

BIOLOGICAL EVALUATION OF GRAINS AS AFFECTED BY PROCESSING

by

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INTRODUCTION

Grain processing has been in the past, is now, and will be in future, one of the most important industries contributing to the survival of man. Processing of grains includes wetting, heating, rolling, grinding, and pelleting. At the present time there is widespread interest in pelleting. Today's modern pellet mills are the descendants of earlier, heavier mills developed originally in Europe. Some of these arrived in this country in the early twenties, and were put to use by a few feed manufacturers. Manufacture of pellet mills in the U.S.A. started about 1929 and because of the mechanical advantages found in handling pelleted feeds, the proportion of total feeds which are pelleted has increased rapidly.

The extent to which pelleting has grown is shown by the overall figure of 56 percent of all manufactured feed thus processed, as determined from the survey conducted in recent years by Wornick (95). In some mills, the combined output of pellets, crumbles, and cubes is now over 80 percent of total feed produced.

There are conflicting ideas and views about the beneficial effect of pelleting. Lunn et al. (60) Carver et al. (22) and Lee et al. (54) in the period 1930 to 1940 reported no benefits from feeding pelleted diets to poultry. Allred and co-workers (6) reported that when various ingredients of the ration were pelleted, ground, and incorporated into mash, the cereal component was most affected.

The purpose of this research was to determine the effect of pelleting on cereal grains and purified starches. Since pelleting involves steam conditioning and compression, these treatments were studied individually and

collectively.

REVIEW OF LITERATURE

Beef Cattle

Experimental feeding with sorghum grain unprocessed, coarsely ground and finely ground, was undertaken by Smith et al. (81). There were only slight variations between lots in amount of weight gain or efficiency of feed conversion, but steers receiving finely ground preparations appeared in better condition. It was noted that some steers fed finely ground grain were reluctant to eat indicating an individual palatability problem. However the market appraisal value was \$1 per hundredweight higher for those cattle fed finely ground grain.

A digestibility trial was conducted using the same basal ration and it was concluded that the finely ground grain was digested better. The digestion coefficients of dry matter, crude protein, ether extract, and nitrogen free extract were highest for the finely ground preparation. Crude fiber, however, had the lowest digestion coefficient of the three materials when finely ground.

Cox and Smith (25) used feedlot tests with steer calves to compare rolled, coarsely ground and finely ground sorghum grain. They observed only minor variations and could make no definite conclusions.

Heifers were the test animals when Cox and Smith (26) compared rolled sorghum grain with finely ground sorghum grain. Again, as in the test with steers there were only minor differences. Palatability was not a factor with the heifers and feed consumption was about equal with both rations.

The pelleting of all or part of the ration has proved successful in many instances if a high percentage of the ration is roughage.

Baker and co-workers (13) compared complete rations, which were finely ground and also pelleted, with coarsely cracked corn and chopped hay as a control. The control lot made significantly better gains and had higher carcass grades and marbling scores than cattle fed the finely ground or pelleted grain. Feed efficiency was not a factor in this test, indicating that palatability may have been a factor in favor of the control lot. The absence of regurgitation when pellets were fed was quite evident and a strong desire for coarse roughage was manifested by the eating of all bedding and vigorous chewing on the wooden fences. In a later experiment (14) a small amount of alfalfa hay was added to the pelleted ration. Rate of gain, rumination and general feedlot performance were improved.

In contrast to above work, Webb and Cmarik (89) reported that a pelleted ration produced more rapid gains, was more efficient, and cost less per hundred pounds of gain when compared with the same ration as a meal.

In a later test (91) these workers compared fattening rations containing ratios of 25, 35 and 45 percent roughage. The steers were self-fed a completely pelleted ration. Only minor differences were observed in this test though slightly greater gains were produced by the pelleted rations. The lower levels of concentrate in the pelleted form were somewhat less efficient than the higher concentrate levels.

Perry (74) self-fed a pelleted fattening ration and compared it with a meal preparation. Purdue supplement A and ground corn were fed in a 1:8 ratio which produced best results for fattening steer calves. Slow rate of gain but more economical gains were produced by the pelleted preparations. Feed consumption was 24 percent lower in the pelleted lots and was apparently the reason for the slow rate of gains. This agrees with the work reported

previously (13), where palatability was a problem with pelleted rations. It was concluded that the beneficial results produced by feeding pelleted roughages did not have the same effect when pelleted concentrates were fed.

Excellent results from a pelleted ration were reported by William (94) who fed a 70 percent roughage ration to yearling steers. Workers in Washington (35) reported results which were not in agreement with findings of most workers. They found no advantage from a pelleted concentrate and roughage diet which was compared to the same ration in the form of a meal. More efficient gains were produced by the pelleted ration which again indicate a consumption problem.

Recently Richardson et al. (76) (77) compared pelleted and rolled sorghum grain with rolled corn. The corn ration produced the best rate of gain, carcass grade, and feed efficiency when fed to fattening steers. The pelleted sorghum grain preparation was superior to the rolled sorghum grain. Rate of gain was better and cheaper gains were produced.

Webb and Cmarik (90) compared roughages fed to wintering steer calves as baled hay, chopped hay, hay pellets, and as silage. The pelleted roughage produced significantly greater gains than either the long or chopped preparations. The silage was extremely wet and non-palatable and decreased consumption resulted in weight losses in this lot. A second trial confirmed the beneficial results gained by pelleting an all roughage wintering ration.

Miller and Park (65) studied roughage preparation for wintering steer calves and observed that the pelleted hay ration produced about 20 percent greater gains and required 100 pounds less feed per hundred pounds of gain. These results were compared with a mixed long hay ration.

McCroskey, et al. (61) studied the effect of pelleting steer fattening

rations of different concentrate and roughage ratios. Forty-eight Hereford steers were individually self-fed in two trials to study the effects of pelleted rations with concentrate to roughage ratios of 1:4 and 4:1 on feedlot performance and carcass grade. Rate of gain and feed intake were significantly increased by pelleting the 1:4 ration. Pelleting the 4:1 ration resulted in no significant change in rate of gain but caused a decrease in feed intake. Feed efficiency on both rations was improved slightly by pelleting.

Kolari, et al. (50) investigated the feedlot performance and certain carcass characteristics of beef cattle when fed: (1) a limited amount of pelleted and long hay; (2) pelleted and ground ear corn. The combinations of pelleted hay with ground ear corn and long hay with pelleted ear corn resulted in significantly improved weight gains. Cattle fed pelleted hay had significantly higher carcass grades and marbling scores than cattle fed baled hay. Cattle fed ground ear corn had significantly higher carcass grades than cattle fed pelleted ear corn.

