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Most of the feed required for poultry production in the Republic of Yemen is imported from Europe. Sometimes, feed shipments arrive later due to lack of hard currencies to pay for the feed or to pay the freight charges. Yemeni broiler producers in such cases feed their birds a single feed ingredient or a mixture of ingredients until feed arrives.

Five experiments were conducted to simulate feed shortage situations. As a single ingredient, barley is the grain of choice in case of feed shortages. When broilers were switched to corn-soy after the single ingredient diets, the compensatory growth was correlated with the severity of reduced growth.

Feeding diets with a mixture of faba beans + sorghum grain with or without 7% herring meal for 21 and 49 days, respectively, reduced significantly ($P<.05$) mean body

weight, total feed consumed, feed efficiency and apparent protein efficiency ratio.

Feeding wheat bran at 10-15% with adjustment for protein and energy from day-old to 49 days of age resulted in significantly ($P<.05$) improved mean body weights compared to the control broilers. Increasing wheat bran levels further gradually reduced body weight and feed consumption. Abdominal fat increased significantly ($P<.05$) when wheat bran inclusion exceeded 20 percent.

Cellulase supplementation did not show any significant interaction with wheat bran in all the measured parameters. Supplementing protease to wheat bran diets significantly ($P<.05$) reduced mean body weight, feed consumption and the feed conversion in broilers. These dramatic effects were proportionally ameliorated by increasing the levels of wheat bran.

Nutritional Implications in Broilers Fed Single or a Combination of Feed Ingredients During Feed Shortages in the Republic of Yemen

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CHAPTER I

INTRODUCTION

One of the main constraints to producing broilers in the Republic of Yemen is the inadequate supply of feed. Almost all the feed required for poultry production at this time is imported mainly from Holland, Belgium and Germany (M. A. Al-Kohlani, Poultry Production Farm Rawdah, Sana'a, the Republic of Yemen, Personal Communication, 1990). It usually takes 14 to 21 days for feed to arrive in Yemen from Europe. Sometimes shipments are late due to lack of hard currencies to pay for the shipments or freight charges. Broiler producers in such cases feed their birds a single ingredient like barley, sorghum or wheat bran or a mixture of two or more ingredients.

Profitability in the broiler industry depends on attaining maximum body weight at market age and also on savings that can be accomplished by matching the available feedstuffs with the nutrient requirements of broilers provided that feed is not costly (Farjo *et al.*, 1986). Broilers are fed high density feeds containing corn, soybean meal, animal fat and supplemental vitamins and minerals to maximize performance and profitability. However, when costs of high density feed such as corn and soybean meal are high, the producer benefits by switching to lower density feedstuffs where the costs of providing equivalent amounts of nutrients are generally less. Feeding low-density feeds will reduce the performance of broilers because they have generally lower energy levels. With low energy, poultry will manipulate their feed intake in accordance with the energy level of the feed, at least until maximum feed intake capacity is attained (Campbell *et al.*, 1984). Home-grown grains and grain by-products may be the alternative sources.

In the Republic of Yemen barley, sorghum grain, faba beans, wheat bran, cottonseed meal, animal and poultry by-products, human food left over (from parties), sesame meal, peas, lentils, blood meal and others are potential poultry feeds. Nutrient levels of wheat, sorghum, faba beans and barley grown in the Republic of Yemen are listed in Table I.1.

The objectives of this study were to simulate feed shortage situations in the Republic of Yemen and to investigate the nutritive status of broilers fed single or a mixture of feed ingredients.

Table I.1. Crude protein and amino acid analysis of wheat, sorghum, faba bean (FB) and barley from the Republic of Yemen

Amino acid[1]	Wheat	Sorghum	FB	Barley
Alanine	.548	.733	1.07	.499
Arginine	.901	.449	3.09	.753
Aspartic acid	.862	.642	2.93	.751
Cystine	.315	.167	.268	.335
Glutamic acid	3.70	1.66	4.16	3.38
Glycine	.625	.265	1.10	.588
Histidine	.323	.177	.647	.281
Isoleucine	.501	.352	1.20	.505
Leucine	1.00	1.17	2.05	.993
Lysine	.417	.222	1.65	.444
Methionine	.152	.0988	.212	.141
Phenylalanine	.596	.401	.998	.653
Proline	1.97	1.07	1.15	2.40
Serine	.735	.435	1.63	.677
Threonine	.241	.177	.535	.268
Tryptophan	.136	.081	.189	.134
Tyrosine	.391	.310	.861	.420
Valine	.601	.443	1.41	.665
Crude protein[1]	14.0	8.85	25.2	13.9

[1] All figures represent percentage.

References

Campbell, G. L., H. L. Classen and R. E. Salmon, 1984. Enzyme supplementation of barley for broilers. Feedstuffs 56(19):26-27.

Farjo, G. Y., A. S. Al-Saigh and I. K. Ibrahim, 1986. Effect of dietary dilution with sand on broiler performance to 8 weeks of age. Br. Poult. Sci. 27:385-390.

CHAPTER II

LITERATURE REVIEW,

ALTERNATIVE FEED INGREDIENTS

Barley

Barley (*Hordeum vulgare*) is one of the principal feedstuffs containing 2510 kcal metabolizable energy (ME)/kg, 11-13% crude protein and about 5% crude fiber. Barley is not used extensively in certain poultry diets because of its low energy content, and because it causes severe sticky and wet droppings in young chickens. Inconsistent nutritional value is another reason barley is not used readily (Gohl *et al.*, 1978; Hesselman *et al.*, 1981, 1982; Campbell *et al.*, 1986; Rotter *et al.*, 1989). The sticky and wet droppings in young chicks may be associated with the presence of beta-glucans.

Beta-glucans

Problems observed with barley have been ascribed to the high fiber content, but more recently to the mixed linked (1→3), (1→4)-beta-glucans (White *et al.*, 1981, 1983). Beta-glucans are present in endosperm cell walls of cereals and the cell wall of the protein-rich aleurone layer (Bacic and Stone, 1981). Beta-glucans contribute to about 75% of the cell wall of the endosperm, the remainder being mainly arabinoxylans, mannose-containing polymers, protein and phenolic compounds (De Silva *et al.*, 1983). Compared to other cereals, barley and oats have relatively high contents of total beta-glucans (Åman and Graham, 1987). Like cellulose, an insoluble fiber fraction, beta-glucan is largely composed of beta 1→4 linked glucose units; however, it differs in that region of beta 1→3 linkages giving the molecule a step-like structure that interferes with hydrogen bonding between adjacent chains, resulting in increased solubility. Soluble beta-glucans have been implicated in contributing to the sticky, wet, unmanageable litter, reducing passage rate and causing digestive upsets due to the increased viscosity of intestinal contents. Hesselman and Åman (1986) reported that beta-glucans can also have antinutritional properties, particularly in chicken diets where they may produce sticky droppings and affect feed intake, growth rate, and feed conversion efficiency. Insoluble beta glucans in grain cell walls encapsulate readily available nutrients such as starch, intracellular protein, and fat and act as a physical hindrance to nutrient hydrolysis and utilization (Campbell *et al.*, 1984).

Beta-glucans content of barley is influenced by genetics and environment. The waxy gene seems to be associated with high glucan content (Newman and Newman, 1987). Environmental factors such as hot and dry weather conditions during the growing season favor the formation of beta-glucans (Willingham *et al.*, 1960). Hesselman and Thomke (1982) indicated that a possible explanation of increasing beta-glucans during hot and dry conditions could be that the seed start to synthesize beta-glucan to increase the water holding capacity or that the formation or action of one or more endogenous beta-glucan hydrolyzing enzymes are inhibited.

Improving the nutritive value of barley

1. Storage

Stoskopf (1985) observed that newly harvested low or high-moisture barley grain should be stored about 4 to 6 weeks to allow it to undergo a sweat period in order to avoid serious losses in cattle, and poultry.

Hesselman *et al.* (1982) mentioned that the effect of beta-glucanase on feed consumption and live weight was correlated with barley beta-glucan contents. When barley is stored anaerobically immediately after harvesting, the beneficial effect of beta-glucanase is reduced due to the fact that moist storage activates the endogenous beta-glucanase which is similar to conditions obtained by the water treatment on barley.

2. Grinding

Hesselman and Åman (1986) stated that the organization of beta-glucans within the cell walls means that they can act as a physical hindrance for nutrient hydrolysis and absorption. Grinding the barley during preparation of the feed reduces the physical hindrance. However, a large part of the grain will remain unaffected, leaving starch and intracellular protein surrounded by cell walls.

3. Water soaking

The antinutritional properties of barley can be effectively overcome by water soaking (Fry *et al.*, 1958). In a follow-up study, Arscott *et al.* (1960) confirmed that water treatment of barley appears to remove an inhibitor or inhibitory action of barley that can be overcome by an appropriate enzymatic supplement. However, the response to barley treatments either by water soaking or enzymatic supplementation depends on barley growing and storage conditions (Hesselman *et al.*, 1981). Willingham *et al.* (1960) found that barley grown under hot and dry conditions has more beta-glucans than those grown under moist conditions, therefore, it responded more to water treatment when fed to broiler chickens. Classen *et al.* (1985) reported that autoclaving prior to water treatment eliminates the improvement from water treatment. This effect may be due to heat-induced destruction of endogenous beta-glucanase that otherwise would be active in the chick intestine (Burnett, 1966). It is well known that water treatment leads to the hydrolysis of beta-glucans in barley.

4. Enzyme supplementation

Animals do not secrete enzymes that can digest beta-glucans (Cheeke, 1991). An increase in nutritive value of barley in broiler chickens by supplementation with various enzymes preparation has been demonstrated (Jensen *et al.*, 1957; Fry *et al.*, 1958; Burnett, 1966; Petersen and Sauter, 1968; Herstad and McNab, 1975). In addition to improved feeding value, Qureshi *et al.* (1980) noted that enzyme supplementation with high levels of barley decreased the sticky dropping condition in the chicks. The response to enzyme supplementation of water-treated barley is influenced by geographical area where barley was grown. Willingham *et al.* (1960) noted that western U. S. barley was more responsive to enzyme supplementation and water treatment than that from the Midwest. Several enzymes have been used to supplement barley, but beta-glucanase has been investigated more often. The feeding value of barley in broiler chickens was improved by the inclusion of a commercial beta-glucanase preparation in the diets (Hesselman *et al.*, 1981, 1982). Beta-glucanase destroys the cell wall structure of barley endosperm (De Silva *et al.*, 1983). A major effect of treating the endosperm with this enzyme was the breakdown of beta-glucans and arabinoxylans, which are the major components of the endosperm cell walls surrounding the starch granules in barley (Hesselman and Åman, 1986). The beneficial effect is caused by enhanced availability of starch to hydrolyzing enzymes within the intestine tract owing to breakdown of endosperm cell walls and aleurone layer (contain beta-glucans), and the gel complex that develops in the intestine may be counteracted with appropriate enzyme supplementation (Campbell *et al.*, 1984). The improvement with enzyme supplementation may be attributed, in part, to higher feed consumption as a consequence of improved passage rate and increased ability for the birds to consume feed to meet energy demands, as well as improved nutrient availability (Campbell *et al.*, 1984). However, like water treatment, the response to enzyme supplementation in barley depends on the geographical and growing conditions such as hot and dry conditions which lead to early harvest of barley (Campbell *et al.*, 1984). Barley with more beta-glucans respond to enzyme treatment more than with lower levels. Hesselman and Åman (1986) reported that beta-glucan in barley comprise only 3-8% of the normal barley. The improvement in performance with beta-glucanase supplementation was unlikely to be a result of utilization of this small portion, beta-glucans, (Åman and Hesselman, 1985). These authors supported the theory of interaction of beta-glucans on starch, the most important source of energy in broiler diets, and nitrogen utilization.

Classen *et al.* (1985) observed that enzyme supplementation improved weight gains and feed-to-gain ratios from 0 to 3 weeks of age. However, there was little or no improvement during the grower-finisher stage, suggesting that enzyme preparation is not as effective in the mature bird. Variability in performance and vent pasting were dramatically reduced in broiler chicks (Rotter *et al.*, 1989). Campbell *et al.* (1984) reported that barley diets without enzymes prolonged days-to-market by 4-5 days, which was reduced to 1.5 days with enzyme addition. These authors also noted that enzyme addition is essential to obtain optimal response of broilers fed barley. Although improvement tends to be greatest in the starter phase, Campbell *et al.* (1984) recommended that enzymes should be included in finisher diets to control litter wetness and possible management problems.

Campbell *et al.* (1986) stated that in laying hens no substantial benefit will ensue from enzyme addition because the adverse effects of feeding barley diminish with age.

Ultimately, whether or not enzymes become an economically viable feed additive will depend on biological performance as well as enzyme cost.

5. Germination

Fengler *et al.* (1990) reported that during germination beta-glucanase increased. Beta-glucanase has been reported by Hesselman and Åman (1985) to change the cellular structure of barley and by de Silva *et al.* (1983) to alter the physical properties of the beta-glucans such as molecular weight and solubility. Thus it is possible that the increased enzyme activity during the germination of barley could improve nutrient availability for chickens.

Incorporating barley in broiler rations

From previous studies it is clear that barley can't be added as the only energy source to broiler rations without a considerable adverse effect. Thus several researchers incorporated barley in combination with other energy sources (grains or fat) to improve the nutritive value of barley. Arscott *et al.* (1955) reported that barley may replace up to one-half of the ground grain component of a high-efficiency broiler ration fed to battery raised chicks when the diets were supplemented with 4 or 8% stabilized fat.

Hesselman and Thomke (1982) reported that the use of barley in commercial broiler chicken diet is often restricted to 25% because of the potential risk of the occurrence of sticky droppings and depressed performance. Arscott *et al.* (1958) mentioned that litter condition appeared adversely affected whenever barley replaced corn entirely even when barley was pelleted. Wet droppings could be related to increased water consumption with increased barley content of the ration. Barley pelleting further stimulated water consumption.

Sorghum

Sorghum (*Sorghum bicolor*) is one of the most important feed crops in the arid and semiarid tropics (Stoskopf, 1985). Sorghum is easier to plant, cheaper to grow and requires less fertilizer and water than corn (Hulan and Proudfoot, 1982). In the developing countries, sorghum is an important source of energy and protein for both humans and animals (Cheeke, 1991). It contains 3310 kcal metabolizable energy per kg, 7-10% crude protein, and 2-3% crude fiber.

Wall and Ross (1970) stated that sorghum has high energy content in the form of starch, but the high tannin content of many varieties which is associated with poor digestibility discouraged its use in poultry diets.

Evaluation of sorghum grain as poultry feed

1. High protein versus low protein sorghum

Protein content of sorghum grain is affected by such factors as location, hybridization and nitrogen fertilization (Burleson *et al.*, 1956; Miller *et al.*,1964). Waggle *et al.* (1967) reported that a diet containing high protein sorghum grain resulted in the most body weight gain while a diet of low protein grain produced the least body weight gain in broilers. Vohra (1975) mentioned that sorghum varieties with low protein content have a better amino acid balance than those of high protein sorghum because the increase of various amino acids is not proportional to the increase in protein levels, therefore, sorghum varieties with a low protein content give a better growth which is attributed to a better balance in essential amino acids. However, Waggle *et al.* (1967) reported that high protein grain sorghum produced significantly more gain than low protein grain when formulated in diets of equal quantities of sorghum grain and soybean meal.

2. Limiting amino acids

The limiting amino acids in sorghum grains are controversial. Adrain and Sayerse (1957) stated that the limiting amino acid in sorghum was lysine, while Vavich *et al.* (1959) reported that lysine and arginine were the amino acids that limited growth of chicks on sorghum grains. As far as sorghum from tropical varieties is concerned, Baptis (1954) found that sorghum was low in lysine, methionine and tryptophan. Some studies have shown that some amino acids of sorghum decrease with an increase in protein content. Virupaksha and Sastry (1968) found that lysine was negatively correlated to the protein content of the sorghum grain. Vohra (1975) reported that sorghum grain is generally deficient in sulfur amino acids.

