete or expanded metal floor pens 4' x 8' in size. Ration treatments within floor comparisons were identical. Diamond-shaped openings measured 1 1/2" x 5/8".
b/ A total of 728 pigs.

Weanling pigs (two per pen) were confined to the expanded metal floor pens in two additional experiments. The first test involved a feeding demonstration in which the control animals fed a fortified corn-soybean meal ration gained 1.71 pounds daily from 40 to 140 pounds. They required 2.56 pounds of feed per pound of gain. In the second test, six littermate pigs were used, and the results are shown in Table 2.

Table 2.--Performance of Pigs Confined to Expanded Metal Floor From Weaning to Market Weight

Sex	No. of animals	Average initial wt., lb.	Average final wt., lb.	Average daily gain, lb.	Feed/lb. gain, lb.
Boars	3	33	236	1.82	3.20
Gilts	3	31	215	1.64	3.28

The animals were removed from the pens three times during the test period for scheduled weighings. On each occasion they walked on concrete walks and cinder lanes a total distance of 400 feet. At the end of the test their feet and legs were in good condition.

In a second series of tests, different flooring materials and designs were evaluated in respect to the effect upon total pig performance. In the first two experiments the pens were approximately 6' x 12' which allowed about 6 1/2 square feet per pig in Experiment 1 and about 5 1/2 square feet in Experiment 2. The results are shown in Table 3.

During the first three or four weeks of Experiment 1, the pigs were uncomfortable because the unheated, uninsulated building did not provide sufficient protection from the cold. Placing a solid overlay for the sleeping area in each pen did not alleviate the discomfort, as the overlay became wet and dirty from manure buildup. Removing the overlay kept the pigs drier and cleaner because they tramped most of the manure through the open spaces. Rate of gain was essentially the same on the two kinds of slats. Pigs on the quarry screen developed bruises and injuries on the pads of their feet and on knees and hams as they increased in weight. There was not sufficient surface area in relation to opening size to provide comfortable support for the animals. After 125 pounds they became increasingly reluctant to move about, developed skin lesions and sores, and did poorly. Pigs on the concrete slats and wood slats showed no ill effects from the flooring. The spacings between the wood slats varied during the progress of the experiment since the edges of the slats wore down or were chewed by the pigs and the slats underwent expansion and contraction as a result of moisture.

In Experiment 2, performance was slightly in favor of the pigs on concrete slats. The wood slats progressively deteriorated, the spacings ranging from 1/2 to 2 inches. The pigs moved cautiously when the spaces increased, and their footing was less sure on the wet slats. These factors caused them to spend less time at the feeder.

The solid oak floor became slick when wet, and wood shavings were used continuously to reduce the slickness. The two feet of flattened expanded steel was only partly effective as a dunging alley. This pen was cleaned daily, whereas the pens with slats were not cleaned during the 84-day experiment.

Of the materials used, the quarry screen was superior in self-cleaning action but was definitely inferior from the standpoint of foot and leg condition.

Experiment 3 is an evaluation of concrete slats, 1 1/2" wood slats and solid concrete floors. Twenty weanling pigs are in each 6' x 12' pen.

In a third series, space allowances for growing-finishing swine on slotted floors are being evaluated. Concrete cross-foundation walls spaced at 8' intervals provide for manure pits under the slats. Each pit slopes from the side of the building to the center and has a drain fitted with a plug that doubles as an overflow pipe so that a given level of liquid can be maintained. Individual pits, or ponds, are drained at different times.

Results of two trials are shown in Table 4. In Experiment 1, rate of gain was not significantly affected by space during the first 50 days. For the last 28 days and for the total period, however, the pigs having 6 1/4 square feet of floor space gained significantly faster than those having 4 square feet. In the second experiment rates of gain were comparable among the three space allowances. This test lasted only 46 days, compared to 78 days in Experiment 1, and final weights were about 157 pounds.

Experiments in progress include space allowance and number of pigs per pen.

Hoefer and Harmon (1961) summarized several experiments involving slotted floors, but no definite space recommendations were suggested.

