THE UTILIZATION OF BARLEY AS A REPLACEMENT FOR CORN BY POULTRY

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INTRODUCTION

When formulating poultry rations, whether it be for broilers, layers, poults, or turkeys, it is inevitable that a large portion of the ration will be comprised of some type of feed grain. Basically grain supplies energy, although a lesser amount of other nutrients are also supplied inasmuch as grain makes up such a large portion of the diet. Since the protein and energy levels in a given ration are closely interrelated, the protein content of a ration regulates the amount of grain to be used. Consequently, a poultry diet may contain anywhere from 40 to 80 per cent grain in ground or whole form depending on the protein level desired.

Feed costs account for approximately 66 per cent of the cost of poultry production. Therefore the grain component, being a major item in the ration, would be a logical place to initiate savings if possible. Corn is presently the leading grain as far as efficiency of performance is concerned. Poultry perform almost equally as well with wheat as the grain component, but current agriculture economic programs have priced this commodity out of the feed market. Barley, oats, and speltz result in lower efficiency when incorporated into a ration.

There are many areas of the United States and the world where corn is as yet not extensively produced. Such areas have to import corn to meet feed requirements or devise means for utilizing other available grains. Such an area exists in the Pacific Northwest where approximately a million acres of land formerly best adapted to wheat production is now being used to produce its second best and often times only alternative crop, barley. This is largely due to the current federal agriculture subsidy program. In these traditional wheat-producing areas barley production has jumped 270 per cent over the 1949-1953 average. The acreage of barley harvested in the Pacific Northwest has increased from a 987,000-acre average for the 1950-1954 period to an average of 1,839,000 acres in the period 1956-1960. It is noteworthy, however, that Northwest corn production has also been on the increase and may be able to meet Northwest feed needs in the near future.

With the above facts in mind, it seemed desirable to investigate the possibilities of improving barley to increase its utilization by poultry so that resulting performance might be comparable to that obtained with corn. The problem was approached involving studies with chicks, poults, and laying hens. Experiments were designed to improve barley utilization by poultry through pelleting, water treatment, and enzyme supplementation. At the same time, attempts were made to determine the mechanism or mechanisms involved.

REVIEW OF LITERATURE

Nutritional Value of Barley

In many respects barley is similar in chemical composition to other cereal grains. High nitrogen-free extract and relatively low protein contents are the common items. From the standpoint of crude fiber content it would appear to contain less fiber than such low energy grains as oats or speltz on the one hand and more fiber than such high energy grains as corn, milo or wheat on the other hand. Protein is of poor quality due to a limited amount of certain amino acids. Barley contains considerable amounts of thiamin and niacin, but as in the case of most cereal grains it is deficient in calcium, vitamins A and D, and riboflavin (55, p. 447).

Early literature concerning the comparative feeding value of barley versus the other common cereal grains for poultry has been reviewed by Crampton (17, p. 1-50). A summary of these investigations indicates little difference between barley, corn and wheat insofar as growth or feed efficiency of chicks is concerned, provided the mineral, protein, and vitamin deficiencies are corrected by supplementation. It was noted that in some instances the greater fiber content of barley may be detrimental.

Barley appeared as palatable as corn for chicks in these early experiments. For layers and breeders it was generally accepted that barley, wheat, and corn are of equal value for egg production when used in a properly balanced ration. Although not a consistent finding, it was noted that corn may maintain body weight more efficiently than barley. It was interesting to note that hens ate less barley than corn when given a choice, indicating perhaps lower palatability of the barley. The early data (17, p. 1-50) was characterized by a wide variability of results not only between stations, but also between successive experiments at the same station.

Very little information is available regarding the feeding value of barley in present-day poultry rations. A recent report by Arscott (4, p. 38-49) comparing barley to corn and wheat for broilers and for layers, is more typical of current observations concerning barley rations for poultry. Results with broilers show that barley could not effectively replace corn as the grain component of the ration without adversely affecting growth and feed conversion. No differences were apparent in egg production when barley replaced corn as the only grain component in the diet of White Leghorn pullets. However, feed per dozen eggs tended to increase as the level of energy decreased from the use of barley. New Hampshire layers not only produced at a lower level with less efficiency when compared to White Leghorns, but were also adversely affected when barley replaced corn as the grain component. Body weight was increased as the energy content of the feed increased for White Leghorns, but not for New Hampshires.

Morrison (55, p. 447) has reported that some of the western-grown barley varieties have thicker hulls and, therefore, are lower in digestible nutrients and feeding value. The relative low feeding value of barley as compared with corn is attributed by most persons to the higher fiber content of barley. However, an examination of the proximate analysis of barley and corn (Table I) would seem to indicate that barley should have a higher feeding value than experimental results have shown it to have (51, p. 28). This would seem especially the case when a comparison is made between dehulled barley and corn which have approximately the same nitrogen-free extract values. A comparison such as this suggests that the major difference in feeding value might be due to the difference in availability of the carbohydrate portion other than crude fiber.

Barley is approximately 75 per cent as valuable as corn for poultry on the basis of productive energy values,

Table I

Proximate Composition* and Energy Values for Barley and Corn

Feedstuff	Dry Matter %	Crude Protein %	Ether Extract %	Crude Fiber %	Ash %	Nitrogen-Free Extr. %	Prod.** Energy Cal./lb.	Metab.*** Energy Cal./lb.
Corn Grain, Dent Grade #2	85.7	10.4	4.6	2.5	1.5	81.0	1,105	1,550
Barley Grain (Midwest)	90.0	13.4	2.1	6.2	3.1	75.2	813	1,320
Barley Grain (Pacific Northwest)	90.7	12.0	1.9	6.3	3.2	76.6	--	--
Barley Grain (Without Hulls)	88.9	14.5	2.1	2.1	2.3	79.0	947	--

* (53, 663 p.) Expressed on moisture-free basis.
** (20, p. 1-37) (63, p. 258-259)
*** (32, p. 31-36)

according to Titus (63, p. 258-259). By utilizing Fraps' productive energy values (20, p. 1-37), however, dehulled barley supplies 86 per cent as much energy as does corn. Hill's metabolizable energy values (32, p. 31-36) rate barley 85 per cent as valuable as corn.

Bolton (15, p. 119-122) has reported studies on the digestibility of the carbohydrate complex of barley, wheat, and maize by the adult fowl. Complete digestion of sugar and starch of these grains occurred, whereas cellulose and lignin prove indigestible, and the pentosan was about one-third digested. The digestible pentosan accounted for about three per cent of the total digestible carbohydrate. In barley and maize the digestible carbohydrate portion was 54.37 and 65.92 per cent, respectively. Meanwhile the nitrogen-free extractive for barley was 64.79 per cent, and that for corn was 68.85 per cent. The available carbohydrate expressed as percentage of digestible carbohydrate proved to be 93.3 for barley and 94.6 for corn.

Studies With Chicks

Numerous attempts to improve the utilization of barley by chicks have been made during the past few years. The results of experiments conducted by Lindblad *et al.*

(48, p. 1067) suggested that neither the productive energy nor the digestible protein content of high barley rations *per se* were the limiting factors in chick performance, but that palatability of the barley may have been concerned. In this case a commercial flavoring ingredient used on high barley rations resulted in findings which indicated increased feed consumption and chick weight gains. On the other hand, Fry *et al*. (23, p. 281-288) failed to improve the performance of chicks on a high barley diet with supplementation of a commercial flavoring material or leucine.

Arscott *et al*. (5, p. 655-662) reported that a high efficiency broiler mash could contain barley up to 25 per cent of the grain component without causing any significant adverse effect on chick growth. Growth depression was observed when either 50 or 100 per cent barley was used in the ration as the grain component, and feed consumption was significantly increased. Only a slight increase in feed consumption occurred when the ration contained barley as 25 per cent of the grain component. The addition of 0.05 per cent dl-methionine, with or without granite grit, to the ration exerted no beneficial effect on the utilization of barley as reflected in chick growth or feed conversion, even though the methionine content of barley is approximately one-half to two-thirds that of corn.

Bearse (10, p. 13-18) reported a broiler ration could contain barley as 50 per cent of the grain component of a ration with only slightly lower growth and feed conversion as compared to an all-corn ration.

The addition of animal fat as a concentrated energy source has proven successful as an aid in improving the utilization of barley for broilers. Arscott et al. (5, p. 655-662) reported that a marked improvement in feed conversion was obtained when four or eight per cent stabilized prime tallow was added to rations containing 25 to 50 per cent barley as the grain component. The improvement was such that these barley-fat rations compared favorably to all-corn rations. However, when fat was added to all-barley rations, feed efficiency did not compare favorably to the all-corn rations. No adverse effect was observed on either growth or feathering when four or eight per cent fat was fed with any level of barley. These data were obtained with broilers raised to market age in batteries.

Extensive broiler floor pen trials were conducted by Arscott et al. (6, p. 117-123) to determine the amount of barley that will efficiently replace the ground corn component in high energy rations fortified with varying levels of stabilized animal fat. The data show that barley may replace one-half to three-fourths of the ground corn in an all-mash ration if these diets contain three and six per cent fat, respectively, with results comparable to an all-corn ration without added fat. It was noted that the addition of three to six per cent fat to all-corn rations resulted in improved performance efficiency, and that all-barley rations produced inferior results in chick growth and feed efficiency in the presence or absence of added fat. Mention is also made of the fact that the adverse effect which barley has upon the litter condition is not improved with the addition of fat to all-barley rations.

A four week battery trial conducted by Fry et al. (23, p. 281-288) has shown that pearled barley as well as barley markedly depresses growth and feed utilization when substituted for all of the corn in a broiler ration. Substitution of pearled barley for one-half the grain component was accomplished with but little detriment to growth and feed utilization. The removal of about 17 per cent of the outer portion of the barley by a pearling process only slightly improved the feeding value of barley. In another four week battery trial the addition of tallow at the five per cent level to diets containing pearled barley as 50 or 100 per cent of the grain component gave growth and feed efficiency results comparable with diets containing corn as the only grain. Tallow supplementation of corn diets resulted in an improvement over the unsupplemented corn diet in this same trial.

The pelleting of chick rations to obtain greater growth than is normal with mash rations was first mentioned in the literature over two decades ago and has since been confirmed and extended by several workers (57, p. 12) (31, p. 16-20) (11, p. 907) (47, p. 1208) (40, p. 234-235) (2, p. 517-518). Bearse *et al*. (11, p. 907) indicated that a pelleted ration containing one-half barley and one-half corn increased growth considerably over the mash form of the same ration for broilers raised to market age. An increased growth response was also noted for the pelleted all-corn ration as compared to the mash form. Lindblad *et al*. (47, p. 1208) replaced up to one-half of the corn and wheat with barley in a practical broiler ration with a resultant reduction in weight of males when the feed was in mash form. However, when the feed was pelleted 50 per cent barley in the ration did not depress male body weight. The efficiency of feed utilization was improved in all cases where the ration was pelleted, even though a reduction of the same occurred when the ration contained 50 per cent barley. In this particular study males responded to pelleting to a greater degree than did females.

Arscott <u>et al</u>. (6, p. 117-123) demonstrated with broilers fed high-efficiency rations that performance efficiency was markedly improved by pelleting all-corn, one-half barley and one-half corn, or all-barley rations in the presence or absence of three per cent animal fat. The improvement was particularly noticeable in those groups fed all-barley pellets with zero or three per cent fat, and the latter compared favorably to the groups receiving all-corn mash with no fat. Litter condition appeared to be adversely affected whenever barley replaced more than one-half corn in either mash or pelleted form. Water consumption increased as the barley content of the diet increased, and also for pelleted versus mash rations.

Allred <u>et al</u>. (2, p. 517-523) likewise presented evidence which showed improved growth rate and feed efficiency by chicks fed a pelleted corn ration. The pelleting effect was obtained in the presence and absence of animal fat. Results also indicated that the pelleting response was the same for rations having different protein levels. Their studies led them to conclude that a large portion of the increased growth response due to pelleting corn rations may be brought about by a chemical change in the feed ingredients. This contention was not supported, however, by Arscott et al. (7, p. 1388-1389) who demonstrated that regrinding barley or corn pellets resulted in no improvement in growth or feed conversion when compared to their unpelleted controls. However, pelleting brought about a marked growth improvement in every instance it was noted. Similar results also at variance with Allred's findings have since been reported by other workers (16, p. 18-26) (54, p. 4-5). Subsequently, Jensen (35, p. 72-73) reported results which indicate that the particular sample of corn used and the fineness of grind may affect the magnitude of the chemical pelleting response. He concluded that the pelleting response is made up of physical and chemical effects, with the physical effect accounting for the larger share of the response and the chemical effect still being an important factor. The physical effect is merely the increased density of the feed which allows the birds to consume a greater amount of a given ration (55, p. 956) (35, p. 72-73).

The value of barley-containing feeds can also be improved by a water treatment of the barley as reported by Fry et al. (22, p. 249-251). The method for water treatment consisted of soaking ground barley in an equal amount, by weight, of tap water overnight, drying at approximately 70° C. in a force-draft oven, and regrinding before using in the ration (24, p. 1119) (43, p. 1220). Chicks reared to four weeks of age on water-treated pearled barley rations grew as well as corn-fed chicks and demonstrated significantly better feed efficiency than the chicks fed the corn or untreated pearled barley diets (22, p. 249-251).

An additional report from the Washington experiment station (24, p. 1119) indicates that besides improvement of ground barley *per se*, water treatment of pearled barley, oats, corn, and other feedstuffs gives improved nutritive value for chicks; however, the greatest improvement in growth and feed efficiency comes from treated barley and oats. Chick response to water-treated grain was not changed by varying the protein level, adding supplemental tallow, or varying the level of the grain in the diet.

Water treatment of barley also brings about a marked improvement in dry matter utilization and reduces the moisture content of the feces as compared to untreated barley (24, p. 1119) (36, p. 42a-44). The usual adherence of feces to wire mesh floor screens of batteries when chicks are fed barley diets is greatly reduced when barley is water treated, producing a screen comparable to one obtained with a corn diet.