Dairy Cattle

Preparation of feed for dairy cattle has advanced rapidly with the pelleting process now being used in the experimental stages. Different grinding textures have also offered variations in feeding value and palatability for the dairy cows.

Olson (71) and Wilber (93) compared digestibility of finely ground, medium ground, and coarsely ground grains. Results indicated that medium or medium fine preparations were the most satisfactory when fed to milking cows.

Gardner and Akers (36) found that dairy calves fed alfalfa pellets in starter type rations consumed twice as much hay pelleted as when baled or

chopped.

Lassiter, et al. (53) did not find an advantage from pelleted feeds when fed to calves in a starter type ration. The consumption of pellets was greater if the calves were given a choice between pelleted and non-pelleted rations but equal amounts were consumed if fed separately.

Beneficial results from pelleting were reported by Hibbs and Conrad (45) who fed a high roughage pellet to calves. The pellets were consumed more rapidly and in greater amounts than the non-pelleted feed.

Gardner's (36) results indicated that pelleted complete rations were eaten more readily by calves with less starter feed intake than chopped and unpelleted hay. The pelleted roughage produced slightly greater gains.

There are conflicting views about the effects of pelleted rations on lactating cows. The effects of pelleting grain, roughage, and complete rations have been studied. Adams and Ward (2) compared a conventional 16 percent protein mash type grain concentrate with the same feed in the form of half-inch diameter pellets. Milk production was not affected by pelleting, but butterfat test, butterfat production, and four percent fat-corrected milk production was depressed significantly. Tigges and Ward (86) fed the same grain concentrate ration as a coarsely ground mixture and as a three-eighth inch diameter pellet to 27 Holstein cows and found no significant difference in milk production, four percent fat-corrected milk. Butterfat test was decreased significantly in cows fed pelleted concentrate.

Bartley and associates (15) fed 0.5 pound of dehydrated alfalfa pellets per 100 pounds body weight as a supplement to the standard ration of grain fed according to the production; alfalfa hay or prairie hay ad libitum; and two pounds of sorgo silage per 100 pounds body weight. They found that by the

addition of dehydrated alfalfa pellets the consumption of hay equivalent per cow per day was increased 3.6 pounds on the alfalfa hay ration, and 4.4 pounds on the prairie hay ration. Increases of 0.86 and 1.2 pounds of four percent fat-corrected milk per cow per day were associated with increased hay intakes. Ensor and co-workers (30) reported that a very rapid and marked depression in butterfat percentage occurred between four and six weeks when rations were fed which produced marked changes in the normal proportions of rumen volatile fatty acids.

Ronning and co-workers (78) found that a pelleted complete ration fed to dairy cows decreased the butterfat test to 1.5 percent and apparently caused digestive upsets. Hand (40) reported that Jersey cows on pelleted complete ration went off feed in the latter part of the third week, and had to be treated with some long hay to prevent death. Cows of three other breeds, Holsteins, Ayrshires, and Guernseys were not affected in this way. Feed consumption was not enhanced significantly by pelleting the complete ration. However, feeding ad libitum amounts of chopped hay and pellets resulted in a large increase in total feed consumption. Butterfat percentage was decreased by feeding coarsely ground pelleted complete ration alone or with the addition of one pound per day of chopped hay to the ration. Ad libitum consumption of both chopped hay and pellets resulted in normal butterfat percentage. Putnam and Davis (75) compared a pelleted complete ration to a mash ration with lactating Milking Shorthorn cows in a short time reversal study and a long term continuous study. They observed no digestive disturbances or depression in milkfat percentage during the use of either form of feed. Blosser (20) concluded that pelleted grain offers sufficient advantage over ground grain so that it will play an increasingly significant role in dairy cattle feeding.

More information is needed before it can be determined whether pelleted roughage will find an important place in dairy cattle feeding. However, from the results of recent research, it may be concluded that wafered or pelleted forage does not increase feed intake or milk yields (Loosli, 59).

Sheep

Neale (68) (69) studied pelleted rations for three-year feeder lambs for a three-year period. The ration consisted of coarse, poor quality alfalfa hay and sorghum grain. In an attempt to make the alfalfa hay more useful, the hay was processed with sorghum grain and molasses into cubes that were self-fed. The non-pelleted rations included only good quality alfalfa hay and sorghum grain.

More rapid gains were produced from the pelleted ration especially when the pellets consisted of a high percent of roughage. It was emphasized in these tests that the pelleted rations could consist of 70 percent poor quality roughage and still be superior to non-pelleted preparations. This increase in rate of gain was offset economically by the cost of pelleting.

Thomas et al. (88), Nobel et al. (70) and Jordan et al. (49) all submitted reports which were in agreement with Neal's work.

Bell et al. (17) reported that pelleted rations were first used at the Kansas Experiment Station in 1948, and that complete rations have been fed in the form of pellets. This study confirmed previous reports of greater efficiency from pelleted feeds and especially from the predominantly roughage rations. It was reported (18) that the apparent advantage from pelleted rations was offset by the cost of dehydration and pelleting.

A summary by Menzies et al. (63) reported that the ratio of 45 concentrate

and 55 percent roughage was superior to higher roughage rations when fed in the form of long or chopped hay and cracked grain. The advantage of pelleting was greater at the higher level of roughage.

Some stations (23) (79) reported little or no effect from pelleted rations for lambs. The Illinois workers (23) found that the pelleted alfalfa meal and corn were of slight value, hardly enough to warrant the cost of pelleting.

Long et al. (58) in a digestibility experiment fed the same ration to the lambs in three different physical states (1) natural (long hay, whole grain), (2) ground and (3) ground and pelleted. Grinding the whole ration lowered its digestibility. Pelleting the ground ration only served to raise the digestibility back to the level of the ration in the natural form.

Attempts to determine the effect of pelleting on digestibility, based on comparison of crude fiber digestion coefficients, have given rise to conflicting reports. John (47) and Hays (43) found apparent crude fiber digestion coefficients to be much lower in pelleted rations but Striegel (85) and Esplin et al. (31) reported little or no difference in crude fiber digestibility.

John (47) reported results of feeding and digestibility trials involving feeding of pelleted ration to lambs. This work confirmed previous work by Cox (24) which found that a ratio of roughage to grain of 55-45 was most efficient in non-pelleted rations but the ratio of 65-35 was more efficient and produced better gains when fed as pellets.

Hays (43) used the same basic ingredients in a later test but as a result of improper rumination a small amount of chopped alfalfa hay was added to the ration. Another factor in this test was the comparison of dehydrated alfalfa

hay to suncured alfalfa hay. The suncured pellets produced greater gain in the feedlot but no apparent differences were observed between the two forms of pellets in the digestion trial. This test confirmed most reports which found increased gains and feed efficiency from the pelleted ration.

