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Title: NON-CONVENTIONAL FEEDSTUFFS IN RABBITS AND POULTRY NUTRITION: UTILIZATION AND EFFECTS OF FEED PROCESSING METHODS.

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Peter R. Cheeke

Several experiments were conducted to evaluate the utilization of non-conventional feedstuffs, feed additives and feed processing methods on the performance of fryer rabbits, layers and broiler chicks, and on the reproductive performance of rabbit does. The study consisted of three sections: (1) utilization of non-conventional feedstuffs. (2) feed additives, and (3) feed processing methods. In section one, buckwheat, almond hulls and cottonseed meal were utilized at various levels in the diets of rabbit fryers and does. The results indicated that the performance of the fryer rabbits was not affected by any dietary levels of the buckwheat, but only up to 40% almond hulls and 10% cottonseed meal supported adequate growth. Levels above 40% and 10% in almond hulls and cottonseed meal, respectively, were observed to be detrimental to the overall performance. Digestibility of nutrients was not significantly affected by any dietary levels of buckwheat and almond hulls, except

ADF digestibility in the buckwheat diets had negative values. Doe reproduction and other performance parameters were significantly impaired with increasing levels of cottonseed meal. Supplementation of triticale, rye and barley - containing diets with a commercial source of ß - glucanase improved the performance of broiler chickens and laying hens. No effects on the growth or nutrient digestibility of triticale, rye and barley diets were observed in rabbits.

Ammoniation was evaluated as a means of detoxifying natural toxins in various seeds and forages. Ammoniation significantly increased the nitrogen content of wheat mill run and toxin-containing seeds and forages, but did not consistently improve the performance of the chicks. The growth rates of broilers fed ammoniated datura seeds, radish seeds, meadowfoam, and vetch seeds, were improved. This may have been due to a decrease in the toxic constituents of the seeds and forages as a result of degradation under alkaline conditions. Ammoniation of certain seeds and plant materials such as tansy ragwort, crotalaria seeds, endophyte infected tall fescue seeds, cottonseed meal, leucaena leaves, pinto beans and raw soybean had little or no effects on broiler chick performance.

It was concluded that non-conventional feedstuffs can be utilized for animal production; however, due to certain constituents of some of the plants, feed additives or feed processing methods like ammoniation are needed to enhance their utilization for animal production.

NON-CONVENTIONAL FEEDSTUFFS IN RABBITS AND POULTRY NUTRITION: UTILIZATION AND EFFECTS OF FEED PROCESSING METHODS

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DEDICATION

This thesis is dedicated to the memory of my late younger brother Samson Tor-Agbidye, (Bsc. Geosciences posthumous), who was called by the Lord on the eve of his graduation through an accidental gun shot. Brother, although many years have passed by, you will be forever remembered, hopefully we will meet at the Lord's feet in heaven!

And also to my children, Msurishima and Taverishima, and those yet to be born. Children do your best and trusting in God, He will guide you through.

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NON-CONVENTIONAL FEEDSTUFFS IN RABBITS AND POULTRY NUTRITION: UTILIZATION AND EFFECTS OF FEED PROCESSING METHODS

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CHAPTER 1

LITERATURE REVIEW

Introduction

Rabbits and poultry have fast reproductive and growth rates, and are excellent species in converting feed into body weight. They are both known to yield high quality protein meat with low fat. Although poultry are known for utilizing high quality feed, they have small body size, a good feed conversion rate and they yield high quality meat. Rabbits also have a small body size but can be raised on relatively small amounts of non-conventional feedstuffs. They can be produced on grain-free diets, mainly on forages and other type of agricultural by-products. The specific advantages of rabbits have been reviewed by Cheeke et al., (1987). Some of these advantages make rabbits a suitable livestock species for meat production in the developing nations.

To combat the problem of food shortages in developing nations, people of various disciplines (biologists, chemists, biochemists, economists, animal scientists, agriculturalists, manufacturers and consumers) have become involved in the investigations of the use of many types of non-conventional feedstuffs that are either partly in use, or are considered to have reasonable potential in the nutrition of livestock. Boda (1990), suggested the use of more intensive productive plants and cereals rich in protein, and utilization of plants and animal by products into animal feed, while Cheeke (1986), suggested the use of small livestock species (microlivestock) such as rabbits, guinea pigs, grasscutter (*Cricetomys Gambianus*) bush rats of Africa, the blue duiker, dwarf Asian deer, iguana, pigeons and the cabybara. This is because the traditional animals such as goats, sheep, cattle and buffalo, require too much space and have lower reproductive rates (Cheeke 1986, Raharjo 1986, Preston and Leng 1987). There are many non-conventional feeds or agricultural by-products with substantial nutritional value and inexpensively available in large quantities. But currently, they are in a limited use, either due to lack of adequate nutritional information, other uses, or presence of some deleterious constituents like alkaloids, toxic amino acids, phenolic compounds, tannins, trypsin inhibitors, carcinogens, glucosinolates etc. Various sources of agricultural by-products and their nutritional characteristics have been reviewed (Dickey et al., 1971, D'Mello and Whitemore 1975, Smith and Adegbola 1985).

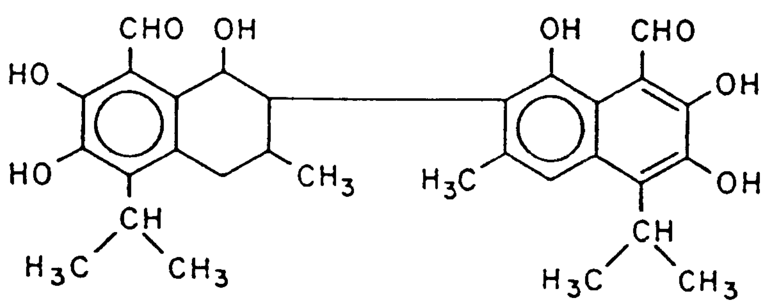
BY-PRODUCTS AS FEEDSTUFFS

Cottonseed Meal

The first record of crushing cotton seed for oil or cake (meal) is associated with the Hindus, where it is believed, the oil was used as a medication for external application. The use of cottonseed oil had earlier been documented in other parts of the world, but it was not until 1768 that extraction of oil was reported in the US. However it was not until fifteen years after the report that a greater interest was developed in this area for oil extraction and (cake) meal production for animal feed (Bailey 1948). Since then, improvements have been made on method of processing for oil and the meal. Presently, commercial processing of cotton is carried out by any one of the four methods; (1) hydraulic pressing; (2) screw pressing; (3) pre-press solvent extraction; (4) direct solvent extract (Beradi and Goldbaltt 1980). The primary objective of any of these methods is to extract oil and to bind the free gossypol pigment in the meal thereby preventing the pigment (unbound gossypol) from being extracted into the oil. Cottonseed meal contains high levels of crude protein (about 40-45%). Its use in animals diets is limited due to the presence of gossypol.

Gossypol is a yellow phenolic compound containing aromatic (benzene) rings with hydroxyl (OH) groups attached. The pigment is found primarily in cotton seeds, but has also been isolated in other parts of the plant, (roots, bark, stem, leaves and taproots) of Gossypium species. Gossypol constitutes about 0.4-1.7% of a cottonseed and is structurally shown to be (2,2'-binaphthalene)-8,8' dicarboxaldehyde - 1,1, '6,6, '7,7'-hexahydroxy 5, 5' diisopropyl 3, 3' dimethyl with a molecular weight of 518.54 and molecular formula or $C_{30}H_{30}O_8$ (figure 1).

Among all the constituents of cottonseed, the pigments have been the subject of numerous studies because of the impact it has had on the oil and the meal relative to its biochemical, physiological and economic influence on livestock feeding and nutrition. Beradi et al., (1980), indicated that the yellow gossypol derivative ($C_{30}H_{30}O_8$) is the major naturally occurring pigment. The gossypol pigment was first isolated by an English chemist Longmore, in 1866; and a Polish chemist (Marchlewski), crystallized the acetic acid derivative and named it gossypol, designating its genus, (Gossypium), and chemical nature, (phenol). In 1915, Withers and Carruth established that gossypol was the toxic factor in cottonseed meal (Abou-Donia 1976, Adams et al., 1960).