The beneficial effects from water treating were subsequently confirmed and extended by Arscott (4, p. 38-49) in relation to previous studies on fat supplementation and pelleting of barley rations. An eight-week floor pen trial was conducted comparing barley versus soaked barley, in mash or pellet form, and with or without three per cent added fat. All rations containing water-soaked barley, except the pelleted barley plus three per cent fat ration, brought about a marked improvement in growth, feed conversion, and the "sticky droppings" condition, and compared favorably to an all-corn mash with no added fat. It was noted that broiler performance on all-barley pellets with three per cent fat appeared comparable to soaked barley with or without fat. Ohio workers (1, p. 1185) have also obtained growth and feed utilization responses from chicks by water soaking the barley.

In 1926, Holst (33, p. 261-265) presented a general discussion on the topic of "artificial" enzymes and poultry feeding. Hastings (30, p. 584-586) later introduced evidence which showed that a fungal enzyme preparation instigated greater growth and improved feed efficiency for chicks when added to a high-fiber mash. Addition of the enzyme to a low-fiber mash brought no advantage. This investigator speculated that the enzyme might be practically applied to the use of fibrous feeds made from ingredients which are more available at certain times than low-fiber ingredients for growing chickens. It was suggested that the supplementing of fiber-splitting enzymes enabled the chickens to utilize some nutrients tied up or made unavailable by fiber.

Over a decade later the use of enzymes to supplement high-fiber feeds, principally barley, was looked upon with renewed interest. The Washington researchers had previously improved the nutritional value of barley by a water soaking treatment and decided that the process may have increased the availability of carbohydrates through enzyme action. Consequently, they attempted to determine the effect of supplementing barley-containing diets with an amylolytic enzyme mixture for chicks. Battery-raised chicks to four weeks of age demonstrated significantly improved growth and feed efficiency on a pearled barley diet supplemented with a mixture of Takadiastase and Clarase over a pearled barley control diet (38, p. 919-921). Balloun et al. (9, p. 302-303) obtained no response from chicks fed a corn basal diet to proteolytic enzyme supplementation.

Arscott (4, p. 38-49) confirmed the early enzyme work reported from the Washington station. In an eight-week floor pen broiler trial a growth response to enzyme supplementation was evident at four weeks, but most of the advantage had disappeared by eight weeks. The results of another eight-week trial showed that higher levels of Clarase and Merck amylolytic enzyme than was used in the previous trial slightly improved chick performance on a barley ration, but growth and feed efficiency failed to compare favorably with the soaked barley treatment or all-corn mash. A marked decrease in the adherence of droppings to the one-half inch wire mesh floor screens was observed for all groups except the all-barley mash group at four weeks of age. The fact that diets containing water-treated barley usually out-perform those supplemented with enzymes is also acknowledged by others (36, p. 42a-44).

Wharton et al. (64, p. 497) reported that four-week chick weights on barley rations were usually about 80 per cent of those for corn-fed groups at their laboratory and that effective levels of amylolytic enzymes increased the average weights to over 90 per cent of the corn-fed birds.

Several researchers have presented evidence indicating that the nutritional value of some eastern and midwestern barley grains is not improved to any great extent by enzyme supplementation (27, p. 102) (39, p. 1221) (1, p. 1185) (34, p. 150-152). Studies of barley from various areas of the country demonstrate that the magnitude of response that can be expected from enzyme supplementation will vary with the area of production of the barley (34, p. 150-152) (65, p. 103-108). Another report (66, p. 539-544) indicates that variety of barley has little influence on chick growth. No significant difference in chick performance was found among eight varieties of barley grown in the Washington area. All eight were significantly improved by either enzyme supplementation or water treatment.

Studies at the Utah State Agricultural Experiment Station have shown that the feeding value of a hulless barley developed there is not improved above that of the better varieties of regular barley for chicks. It is possible, however, to improve the nutritional value of the hulless barley by the addition of fungal or bacterial enzymes and by water treatment as in the case of normal barleys (19, p. 1199).

Fritz _et al_. reported effects of enzymes on high-fiber diets (wheat middlings) for chicks. Although growth was improved in most instances, the addition of an enzyme did not make a high-fiber diet equivalent to a corn diet (21, p. 1205).

Studies With Turkeys

Results from the Washington experiment station indicate that turkeys respond to barley rations which have been pelleted, supplemented with fat, water treated, or supplemented with enzymes in much the same manner as chickens do. Broad Breasted Bronze poults raised to four weeks of age exhibited a highly significant growth response and increased feed efficiency to pelleted barley and corn diets. A greater response to pelleting was observed with the low-energy diets than with high-energy diets (2, p. 517-523). Data from four-week poult trials also show increased nutritional value of barley by water soaking (26, p. 372-375). Supplementation of barley diets with crude amylolytic enzyme preparations likewise resulted in increased growth and feed efficiency (25, p. 1120) (67, p. 1253) (26, p. 372-375) (29, p. 30-42). Turkeys from seven to 18 weeks of age have shown improved gains and feed efficiency from enzyme supplemented barley diets (52, p. 15-16).

Harper (29, p. 30-42) demonstrated that Broad Breasted Bronze poults to eight weeks of age fed one-half barley and one-half corn or all-barley rations in pelleted form yielded growth rates well above the mash forms that were almost equal to a pelleted corn ration. The results for pelleted corn itself were well above those obtained with corn mash. Feed conversion was improved when any of the rations were pelleted. A marked detrimental effect on litter as compared to a corn ration was incurred by feeding barley in mash or pellet form. Pelleting did not improve upon a one-half barley and one-half corn mash ration for eight to 24-week-old turkeys, nor did pelleting aid an all-barley ration which supported poorer growth and feed conversion than did the one-half barley and one-half corn ration.

Enzyme supplementation (Clarase 300) of barley rations for Beltsville Small White turkeys to 14 weeks of age produced growth and body weights equivalent to corn rations. However, in a later trial growth of poults of the same breed raised to eight weeks on barley rations supplemented with enzyme (HT-440, 1 gm./lb.) was not improved. In addition, the wet litter problem in these trials was not materially improved by the enzyme supplement additions. The failure to obtain a growth response with enzymes from turkeys has been encountered from time to time at the Oregon experiment station.

More recently Leong _et al_. (44, p. 1221-1222) observed improved growth from small additions of a crystalline proteolytic enzyme, but the results did not equal the growth obtained from the addition of crude enzyme supplements to barley rations.

Studies With Layers

Peterson (59, p. 6) noted that egg production for White Leghorn layers was equally good irrespective of the level of barley (10-63%) present in the mash of a mash-scratch diet.

Egg production of White Leghorn pullets is not adversely affected when barley replaces corn in the presence or absence of six per cent fat in the diet, but feed per dozen eggs increases as the level of energy is decreased from the use of barley in the diet. Both egg production and feed efficiency appeared adversely influenced with New Hampshires when all-barley mash was fed (4, p. 38-49). In a study comparing different mash-scratch ratios for New Hampshires, a diet consisting of one-half commercial breeder mash and one-half barley scratch resulted in depressed egg production when compared to a similar ration where mixed scratch grain served as the scratch portion of the diet (49, p. 1-3). In laying trials conducted with White Leghorn pullets, water treatment or amylolytic enzyme supplements for barley did not bring about an increase in body weight, rate of lay, feed required per dozen eggs or decrease in water consumption (14, p. 1184). Some enzyme preparations tended to reduce litter moisture with barley rations. The rate of lay obtained with the barley diets was the same as obtained with the corn rations for the White Leghorn pullets used in this study.

Berg (12, p. 1132) later reported that enzyme supplementation of barley rations for hens did not affect rate of lay, feed per dozen eggs, body weight gains, hatchability of fertile eggs, or such egg-quality characters as weight, shell quality, albumin quality or yolk color. Except for a small reduction in feed required per dozen eggs, the effects of water treatment were identical to those of enzyme addition. The fungal enzyme preparation did decrease litter moisture, however.

Still more recently, Berg (13, p. 12) reported studies in which White Leghorns were fed diets containing barley, corn, and barley plus enzymes from one day of age to 45 weeks of age. The addition of enzymes to barley during the growing period or fed to pullets during the laying period had no effect on egg production or on efficiency of feed utilization by the laying pullets.

Somewhat contradictory to the evidence presented by the Washington station, Nelson and Hutto (56, p. 1229) reported that the addition of enzymes or water treating the barley improved both the production and feed efficiency of White Leghorn pullets in floor pens over the barley-fed groups. In cages the barley group supplemented with enzymes had the highest production and the most efficient feed utilization. A significant increase in hatchability was derived from the enzyme-supplemented diet over both the barley and water-soaked barley diets. There was little difference in egg size, egg quality, or weight gains between the different diets. Peterson (60, p. 10-12) has also noted that addition of an enzyme to a barley diet improved egg production by four per cent and also benefitted feed conversion for layers.

Studies With Other Livestock

A limited review of the literature reveals that attempts at improving the nutritional value of barley for larger classes of livestock are somewhat similar to those with poultry, although the emphasis seems to be with pelleting.

Larsen (41, p. 1-52) recently demonstrated barley to be 86 per cent as valuable as corn in promoting rate of gain for swine. At the North Dakota Agricultural Experiment Station pigs receiving pelleted barley rations gained 11.8 per cent faster on 9.8 per cent less feed over those fed the same ration in meal form (18, p. 16-20). The pelleting and regrinding of a ration for feeding in meal form did not appreciably improve rate of gain, nor feed efficiency. In other trials at this same station, pelleted barley rations made cheaper gains in cost per pound of pork than comparable corn rations.

Other research at the University of Minnesota Northwest Experiment Station for 1958 indicated that pigs on barley pellets gained as well as hogs on ground yellow corn and had resultant savings of 52 pounds of feed per 100 pounds of gain (58, p. 100). The benefits of pelleting barley rations for swine have also been reported from Oregon (42, p. 601-606).

Lewis et al. (45, p. 1047-1050) have reported studies on the qualitative and quantitative protein and carbohydrate requirements of early-weaned pigs which indicate an insufficiency of proteolytic and amylolytic digestive enzymes. Supplementation of soybean protein and casein basal diets for baby pigs with certain proteolytic enzymes increased gains and feed efficiency as much as 29 and 23 per cent, respectively.

Oregon trials demonstrated that crude amylolytic enzyme supplementation did not enhance the feeding value of barley for swine, nor did water soaking of the whole barley *per se* (41, p. 1-52). However, water soaking of barley with 2.5 and 10.0 per cent malt resulted in a reported trend toward improved feed efficiency, and a slight increase in growth was obtained from the 2.5 per cent malt group. No positive growth response occurred in the 10.0 per cent malt group; in fact, a growth depression was noted. A subsequent study at the Oregon station revealed that supplementation of barley rations with 2.5 per cent barley malt did not further enhance growth rate of pigs fed barley rations in mash or pellet form, although feed conversion was slightly improved in two out of three groups (42, p. 601-606).

Regarding the use of enzymes for ruminants, field trials conducted by companies manufacturing enzymes have given responses approximately 50 to 60 per cent of the time. This presents a situation similar to that in poultry where positive responses are not obtained under all conditions (37, p. 10).

EXPERIMENTAL PROCEDURE

Floor Pen Chick Studies

Unless otherwise noted, these experiments involved day-old Red Vantress X New Hampshire broiler-type chicks of mixed sex reared to eight weeks of age in floor pens in a forced-draft ventilated building under infra-red heat lamps and 24-hour lights. Wood planer shavings spread about four inches thick were used throughout as litter. Each pen contained 48-52 birds, and in later experiments the pens were partitioned, giving duplicate pens which contained 24-26 chicks. Each bird had a floor space allowance of approximately one square foot. Feed and water were provided *ad libitum* utilizing hanging-fountain type waters and cylindrical eighty pound capacity feeders, and hanging tube type feeders in the partitioned pens. The tip of the outside toe of female chicks was clipped off for identification purposes as the chicks were put into the pens.

All chicks were weighed and feed consumption data recorded at the end of four and eight weeks. Feed conversion data, corrected for mortality, were obtained on the basis of total body weights and feed consumed. In addition, cumulative water consumption data were obtained for each pen. This involved measurements for a 24-hour period during the middle of each week with hanging water fountains. The weekly consumption was corrected for evaporation, divided by the number of surviving chicks, cumulated, and multiplied by the number of days per week. Four-week accumulated droppings data as described previously were obtained by employing identical treatments in duplicate, for battery-reared chicks.

The broilers indicated in the studies depicted on Tables III and VI; IV, V, VII, VIII, and IX were reared using basal diets one and two (Table II), respectively.

Battery Chick Studies

In thirteen experiments day-old chicks of mixed sex were raised in batteries equipped with raised wire floors (one-half inch mesh), sub-floor electric heating units, and a continuous-flow water system to four weeks of age. A Red Vantress X New Hampshire broiler-type chick was utilized throughout these trials except for two experiments where New Hampshire X Delaware chicks were used.

The tip of the outside toe of female chicks was clipped off for identification purposes as the chicks were placed into the battery. Each pen contained 12 chicks at the start except for two trials where 14 chicks were used.