Incorporating sorghum grain in poultry ration

Sorghum grains have been substituted on an equal weight basis in place of corn in practical poultry rations containing 20% or more protein with only a slight effect on chick growth. However, high tannin (6.06%) sorghum grain reduced significantly growth in Japanese quail compared to low tannin (.02%) (Garwood and Rogler, 1987). Armstrong *et al.* (1973) mentioned that chicks fed bird resistant sorghum (high tannin) had depressed growth and feed conversion in comparison to chicks fed diets containing corn or nonbird-resistant sorghum (low tannin). Chang and Fuller (1964), Damron *et al.* (1968) and Stephenson *et al.* (1968) stated that the growth depression and reduced feed conversion experienced when sorghum grains were fed to chicks might be related to tannin contents. This finding has been confirmed by the report of Rostagno *et al.* (1973) who observed that chicks fed corn-based diets consistently exhibited superior weight gains and, in some cases, superior feed conversion when compared to chicks fed diets containing sorghum grains having either a high, intermediate or low level of tannin. Furthermore, it has been stated that high concentrations of tannin have been shown to reduce feed intake (Rostagno *et al.*, 1973; Herstad, 1980) and nutrient digestibility and nitrogen retention (Nelson *et al*, 1975). These effects adequately illustrate the poor performance of chicks fed sorghum grain with high tannin content (Ibrahim *et al.*, 1988).

Antinutritive factors in sorghum grain

Negative effects of sorghum grain are usually attributed to potential anti-nutritive factors among which tannins and phytic acid are considered the most important (Ibrahim *et al.*, 1988).

1. Tannins

Tannins occur primarily in the testa and pericarp, the outer most layers of the kernel (Cheeke, 1991). Sorghum tannins are polyphenolic compounds of a type known as condensed tannins. These compounds reduce the palatability of feed, react with the digestive enzyme which, in turn, reduce nutrient digestibility and react with dietary protein to form indigestible complexes. Teeter *et al.*, (1986) noted that the toxic effects of tannin have been ascribed, in part, to reduced nitrogen digestibility and hence reduced nitrogen retention. Sorghum grains have been reported to cause leg abnormalities due to either lack of mineral deposition or collagen formation or both, with tannins acting either in the digestive tract or directly on bone tissue (Ibrahim *et al.*, 1988).

The following techniques are used to alleviate tannin effects.

a. Methyl donor

Several methods have been investigated to overcome growth depression caused by tannin content in sorghum grain. Methyl donor is one of these methods that has been discussed in detail. Chang and Fuller (1964) showed that the addition of methionine, choline and other methyl donors helped overcome growth depression in chicks presumably by detoxifying absorbed tannins. In other studies, Armstrong *et al.* (1973) and Featherston and Rogler (1975) have shown that methionine supplementation in sorghum-soybean meal diets suboptimal in protein completely overcame the growth-depressing effect in chicks fed high tannin grains. Potter and Fuller (1968) related the effect of methyl donor to the fact that tannic acid is hydrolyzed to gallic acid which, in turn, is methylated and excreted in the urine as 4-O-methyl gallic acid. This explains why the addition of methyl donor alleviates adverse effects imposed by tannic acid. In contrast, Elkin *et al.* (1978) suggested that methionine is probably acting as an essential amino acid for protein synthesis and is not acting in detoxification of tannin. Methionine supplementation did not significantly increase any of the parameters measured in chicks consuming the low tannin diet, but the addition of 0.15% d,l methionine to the high tannin sorghum diet approximately doubled the amount of feed consumed and excreta voided by chicks. On the other hand, Vohra *et al.* (1966) reported that nonpositive effect from the addition of methyl group donors to diets containing tannic acid was observed. These workers noted that methionine supplementation can overcome the detrimental effect of sorghum tannins on growth rate without correcting poor digestibility, suggesting that the chick can compensate for inferior digestibility by increasing feed consumption.

b. Effects of reconstitution on tannins

Reconstitution is defined as high-moisture storage of grain (Mitaru *et al.*, 1985). During reconstitution tannins polymerize to form larger oligomers which lose their ability to bind proteins and to solubilize in methanol or water (Mitaru and Blair, 1984). Goldstein and Swain (1963) showed that tannin polymers of above 10 flavan monomers are too large to fit the protein orientation for crosslinking. Reichert *et al.* (1980) showed that anaerobic storage of moist grain deactivated tannins and improved the nutritional quality of the high tannin sorghum for rats. Mitaru *et al.* (1985) noted that the greatest reduction of extractable tannin content occurred in the first 10 days of storage and then gradually fell to lower values at 20 days. Reconstitution significantly improved the weight gains of broilers with high tannin sorghum, but not grains with low tannin sorghum. In addition, this method is an effective method to detoxify tannin in the sorghum grain; however, to fully utilize this technique in a commercial setting would likely necessitate feeding higher moisture rations to poultry unless economical methods are available to dry detoxified grains.

c. Mechanical and chemical treatments

Other techniques have been used to deactivate or reduce tannin content such as mechanical abrasion (Chibber, 1978); chemically treating sorghum grains with alkali

(Price *et al.*, 1979); sodium hydroxide (Blessin *et al.*, 1971); or with concentrated ammonia solution (Price and Butler, 1978), adding polyethylene glycol (PEG) (Ford and Hewitt, 1979), adding extra phosphorus (Ibrahim *et al.*, 1988) and plant breeding (Stoskopf, 1985). The techniques to be used should be inexpensive and practical under field conditions.

2. Phytic acid

Phytic acid is an organic compound containing six phosphates. Phytates chelate with various minerals such as copper, manganese, iron, calcium, and magnesium producing phytates which render these minerals unavailable. The incidence of leg abnormalities was high in chicks fed sorghum grain compared to those fed corn (Ibrahim *et al.*, 1988). Locomotor disorders were also virtually, but not completely, eliminated by phosphorus treatment.

Wheat Bran

Wheat bran is composed of pericarp and testa of the wheat grain and also carries the aleurone cell layer that contains nearly 15% of the protein and between 50 and 80% of the minerals in the kernel (O'Dell *et al.*, 1972). However, its cells have such relatively thick cell walls compared to endosperm cells that the question arises as to whether the nutrients in raw whole bran are completely available (Saunders *et al.*, 1968). Wheat bran constitutes approximately 15% of the whole wheat grain (Shetlar *et al.*, 1947). It contains 1240 kcal metabolizable energy per kg, 17% crude protein and 10% crude fiber of which around 80% are cellulose and hemicellulose (Saunders *et al.*, 1972). According to Saunders *et al.* (1969), the aleurone layers constitutes 30-50% of the bran, and an appreciable portion of this is not utilized by chickens. The aleurone layer of hard wheat is more uniform and cleaves more easily than that of soft wheat. Bran may have been broken into smaller pieces, but all tissues except aleurone cells remained intact and appeared to be highly resistant to digestion (Harbers *et al.*, 1980). Most of the bran protein and other nutrients remain trapped in the aleurone cells and are poorly absorbed (Saunders *et al.*, 1972). Wheat bran is relatively low in available energy and high in fiber content (Cave *et al.*, 1965a). Wheat bran is quite palatable and is well known for its ability to prevent constipation in humans because of its swelling and water-holding capacity. Cheeke (1991) reported that bran has a high capacity to absorb water and swell because of its fiber and nonstarch carbohydrates (e.g. glucans) and has a bulk effect in the colon, giving it laxative properties. Bran has an amino acid balance superior to that of whole wheat in addition to being a good source of the water soluble vitamins, except for niacin which is in the unavailable form and phosphorus that exists as phytate (Cheeke, 1991).

Nutritive value of wheat bran

The amino acid pattern of wheat by-products was compared with other plant sources of protein (Barton-Wright and Moran, 1946). High content of lysine, tryptophan and arginine were found in the by-products. The value of a protein source lies not only in its amino acid content and pattern, but also in its potential to complement the amino acid pattern of other proteins in the same rations. Wheat bran has been fed to laying hens and turkeys at levels as high as 30% with no lowering of egg production; however, the body weights of these birds declined throughout the laying period. Slower growth of chicks fed wheat by-products is primarily due to the low energy values associated with these feedstuffs, but this is exacerbated by the relatively low digestibility of the fat. Lairon *et al.* (1985) suggested that wheat bran may exert an inhibitory effect on the activity of pancreatic lipase which leads to increased fecal fat. Cave *et al.* (1965b) reported that the protein content of wheat by-products is relatively high, and the digestibility, the protein efficiency ratio, and the biological value of the protein compared favorably with those of other proteins. Lee *et al.* (1985) reported that body weight gain was gradually decreased as the dietary level of wheat bran increased in broilers at 4 weeks of age. On the other hand, calcium requirements for growing chickens increased as the content of high fiber ingredients such as wheat by-products was increased in the diets. High fiber decreased feed intake with increasing levels of wheat bran.

Deleterious factors in wheat bran

Wheat bran has a laxative action due to a soluble phosphate compound known as phytin, which occurs in considerable amounts (USDA, 1907). In addition, wheat bran binds certain minerals essential for chickens. Among the minerals that are bound by bran (fiber) are calcium, magnesium, zinc and iron. In addition, Lease (1968) noted that fiber sources may contain phytic acid which has been shown to reduce calcium and zinc availability to chicks. Wheat bran also binds to vitamin D (Omaye *et al.*, 1983). Reinhold *et al.* (1981) reported that iron binding by fiber is strongly inhibited by ascorbic acid, phytic acid and EDTA in low concentration.

Processing methods to improve the nutritive value of wheat bran

The aleurone layer of wheat bran is considered to be the source of nutrients that become available only after the rupture of the aleurone cell walls (Harbers *et al.*, 1980). Therefore, some form of processing must be carried out to disrupt the aleurone cell walls in order to maximize the digestibility of bran (Sunders and Jensen, 1987).

1. Pelleting

Allred *et al.* (1957) reported that pelleting of wheat bran at high temperature and pressure improves the availability of some of the nutrients or destroys a toxic factor present on the feed. By steam pelleting, Cave *et al.* (1965a,b) obtained an increase of 30% in metabolizable energy. Steam pelleting and regrinding also significantly improved the protein digestibility of bran (Olsen and Slinger, 1968).

2. Enzyme treatment

Other processing methods to improve the nutritive value of wheat bran include enzyme treatment. Nahm and Carlson (1985) reported that cellulase supplementation improved the digestibility of cell wall components and the solubility of minerals (calcium, phosphorus, iron, zinc and copper) of wheat bran in broilers.

Faba Beans

The high costs of vegetable and animal protein sources make it beneficial to look at alternate sources of protein for poultry feed (Kadirvel and Clandinin, 1974). One such alternative protein source is faba beans (*Vicia faba L.*). Compared to other vegetable protein sources, faba beans have about 2370 kcal metabolizable energy, 26% crude protein and 8% crude fiber (Allen, 1990).

Nutritive values of faba beans

Faba beans have a high content of nonprotein nitrogen (NPN) amounting to approximately 34% of the crude protein while soybean meal contain only about 8% of crude protein as NPN (Ilian *et al.*, 1985). The chemical value of NPN in faba beans has not been investigated, but the majority is believed to be nucleosidic in nature (i.e., vicine, aglycones, divicine and isouramil). The amino acid composition of protein from faba beans was found to be comparable to protein in soybeans on the basis of true protein content, except for sulfur amino acids (cystine and methionine) which were found to be lower (Hodgson *et al.*, 1975). Ilian *et al.* (1985) reported that the energy level in faba beans is comparable to that of soybean, but the mineral content of faba beans is less than that of soybean except for iron. As far as growth is concerned, Blair and Bolton (1968) noted that no adverse effects on body weight gain or feed conversion were observed when broiler-type chicks were fed rations containing up to 30% faba beans from 4 to 9 weeks of age. However, other researchers found a significant decrease in body weight gain and feed efficiency of chicks as the proportion of faba beans in the diet was increased (Blair *et al.*, 1970; Wilson and McNab, 1972). A number of researchers have shown that faba beans when supplemented with methionine are a suitable protein supplement for growing chickens and turkeys (Blair and

Bolton, 1968; Blair *et al.*, 1970; Wilson and McNab, 1972; Marquardt and Campbell, 1973; Kadirvel and Clandinin, 1974; Marquardt *et al.*, 1974; Savage *et al.*, 1986).

Brisson *et al.* (1950) reported better feathering and slightly better growth when choline was also added. Blair and Bolton (1968) observed that no adverse effects on feather growth were detected when the diet contained 30% faba beans, suggesting that choline was not limiting. Blair *et al.* (1970) reported that feed consumption or mortality were not affected as the proportion of faba beans increased in the diet.

Antinutritional factors

Faba beans contain antinutritional factors such as trypsin inhibitors, tannins, haemaglutinins and nucleosides (divicine and isouramil).

Blair *et al.* (1970) mentioned that a trypsin inhibitor in raw faba beans reduces digestibility of protein. However, Kadirvel and Clandidin (1974) observed that raw faba beans contain only about 4% of the trypsin inhibitor activity of raw soybeans. Thus, they believed the presence of trypsin inhibitor in the faba beans is likely only to affect the nutritional value of the diet when the beans are included at very high levels.

Faba beans contain a very low level of tannin. Kadirvel and Clandinin (1974) reported that a diet containing 35% faba beans will have .14% tannin which is not detrimental to the growth of chicks and turkey poults. Wilson and McNab (1972) found no improvement in the growth in chicks fed tannin-free diets.

Faba beans contain both thermolabile (Marquardt and Ward, 1979) and thermostable antinutritional compounds (Olaboro *et al.*, 1981a,b). Muduuli *et al.* (1981, 1982) have demonstrated that the thermostable depressing factors in faba beans were vicine and covacine. These compounds when fed to laying hens reduced egg size, egg production, yolk size, and the fertility and hatchability of eggs, increased yolk fragility, incidence of yolk blood spots, elevated the levels of plasma lipid and lipid peroxides, glutathione and erythrocyte hemolysis *in vitro* and depressed plasma vitamin E levels.

Methods to improve nutritive values of faba beans

Ward *et al.* (1977) demonstrated that autoclaving improved the nutritional quality of faba beans which contained a high proportion of hulls. Based on this finding, the major antinutritional factor (heat-labile) is associated with the hulls. Marquardt *et al.* (1975) confirmed that all the hemagglutinin activity of the beans was associated with the cotyledon, and 60% of the trypsin inhibitor activity was associated with the hulls.

Pelleting is another method of improving the nutritive value of faba beans. Blair and Bolton (1968) reported that broilers fed pelleted diets containing up to 30% faba beans from 4 to 9 weeks of age grew satisfactorily.

Extrusion through the dies in a pelleting machine was sufficient to inactivate some of the antinutritional factor(s). Blair *et al.* (1970) reported that field beans (faba beans) can be included in pelleted compounded diets at concentrations of up to about 25 percent, provided the diet has been formulated to ensure that no essential nutrients, such as methionine and choline, are deficient. Finally, the decision whether to use faba beans in a mixed feed is largely dictated by the nutrient content, physical quality and the price structure (Hebblethwaite, 1983).

The nutrient contents of barley grain, Pacific coast barley, sorghum grain, wheat bran and faba beans are presented on Table II.1.

Table II.1. Composition of barley grain (BG), Pacific coast barley (PCB), sorghum grain (SG), wheat bran (WB) and faba beans (FB)

	BG	PCB	SG	WB	FB
Dry matter, %	89	88	88	88	89
Crude protein, %	11.5	10	11	14.8	25.7
Crude fat, %	1.9	2.2	2.8	4	1.4
Crude fiber, %	5	6	2	10	8.2
Calcium, %	.08	.06	.04	.14	.14
Total phos., %	.42	.4	.29	1.17	.54
ME, kcal/kg	2620	2332	3256	1256	2370
True ME, kcal/kg	3025	2805		1705	
Methionine, %	.18	.18	.1	.2	.25
Cystine, %	.25	.22	.2	.3	.14
Lysine, %	.53	.39	.27	.6	1.52
Tryptophan, %	.17	.15	.09	.3	.24
Threonine, %	.36	.29	.27	.48	.98
Isoleucine, %	.42	.4	.6	.6	1
Histidine, %	.23	.2	.27	.3	.6
Valine, %	.62	.46	.53	.7	1.22
Leucine, %	.8	.6	1.4	.9	1.6
Arginine, %	.5	.45	.4	1.07	2.2
Phenylalanine, %	.62	.47	.45	.57	.98
Glycine, %	.36	.3	.3	.9	1
Vitamins:					
E, IU	36	36	12.2	10.8	1
Thiamine, mg/kg	5	4	3.9	6	5.5
Riboflavin, mg/kg	2	1.3	1.2	3.1	1.6
Pant. acid, mg/kg	6.4	7.3	11	29	2.7
Biotin, mg/kg	.2	.15	.18	.11	.1
Folic acid, g/kg	.4	.3	.200	1.8	-
Choline, mg/kg	1.03	.93	.68	.98	1.67
Niacin, mg/kg	57	44	43	321	22
Minerals					
Na, %		.03	.02	.03	.06
.08					
K, %	.56	.56	.34	1.2	1.2
Mg, %	.12	.12	.2	.55	.13
S, %	.15	.15	.09	.22	-
Mn, ppm	16.3	16.3	12.9	100	8.4
Fe, ppm	50	50	52	170	65
Cu, ppm	7.6	7.6	14.1	10.3	4.1
Zn, ppm	15.3	15.3	13.7	95	42
Se, ppm	.35	.1	-	.75	-

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CHAPTER III

EFFECT OF FEEDING SINGLE FEED INGREDIENT FORTIFIED WITH VITAMINS AND MINERALS ON BROILER PERFORMANCE[1]

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Abstract

An experiment was conducted to simulate feed shortages and to determine the effect on broiler performance and compensatory growth of feeding single feed grains (barley, sorghum grains and wheat bran). All broilers were fed a corn-soy 23% crude protein starter diet for the first 28 days. From 29 to 42 or 49 days, they were fed either barley, sorghum or wheat bran diets supplemented with vitamins and minerals.