Performance of growing-finishing swine on slats over water has been satisfactory. Odor, though perhaps of no measurable concern to the pig, becomes quite offensive to workmen when ventilation (air replacement) is inadequate. The odor is most noticeable when the pits are drained, but absent when they are filled with fresh water. The actual cause has not been determined. It has been estimated (Hanson, 1962) that anaerobic action at 60° F. produces gas that is about 80 per cent carbon dioxide, 15 to 20 per cent methane, and traces of other gases. It is also suggested that oxygen lack would be the primary limiting factor in a tightly enclosed

house should power failure occur and render the ventilation system useless.

There have been some reported, but unsubstantiated, observations that animals in houses having lagoons under the slats "slow-up" after about 150 pounds in weight. Accumulation of carbon dioxide at floor level or inadequate oxygen supply for the size and number of animals may cause this lethargic behavior and slower growth. Other gases or environmental factors such as too limited floor space may be involved.

Much more information on the biological activity in lagoons or manure pits under slats in tightly enclosed buildings is needed before factual ventilation requirements can be established.

Slotted floors, partial or complete, are also being used in farrowing facilities. Different systems have seemingly been equally effective in reducing labor, eliminating bedding, and keeping baby pigs clean and dry. It is imperative, however, that the pigs be protected from drafts.

Summary

Slotted-floor housing units have encouraged intensified confinement systems of swine production. Current data available indicate that total swine performance is comparable to that realized from animals on solid floors. And there is no evidence to suggest that nutritional considerations are significantly different.

In Illinois tests concrete slats proved superior to fir timber slats in durability and ease of cleaning. Elm and oak timber are preferable when wood slats are used. Quarry screen was excellent from the self-cleaning aspect but completely unsatisfactory for use because of injury to feet and legs of animals over 100 pounds in weight.

Optimum space allowances for pigs of various ages have not been determined. Amount of floor space per pig should be limited sufficiently to prevent manure buildup on the slats. This results in animals staying cleaner.

Slats should run parallel to the feed trough and areas of heavy traffic to most effectively use the total surface area. Rough edges and uneven spaces impede movement and may injure the pigs.

Slotted floors can reduce labor and provide a more sanitary environment for the animals. They have been effectively used in portable units and farrowing facilities as well as confinement growing-finishing units. Ventilation requirements are not definitely established.

Table 3.--Comparison of Concrete Slats, Wood Slats, Quarry Screen, and Solid Oak Floor

	No. of pigs	Av. initial wt., lb.	Av. final wt., lb.	Av. daily gain, lb.	Feed/lb. gain, lb.	Av. daily feed, lb.
Experiment 1 (January 18 to April 24, 1961)						
Concrete slats[a]	10	48	188	1.49	----[e]	----[e]
Wood slats[b]	10	49	182	1.40	----	----
Quarry screen[c]	10	51	166	1.18	----	----
Experiment 2 (August 23 to November 15, 1961)						
Concrete slats	12	58	187	1.52	3.57	5.52
Wood slats	12	56	178	1.42	3.70	5.24
Solid board floor[d]	12	58	177	1.42	3.45	4.89

a/ Slat dimensions were 5" top width, tapered to 3" bottom width, 4" deep, spaced 1" apart.
b/ Made by cutting 4" x 8" Douglas fir timbers into equal parts. Cutting was at 15° angle to provide taper on one side of each slat. Top width, about 4 1/4", spaced 1" apart.
c/ Quarry screen openings, about 1" square.
d/ Solid floor of 2" x 12" rough oak boards. A 2' strip of expanded metal was in one end of pen for dunging alley.
e/ Feed requirements undetermined since ration was automatically supplied to each pen from central storage tank.

Table 4.--Effect of Floor Space Upon Performance of Growing-Finishing Pigs on Slotted Floor Over Water

	Square feet of floor space per pig: 4	6 1/4	8
Experiment 1[a]			
Number of pigs	33[b]	33[b]	
Average weight, lb.			
Initial	38	37	
After 50 days	117	121	
After 78 days	162	171	
Average daily gain, lb.			
First 50 days	1.59	1.68	
Last 28 days	1.60	1.76	
Total period	1.59	1.71	
Experiment 2[c]			
Number of pigs	28[d]	28[d]	28[d]
Average weight, lb.			
Initial	66	65	68
After 34 days	129	132	133
After 46 days	155	157	157
Average daily gain, lb.			
First 34 days	1.89	1.97	1.96
Last 12 days	2.08	2.06	2.02
Total period	1.94	2.00	1.98

a/ November 27, 1961 to February 13, 1962.
b/ Three pens of 11 pigs each.
c/ February 26, 1962 to April 12, 1962.
d/ Four pens of 7 pigs each.