Table II

Composition of Basal Diets

FEEDSTUFF	RATION (%)						
	Broiler				Poult	Layer	
	1	2	3	4	5	6	7
Ground grain component[1]	61.2500	61.0875	61.2675	61.23	40.6375	75.75	77.00
Soybean oil meal (44% prot.) sol.[2]	22.00	22.00	24.810	22.00	35.00	13.75	12.50
Fish meal (70% prot.)	5.00	5.00	5.00	5.00	7.50	3.00	3.00
Meat and bone meal (50% prot.)	--	--	--	--	5.00	--	--
Corn gluten meal	3.00	3.00	--	3.00	--	--	--
Whey	2.50	2.50	2.50	2.50	5.00	--	--
Alfalfa meal (20% prot.) dehy.	2.00	2.00	2.00	2.00	2.50	3.00	3.00
Bonemeal, special steamed	2.25	2.25	2.25	2.25	1.75	2.50	2.50
Limestone flour	1.25	1.25	1.25	1.25	1.50	1.00	1.00
Salt, iodized	0.30	0.30	0.30	0.30	0.50	0.50	0.50
Vitamin and mineral additives	0.42[6]	0.50[3]	0.50[3]	0.37[5]	0.50[4]	0.50[4]	0.50[4]
dl-Methionine (98%)	0.05	0.05	0.06	0.05	--	--	--
Sulfaquinoxaline (25%)	--	0.0625	0.0625	0.05	0.0625	--	--
Penicillin (4 gm./lb.)	--	--	--	--	0.05	--	--
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1 Barley replaced corn on weight basis except for rations 6 and 7 containing corn and barley, respectively.

2 Where animal fat is indicated in subsequent tables, 0.7% added soybean meal is included for each 3% of fat at the expense of the ground grain component.

Table II (Continued)

3 Nopcosol M5; supplied/lb. of mixture: vit. A, 300,000 U.S.P.U.; vit. D_3, 100,000 I.C.U.; vit. E, 100 I.U.; vit B_2, 300 mg.; niacin, 2,000 mg.; pantothenic acid, 400 mg.; choline, 20,000 mg.; vit. B_{12} activity, 0.4 mg.; proc. penicillin, 0.3 gm.; B.H.T., 11.34 gm.; Mn, 5.4 gm.; I, 109 mg.; Fe, 1.8 gm.; Cu, 182 mg.

4 Nopcosol M6; supplied/lb. of mixture: vit. A, 500,000 U.S.P.U.; vit. D_3, 200,000 I.C.U.; vit. B_2, 350 mg.; pantothenic acid, 300 mg.; vit. E, niacin, choline, vit. B_{12} activity, B.H.T., Mn, I, Fe, and Cu values same as in Nopcosol M5.

5 Choline Cl (25%), 0.20%; vit. A(10,000 U.S.P.U./gm.), 0.05%; vit. D_3(1,500 I.C.U./gm.), 0.05%; vit. B_2(8 mg./gm.), 0.07%; and in gm./100 lb.: Ca-pantothenate (32 gm./lb.), 3.60; niacin, 1.00; vit. B_{12}(1 mg./gm.), 0.15; Mn SO_4 (77%), 16.44.

6 As 5 except: Mn SO_4 (70%), 18.1 gm./100 lb.; antibiotic-B_{12} suppl. (2 gm. proc. penicillin; 3 mg. B_{12}/lb.), 0.05%; no vit. B_{12} *per se*.

Duplicate pens were utilized for the treatments in most of the trials reported. Feed and water were supplied ad libitum. At the end of two weeks one-inch extensions were placed on the feed troughs to prevent wastage. Room temperature was maintained between 70° and 80° F., depending upon the age of the chicks, and lights were supplied 24 hours a day.

Individual chick weights and feed-consumption data were obtained as previously described at the end of four weeks. The wire floor screens were also weighed at four weeks. The difference between the screen, dirty and clean, divided by the number of surviving chicks in the pen, gave an accumulated dropping-per-chick value which is considered a good measure of the "sticky dropping" condition induced by barley diets.

Basal diets two, three, and four (Table II) were employed in the broiler studies shown on Tables X-XVI, XVII-XVIII, and XIX, respectively. Differences in the broiler basal diets occurred either due to the fact that different vitamin and mineral supplements were used as the situation required or because of availability of feedstuffs.

Poult Trials

Poult trials using single groups of Broad Breasted Bronze poults in one instance and duplicated lots of Beltsville Small White poults in a second trial were conducted to compare rations containing corn, barley, water-treated barley, and barley supplemented with a crude amylolytic enzyme preparation. The Broad Breasted Bronze birds were reared in the aforementioned chick batteries, but the Beltsville Small White series was carried out utilizing a Jamesway hover-type battery at the turkey farm. Care and management of the poults was essentially the same as mentioned earlier for broilers, although grit was sprinkled over the feed to stimulate feed consumption early in the study. Basal diet five (Table II) was employed in these trials (Table XX). Data were obtained as previously described for battery-reared broilers.

Laying Hen Studies

The experimental design for the first hen experiment consisted of eight single treatments comparing all-barley and all-corn mash rations unsupplemented and supplemented with a crude amylolytic enzyme preparation for both White Leghorn and New Hampshire layers. For the second hen study duplicate pens of White Leghorns were used to compare an all-barley mash ration versus an all-barley pelleted ration.

The basal rations used are shown in Table II as six and seven containing corn and barley, respectively. In view of the increased protein content of barley, a portion of the soybean meal was deleted to maintain a constant protein level.

Prior to the start of the first hen experiment 280 Oregon Agricultural Experiment Station outcross White Leghorn pullets and 192 Oregon Agricultural Experiment Station strain of Nichol's New Hampshire pullets were housed and distributed into eight 16 X 16 ft. floor pens at the rate of 70 and 48 birds per pen, respectively, for the two breeds. Likewise, 276 Oregon Agricultural Experiment Station outcross White Leghorn pullets were distributed into four 16 X 16 ft. floor pens with 69 birds per pen for the second hen experiment.

All birds were subjected to a routine management program throughout the growing period approved by the poultry department. The pullets were transferred to floor pens at approximately 4.5 months of age, and the experiments were started when the birds reached about 50 per cent lay. Feed and water were supplied ad libitum, and at least 14 hours of light were provided from October through May. Daily egg production, mortality, monthly feed consumption, and initial and final body weight data were recorded during the ten and nine-month periods for the first and second experiments, respectively. In addition, cumulative water consumption data was obtained for each pen. The birds were required to drink from hanging type waterers for a 24-hour period before the actual 24-hour test period began, then the procedure was similar to that described for floor pen reared broilers. No culling was practiced during the experiments.

Terms, Procedures and Additives

Among the data reported herein, the terms water-treated or water-soaked barley refer to ground barley which has been soaked with an equal amount, by weight, of cold tapwater for approximately one-half hour. The water-soaked barley then was spread to a depth of about one inch on trays and dried at 50°-70° C. for approximately 24 hours in a thermostatically controlled, forced air, steam heated drier.

A similar procedure was followed when soaking barley with 95 per cent ethyl alcohol, except with ethanol the soaked barley was dried for approximately 24 hours in trays over a steam vat at 70°-80° C.

The corn-water extract used for soaking barley and mentioned in Table XIV was obtained by stirring one pound finely ground corn to five pounds water for one-half hour and then straining through a muslin cloth.

The barley-water mentioned in Table XI was prepared daily by stirring one pound of finely ground barley with five pounds of tap water for one and one-half hours. The mixture was then strained through a muslin cloth and fed as the chicks' only source of water.

Autoclaving of barley or water-soaked barley was carried out for one hour at 15 pounds P.S.I. Barley-water was autoclaved for 30 minutes at the same pressure.

A 4/32 and 6/32 inch pellet was fed the broilers and layers, respectively, where indicated. Three per cent prime stabilized tallow (Calogen)[1] is used where added fat is indicated.

Enzyme and malt supplements were added to the diet at the expense of the ground grain component. Unless otherwise noted, Dawenzyme served as the enzyme supplement in these investigations.

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[1] Calogen--stabilized with Tenox R which contains citric acid (anhydrous), 20%; butylated hydroxy anisole, 20%; and propylene glycol, 60%.

Statistical Procedures

All data involving reported differences have been statistically treated using analysis of variance and Least Significant Differences[2] computed (46, p. 553). Inasmuch as some of the broiler data shown in Tables III-IX or XI-XIX have only a few degrees of freedom and consequently require very high F values for significance, a pooled error mean square[3] was obtained for the two respective groups of tables and utilized in calculating the L.S.D. values for these data since the trials concerned were similar in design, location, and management. The pooled L.S.D. values have been designated (A) for the floor pen chick studies and (B) or (C) for the battery chick studies. Different pooled L.S.D. values are utilized for the battery studies because the number of observations per treatment total (the letter n of the L.S.D. formula) throughout the battery studies was either one of two figures, rather than being constant as in the case of the floor pen studies. Several experiments were replicated

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[2] $\sqrt{\dfrac{2\ (\text{error mean square})}{n}}$

[3] Pooled error mean square =

$$\frac{\text{sum (error SS for each experiment involved)}}{\text{sum (error d.f. for each experiment involved)}}$$

over a period of time and the resulting data averaged for statistical analysis. In all of the experiments body weights were expressed on a weighted basis for sex and then employed in the analysis.

In view of the non-replicated treatments involved in one of the laying hen studies, the resulting data could not be treated by analysis of variance. It did seem desirable, however, to have some basis for comparison, and data from White Leghorn studies of similar nature, design and management from four prior years were available. Therefore it was assumed that the coefficient of variation for the present study was similar to that of the earlier studies, thus permitting the calculation of workable estimated L.S.D. values[4] for the White Leghorn data. This treatment was also applied where noted to the second laying experiment in view of the limited degrees of freedom present.

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[4] $$L.S.D._2 = \frac{\bar{\bar{X}}_1}{\bar{\bar{X}}_2} \cdot \frac{L.S.D._1}{\sqrt{n_1}}$$

where: $\bar{\bar{X}}$ equals grand mean, n_1 equals number of replications in earlier trials, and $L.S.D._1$ is the L.S.D. value from previous experiments.

RESULTS

Chick Floor Pen Studies

The eight-week results for the floor pen broiler studies are summarized in Tables III through IX. As previously noted, a pooled error mean square was utilized in calculating a common set of L.S.D. values for this group of tables, and the results are reported here using these pooled L.S.D. values. Data from the first study, involving all-barley rations with pellets, three per cent fat, and an amylolytic enzyme (Dawenzyme, 5 lbs./T.) as major variables, are presented in Table III. Crude amylolytic enzyme supplementation of barley resulted in significant growth improvement over the unsupplemented barley treatment, as did pelleting and various combinations of the three variables. Nevertheless, the use of the enzyme on barley mash still resulted in significantly less growth than the all-corn mash. The combination of enzyme and fat used with a pelleted barley ration supported slightly better growth than did the control corn mash ration. A growth response equal to that obtained from the corn mash ration resulted from either the use of the enzyme plus three per cent fat on barley mash or enzyme supplementation of a pelleted barley ration. Pelleting barley mash

Table III

Influence of Enzymes, Fat, and Ration Form on Efficiency of Utilization of Barley by Broilers

Group	Treatment	Average 8-week Data[1]			
		Body Weight (lbs.)	Feed Conv. (lbs.)	Water Cons. (lbs.)	Litter Condition
1	Corn Mash	2.85 (98)[2]	2.28	10.8	Excellent
2	Barley Mash	2.43 (94)	2.70	14.9	Poor
3	Barley Mash + Enzyme[3]	2.67 (93)	2.54	13.6	Good
4	Barley Mash + Enzyme + 3% Fat	2.84 (93)	2.46	13.3	Good
5	Barley Mash + Enzyme + 3% Fat Pelleted	2.88 (93)	2.35	13.7	Good
6	Barley Mash + 3% Fat Pelleted	2.78 (97)	2.43	14.8	Fair
7	Barley Mash + Enzyme Pelleted	2.85 (94)	2.57	15.1	Good

Table III (Continued)

Group	Treatment	Average 8-week Data[1]			
		Body Weight (lbs.)	Feed Conv. (lbs.)	Water Cons. (lbs.)	Litter Condition
8	Barley Mash - Pelleted	2.80 (94)	2.55	15.9	Poor
	Pooled L.S.D.(A) (.05)	.15	.16	1.2	

1 Average of two experiments.
2 Survivors--50 White Vantress and Red Vantress X New Hampshire chicks of mixed sex per group at start, respectively.
3 Clarase 300 (2 gm./lb.) used in experiment #1; Dawenzyme (5 lbs./T.) used in experiment #2.

alone with or without fat also gave a significant growth response that was only slightly less than that obtained with the all-corn diet.

Feed conversion was significantly improved by the various treatments to the barley mash except for the enzyme-pelleted and the pelleted groups. In general, a further improvement was noted in the presence of fat. The combination of all three variables on a barley ration produced the best feed conversion among the barley diets that was not significantly different from that obtained with the all-corn ration.

The marked increase in water consumption common for barley diets appeared slightly decreased by enzyme supplementation, and slightly increased for pelleted treatments. The "sticky dropping" or wet litter condition created by barley rations was greatly improved only in the presence of the enzyme preparation.

In Table IV results are presented to determine if the greater protein content normally present in barley exerts any detrimental effect in the event the soybean meal content of the ration is reduced to maintain a constant protein level in the ration on the basis of the chemical analysis of barley. In view of the previous data, the adjustment was made on a pelleted barley ration supplemented

Table IV

Influence of Increased Barley and Reduced Protein on Efficiency of Utilization by Broilers Fed All-Barley Diets

Group	Treatment (Grain Component)	Average 8-week Data[1] Body Weight (lbs.)	Feed Conv. (lbs.)	Water Cons. (lbs.)
1	61.25% Corn Mash	2.84 (99)[2]	2.31	11.2
2	61.25% Barley Mash	2.29 (95)	2.78	15.7
3	57.30% Barley + Enzyme[3] + 3% Fat - Pelleted	2.88 (92)	2.34	14.2
4	62.30% Barley[4] + Enzyme + 3% Fat - Pelleted	2.89 (97)	2.40	14.3
	Pooled L.S.D.(A) (.05)	.15	.16	1.2

1 Average of two experiments
2 Survivors--Each group contained 50 RV X NH chicks of mixed sex at start.
3 Dawenzyme (5 lbs./T.)
4 Chemical analysis of barley indicated it contained 12.1% protein--adjustment was made by increasing barley and reducing soybean meal contents by 5%.

with three per cent fat and an amylolytic enzyme preparation by increasing the barley content five per cent at the expense of soybean meal. It is evident that lowering the protein content of such a barley ration exerted no detrimental effect on growth, although feed conversion appeared somewhat greater. Water consumption was greatly increased for all barley treatments. Again it is evident that comparable results to the all-corn diet were obtained when an all-barley mash was pelleted and supplemented with fat and an amylolytic enzyme.