Feeding a single ingredient resulted in significantly (P <.05) reduced body weight gain. Broilers fed sorghum either for 14 (29 to 42 days of age) or 21 days (29 to or 49 days of age) significantly consumed less feed and had inferior feed conversion, lowered apparent protein efficiency ratio and total plasma protein compared to the corn-soy fed broilers. Broilers fed barley for 21 days had significantly poorer feed conversion and lower total plasma protein compared to the broilers fed the corn-soy diet. When wheat bran was fed to broilers for 14 days (29 to 42 days of age), significant reductions in feed conversion and lowered apparent protein efficiency ratio were observed compared to the broilers fed corn-soy diets.

Feeding a corn-soy diet after a single ingredient diet resulted in compensatory growth which was correlated with

the severity of growth reduction during the single ingredient feeding.

In case of feed shortages, barley is the single grain of choice while wheat bran can be used for maintenance purposes only.

Introduction

Corn and soybean meal are the most common feed ingredients that are used to manufacture feed for the poultry industry in the Republic of Yemen. These ingredients are imported from Europe since soybean are not grown in Yemen and corn is very expensive. Delays in the shipments of poultry feeds cause the Yemeni poultry farmers to look for substitutes to feed their poultry during feed shortages. The potential ingredients that are available in appreciable quantities are barley, sorghum and wheat bran. Some poultry farmers in such a crisis feed a single ingredient or a combination of two or more ingredients.

Literature on feeding single ingredients is almost totally lacking except for one study by Cook and Sunde (1984). This study demonstrated the effects of feeding single ingredients or a combination of ingredients on Single Comb White Leghorn and broiler chicks for the first 3 to 4 weeks. Feeding a single ingredient (corn) or combination of ingredients (corn and soybean) without mineral supplementation resulted in little or no growth during the study, but a combination of corn and soybean as sources of energy and protein, respectively, with mineral supplementation enhanced rate of growth. Cook and Sunde (1984) did not investigate the effect of feeding either barley, sorghum or wheat bran alone. In their studies, they only assessed the effect of feeding single ingredients (corn or soybean) or combination of ingredients (corn and soybean) on the starter period and did not evaluate compensatory growth when birds switch back to complete diets.

Therefore, the objectives of this study were to simulate feed shortage and to determine the effect on broiler performance and compensatory growth of feeding single feed grains (barley or sorghum) or milling by-product (wheat bran).

Materials and Methods

Six hundred day-old straight run commercial broiler strain cross chicks were divided into six treatments. Each treatment consisted of four replicates of 25 chicks each. They were placed in floor pens (1.2 m X 3 m/pen) which were covered with 5 cm deep wood shavings litter. Artificial light (12.56 lux) was provided from day-old to 49 days of age. Feed was provided *ad libitum* in a hanging tube feeder (45.7 cm diameter), and water was provided in a Plasson hanging waterer in each pen. All chicks were fed corn-soy starter diets (Table III.1) from 1 to 28 days of age. At 29 days of age, the chicks received the following treatments: 1) Corn-soy broiler finisher diet (Table III.1) from 29 to 49 days of age; treatments 2 and 3) barley or sorghum diets fortified with vitamins and minerals, respectively, from 29 to 49 days of age;

treatments 4, 5, and 6) barley, sorghum or wheat bran diets supplemented with vitamins and minerals from 29 to 42 days followed by the corn-soy finisher diet from 43 to 49 days of age (Tables III.1 and III.2). Body weight gains, total feed consumption, feed conversion, apparent protein efficiency ratios, total plasm protein and hematocrit were determined at 28 and 49 days of age for Treatments 1, 2 and 3 and at 28, 42 and 49 days of age for Treatments 1, 4, 5 and 6. Mortality was recorded daily.

At 4 weeks of age, 2 males and 2 females from each replicate of each treatment were randomly selected to be blood donors. Blood samples were collected at the beginning and end of feeding a single ingredient and at the end of the experiment. Venipuncture from the branchial vein was used to collect blood into two heparinized capillary tubes from each chick. The marked end of each capillary tube was dipped into a clay tray to seal the marked end. The tubes were centrifuged for 5 min in International Micro-Capillary Centrifuge, Model MB[3] and hematocrit was determined by using the Micro Hematocrit Reader[4]. Total plasma protein was determined by using the 10400 A TS meter (refractometer)[5]. The instrument was held in a horizontal position and the plasma sample was

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[3] International and Equipment Company, Needham HTS, MA.
[4] Phillips-Drucker, Astoria, Oregon, USA.
[5] AO American Optical, Scientific Instrument Division, Box 123, Buffalo, NY 14240.

placed on the exposed portion which is at the bottom of the measuring prism. The plasma was drawn into the space between the prisms by capillary action. The refractometer was aimed at a bright light and total plasma protein was directly read.

Percentage data were converted to arcsine prior to analysis in order to stabilize the variance. The data were analyzed using one way analysis of variance for a completely randomized design as outlined by Snedecor and Cochran (1980). Fisher Protected Least Significant Differences were used to separate significant differences in treatment means as outlined by Petersen (1985). All statements of significance are based on the probability level of .05.

Results and Discussion

Mean body weight gain, total feed consumption (g/bird), feed conversion, apparent protein efficiency ratios, total plasma protein and percent hematocrit of broilers fed diets containing solely either barley, sorghum or wheat bran either from 29 to 42 or 29 to 49 days of age are presented in Tables III.3 and III.4. Mean body weight gain, feed consumption, feed conversion, and apparent protein efficiency ratios of broilers fed corn-soy finisher diets for 7 days following feeding a single ingredient (barley, sorghum or wheat bran) for 14 days are presented in Table III.5.

When a single ingredient, fortified with vitamin and mineral premixes without adjusting for energy or protein, was fed from 29 to 42 or 29 to 49 days of age, mean body weight gains of males, females or mixed sex broilers were significantly reduced (Tables III.3 and III.4). Feed consumption was significantly reduced when broilers were fed either sorghum or wheat bran compared to a corn-soy diet. These differences may be attributed to the low caloric density of wheat bran and the higher energy level of sorghum. The chicken is able to increase its intake of nutrients to compensate for low energy (Hill and Dansky, 1954), but its ability to increase the amount of bulk is limited physically (Cave *et al*, 1965). Sorghum has higher metabolizable energy (3256 kcal/kg) than either barley (2332 kcal/kg) or wheat bran (1256 kcal/kg). It is well established that if all nutrients are available, birds will eat to satisfy their energy requirements; thus birds on sorghum ate less feed than those on barley or wheat bran.

Significant differences were found between barley, sorghum and wheat bran diets compared to corn-soy in feed conversion (Tables III.3 and III.4). This is attributed to imbalances of amino acids in single ingredients (barley, sorghum and wheat bran) and low energy (barley and wheat bran). For maximum growth and optimal feed efficiency all nutrients required by the birds should be available in the proper amount and all at once.

No significant differences in apparent protein efficiency ratios were found between corn-soy and barley diets, but significantly lowered ratios were found when broilers were fed sorghum or wheat bran from 29 to 42 days of age (Table III.3). This difference could be ascribed partially to the indigestibility of sorghum protein which is reduced by tannins which bind protein and form insoluble protein (Cheeke, 1991). Wheat bran contains approximately 17% protein (on moisture-free basis) of which slightly more than half is available to monogastric animals (Neudoerffer and Smith, 1969), because the protein of wheat bran is encapsulated by cell walls (aleurone layers) which render wheat bran protein unavailable to be digested (Harbers *et al.*, 1980).

No significant differences were found among treatments in apparent protein efficiency ratio when either barley or sorghum were fed to broilers from 29 to 49 days of age. This may be due to the physiological ability of broilers to tolerate the adverse effect of sorghum as they became older.

Feeding sorghum to broiler chickens either for 14 or 21 days resulted in significant reduction in total plasma protein compared to broilers fed the corn-soy diet (Tables III.3 and III.4). This could be due to binding of tannins to amino acids, and therefore, reduce protein and amino acid availability. However, no significant differences between corn-soy, barley or wheat bran diets in total plasma protein were observed when single ingredients were fed from 29 to 42 days of age (Table III.3). This observation can not be ascertained. Total plasma protein increases with the increasing protein content of a given single ingredient. In the case of the corn-soy diet which is well designed with well- balanced amino acids and optimal energy, protein is utilized in muscle synthesis instead of circulating in the blood, but wheat bran showed the highest level of total plasma protein with the poorest body weight gain (Table III.3).

A significantly higher level of hematocrit of female broilers fed barley diet was found compared to female broilers fed corn-soy or sorghum diets from 28 to 49 days of age (Table III.4). These differences can not be explained.

Broilers fed corn-soy finisher diet for 7 days (42 to 49 days of age) following feeding a single ingredient (barley, sorghum or wheat bran) for 14 days resulted in significantly better mean body weight gain compared to the broilers fed the corn-soy diet for the whole growing period (Tables III.5). These differences may be attributed to compensatory growth which has been reported by Wilson and Osbourn (1960) and may be affected by the nature of the restricted diet, the severity of undernutrition, the duration of undernutrition, the stage of body development at the commencement of undernutrition, the relative rate of maturity of the species and the pattern of re-alimentation.

The ratios of gain (compensatory growth) from 42 to 49 days of age to total body weights at 42 days of age of male and female broilers fed corn-soy diets for the whole growing period or after single ingredients (barley, sorghum or wheat bran) were 28% and 27%, 42% and 37%, 54 and 52%, 60% and 55%, respectively (Figure III.1). The severity of growth depression plays a major role in compensatory growth which is in agreement with Reid and White (1977) who reported that physiological aging is retarded and prolonged by undernutrition, but it is accelerated by overnutrition.

There were significant decrease in feed consumption between broilers fed a corn-soy diet after feeding barley or sorghum compared to a corn-soy diet fed the entire growing period (Table III.5). These differences could be attributed to differences in body weight, appetite, and health of the broilers. No significant differences in feed consumption were shown between broilers fed corn-soy diet for the entire growing period compared to broilers fed corn-soy finisher diets after wheat bran. This could be accredited to the fact that subnutritional requirements enhanced appetite. Thus birds on corn-soy after wheat bran diets consumed more feed (Wilson and Osbourn, 1960).

For the 42 to 49 day period, significantly better feed conversion and apparent protein efficiency ratios were obtained when a corn-soy diet was fed after feeding a single ingredient. Feed depression or suboptimal nutrition improves the utilization of feed (Wilson and Osbourn, 1960).

Broilers fed a corn-soy diet after feeding sorghum from 29 to 42 days had significantly lowered total plasma protein compared to broilers fed a corn-soy diet throughout the experiment. This may be due to the long lasting effect of tannins.

Hematocrit of broilers fed single ingredients for 14 days followed by a corn-soy diet or single ingredient for 21 days did not show consistent results in males and females at 49 days of age. This discrepancy could not be explained.

Litter condition appeared very wet whenever wheat bran constituted the entire broiler diets. Wheat bran has the capacity to absorb water and swell due to its fiber content and beta-glucans (Cheeke, 1991). Feeding barley for 14 or 21 days also caused wet and sticky droppings which is in agreement with Arscott and Rose (1960) and Hesselman and Åman (1986).

Table III.6 shows the overall mean body weight and total mortality of broilers fed a corn-soy diet for 28 days, then fed single ingredients for either 14 or 21 days. Mean body weights of broilers are negatively correlated with the duration and type of the single ingredient fed. Broilers fed either barley or sorghum for 21 days had reduced mean body weights compared with feeding these ingredients for 14 days (Table III.6). No significant differences were found among treatments in mortality.

Feeding a single ingredient (barley, sorghum or wheat bran) without adjusting for energy and protein caused dramatic effects on broiler performance. During feed shortage, either barley or sorghum diets can be fed for short periods (1 to 14 days); however, there will be growth reduction. Compensatory growth can be realized if the duration of feeding single ingredient diets is for a short period (14 days).

Table III.1. Composition of the single ingredient diets

	Corn soy		Single ingredient diets		
Ingredient	Starter	Finisher	Sorghum	Barley	Wheat bran
	-	-	-	-	97.33
Barley	-	-	-	96.91	-
Sorghum (milo)	-	-	96.87	-	-
Corn, yellow	60.35	65.52	-	-	-
Soybean meal (47.5%)	32.25	27.50	-	-	-
Meat meal w/bone	5.00	5.00	-	-	-
Alfalfa meal dehy. (17%)	1.00	1.00	-	-	-
Def. Phos. (32% Ca, 18% P)	.42	.25	2.00	1.95	.67
Ground limestone	.35	.13	.58	.59	1.45
Salt (iodized)	.25	.25	.25	.25	.25
Vitamin premix[1]	.20	.20	.20	.20	.20
d,l methionine (98%)	.13	.13	-	-	-
Trace mineral premix[2]	.05	.05	.05	.05	.05
Amprolium premix[3] (25%)	.05	.05	.05	.05	.05
Calculated analyses:					
Crude protein, %	23.34	21.5	8.8	8.4	15.3
Metab. eng., kcal/kg	2952	3016	3268	2538	1267
Lysine, %	1.27	1.14	.28	.57	.57
Calcium, %	.97	.82	.91	.91	.91
Avail. Phos., %	.48	.45	.45	.45	.45
Methionine, %	.50	.44	.50	.50	.50
Meth + cyst., %	.89	.80	.64	.74	.74
Crude protein, % (analyzed)[4]	23.34	21.54	9.08	9.90	15.76

[1] Supplies per kilogram of feed: Vitamin A, 3300 IU; vitamin D_3, 1100 ICU; riboflavin, 3.3 mg; d-pantothenic acid, 5.5 mg; niacin, 22 mg; choline, 191 mg; vitamin B_{12}, 5.5 ug; vitamin E, 1.1 IU; vitamin K, .55 mg; folacin, .22 mg.

[2] Supplies per kilogram of feed: calcium 97.3 mg; manganese, 60 mg; iron, 20 mg; iodine, 1.2 mg; zinc, 27.5; cobalt, .2 mg; copper, 2 mg.

[3] Gratuitously provided by Merck and Co., Inc., Rahway, NJ.

[4] Determined by Kjeldahl method.

Table III.2. Experimental design

Dietary treatments and periods fed					
Starter	Age (days)	Diet	Age (days)	Diet	Age (days)
Corn-soy	1-28	Corn-soy	29-49	-	-
Corn-soy	1-28	Barley	29-49	-	-
Corn-soy	1-28	Sorghum	29-49	-	-
Corn-soy	1-28	Barley	29-42	Corn-soy	43-49
Corn-soy	1-28	Sorghum	29-42	Corn-soy	43-49
Corn-soy	1-28	Wheat bran	29-42	Corn-soy	43-49

Table III.3. Mean body weight (wt.) gain, total feed consumed (F cons), feed conversion (F conv), apparent protein efficiency ratio (APER), total plasma protein (TPP), and hematocrit of broilers fed a single ingredient fortified with vitamins and trace mineral supplementation from 29 to 42 days of age

Dietary treatment		Mean body wt. gain[1]						TPP[1]		Hematocrit	
Age	(days)	Male	Female	M+F	F cons[1]	F conv[1,2]	APER[1],[3]	Male	Female	Male	Female
		-	g	-	g/bird			g/100 ml		-%-	
Corn-soy	29-42	942^{a}	793^{a}	868^{a}	2192^{a}	2.52^{b}	1.89^{a}	4.23^{a}	4.0^{a}	35^{a}	32^{a}
Barley	29-42	420^{b}	421^{b}	421^{b}	2299^{a}	5.52^{b}	1.85^{a}	3.98^{ab}	3.9^{ab}	35^{a}	35^{a}
Sorghum	29-42	276^{c}	193^{c}	234^{c}	1817^{c}	6.89^{b}	1.42^{b}	3.58^{b}	3.4^{b}	38^{a}	34^{a}
Wheat bran	29-42	57^{d}	47^{d}	52^{d}	1992^{b}	61^{a}	$.17^{c}$	4.25^{a}	4.35^{a}	39^{a}	37^{a}
SEM[4]		25	22	16	51	15	.08	.13	.17	7	2

[1] Mean values in each column with different superscripts are significantly different ($P < .05$).
[2] Feed conversion is grams of feed consumed per gram of body weight gain
[3] APER is grams in body weight gain per gram of protein consumed.
[4] SEM is the standard error of the mean.