Meyer (64) suggested that the increased rate of gain from pelleted rations was due to increased feed intake and a more rapid passage of ingesta from the reticulo-rumen. Other workers (23) (32) have shown that a palatability factor, and not an increase in feed efficiency was responsible for the additional rate of gain. Bell (18), on the other hand, reported an increased feed efficiency from the pelleted ration.

Weir, et al. (92) reported that pelleting was particularly advantageous for lambs when straight roughage rations were compared. The addition of 30 percent concentrate to the ration did not significantly increase gains but did increase feed efficiency.

John (48) found that pelleted rations produced greater and more efficient gains than similar non-pelleted rations. Pelleted rations with a ratio of 65 percent alfalfa hay and 35 percent ground corn were superior to the non-pelleted ration of the same ratio.

Swine

Some work has been conducted by this station and others whereby sorghum grain has been compared to corn.

Aubel (10) fed sorghum to swine as whole, rolled and ground grain. The whole grain was apparently least palatable.

Loeffel (57) compared sorghum to corn and reported that the whole grain was more palatable than shelled corn and also produced slightly greater gains.

The gains from the sorghum grain were not as efficient as those produced by the shelled corn.

Aubel (11) did not find that sorghum grain produced greater gains than corn, but did agree that corn was more efficient. Aubel (12) found that corn and supplement in the form of pellets produced greater feed efficiency than either the ground or mixed rations.

It has been demonstrated by Dinusson et al. (27) (28), Thomas and Flower (87), Dinusson and Bolin (29) that pelleting barley rations for swine resulted in improved growth and efficiency of feed conversion.

Larsen and Oldfield (52) reported that pelleting did not improve corn rations for pigs. Pigs fed barley pellets gained weight more rapidly than those fed barley meal and had a significantly improved efficiency of feed conversion. It was suggested that certain chemical changes occur in the carbohydrate fraction of the ration when pelleted. The primary benefits of pelleting apparently are a reduction of feed wastage.

Poultry

The digestibility of whole, cracked, and finely ground Argentine Flint corn was studied by Fritz (33) at Beltsville, U.S.D.A. Research Center with Rhode Island cockerels which were surgically altered so that urine and feces were voided separately. In general grinding improved the digestibility of corn slightly.

Molyneux (66) recorded an appreciably greater gain in body weight in pens where the birds were fed pellets. She found that the birds receiving mash had eaten slightly more feed than those receiving pellets, but there was a five percent difference in egg production in favor of the mash-fed

birds, which may account for their increased feed consumption.

Lunn et al. (60) reported no benefits from feeding pelleted diets to poultry.

Patton et al. (72) reported that chicks fed pelleted ration gained more weight, and consumed less feed than chicks fed unpelleted ration. The mash fed chicks consumed 5.55 percent more feed than pellet fed chicks. Weighted average showed that the pelleted fed chicks gained 6.6 percent more than mash fed chicks. The mash fed chicks consumed 10.81 percent more feed per unit of gain than pellet fed chicks.

Carver et al. (22) while investigating the various methods of feeding turkeys, observed no significant difference at twenty-eight weeks in body weight of either hens or toms fed mash, mash and pellets or pellets supplemented with scratch grain and green feed.

The lots fed mash, mash and pellets, and pellets ate practically the same amounts of feed during the twenty-eight weeks. It was observed that the pelleted feed was more attractive and palatable than mash to the young turkeys from two to ten days of age.

Heywang and Morgan (44) found that pellet-fed Leghorn cockrels were significantly heavier at 12 weeks of age than mash fed birds. The average weight of pullets receiving the pelleted all mash diet at the age of 12 weeks and 22 weeks was significantly greater than that of the pullets receiving the unpelleted all mash diet.

The total average feed consumption per chick of all the chicks receiving the pelleted all mash diet was slightly greater than that of all the chicks receiving the unpelleted all mash diet.

Zieganhagen et al. (96) reported a significant increase in growth of

turkey poults when mash rations were fed in the form of pellets or granules.

Morris (67) observed that body weights were uniformly heavier and the condition of the birds was better in the pen receiving pellets.

Goodearl and Moore (37) confirmed the increased growth and feed efficiency by feeding pelleted rations to poults. They also reported much better market quality of the birds fed pellets.

Slinger et al. (80) found greater differences between pelleted and unpelleted mashes. The weight of all the Broad-breasted Bronze turkeys receiving pellets were greater significantly than those receiving mash. Pelleting mashes containing 10 percent dehydrated alfalfa showed no improvement over unpelleted mashes, but mashes containing 15 and 20 percent dehydrated alfalfa were improved in feed efficiency by pelleting.

Stewart and Upp (84) reported no effect from pelleting or granulating an all mash ration and suggested that there is a possible cannibalism problem in birds fed pellets or granules alone. This report suggested that the usefulness of pelleted feeds in poultry production was questionable.

Lillie et al. (55) found that birds were much more tolerant of a high level of oat hulls or alfalfa in the diet when the feed was pelleted.

Bearse et al. (16) reported that pelleting rations containing 8, 13, and 18 percent fiber increased growth rate and feed efficiency in Leghorn pullets. Differences between mash and pellets became more marked as fiber level increased. This improvement was progressively greater as the fiber level of the ration increased.

Jensen and McGinnis (46) studied the effect of pelleting diets with different levels of dehydrated alfalfa for laying hens. Diets containing from 10 to 25 percent dehydrated alfalfa were fed to White Leghorn hens for

a period of 24 weeks. No significant differences in egg production or egg weight were evident among the various treatments. All groups fed pellets made substantial gains in body weight during the experiment, and all groups fed mash lost weight. A progressive increase in feed consumption occurred with hens fed pelleted diets as the level of alfalfa increased.

Lanson and Smyth (51) reported that White Plymouth Rock broiler chicks fed pellets entirely or as one-third of total feed were superior to mash-fed broilers at 10 weeks of age in average weight and feed conversion.

Lindbald et al. (56) observed that pelleting the broiler ration high in barley overcame the depressing effect noticed when fed in mash form. Pelleting improved the efficiency of feed utilization. Allred et al. (5) obtained increased rate of growth with chicks which were fed pellets and re-ground pellets. It was suggested that a large part of the growth response due to pelleting was brought about by chemical changes in the feed ingredients.

Arcott (7) reported that pelleting rations containing all corn, 1/2 barley-1/2 corn or all barley in the presence or absence of 3 percent fat affected a marked improvement in performance efficiency.