Data concerning the feeding of a pelleted barley ration or a reground pelleted barley ration are reported in Table V. Pelleting of the barley ration gave a significant growth response, but resulted in no improvement in feed conversion. Neither growth nor feed conversion compared favorably with that obtained from corn. When the pelleted barley ration was reground, the growth response was significantly reduced and no longer significantly greater than the all-barley mash. Feed conversion was adversely affected following regrinding. Water consumption was greater for the birds fed barley rations in comparison with the corn ration and was significantly increased by pelleting. However, water consumption was not significantly greater when the barley ration was reground.

Table V

Influence of Reground Pellets on Performance of Broilers Fed All-Barley Feeds

Group	Treatment	Average 8-week Data[1] Body Weight (lbs.)	Feed Conv. (lbs.)	Water Cons. (lbs.)
1	Corn Mash	2.92 (52)[2]	2.25	13.2
2	Barley Mash	2.43 (50)	2.60	15.9
3	Barley Pelleted	2.75 (50)	2.57	17.5
4	Barley Pelleted - Reground	2.54 (46)	2.81	16.9
	Pooled L.S.D.(A) (.05)	.15	.16	1.2

1 Average of duplicate pens.
2 Survivors--Each group consisted of 26 RV X NH chicks of mixed sex at start.

The results of experiments involving lowering the levels of enzyme supplementation (5, 2.5 and 1.25 lbs./T.) to a pelleted barley ration containing fat are presented in Table VI. As was previously the case, the all-barley mash resulted in depressed growth and adverse feed conversion. All treatments to the barley mash resulted in significant improvement in growth and feed conversion. When compared to the corresponding ration without enzymes, a significant improvement occurred in growth at the two highest enzyme levels and in feed conversion for only the higher enzyme level. Feed conversion appears progressively improved as the level of supplemented enzyme was increased. In contrast to previous trials, growth and feed efficiency in this experiment did not compare as favorably to that obtained from corn when a pelleted barley ration was supplemented with three per cent fat and an amylolytic enzyme. Water consumption was increased in the presence of barley, further increased on the fat-pelleted group, but reduced in the presence of varying enzyme levels. Accumulated droppings were markedly decreased in the presence of varying enzyme levels.

Table VII gives results obtained by supplementing a one-half barley and one-half corn pelleted diet with various levels of crude amylolytic enzyme preparation.

Table VI

Influence of Enzyme Levels on Performance of Broilers Fed an All-Barley Diet

Group	Treatment	Average 8-week Data[1] Body Weight (lbs.)	Feed Conv. (lbs.)	Water Cons. (lbs.)	Accumulated Droppings[3] (gms.)
1	Corn Mash	2.94 (96)[2]	2.28	12.0	1.0
2	Barley Mash	2.22 (95)	2.76	14.7	25.1
3	Barley Mash + 3% Fat Pelleted	2.66 (95)	2.55	16.2	15.9
4	As 3 + Enzyme (5 lbs./T.)	2.83 (91)	2.38	13.9	0.6
5	As 3 + Enzyme (2.5 lbs./T.)	2.81 (95)	2.44	14.9	1.2
6	As 3 + Enzyme (1.25 lbs./T.)	2.78 (95)	2.47	14.4	2.2
	Pooled L.S.D.(A) (.05)	.15	.16	1.2	

1 Average of two experiments.

2 Survivors--50 and 48 RV X NH chicks of mixed sex per group at start.

3 Data obtained from duplicated lots of chicks raised on wire floors with ½-inch wire mesh to four weeks of age.

Table VII

Effect of Different Enzyme Levels on Performance of Broilers Fed Rations Containing 50 per cent Barley and 50 per cent Corn

Group	Treatment	Average 8-week Data[1]			Accumulated Droppings[3]
		Body Weight (lbs.)	Feed Conv. (lbs.)	Water Cons. (lbs.)	(gms.)
1	All-Corn Mash	2.91 (46)[2]	2.26	11.6	1.3
2	All-Barley Mash	2.17 (46)	2.70	13.1	23.2
3	½ Corn - ½ Barley Pelleted	2.92 (46)	2.30	14.5	3.7
4	As 3 + Enzyme (2.5 lbs./T.)	2.97 (46)	2.20	13.7	2.0
5	As 3 + Enzyme (1.25 lbs./T.)	3.02 (45	2.23	13.8	1.3
6	As 3 + Enzyme (0.625 lbs./T.)	2.93 (48)	2.28	13.1	4.4
	Pooled L.S.D.(A) (.05)	.15	.16	1.2	

1 Average of duplicate pens.

2 Survivors--48 RV X NH chicks of mixed sex per group at start.

3 Data obtained from duplicate lots of chicks raised on wire floors with ½-inch wire mesh to four weeks of age.

Broilers reared on the one-half barley and one-half corn pelleted diet grew as well as those fed the all-corn mash diet and converted feed almost as efficiently. Enzyme supplementation of the one-half barley and one-half corn pelleted diet at the levels of 2.5, 1.25, or 0.625 lbs./T did not materially improve growth or feed conversion beyond that obtained from the pelleted ration alone. Accumulated dropping data show a marked improvement regardless of the enzyme level whenever the pelleted one-half barley and one-half corn ration was used as compared to the all-barley mash ration. Increased water consumption was observed when barley became a variable. A slight decrease in consumption was again observed, but proved significant only at the lower enzyme level.

An experiment conducted to determine the effectiveness of barley malt additions to a barley mash diet was conducted with the results shown in Table VIII. Broiler growth was significantly improved when 2.5, 5.0, or 10 per cent levels of barley malt were utilized in an all-barley mash ration, but only at the 10 per cent level was growth comparable to the group receiving the enzyme *per se*. Feed conversion values, however, unlike the response to enzyme supplementation, were not consistently reduced by barley malt additions at the levels used. The higher water

Table VIII

Broiler Performance on an All-Barley Diet as Influenced by Barley Malt

Group	Treatment	Average 8-week Data[1] Body Weight (lbs.)	Feed Conv. (lbs.)	Water Cons. (lbs.)	Accumulated Droppings[3] (gms.)
1	Corn Mash	2.92 (52)[2]	2.25	13.2	0.6
2	Barley Mash	2.43 (50)	2.60	15.9	32.6
3	As 2 + Enzyme (5 lbs./T.)	2.77 (52)	2.44	14.3	1.1
4	As 2 + 2.5% Barley Malt	2.64 (51)	2.62	16.1	35.6
5	As 2 + 5% Barley Malt	2.67 (51)	2.50	16.1	16.7
6	As 2 + 10% Barley Malt	2.78 (48)	2.57	15.9	5.6
	Pooled L.S.D.(A) (.05)	.15	.16	1.2	

1 Average of duplicate pens.
2 Survivors--Each group consisted of two duplicate pens of 26 RV X NH chicks of mixed sex at start.
3 Data obtained from duplicate lots of chicks raised on ½-inch wire mesh screen floors to four weeks of age.

consumption noted for the barley ration was not lowered by the use of barley malt, but was significantly lowered in the presence of the enzyme. The "sticky dropping" condition as evidenced by accumulated droppings was not improved by using 2.5 per cent barley malt, only slightly lessened with the use of 5.0 per cent malt, but compared favorably to the alleviating effect of enzyme supplementation when 10.0 per cent barley malt was used.

The data in Table IX are the results of two somewhat similar broiler experiments involving various levels of water-treated barley in a pelleted all-barley ration with 3 per cent fat (Series I) or an all-barley mash ration (Series II). In series I the rations containing water-soaked barley resulted in significantly increased growth when at least one-half the ground barley was replaced by soaked barley. A similar improvement in growth was obtained in the presence of an amylolytic enzyme supplement. While no significant differences were noted for feed conversion, improvement is apparent as the amount of soaked barley increases. The enzyme also exerted little if any effect in this regard. Water consumption was significantly elevated in the presence of barley, and in contrast to previous trials was not materially lowered in the presence of the enzyme or soaked-barley treatments. Accumulated

Table IX

Comparative Effects of Varying Amounts of H_2O Treated Barley in All-Barley Rations, an Enzyme All-Barley Combination, and an All-Corn Ration on Performance of Broilers Fed All-Mash Rations or Rations in Pellet Form With Fat

	Treatment						Average 8-week Data[1]			
	Group	Grain Comp.	Amount Water Treated	Form	Added Fat (%)	Enz.	Body Weight (lbs.)	Feed Conv. (lbs.)	Water Cons. (lbs.)	Accumulated Droppings[3] (gms.)
SERIES I	1	Corn	--	Mash	--	--	2.87 (52)[2]	2.29	12.9	0.8
	2	Barley	--	Mash	--	--	2.47 (51)	2.63	15.7	43.0
	3	Barley	--	Pellet	3	--	2.61 (52)	2.41	15.4	6.1
	4	Barley	1/8	Pellet	3	--	2.71 (50)	2.39	15.1	12.3
	5	Barley	1/4	Pellet	3	--	2.71 (51)	2.37	15.2	7.6
	6	Barley	1/2	Pellet	3	--	2.93 (50)	2.33	15.5	1.0
	7	Barley	All	Pellet	3	--	2.88 (49)	2.29	14.6	0.7
	8	Barley	--	Pellet	3	+	2.86 (52)	2.39	15.1	1.0
	Pooled L.S.D.(A) (.05)						.15	.16	1.2	
SERIES II	1	Corn	--	Mash	--	--	2.92 (52)	2.25	13.2	0.6
	2	Barley	--	Mash	--	--	2.43 (50)	2.60	15.9	32.6
	3	Barley	1/4	Mash	--	--	2.48 (51)	2.58	15.9	12.8
	4	Barley	1/2	Mash	--	--	2.80 (52)	2.45	13.0	0.8
	5	Barley	All	Mash	--	--	2.76 (52)	2.46	14.8	0.9
	6	Barley	--	Mash	--	+	2.77 (52)	2.44	14.3	1.1
	Pooled L.S.D.(A) (.05)						.15	.16	1.2	

1 Average of duplicate pens.
2 Survivors--Each group consisted of 26 RV X NH chicks of mixed sex at start.
3 Data obtained from duplicate lots of chicks raised on 1/2 inch wire mesh screen floors to four weeks of age.

droppings were comparable to the all-corn diet or barley-enzyme ration when soaked barley replaced at least one-half the barley.

In series II substitution of increasing levels of water-treated barley at the expense of ground barley in all-barley mash rations resulted in significantly increased body weights, improved feed conversion, and significantly decreased water consumption only when at least one-half of the grain component was replaced. The accumulated droppings were comparable to those produced by a corn ration when one-half or all water-treated barley was used. Again, the supplementation of the barley mash ration with an amylolytic enzyme gave results similar to the one-half or all water-soaked barley rations. Water consumption was also significantly decreased when the barley diet contained an enzyme supplement.

Chick Battery Studies

The four-week results for the chick battery studies are cited in Tables X through XIX. As was previously indicated, a pooled error mean square was utilized in calculating two sets of common L.S.D. values for Tables XI through XIX, and the results are here again reported using these pooled values.

One of the earlier battery studies designed to uncover the mechanism(s) involved in improving barley by water treatment or enzyme supplementation is given in Table X. Autoclaved barley mash depressed growth, feed conversion and increased accumulated droppings, as did the untreated barley mash ration.

The influence of a barley-water extract with or without an enzyme supplement or an autoclaved barley-water extract, when fed as the only source of water, on a corn mash diet is shown in Table XI. No beneficial or detrimental effect could be observed in growth, feed conversion and accumulated droppings from the various water intake treatments when applied to a corn base diet.

The results of a more extensive experiment in which barley was autoclaved at various stages of the water treatment procedure are cited in Table XII. It is of interest to note that whether barley was merely water treated or autoclaved before soaking, after drying, or during the soaking procedure, a marked growth response occurred which was significant in each case. Except for the soaked, autoclaved and dried barley group, growth from all the water-treated barley groups appeared comparable to the all-corn control ration. Feed conversion was significantly improved when water-treated barley was used *per se* or

Table X

Influence of Autoclaved Barley on Chick Growth, Feed Conversion, and "Sticky Droppings" Condition

Group	Treatment	Average 4-week Data		
		Body Weight (gms.)	Feed Conv. (lbs.)	Accumulated Droppings (gms.)
1	Corn Mash	348 (12)[1]	1.77	2.1
2	Barley Mash	258 (11)	2.15	50.2
3	Barley Mash - Autoclaved	257 (11)	2.09	53.4

[1] Survivors--Each group consisted of 12 NH X D chicks of mixed sex at the start.

Table XI

The Effect of Barley-Water Extract on Performance of Chicks Fed All-Corn Rations

Treatment			Average 4-week Data[1]		
Group	Feed	Water	Body Weight (gms.)	Feed Conv. (lbs.)	Accumulated Droppings (gms.)
1	Corn Mash	Water	351 (36)[2]	1.75	1.5
2	Corn Mash	Barley Water	358 (22)	1.75	1.5
3	Corn Mash	Autoclaved Barley Water	362 (24)	1.71	4.4
4	Corn Mash + Enzyme[3]	Barley Water	362 (25)	1.72	2.2
	Pooled L.S.D.(B) (.05)		35	.15	

1 Average of two experiments
2 Survivors--Each pen contained 12 NH X D chicks of mixed sex at start.
3 Dawenzyme (10 lbs./T.)