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FEEDING THE REPLACEMENT PULLET

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The nutritional requirements of replacement pullets are the least known in relationship to their economic importance of any class of poultry. As an example of this, the National Research Council publication on the nutrient requirements of poultry does not list a single amino acid requirement of growing pullets, and the other nutrient requirements that are published are, for the most part, projections of broiler chick requirements.

This lack of requirement information either stems from or is partially the cause of the wide variety of feeding programs that are currently used to grow replacement pullets. Probably nowhere else in the poultry industry is there less consistency in management and feeding programs than in this particular area. Programs have been devised that vary from 6 to 24 hours of light at 8 weeks of age, to range versus complete confinement, and from full feeding a high energy ration to restricted feeding a low energy ration. All have had some success, which points to the fact that the pullet can adjust to a wide variety of rations and management conditions.

The obvious goal of any program for replacement pullets is to produce a pullet which will mature sexually at a desired time and which once in production will be in a physical condition that will allow her to lay at her maximum rate for the year. A second major goal, which often necessitates a compromise with the first, is to produce the pullet at the most economical cost. This economic factor also contributes to the use of the wide variety of feeding programs currently practiced today.

In general the feeding of pullets can be broken down into three major categories. These are generally designated; 1. full-feeding of a well balanced, low to medium fiber ration; 2. limited feeding (by controlling feed available to the birds) of a well balanced, low to medium fiber ration; 3. full feeding of a ration deficient in one or more nutrients (usually energy or protein). Range rearing versus confinement can be an additional variable for all of the above.

Full feeding of a low to medium fiber ration which is well balanced is still one of the more popular methods used today. This feeding program has the advantage of keeping the birds in good condition

(both in appearance and flesh). The pullets have greater nutrient reserves at the start of production. This is also an advantage in the case of a disease outbreak during the growing period. With this type of program one can be more assured of the fact that the birds are consuming all the nutrients in adequate amounts.

The main disadvantage of this type of program is that quite frequently it is not the most economical means of rearing pullets, and secondly with high energy levels it will lead to more rapid sexual maturity than desired. Thus the use of programs allowing only limited feed intake have come to play a more prominent place in the rearing of pullets. This type of program is of value especially for replacement broiler strains where there is a tendency for the rapidly growing pullets to become too fat. In this program pullets are either limited in quantity of feed normally given per day or limited in the amount of time they have to consume the feed (short day program - requires windowless house and a special lighting program).

A third method of restriction feed intake attempted recently at the University of Minnesota (1) is the "skip-a-day program." This program, used with success by Singsen of the University of Connecticut (2) for broiler hens in production, markedly retarded sexual maturity of broiler-type replacement pullets in the Minnesota study. In the experiment reported in Table 1, 100 pullets of Columbian and New Hampshire breeding were placed on the following treatments: 1. full fed a standard (corn, oats-soybean meal type) grower ration having a medium energy level. 2. fed the same ration for six days of the week but given nothing on the seventh. 3. fed the same ration for three days then given nothing on the fourth. The values indicate no difference in body weight at the end of the experiment, slightly less feed consumed by the "skip-a-day" lots and as previously indicated a delayed sexual maturity for the birds not full fed. No differences between lots were observed in mortality; however the pullets which were on the "skip-a-day in four" were definitely more variable with some very poor looking birds. This variation was not a problem in the "skip-a-day in 7" group.

Limiting feed intake by giving only 75 to 80% of normal consumption has been accepted by a number of commercial started pullet raisers, since in this type of program feed costs can be standardized and also can be reduced. Observations on this type of restriction by the Mississippi workers (3) and by Ringrose of New Hampshire (4) have indicated a marked delay in sexual maturity and increase in egg size and in general a decrease in hen house mortality.

The principal disadvantages of this type of program are that birds are not always occupied since feed is not available at all times. In certain cases this has led to cannibalism and to wide variations in body weights, (since there is greater competition for feed, the weaker birds are forced to get by with less). There are also somewhat greater labor costs with this type of program.