Gossypol
Cottonseed meal contains a toxic polyphenol called gossypol. Gossypol causes reduced growth and feed intake, cardiac lesions, and male infertility.

Figure 1.1. Chemical structure of gossypol

Cottonseed meal and gossypol effect on livestock.

Gossypol causes three main problems in the livestock industry: (1) tissue pathology and physiological effects. (2) binding of the epsilon amino group of lysine, resulting in a reduction in lysine availability. (3) discoloration of the egg yolk after storage of eggs from layers fed cottonseed meal. There are marked species differences in terms of response to the toxic effect of gossypol in cottonseed meal (Beradi and Goldblatt 1980).

Ruminants

Ruminants are less susceptible than non-ruminants to gossypol toxicity. The mechanism is thought to involve the toxic free gossypol becoming bound to soluble proteins in the rumen and to the epsilon amino group of lysine forming a permanent bond, thereby preventing gossypol absorption. The bond is not easily broken by proteolytic enzymes secreted in the lower gut. The rumen microbes may have a role in this process (Reiser and Fu 1962). If the rumen detoxification process is by passed for some reason, toxicity can occur with varying toxicity signs and symptoms. Young calves with functionally undeveloped rumens are more susceptible to gossypol toxicity than adult bovines (Martin 1990, Holmberg et al., 1988).

Gossypol toxicosis in sheep can be caused by ingestion of large amounts of gossypol-containing diets or injection of gossypol acetic acid (GAA) (Morgan et al., 1989). The situation in sheep production is the need for earlier weaned lambs (6-8 weeks of age) during which its rumen has three stages of development: (1) nonruminant phase, from birth to three weeks old; (2) transitional phase from three weeks to eight, and (3) a functioning ruminant phase, from eight weeks onward. In young lambs, an intake of gossypol-containing diet may result in similar toxicity symptoms, hence young sheep (lamb) of less than eight weeks can be treated as nonruminants (Martin 1990, Waldroup and Coombe 1960, and National Research Council 1984).

Poultry

Utilization of cottonseed meal in poultry diets is limited by the constituents of the meal that affect or limit its efficient utilization. These include oil, gossypol, fiber, lack of available amino acids (lysine) and total protein. Detrimental effects in poultry include reduced feed intake, efficiency of feed utilization, growth rates, fertility and or hatchability, egg production, physiological and biochemical findings as well as increased mortality rates, especially if the dietary levels of free gossypol exceed 0.04% (Phelps 1966, Abou-Donia and Lyman 1970, Vohra et al., 1974, Fitzsimmons et al., 1989). Although gossypol causes discoloration of egg yolks and whites, iron salts such as ferrous sulfate ($FeS0_4 .7H_20$) inactivate gossypol, hence reducing effects on egg yolk and white yolk (Fletcher et al., 1953 Kemmerer et al., 1965).

Swine

Deleterious effects of gossypol have limited the efficient use of cottonseed meal in the diets of swine. Signs of gossypol toxicity in swine include labored breathing, (dyspnea), decreased growth rate and anorexia. Postmortem findings can include fluid accumulation in the peritoneal cavities, edema, and congestion in the liver and lungs (Haschek et al., 1989, Morgan 1989).

Laboratory Animals

Rabbits, rats and mice are the most common species of animals used in the evaluation of the nutritional, pathological or fertility effects of gossypol. Herman and Smith (1973) reported that as the dietary levels of the gossypol increased, the rate of iron absorption tended to decline in rats fed different levels of gossypol-containing diets. Braham and Bressani (1975) observed that weight gain of rats was adversely affected by gossypol in the diets. Menual (1923), using gossypol crystallized from acetic acid, orally administered 0.5 gm to rabbits of about 4 lbs (2 kg) and reported that the rabbits ceased eating, but had no symptoms of gossypol poisoning. Cheeke and Amberg (1972) reported that rabbits fed a diet containing 13.5% CSM showed reduced growth, but supplementation with lysine and methionine improved weight gains. They concluded that the poor performance observed in the unsupplemented group was due to an amino acid deficiency rather than gossypol problems. Johnston and Berrio (1985) observed that feeding cottonseed meal-based diets to lactating does resulted in reduced milk production and poor litter growth. But McNitt et al., (1982) reported no significant difference with respect to rate of gain, feed efficiency, and semen quality when fryer rabbits were fed up to 17% CSM based diets. Literature dealing with utilization of cottonseed in rabbits has been reviewed by Mcnitt (1981).

Antifertility effects of cottonseed meal or gossypol

Cottonseed meal and other cottonseed products have long been used to supplement other protein sources or protein deficient diets for both human and animals. Antifertility effects were identified during the 1950s due to lack of child birth for a period of over ten years in the Habethi province of China, where cottonseed oil had been used in the people's diet. Several investigations were initiated in the 1960's on both animals and humans, leading to the discovery that gossypol is capable of inhibiting male fertility (Anonymous 1978). About 4,000 men placed on a 20 mg gossypol pill per day for more than six months became infertile with an antifertility efficacy of 99.9%. This was evaluated by sperm examination which showed decreased motility and malformed spermatozoa, followed by gradual drop in sperm count until azoospermia was achieved. The process by which gossypol exerts its effect on spermatozoa is that the gossypol first damages the spermatids, and then with increase in dosage, spermatocytes are damaged, subsequently, the spermatids and spermatocytes are exfoliated with numerous dead spermatozoa, with dead heads and separated tails causing a decreased count in sperm and azoospermia (Zirkle et al., 1988). Randel et al., (1992) has reviewed literature on the effects on gossypol and cottonseed products on the fertility of various species of animals.

Effects on blood constituents and enzymes

In the digestive tract, the microvilli of the small intestinal lining are exposed to gossypol when cottonseed products are consumed. Gossypol that is found in cottonseed products can react with enzymes like pepsinogen to form a zymogen (inactive pepsinogen) called gossypolpepsinogen that cannot be inactivated. The substance can be absorbed and transported from the gastrointestinal tract to the liver, kidneys, muscles, fat and other tissues and could interfere with several types of enzymes. If not absorbed, it can bind the epsilon group of lysine and phospholipids in the cytoplasmic membrane altering membrane permeability and causing a change in the intracellular potassium concentration (Finlay et al., 1973, Wong et al., 1972, Morgan et al., 1988).

Effects of gossypol on other enzymes like the transaminases, serum glutamic oxaloacetic transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT) have also been demonstrated. Morgan et al. (1988) and Braham et al. (1967) indicated that in organs like skeletal muscles, liver, heart, and brains where large quantities of enzymes abound, a mild injury from substances like gossypol will cause the release of enzymes into the circulatory system thereby inhibiting their activities. However, Ali and El-Sewedy (1984) suggested that gossypol had no effects on SGOT and SGPT. Gossypol has also been associated with irreversibly inhibiting DNA synthesis (McClathy et al., 1985, Adlakha et al., 1989). But it has been indicated that gossypol does not interact directly with DNA but, rather with some of the enzymes involved in DNA replication like adenylate cyclase (ATP pyrophosphate lyase) in a dose dependent manner. Gossypol has also been shown to exert a wide spectrum of effects on disease conditions like tumor and HIV virus (Wu et al., 1989); membrane structural / functional perturbations (membrane order liposome permeability), (DePeyster et al., 1986); and on lipid membranes (Reyes et al., 1984). The effects of cottonseed meal or cottonseed products and / or gossypol acetic acid on various other species of animals have been investigated by several researchers, and others have extensively reviewed literature dealing with this subject in both humans and animals (Markman and Rzhekhin 1968; Beradi and Golblatt 1980; Coppock et al., 1987; Shandilya and Clarkson 1982).