Table XII

Evidence for an Inhibitory Action in the Utilization of Barley by Chicks as Illustrated by Various Sequences of Soaking, Drying, and Autoclaving Barley and Autoclaving an Enzyme

Group	Treatment	Average 4-week Data[1] Body Weight (gms.)	Feed Conv. (lbs.)	Accumulated Droppings (gms.)
1	Corn Mash	455 (24)[2]	1.69	1.4
2	Barley Mash	350 (24)	2.12	30.9
3	Barley-Soaked-Dried-Mash	425 (23)	1.93	1.9
4	Barley-Autoclaved-Soaked-Dried-Mash	445 (24)	1.88	1.9
5	Barley-Soaked-Dried Autoclaved-Mash	426 (24)	1.89	2.0
6	Barley-Soaked-Autoclaved-Dried-Mash	400 (24)	1.97	2.7
7	Barley Mash + Enzyme[3]	414 (24)	1.90	2.3
8	Barley Mash + Autoclaved Enzyme	382 (23)	1.92	25.5
	Pooled L.S.D.(B) (.05)	35	.15	

[1] Average of duplicate pens.

[2] Survivors--Each group contained 12 RV X NH chicks of mixed sex at start.

[3] Dawenzyme (10 lbs./T.).

autoclaved before soaking, after drying, or during soaking. These results, however, did not compare with those obtained from corn. The "sticky droppings" condition was significantly improved regardless of the sequence of autoclaving. For comparison, the barley mash ration supplemented with a crude amylolytic enzyme preparation also significantly improved growth, feed conversion, and accumulated droppings in a manner very similar to that obtained from soaking. On the other hand, the barley mash ration supplemented with an autoclaved amylolytic enzyme, while appearing to have some effect on growth, did not elicit a significant growth response nor did it clear up the "sticky droppings" condition, although a significant improvement did occur in feed conversion.

The data presented in Table XIII were obtained from an experiment conducted to determine whether or not water of a certain pH is an important factor in the water treatment process. The varied treatments consisted of barley soaked as previously described in tap water (pH 8.0) and barley soaked in water which had been previously adjusted to a pH of 4.0 or 12.0 by HCl or NaOH, respectively. Growth and feed conversion appeared improved whenever water-treated barley was fed, but for this particular experiment were significant only for the group where water

Table XIII

Effect of Water Treating Barley at Different pH Levels on Chick Response

Group	Treatment	Average 4-week Data[1]		
		Body Weight (gms.)	Feed Conv. (lbs.)	Accumulated Droppings (gms.)
1	Corn Mash	453 (26)[2]	1.73	0.9
2	Barley Mash	388 (24)	1.94	81.5
3	Barley Mash - Water Treated[3]	407 (24)	1.87	6.8
4	Barley Mash - Water Treated (acid)[4]	427 (23)	1.76	4.6
5	Barley Mash - Water Treated (alkaline)[5]	409 (24)	1.80	5.0
	Pooled L.S.D.(B) (.05)	35	.15	

[1] Average of duplicate pens.

[2] Survivors--Each pen contained 12 RV X NH chicks of mixed sex at start.

[3] Barley soaked in ordinary tap water (pH 8.0).

[4] As footnote #3 with water brought to pH 4.0 by addition of concentrated HCl.

[5] As footnote #3 with water brought to pH 12.0 by addition of $NaOH$.

of pH 4.0 was used. Accumulated droppings were reduced regardless of the pH of the water used for soaking.

Another experiment involved soaking barley either in water or a corn-water extract or a combination of the two treatments, the results of which are outlined in Table XIV. Diets where water-treated barley, barley soaked in a corn-water extract, or a combination of the two treatments served as the grain component, resulted in growth responses that were significant and were comparable to those obtained from a corn diet. Feed conversion was also markedly improved for either type of water treatment alone or in combination, as were the accumulated droppings when compared to the barley mash ration.

Table XV presents the results of an experiment conducted to determine whether or not an aqueous solution other than water would bring about improvement in the nutritional value of barley. Chicks fed a water-treated barley ration responded with significantly improved body weights and feed conversion. Accumulated droppings were again markedly reduced. On the other hand, growth of chicks fed a ration composed of barley soaked with 95 per cent ethanol appeared depressed even further than for chicks on the untreated barley diet. Feed conversion, while significantly improved on water-soaked barley,

Table XIV

Influence of Water Treatment and/or Corn-Water Treatment of Barley on Chick Performance

Group	Treatment	Average 4-week Data[1] Body Weight (gms.)	Feed Conv. (lbs.)	Accumulated Droppings (gms.)
1	Corn Mash	442 (25)[2]	1.68	0.7
2	Barley Mash	402 (24)	1.92	15.3
3	As 2-Water Treated	466 (24)	1.69	1.1
4	As 2 - Corn-Water Treated	448 (23)	1.72	2.8
5	As 3 - Corn-Water Treated	477 (21)	1.72	1.0
	Pooled L.S.D.(B) (.05)	35	.15	

[1] Average of duplicate pens.

[2] Survivors--Each pen contained 12 RV X NH chicks of mixed sex at start.

Table XV

Chick Response to Ethanol-Treated Barley

Group	Treatment	Average 4-week Data[1] Body Weight (gms.)	Feed Conv. (lbs.)	Accumulated Droppings (gms.)
1	Corn Mash	451 (48)[2]	1.73	0.8
2	Barley Mash	383 (47)	1.97	79.8
3	Barley Mash - Water Treated	418 (47)	1.81	5.3
4	Barley Mash - Ethanol Treated	367 (44)	1.87	41.4
	Pooled L.S.D.(C) (.05)	25	.11	

[1] Average of two experiments, each with duplicate pens.

[2] Survivors--Each pen contained 12 RV X NH chicks of mixed sex at start.

appeared to be only slightly improved for the ethanol-treated barley ration. Even though the group fed ethanol-treated barley had a lower numerical value for accumulated droppings than did the untreated barley group, experience has shown that any accumulated dropping value of this magnitude will not constitute an improvement in the "sticky droppings" condition.

Several of the chick battery studies dealing with the mechanism(s) for improving the nutritional value of barley involved enzyme supplementation as well as the water treatment of barley, the latter of which has been emphasized somewhat up to this point.

A study was initiated to determine to what extent the acid environment of the chick's digestive tract might inactivate enzyme supplements to barley mash rations. Table XVI summarizes the findings of two such trials. A barley mash ration supplemented with a crude amylolytic enzyme preparation promoted significant improvements in growth, feed conversion, and accumulated droppings. Likewise where the enzyme preparation was soaked in an equal amount, by weight, of highly acid (pH 1.0) water solution to overcompensate for the pH values found in the fowl's digestive tract, growth and feed conversion were similarly improved, and the accumulated droppings markedly decreased. The

Table XVI

The Effects of Supplementing a Barley Ration for Chicks with a Crude Enzyme Previously Treated in Acidic Medium

Group	Treatment	Average 4-week Data[1]		
		Body Weight (gms.)	Feed Conv. (lbs.)	Accumulated Droppings (gms.)
1	Corn Mash	423 (50)[2]	1.74	0.7
2	Barley Mash	335 (51)	2.12	107.5
3	Barley Mash + Enzyme[3]	382 (50)	1.93	2.4
4	Barley Mash + Treated Enzyme[4]	369 (47)	1.98	1.0
	Pooled L.S.D.(C) (.05)	25	.11	

[1] Average of two experiments each with duplicate pens.

[2] Survivors--Each pen contained 12-14 RV X NH chicks of mixed sex at start.

[3] Dawenzyme (10 lbs./T.).

[4] Dawenzyme (10 lbs./T.) soaked for 20 hours in an equal amount, by weight, of distilled water brought to pH 1.0.

unsupplemented barley mash ration depressed all aspects of chick performance recorded. Performance from the standpoint of growth and feed conversion did not compare to the corn mash control.

Table XVII shows the influence of certain amylolytic or proteolytic enzyme supplements to barley mash rations on chick performance. The barley mash group receiving an amylolytic enzyme source (HT-550F) resulted in some growth improvement that was not significant when compared to the unsupplemented barley mash group.[5] Feed conversion, however, was significantly improved with the use of this enzyme preparation, and the accumulated droppings were markedly reduced. The use of another enzyme source that was primarily amylolytic (Spitase) resulted in significant improvements in growth, feed conversion, and accumulated droppings when compared to the unsupplemented barley ration. Supplementation of barley mash with either crystalline proteolytic enzymes (Nagarse) or (P-K Enzyme) exerted no effect on growth at these levels when compared to that obtained from the unsupplemented barley ration. Feed conversion was significantly improved by one proteolytic enzyme (Nagarse), but not by the other (P-K Enzyme).

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[5] It should be noted that the level used in this trial was lower than normally recommended for this product (see Table XVIII).

Table XVII

Chick Performance as Influenced by Proteolytic or Amylolytic Enzyme Supplementation of Barley Rations

Group	Treatment	Average 4-week Data[1]		
		Body Weight (gms.)	Feed Conv. (lbs.)	Accumulated Droppings (gms.)
1	Corn Mash	439 (24)[2]	1.65	0.8
2	Barley Mash	358 (23)	2.14	77.9
3	Barley Mash + HT-550[3] (.375 lbs./T.)	375 (23)	1.99	2.4
4	Barley Mash + Spitase[4] (5.4 gms./lb.)	419 (24)	1.93	10.3
5	Barley Mash + Nagarse[5] (.24 mg./lb.)	350 (24)	1.93	53.2
6	Barley Mash + P-K Enz.[6] (2 mg./lb.)	340 (23)	2.25	60.6
	Pooled L.S.D.(B) (.05)	35	.15	

1 Average of duplicate pens.
2 Survivors--Each pen contained 12 RV X NH chicks of mixed sex at start.
3 Crude preparation of amylolytic enzyme.
4 Crude mixture of amylase and protease from *Bacillus subtillis*.
5 Pure crystalline protease from *Bacillus subtillis*.
6 Proteolytic enzyme from Streptomycin (*Actinomycetes protease*).

Neither of the proteolytic enzymes reduced the "sticky droppings" condition when used at these levels.

The results of an experiment conducted to investigate chick performance on barley grains grown in various areas of the country are presented in Table XVIII. The different barley grains were fed without treatment, with an amylolytic enzyme (HT-550F), or after being water treated. Barley grains native to another area, but grown in the Willamette Valley, were also fed, but without further treatment due to an inadequate supply.

In every instance the untreated barley rations depressed chick growth, impaired feed conversion, and resulted in severe "sticky droppings". On the other hand, it was interesting to note that either water treatment or amylolytic enzyme supplementation of feed (A) and malting (B) grade Hannchen barley, feed grade Eastern barley (C), and malting grade Montana barley (D) resulted in a significant growth response. A marked reduction of accumulated droppings likewise accompanied these groups. Feed conversion for the feed (A) and malting (B) grades of Hannchen barley, and malting grade Montana barley (D) was significantly improved by both enzyme supplementation and water treatment. Feed conversion appeared somewhat improved, but not significantly for enzyme-supplemented and water-treated feed grade Eastern barley (C).

Table XVIII

Chick Performance as Influenced by Various Barley Grains, Water and Enzyme Treatment of These Grains, and Barley Locally Grown but Native to Another Area

Treatment				Average 4-week Data[1]		
Group	Grain Component	Water Treated	Enzyme[2]	Body Weight (gms.)	Feed Conv. (lbs.)	Accumulated Droppings (gms.)
1	Corn	--	--	424 (27)[3]	1.77	0.3
2	Corn	--	+	439 (27)	1.72	0.5
3	Corn	+	--	407 (28)	1.60	0.1
4	Barley A[4]	--	--	305 (26)	2.06	54.5
5	Barley A	--	+	401 (28)	1.85	0.5
6	Barley A	+	--	390 (28)	1.80	2.4
7	Barley B[5]	--	--	328 (27)	2.13	59.6
8	Barley B	--	+	389 (25)	1.98	1.0
9	Barley B	+	--	399 (28)	1.87	0.8
10	Barley C[6]	--	--	331 (28)	2.08	44.1
11	Barley C	--	+	380 (27)	1.98	2.7
12	Barley C	+	--	371 (28)	1.94	4.7
13	Barley D[7]	--	--	302 (28)	2.09	105.0
14	Barley D	--	+	405 (26)	1.89	1.3
15	Barley D	+	--	406 (28)	1.79	2.3

Table XVIII (Continued)

Treatment				Average 4-week Data[1]		
Group	Grain Component	Water Treated	Enzyme[2]	Body Weight (gms.)	Feed Conv. (lbs.)	Accumulated Droppings (gms.)
16	Barley E[8]	--	--	309 (14)	2.14	119.2
17	Barley F[9]	--	--	233 (14)	2.61[10]	132.7
	Pooled L.S.D.(B) (.05)[11]			35	.15	

1 Av. of duplicate pens except groups 16 and 17.
2 HT-550F (1.1 lbs./T.).
3 Survivors--each group consisted of 14 RV X NH chicks of mixed sex at start.
4 Feed Grade Hannchen barley (from Pacific Northwest).
5 Malting Grade Hannchen barley (from Pacific Northwest).
6 Feed Grade Eastern barley.
7 Malting Grade Montana barley (Betzes-A).
8 Mixture (equal amounts) of Midwestern varieties Kindred and Trail, grown in Willamette Valley.
9 Mixture (equal amounts) of Western varieties Hannchen and Atlas '57, grown in Willamette Valley.
10 Excessive wastage by chicks due to consistency of the barley.
11 Statistics not applicable to groups #16 and 17.

Two midwestern and two western varieties of barley, Kindred and Trail, and Hannchen and Atlas '57, respectively, were grown locally, but due to the limited amounts available the varieties were combined in equal proportions according to area and fed as previously noted. The locally grown midwestern barley ration (E) depressed chick performance to about the same extent as the other untreated barley grains mentioned above. The locally grown western barley ration (F) depressed chick performance still further. It should be noted that both barley grains contained considerable amounts of awns, roughage, and other foreign material.