Table III.4. Mean body weight gain, total feed consumed (F cons), feed conversion (F conv), apparent apparent protein efficiency ration (APER), total plasma protein (TPP), and hematocrit of broilers fed a single ingredient from 28 to 49 days of age

Dietary treatment											
Age	(days)	Mean body wt. gain[1]						TPP[1]		Hematocrit[1]	
1-28	29-49	Male	Female	M+F	F cons[1]	F conv[1,2]	APER[1],[3]	Male	Female	Male	Female
	-	g	-	-	g/bird			g/100 ml		- % -	
C-S[5]	C-S	1493[a]	1245[a]	1369[a]	3499[a]	2.55[b]	1.71[a]	4.2[a]	4.1[a]	33[a]	33[b]
C-S	Barley	705[b]	630[b]	667[b]	3446[a]	5.16[a]	1.96[a]	3.6[b]	3.5[b]	33[a]	36[a]
C-S	Sorghum	454[c]	412[c]	433[c]	2550[b]	5.80[a]	1.86[a]	3.6[b]	3.3[b]	34[a]	30[b]
SEM[4]		25	24	22	69	.25	.09	.15	.13	2	1

[1] Mean values in each column with different superscripts are significantly different ($P < .05$).
[2] Feed conversion is grams of feed consumed per gram of body weight gain.
[3] APER is grams in body weight gain per gram of protein consumed.
[4] SEM is the standard error of the mean.
[5] C-S is corn-soy diet.

Table III.5. Mean body weight gain, feed consumed (F cons), feed conversion (F conv), apparent protein efficiency ratio (APER), total plasma protein (TPP), and hematocrit of broilers fed a corn-soy diet from 43 to 49 days after feeding a single ingredient from 29 to 42 days of age

Dietary treatment		Mean body wt. gain[1]						TPP[1]		Hematocrit	
Age	(days)										
29-42	43-49	Male	Female	M+F	F cons[1]	F conv[1,2]	APER[1,3]	Male	Female	Male	Female
		-	g	-	g/bird			g/100 ml		- % -	
C-S[5]	C-S	550[c]	453[c]	502[c]	1303[a]	2.61[a]	1.84[c]	4.18[ab]	4.08[b]	33[a]	33[a]
Barley	C-S	603[bc]	485[bc]	544[ab]	1199[b]	2.14[b]	2.23[b]	4.1[ab]	4.3[ab]	35[a]	32[a]
Sorghum	C-S	716[a]	570[a]	643[a]	1107[c]	1.72[c]	2.76[a]	3.7[b]	4.2[b]	27[a]	32[a]
Wheat bran	C-S	654[ab]	529[ab]	591[ab]	1304[a]	2.22[b]	2.15[b]	4.7[a]	4.6[a]	37[a]	31[a]
SEM		30	22	19	27	.07	.07	.19	.13	2	3

[1] Mean values in each column with different superscripts are significantly different (P < .05).
[2] Feed conversion is grams of feed consumed per gram of body weight.
[3] APER is grams in body weight gain per gram of protein consumed.
[4] SEM is the standard error of the mean.
[5] C-S is corn-soy diet

Table III.6. Mean body weight and total mortality of broilers fed a corn-soy diet from 1 to 28 days followed by feeding a single ingredients from 29 to 42 or 49 days of age

Dietary treatment						
Age		(days)	Mean body weight[1]			Total mortality
1-28	29-42	43-49	Male	Female	M+F	
			-	g	-	%
C-S[3]	C-S	C-S	2506[a]	2152[a]	2329[a]	4
C-S	Barley	Barley	1739[c]	1539[c]	1639[c]	4
C-S	Sorghum	Sorghum	1503[d]	1300[d]	1401[d]	4
C-S	Barley	C-S	2029[b]	1783[b]	1906[b]	0
C-S	Sorghum	C-S	2038[b]	1729[b]	1884[b]	5
C-S	Wheat bran	C-S	1749[c]	1497[c]	1623[c]	3
SEM[2]			28	29	21	2

[1] Mean values in each column with different superscripts are significantly different ($P<.05$)

[2] SEM is the standard error of the mean.

[3] C-S is corn-soy diet.

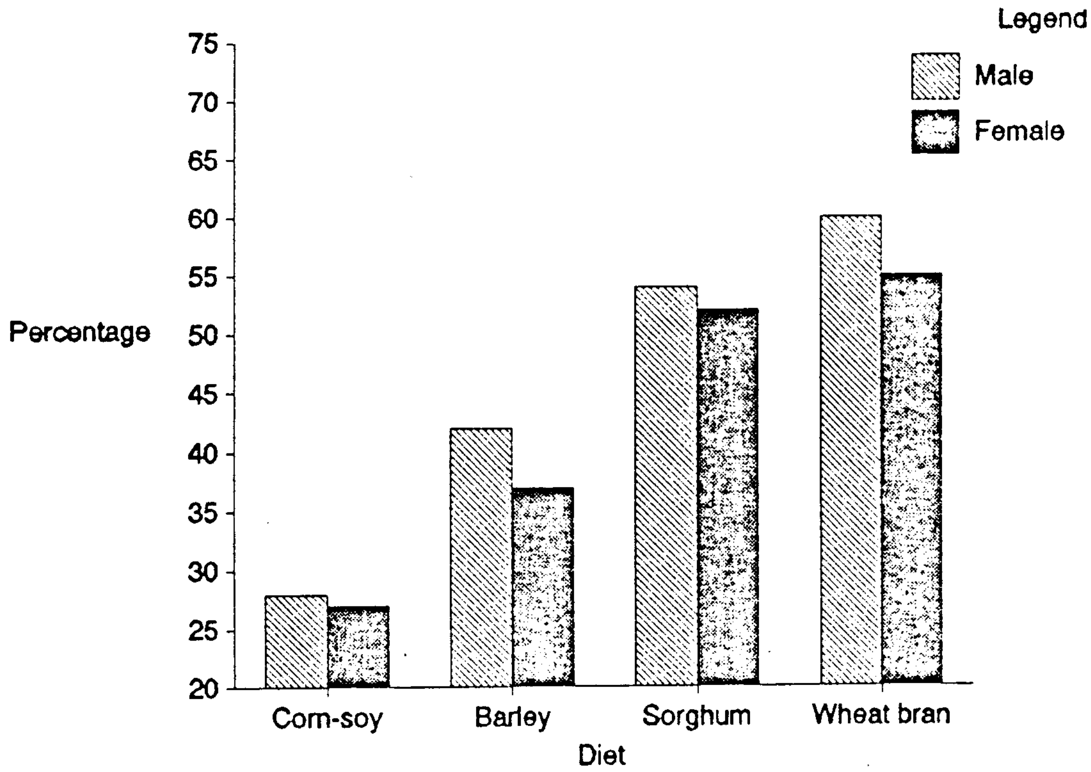

Figure III.1. Compensatory growth of broilers fed corn-soy diets from 43 to 49 days of age after single ingredients (barley, sorghum and wheat bran) from 29 to 42 days of age

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CHAPTER IV

EFFECT OF FEEDING MIXED FABA BEANS AND SORGHUM WITH OR WITHOUT HERRING MEAL ON BROILER PERFORMANCE[1]

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Abstract

An experiment was conducted to simulate feed shortage and to determine the effect on broiler performance and compensatory growth by mixing faba beans (FB) and sorghum (S) with and without 7% herring meal (HM). One group of broilers was fed FB+S+HM from 1 to 49 days of age, while the other group was fed FB+S from 1 to 21 days of age followed by corn-soy diets from 22 to 49 days of age.

Feeding either FB+S+HM or FB+S for the first 21 days significantly ($P<.05$) reduced mean body weight gains and total feed consumed and had less efficient feed conversion, and apparent protein efficiency ratios.

Switching broilers that were fed FB+S diet at 22 days of age to a corn-soy diet resulted in improved body weight gains, feed conversion and better feed conversion. However, these parameter improvements eventually decreased with time.

On the average, abdominal fat of broilers fed FB+S+HM tended to be higher than that of the broilers fed FB+S diet at 49 days of age.

In case of feed shortage FB+S+HM can be fed for the entire growing period with some depression in broiler performance and increased incidence of leg abnormalities.

Introduction

Avoiding feed shortages and reducing the feed costs in poultry production in the Republic of Yemen have always been of major concern. These reasons prompted us to look at alternate feedstuffs for sources of protein and energy for poultry feed. The potential feedstuffs as sources of protein and energy for poultry feeds are faba beans and sorghum, respectively, which are grown in the Republic of Yemen.

Faba beans have about 27% crude protein (Allen, 1990) and is higher in lysine than cereal proteins (Clarke, 1970). Blair *et al.* (1970) reported that inclusion of faba beans in the diet of broilers resulted in significantly less efficient feed conversion and body weight gain to 4 and 8 weeks of age. Several hypotheses have been mentioned for the poor growth of broilers fed diets containing high levels (30 or 45%) of faba beans. The presence of trypsin inhibitor, unutilized protein, or deficiencies in choline and/or sulfur containing amino acids were hypothesized. Savage *et al.* (1986) stated that feeding high levels of faba beans (60%) to turkey poults from day-old to 21 days of age resulted in significantly reduced growth and increased incidence of perosis.

However, Blair *et al.* (1970) stated that broilers fed faba beans up to 30% consumed significantly more feed, had better feed conversion, and weighed more than the broilers fed the control diet. But when the faba bean level increased to 45% in the diet, feed conversion was significantly inferior compared to the control.

Sorghum grain contains about 3310 kcal metabolizable energy per kilogram. Sorghum grain with low tannins have been mixed in practical poultry diets to replace corn. A slight negative effect on chick growth was observed (Armstrong *et al.*, 1973). However, high tannin sorghum grain depressed growth when compared to broilers fed either corn or low tannin sorghum. High tannin sorghum reduced feed intake (Rostagno *et al.*, 1973), nutrient digestibility and nitrogen retention (Nelson *et al.*, 1975).

No other studies have used broiler diets consisting of faba beans and sorghum as major protein and energy sources, respectively, with or without herring meal from 1 to 21 days or 49 days of age.

The objective of this study was to simulate a feed shortage and to determine the effect on performance and compensatory growth of mixing faba beans and sorghum supplemented with or without herring meal.

Materials and Methods

Three hundred one-day old mixed sex commercial broiler strain cross chicks were equally allocated randomly into three dietary treatments. Each treatment consisted of four replicates of 25 chicks each. The chicks were placed in floor pens (1.2 m X 3 m/pen) which were covered with 5 cm deep wood shavings litter. Artificial light (12.56 lux) was provided from day-old to 49 days of age. Feed was provided *ad libitum* in a hanging tube feeder (45.7 cm diameter), and water was provided in Plasson hanging waterers in each pen. The first group of broilers was fed a corn-soy starter diet (Table IV.1) from 1 day to 49 days of age. Broilers in the second group were fed 30% faba beans (FB) and 60% sorghum (S) supplemented with 7% herring meal (HM) and vitamin and mineral premixes from 1 day old to 49 days of age (Table IV.1). Broilers in the third group were fed 30% faba beans (FB)and 66.5% sorghum (S) supplemented with vitamin and mineral premixes from day-old to 21 days of age and then followed by a corn-soy diet from 22 to 49 days of age. Essential amino acid ratios based on protein content of each ration were corrected by adding synthetic amino acids to those with a lower ratio in order to avoid imbalance of amino acid content.

The parameters measured were mean body weight gain, feed consumed with adjustment made for mortality, feed conversion, apparent protein efficiency ratios, total plasma protein, hematocrit and abdominal fat. Body weight gains, feed consumed, feed conversion and apparent protein efficiency ratio were calculated weekly starting from 21 days of age. Total plasma protein and hematocrit were measured by the same procedures outlined earlier (Chapter

III). Two males and two females from each pen were selected randomly at the end of the experiment to determine the level of abdominal fat. Fat surrounding the proventriculus and gizzard and the fat pad was removed and weighed. Mortality was determined daily. Leg abnormalities were observed visually.

Data were analyzed as mentioned earlier (Chapter III).

Results and Discussion

Feeding faba beans and sorghum with 7% herring meal (FB+S+HM) from 1 to 49 days of age or faba beans and sorghum (FB+S) from 1 to 21 days followed by corn-soy diets from 22 to 49 days to broilers resulted in significantly reduced body weight gain (Tables IV.2 and IV.7) when compared to broilers fed the corn-soy diets. Depressed growth could be related to low protein levels in FB+S+HM and FB+S (Table IV.1). It has been documented that low protein causes growth retardation (Fancher and Jensen, 1989). In addition to lower protein levels, sorghum is low in lysine and arginine (Vavich *et al.*, 1959) which can limit growth in chicks fed on sorghum grains. Moreover, sorghum grains contain high tannin content which reacts with digestive enzymes and dietary protein resulting in reduced nutrient digestibility and forming an undegradable complex, respectively (Cheeke, 1991). On the other hand, faba beans, the major protein source in the FB+S+HM or FB+S diets, contain antinutritional factors such as tannin, protease inhibitors and lectins which bind to specific receptor sites on the surface of the intestinal cells (Nakata and Kimura, 1985; Rouanet *et al.*, 1985; and Aletor, 1987) and disturb the enzymic function of the brush border membrane. The disruption of intestinal microvilli is likely to interfere with the normal secretory and absorptive function in the gut and results in growth depression. This reduction was more pronounced during 1 to 35 days of age (Tables IV.2, IV.3 and IV.4). From 35 to 49 days of age no significant differences were found in body weight gain (Table IV.5, IV.6 and IV.7). This could be due to protein requirements which decrease with age in addition to more tolerance to antinutritional factors found in sorghum and faba beans. The body weight of broilers fed FB+S for the first 21 days then switched to a corn-soy diet did not completely compensate for growth depression by 49 days of age (Figure IV.1).

Broilers fed the corn-soy diet consumed significantly more feed than those fed either FB+S+HM or FB+S followed by the corn-soy diet (Tables IV.2 and IV.7). These differences could be ascribed to the differences in body size. Broilers fed the corn-soy diets were larger than the FB+S+HM or FB+S fed broilers.

Feed conversion was significantly inferior in FB+S compared to the corn-soy diet at 21 days of age (Table IV.2). When broilers on FB+S were switched to the corn-soy diet, feed conversion was superior to broilers fed either corn-soy or FB+S+HM. This improvement in feed conversion was more pronounced directly after switching from FB+S to corn-soy diet, but decreased as time went by (Tables IV.3, IV.4, IV.5 and IV.6). This finding is in agreement with Brody *et al.* (1980) who reported that undernourished animals lower their metabolic rate which will continue for a short while into the re-alimentation period, but if re-alimentation is prolonged, the rate will eventually increase and the efficiency of feed conversion will steadily decrease as the re-alimentation period progresses.

Broilers fed the corn-soy diet had a significantly better apparent protein efficiency ratio at 21 days of age than the broilers fed FB+S+HM or FB+S diets (Table IV. 2). When undernourished broilers were switched to the corn-soy diet, apparent protein efficiency ratio significantly surpassed the apparent protein efficiency ratio of broilers fed the corn-soy or FB+S+HM, especially immediately after the initiation of re-alimentation; however, this improvement in apparent protein efficiency ratio gradually decreased as the re-alimentation period progressed (Tables IV.3, IV.4, IV.5 and IV.6).