Allred et al. (6) studied the effect of pelleting individual ingredients and complete rations on the growth and feed efficiency of chicks. It was reported that both a physical and non-physical change occurred during pelleting each of which significantly increased growth and feed efficiency beyond that of chicks fed unpelleted rations. When individual ingredients were pelleted, re-ground, and incorporated into an otherwise unpelleted ration, the only ingredients affected were corn and rye, as measured by chick performance.

Arcott et al. (8) conducted experiments to test the hypothesis that

the pelleting response noted on high barley or corn ration may be due to a chemical change in feed resulting from pelleting. Regrinding barley or corn pellets resulted in no improvement in growth or conversion as compared with their unpelleted controls. In every instance, however, pelleting effected a marked improvement in growth.

Black et al. (19) reported that birds fed pellets, either ad libitum or in restricted amounts, gained significantly more weight than corresponding groups of birds on mash.

Arcscott and Rose (9) investigated the effect of pelleting on the utilization of western barley in broiler rations. Pelleting resulted in improvement in performance efficiency.

Ham et al. (38) reported that pelleting of mash diets improved the growth rate of chicks and poults. Pelleted barley over barley mash showed greatest improvement.

It was shown that the so-called "pellet response" was not due to some chemical change taking place as a result of pelleting process. The added or increased growth received from feeding of pellets was due primarily to the increased feed consumption.

MATERIALS AND METHODS

Equipment

All experiments were conducted in the Small Animal Research Laboratory. Room temperature was maintained between 70 and 75° F by thermostatically controlled heating radiators. Lighting was continuous.

Six circular cages placed on a wire screen floor were used for groups of

chicks on restricted feeding. Each cage was divided into 12 separate compartments. Two small cups, one for feed and the other for water painted black and silver, respectively, were hung outside each compartment and were available from within. The cups were labelled for identification.

A five-deck starting battery with 10 separate compartments fitted with heaters, waterers and feeders for small experimental lots of chicks was used for the groups of chicks on ad libitum feeding. Glazed white paper was used to catch the droppings and spilled feed in all the groups.

Rations

Purified starches were added at two levels, 40 percent and 57 percent to a basal ration complete in all known nutrients.

Starches tested included pre-gelatinized corn and unmodified corn, sorghum grain, potato, and high-amylose corn.

The composition of basal ration is shown in Table 1.

In addition to the above mentioned purified starches, the following processed cereal grains were also tested, corn ground, corn commercially pelleted (with and without steam conditioning), corn steamed, sorghum grain ground, commercially pelleted (with and without steam conditioning), steamed, laboratory die pelleted and finely ground. The cereal grains constituted 69 percent of the ration as the only source of carbohydrate. The formula of the complete ration is shown in Table 2, while the proximate analysis of the grains and complete rations are shown in Table 3.

The vitamin and mineral premixes were prepared separately by the use of pestle and mortar. All rations were hand mixed in large enameled trays.

Processing of Purified Starches and Grains. Purified starches were

Table 1. Composition of basal ration.

Ingredients	: Experiment I : Experiment II : Experiment III and VII		
	Pounds	Pounds	Pounds
Casein	50	50	50
Lactalbumin	10	10	10
Sucrose	12	12	12
Alphacell	2	--	--
Corn fiber	--	4	--
Ground feathers	--	--	4
Glucose	12	10	10
Wesson Oil	6	6	6
Salt Mix*	6	6	6
Vitamin Mix**	2	2	2
Total	100	100	100

*Salt Mix

Calcium carbonate	100	grams
Calcium phosphate	160	"
Potassium phosphate	76	"
Sodium Chloride (iodized)	40	"
Manganese Sulphate	24	"
Potassium Chloride	20	"
Magnesium sulphate	30	"
Ferric Citrate	1.0	"
Zinc Sulphate	0.2	"
Cupric Sulphate	0.2	"
Potassium Iodide	0.1	"
Cobalt Chloride	0.02	"

**Vitamin Mix

Glycine	50	grams
L. Arginine Hydrochloride	25	"
Choline Chloride	25	"
Vitamin D ₃ (Delsterol)	14	"
Vitamin E (Alpha-tocopherol)	0.2	"
Vitamin B ₁₂ (tritorate)	0.5	"
Niacin	0.75	"
Calcium pantothenate	0.75	"
Biotin	5.0	mgs.
Folic Acid	30	"
Inositol	0.3	grams
Para-Amino-Benzoic Acid	0.5	"
Pyridoxine	0.15	"
Riboflavin	0.15	"
Thiamin	0.2	"
Menadione (Vitamin K)	0.05	"
Vitamin A (10,000 USP / gram)	15.0	"
Fine Shorts to make	450	"

Table 2. Composition of complete ration for Experiment, IV, V, VI and VII.

Ingredients	:	Pounds
Corn/sorghum grain		69.0
Casein		17.5
Lactalbumin		5.0
Alphacell		1.0
Wesson Oil		1.5
Salt Mix*		4.0
Vitamin Mix**		2.0
Total		100.0

*Salt Mix

Calcium carbonate	90	grams
Calcium Phosphate	120	"
Potassium Phosphate	65	"
Sodium Chloride (iodized)	40	"
Manganese Sulphate	24	"
Potassium Chloride	40	"
Magnesium Sulphate	30	"
Ferric Citrate	1.0	"
Zinc Sulphate	0.2	"
Cupric Sulphate	0.2	"
Potassium Iodide	0.1	"
Cobalt Chloride	0.02	"
Fine Shorts to make	450.0	"

**Vitamin Mix

Glycine	100	grams
L. Arginine Hydrochloride	50	"
D. L. Methionine	12	"
Choline Chloride	25	"
Vitamin D ₃ (Delsterol)	14	"
Vitamin E. (Alpha-tocopherol)	0.2	"
Vitamin B ₁₂ (tritorate)	0.5	"
Niacin	0.75	"
Calcium Pantothenate	0.75	"
Biotin	5.0	mgs.
Folic Acid	30.0	"
Inositol	0.3	grams
Para-Amino-Benzoic Acid	0.5	"
Pyridoxin	0.15	"
Riboflavin	0.15	"
Thiamin	0.2	"
Menadione (Vitamin K)	0.05	"
Vitamin A (10,000 USP/gram)	15.0	"
Fine Shorts to make	450.0	"

Table 3. Analysis of processed grains and complete rations.