FEED ADDITIVES

Feed additives are defined as non-nutritive substances that can be added to feeds to improve the efficiency of feed utilization, feed acceptance, health and metabolism of the animal in one way or the other. There are many different types feed additives, however Cheeke (1991) classified feed additives into four broad classes based on either their principal biological or economic effects:

I. Additives that influence feed stability of feed manufacturing and feed properties.

II. Additives that modify growth, feed efficiency, metabolism and performance.

III Additives that modify animal health.

IV. Additives that modify consumer acceptance.

Scott et al., (1982) stated that another class of additive is that which is used to potentiate the disease-curing effects of antibiotics.

Certain naturally occurring substances of plant origin like pectins, tannins, polysaccharides, cellulose, and beta-glucans are sometimes found in feedstuffs that nonruminant animals cannot digest, because they do not synthesize the required enzymes. However, commercially produced enzymes such as cellulases and ß-glucanase are used to aid digestion in nonruminants fed feedstuffs containing such substances as **barley, triticale** and **rye.**

Barley

Barley (*Hordeum vulgare*) is widely grown in the northern areas of North America (US and Canada), Europe, China, and the Soviet Union. It ranks fourth among the grains of the world after corn, wheat and rice, and it is also a source of energy used as a livestock as a feedstuff. Although barley is lower in digestible energy than corn and sorghum, it is higher in protein content and quality than corn. Its lower energy value is associated with its high fiber, lower starch and the high contents of a poorly digested water-soluble carbohydrates called **ß-glucans** (Edney et al., 1989, Petterson et al., 1990).

ßeta-glucans are a part of the hemicellulose component of the plant cell structure that contain a polymerized ß-glucose linked together by a chemical bond known as $(1\rightarrow3)(1\rightarrow4)$ ß-D-glucan. They are viscous, hygroscopic, gummy and are different from those found in starch ($\alpha\rightarrow1\rightarrow4$ and α-$1\rightarrow6$). The hygroscopic and gummy material causes wet and sticky feces and is responsible for wet litter problems in poultry. Glucans can also impede nutrient absorption resulting in plugging of the vent, particularly in chicks (pasty vents). The viscous content is responsible for preventing the formation of micelles, thus inhibiting the absorption of fat and other nutrients. On the average, some varieties of barley, particularly those grown in the Pacific Northwest, are known to contain up to 1.5 - 8% ß-D glucan (Rotter et al., 1989a, Campbell and Classen 1989).

The deleterious effects of the ß-glucan content of barley can be overcome either by soaking or steeping in water, and by additions of commercially prepared enzymes (ß-glucanase) to diets containing the grains. Soaking or steeping is believed to activate the ß-glucanase enzyme already present in barley seeds, hence reducing the glucan effects. The commercially prepared enzyme (ß-glucanase) and other complex carbohydrate digesting enzymes aid nonruminant animals in digestion of the grains and improve the utilization of ßeta glucan containing diets (Petterson et al., 1990; Cheeke 1991; Campbell and Classen 1989).

Utilization of barley in poultry and turkeys

The beneficial effects of incorporating ß-glucanase into the diets of broiler chickens containing barley is well documented. Campbell and Classen (1989) indicated that when ß-glucanase was added to barley, it resulted in the cleavage of the ß-glucan chain and reduction of the viscosity effect, thereby eliminating the encapsulating effect of the ß-glucan and exposing the intracellular starch and protein to the endogenous enzymes for proper digestion. Inclusion of enzyme preparation (B-glucanase) in the diets of chickens containing barley and rye resulted in improved body weight gain, feed intake, feed efficiency and energy digestibility (Petterson et al., 1990). Enzyme supplementation can also reduce the incidence of pasted vent (Rotter et al., 1989b, Hasselman et al., 1982) indicated that apart from improvement in general performance and reduction in fecal moisture, enzyme supplementation also resulted in improved cage cleanliness. Classen et al. (1988) indicated that addition of enzyme increased fat and starch absorption in chicks fed diets containing hull-less barley.

Layers have a lower energy requirement than broilers, so a lower energy feedstuff like barley seems to be a more suitable ingredient for layers than for broilers.

However, it has been suggested that one of the periods of concern in feeding barley to layers is between the age of 20-40 weeks. During this time the layers have higher energy needs and begin to increase their feed consumption to meet both egg production and body tissues demands, but cannot adequately increase the consumption of low energy density feedstuffs. Another problem of feeding barley-containing diets to layers during this time is that it can increase the high moisture content of the excreta resulting in dirty eggs (Campbell and Classen, 1989). However, Coon et al. (1988) reported that feeding layers of 20-36 weeks of age on varying levels of barley, (17, 33, 50, 67, 83 and 100%) did not affect egg production and egg weights. However, following a reduction of the metabolizable energy, crude protein, lysine and methionine in the diets of the same layers at 36 - 64 weeks of age, egg production, egg weights and body weights were significantly decreased.

Supplementation of hull-less barley with ß-glucanase significantly improved weight gains, feed conversion, passage rate and fat digestibility in 0 - 4 weeks old short comb white leghorn cockerels; but at 4 - 6 weeks of age, there was no significant difference in all the parameters evaluated with or without enzyme supplementation (Salih et al., 1991). The general performance was more related to age than treatment. Rotter et al., (1990a) evaluated the use of enzyme supplementation in adult roosters fed barley-containing diets, and reported that enzyme supplementation increased the overall energy value of the barley grains by 3%, but the general performance was not affected by supplementation.

Turkeys respond in a similar manner as broilers when fed barley diets with enzyme supplementation. Campbell and Classen (1989) and Muirhead (1990) reported that addition of ß-glucanase to barley-containing diets for turkeys significantly increased body weight, carcass yield and feed conversion and reduced mortality and litter moisture. They also indicated that ingredient cost including that of the enzyme was significantly reduced when barley was used, and they concluded that additions of enzyme and fat to barley was necessary to achieve the maximum performance in turkeys.

Rye

Rye (*Secale cereale L*) is believed to have originated from south western Asia. It is a hardy plant and has the ability to grow in sandy soils of low fertility, hence it is grown in areas not generally suitable for growing other cereals. Rye grain is used for making bread, and can also be used as a livestock feed. The green plant is often used for livestock forage. The protein value of rye seeds (6.5% - 14.5%) compares with that of other grains, and is considered to be superior to that of wheat and most other cereals in biological value. However, the availability of the protein is reduced due to the presence of trypsin and chymotrypsin inhibitors and some constituents like alkyl resorcinols, pectins, pentosans, water soluble glucan, which are also known to limit its efficient utilization in animal feeding (Bushuk 1976;

Cheeke 1991).

Utilization of rye in poultry

As in barley, beneficial effects of enzyme supplementation of rye have been reported. Proudfoot and Hulan (1986) fed varying levels of ground rye grain (0, 5, 10, 15, 50 and 25 %) to layers and reported that egg production and feed efficiency were lower in diets containing higher levels of rye, but other performance parameters like egg specific gravity, egg weight and haugh unit were not affected as a result of dietary treatments. It was concluded that up to 25% rye can be included in the diets of layers without any adverse effects on specific gravity, egg weight and / or haugh unit values. Diets containing more than 40% rye are known to cause depression in egg production (Campbell and Campbell 1989; Petterson and Äman 1988). Petterson et al., (1991) indicated that enzyme supplementation of rye, barley and wheat-containing diets in layers diminished the high viscosity of the grains and resulted in improvement of weight gain, egg production, starch digestibility and sticky dropping incidence.

Triticale

Triticale was developed by crossing wheat (*Triticum durum*) and rye (*Secale cereale*) for the purpose of combining the grain yield, flour quality and disease resistant abilities of wheat with the vigor, winter hardiness, and protein content of rye to produce a superior grain. There are over 55 varieties that are grown all over the world today, most of which are similar to wheat grain in production (Maurice et al., 1989, Cheeke 1991).