No significant differences were observed among the dietary treatments in total plasma protein or hematocrit at 49 days of age. In contrast, significant differences were noted among females fed either FB+S+HM or corn-soy after

FB+S in total plasma protein at 28 days (Table IV.3). Females are more sensitive to protein levels in the diet than males, especially at early stages. This is in agreement with Leeson *et al.* (1988) who indicated that female birds responded more to higher protein than males.

Abdominal fat at 49 days of age was affected by energy and protein sources and sex and body weight of the birds. Broilers fed FB+S+HM may have consumed higher energy levels and lower levels of amino acids which could increase abdominal fat deposition more than either corn-soy diets for the entire growing period or corn-soy diet after FB+S until slaughtering time. This is in agreement with Spring and Wilkinson (1957) who reported that increasing the energy resulted in increased body fat. Mabray and Waldroup (1981) reported that abdominal fat could be significantly increased by reducing amino acid levels within a given energy level. It is also clear (Table IV.8) that males had less abdominal fat levels than females. This agrees with the results obtained by Deaton and Lott (1985) that abdominal fat of females expressed as percentage of body weight increased more than that of males compared at the same age.

No significant differences in total mortality (Table IV.8) were observed among the treatments.

Leg abnormalities were more prevalent in broilers fed FB+S+HM. This could be related to feeding faba beans and herring meal. Sorghum and faba beans contain tannins. Elkin et al. (1978) suggested that absorbed tannin may cause cross linking in collagen molecules which alter the organic matrix of the bone. In addition, fish meal has been reported by Halpin and Baker (1986) to decrease the utilization of manganese, thereby increasing the severity of perosis.

In cases of feed shortages, faba beans and sorghum grain may be mixed with herring meal, vitamin and trace mineral premixes and fed to broilers for the entire growing period, but growth depression must be expected; however, the depression will not be so severe as for broilers fed FB+S diets. Leg abnormalities may be encountered also.

Table IV.1. Composition of the corn-soy, faba beans + sorghum with or without herring meal diets

	Corn-soy			
Ingredient	start	finish	FB+S+HM[3]	FB+S[4]
Corn, yellow	60.35	65.52	-	-
Sorghum (milo)	-	-	59.95	66.49
Soybean meal (47.5%)	32.20	27.00	-	-
Faba beans	-	-	30.00	30.00
Herring meal	-	-	7.00	-
Meat meal w/bone	5.00	5.00	-	-
Alfalfa meal dehy. (17%)	1.00	1.00	-	-
Def. phos. (32% Ca, 18% P)	.42	.25	1.30	1.86
Ground limestone	.35	.13	1.05	1.05
Salt (iodized)	.25	.25	.25	.30
Vitamin premix[1]	.20	.20	.20	.20
d,l methionine (98%)	.13	.10	.15	-
Trace mineral premix[2]	.05	.05	.05	.05
Amprolium pemix (25%)[5]	.05	.05	.05	.05
Calculated analyses:				
Crude protein, %	23.34	21.54	18.36	13.90
Metab. eng, kcal/kg	2952	3016	3052	3066
Lysine, %	1.27	1.14	1.04	.66
Calcium, %	.97	.82	1.01	1.04
Avail Phos., %	.48	.45	.45	.45
Methionine, %	.50	.44	.40	.11
Meth. + cyst., %	.89	.77	.58	.25
Crude protein[6], % (analyzed)	23.34	21.54	17.00	14.00

[1] Supplies per kilogram of feed: vitamin A, 3300 IU; vitamin D_3, 1100 ICU; riboflavin, 3.3 mg; d-pantothenic acid, 5.5 mg; niacin, 22 mg; choline, 191 mg; vitamin B_{12}, 5.5 ug; vitamin E, 1.1 IU; vitamin K, .55 mg; folacin, .22 mg.

[2] Supplies per kilogram of feed: calcium 97.3 mg; manganese, 60 mg; iron, 20 mg; iodine, 1.2 mg; zinc, 27.5; cobalt, 0.2 mg; copper, 2 mg.

[3] Faba beans + sorghum + herring meal

[4] Faba beans + sorghum

[5] Gratuitously provided by Merck and Company, Rahway, NJ.

[6] Determined by Kjeldahl method.

Table IV.2. Mean body weight gain, total feed consumption (F cons), feed conversion (F conv) and apparent protein efficiency ratio (APER) of broilers either fed faba beans + sorghum + 7% herring meal (FBS+HM) or faba beans and sorghum (FBS) diets from 1 to 21 days of age

Dietary treatment	Body weight gain[1]			F cons[1]	F conv[1,2]	APER[1,3]
	Male	Female	M+F			
	-	g	-	g/bird		
Corn-soy	601[a]	542[a]	571[a]	886[a]	1.55[c]	2.76[a]
FB+S+HM	467[b]	407[b]	434[b]	849[b]	1.96[b]	2.19[b]
FB+S	128[c]	85[c]	106[c]	356[c]	3.36[a]	1.28[c]
SEM[4]	8	8	5	10	.04	.02

[1] Mean values in each column with different superscripts are significantly different ($P<0.05$).
[2] Feed conversion is grams of feed consumed per gram body weight gain.
[3] APER is grams in body weight gain per gram of protein consumed.
[4] Standard error of the mean

Table IV.3. Mean body weight gain, feed consumption (F cons), feed conversion (F conv), apparent protein efficiency ratio (APER), total plasma protein (TPP), and hematocrit of broilers fed faba beans + sorghum and herring meal (FB+S+HM) or corn-soy diet from 22 to 28 days of age

Dietary treatment											
Age	(days)	Mean body wt. gain[1]						TPP[1]		Hematocrit[1]	
29-42	43-49	Male	Female	M+F	F cons	F conv[1,2]	APER[1,3]	Male	Female	Male	Female
	-	g	-	-	g/bird			g/100 ml		- % -	
C-S[5]	C-S	448[a]	362[a]	405[a]	837[a]	1.86[b]	2.30[b]	3.35[a]	3.4[a]	31[a]	31[ab]
FB+S+HM	FB+S+HM	300[b]	273[ab]	286[b]	747[b]	2.32[a]	1.90[c]	3.13[ab]	3.0[b]	32[a]	34[a]
FB+S[6]	C-S	288[b]	255[b]	272[b]	391[c]	1.24[c]	3.47[a]	3.05[b]	2.6[c]	29[a]	29[b]
SEM[4]		23	23	24	17	.12	.12	.7	.1	2	.1

[1] Mean values in each column with different superscripts are significantly different ($P<.05$).
[2] Feed conversion is grams of feed consumed per gram of body weight gain.
[3] APER is grams in body weight gain per gram of protein consumed.
[4] Standard error of the mean
[5] C-S is corn-soy diet.
[6] FB+S is faba beans + sorghum.

Table IV.4 Mean body weight gain, total feed consumed (F cons), feed conversion(F conv.) and apparent protein efficiency ratio (PER) of broilers fed faba beans + sorghum with 7% herring meal (FB+S+HM) or corn-soy diet from 29 to 35 days of age

Dietary treatment		Mean body weight gain[1]					
Age (days)							
1-21	22-35	Male	Female	M+F	F cons[1]	F conv[1,2]	APER[1,3]
		-	g	-	g/bird		
C-S[5]	C-S	492[a]	415[a]	454[a]	979[a]	2.16[b]	1.99[b]
FBS+HM	C-S	386[b]	313[b]	349[b]	874[b]	2.51[a]	1.71[c]
FBS[6]	C-S	347[b]	310[b]	329[b]	601[c]	1.83[c]	2.34[a]
SEM[4]		20	21	14	16	.05	.12

[1] Mean values in each column with different superscripts are significantly different (P<.05).
[2] Feed conversion is grams feed consumed per gram of body weight gain.
[3] APER is grams in body weight gain per gram of protein consumed.
[4] Standard error of the mean
[5] C-S is corn-soy diet
[6] Faba beans + sorghum

Table IV.5 Mean body weight gain, total feed consumed (F cons), feed conversion (F conv), apparent protein efficiency ratio (APER) of broilers fed mixed faba beans + sorghum with herring meal (FB+S+HM) and corn-soy diet from 36 to 42 days

Dietary treatment		Mean body weight gain[1]					
Age	(days)						
1-21	22-42	Male	Female	M+F	F cons[1]	F conv[1,2]	APER[1,3]
		-	g	-	g/bird		
C-S[5]	C-S	534[a]	396[a]	465a	1121[a]	2.41[a]	1.78[c]
FB+S+HM	FB+S+HM	531[a]	367[a]	449[a]	950[b]	2.11[b]	2.78[b]
FBS[6]	C-S	479[a]	384[a]	432[a]	848[c]	1.97[b]	3.69[a]
SEM[4]		22	11	10	28	.05	.09

[1] Mean values in each column with different superscripts are significantly different (P<.05).
[2] Feed conversion is grams of feed consumed per gram of body weight gain.
[3] APER is grams in body weight gain per gram of protein consumed.
[4] Standard error of the mean
[5] Corn-soy diet
[6] Faba beans + sorghum

Table IV.6 Mean body weight gain, feed consumed (F cons), feed conversion (F conv), apparent protein efficiency ratio (APER), total plasma protein (TPP) and hematocrit of broilers fed faba beans + sorghum + herring meal (FB+S+HM) or corn-soy diets from 42 to 49 days of age

Dietary treatment		Mean body wt. gain[1]						TPP		Hematocrit	
Age	(days)										
1-21	22-49	Male	Female	M+F	F cons[1]	F conv[2]	APER[3]	Male	Female	Male	Female
		-	g	-	g/bird			g/100 ml		-%-	
C-S[5]	C-S	468[a]	358[a]	413[a]	1057[a]	2.58[a]	1.68[a]	4.15[a]	4.20[a]	34[a]	36[a]
FB+S+HM	FB+S+HM	396[a]	259[a]	328[a]	1040[a]	2.77[a]	1.59[a]	4.08[a]	4.20[a]	36[a]	36[a]
FB+S[6]	C-S	388[a]	312[a]	350[a]	859[b]	2.48	1.74[a]	3.90[a]	3.78[a]	31[a]	34[a]
SEM[4]		26	34	24	30	.19	.11	.1	.18	2	1

[1] Mean values in each column with different superscripts are significantly different (P<.05).
[2] Feed conversion is grams of feed consumed per gram of body weight gain.
[3] APER is grams body weight gain per gram of protein consumed.
[4] Standard error of the mean
[5] Corn-soy diet
[6] Faba beans + sorghum

Table IV.7. Mean body weight gain, feed consumption (F cons), feed conversion (F conv), apparent protein efficiency ratio (APER), total plasma protein (TPP), and hematocrit of broilers fed a combination of faba beans + sorghum with herring meal (FB+S+HM) and corn-soy diet from 22 to 49 days of age

Dietary treatment		Mean body wt. gain[1]						TPP		Hematocrit	
Age	(days)										
1-21	22-49	Male	Female	M+F	F cons[1]	F conv[1,2]	APER[1,3]	Male	Female	Male	Female
		-	g	-	g/bird			g/100 ml		-%-	
C-S[5]	C-S	1945[a]	1531[a]	1737[a]	3993[a]	2.30[b]	2.03[b]	4.15[a]	4.20[a]	34[a]	36[a]
FB+S+HM	FBS+HM	1612[b]	1213[b]	1413[b]	3610[b]	2.56[a]	1.83[c]	4.08[a]	4.20[a]	36[a]	36[a]
FBS[6]	C-S	1503[c]	1261[b]	1382[b]	2699[c]	1.95[c]	2.41[a]	3.90[a]	3.78[a]	31[a]	34[a]
SEM[4]		28	49	32	49	.05	.04	.10	.18	2	1

[1] Mean values in each column with different superscripts are significantly different ($P<.05$).
[2] Feed conversion is grams of feed consumed per gram of body weight gain.
[3] APER is grams in body weight gain per gram of protein consumed.
[4] Standard error of the mean
[5] Corn-soy diet
[6] Faba beans + sorghum

Table IV.8. Abdominal fat and total mortality (T mort) of broilers fed faba beans + sorghum with herring meal (FB+S+HM) from 1 to 49 days or faba beans + sorghum (FB+S) from 1 to 21 days followed by corn-soy (C-S) diet from 21 to 49 days

Dietary treatment		Abdominal fat (percent)			
Age	(days)				
1-21	22-49	Male	Female	M+F	T mort[1]
		-	%	-	%
C-S	C-S	1.76[b]	2.43[a]	2.09[ab]	6[a]
FB+S+HM	FB+S+HM	2.22[a]	2.37[a]	2.29[a]	14[a]
FB+S	C-S	1.58[b]	1.90[b]	1.74[b]	5[a]
SEM[2]		.2	.12	.13	4

[1] Mean values in each column with the different superscripts are significantly different ($P<0.05$).
[2] Standard error of the mean

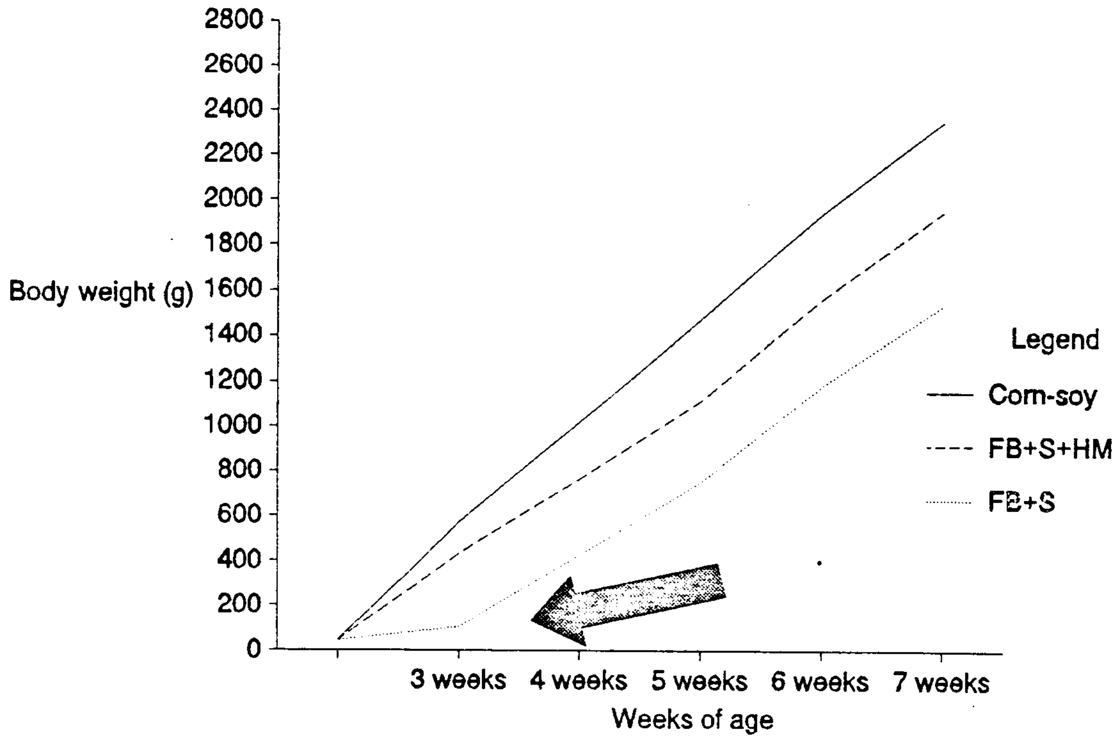

Figure IV.1 Compensatory growth of broilers fed corn-soy diet from 22 to 49 days of age after faba beans-sorghum (FBS) diet from day-old to 21 days of age

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CHAPTER V

DETERMINATION OF THE FEEDING VALUE OF WHEAT BRAN IN BROILER RATIONS[1]

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Abstract

Wheat bran in the Republic of Yemen is in relatively abundant supply and it is cheap. For these reasons, this feedstuff becomes attractive for use in poultry feed during feed shortages. Isonitrogenous and isocaloric diets were designed with graded levels (0, 5, 10, 15, 20, 25 and 30%) of wheat bran and fed to broilers to 7 weeks of age to determine the feeding value of wheat bran.

Incorporating 10 to 20% wheat bran into broiler diets from day-old to 7 weeks significantly ($P<.05$) increased mean body weight compared to that of broilers fed the corn-soy diet. Feed consumption of broilers fed 15% wheat bran was significantly higher than for the corn-soy diet group.

Abdominal fat was significantly higher when broilers were fed 25 or 30% wheat bran compared to the broilers fed the corn-soy diet.