	: %	: %	: %	: %	: %
	: Moisture	: Protein	: Ash	: Crude Fat	: Crude Fiber
Ground corn-mixed ration	10.0	26.7	3.95	4.4	1.6
Steamed corn-mixed ration	10.9	26.7	3.97	4.3	1.7
Conditioned-pelleted corn mixed ration	9.2	27.8	4.05	4.2	1.8
Milo-ground, mixed ration	9.7	26.5	3.98	3.6	1.7
Milo-steamed, mixed ration	11.1	26.3	4.35	3.9	1.7
Milo-conditioned-pelleted, mixed ration	10.7	26.5	3.25	3.9	1.7
Ground-corn, grain only	9.5	9.5			
Steamed corn, grain only	10.4	9.5			
Conditioned Pelleted corn, grain only	13.5	9.0			
Milo-ground-grain only	12.1	8.2			
Milo-steamed grain only	13.7	8.4			
Milo-conditioned pelleted grain only	13.5	8.4			

pelleted in a laboratory die using compression by a hydraulic pressure testing machine. Grains were ground through a Jacobson Hammer Mill and pelleted in a laboratory die^{and} by a Master Model California Pellet Mill in the Kansas State University Experimental Feed Mill. The ground grains were steamed in the conditioning chamber of the pellet mill. Processed purified starches, and the cereal grains were reground through a Willy Mill using Tyler No. 28, and 18 screens respectively.

Experimental Birds. A total of 641 day old sexed cockrels were used in

all tests. The chicks were Hyline breed, and were purchased from Combs Poultry Farm, Sedgwick, and Lowe Hatchery, Topeka.

Experimental Procedure. The chicks were kept in a two-deck starting battery, and were fed a complete ration for six days prior to randomization and starting on the experimental ration. All the chicks were wingbanded for identification. The chicks were weighed at seven days of age, and randomized into different groups. They were then transferred to circular cages for individual, restricted feeding, or a five-deck battery for ad libitum feeding. Chicks on restricted feeding were weighed every third day, while those on ad libitum feeding were weighed once a week, and weights recorded. The chicks on restricted feeding were fed a weighed amount of feed. The feeding was done at the same time each day, and the record kept of daily feed weigh-out. The leftover feed was weighed at the close of the experiment.

To decrease feed waste, chicks fed ad libitum were fed twice a day, and feed consumption was recorded weekly on each weigh day.

Fresh water was available to chicks at all times. The waterers and cups were washed daily and water changed twice a day.

The spilled feed under circular cages was picked up three times a day to keep the wastage to the minimum. The glazed white paper under the circular cages to catch the droppings and spilled feed was changed daily, while that covering the dropping pans in the five-deck battery was changed twice a week. The droppings were removed, and spilled unsoiled feed picked up daily.

The chicks on restricted feeding were fed for 15-21 days, while those on ad libitum feeding were fed for 26-28 days.

Differences between treatments were tested by using "Student's" t test, and the significant levels reported in every case refer to a one tailed test (82).

EXPLANATION OF PLATE I

Circular cages used for individual,
restricted feeding.

PLATE I



RESULTS AND DISCUSSION

Restricted Feeding - Low Level of Purified Starches

Chick average initial weight, final weight, weight gain, feed consumed, and feed conversion are shown in Table 4. Statistical analysis is given in Tables 8 and 9. Chicks fed pelleted starches of corn, sorghum grain, and potato gained more weight during the test period than those fed the control material. The differences being significant at the 0.05 level. Chicks fed pelleted pre-gelatinized and pelleted high-amylose corn starches were not significantly different in weight gain than those fed control starches.

Feed conversion was significantly ($P < 0.01$) better in those test chicks fed pelleted potato starch than those fed unpelleted potato starch. No significant difference was found in feed conversion of chicks on other starches.

The difference in weight gain between chicks fed pelleted and unpelleted starch was greatest for potato and less for other starches in the following order: corn, sorghum grain, high-amylose corn, and pre-gelatinized corn.

Chicks fed raw potato starch gained less than those fed any other starch. This data indicate that unmodified potato-starch is poorly utilized by chicks but can be improved by mechanical processing. This is in agreement with the work of Booher, et al. (21) who concluded (1) that the digestion resistant property of unmodified potato-starch resides in the outer layers of the organized granules, and (2) conditions which increase the digestibility of potato-starch include various modifications (such as ball-milling) which produce obvious hydration of the granules.

It has been reported by Hastings, et al. (41) that the shear accompanying

Table 4. Average initial weight, final weight, weight gain, feed consumed, and feed conversion of chicks fed 40 percent purified starch rations.

	Basal ration ¹	Corn-starch unpelleted	Corn-starch pelleted	Corn-starch pre-gelatinized unpelleted	Corn-starch pre-gelatinized pelleted	Sorghum grain starch unpelleted	Sorghum grain starch pelleted	High-amylose corn-starch unpelleted	High-amylose corn-starch pelleted	Potato-starch unpelleted	Potato-starch pelleted
Number of chicks	22	16	16	10	12	10	10	6	6	12	12
Av. initial weight grams	53.45	55.67	55.16	54.10	60.50	55.88	53.00	62.00	62.17	60.67	60.67
Av. final weight grams	65.66	81.47	85.42	86.50	90.08	85.69	84.50	88.84	87.84	77.17	82.34
Av. weight gain grams	7.21	25.80	30.26	32.40	29.58	29.81	31.50	26.84	25.67	16.50	21.67
Av. feed consumed grams	51.00	82.10	82.31	81.05	88.36	80.99	81.05	92.52	92.52	88.36	88.36
Feed conversion (Grams of feed per gram of weight gain)	7.08	3.18	2.72	2.50	2.99	2.72	2.57	3.45	3.60	5.36	4.24

¹Complete ration without added starch.

extrusion of material through a pellet die is responsible for starch granule damage as shown by increased susceptibility to alpha and beta amylases in vitro.

Restricted Feeding - High-Level of Purified Starches

Chick average initial weight, final weight, weight gain, feed consumed and feed conversion are shown in Table 5. Statistical analysis is given in Tables 8 and 9. These rations were, in general, less acceptable to the chicks than low level starch rations. It seems that the process of pelleting made the starch more susceptible to hydration in the digestive tract of the chick and restricted normal intake and subsequent passage through the bird.

Pelleted potato-starch rations were more acceptable than those of any other starch. Rations containing pelleted high-amylose and pelleted pre-gelatinized corn starches were less acceptable than any other rations. Chicks fed pelleted potato starch gained significantly ($P < 0.05$) more weight than those fed unpelleted starch, and had correspondingly better feed conversion ($P < 0.01$). Chick growth and feed conversion data for other test rations could not be analyzed because many birds refused to consume sufficient feed to increase body weight.