Utilization of triticale in poultry

Triticale has not lived up to its expectations, especially as a livestock feed, because it contains tannins, trypsin and chymotrypsin inhibitors and other antinutritional factors like alkyl-resorcinols which are responsible for inhibiting the digestion of triticale protein and interfering with poultry performance. Ruiz et al., (1987) reported that when triticale partially replaced corn in the diets of broiler chicks, the mean body weight was lower compared to the corn based diet, and about 58% of the birds had pasted vent. As with other ß-glucan-containing grains, enzyme supplementation has some beneficial effects. Petterson and Äman (1988) indicated that triticale (Sv 8008) grain without supplementation gave an intermediate production level, but upon supplementation with enzyme, the performance increased to that of wheat, suggesting that enzyme supplementation improved utilization of triticale in broiler chickens. Similar observations have also been reported by Charles (1985). Other reports have also indicated that feeding layers varying levels of triticale (0, 50, and 100%) produced no deleterious effects on feed intake, body weights, feed conversion, egg production, shrinkage and dressing percentage, Maurice et al., 1989). They also suggested that triticale may be a better alternative feed source than barley in layer diets. It has been suggested that lower egg production and performance of layers fed triticale may be due to a deficiency of one or two essential amino acids and fatty acid, particularly linoleic.

FEED PROCESSING METHODS

There is an abundance of by-products and other non-conventional feedstuffs in the world that can be used as alternative sources of energy and protein feedstuff for livestock production, but often the techniques for making them more profitable for animal feeding systems are unknown or too difficult to implement for efficient livestock production. As a result, millions of tons of potentially valuable feed are either discarded or underutilized on annual basis, and in many instances, they have become environmental or pollution problems (Boda 1990). As a result of economic and ecological pressures on the environment, the need for efficient disposal of such products has become of paramount importance. A possible effective disposal method is by way of converting these products of various sources (agricultural by-products, forestry products, animal wastes, municipal refuse and crop residues) into energy sources for livestock feeds (Huber 1981). Such sources can be effectively converted into livestock feeds through different feed processing methods. One such method is ammoniation; others may include hydrolysis, composting, dehydration, cooking, grinding and extrusion.

Ammoniation

Ammoniation is one of the feed processing methods that can be employed in treatment of fibrous feedstuff, crop residues, and other types of by-products to improve their utilization in livestock feeding. It was first studied in Germany many years ago after a marked improvement was achieved by treatment of straw with caustic soda (NaOH) (Sundstól and Coxworth 1984). Ammoniation can be accomplished by either the use of ammonia hydroxide (NH_3OH) or gaseous ammonia, both of which are effective in dissolving lignin, solubilizing hemicellulose, causing swelling of cellulose and providing supplemental nitrogen that can utilized by microbes for protein synthesis (Sundstól and Coxworth 1984, Cheeke 1991).

Ammonia (NH_3) is a colorless gas with penetrating odor under standard conditions, and has a molecular weight of 17.03. Under laboratory conditions ammonia may be formed as the product of a number of chemical reactions which may include the following:

1. Ammonia salts with a strong base. [$NH_4^+ + OH \leftrightarrow NH_3\uparrow + H_2$].

2. Hydrolysis of urea. [$(NH_2)_2Co + H_2O \rightarrow 2NH_3 + CO_2$].

3. Nitrogen with hydrogen in the presence of a catalyst.

$$[\tfrac{1}{2}N_2 + 1\tfrac{1}{2}H_2 \leftrightarrow NH_3 + CO_2 + 11 \text{ Kcal/mole}].$$

(National Academy of Science 1979).

Although urea can be used as a source of ammonia for treatment of straw, it may be less effective than anhydrous ammonia because of the formation of a carbonate which decreases the Ph of the straw, hence reducing the alkalinity effect of the conformational changes in fiber. Ammonia can also be generated from other nitrogenous materials such as poultry manure, and human and animal urine. The use of the latter has been researched in Bangladesh; however, they are relatively new techniques currently being developed (Preston and Leng 1987, Makkar and Singh 1987).

The beneficial effects of treating straw with ammonia under different conditions have been reviewed (Sundstól and Coxworth 1984). Zorrilla-Rios et al., (1985) reported that ammoniation of straw increased crude protein, cell wall constituents, rumen ammonia and dry matter. They also indicated that ammoniation improved feed intake and dry matter digestibility. Brown et al., (1987) reported that dry matter intake, daily gain, and feed to gain ratio were improved as a result of treating low quality forage (limpograss and straw) with ammonia. They also indicated that the apparent digestion coefficients of organic matter, neutral detergent fiber, acid detergent fiber and hemicellulose were improved, and concluded that ammoniation could provide an opportunity for improving the feeding value of low quality forages by providing an option to the traditional winter feeding programs. Other beneficial effects of ammoniating low quality forages and by-products on beef cattle and buffalo calves have been reported (Ibrahim et al., 1985, Makkar and Singh 1987, Ward and Ward 1987, Tiwari et al., 1990). However, Alhassan and Aliyu (1991) found that although the digestibility of organic matter, crude protein and feed intake were improved as a result of treating corn straw with urea, weight gain was not influenced. Grings and Males (1987) also did not find any improvement in the performance of beef cattle fed ammonia treated wheat straw.

Harrera-Saldana et al., (1983) reported that treating wheat straw with anhydrous ammonia and ammonium hydroxide (NH_4OH) improved utilization of nutrients such as dry matter, organic matter, and acid detergent fiber in sheep. Streeter and Horn (1984) indicated that lambs fed ammoniated wheat straw consumed 34% more, and the nutrient digestibility, ruminal Ph and plasma urea concentration were higher when compared to those fed untreated wheat straw. Similar observations in sheep have been reported (Brand et al., 1989a; Llamas-Lamas and Combs 1990; Schneider and Flachowsky 1990).

Straw and other fibrous materials are important in the maintenance of digestive transit, normal function and formation of hard feces, and also in preventing enteritis in rabbits (Lebas and Leplace 1977, Uden and Van Soest 1982, Cheeke et al., 1987). However, Fayek et al., (1989) did not report any beneficial effects in growing rabbits when they were fed urea treated saw dust.

Apart from improvement in the quality of straw and other low quality roughage for animal feeding, ammoniation has been reported to be beneficial as a means of detoxification of toxic constituents of plants and by-products. Bell et al., (1984) reported that glucosinolate content of mustard and other brassicca meals was reduced as a result of ammonia treatment. Norred and Morrissey (1983) found that ammoniation of aflatoxin-containing corn eliminated its toxicity in rats. Ammoniation of sweet clover hay increased the nitrogen content and reduced dicourmarol levels and prevented the bleeding disease associated with sweet clover hay when fed to livestock (Sanderson et al., 1985). Kerr et al., (1990) reported that ammoniation of endophyte-infected tall fescue hay reduced its toxicity to steers. They concluded that ammoniation may be a practical solution to some of the fescue related economic problems in cattle.

The toxic constituents of plants have different types of biological impact on different species of livestock. Pyrrolizidine alkaloids (PA's), found in plants like tansy ragwort, (*Senecio jacobaea*), Crotalaria (*Crotalaria spectabilis*), tall fescue (*Festuca arundinacea*) and various other species (*Heliotropium, Echium* and *Amsinckia*) are usually bitter in taste and function primarily as the chemical defense mechanism of plants. The PA's are not poisonous until metabolized by liver tissue to hepatoxic metabolites (pyrroles) causing irreversible liver damage. The PA's are hepatoxic to many animals and are responsible for losses of large numbers of livestock throughout the world (Buckmaster et al., 1984; Cheeke and Shull 1985; Cheeke 1988; Deyo and Kerkvliet 1990).

Hooper and Scalan, (1977) indicated that feeding chicks and pigs varying levels of crotalaria seeds caused decreased weight gain and high rate of mortality. Crotalaria is not only hepatoxic, it can also damage pulmonary, renal organs and cause fetal death and malformations in animals (Johnston and Smart, 1983). Goeger et al., (1982) reported that feeding tansy ragwort to lactating and kid goats resulted in mortality with obvious signs of alkaloid toxicosis. Cheeke (1984) indicated that cattle and horses are more susceptible than goats, sheep and other non-ruminant herbivores (rabbits, gerbils, guinea pigs,and hamsters) to alkaloid toxicosis.