Under the conditions of this experiment, wheat bran can be incorporated in broiler rations up to 25% with fat supplementation. For maximum performance and ease of mixing the rations, 10-15% wheat bran is suggested to be added into broiler diets without an adverse effect on broiler performance.

Introduction

Wheat bran in the Republic of Yemen is available at relatively low cost and in good supply. During feed shortages this feedstuff becomes attractive to use in poultry feeds. Wheat bran, on the average, represents about 20% of the wheat grain. On a dry weight basis, it is composed of 16-17% protein (D'Applonia, 1979). Neudoerffer and Smith (1969) reported that birds can not utilize the nutrients from this ingredient to an appreciable extent. Nahm and Carlson (1985) incorporated isonitogenous graded levels of wheat bran diets up to 20 percent. Feeding wheat bran (10, 20% or 20% + .08% cellulase) from 3 to 8 weeks significantly (P<.05) reduced body weights and significantly (P<.05) increased feed consumption. However, poor feed conversion was significantly (P<.05) affected at 20% wheat bran with or without cellulase treatment. Lee *et al.* (1985) stated that body weight gain and feed consumption decreased as wheat bran increased while feed efficiency was not affected when isonitorgenous and isocaloric graded levels (0, 5 and 10%) of wheat bran diets were used from day-old to 4 weeks of age. Both studies did not include the entire growing period (1 to 49 days of age) and the levels were not high enough (5-20% wheat bran). In addition, Nahm and Carlson (1985) reported on broiler diets that were not isocaloric.

Therefore, the purpose of the study was to ascertain the optimal levels of wheat bran that can be included in broiler diets from 1 to 49 days during feed shortages.

Materials and Methods

Eight hundred forty one-day old chicks (Peterson by Arbor Acres) were randomly allocated into seven treatments. Each treatment consisted of four replicates of 30 chicks each. They were placed in floor pens (1.2 m X 3 m/pen) which were covered with 5 cm deep wood shavings litter. Artificial light (12.56 lux) was provided from day-old to 49 days of age. Feed was provided *ad libitum* in a hanging tube feeder (45.7 cm diameter), and water was provided in Plasson hanging waterers in each pen. The seven dietary treatments were a corn-soy diet and diets with wheat bran ranging from 0 to 30% in increments of 5 percent. The diets were calculated to be isonitrogenous and isocaloric and were fed from 1 to 49 days of age (Table V.1). Body weight, feed consumption, feed conversion and apparent protein efficiency ratio were determined at 2, 4 and 7 weeks of age. Mortality was recorded daily. Two males and two females from each pen were selected randomly at the end of the experiment to determine the level of abdominal fat. Fat surrounding the proventriculus and gizzard and the fat pad was removed and weighed. Mortality was determined daily.

The data were analyzed using one way analysis of variance for a completely randomized design as outlined by Snedecor and Cochran (1980). Fisher Protected Least Significant Differences were used to separate significant differences in treatment means as outlined by Petersen (1985).

Results and Discussion

Data for mean body weights, feed consumed, feed conversion and apparent protein efficiency ratio for 2 and 4 weeks of age are presented in Tables V.2 and V.3, respectively. Body weight, feed consumption, feed conversion, apparent protein efficiency ratio, abdominal fat (slaughtering time) and total mortality at 7 weeks of age are presented in Table V.4.

The body weight of male broilers fed 10 and 15% wheat bran from day-old to 7 weeks of age were significantly higher than that of the corn-soy fed broilers. This may be due to the ability of wheat bran to secure optimum peristaltic action and to enable the digestive juices to act fully on the feed nutrients (Senior, 1948). Like males, feeding 10 and 15% wheat bran from day-old to 7 weeks of age significantly increased the body weight of females compared to the females fed the corn-soy diets.

Feed consumption of broilers fed graded levels of wheat bran from day-old to 4 weeks was the highest at 5% wheat bran (Table V.2) and decreased as wheat bran levels increased. However, feed consumption of broilers fed wheat bran from day-old to 7 weeks of age was the highest at 15% (Table V.4). The reason for this observation is unknown. It may be due to the birds' ability to utilize more wheat bran as they grow older due to more enzymatic secretion or more grinding of bran in the gizzard. Decreasing feed intake with increasing wheat bran level in the diet is in agreement with Lee *et al.* (1985).

Feed conversion at 2 weeks of age (Table V.2) did not increase as expected when the wheat bran level increased. This could be related to the animal fat that was added proportionally to wheat bran levels which results in lower heat increment (Scott *et al.*, 1982).

The apparent protein efficiency ratio in broilers fed 5% wheat bran from day-old to 2 weeks (Table V.2) was significantly reduced compared to the corn-soy diet. This can be related to higher percentage fat as wheat bran increased. But no effect on apparent protein efficiency ratios were observed at 4 and 7 weeks of age (Table V.3 and V.4).

The abdominal fat of males and females at 7 weeks of age (slaughtering time) seemed to significantly increase with increasing levels of wheat bran (Table V.4). This observation is in agreement with Ilian *et al.* (1985) who reported that the use of animal fat to satisfy the energy requirements of the birds resulted in higher percentage of abdominal fat.

No significant differences were found among treatment in total mortality from day-old to 7 weeks or feed conversion at 4 and 7 weeks (Tables V.3 and V.4).

Under the conditions of this experiment wheat bran can be added in poultry rations up to 25% with fat supplementation. For maximum performance and ease of mixing the rations, 10-15% can be added without a major adverse effect on broiler performance.

Table V.1. Composition of the wheat bran diets

Ingredient	Levels of wheat bran (%)						
	0	5	10	15	20	25	30
Corn, yellow	61.72	60.1	52.71	45.5	38.13	31.09	23.64
Soybean meal, 47.5%	32.6	31.3	31.1	30.8	30.6	30.3	30.10
Wheat bran	-	5.0	10.0	15.0	20.0	25.0	30.00
Cellulose	2.4	-	-	-	-	-	-
Animal fat	-	.3	2.9	5.4	8.0	10.5	13.1
Def. phos. (32% Ca, 18% P)	2.0	1.9	1.9	1.8	1.8	1.7	1.6
Ground limestone	.57	.62	.66	.69	.72	.65	.79
Salt (iodized)	.25	.25	.25	.25	.25	.25	.25
Vitamin premix[1]	.20	.20	.20	.20	.20	.20	.20
d,l methionine (98%)	.16	.17	.18	.19	.20	.21	.22
Trace mineral premix[2]	.05	.05	.05	.05	.05	.05	.05
Amprolium premix[3] (25%)	.05	.05	.05	.05	.05	.05	.05
Calculated analyses:							
Crude protein, %	21.00	21.00	21.00	21.00	21.00	21.00	21.00
Metab eng, kcal/kg	2907	2907	2907	2907	2907	2907	2907
Calcium, %	.97	.97	.97	.97	.97	.97	.97
Avail Phos., %	.48	.48	.48	.48	.48	.48	.48
Lysine, %	1.11	1.09	1.10	1.10	1.10	1.10	1.11
Methionine, %	.34	.34	.33	.32	.32	.31	.30
Meth. + cyst., %	.71	.70	.69	.68	.66	.66	.64

[1] Supplies per kilogram of feed: Vitamin A, 3300 IU; vitamin D_3, 1100 ICU; riboflavin, 3.3 mg; d-pantothenic acid, 5.5 mg; niacin, 22 mg; choline, 191 mg; vitamin B_{12}, 5.5 ug; vitamin E, 1.1 IU; vitamin K, 0.55 mg; folacin,0.22 mg.

[2] Supplies per kilogram of feed: calcium 97.3 mg; manganese, 60 mg; iron, 20 mg; iodine, 1.2 mg; zinc, 27.5; cobalt, 0.2 mg; copper, 2 mg.

[3] Gratuitously provided by Merck and Co., Inc., Rahway, NJ.

Table V.2. Mean body weight, total feed consumption (F cons), feed conversion (F conv), and apparent protein efficiency ratio (APER) at 14 days of age of broilers fed graded levels of wheat bran (WB)

Dietary treatment	Mean body weight[1]			F cons[1]	F conv[1,2]	PER[1,3]
	Male	Female	M+F			
	-	g	-	g/bird		
Corn-soy	335[a]	321[a]	328[a]	434[d]	1.54[c]	3.10[a]
+ 5% WB	338[a]	316[a]	327[a]	506[a]	1.80[a]	2.67[c]
+ 10% WB	342[a]	329[a]	336[a]	475[ab]	1.63[bc]	2.92[ab]
+ 15% WB	331[a]	313[ab]	322[a]	468[bc]	1.69[ab]	2.82[ab]
+ 20% WB	329[a]	317[a]	323[a]	452[bcd]	1.62[bc]	2.94[ab]
+ 25% WB	321[a]	315[a]	318[a]	429[d]	1.57[bc]	3.03[ab]
+ 30% WB	324[a]	296[b]	310[a]	437[cd]	1.65[bc]	2.89[abc]
SEM[4]	8	6	6	11	.04	.08

1 Mean values each column having different superscripts are significantly different ($P<0.05$).
2 Feed conversion is grams of feed consumed per gram of body weight gain.
3 APER is grams in body weight gain per gram of protein consumed.
4 Standard error of the mean.

Table V.3. Mean body weight, total feed consumed (F cons), feed conversion (F conv) and apparent protein efficiency ratio (APER) in broilers fed graded levels of wheat bran (WB) at 28 days of age

Dietary treatment	Mean body weight[1]			F cons	F conv[2]	APER[3]
	Male	Female	M+F			
	-	G	-	g/bird		
Corn-soy	951[a]	847[bc]	899[a]	1517[a]	1.78[a]	2.68[a]
+ 5% WB	982[a]	840[bc]	911[a]	1664[a]	1.92[a]	2.49[a]
+ 10% WB	999[a]	899[a]	949[a]	1622[a]	1.79[a]	2.65[a]
+ 15% WB	991[a]	899[a]	945[a]	1621[a]	1.80[a]	2.64[a]
+ 20% WB	989[a]	888[ab]	939[a]	1600[a]	1.79[a]	2.66[a]
+ 25% WB	954[a]	878[abc]	916[a]	1570[a]	1.80[a]	2.64[a]
+ 30% WB	950[a]	832[c]	891[a]	1529[a]	1.81[a]	2.63[a]
SEM[4]	18	17	16	39	.05	.05

[1] Mean values in each column having different superscripts are significantly different ($P<0.05$).
[2] Feed conversion is grams of feed consumed per gram of body weight gain.
[3] APER is grams in body weight gain per gram of protein consumed.
[4] Standard error of the mean.

Table V.4. Mean body weight, total feed consumption (F cons), feed conversion (F conv) and apparent protein efficiency ratio (APER), abdominal fat and total mortality (T mort) of broilers fed graded levels of wheat bran (WB) from day-old to 49 days of age

Dietary treatment	Mean body weight[1]			F cons[1]	F conv[1,2]	APER[1,3]	Abdominal fat			Total mortality
	Male	Female	M+F				Male	Female	M+F	
	-	g	-	g/bird			-	%	-	%
Corn-soy	2416^{cd}	1965^{c}	2191^{cd}	4780^{cd}	2.23^{a}	2.14^{a}	1.78^{a}	1.89^{c}	1.83^{c}	3^{a}
+ 5% WB	2488^{abc}	1993^{bc}	2241^{bcd}	5042^{abc}	2.30^{a}	2.08^{a}	1.64^{a}	2.19^{bc}	1.92^{c}	2^{a}
+ 10% WB	2556^{a}	2115^{a}	2335^{a}	5140^{abc}	2.24^{a}	2.12^{a}	2.19^{a}	2.77^{ab}	2.48^{ab}	4^{a}
+ 15% WB	2520^{ab}	2103^{a}	2312^{ab}	5257^{a}	2.32^{a}	2.05^{a}	1.93^{a}	2.57^{abc}	2.25^{bc}	4^{a}
+ 20% WB	2507^{abc}	2088^{ab}	2297^{ab}	5101^{abc}	2.27^{a}	2.10^{a}	1.88^{a}	2.61^{ab}	2.24^{bc}	3^{a}
+ 25% WB	2437^{bcd}	2084^{ab}	2260^{abc}	4968^{bc}	2.24^{a}	2.12^{a}	2.34^{a}	3.14^{a}	2.74^{a}	3^{a}
+ 30% WB	2369^{d}	1963^{c}	2165^{d}	4705^{d}	2.22^{a}	2.15^{a}	2.28^{a}	3.23^{a}	2.75^{a}	6^{a}
SEM[4]	35	33	27	51	.04	.03	.18	.24	.17	2

[1] Mean values in each column having different superscripts are significantly different ($P<0.05$).
[2] Feed conversion is grams of feed consumed per gram of body weight gain.
[3] APER is grams in body weight gain per gram of protein consumed.
[4] Standard error of the mean.

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CHAPTER VI

FEEDING VALUE OF CELLULASE OR PROTEASE TREATED WHEAT BRAN IN BROILER PERFORMANCE, ACID DETERGENT FIBER DIGESTIBILITY AND NITROGEN RETENTION[1]

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Abstract

Wheat bran is found in relatively abundant supply and is reasonably cheap in the Republic of Yemen, but it requires a processing method to further improve the utilization of its nutrients by broilers. Two experiments were conducted to evaluate the effect of enzymatic supplementation (Cellulase and Protease) of wheat bran diets. In Experiment 1, a completely randomized, 3 X 3 factorial design was utilized with three wheat bran levels (0, 15 and 30%) and with 0, 50 and 100 mg/kg cellulase levels (activity 4.4 mg/g). In Experiment 2, 3 X 2 factorial was employed with three wheat bran levels (0, 15 and 30%) and with 0 and 2 mg/g protease levels (activity .30 mg/g). The broilers were raised in battery cages to 21 to of age.

No significant wheat bran X cellulase interactions in mean body weight, total feed consumed, feed conversion, apparent protein efficiency ratio, acid detergent fiber digestibility or apparent nitrogen retention were observed. were found.

Feeding broilers the 30% wheat bran diet seemed to improve mean body weight, increase feed consumption and reduce acid detergent fiber digestibility compared to the broilers fed the corn-soy diet.

Cellulase supplementation did not significantly improve all the measured parameters when compared to the unsupplemented diet.

Supplementing protease in the diets resulted in significant wheat bran xprotease interactions. Protease supplementation significantly reduced mean body weight and feed consumption, but this reduction was proportionally ameliorated by increasing wheat bran levels. Feed conversion and apparent protein efficiency ratio were poorer ($P<.05$) with protease supplementation, but these adverse effects were alleviated as the wheat bran level increased in the diet. Acid detergent fiber digestibility was significantly reduced with increasing wheat bran levels. Apparent nitrogen retention was not affected by wheat bran X protease interaction. However, apparent nitrogen retention was lowered with increasing levels of wheat bran and enhanced by protease.

Cellulase supplementation in wheat bran diets increased overall mean body weight of broilers, but any economical feasibility remained to be assessed. Protease supplementation was detrimental to broilers performance, however, wheat bran seemed to alleviate this adverse effect.

Introduction

During period of feed shortage in the Republic of Yemen, use of local feedstuffs becomes necessary. One of these feedstuffs is wheat bran. This feedstuff can play an important role in providing the necessary poultry feed because it is in relatively abundant supply and it is cheap. However, Shelter *et al.* (1947) reported that it is poorly utilized by chicks due to the aleurone layer and holocellulose (cellulose and hemicellulose). The aleurone layer constitutes 30-50% of the bran (Saunders *et al.*, 1969). The aleurone layer trapped nutrients that could be made available to the chicks. On a moisture-free basis, wheat bran contains 17% protein and 70% carbohydrates of which is 80% cellulose and hemicellulose (Saunders *et al.*, 1972).

Thus, appropriate processing methods to enhance the digestibility of holocellulose and disrupt the aleurone cell walls for maximum utilization of wheat bran have been investigated. Several processing procedures have been attempted such as steam-pelleting wheat bran (Cave *et al.*, 1965a,b), steam-pelleting and regrinding (Olsen and Slinger, 1968), pretreatment of bran with sodium hydroxide, ammonium hydroxide or hydrochloric acid before pelleting (Kuzmicky *et al.*, 1978) and enzymatic (cellulase) treatment (Nahm and Carlson, 1985). Steam-pelleting and regrinding improved protein utilization, but did not rupture the beta-1, 4 glucose linkage of cellulose, without which no larger scale improvement in digestibility of the carbohydrate fraction can be brought about (Neudoerffer and Smith, 1969). Sulfuric acid treatment of fibrous substance has been tried by Seaman *et al.* (1963) to liberate glucose from cellulose, but the protein was destructed. On the basis of these considerations, the enzymic processes seemed best suited for absorption from wheat bran two chemically unrelated substances, cellulose and protein, without destroying one during the modification of the other. About one-third of wheat bran is in the form of indigestible cellulose, but is about 17% protein, of which only slightly more than one-half is available for absorption by monogastrics (Neudoerffer and Smith, 1969).