Restricted Feeding - Cereal Grains

Average chick initial weight, final weight, weight gain, feed consumed, and feed conversion are shown in Table 6. Statistical analysis is given in Tables 10a, 10b, 11a and 11b. Chicks fed corn, commercially pelleted or steamed gained significantly ($P < 0.05$) more weight than those fed ground material. These results substantiate the work of Ackerson (3) who reported

Table 5. Purified starches high level. Average initial weight, final weight, weight gain, feed consumed, and feed conversion of chicks fed 57 percent purified starch rations.

	Corn-starch unpelleted	Corn-starch pelleted	Corn-starch pre-gelatinized unpelleted	Corn-starch pre-gelatinized pelleted	High-amylose corn-starch unpelleted	High-amylose corn-starch pelleted	Sorghum grain starch unpelleted	Sorghum grain starch pelleted	Potato-starch unpelleted	Potato-starch pelleted
Number of chicks	16	16	10	9	3	3	10	10	9	9
Average initial weight grams	55.33	54.89	56.00	58.50	62.00	62.50	53.60	55.75	60.44	59.00
Average final weight grams	97.55	89.56	96.75	99.00	92.34	92.00	98.60	96.50	85.00	89.25
Average weight gain grams	42.22	34.67	40.75	40.50	30.34	29.50	45.00	40.75	24.56	30.25
Average feed con- sumed grams	114.49	114.20	112.68	118.73	129.50	120.33	113.99	112.39	121.72	120.75
Feed conversion (Grams of feed per gram of weight gain)	2.71	3.29	2.77	2.93	4.27	4.08	2.53	2.73	4.96	3.99

Table 6. Restricted feeding of cereal grain rations. Average chick initial weight, final weight, weight gain, feed consumed and feed conversion of chicks fed restricted amounts of 69 percent cereal grain rations.

	Corn-ground	Corn-pressed	Corn-dry pelleted	Corn-commercially pelleted	Corn-steamed	Sorghum grain ground	Sorghum grain pressed	Sorghum grain finely ground	Sorghum grain dry pelleted	Sorghum grain steamed	Sorghum grain commercially pelleted	Corn-all treatments	Sorghum grain all treatments
Number of chicks	24	6	12	24	24	24	12	6	12	24	24	90	102
Average initial weight grams	64.00	64.83	70.00	64.00	64.33	64.29	69.64	73.67	70.25	63.95	63.86	64.95	66.09
Average final weight grams	151.38	168.33	158.58	155.88	153.66	147.83	161.46	160.67	161.50	147.00	148.36	155.28	151.90
Average weight gain grams	87.38	103.50	88.58	91.88	89.33	83.54	91.82	87.00	91.25	83.05	84.50	90.33	85.81
Average feed consumed grams	197.78	219.00	211.50	197.65	197.58	197.75	212.13	204.00	211.50	195.25	198.09	200.88	201.10
Feed conversion (Grams of feed per gram of weight gain)	2.26	2.12	2.39	2.15	2.21	2.37	2.31	2.35	2.32	2.35	2.34	2.22	2.34

that when rations high in hybrid corn were pelleted and fed to chicks in individual feeders, a greater growth and better feed conversion were observed than in unpelleted rations. However, Ackerson's pelleted rations were fed in pellet form, not reground as was done in the present study. This worker suggested that pelleting had a favorable effect on the starch of the hybrid corn and gave a better response in young chicks.

There were no significant differences in weight gain among chicks fed commercially pelleted, steamed or ground sorghum grain. Chicks fed rations containing corn or sorghum grain pelleted by means of a laboratory die were not significantly different in weight gain than those fed unpelleted grains. The groups of chicks fed commercially pelleted corn or sorghum grain without steam conditioning or finely ground sorghum grain were not significantly different in weight from those fed control material. Chicks fed commercially pelleted or steamed corn had significantly ($P < .001$, and $P < .050$ respectively) better feed conversion than those fed ground corn. No significant difference in feed conversion was observed between the groups of chicks fed ground, steamed or commercially pelleted sorghum grain. This finding is not similar to the results found when purified sorghum grain starch was fed. If an increased efficiency of starch utilization occurred in pelleted sorghum grain, it was countered by some other reactions, possibly an indigestible combination of reducing sugars and amino acids. Evidence was found that considerable increase in fluorescence (indicating the Maillard reaction) occurred in extracts of pelleted grains.

Ad Libitum Feeding - Cereal Grains

Average chick values for initial weight, final weight, weight gain, feed

consumed and feed conversion are shown in Table 7. Statistical analysis is given in Table 12. There were non-significant differences in weight gain between the groups of chicks fed ground, steamed or commercially pelleted corn. These results are substantiated by the unpublished work of Hastings and Sanford (42), and Akram and Sanford's unpublished work (4), but disagree with those reported by Allred et al. (6), who observed significant increase in growth rate, and feed efficiency with chicks fed pelleted and reground corn incorporated in a complete ration. Chicks fed commercially pelleted sorghum grain had significantly ($P < .001$) lower rate of gain than those fed ground material. The possible explanation for this depressed rate of growth might be as follows: Sorghum grain is normally deficient in lysine, and methionine, and perhaps on border line in some other essential amino acids. The grain is lower in fat content than corn, and more work has to be done to extrude the material through the pellet die during the process of pelleting. This extra work may produce more heat, which might have caused destruction of part of the essential amino-acids. There is also evidence of maillard reaction in which an indigestible combination of reducing sugars and amino acids takes place. Thus the normal deficiency of essential amino acids like lysine and methionine might have been further aggravated by processing. Feed conversion could not be analyzed as individual chick's feed consumption was not known.

In the seventh feeding trial, the test ration containing ground corn was observed to be sticking and forming balls between the beaks of chicks. Continuous, unrestricted intake of feed was not possible and chicks on this ration had lower rate of growth than those fed the same type of ration in the previous tests. Probably the presence of pines in the ground material may

be the cause of this trouble. The data of this group have not been included in the analyses reported.

Restricted Versus Ad Libitum Feeding

Chicks fed restricted amounts of ration containing commercially pelleted or steamed corn gained significantly more weight and had better feed conversion than those fed a ration containing ground corn, while chicks fed commercially pelleted or steamed corn ad libitum were not significantly different in weight gain than those fed ground material. The possible explanation for the significant improvement in weight gain and feed conversion observed with chicks fed restricted amounts of ration containing commercially pelleted or steamed corn might be as follows:

Under restricted feeding conditions less than optimum nutrients are available and the chicks are sensitive to any improvement in feeding value. However, under ad libitum feeding conditions, there was at all times excess of nutrients over optimum requirements of the chicks, so pelleting or steaming of corn could not show its beneficial effect in the improvement of growth rate of the birds over their control groups.