To overcome some of these disadvantages and retain the advantage of limited feeds, low costs, and delayed sexual maturity, a number of programs have been developed which allow the birds to consume all the feed they desire but limit the effective nutrient intake by diluting the ration with fiber. This program allows the birds to consume as much total feed as they desire, but since the birds have a limited capacity to consume greater quantities of fiber they are limited in the effective nutrients they can consume.

Many claims have been made for this type of program with a great deal of contradiction between experiments for some of them. The main advantages however do appear to be delayed sexual maturity and the larger egg size that accompanies this and decreased feed costs. More variable in effect are observations on increased laying house livability and greater egg production.

This use of restricted feeding programs by restricting effective energy intake does have the disadvantage that the birds consume large quantities of the high fiber feed. In a report from the University of Florida (5) a simultaneous deficiency of protein and energy reduced the total feed consumed. In addition, Harms and Waldoup of the Florida Station found such a program delayed sexual maturity of birds by approximately 10 additional days over pullets which received adequate levels of protein.

The use of restricted protein intake in an attempt to delay sexual maturity also has been studied at Minnesota (6). The diet used in this experiment and some of the results appear in Tables 2 and 3 respectively. The data indicate small differences in body weight over the wide variety of protein levels fed. It had been anticipated that levels in the range of 12.5 and 10.5% would cause a marked depression. However, the fact that such a depression did not occur indicates that pullets can grow well on protein levels well below those recommended by many nutritionists, which in many programs are 17 or 18% of the diet.

This observation on the low protein needs of the growing pullet also has been made by Blaylock (7) who observed that the protein requirement of pullets was as low as 12% by 12 weeks of age. Berg and Bearse (8) also noted a similar low protein requirement during the period from 12 to 16 weeks of age. Observations of the

pullets in this study during their early production period indicated that the lower protein levels delayed sexual maturity, increased egg size, and lowered early egg production very slightly.

The brief review of the wide variety of feeding programs available and in use today indicates why it is difficult to speak of specific nutritional requirements for replacement pullets. What may be a satisfactory level of a given nutrient in one program may not be in another. What is probably the saving factor for many of these programs is that large excesses of most nutrients are utilized. This is certainly true for protein, most of the supplemental mineral elements such as calcium, phosphorous and sodium and this is also true for most vitamins.

Certainly this is one area of poultry nutrition which needs much basic work in determining minimal nutrient requirements before feeding programs which are nutritionally balanced can be developed.

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Table 1. Effect of Skip-a-Day Feeding Program on Replacement Pullet Performance 1/

Treatment	Wt. at 21 weeks	Ave. Feed Consumption	Egg Production 2/
	(lbs.)	(lbs.)	(%)
Full Fed	5.44	18.8	20
Skip-a-day in 7	5.42	17.6	10
Skip-a-day in 4	5.43	17.6	9

1/ Values represent 100 Columbian and New Hampshire females per treatment during the period from 10 to 21 weeks.

2/ From 19 to 21 weeks.

Table 2. Basal Ration

	%
Ground yellow corn	72.50
Soybean meal, dehulled	16.00
Fish solubles (carrier dried)	2.50
Dried Whey	2.50
Alfalfa meal	2.50
Dicalcium phosphate	1.76
Calcium carbonate	1.24
Salt, iodized	.50
Trace mineral (Delamix)	.10
Vitamin premix	.40
Total	100.00
Crude protein	16.5
Productive Calories/lb.	957
Calories/protein	58

Table 3. Protein Requirements for Replacement Pullets

% Protein		Av. Pullet Weight (gms.)		Feed and Protein Consumption (lbs. 10-20 wks.)	
10-15 Weeks	15-20 Weeks	15 Weeks	20 Weeks	Feed	Protein
16.5	16.5	1194	1391	9.9	1.63
16.5	14.5	1195	1370	10.1	1.57
16.5	12.5	1205	1379	10.0	1.45
14.5	14.5	1196	1384	9.9	1.44
14.5	12.5	1194	1362	9.3	1.25
14.5	10.5	1200	1342	10.1	1.26
12.5	12.5	1169	1374	9.6	1.21
12.5	10.5	1160	1337	9.9	1.14