Few studies have been conducted to determine the effect of enzyme addition to wheat bran diets. Nahm and Carlson (1985) fed graded levels of wheat bran (0, 10, 20% and 20% + .008% cellulase) from 3 to 8 weeks of age. They found that cellulase supplementation significantly ($P<.05$) reduced feed consumption and apparently improved feed:gain ratio. They also noted that cellulase significantly ($P<.05$) enhanced the digestibility of the wheat bran cell wall and made minerals (calcium, phosphorus, iron, zinc and copper) more available for absorption. Neudoerffer and Smith (1969) reported that enzymic combination of cellulase and protease improved the nutritional value of wheat bran in the rat.

Therefore, the objectives of these studies were to determine the effects of cellulase or protease supplementations in broiler diets containing graded levels of wheat bran on broiler performance and to assess whether there are improvements of acid detergent fiber digestibility and apparent nitrogen retention.

Materials and Methods

Experiment 1

One hundred sixty-two chicks broiler strain cross (Peterson X Arbor Acres) were feather sexed and wing-banded at hatching time. The chicks were housed in electrically heated batteries (3 males and 3 females per each replicate) with raised-wire floors from day-old to 21 days of age (end of the experiment). Feed and water were supplied *ad libitum*. The chicks were fed isonitrogenous, isocaloric diets (Table VI.1), and fluorescent light provided 24 hr illumination throughout the experiment. The experiment was designed in a 3 X 3 factorial arrangement with three levels of wheat bran (0, 15 and 30%) and three cellulase[6] levels 0, 50 and 100 mg/kg (activity 4.4 mg/g) as the main effects. Each treatment was replicated thrice.

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[6] Sigma Chemical Co., St. Louis, MO.

Experiment 2

The management and housing of the broiler chicks in this experiment were similar to Experiment 1. One hundred eight chicks were feather sexed and wing-banded at hatching time. The experiment design was a 3 X 2 factorial arrangement with wheat bran and protease levels serving as the main effects. Wheat bran levels were 0, 15, and 30% in the diets, and the protease levels were 0 and 2 mg protease[7] (activity .30 mg/g) per gram diet.

In both experiments individual body weight by sex, total feed consumed, feed conversion, and the apparent protein efficiency ratio at 7, 14 and 21 days of age were determined. Mortality was recorded daily. Excreta were quantitatively collected for two 24-hr periods from two 3-week-old chicks, (1 male and 1 female), per treatment and acid detergent fiber (ADF) digestibility and apparent nitrogen retention were determined. The excreta from all treatments were immediately weighed, placed in aluminum foil and dried at 37 C (100 F) for 24 hr, cooled and then weighed. Enough samples of feed and excreta of each replicate were ground through a 20-mesh screen for determining acid detergent fiber digestibility (ADF) and apparent nitrogen retention (ANR). Two samples each of excreta and feed were weighed from each replicate and were used to determine ADF (Waldern, 1971). Duplicate samples

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[7] Sigma Chemical Co., St. Louis, MO.

weighing approximately 1 g were used to determine apparent nitrogen retention by the Kjeldahl method.

Percentage data were converted to arcsine prior to analysis in order to stabilize the variance. The data were analyzed as a factorial in a completely randomized design by two-way ANOVA as described by Snedecor and Cochran (1980) utilizing the computer program by the statistical analysis system (SAS Institute, 1986). Variable means for treatments showing significant differences were determined using Tukey's Test. All statements of significance are based on the probability level of .05.

Results and Discussion

Experiment 1

No significant wheat bran X cellulase interactions at the end of 7 days (Table VI.3), 14 days (Table VI.4) and 21 days (Table VI.5) were observed in mean body weight, feed consumed, feed conversion, apparent protein efficiency ratio, acid detergent fiber digestibility, apparent nitrogen retention and total mortality. Feeding 15 or 30% wheat bran to broilers for 21 days resulted in significantly increased mean body weights of mixed-sexed and female broilers when compared to broilers fed no wheat bran. This improvement in body weight could be attributed to the addition of animal fat to the wheat bran diets (Table VI.1). Fat is more efficiently utilized than carbohydrates due to less heat increment (Scott *et al.*, 1982). Another reason for the difference may be due to more feed consumption per bird (Table VI.4) when wheat bran was added. These results did not agree with Lee *et al.* (1985) and Nahm and Carlson (1985) who reported that body weight decreased with increasing levels of wheat bran. Nahm and Carlson (1985) did not adjust energy in their diets which could explain the differences between the two studies.

Feed consumptions at 14 were significantly increased when wheat bran was incorporated in the diets at either 15 or 30 percent. Feed consumption at 21 days of age significantly ($P<.05$) increased at 30% wheat bran. The reason for the increase in feed intake could be attributed to palatability of wheat bran and the age of the broilers.

Feed conversion and apparent protein efficiency ratio of broilers fed 15 and 30% wheat bran from day-old to 21 days of age did not follow the same trend as body weight and feed consumption. Feed conversion was significantly poorer at 14 days of age with increasing wheat bran levels in the diets. This is in agreement with Nahm and Carlson (1985). These findings are not understood. The apparent protein efficiency ratio was significantly better with increasing wheat bran levels at 7 days (Table VI.3), but this improvement diminished as the birds grew older. The reason is not clearly understood, however at an early age, chicks require higher protein levels which, in turn, may utilize protein more efficiently.

Cellulase supplementation to wheat bran diets did not have any effect on broiler performance at 7, 14 and 21 days of age (Tables VI.3, VI.4 and VI.5). This finding is not in agreement with Nahm and Carlson (1985) who reported that adding cellulase at .008% to 20% wheat bran diet significantly reduced (P<.01) feed consumption, numerically reduced feed:gain ratio and improved acid detergent fiber digestibility. The diets in Nahm's studies were isonitrogenous, but not isocaloric, which could have caused the differences between these studies.

A significant decrease in acid detergent fiber digestibility was found as wheat bran levels increased (Table VI.6). This may be attributed to the limited ability of broilers to digest fiber.

The apparent nitrogen retention by broilers fed 15% wheat bran from 1 to 21 days of age was significantly higher than for broilers fed either none or 30% wheat bran (Table VI.6). The reason for these differences is not understood; however, wheat bran compared with other plant sources of protein have higher contents of lysine and arginine (Barton-Wright and Moran, 1946), which has the potential to complement the amino acids of other proteins in the same ration. This ability of wheat bran may decrease when the physiological level to utilize wheat bran is exceeded.

Experiment 2

There were significant wheat bran X protease (WB X P) interactions in mean body weight, feed consumption, feed conversion, apparent protein efficiency ratio, acid detergent fiber digestibility, apparent nitrogen retention and mortality. However, the adverse effects on mean body weight, feed consumption and feed conversion were partially ameliorated with increasing the levels of wheat bran in the diets. These observations could be related to adding excess levels of protease which, in turn, reduced palatability of the feed and/or produced toxic effects in the birds. Adding 15 or 30% wheat bran may improve the palatability and/or reduce the toxic effect. Improving the palatability of the feed may be more possible because the broilers were very active and eager to eat, but after starting to eat, they did not continue, but instead began picking on the metal cages.

Feeding 30% wheat bran diet resulted in significant increases in mean body weights of females and mixed-sex broilers at 7, 14 and 21 days of age compared to broilers fed either 0 or 15% wheat bran diets (Tables VI.7, VI.8, and VI.9). Mean body weight of males followed the same trend as females. The effect of wheat bran was significantly pronounced at 14 and 21 days of age (Tables

VI.7, VI.8 and VI.9). The increased mean body weight when 30% wheat bran diet were fed could be related to either the ability of wheat bran to ensure optimum peristaltic action and enhance digestible enzymatic action (Senior, 1948) or to increased feed consumption.

The feed consumption from day-old to 21 days of age of broilers fed 30% wheat bran diet was significantly higher than for broilers fed either 0 or 15% wheat bran diets (Tables VI.7, VI.8 and VI.9). Feed consumption was also significantly higher at 21 days when a 15% wheat bran diet was fed (Tables VI.8 and VI.9). This may be attributed to palatability of wheat bran. .

The feed conversion at 14 days of broilers fed either 15 or 30% wheat bran diets was better compared to the broilers fed the control diet. Supplementing 4.17 and 11.44% fat to 15 or 30 wheat bran diets, respectively, could be the reason for better feed utilization.

The apparent protein efficiency ratio of the broilers fed a 30% wheat bran diet was significantly better at 14 days of age than with the diets without wheat bran. However, no significant differences in apparent protein efficiency ratios at either 7 or 21 days of age were observed among treatments.

Supplementing protease 2 mg/g in the diets fed to broilers from 1 to 21 days of age resulted in significantly reduced mean body weights, feed consumption and poorer feed conversion than for the broilers fed the unsupplemented diets (Tables VI.7, VI.8 and VI.9). a significant reduction in apparent protein efficiency ratio was observed at 7 days of age. However, no differences were observed at 14 and 21 days of age.

The digestibility of acid detergent fiber decreased significantly with increasing levels of wheat bran (Table VI.10). This could be related to the birds' physiological capacity to digest fiber.

Apparent nitrogen retention was significantly reduced in chicks fed the 30% wheat bran diet than the chicks fed the control diet. This could be related to the protein in wheat bran not being readily available to the chicks due to the lack of an enzymes in the bird to break down aleurone layers which contain most of the protein. It seemed that supplementing protease enhanced nitrogen retention.

Under the conditions of these experiments cellulase supplementation to wheat bran-containing diets slightly improved overall mean body weight, however, protease seemed to be detrimental to broiler performance.

Table VI.1. Composition of the wheat bran (WB) diets with or without cellulase (C)

Ingredient: WB, %	0			15			30		
C, mg/g	0	50	100	0	50	100	0	50	100
	-	%	-	-	%	-	-	%	-
Corn, Yellow	61.82	61.82	61.82	45.43	45	45	24.46	24	24.01
Soybean meal, 47.5%	32.33	32.33	32.33	30.41	30.49	30.49	29.35	29.43	29.43
Wheat bran	-	-	-	15.00	15.00	15.00	30.00	30.00	30.00
Animal fat	-	-	-	5.35	5.52	5.52	12.48	12.66	12.66
Cellulose	1.95	1.94	1.94	-	.18	.17	-	-	-
Monocal phosphate (16% Ca, 24% P)	1.57	1.57	1.57	1.42	1.42	1.42	1.27	1.27	1.27
Ground limestone	1.54	1.54	1.54	1.57	1.57	1.57	1.59	1.59	1.59
Salt (iodized)	.25	.25	.25	.25	.25	.25	.25	.25	.25
d,l Methionine (98%)	.24	.24	.24	.27	.27	.27	.30	.30	.30
Vitamin premix[1]	.25	.25	.25	.25	.25	.25	.25	.25	.25
Trace mineral premix[2]	.05	.05	.05	.05	.05	.05	.05	.05	.05
Calculated analyses:									
Crude protein, %	21	21	21	21	21	21	21	21	21
Metab. eng, kcal/kg	2907	2907	2907	2907	2907	2907	2907	2907	2907
Calcium, %	.95	.95	.95	.95	.95	.95	.95	.95	.95
Avail. phos., %	.45	.45	.45	.45	.45	.45	.45	.45	.45
Lysine, %	1.10	1.10	1.10	1.10	1.10	1.10	1.11	1.11	1.11
Methionine, %	.57	.57	.57	.57	.57	.57	.57	.57	.57
Meth. + cyst., %	.93	.93	.93	.93	.93	.93	.93	.93	.93

[1] Supplies per kilogram of feed: Vitamin A,3300 IU; Vitamin D3, 1100 ICU; riboflavin, 3.3 mg; d-pantothenic acid, 5.5 mg; niacin, 22 mg; choline, 191 mg; vitamin B_{12}, 5.5 ug; vitamin E, 1.1 IU; vitamin K, 0.55 mg; folacin, 0.22 mg.

[2] Supplies per kilogram of feed: calcium 97.3 mg; manganese, 60 mg; iron, 20 mg; iodine, 1.2 mg; zinc, 27.5; cobalt, 0.2 mg; copper, 2 mg.

Table VI.2. Composition of the wheat bran (WB) diets with or without protease (P)

Ingredient: WB, %	0		15		30	
P, mg/g	0	2	0	2	0	2
			——— % ———			
Corn, yellow	62.04	62.04	48.69	48.72	26.99	27.74
Soybean meal, 47.5%	30.14	30.14	27.66	27.65	26.73	26.59
Wheat bran	-	-	15.00	15.00	30.00	30.00
Animal fat	-	-	4.17	4.36	11.57	12.78
Cellulose	3.46	3.26	.21	-	.52	-
Monocal phosphate (CA, P)	1.59	1.59	1.43	1.43	1.29	-
Ground limestone	1.55	1.55	1.59	1.59	1.61	1.61
Granite grit	.40	.40	.40	.40	.40	.40
d,l methionine (98%)	.27	.27	.30	.30	.33	.33
Salt (iodized)	.25	.25	.25	.25	.25	.25
Vitamin premix[1]	.25	.25	.25	.25	.25	.25
Trace mineral premix[2]	.05	.05	.05	.05	.05	.05
Calculated analyses:						
Crude protein, %	20.00	20.00	20.00	20.00	20.00	20.00
Metab. eng.	2907	2907	2907	2907	2907	2907
Calcium, %	.95	.95	.95	.95	.95	.95
Avail. phosphorus, %	.45	.45	.45	.45	.45	.45
Lysine, %	1.10	1.10	1.10	1.10	1.11	1.11
Methionine, %	.57	.57	.57	.57	.58	.58
Meth. + cyst., %	.93	.93	.93	.93	.93	.93

[1] Supplies per kilogram of feed: vitamin A,3300 IU; Vitamin D3, 1100 ICU; riboflavin, 3.3 mg; d-pantothenic acid, 5.5 mg; niacin, 22 mg; choline, 191 mg; vitamin B_{12}, 5.5 ug; vitamin E, 1.1 IU; vitamin K, 0.55 mg; folacin, 0.22 mg.

[2] Supplies per kilogram of feed: calcium 97.3 mg; manganese, 60 mg; iron, 20 mg; iodine, 1.2 mg; zinc, 27.5; cobalt, 0.2 mg; copper, 2 mg.

Table VI.3. Mean body weight, feed consumed (F cons), feed conversion (F conv), and apparent protein efficiency ratio (APER) of broilers fed graded levels of wheat bran (WB) with graded levels of cellulase (C) at 7 days of age

	Mean body weight					
Treatment	Male	Female	M+F	F cons	F conv	APER[1]
	-	g	-	g/bird		
WB, %	NS	NS	*	NS	NS	*
0	127	117	122[b]	121	1.58	2.84[b]
15	132	128	130[ab]	123	1.45	3.15[ab]
30	136	127	131[a]	129	1.50	3.20[a]
SEM	4	3	2	4	.04	.09
C, mg/kg	NS	NS	NS	NS	NS	NS
0	130	128	129	128	1.53	3.12
50	127	116	123	118	1.51	2.87
100	136	127	131	127	1.48	3.20
SEM	4	3	2	4	.04	.09
WB xC	NS	NS	NS	NS	NS	NS
0 0	130	125	128	129	1.56	3.06
0 50	123	111	117	110	1.51	2.68
0 100	126	114	120	124	1.66	2.77
15 0	127	140	133	131	1.48	3.28
15 50	128	114	121	110	1.45	2.82
15 100	139	131	135	128	1.42	3.34
30 0	132	120	126	125	1.55	3.01
30 50	134	124	129	133	1.58	3.11
30 100	142	135	139	129	1.38	3.47
SEM	6	6	4	7	.07	.16

* P<.05

[1] APER is grams in body weight gain per gram of protein consumed.