Jimsonweed or thorn apple (*Datura stramonium*) contains tropane alkaloids including atropine known to affect the central nervous system and causing other types of impact on livestock performance. Day and Dilworth (1984) reported that a dietary level of 3% and 6% jimsonweed drastically depressed performance of young broilers. However, Flunker et al., (1987) indicated that more than 3% of jimsonweed seed would be required to depress performance in broilers. Other effects of jimsonweed seeds reported included depressed weight gain, decreased serum albumin and serum calcium, increased liver and testes weights, increased serum alkaline phosphate and blood nitrogen of rats (Dugan et al., 1989, Crawford and Freidman 1990).

Tall fescue (*Festuca arundinacea*) is a vigorous, coarse perennial grass grown in pronounced clumps. There are several types of alkaloids in tall fescue with perloline as the major ones implicated in fescue toxicoses and a number of physiological problems in animals. The toxicity of tall fescue is due to the infection of the plant by the endophytic fungus (*Epichlore typhia*) which upon parental administration or ingestion can result in symptoms of convulsion, muscular incoordination, increased pulse and respiration rates, mild photosensitization and coma. The ergot peptide alkaloids (*ergovaline*) produced by the endophyte in tall fescue also causes fescue toxicosis, causing decreased prolactin, increased body temperature, and powerful vasoconstrictive effects. The tall fescue alkaloids can also cause prolonged gestation, thickened placentas, large weak foals, dystocia, agalactia in pregnant mares, neurohormonal imbalances of prolactin and melatonin, restricted blood flow to internal organs, aberrant reproduction, decreased growth, slow maturation and a general decrease in livestock performance particularly cattle and sheep (Cheeke and Shull, 1985, Porter and Thompson 1992).

Apart from the major oil seeds like soybean and cottonseed meals which are traditionally used as protein sources in animal feeds, there are also many others that could as well be utilized for the same purpose. Some of these are in the brassica family which include cabbage, brussels sprouts, kohlrabi, kale, meadow foam, rapeseed, broccoli, radish, mustard and turnips. The brassica family plants are known to contain glucosinolates (glycosides of ß-D- thioglucose) that yield isothiocyanates, nitrile, and thiocyanates on hydrolysis by an enzyme system producing varying adverse effects on livestock consuming them. The major effects of glucosinolates products in animal production include goiter (enlarged thyroid gland), decreased feed intake, liver and kidney lesions, and poor performance in animals consuming them (Cheeke and Shull 1985; Vermorel et al., 1988; Bell et al., 1987; Rowan and Lawrence 1986; Bourden and Aumaître 1990). However, it has been reported that the deleterious effects of glucosinolate can be lowered by ammoniation. Canola seeds containing high levels of glucosinolates, treated with lime or ammonia, resulted in a lowered tainting potential by reducing the progoitrin, soluble tannin, sinapine contents and improved feed intake in pigs, but the treatment effects were not sufficient to prevent the trimethylamine effects on eggs (Fenwick et al., 1984; Bell et al., 1987). Another glucosinolate containing seed, meadowfoam has been evaluated as a feed for nonruminants, rabbits and chickens, and a satisfactory performance observed in lambs that were fed raw meadowfoam. Miller and Cheeke (1986) indicated that up to 25% of meadowfoam could be fed to beef cattle without adverse effects on performance. The effects of other classes of toxicant containing seeds and forages like kohlrabi, whole cottonseed, vetch seeds, leucaena leaves, pinto and kidney beans, bracken fern and raw soybean on the performance of livestock have been documented (Cheeke and Shull, 1985; Cheeke, 1991; Fenwick, 1988; Gumbmann et. al., 1989).

It is clear that some of these toxic containing forages and seeds cannot be effectively utilized for livestock production without processing to achieve good performance. The purposes of processing any feedstuff and by-product for animal feeding are mainly to eliminate their negative effects, hence bringing about improvement in digestibility, palatability, acceptability as well as alteration of particle size, extension of shelf life, increase in nutrient make up, and detoxification of toxic constituents. The motivation for this study dealing with ammoniated feedstuffs was to assess the potentials of ammoniation as a feed processing method on animal performance, digestibility, palatability, acceptability, nutrient make up, and detoxification of toxic-containing products (seeds and forages) of different classes of toxicants. The overall main objectives of this study were :

1. To evaluate the nutritional value of various non conventional feedstuffs on the performance of rabbits and broiler chickens.

2. To evaluate the effect of ß-glucanase supplementation in high and low glucan barley, triticale and rye diets on the performance of rabbits, broiler chicks and laying pullets.

3. To determine the effects of ammoniation (feed processing methods) on the nutritional value of wheat mill run and toxic containing forages and seeds on the performance of rabbits and broiler chickens.

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PART ONE: UTILIZATION OF BY-PRODUCTS

CHAPTER 2

NUTRITIONAL EVALUATION OF BUCKWHEAT (Fagopyrum esculentum) IN DIETS OF WEANLING RABBITS

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ABSTRACT

The effect of dietary buckwheat level on the digestibility of buckwheat-containing diets and the performance of weanling rabbits was evaluated. Seventy-two 4-week-old New Zealand White weanling rabbits of both sexes were randomly assigned to one of the six treatment groups with twelve rabbits per treatment. The experimental diets consisted of a high fiber control (OSU 7); a corn-based diet (basal) and diets with 10%, 20%, 40%, and 60% buckwheat in place of corn. The diets were balanced to be isonitrogenous and equicaloric. Average daily feed intake (g) was highest with OSU 7 (130) but not significantly different (P>0.05) from diets containing 40% (119) and 60% (115) buckwheat. Average daily feed intakes of the basal (108) and buckwheat-containing diets were also not significantly different (P>0.05). Average daily gain was lowest in 20% buckwheat (34) but was not significantly different (P>0.05) from all other diets except 40% buckwheat which had an average daily gain of 39 g. Feed efficiency was poorest with OSU 7 (3.70) but was not significantly different from the rest of the diets except the basal and the 10% buckwheat which had the best efficiency ratios of 3.00 and 2.90, respectively. Nitrogen digestibility was similar across all dietary treatments. Dry matter digestibility and energy digestibility (63%) were significantly lower (P<0.05) in the OSU 7 diet compared to the other diets. The buckwheat-containing diets were not significantly different (P>0.05) with respect to DM digestibility. The ADF digestibility was lowest in all diets containing buckwheat and was significantly higher (P<0.05) with the OSU 7 (21%) and basal (11%) diets. Hence

it appears that buckwheat can be used at levels of at least 60% of the diet without adverse effects on weight gain, daily intake, and feed efficiency, digestibility of dry matter, nitrogen and energy.

INTRODUCTION

Buckwheat is a summer annual crop, grown widely throughout the world. It is believed to have originated from Central and North East Asia. Currently the major world producers include USSR, China, Japan, Poland, Canada, Brazil, United States and Australia. In the US it is concentrated in the Northeast and North Central states (Pomeranz, 1983; Cheeke and Shull, 1985; Anderson and Bowland, 1981). Buckwheat is not a cereal grain because it is not of a grass family. Cheeke (1991) stated that buckwheat is lower yielding than other grains, except it is more productive than other grains when grown on infertile soils. Moreover, it can be grown as a "catch crop" after the failure of another crop or when its too late to plant a cereal crop (Anderson and Bowland, 1984; Pomeranz 1983). Buckwheat can also be grown as a cover crop or green manure crop, and can be harvested within 80-90 days. The seeds, (dark brown or black and pyramidal in shape) can be processed into flour used for pancakes, gruel, bread, pasta products and semolina as human food, whereas the culls are used for livestock feeding.