Water treatment or enzyme supplementation of a corn mash ration did not prove beneficial on the characters measured except for an improvement in feed conversion when water treated.

Table XIX presents data showing the effects of an antibiotic (Zinc Bacitracin, 4 gm./T.) on chick performance as influenced by changes in intestinal microflora content and/or enzymatic activity. Zinc bacitracin added to a corn or barley mash ration resulted in growth responses that were barely significant for corn and non-significant for barley when compared to the all-corn or barley control, respectively. No beneficial effect was noted from

Table XIX

Effect of the Antibiotic Zinc Bacitracin on Chick Growth and Feed Efficiency as Influenced by Changes in Intestinal Microflora Content and/or Enzymatic Activity

Group	Treatment	Average 4-week Data[1]		
		Body Weight (gms.)	Feed Conv. (lbs.)	Accumulated Droppings (gms.)
1	Corn Mash	426 (46)[2]	1.68	0.7
2	Corn Mash + Zinc Bacitracin (4 gms./T.)[3]	451 (47)	1.67	0.8
3	Barley Mash	347 (44)	1.95	75.6
4	Barley Mash + Zinc Bacitracin (4 gms./T.)	365 (42)	2.00	69.1
5	Barley Mash + Enzyme[4]	394 (45)	1.85	2.5
	Pooled L.S.D.(C) (.05)	25	.11	

1 Average of duplicate experiments, each of which contained duplicate pens.

2 Survivors--Each pen contained 12 RV X NH chicks of mixed sex at start.

3 Included by an equivalent amount of "Baciferm" (181.6 lbs./T.).

4 Dawenzyme (10 lbs./T.).

the antibiotic addition on feed conversion or accumulated droppings. On the other hand, the barley mash control ration supplemented with an amylolytic enzyme resulted in significant growth and feed conversion responses and a marked improvement in the "sticky droppings" condition.

Poult Studies

Studies of four weeks duration were carried out to determine whether or not poults responded to water treatment and enzyme supplementation of barley mash diets similar to chicks. Table XX presents data in series I and II from Broad Breasted Bronze and Beltsville Small White poults, respectively.

In series I the barley mash ration depressed growth, created the typical "sticky droppings" condition, and depressed feed conversion for Broad Breasted Bronze poults. Growth was not improved to any extent when the ration contained water-treated barley, contrary to the results obtained with chicks. However, feed conversion approached that obtained on the corn ration, and the "sticky droppings" condition was overcome. The barley mash ration supplemented with an amylolytic enzyme (Dawenzyme, 10 lbs./T.) appeared to support somewhat better growth than did the corn control diet, and gave almost as good feed

Table XX

Influence of Enzyme and Water Treating All-Barley Rations on Poult Performance

Group	Treatment: Grain Component	Treatment: Water Treated	Treatment: Enzyme	Average 4-Week Data: Body Weight (gms.)	Average 4-Week Data: Feed Conv. (lbs.)	Average 4-Week Data: Accumulated Droppings (gms.)
			SERIES I[1]			
1	Corn	--	--	547 (14)[3]	1.52	3.7
2	Barley	--	--	503 (12)	1.63	17.5
3	Barley	+	--	516 (12)	1.55	4.6
4	Barley	--	+[4]	563 (11)	1.56	7.1
			SERIES II[2]			
1	Corn	--	--	329 (29)	1.91	6.4
2	Barley	--	--	317 (29)	1.88	81.7
3	Barley	+	--	397 (30)	1.67	29.1
4	Barley	--	+[5]	310 (30)	1.75	9.3
		L.S.D.(.05)		30	--	

1 Broad Breasted Bronze poults were used--14 per pen.
2 Beltsville Small White poults were used--duplicate pens of 15 per pen.
3 Survivors.
4 Dawenzyme (10 lbs./T.).
5 HT-550F (1.1 lbs./T.).

conversion. This ration also materially decreased the accumulated droppings. It should be noted that growth was not significantly different for any of the treatments in this series.

Growth was only slightly depressed and feed conversion not affected for the Beltsville Small White poults in series II fed the barley ration. However, the "sticky droppings" condition was very evident. The water-treated barley ration supported a marked increase in body weights that were greater than those obtained from the corn mash diet. This group of poults also converted feed more efficiently than the corn control group. Although the accumulated droppings were less than with the untreated barley ration, the "sticky droppings" condition still persisted at this level, which appeared unusual for a water-treated ration. Supplementation of the barley ration with an amylolytic enzyme (HT-550F, 1.1 lbs./T.) exerted no effect on growth. The enzyme-supplemented barley ration did improve feed conversion and markedly lowered the accumulated droppings.

<u>Laying Hen Studies</u>

Both White Leghorn and New Hampshire pullets were used to study the effects of supplementing corn and barley all-mash rations with amylolytic enzymes (Dawenzyme, 5 lbs./T.). Ten-month data from this study are presented in Table XXI. No difference in egg production was noted for White Leghorn layers fed either a barley ration with or without enzymes or the corn ration. However, significantly more feed was consumed on the barley rations, thus reflecting more feed required to produce a dozen eggs. Body weight gains were greater for the corn-fed White Leghorns as compared to those fed barley with or without the enzyme. Water consumption was increased for the barley rations, although enzyme supplementation brought about a slight decrease in intake. It is interesting to note that enzyme supplementation of the corn ration fed to White Leghorns gave rise to a significant increase in egg production and a significant decrease in feed per dozen eggs when compared to the corn control ration.

As previously noted for White Leghorns, the New Hampshire pullets produced equally well on barley and corn all-mash diets and consumed more of the barley rations as compared to the corn rations. Barley-fed New Hampshires likewise consumed considerably more water than those fed

Table XXI

Effect of Enzyme Supplementation of All-Barley and All-Corn Mash Rations on Performance of White Leghorn and New Hampshire Layers

Treatment	Other	Average 10 Month Data[5]					
		Egg Prod.[1] (%)	Feed/Hen[3] (lbs.)	Feed/Doz. Eggs (lbs.)	Gain Body Wt./Hen (lbs.)	Mortality (%)	Water Cons.[4] (lbs.)
				WHITE LEGHORNS			
Corn (All-Mash)	--	64.02	69.70	4.34	0.8	14.3 (70)[2]	104.47
Barley "	--	64.91	74.24	4.53	0.6	8.6 (70)	127.79
Corn "	Enz.	68.34	69.80	4.04	0.8	12.7 (70)	108.16
Barley "	Enz.	64.77	74.05	4.55	0.7	15.7 (70)	122.50
Estimated L.S.D. (.05)		3.41	2.78	.19			
				NEW HAMPSHIRES			
Corn (All-Mash)	--	53.02	94.68	7.08	1.4	10.4 (48)	146.46
Barley "	--	51.40	99.79	7.74	0.8	16.7 (48)	188.13
Corn "	Enz.	52.62	94.13	7.07	1.6	8.3 (48)	148.21
Barley "	Enz.	52.42	101.78	7.68	1.3	8.3 (48)	175.20

1 Hen day basis.
2 Figures in parentheses represent number started in pen.
3 Calculated fron an actual count of 305 days.
4 Calculated for 8 months (Oct.-May).
5 Bronchitis diagnosed Feb. 1959.

corn diets. Water consumption again appeared lowered by enzyme supplementation of the barley diet. Body weight gains were greater for the corn rations. Amylolytic enzyme supplementation of either corn or barley rations did not benefit egg production for New Hampshires, nor did it seem to have much effect on feed required per dozen eggs. New Hampshires fed the enzyme-supplemented barley ration compared more favorably in body weight gains to corn-fed layers than to those fed the unsupplemented barley ration.

It is interesting to note also the difference in rate of production, feed consumption, and water consumption between White Leghorn and New Hampshire layers.

Table XXII presents data from a nine-month study involving White Leghorns on the influence of pelleting an all-barley ration for layers. The pelleted all-barley ration fed to White Leghorn layers did not increase egg production, but the hens did consume considerably more feed and required significantly more feed per dozen eggs than their counterparts fed the all-barley mash diet. Body weight gains increased for those birds on the pelleted versus the mash ration. The pelleted barley ration induced further increased water consumption as compared to that brought about by the barley mash diet.

Table XXII

Performance of White Leghorn Layers as Influenced by a Pelleted All-Barley Diet

		Average 9-Month Data[5]					
Treatment	Form	Egg Prod.[1] (%)	Feed/Hen[3] (lbs.)	Feed/Doz. Eggs (lbs.)	Gain Body Wt./Hen (lbs.)	Mortality (%)	Water Cons.[4] (lbs.)
Barley	All Mash	61.16	73.79	4.97	0.45	10.85 (138)[2]	114.45
Barley	Pelleted	62.03	79.85	5.17	0.64	15.00 (138)	123.05
Estimated L.S.D. (.05)		3.41	2.78	.19			

1 Hen day basis.
2 Figure in parentheses represents number birds started per treatment; each treatment consisted of duplicate pens of 69 birds each.
3 Calculated from an actual count of 272 days.
4 Calculated for 7 months (Nov.-May).
5 Bronchitis diagnosed Jan. 1959.

DISCUSSION

The data presented from the numerous floor pen and battery trials conducted during the course of these investigations indicate that barley rations can be better utilized by chicks with the aid of fat addition, pelleting, water treatment of barley *per se*, or supplementation with a source of amylolytic enzymes. Optimum or near optimum responses are obtained only when certain combinations of treatments are used. Evidence for an inhibitory action in barley has been noted that can be overcome by water treatment of barley, amylolytic enzymes, and corn using such criteria as growth, "sticky droppings", water consumption, and feed consumption.

Much of this is borne out by an interesting comparison between corn mash and various other rations prepared from results of the eight-week floor pen experiments, and presented in Table XXIII. The comparison is based upon the relative performance efficiency values[6] with the value of 100 being assigned to the corn mash ration. From this standpoint barley appeared about 30 per cent less efficient than corn for broilers. It is also apparent that water

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6 Determined by dividing body weight squared by feed consumption times 100 and expressing on a relative basis.

Table XXIII

Relative Performance Efficiency Values[1] From Eight-Week Old Broilers Fed Various Rations

Ration and Treatments	Per Cent
Corn Mash	100.0
Barley Mash	69.3
Barley Mash + Amylolytic Enzyme	84.9
Barley Mash - Water Treated	88.2
Barley Mash + Amylolytic Enzyme + Animal Fat - Pelleted	94.6
Barley Mash - Water Treated + Animal Fat - Pelleted	98.9
½ Corn Mash + ½ Barley Mash Pelleted	99.8

[1] Determined by dividing body weight squared by feed consumption times 100 and expressing on a relative basis with corn equal to 100.

treatment or amylolytic enzyme supplementation of mash type rations did not make barley comparable to corn for eight-week broilers, although much of the depressing effect was overcome. This comparison suggests that a barley ration for broilers requires a combination of treatments, namely, pelleting, added fat, and water soaking or amylolytic enzyme supplementation to approach the value of a corn mash ration. It is also interesting to note how well the one-half barley and one-half corn pelleted ration compares with the corn mash ration.

A visual description of the "sticky droppings" condition induced by all-barley rations and mentioned frequently throughout this study can be observed in Figure 1. Such a problem does not exist with corn rations, and the screens are essentially clean. As noted previously, a striking effect of both water treatment and crude amylolytic enzyme supplementation of barley rations is the marked reduction of accumulated droppings. In most instances, the screens will then resemble those from a corn ration. Several workers have mentioned or described this effect, but have not taken advantage of it as a good indication of improved barley utilization (25, p. 1120) (23, p. 281-288) (36, p. 42a-44) (39, p. 1221) (3, p. 14-16).

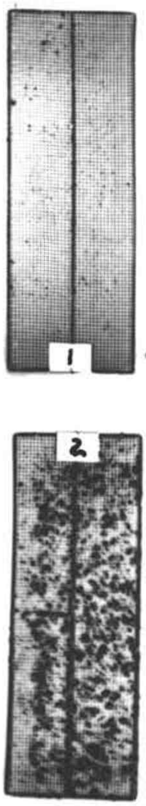

Figure 1.

Wire mesh (½ inch) floor screens from battery brooder at the end of a four-week experimental period. Chicks reared on screen # 1 were fed a corn ration while chicks reared on screen # 2 were fed a barley ration. Chicks fed water treated or amylolytic enzyme supplemented barley rations produce a screen similar in appearance to screen # 1.

The floor pen experiments (Table III) involving all-barley rations with pellets, three per cent fat, and an amylolytic enzyme as the major variables further extend previous work reported by Arscott *et al*. (6, p. 117-123). In their studies an all-barley pelleted ration with three per cent fat compared favorably to an all-corn mash ration with no fat as far as growth, feed conversion, and performance efficiency were concerned. This ration, however, failed to alleviate the "sticky droppings" condition and the increased water consumption caused by barley rations. The data from the present study show that a pelleted all-barley ration with three per cent fat and supplemented with a crude amylolytic enzyme preparation resulted in growth and feed conversion comparable to that obtained with the corn mash ration, and slightly lowered water consumption. It is interesting to note that the "sticky droppings" condition was removed wherever the enzyme supplement was used.

Taking into consideration the lower energy values of barley and the improvements in barley utilization by addition of fat would suggest that the lower nutritional value of barley is due to the unavailability of carbohydrates other than crude fiber, perhaps energy *per se*. However, Arscott *et al*. (6, p. 117-123) were not able to further improve a one-half barley and one-half corn plus three per cent fat ration with additional fat, while a corn ration supplemented with three per cent fat outperformed a one-half barley and one-half corn ration with three per cent fat. In view of this observation and the additional improvements incurred by enzyme supplementation in the present study, it would appear that some factor(s) other than or in addition to energy is involved in improving the utilization of barley.

The improvement brought about by pelleting all-barley mash rations in the presence or absence of fat, and the failure to obtain this same response when a pelleted all-barley ration was reground (Tables III and V) is in agreement with previous reports by Arscott et al. (7, p. 1388-1389), Combs (16, p. 18-26), and Mitchell and Goff (54, p. 4-5). This does not support the contention of Allred et al. (2, p. 517-523) or Jensen (35, p. 72-73) that the pelleting response is made up of two factors, a physical and a chemical effect.