Table VI.4. Mean body weight, feed consumed (F cons), feed conversion (F conv), and apparent protein efficiency ratio (APER) of broilers fed graded levels of wheat bran (WB) with graded levels of cellulase (C) at 14 days of age

	Mean body weight					
Treatment	Male	Female	M+F	F cons	F conv	APER[1]
	-	g	-	g/bird		
WB, %	NS	*	*	*	*	NS
0	299	269[b]	284[b]	386[c]	1.40[c]	2.91
15	327	309[a]	318[a]	421[b]	1.53[b]	3.01
30	344	316[a]	331[a]	450[a]	1.64[a]	2.96
SEM	13	11	8	8	.03	.08
C, mg/kg	NS	NS	NS	NS	NS	NS
0	321	309	315	422	1.53	3.01
50	310	285	298	412	1.50	2.84
100	341	300	320	424	1.54	3.02
SEM	13	11	8	8	.03	.08
WB xC	NS	NS	NS	NS	NS	NS
0 0	308	288	298	398	1.45	3.00
0 50	278	268	273	374	1.36	2.81
0 100	311	250	281	386	1.41	2.91
15 0	310	337	323	427	1.55	3.04
15 50	339	278	309	407	1.48	3.00
15 100	334	312	323	428	1.56	2.97
30 0	343	303	323	439	1.57	2.99
30 50	313	310	312	453	1.65	2.72
30 100	376	338	357	456	1.66	3.18
SEM	23	19	14	14	.05	.13

* $P<.05$

[1] APER is grams in body weight gain per gram of protein consumed.

Table VI.5. Mean body weight, feed consumed (F cons), feed conversion (F conv), and apparent protein efficiency ratio (APER) of broilers fed graded levels of wheat bran (WB) with graded levels of cellulase (C) at 21 days of age

Treatment	Mean body weight			F cons	F conv	APER[1]
	Male	Female	M+F			
	-	g	-	g/bird		
WB, %	NS	NS	NS	*	NS	NS
0	569	495	532	817[b]	1.68	2.76
15	595	540	567	856[ab]	1.65	2.72
30	622	544	583	903[a]	1.68	2.65
SEM	17	22	16	20	.03	.07
C, mg/kg	NS	NS	NS	NS	NS	NS
0	574	538	556	845	1.65	2.72
50	600	523	562	871	1.69	2.73
100	611	518	565	860	1.66	2.67
SEM	17	22	16	20	.03	.07
WB xC	NS	NS	NS	NS	NS	NS
0 0	572	512	542	805	1.62	2.85
0 50	533	512	522	836	1.75	2.59
0 100	601	461	531	809	1.67	2.83
15 0	549	567	558	842	1.65	2.68
15 50	640	516	578	862	1.63	2.81
15 100	594	537	566	864	1.66	2.65
30 0	602	536	569	887	1.69	2.62
30 50	627	541	584	915	1.70	2.79
30 100	637	556	596	908	1.65	2.52
SEM	30	38	28	35	.04	.13

* $P<.05$

[1] APER is grams in body weight gain per gram of protein consumed.

Table VI.6. Acid detergent fiber (ADF) digestibility, apparent nitrogen retention (ANR) and total mortality of broilers fed graded levels of wheat bran (WB) and cellulase (C) at 21 days

Treatment		ADF	ANR	Total mortality
		%	%	%
WB, %		*	*	NS
0		19.33[a]	66.9[b]	3.7
15		9.42[b]	73.4[a]	11.1
30		7.20[c]	65.5[b]	5.6
SEM		.14	1.3	3.2
C, mg/kg		NS	*	*
0		11.97	68.9[ab]	3.7[ab]
50		12.04	65.9[b]	14.8[a]
100		11.94	71.1[a]	1.9[b]
SEM		.14	1.3	3.2
WB	xC	NS	NS	NS
0	0	19.32	67.8	0
0	50	19.69	65.8	11.1
0	100	18.97	67.2	0
15	0	9.55	74.9	5.6
15	50	9.27	70.2	27.8
15	100	9.42	75.1	0
30	0	7.03	64.0	5.6
30	50	7.15	61.7	5.6
30	100	7.41	70.9	5.6
SEM		.24	2.3	5.6

* $P<.05$

Table VI.7. Mean body weight, feed consumed (F cons), feed conversion (F conv), and apparent protein efficiency ratio (APER) of broilers fed graded levels of wheat bran (WB) and protease (P) at 7 days of age

		Mean body weight				
Treatment	Male	Female	M+F	F cons	F conv	APER[1]
	-	g	-	g/bird		
WB, %	NS	*	*	*	*	NS
0	98	85[b]	92[b]	80[b]	2.59[a]	2.49
15	92	93[b]	93[b]	89[b]	2.32[ab]	2.51
30	110	111[a]	110[a]	110[a]	1.75[b]	2.91
SEM	7	5	4	3	.16	.18
P, mg/g	*	*	*	*	*	*
0	128[a]	117[a]	122[a]	115[a]	1.5[b]	3.39[a]
2	71[b]	76[b]	73[b]	72[b]	2.94[a]	1.88[b]
SEM	6	4	3	3	.13	.15
WB xP	*	*	*	*	*	*
0 0	136	114	125	111	1.43	3.62
0 2	59	57	58	49	3.75	1.35
15 0	119	116	118	108	1.50	3.37
15 2	63	71	67	70	3.14	1.64
30 0	129	121	125	125	1.58	3.19
30 2	91	100	96	96	1.92	2.63
SEM	10	6	6	5	.23	.26

* $P<.05$

[1] APER is grams in body weight gain per gram of protein consumed.

Table VI.8. Mean body weight, feed consumed (F.cons.),feed conversion (F.conv.), and apparent protein efficiency ratio (APER) of broilers fed graded levels of wheat bran (WB) and protease (P) at 14 days of age

	Mean body weight					
Treatment	Male	Female	M+F	F cons	F conv	APER[1]
	-	g	-	g/bird		
WB, %	*	*	*	*	*	*
0	159[c]	172[b]	165[c]	230[c]	2.38[a]	2.30[b]
15	208[b]	206[b]	207[b]	283[b]	1.97[b]	2.80[ab]
30	269[a]	263[a]	266[a]	366[a]	1.67[b]	3.06[a]
SEM	8	10	7	8	.08	.17
P, mg/g	*	*	*	*	*	NS
0	296[a]	285[a]	290[a]	402[a]	1.65[b]	2.89
2	128[b]	143[b]	136[b]	185[b]	2.36[a]	2.55
SEM	6	8	6	7	.07	.17
WB xP	*	*	*	*	*	NS
0 0	234	270	252	358	1.73	2.54
0 2	83	75	79	102	3.03	2.06
15 0	314	286	300	405	1.59	3.07
15 2	101	126	114	162	2.35	2.53
30 0	339	299	319	443	1.62	3.05
30 2	200	228	214	289	1.72	3.06
SEM	11	14	10	12	.12	.24

* $P<.05$

[1] APER is grams in body weight gain per gram of protein consumed.

Table VI.9. Mean body weight, feed consumed (F cons), feed conversion (F conv), and apparent protein efficiency ratio (APER) of broilers fed graded levels of wheat bran (WB) and protease (P) at 21 days of age

Treatment	Average body weight			F cons	F conv	APER[1]
	Male	Female	M+F			
	-	g	-	g/bird		
WB, %	*	*	*	*	*	NS
0	295[c]	303[c]	299[c]	480[c]	2.08[a]	2.68
15	382[b]	386[b]	384[b]	608[b]	1.85[ab]	2.79
30	485[a]	471[a]	478[a]	762[a]	1.76[b]	2.70
SEM	17	11	10	11	.06	.15
P, mg/g	*	*	*	*	*	NS
0	534[a]	506[a]	520[a]	843[a]	1.78	2.61
2	240[b]	268[b]	254[b]	391[b]	2.01	2.84
SEM	14	9	8	9	.05	.12
WB xP	*	*	*	*	*	NS
0 0	443	482	463	753	1.80	2.67
0 2	146	124	135	207	2.36	2.69
15 0	576	523	550	877	1.74	2.64
15 2	187	249	218	339	1.96	2.94
30 0	583	511	547	898	1.79	2.50
30 2	387	430	408	626	1.73	2.89
SEM	24	16	14	15	.09	.21

* $P<.05$

[1] APER is grams in body weight gain per gram of protein consumed.

Table VI.10. Acid detergent fiber (ADF) digestibility, apparent nitrogen retention (ANR) and total mortality of broilers fed graded levels of wheat bran (WB) and protease (P) at 21 days of age

Treatment		ADF	ANR	Total mortality
		%	%	%
WB, %		*	*	NS
0		17.6[a]	77.1[a]	2.8
15		9.6[b]	74.5[a]	2.8
30		6.4[c]	65.3[b]	.0
SEM		.2	1.6	2.3
P, mg/g		NS	*	NS
0		11.3	69.6[b]	3.7
2		11.0	73.7[a]	.0
SEM		.1	2.2	1.9
WB	xP	*	NS	NS
0	0	17.2	73.8	5.6
0	2	17.9	76.4	.0
15	0	9.9	74.3	5.6
15	2	9.1	74.8	.0
30	0	6.8	60.6	.0
30	2	6.1	70.0	.0
SEM		.2	2.2	3.2

* P<.05

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CHAPTER VII

CONCLUSION AND RECOMMENDATIONS

Nutritional implications on broiler performance by feeding either single or a mixture of feed ingredients or a combination of varied levels of wheat bran and enzymatic supplementations in wheat bran diets to simulate feed shortages in the Republic of Yemen were determined in five experiments utilizing feed ingredients derived in the USA.

Feeding a single ingredient without adjusting for energy and protein adversely affected broiler performance. In case of feed shortages, barley or sorghum fortified with vitamin and mineral premixes can be fed for short periods (1-2 weeks), especially toward the end of the growing period, while wheat bran can only be used for maintenance purposes.

Mixed grain containing sorghum and faba beans can be fed to broiler chickens from 1 to 49 days of age if 7% herring meal, vitamin and mineral premixes were supplemented. However, growth depression and leg abnormalities may occur. The higher frequency of leg abnormalities needs to be further investigated.

Wheat bran was incorporated in isonitrogenous and isocaloric broiler diets up to 25% without adverse effect on performance. High levels of wheat bran (more than 25%), which is characterized by low energy, need high levels of animal fat which make mixing the diets very difficult. The optimal range for incorporating wheat bran is 10-15% in an isocaloric diet.

Supplementing cellulase (50 and 100 mg/kg diet) or protease (2 mg/g diet) with activities of 4.4 mg/g solid or .30 mg/g solid, respectively, in isonitogenous and isocaloric wheat bran diets did not improve the nutritive value of wheat bran. On the contrary, supplementation of protease adversely affected broiler performance by reducing feed consumption.

The digestibility of acid detergent fiber was significantly reduced when wheat bran levels increased in the diet regardless of the enzymatic supplementations. However, protease supplementation seemed to enhance the apparent nitrogen retention.

The feed grains utilized in these experiments were grown in the USA. These experiments provided information on the potential of feed grains as a single source of feeds. Further testing with broilers on the nutritive values of Yemeni feedstuffs is encouraged because feedstuffs grown in the Republic of Yemen are grown in sunny and dry climate most of the year.

The potential to utilize Yemeni feedstuffs for feeding poultry could be examined by further processing of the feedstuffs. One method of further processing of the feed grains is grinding the whole feed grains. Grinding feed grains disrupts the cell walls and reduces the physical hindrance of the digestive enzymes, thereby, improving the nutritive value of the grains.

Enzyme supplementations have been investigated in this study; however, supplementation of enzymes such as beta-glucanase and cellulase to broiler rations containing barley or wheat bran diets, respectively, could be further investigated to determine the nutritive values of the feed grains.

Sun-curing of blood from animal slaughter houses is another method to obtain blood meal which can be fed to broilers.

Two alternative sources of poultry feed are left-over bread (Kedam), which is composed of many types of flours, and animal offal from slaughter houses. Animal offal contains high percentage of fat and crude protein which could be utilized as poultry feedstuff if properly processed.

Research on these methods of processing of feed grains and on by-products for poultry feed becomes necessary when the sources of complete mixed poultry feed, corn-soybean meal are not readily available.

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APPENDICES

APPENDIX 1

Effect of Feeding Single Ingredient Fortified
With Vitamins and Minerals on Broiler Performance
(Pre-Treatment Period)

The data contained in this appendix provide the reader with mean body weight, feed consumed, feed conversion, apparent protein efficiency ratio, total plasma protein and hematocrit at 28 days of age (before the commencement of the experiment).

Table A1.1. Mean body weight, total feed consumed (F cons), feed conversion (F conv), apparent protein efficiency ratio (APER), Total plasma protein (TPP), and hematocrit of broilers fed corn-soy diet prior to feeding a single ingredient from 1 to 28 days of age (Experiment 1)

Dietary treatment		Mean body weight						TPP		Hematocrit	
Age	(days)	Male	Female	M+F	F cons	F conv[1,2]	APER[1,3]	Male	Female	Male	Female
		-	g	-	g/bird			g/100 ml		- % -	
Corn-soy	1-28	1015	906	960	1706	1.78	2.30	3.8	3.5	32	34
Corn-soy	1-28	1034	934	984	1678	1.73	2.37	3.7	3.4	32	32
Corn-soy	1-28	1049	888	968	1700	1.76	2.33	3.6	3.55	33	30
Corn-soy	1-28	1007	877	942	1688	1.79	2.28	3.7	3.4	38	32
Corn-soy	1-28	1048	906	977	1707	1.74	2.34	3.8	3.8	37	31
Corn-soy	1-28	1040	922	981	1688	1.72	2.38	3.4	3.8	37	38
SEM[4]		24	26	30	16	.05	.05	.13	.15	2.9	2.6

[1] Mean values in the same column were not significantly different (P>.05).
[2] Feed conversion is grams of feed consumed per gram of body weight gain.
[3] PER is gain in body weight per gram of protein consumed.
[4] SEM is the standard error of the mean.

APPENDIX 2

Mean Squares of Mean Body Weight, Feed Consumed, Feed Conversion, Apparent Protein Efficiency Ratio, Acid Detergent Fiber Digestibility, Nitrogen Retention and Total Mortality (Experiments 4 and 5)

The data in this appendix provide the reader with mean squares of mean body weight, feed consumption (F cons), feed conversion (F conv), apparent protein efficiency ratio (APER), total mortality, acid detergent fiber digestibility (ADF), and apparent nitrogen retention (ANR) of broilers fed cellulase or protease treated wheat bran from day-old to 21 days of age (Experiments 4, 5)

Table A2.1. Mean squares of mean body weight, feed consumptions (F cons), feed conversions (F conv), apparent protein efficiency ratio (APER), total mortality (Total mort), acid detergent fiber (ADF) digestibility and apparent nitrogen retentions (ANR) of broilers fed graded levels of wheat bran (WB) and cellulase (C) from day-old to 21 days of age

			Mean squares								
			Mean body weight								
Age (days)	Source of variations	df	Male	Female	M+F	F cons	F conv	APER	Total mort	ADF	ANR
			--	10^2	--						
7	WB	2	2.1	3.5	2.5	1.8	.04	.34			
	C	2	1.4	3.7	1.9	3.0	.01	.26			
	WB X C	4	.6	2.4	1.0	2.0	.03	.14			
14	WB	2	47	61	53	91	.12	.02			
	C	2	22	13	13	4	.01	.09			
	WB xC	4	13	17	6	4	.01	.05			
21	WB	2	64	67	62	168	.003	.03	134	376	10
	C	2	31	10	1.5	16	.004	.01	443	.03	4
	WB xC	4	38	19	5	2	.01	.06	165	.26	1.12

Table A2.2 Mean squares of mean body weight, feed consumptions (F cons), feed conversion (F conv), apparent protein efficiency ratio (APER), total mortality (Total mort), acid detergent fiber (ADF) digestibility, and apparent nitrogen retentions (ANR) of broilers fed graded levels of wheat bran (WB) and cellulase (C) from day-old to 21 days of age

			Mean squares								
			Mean body weight								
Age (days)	Source of variations	df	Male	Female	M+F	F cons	F conv	APER	Total mort	ADF	ANR
			--	10^2	--						
7	WB	2	5	10	7	15	1.1	.34			
	C	1	146	74	107	84	9	10.4			
	WB X C	2	6	5	5	4	1.5	1.2			
14	WB	2	184	127	154	281	.76	.88			
	C	1	1265	905	1077	2126	2.3	.52			
	WB xC	2	23	61	28	46	.54	.14			
21	WB	2	545	420	480	1201	.16	.02	15.4	198	181
	C	1	3901	2543	3186	9183	.25	.24	61.8	.4	77.5
	WB X C	2	139	302	182	363	.15	.06	15.4	1.0	32.5