Buckwheat contains about 11 to 13% crude protein of high biological value, and is an excellent source of essential amino acids especially, lysine, which is limiting in the cereal grains. The essential amino acids in buckwheat are similar to that of cereal grains and eggs (Pomeranz, 1983; Beiley and Pomeranz, 1975). According to Pomeranz (1983), the molecular weight of starch in buckwheat is between 240,000 - 260,000 with the polysaccharide consisting mainly of xylose, mannose, galactose and glucuronic acid. The same author also indicated that the grain is fairly rich in thiamin and riboflavin, while Cheeke (1991), indicated that it is fairly high in fiber content, which reduces the digestible energy value of the grain.

Farrell (1978) in a growth study of rats and chickens reported that buckwheat in a mono-grain diet was superior to other grains. Anderson and Bowland (1984) concluded that buckwheat can be utilized as a replacement for 20-60%, of barley in the diets of growing pigs. Other species of livestock in which buckwheat has been utilized as a supplement include; laboratory rats, (Thacker et al., 1983; Harrold et al., 1980); sheep, (Nicholson et al., 1976). In most cases the conclusion seems to be consistent, that buckwheat is an excellent source of amino acids and can be used to replace cereal grains up to 60% without adverse effect on the performance of the animals.

Even though certain nutritional characteristics of buckwheat have been shown to compare with those of cereal grains, buckwheat is also known to have some deleterious effects and it has been indicated that buckwheat contains high fiber which causes low concentration of soluble carbohydrates in the diets. Thacker

(1983b) also reported that buckwheat contains high levels of tannins. Dietary tannins are responsible for a wide range of nutritional problems including mortality, diminished weight gains and lower efficiency of feed utilization, as well as increased fecal nitrogen. The main physiochemical property of tannins is their strong capacity for binding to proteins (Butler 1989). As a consequence of this propensity for binding protein, enzyme activities are also inhibited under conditions where an enzyme is the only protein available for binding to the tannin. Tannins are also known to have a severe effect on the performance of immature non-ruminants but less on mature ruminants animals (Ikeda, et al., 1986; Butler 1989). According to Pomeranz (1983), buckwheat seeds contain trypsin inhibitory activity particularly against trypsin and α-chymotrypsin but little or no effect on pepsin and papain. Mulholland and Coombe (1979) stated that buckwheat contains a compound called fagopyrin which is a photosensitizing agent. Such agents if absorbed may react with ultraviolet light (sunlight) to produce severe skin lesions; thus animals fed buckwheat may develop photosensitization of the skin if exposed to sunlight.

Because of its similarity with cereal grains and its superior protein and amino acid quality, buckwheat is often used to replace some cereal grains in the diets of different species of livestock (Anderson and Bowland, 1984; Harrold et al., 1980; Thacker et al., 1983; Farrell, 1978; Nicholson et. al., 1976). Farrell (1978) indicated that buckwheat in a mono-grain diet was superior to other cereals in studies with rats and chickens, while Nicholson et. al. (1976) concluded that tartary buckwheat was a satisfactory grain substitute for ruminant animals.

However, there is no data on the utilization of buckwheat by rabbits. The high fiber content of buckwheat makes it of limited use with other non-ruminant species. In spite of the fact that fiber is poorly digested by rabbits, fiber is known to play an important role in maintaining normal functions of the digestive tract and in preventing enteritis which is a common problem in rabbit production (Cheeke et al., 1986). Hence, the high fiber level coupled with the high protein and amino acid content of buckwheat suggest that it could have application in rabbit feeding. Thus, the objective of this study was to determine the effect of buckwheat level on the performance of weanling rabbits and to measure the digestibility of buckwheat-containing diets.

MATERIALS AND METHODS

The proximate composition of buckwheat and the other major dietary ingredients was determined (Table 2.2) and the ration was formulated to the specifications for rabbit diets (NRC, 1977; Cheeke, 1987). Diet compositions are presented in Table 2.1. The main differences in the diets were that the standard OSU 7 had no corn and no buckwheat, but 54% alfalfa, while the basal diet had 30% corn with no buckwheat. The remaining diets had increasing levels of buckwheat, 10%, 20%, 40% and 60%. As the levels of buckwheat increased, the levels of corn which buckwheat was replacing decreased in such a manner that at 40% and 60% levels of buckwheat, corn was completely absent. All other nutrients were balanced to meet the requirements of growing rabbits, and all diets were fed ad libitum.

Seventy-two 4-week-old New Zealand White rabbits of both sexes were weighed and randomly assigned to the six dietary treatments, with 12 rabbits per treatment. The animals were housed in a conventional rabbit facility at the OSU Rabbit Research Center. Each animal was placed in an individual cage measuring 30 x 76 x 46 cm, equipped with an automatic watering device and "J"-type galvanized metal feeder with a screen bottom.

The experiment lasted for 28 days during which total feed consumption was recorded, as well as incidence of enteritis and mortality rates. After three weeks, a fine mesh wire fashioned to collect feces was placed underneath each of the cages. Total fecal collection was conducted daily for seven days for every animal, with the samples placed in plastic zip-lock bags and frozen at -4°C. The fecal samples were weighed and then dried in an oven at 60°C for 72 h and air equilibrated for 48 h. The fecal samples were then ground using a Wiley mill to pass through 1 mm mesh. At the end of 28 d, the final weight gain of each animal was recorded and total feed intake calculated. The results were used to calculate the daily weight gain, daily feed intake and feed efficiency while the ground fecal samples were used to determine the digestibility of nutrients (Table 2.3).

Calculation for determination of nutrients was done on a dry matter basis; all proximate analyses were done using the standard procedures of AOAC (1984). Gross energy was determined using a Parr adiabatic bomb calorimeter according to methods outlined by the manufacturer. Acid detergent fiber was determined by method of Van Soest (1963). The data were analyzed for significance by SAS analysis of variance using Tukey's t-test.

RESULTS AND DISCUSSION

Chemical composition of the diets is shown in table 2.2. Dry matter content was similar in all the diets. Gross energy was lower in the OSU 7 diet (3953.55 kcal/kg) as compared to all others, in which values ranged from 4100.00 kcal/kg (basal diet) to 4018.26 kcal/kg (60% buckwheat). Overall there were no significant differences in gross energy among the diets. Acid detergent fiber (ADF) (22.98%) in OSU 7 was significantly ($P<0.05$) higher than for all other diets. Since high fiber diets are known to reduce the energy value of feedstuffs (Cheeke, 1983; Evans et. al., 1983; Cheeke et. al., 1986; Cheeke, 1991) it is not surprising that OSU 7 with 54% alfalfa and 22.98% ADF was lower in energy level. Also, since energy level of a feed determines its intake (Cheeke, 1991), it was observed that both the total intake and daily feed intake of OSU 7 was significantly higher ($P<0.05$) than the basal, 10% and 20%, but was not significantly ($P>0.05$) higher than 40% and 60% buckwheat (Table 2.3). Average daily gain with the 40% buckwheat (40%) was significantly higher ($P<0.05$) than 20% (33.70), but was not significantly higher ($P>0.05$) than any other diets. This difference could not be attributed entirely to dietary effect because some of the rabbits on 20% buckwheat had diarrhea and poor overall gain, hence reflected in their average daily gain.

Feed efficiency ratios were not significantly (P>0.05) different between the basal (3.00) and remaining buckwheat-containing diets (10%, 2.90; 20%, 3.30; 40%, 3.10; 60%, 3.30), but OSU 7 with a feed efficiency ratio of 3.79 was significantly different (P<0.05) from the rest of the diets. Thacker et al., (1983) and Harrold et al., (1980) fed graded levels of common and wild buckwheat to weanling rats and both indicated that inclusion of buckwheat in the diets improved weight gain, feed intake and feed conversion efficiency. In contrast, Farrell (1978) and Anderson and Bowland (1984) indicated that inclusion of buckwheat at 25, 50, 75 and 100% did not significantly affect daily feed consumption, average daily gain, or feed efficiency in the diets of rats, pigs and chickens. Also, Nicholson et. al., (1976) indicated that inclusion of buckwheat in diets of steers did not affect their rate of gain. The results of this study agree with the findings of Anderson and Bowland (1984), Nicholson et. al., (1976) and Farrell (1978).