Adjusting the protein level on a pelleted barley ration with three per cent fat and a crude amylolytic enzyme preparation by increasing the barley content five per cent at the expense of soybean meal to maintain isonitrogenous rations when compared to corn rations did not benefit or adversely affect growth or feed conversion (Table IV). These results indicate that the greater protein content normally present in barley as compared to corn is not a factor responsible for the depressed performance of chicks fed barley rations. Indeed the increased protein in barley may be utilized in reducing protein supplied by soybean meal in formulating feeds. Fry et al. (23, p. 281-288) on the other hand, obtained depressed chick growth and poorer feed utilization when the protein content of a pearled barley mash ration was lowered by increasing the barley content of the ration 8.2 per cent at the expense of soybean meal. It is difficult, however, to ascertain whether or not similar findings would have been obtained had this ration also been pelleted and supplemented with fat and an enzyme preparation.

The data obtained from two floor pen studies involving supplementation of a pelleted barley ration containing three per cent fat or a pelleted one-half barley and one-half corn ration with lowered levels (5.0, 2.5, 1.25 lbs./T.) of a crude amylolytic enzyme preparation are quite interesting. In the first study (Table VI) the pelleted barley ration containing three per cent fat and enzymes gave significantly improved performance over a barley mash ration, but did not compare as favorably with a corn ration as it did in a previous experiment (Table III). Growth and feed conversion appeared to be progressively improved as the level of enzyme was increased up to the highest level of supplementation. It is interesting to note that all levels of enzyme supplementation cleared up the "sticky droppings" condition which still persisted with the pelleted barley ration containing three per cent fat, and slightly lowered water consumption which had been increased for barley rations and still further increased for the barley-fat-pelleted ration.

On the other hand, the results from the second study (Table VII) show that a pelleted one-half barley and one-half corn ration supported growth and feed conversion comparable to the corn mash ration, and likewise did not elicit the "sticky droppings" condition. As noted in the results, performance was already comparable to that of a corn ration and was not materially improved by the various levels of enzyme supplementation. Increased water consumption was again observed when barley was a variable, and appeared slightly lowered by the presence of enzymes. There appeared to be a trend of improved feed conversion as the level of enzyme used increased.

It is rather interesting that the lowest level of enzyme supplementation alleviated the "sticky droppings" problem for the pelleted all-barley, fat-containing ration and decreased water consumption, while the higher levels of enzyme supplementation were necessary to obtain the greatest improvement in growth and feed conversion for the same type ration. This observation raises the question as to whether or not the alleviated "sticky droppings" condition is a direct result of improved barley utilization. If this were the case, one would expect the "sticky droppings" condition to improve progressively as the enzyme level increased instead of being cleared up equally as well by all the levels used. The enzymes appeared to be of much less benefit to the one-half barley and one-half corn pelleted ration, because the chicks were better able to cope with the depressing effects of barley when it constituted only 50 per cent of the ration.

As noted previously, an investigation on the possibilities for improving the utilization of barley by swine (41, p. 1-52) included the use of barley malt, a product with high diastatic power. The swine data suggested certain possibilities, and consequently the aforementioned floor pen broiler experiment concerning the addition of barley malt at levels of 2.5, 5.0, and 10.0 per cent to barley mash rations was undertaken (Table VIII). The data from this experiment indicate that barley malt fed at the

10.0 per cent level may be of use in improving the utilization of all-barley mash rations for chicks. The effects of 10.0 per cent barley malt supplementation of a barley ration on chick growth and in improving the "sticky droppings" condition appear to be somewhat similar to those produced by a crude amylolytic enzyme preparation, except for the failure to improve feed conversion.

That 10.0 per cent malt is effective for improving chick growth has also recently been reported by Laerdal (39, p. 1221). Willingham *et al.* have obtained improved growth and feed utilization by supplementing a barley diet for chicks with 2.5 per cent of a special malted barley (66, p. 539-544). On the other hand, Fry *et al.* have shown supplementation of pearled barley diets with malt diastase to be ineffective for improving barley utilization with poults (26, p. 372-375).

The data obtained from floor pen reared broilers fed varying levels of water-treated barley in either pelleted all-barley rations containing three per cent fat or all-barley mash rations indicate the amount of water-treated barley necessary in barley rations to obtain improved utilization (Table IX). At least one-half of the barley needed to be water treated for the pelleted all-barley rations containing three per cent fat to obtain significantly improved performance. It should be noted that the rations containing one-half or all water-treated barley were comparable to the corn mash ration except for water consumption. It is interesting that the pelleted all-barley plus three per cent fat ration supplemented with an enzyme resulted in performance similar to that produced on the ration containing all water-treated barley, except that feed conversion did not appear improved.

The one-half and all water-treated, all-mash rations also resulted in significantly improved performance over the control ration. It is noteworthy that growth and feed conversion did not compare favorably with those obtained from the corn mash ration in this experiment where the effects of pelleting and added fat were absent. On the other hand, the "sticky droppings" condition was cleared up by using either of the higher levels of water-treated barley. Here again, the effects of an enzyme supplement to the all-barley mash ration were equivalent to those obtained from either the one-half or all water-treated barley-containing rations.

It is evident that at least one-half of an all-barley ration needs to be water treated to obtain the best utilization of barley diets for broilers whether pelleted and containing added fat or in all-mash form.

There appears to be a striking similarity between the effects of soaking one-half the barley in a pelleted barley ration containing three per cent fat, and using a pelleted one-half corn and one-half barley ration as mentioned earlier in connection with enzyme levels. In both instances the depressing effects of a barley ration were overcome by substituting one-half of the ration with a feedstuff known to produce good results. There is no questioning the feed value of corn, and the improved nutritional value of water-treated barley has been discussed to some extent already in this study and to great lengths by other investigators. It would appear, therefore, that barley contains some factor(s) which depresses chick performance, the effects of which can be overcome by water treating the barley as well as by enzyme supplementation or overshadowed when a ration contains only 50 per cent untreated barley.

The similar results obtained by water treatment or enzyme supplementation leads to speculation as to whether or not the two treatments are accomplishing their respective improvements in barley utilization by the same action. Unpublished data from this station would indicate that the water treatment and enzyme effects are similar in nature inasmuch as the effects were not additive. This is in accord with a report by Jensen (36, p. 42a-44), who also pointed out that this would not necessarily eliminate the possibility of reaching the same point by two different mechanisms.

Since the initial report on water treatment of barley (22, p. 249-251) and the subsequent report on enzyme supplementation of barley (38, p. 919-921) many investigations have been undertaken to determine the actual mechanism(s) by which this improvement in barley utilization by poultry is obtained. Most of the four-week battery experiments reported in this study were of an exploratory nature, attempting to shed some light on the mechanism(s) involved. As noted in the first mentioned chick battery experiment (Table X), merely autoclaving the barley did not improve its utilization by chicks. Fry *et al*. (26, p. 372-375) have shown this also to be the case for poults. A treatment such as this would tend to indicate that whatever is the cause of poor utilization of barley by poultry, it is not likely a heat-labile factor.

The data obtained from the experiment where chicks were forced to drink a barley-water extract in conjunction with an all-corn mash ration could be indicative of at least two theories (Table XI). Since the typical depression resulting from barley rations was not exhibited by these chicks one could postulate, if thinking in terms of an objectionable factor, that the factor simply did not appear to be water soluble. On the other hand, and probably much more likely, perhaps the barley-water extract did not furnish enough barley to enhance poor utilization as appeared to be the case in the aforementioned floor pen experiments where one-half of the diets were corn or water-treated barley. In other words, the corn diet used may have masked any possible effect. Also evident in this experiment was the failure of a crude amylolytic enzyme preparation to promote improved growth or feed conversion for chicks fed a corn mash ration. This is in agreement with a report by Fry _et al_. (25, p. 1120), and contrary to an investigation where supplementation of an all-corn ration with amylolytic enzymes brought about growth stimulation in some instances (64, p. 497).

The results from the experiment outlined in Table XII are very interesting and enlightening in regard to the mechanism involved in improving the utilization of barley by the water treatment process. The results show that autoclaving barley either before or after soaking or after drying does not appear to destroy the response obtained from water treatment. Investigators at the Washington experiment station have, intermittently, autoclaved barley at various stages of the water treatment process in conjunction with different experiments. However, the reported results have not appeared in agreement with one another. For example, Fry _et al_. (24, p. 1119) (26, p. 372-375) reported improvement in the nutritional value of pearled barley whether the barley was autoclaved before or after water treatment. Thomas _et al_. (61, p. 1254) (62, p. 198-200) mentioned that the improved nutritional value of water-treated barley was not lowered by autoclaving, and later reported that autoclaving previously water-treated barley in the presence of 25 or 125 per cent moisture did not lower its nutritional value for chicks. On the other hand, Jensen (36, p. 42a-44) reported that after autoclaving barley while wet and then drying as for normally water-treated barley, no improvement in the utilization of barley is obtained. Two reports by Willingham _et al_. (66, p. 539-544) (67, p. 1253) likewise stated that when barley was autoclaved wet and then dried, growth and feed utilization were not improved. Jensen (34, p. 150-152) mentioned that generally reduced improvement and more variable results were obtained by autoclaving barley after adding water and then drying at 70° C., but reported that no improvement was obtained when wet barley was autoclaved and then dried at 95° C. Willingham _et al_. (65, p. 103-108) have also reported that autoclaving wet barley and then drying at 95° C. markedly lowered the nutritional value of an Eastern barley blend. Anderson (3, p. 14-16) also has reported that drying barley at 90° C. after water soaking decreased chick growth as compared to drying between 30° and 60° C.

In view of the data obtained from the present study and that presented by the above-mentioned investigators regarding the effect of autoclaving barley at various points of the water treatment process, a discussion of the mechanism responsible for improving barley by water treatment seems to be in order. From their investigations concerning water treatment of barley and enzyme supplementation, Washington workers have indicated that the mechanism of improvement of barley by water treatment involves the action of enzymes inherent in barley on components of the barley (36, p. 42a-44) (50, p. 1-2) (66, p. 539-544).

More recently Jensen (34, p. 150-152) has postulated that the improvement from water treatment of barley is brought about by microorganisms contaminating barley. When these microorganisms are subjected to the water and temperature of the water treatment process, they grow and synthesize enzymes which can then act on barley. This hypothesis was based upon the data mentioned earlier where variable results were obtained by autoclaving barley after adding water and then drying at 70° C. while no improvement was obtained by autoclaving wet barley and drying at 95° C. Also, a bacterial organism isolated from the Washington laboratory brought about improved growth similar to regular water treatment of barley when barley was inoculated with it after wet autoclaving.

Thomas et al. (61, p. 1254) (62, p. 198-200) and McGinnis (50, p. 1-2) also have more recently supported a microbial theory. They have reported higher bacterial counts for water-treated barley than for untreated barley. These workers were able to improve the nutritional value of sterilized barley by inoculating the barley with a culture of Bacillus subtilis or a culture of Gram-positive rod organisms isolated from laboratory dust. Such results suggested that the improvement obtained by water treating is due to a fermentation action by bacteria, molds, or both. However, autoclaving water-treated barley in the presence of 25 or 125 per cent added moisture did not lower its nutritional value. This indicated the barley was improved prior to its incorporation in the diet, and did not depend upon microbially produced enzymes acting in the digestive tract of the chick.

That part of the response from water treatment of barley may be due to antibiotic synthesis by microorganisms has also recently been suggested by Jensen (37, p. 10) and McGinnis (50, p. 1-2). They have reported that addition of both bacitracin and a dry enzyme supplement to a barley feed gave growth equivalent to a diet with water-treated barley, whereas addition of either supplement alone did not support growth equivalent to a water-treated barley diet.

Returning to the experiment under discussion (Table XII), it is evident that improved utilization of barley very similar to that obtained by water treatment was also obtained by supplementing a barley ration with a crude amylolytic enzyme preparation. However, and this appears to be a significant point, supplementation of a barley ration with an <u>autoclaved</u> crude amylolytic enzyme preparation did not markedly improve growth or the "sticky droppings" condition, two of the most consistent indications of improved utilization of barley. This suggests that the enzymes were materially inactivated by the autoclaving process. Therefore, in view of the marked improvements incurred by water treating barley whether the barley was autoclaved either before or during soaking or after drying, it would appear that at least part of the response obtained here does not involve enzymes *per se*.

This is somewhat contrary to the aforementioned theories forewarded by other investigators. The mechanism by which water treatment improves the utilization of barley could perhaps be explained in terms of an inhibitor. It appears plausible that water soaking removes or overcomes an inhibitor or an inhibitory type reaction present in barley which can also be overcome by appropriate enzyme supplementation. Other workers have recognized this possibility, but have not developed it. For example, Fry et al (22, p. 249-251) reported that an irreversible change had occurred in water-treated barley.

The data presented in Table VIII suggest that pH of the water used in soaking is not a critical factor. Although the barley soaked in water of acid pH promoted the only significant growth response in this experiment, there were no significant differences between any of the water-treated groups. Furthermore, the "sticky droppings" condition was improved equally well for all three water-treated groups. Experience from this laboratory and results from other water-treated groups throughout this study indicate that the growth and feed conversion figures for the water-treated group are below their normal values. This is partially in agreement with a report from the Ohio Agricultural Experiment Station (1, p. 1185) where soaking barley in dilute acid gave a response similar to normal water treatment, but where soaking in dilute alkali had no effect. These workers mentioned that fermentation was not observed when acid solutions were used, thus suggesting that fermentation after water soaking is not essential for the production of a growth response. Observations on fermentation were not made on the experiment in this study, but if fermentation is not necessary for response from water-treated barley, this would not support the microbial fermentation contention previously put forth.