Corn Versus Sorghum Grain

Referring to data shown in Tables 6, 10c and 11c, in restricted feeding tests chicks fed ground, steamed or commercially pelleted corn gained significantly ($P < .025$, $P < .010$, $P < .010$, respectively) more weight than those fed ground, steamed or commercially pelleted sorghum grain. Similarly ground, steamed, or commercially pelleted corn had significantly ($P < .025$, $P < 0.010$, $P < 0.025$, respectively) better feed conversion than ground, steamed or

commercially pelleted sorghum grain.

The data given in Tables 7 and 12a indicate that in ad libitum feeding experiments, chicks fed commercially pelleted corn gained significantly ($P < 0.005$) more weight than those fed commercially pelleted sorghum grain.

The results of these studies are in agreement with those of Adams (1), but differ from those of Paynee (73), Melass (62), Hammonds (39), and Stephenson et al. (83).

Table 7. Average initial weight, final weight, weight gain, feed consumed, and feed conversion of chicks fed ad libitum 69 percent cereal grain ration.

	Corn ground	Corn-dry pelleted	Corn commercially pelleted	Corn steamed	Sorghum grain ground	Sorghum grain pressed	Sorghum grain finely ground	Sorghum grain dry pelleted	Sorghum grain steamed	Sorghum grain commercially pelleted	Corn all treatments	Sorghum grain all treatments	
Number of chicks	31	9	31	31	31	9	9	9	31	31	102	120	
Av. initial weight grams	62.17	62.11	64.16	65.81	70.65	62.88	68.11	60.89	66.42	62.00	67.08	68.55	
Av. final weight grams	381.28	360.89	372.35	358.74	382.94	347.38	356.00	360.00	368.52	340.16	358.90	358.27	
Av. weight gain grams	319.11	298.78	308.19	292.93	312.29	284.50	287.89	299.11	302.10	273.96	291.82	289.72	
Av. feed consumed grams	501.06	545.78	537.03	521.83	513.68	529.25	584.78	564.44	529.26	504.61	536.97	545.72	
Feed conversion (Grams of feed per gram of weight gain)	1.60	1.83	1.74	1.78	1.64	1.86	2.03	1.89	1.75	1.84	1.84	1.89	

Table 8. Level of significance of weight gain of chicks fed 40 percent purified starch rations.¹

Comparisons	Degrees of Freedom	Mean Difference	Level of Significance
Corn-starch pelleted versus unpelleted	11	4.50	P 0.05
Corn-starch pre-gelatinized pelleted versus unpelleted	6	1.83	N.S ²
Sorghum grain starch pelleted versus unpelleted	7	5.25	P < 0.010
High-amylose corn-starch pelleted versus unpelleted	4	0	N.S
Potato-starch pelleted versus unpelleted	11	4.34	P < 0.050
Potato-starch pelleted versus unpelleted ³	5	5.67	P < 0.050

¹Using paired comparison one tailed "Student's" t test.

²Non-significant.

³Fed at 57 percent level.

Table 9. Level of significance of feed conversion of chicks fed 40 percent purified starch rations.¹

Comparisons	: Degrees of : Freedom	: Mean : Difference	: Level of : Significance
Corn-starch pelleted versus unpelleted	9	0.401	N.S. ²
Corn-starch pre-gelatinized pelleted versus unpelleted	9	0.538	N.S.
High-amylose corn-starch pelleted versus unpelleted	5	0.065	N.S.
Sorghum grain starch pelleted versus unpelleted	7	0.110	N.S.
Potato-starch pelleted versus unpelleted	10	2.021	$P < 0.010$
Potato-starch pelleted versus unpelleted ³	6	1.190	$P < 0.010$

¹Using paired comparison one tailed "Student's" t test.

²Non-significant.

³Fed at 57 percent level.

Table 10a. Level of significance of weight gain of chicks fed restricted amount of 69 percent corn rations.¹

Comparisons	Degrees of Freedom	Mean Difference	Level of Significance
Corn commercially pelleted versus corn ground	21	3.73	$P < 0.05$
Corn steamed versus corn ground	20	3.52	$P < 0.05$
Corn commercially pelleted versus corn steamed	19	0.70	N.S ²
Corn dry pelleted versus corn ground	11	-8.84	N.S
Corn pelleted through laboratory die versus corn ground	5	1.00	N.S

¹Using paired comparison one tailed "Student's" t test.

²Non-significant.

Table 10b. Level of significance of weight gain of chicks fed restricted amount of 69 sorghum grain rations.¹

Comparisons	: Degrees of Freedom	: Mean Difference	: Level of Significance
Sorghum grain steamed versus sorghum grain ground	19	0.85	N.S ²
Sorghum grain commercially pelleted versus sorghum grain ground	21	0.90	N.S
Sorghum grain dry pelleted versus sorghum grain ground	11	-2.17	N.S
Sorghum grain pelleted through laboratory die versus sorghum grain ground	9	-0.60	N.S
Sorghum grain commercially pelleted versus sorghum grain steamed	17	0.39	N.S
Sorghum grain finely ground versus sorghum grain ground	5	-2.34	N.S

¹Using paired comparison one tailed "Student's" t test.

²Non-significant.

Table 10c. Level of significance of weight gain of chicks fed restricted amount of corn and sorghum grain rations.¹

Comparisons	: Degrees of Freedom	: Mean Difference	: Level of Significance
Corn ground versus sorghum grain ground	22	4.61	P<0.025
Corn commercially pelleted versus sorghum grain commercially pelleted	19	7.35	P<0.010
Corn steamed versus sorghum grain steamed	18	6.68	P<0.010

¹Using paired comparison one tailed "Student's" t test.

Table 11a. Level of significance of feed conversion of chicks fed restricted amount of corn rations.¹

Comparisons	: Degrees of Freedom	: Mean Difference	: Level of Significance
Corn commercially pelleted versus corn ground	20	0.182	P<0.001
Corn steamed versus corn ground	20	0.091	P<0.050
Corn commercially pelleted versus corn steamed	19	0.175	N.S ²

¹Using paired comparison one tailed "Student's" t test.

²Non-significant.

Table 11b. Level of significance of feed conversion of chicks fed restricted amount of 69 percent sorghum grain rations.¹

Comparisons	Degrees of Freedom	Mean Difference	Level of Significance
Sorghum grain commercially pelleted versus sorghum grain ground	21	-0.007	N.S ²
Sorghum grain steamed versus sorghum grain ground	19	-0.014	N.S
Sorghum grain commercially pelleted versus sorghum grain steamed	17	-0.033	N.S

¹Using paired comparison one tailed "Student's" t test.

²Non-significant.