Mortality rates (33%) were highest from the basal and 60% buckwheat diets, followed by OSU 7 and 40% buckwheat (25%), but lowest with the 10% and 20% buckwheat diets (1 and 2 animals, respectively). The mortality rates were as a result of enteritis which is known to occur when a diet is low in fiber and high in starch, thus establishing gut conditions of hypomotility, prolonged availability of substrate to bacteria in the cecum and a rich supply of substrate to proliferate and produce toxins which then kill the rabbit (Cheeke et al., 1986).

Digestibility of nutrients

There were no significant differences (P>0.05) in digestibility of crude protein among treatments (Table 2.3). Dry matter and energy digestibility values of OSU 7 were significantly lower (P<.05) than for the other diets. The digestibility of ADF was decreased with increasing levels of dietary buckwheat, with negative values in all buckwheat-containing diets irrespective of percent composition. This is an indication that the fiber in buckwheat is poorly digested. Ikeda et al., (1986) indicated that dietary fiber can have an inhibitory effect on the assimilation of certain nutrients from the gastrointestinal tract. These authors also indicated that feeding animals high fiber-containing diets can result in reduced availability of dietary proteins. This was not observed, however, in this study; the digestibility of nitrogen values were similar in all treatments. Our results were also comparable to those reported by Thacker et al., (1983) who indicated that the digestibility of buckwheat fed to rats was 67.4% for dry matter, 65.8% for nitrogen, and 66.5% for energy. Similar values were reported by Anderson and Bowland (1984).

The amino acid composition of the major dietary ingredients and the experimental diets were calculated table 2.4. The diets were adequate in all essential amino acids except phenylalanine + tyrosine, which were 85% in the 40% buckwheat, 90% in the 20% buckwheat, and 95% in the 10% buckwheat and basal diets, relative to the requirement as outlined by NRC (1977) and Cheeke (1987). However, because of the imprecision with which the requirement is known, it is not possible to state with certainty that these amino acids were deficient. Beiley and Pomeranz (1975), and Thacker et al. (1983) indicated that due to its high levels of essential amino acids, buckwheat seems to be a valuable supplement to grains that are limiting in essential amino acids, especially lysine. Buckwheat is known to be high in amino acids compared to other cereals, and amino acids are usually used to compare nutrient composition of feed ingredients. However, the composition does not reveal the extent of the availability of these indispensable amino acids and/or the overall utilization of the protein moiety of the feed ingredient either per se or as a complement to other protein in the ration (Beiley and Pomeranz (1975).

CONCLUSION

From this experiment, it may be concluded that even though fiber in buckwheat is poorly digested, buckwheat used in a suitable mixture of up to 60% in the diets of weanling rabbits will not adversely affect their performance in terms of average daily intake, average daily gain and feed efficiency, as well as digestibility of dry matter, nitrogen and energy.

Table 2.1. Composition of the buckwheat experimental diets on as fed basis

		Buckwheat diet % composition				
Ingredients	OSU 7	Basal	10	20	40	60
Ground corn	-	30.0	22.0	14.0	-	-
Dehydrated alfalfa	54.0	20.0	20.0	20.0	20.0	20.0
Soybean meal	20.0	10.0	10.0	9.0	8.0	10.0
Wheat mill run	21.0	34.0	32.0	31.0	26.0	4.0
Buckwheat	-	-	10.0	20.0	40.0	60.0
Vegetable oil	1.25	1.0	1.0	1.0	1.0	1.0
Molasses	3.0	3.0	3.0	3.0	3.0	3.0
**Trace mineral salt	0.5	0.5	0.5	0.5	0.5	0.5
Dicalcium phosphate	0.25	0.75	0.75	0.75	0.75	0.75
Limestone	-	0.5	0.5	0.5	0.5	0.5
*Vitamin premix	-	0.25	0.25	0.25	0.25	0.25

* The vitamin premix supplied the following quantities per kilogram of feed: Vitamin A 3,300IU; vitamin D 1,100IU; vitamin E 1.1IU; vitamin K 0.55 mg; vitamin B_{12} 0.0055 mg; riboflavin 3.3 mg; pantothenic acid 5.5 mg; niacin 22 mg; choline chloride 220 mg; folic acid 0.22 mg; ethoxyquin 64.43 mg.

**Trace mineral premix supplied per kilogram of feed, the following: Calcium 107.5mg; manganese 60mg; iron 20mg; zinc 28mg; copper 2mg; iodine 1.2mg and cobalt 0.205mg.

Table 2.2. Chemical composition of the buckwheat experimental diets and the major ingredients.

Nutrient composition

Diets	[b]Gross energy Kcal/kg	[b]Dry matter%	[b]Crude protein%	[a]Acid detergent fiber%	[a]Neutral detergent fiber%	[a]Fat%	[a]Ash%
OSU 7 (Control)	3953.55	90.82	21.28	22.98	33.65	5.72	7.45
Basal	4100.43	89.23	17.16	11.63	26.20	3.65	4.77
10% Buckwheat	4045.17	89.27	17.93	9.96	27.73	4.71	4.79
20% Buckwheat	4041.91	89.20	18.16	10.01	29.94	3.64	4.81
40% Buckwheat	4033.64	88.83	18.66	10.54	32.07	3.54	3.83
60% Buckwheat	4018.26	88.63	18.84	11.35	28.75	4.10	4.08
Major Ingredients							
Buckwheat	2970.00	93.20	14.00	16.70	29.30	2.79	2.34
Corn	3500.00	89.00	9.60	3.00	7.35	3.80	1.30
Wheat mill run	3200.00	90.00	15.80	12.83	42.90	4.10	5.69
Alfalfa	2024.00	92.63	18.78	34.02	41.00	2.70	9.70
Soybean meal	3166.00	89.00	44.60	9.00	12.50	17.20	5.10

[a] NRC., 1984 and calculated values. [b] Analytical values

Table 2.3. Performance of weanling rabbits fed buckwheat (BW) containing diets

Item	OSU 7	Basal	10% BW	20% BW	40% BW	60% BW
Average feed intake (g)	129.50^{a}	108.20^{b}	108.40^{b}	108.80^{b}	119.10^{ab}	115.10^{ab}
Average daily gain (g)	36.60^{ab}	36.10^{ab}	37.50^{ab}	33.70^{b}	38.60^{a}	35.00^{ab}
Feed/gain	3.70^{a}	3.00^{b}	2.90^{b}	3.30^{b}	3.10^{b}	3.30^{b}
Mortality No/12	3.00	4.00	1.00	2.00	3.00	4.00
Mortality%	25	33.30	8.30	16.70	25	33.30
Nutrient digestibility%						
Dry matter	62.59^{b}	70.40^{a}	71.95^{a}	69.43^{a}	70.27^{a}	73.17^{a}
Crude protein	75.74	72.20	74.96	73.31	76.03	75.66^{NS}
Energy	62.50^{b}	71.74^{a}	72.82^{a}	70.46^{a}	71.31^{a}	63.78^{a}
**Acid detergent fiber	20.57^{a}	11.23^{ab}	-5.52^{a}	-3.25^{bc}	-29.47^{d}	-17.73^{cd}

^{a,b,c,d} Means within the same row with different superscripts differ significantly ($P<.05$); ($P<.01^{**}$)

Table 2.4. Calculated amino acid profile of the experimental diets and the major ingredients.