The data presented in Table XIV shows that soaking barley in corn-water extract seems to give the same improvements brought about by normal water treatment. Water treatment of barley followed by corn-water treatment did not significantly improve performance. This is not in agreement with a report by Dobson and Anderson (19, p. 1199) where they obtained additional improvement in water soaking if a variety of hulless barley was soaked in an extract of corn, wheat, or milo. They also concentrated a corn extract under vacuum and then added it to a soaked barley diet with a resultant marked increase in growth and improvement in feed efficiency.

That water *per se* is a necessary factor in the improvement of barley by water treatment is indicated by the data shown in Table XV. The feeding value of barley was not improved when 95 per cent ethanol was substituted for water in the water treatment process. In view of the growth depression noted, one might postulate that ethanol in some manner enhances the inhibitory action present in barley. Avigad (8, p. 587-593) has shown that the inhibition exerted by fructose on the enzymic hydrolysis of alpha-glucosides is due to competition of fructose with water for glucosyl units transferred by the enzyme. It is not impossible that something of this nature is occurring in barley.

Experiments were also conducted to study different aspects of improving barley utilization by enzyme supplementation. The data shown in Table XVI in which the enzyme supplement was soaked with equal amounts of a highly acid solution suggest that the low pH concentration prevailing in the chick's digestive tract probably does not inactivate a material amount of a crude enzyme supplement.

Improved nutritional value of barley was obtained by supplementation with two predominately amylolytic enzyme preparations as the data shows in Table XVII. However, two crystalline proteolytic enzyme preparations at the levels used did not improve barley utilization. Very little, if any, improved utilization of barley by supplementation with proteolytic enzymes was found also by

Anderson (3, p. 14-16). On the other hand, Leong et al. (44, p. 1221-1222) obtained a response from a crystalline proteolytic enzyme indicating that more than one enzyme is involved in improving the utilization of barley. However, this work was done with turkey poults, and the response from proteolytic enzyme supplementation of a barley diet was only about one-half of that obtained when barley diets were supplemented with a crude fungal enzyme preparation.

Investigations carried out at the Washington and Utah stations have indicated that crystalline alpha-amylase is inactive as far as improving utilization of barley is concerned (67, p. 1253) (3, p. 14-16). This is rather confusing, because usually the most active enzyme preparations are those sold primarily for their alpha-amylase activity.

The results of the experiments shown in Table XVIII do not lend support to the results of other investigations, previously mentioned in the review of literature, where the utilization of some barley grains from the Midwest and Eastern part of the country was not improved upon by enzyme supplementation. It is apparent in this experiment that supplementation with a crude enzyme preparation (HT-550F, 1.1 lbs./T.) or water treatment greatly improved the utilization of samples of barley grains produced in the West, Midwest, and the East. It is noted, however, that the magnitude of response to either treatment appeared slightly lower as far as feed conversion is concerned for the Eastern barley. It is unfortunate that the quantity of Midwestern barley grown locally was limited, as it would have been interesting to observe the response obtained from water treatment or enzyme supplementation of such barley.

The results of this experiment are at variance with the results recently reported by Willingham et al. (65, p. 103-108) where barley grown in the Midwest and East generally did not respond as well to enzyme supplementation as did barley grown in the West. However, all samples were significantly improved by water treatment, although the magnitude of response seemed slightly better for Western barley. Since the variation in responses to enzymes with different barley samples could not be correlated with differences in proximate analysis, these workers explained the variation in terms of the microbial theory. It was mentioned that certain geographical areas may have better environmental conditions for growth of these microorganisms than other areas. Although marked differences in response to the various treated barley grains were not noted in this experiment, those variations which have been reported elsewhere could just as well be explained in terms of an inhibitor or inhibitory action.

From the data presented in Table XIX, it is apparent that addition of the antibiotic, zinc bacitracin, to either corn or barley diets was beneficial in improving their utilization by chicks only from the standpoint of growth responses, which were barely significant for the corn diets but nonsignificant for the barley diets. On the other hand, supplementation of barley with a crude enzyme preparation resulted in significant growth and feed conversion responses. A noteworthy observation is the fact that the antibiotic appeared to have no effect on the "sticky droppings" condition, whereas enzyme supplementation markedly improved this situation for the barley ration.

As mentioned earlier, other workers have obtained significant growth responses by using bacitracin, and suggested that part of the response from water treating barley may be due to antibiotic synthesis by microorganisms. This suggestion would only be possible if microorganisms are responsible for the water treatment effect. Only a very small growth improvement has been observed when corn is water treated, and corn diets are not generally improved by enzyme supplementation (31, p. 150-152).

However, water treatment of corn did not benefit growth in this study (Table XVIII). It should be noted from the results in the antibiotic experiment that the slight growth response from addition of the antibiotic to the corn ration was similar to the response obtained from antibiotic addition to the barley ration. Therefore, it appears unlikely that part of the response to water treatment of barley is due to the effect of antibiotics. The contribution of the antibiotic bacitracin to the total improvement in the utilization of barley appears to be a minor one, as evidenced by its failure in this experiment to improve feed conversion or the "sticky droppings" condition.

Generally speaking, the data cited in Table XX indicate that like chicks, turkey poults are better able to utilize barley rations which have been water treated or supplemented with an enzyme preparation. However, the improved utilization does not appear to be anywhere near as consistent for poults as that obtained with chicks, and variability in type of responses is evident between Broad Breasted Bronze and Beltsville Small White poults reared to four weeks.

From the results presented in Table XXI it appears that both White Leghorn and New Hampshire layers produce equally well on barley or corn all-mash diets, although those fed the barley diets required considerably more feed per dozen eggs, consumed a great deal more water, and weighed less than birds fed corn diets. Utilization of barley was not measurably improved for either White Leghorn or New Hampshire layers by supplementation with a crude amylolytic enzyme preparation, although water consumption was slightly lowered when the enzyme was present. These results are largely in agreement with investigations reported by Berg and Bearse (14, p. 1184) for White Leghorns, except they did not obtain a reduction in water consumption in the presence of the enzyme. The results are at variance with a report dealing with enzymes for White Leghorns by Nelson and Hutto (56, p. 1229) and a previous report by Arscott (4, p. 38-49) and McCluskey (49, p. 1-3) which mentioned depressed egg production for New Hampshires when all-barley mash was fed or barley constituted the sole grain in the scratch portion of the diet. The increased egg production and the lower amount of feed required per dozen eggs for White Leghorns fed a corn mash diet supplemented with an amylolytic enzyme preparation were unexpected. This particular treatment should be repeated later to see if the results can be confirmed.

The fact that younger birds respond to enzyme supplementation of barley diets and older birds apparently do not is perplexing. Perhaps this paradox can partly be attributed to the degree to which an all-barley ration depresses chick performance on the one hand and laying hen performance on the other. Throughout this study it has been evident that an all-barley ration depresses growth, raises feed conversion values, increases water consumption, and creates a "sticky droppings" condition for chicks. Meanwhile for laying hens, egg production does not appear to be depressed, but feed required per dozen eggs is increased, water consumption is increased, and the litter condition is not good. In view of this, one wonders why growth is depressed for broilers while egg production is not affected for laying hens when barley diets are fed. Perhaps the specific metabolic system involved in the utilization of barley is more fully developed in the older bird. For instance, the older bird may have a near-sufficient supply of amylolytic type enzymes to better break down barley components or to counteract an inhibitor as the case may be.

Pelleting an all-barley ration for White Leghorns did not appear beneficial according to the results cited in Table XXII. Again, this is contrary to results with chicks.

The experiments in this study have illustrated that chicks will better utilize barley rations which have been pelleted, fortified with added fat, supplemented with a crude amylolytic enzyme preparation, a combination of these, or water treated. As of yet the actual mechanism(s) involved in the water treatment process or in the use of crude enzyme preparations is not completely known. Many investigations have been undertaken in the past few years along this line and have expanded the use of enzyme products throughout the feed industry. However, further investigations must be carried out to uncover the actual mechanism(s) involved, thus enabling a more definitive use of enzymes with feeds. More than likely, future research on this subject will be more of a biochemical nature.

SUMMARY

Investigations involving numerous experiments utilizing chicks, poults, and laying hens have been conducted in an attempt to improve the utilization of barley in order that it might satisfactorily replace corn as the grain component in poultry rations.

Floor pen experiments of eight weeks duration with crossbred broilers have been conducted to determine the effects of the following variables in conjunction with barley rations: pelleted mash with animal fat plus an enzyme, adjusted protein, reground pellets, reduced enzyme levels, reduced soaked barley content, and barley malt additions. A pelleted barley diet containing added fat and a crude amylolytic enzyme supplement supported growth and feed conversion comparable to those from an all-corn mash ration in most trials, and markedly reduced the "sticky droppings" condition. No apparent detrimental effects were observed when barley replaced a portion (5%) of the soybean meal in a ration to provide an iso - nitrogenous comparison between corn and barley rations. When a pelleted barley diet was reground, the growth response from pelleting was not apparent and feed conversion was increased. Enzyme (Dawenzyme) levels of 1.25, 2.5, and 5.0 lb./T. used on pelleted barley diets

containing three per cent animal fat resulted in improved growth, better feed conversion, and reduced water consumption as the enzyme level increased. The "sticky droppings" condition was markedly reduced for all enzyme levels. When corn replaced one-half of the barley in a pelleted ration growth and feed conversion were comparable to those obtained from a corn mash ration, and the "sticky droppings" condition was not evident. Supplementation of such a ration with enzyme at 0.625, 1.25, or 2.5 lbs./T. did not prove beneficial except for a slight reduction in water consumption. When water-treated barley replaced 1/8, 1/4, 1/2, and all-barley in a pelleted ration containing fat, growth and feed conversion were improved as the level of soaked barley increased, and appeared optimum at the one-half replacement level. Similar but less efficient results were obtained with an all-mash series. The "sticky droppings" condition was markedly improved above the 1/4 replacement level for both series, but water consumption was decreased only on the mash series above the 1/4 level. Growth and droppings comparable to those from an enzyme supplemented barley ration were obtained only when at least 10.0% barley malt was added to a barley ration. However, feed conversion was not improved at this level.

Battery experiments of four weeks duration with crossbred broilers have been conducted primarily in an attempt to clarify the mechanism(s) by which barley utilization is improved by enzyme supplementation or water treatment. No beneficial or detrimental effects were obtained by supplying water through barley-water extracts, with or without autoclaving, along with a corn base ration. Merely autoclaving barley did not improve its utilization. The beneficial effect derived from water treating barley was not destroyed by autoclaving either before or during soaking or after drying. On the other hand, autoclaving an enzyme supplement destroyed the response usually obtained from enzyme supplementation of barley rations. Improved growth, better feed conversion, and a marked reduction in accumulated droppings were obtained when barley was soaked in water, regardless of pH (4.0, 8.0, or 12.0). When barley was soaked in a corn-water extract, performance was comparable to normal water-treated barley, but the response did not appear additive. Barley treated with 95 per cent ethanol rather than water did not improve performance; in fact, growth was depressed even further.

Significantly, increased growth and improved feed conversion as well as marked reduction of accumulated droppings were obtained on a barley ration supplemented with an enzyme preparation which had previously been soaked in an acid solution (pH 1.0). When barley rations were supplemented with either of two different crude enzyme preparations, chiefly amylolytic in nature, growth, feed conversion, and the "sticky droppings" condition were all improved. However, when either of two different crystalline proteolytic enzymes were used, performance was slightly depressed except for improved feed conversion in one instance. Depressed growth, increased feed conversion, and the "sticky droppings" condition were evident when chicks were fed feed and malting grade Hannchen barley, malting grade Montana barley, and feed grade Eastern barley. These same measures of performance were markedly improved by either supplementation with a crude amylolytic enzyme or water treatment for all the barley grains mentioned, with the exception that feed conversion was not significantly improved in the case of feed grade Eastern barley. A blend of two locally grown Midwestern barley varieties also depressed chick performance. A blend of two Western barley varieties similarly grown depressed performance still further. When zinc bacitracin was added to corn and barley rations, significant and nonsignificant growth responses were observed, respectively; however, feed conversion and the "sticky droppings" condition were not improved. Feed conversion was the only aspect of performance improved when water-treated corn was fed. Enzyme supplementation of a corn ration was without effect.

Data from certain of these studies are interpreted as supporting the hypothesis that water treatment of barley apparently removes an inhibitor or an inhibitory action which can also be overcome by an appropriate enzyme supplement.

Battery trials of four weeks duration were conducted with Broad Breasted Bronze and Beltsville Small White poults to determine if enzyme supplementation and water treatment also improved barley utilization for young turkeys. Both feed conversion and the "sticky droppings" condition were improved by either amylolytic enzyme supplementation or water treatment of barley for Broad Breasted Bronze poults. Growth, however, was improved only with the enzyme. For Beltsville Small White poults the barley ration did not depress feed conversion, and only slightly depressed growth, but the "sticky droppings" condition was very evident. In this instance only the water-treated barley ration improved growth, whereas feed conversion was improved both on the water-treated and enzyme-supplemented rations. On the other hand, the "sticky droppings" condition was markedly improved only on the ration supplemented with enzymes.

Floor pen studies of nine to ten months duration have been conducted to determine the value of a crude amylolytic enzyme supplement and pellets in improving the utilization of barley for layers. No differences in egg production were observed when either New Hampshire or White Leghorn layers were fed barley diets with or without an enzyme supplement as compared to an all-corn ration. Both feed and water consumption were elevated for both breeds on the barley-containing diets. Likewise, when barley rations were pelleted for White Leghorns elevated feed and water consumption were the only differences in production noted. Body weights appeared depressed for barley diets, but improved, particularly for the New Hampshires, when the barley diet contained enzymes, and for the White Leghorns when the barley rations were pelleted. Improved egg production and decreased feed per dozen eggs were obtained only from White Leghorns when a corn diet was supplemented with enzymes.

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