Table 11c. Level of significance of feed conversion of chicks fed restricted amount of 69 percent cereal grain rations.¹

Comparisons	Degrees of Freedom	Mean Difference	Level of Significance
Corn ground versus sorghum grain ground	22	0.131	$P < 0.025$
Corn steamed versus sorghum grain steamed	18	0.192	$P < 0.010$
Corn commercially pelleted versus sorghum grain commercially pelleted	20	0.173	$P < 0.025$

¹Using paired comparison one tailed "Student's" t test.

Table 12. Level of significance of weight gain of chicks fed ad libitum 69 percent cereal grains rations.¹

Comparisons	: Degrees of Freedom	: Mean Difference	: Level of Significance
Corn commercially pelleted versus corn ground	18	1.58	N.S ²
Corn steamed versus corn ground	29	4.90	N.S
Corn commercially pelleted versus corn steamed	30	14.77	N.S
Sorghum grain ground versus sorghum grain commercially pelleted	30	48.67	$P < 0.001$
Sorghum grain steamed versus sorghum grain ground	28	1.89	N.S
Sorghum grain commercially pelleted versus sorghum grain steamed	30	19.00	N.S

¹Using paired comparison one tailed "Student's" t test.

²Non-significant.

Table 12a. Level of significance of weight gain of chicks fed ad libitum 69 percent cereal grains.¹

Comparisons	: Degrees of Freedom	: Mean Difference	: Level of Significance
Corn ground versus sorghum grain ground	18	6.95	N.S ²
Corn steamed versus sorghum grain steamed	30	8.94	N.S
Corn commercially pelleted versus sorghum grain commercially pelleted	30	40.7	$P < 0.005$

¹Using paired comparison one tailed "Student's" t test.

²Non-significant.

SUMMARY

A series of seven feeding tests was conducted with sexed Hyline cockerels to study the effect of pelleting on purified starches and the effect of processing on cereal grains.

Chicks fed restricted amounts of rations containing low level (40 percent) pelleted starches of corn, sorghum grain and potato gained significantly more weight during the test period than those fed unpelleted starch rations. Chicks fed pelleted pre-gelatinized and pelleted high-amylose corn-starch rations were not significantly different in weight gain than those fed control rations. Chicks fed pelleted potato starch had significantly better feed conversion than those fed control potato starch. However, no significant improvement in feed conversion was observed with chicks fed pelleted starches of corn, sorghum grain, pre-gelatinized and high-amylose corn.

Rations containing high level test (57 percent) starches either pelleted or unpelleted were less acceptable to chicks than those rations containing low level starches. Pelleted potato starch had greater acceptability than the pelleted starches of corn and sorghum grain. Chicks fed rations containing pelleted high-amylose corn-starch and pelleted pre-gelatinized corn-starch had less feed consumption than other groups. Chicks fed rations containing high level of pelleted potato-starch gained significantly more weight than those fed unpelleted starch and had correspondingly better feed conversion.

Chicks fed restricted amounts of rations containing corn commercially pelleted or steamed gained significantly more weight and had better feed conversion than those fed ground material. No significant differences in weight gain or feed conversion were observed among the groups of chicks fed restricted

amounts of commercially pelleted, steamed or ground sorghum grain rations. Chicks fed rations containing corn or sorghum grain pelleted through a laboratory die were not significantly different in weight gain from those fed ground grains. There was non-significant differences in weight gain among the groups of chicks fed corn or sorghum grain commercially pelleted (without steam conditioning) or finely ground sorghum grain and the control materials.

Chicks fed commercially pelleted or steamed corn ad libitum were not significantly different in weight gain than those fed ground materials. However, chicks fed commercially pelleted sorghum grain had significantly lower rate of growth than those fed ground grain.

Chicks fed restricted amount of rations containing ground, steamed or commercially pelleted corn grain gained significantly more weight and had better feed conversion than those fed rations containing ground, steamed or commercially pelleted sorghum grain.

Chicks fed commercially pelleted corn ad libitum gained significantly more weight than those fed commercially pelleted sorghum grain.

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BIOLOGICAL EVALUATION OF GRAINS AS AFFECTED BY PROCESSING

by

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A series of seven feeding tests was conducted with sexed cockrels of Hyline breed to study the effect of pelleting on purified starches, and the effect of processing on cereal grains. Chicks in restricted feeding experiments were kept in individual compartments of circular cages, fed once a day, and weighed every third day. Total feeding time was 15-21 days.

Chicks fed ad libitum were kept in five-deck battery, fed for 26-28 days, and weighed once a week.

Fresh water was available at all times to chicks under restricted as well as ad libitum feeding. Purified test starches were added to a complete basal ration, balanced in all nutrients, at two levels, low (40 percent), and high (57 percent). Cereal grains were added at only one level and constituted 69 percent of the balanced ration.

Chicks fed restricted amounts of ration containing low level pelleted starches of corn, sorghum grain, and potato, gained significantly more weight during the test period than those fed unpelleted starches. Chicks fed pelleted pre-gelatinized, and pelleted high-amylose corn starch were not significantly different in weight gain than those fed control starches. Chicks fed pelleted potato-starch had significantly better feed conversion than those fed control potato starch. No significant improvement in feed conversion was observed with chicks fed pelleted starches of corn, sorghum grain, pre-gelatinized corn, and high-amylose corn.

Rations containing high level pelleted starches fed in restricted amounts were less acceptable than those containing unpelleted starches. Rations containing pelleted potato starch had greater acceptability than those containing other starches. Chicks fed rations containing pelleted high-amylose corn starch, and pelleted pre-gelatinized corn starch had less

feed consumption than other groups. Chicks fed pelleted potato starch gained significantly more weight and had better feed conversion than those fed unpelleted material.

Chicks fed restricted amounts of rations containing corn commercially pelleted or steamed gained significantly more weight and had better feed conversion than those fed ground materials. No significant differences in weight gain or feed conversion were observed among the groups of chicks fed restricted amounts of commercially pelleted, steamed, or ground sorghum grain rations. Chicks fed rations containing corn or sorghum grain pelleted through a laboratory die were not significantly different in weight gain and feed conversion from those fed ground grains. There were non-significant differences in weight gain and feed conversion between the groups of chicks fed corn or sorghum grain dry pelleted or finely ground sorghum grain and the control materials.

Chicks fed commercially pelleted or steamed corn ad libitum were not significantly different in weight gain than those fed ground grain. Chicks fed commercially pelleted sorghum grain had significantly lower growth rate than those fed unpelleted grain.

Chicks fed restricted amounts of rations containing ground, steamed or commercially pelleted corn gained significantly more weight and had better feed conversion than those fed rations containing ground, steamed, or commercially pelleted sorghum grain.

Chicks fed commercially pelleted corn ad libitum gained significantly more weight than those fed commercially pelleted sorghum grain.