Diets	Crude protein	Arginine	Histidine	Isoleucine	Leucine	Lysine	Methion. + Cystine	Phenyl. + tyrosine	Threonine	Tryptophan	Valine
Control	21.28	1.29	0.49	1.08	1.63	1.10	0.68	1.54	0.86	0.32	1.11
Basal	17.16	0.96	0.38	0.76	1.34	0.70	0.55	1.05	0.63	0.22	0.86
10% BW	17.93	1.00	0.38	0.75	1.29	0.75	0.56	1.04	0.63	0.23	0.86
20% BW	18.16	1.02	0.37	0.73	1.21	0.74	0.54	0.99	0.62	0.23	0.84
40% BW	18.66	1.07	0.36	0.69	1.07	0.72	0.52	0.94	0.62	0.23	0.80
60% BW	18.84	1.13	0.35	0.66	0.99	0.77	0.51	1.04	0.62	0.24	0.76
Ingredients											
Alfalfa	18.79	0.80	0.32	0.84	1.26	0.73	0.52	1.33	0.70	0.28	0.84
Wheat mill run	19.62	0.94	0.40	0.70	1.20	0.57	0.56	0.50	0.36	0.23	0.89
Soybean meal	44.60	3.28	1.15	2.39	3.52	2.93	1.40	3.60	1.81	0.62	2.34
Corn	9.60	0.50	0.20	0.37	1.10	0.24	0.42	0.85	0.39	0.90	0.52
Buckwheat	14.00	1.02	0.26	0.37	0.56	0.61	0.40	0.65	0.46	0.19	0.54

Calculated amino acid content (NRC. 1984).

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CHAPTER 3

EVALUATION OF ALMOND HULLS AS A FEEDSTUFF FOR RABBITS

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ABSTRACT

Fifty weanling New Zealand White rabbits were randomly allotted to five treatments (five males and five females per treatment) and used in a 28 d digestion and performance trial. The trial compared a standard Oregon State University doe herd diet (OSU 4) with diets containing 0% almond hulls (AH), 20% AH, 40% AH and 60% AH, respectively, as replacements for equal amounts of alfalfa meal (ALF). Soybean meal (SBM) and wheat mill run (WMR) were used to maintain similar levels of protein and energy in the diets. In vitro rumen dry matter digestibility (IVDMD) potentials of ALF, WMR, AH and AH plus urea (AH-U, 20% CP) were also measured. AH contained adequate levels of the major chemical components used in rabbit nutrition except for a lower CP content of 6.3%. The percent digestibilities of dry matter (DDM), organic matter (DOM) and gross energy (DGE) among the diets tended to decrease with increasing levels of AH in the diets up to 40% AH and then increased at the 60% AH level. DDM, DOM and DGE values of the AH diets were comparable to those of the OSU 4 and 0% AH diets, indicating that AH could serve as a source of utilizable nutrients for growing rabbits as replacement for ALF. DCP was higher for the OSU 4 and 0% AH diets than for the AH diets. Among the AH diets, CP digestibility was higher for the 20% AH diet than for the 40% AH and 60% AH diets. Digestibility of ash was also higher for the 20% AH diet than for the other AH diets. Average final live weight, live daily gain, daily feed intake and feed efficiency were lower for the 60% AH diet than for the other diets, with no differences among the other diets. AH contained good pellet binding properties. However, pellets made from the 60% AH diets were too hard and resulted in reduced feed consumption. IVDMD values for AH and ALF were similar, suggesting similar cecal fermentation potential in rabbits. AH could be successfully incorporated into the

diet of growing rabbits up to a level of 40% as replacement for ALF without any adverse effects on performance and nutrient digestibility.

INTRODUCTION

The high cost of conventional feed ingredients in rabbit nutrition has generated interest in exploring alternative, inexpensive feed sources. Recent work on the use of almond hulls in livestock diets has involved dairy cattle (Aguilar et al., 1984), dairy goats (Reed and Brown, 1988) and horses (Perks et al., 1989). Reed and Brown (1988) pointed out that almond hulls (the dried fleshy pericarp of almond fruit) are one of the few horticultural by-products that are dried in the harvesting process, and they contain high levels of sugar which could serve as a source of highly digestible carbohydrate in rabbit nutrition. The objective of this study was to evaluate the nutritive value of almond hulls as a replacement for various levels of alfalfa meal on performance and nutrient digestibility of weanling rabbits.

MATERIALS AND METHODS

The nutritive value of almond hulls for rabbits was evaluated in a digestion and performance trial using 50 weanling New Zealand White rabbits (5 weeks old, average weight 973 g) allotted at random (by sex) to 5 treatments with 10 rabbits (5 males and 5 females) per treatment. The trial compared a standard Oregon State University diet (OSU 4) with diets which contained 0, 20, 40 and 60% almond hulls, respectively, as replacements for equal amounts of alfalfa meal. Soybean meal and wheat mill run were added to the various diets to maintain similar levels of protein and energy, respectively. All diets were pelleted and fed ad libitum to the animals during the 28 day experimental period. The ingredient composition of the experimental diets is shown in table 3.1. The chemical composition of almond hulls, alfalfa meal and wheat mill run which served as the major ingredients in the diets is shown in table 3.2. Table 3.3 shows the chemical composition of the various diets.

The experimental animals were kept in individual cages equipped with automatic waterers. Fecal collection screens were attached to the bottom of each cage during the third week and total daily feces voided by each animal during this period were kept in labeled plastic bags at 5° C. Grab samples (about 100 g) of each experimental feed were collected during each feeding and kept in air-tight polytene bags. Sub-samples of each experimental diet were mixed together, ground in a Wiley mill (20-mesh screen) and kept in covered plastic containers for further analysis. Cumulative fecal samples of each experimental animal were dried in an oven at 60° C for 48 h, ground and kept in similar manner as the feed samples. The experimental feeds and feces were analyzed for dry matter (DM), organic matter (OM), crude protein (CP) and ash by the AOAC (1975) procedures. Acid detergent fiber (ADF) was determined by the method of Van Soest (1963) as described in the modified micro-procedure of Waldern (1971). Cell-wall constituents (CWC) and cell contents were determined by the method of Van Soest and Marcus (1964). Gross energy was determined using a Parr adiabatic oxygen bomb calorimeter. Similar analyses were conducted on almond hulls (AH), alfalfa meal (ALF) and wheat mill run (WMR) which formed the major portions of the diets.

Triplicate ground samples (.5 g) each of alfalfa meal, wheat mill run, almond hulls and almond hulls plus urea (20% CP) were used as substrates for in vitro fermentation. Rumen fluid for the in vitro incubation was obtained from a rumen-fistulated crossbred cow maintained on grass pasture and a high energy concentrate supplement for two weeks prior to collection. Rumen fluids were collected 2 h after the morning feeding and filtered through two layers of cheese cloth into a pre-warmed thermos bottle (39 °C). Closed in vitro incubations were conducted by the method described by Goering and Van Soest (1970).

Data for the digestion and performance trial were analyzed using the general linear models procedure and means were compared by the Tukey's studentized range test. Those for in vitro digestion studies were analyzed by use of a one-way analysis of variance as described by Neter and Wasserman (1974). Means were compared using the LSD as outlined by Steel and Torrie (1980).

RESULTS AND DISCUSSION

The chemical components of almond hulls were similar to those contained in feed ingredients that are commonly used in rabbit nutrition (Table 3.2) except for the lower crude protein level. This indicates that a supplemental source of protein is needed when high levels of almond hulls are fed to rabbits. The experimental diets (Table 3.3) were similar in nutrient composition needed in rabbit nutrition and the levels were more than adequate for the nutritional requirements of weanling rabbits.

The percent digestibilities for components of the experimental diets are shown in Table 3.3 Digestibility of DM was higher ($P<.05$) for the 0% almond hull (0% AH) and the 60% almond hull (60% AH) diets than for the OSU 4 and the 40% almond hull (40% AH) diet with no differences ($P>.05$) among the other diets. The percentage of digestible OM was higher ($P<.05$) for the 0% AH and 60% AH diets than for the other diets with no differences ($P>.05$) among the other diets. Digestibilities of DM and OM tended to decrease with increasing levels of AH in the diets up to 40% AH and then increased at the 60% AH level. This was probably a reflection of the lower DM and OM consumption at the 60% AH level (Table 3.3). However, the percentage DM and OM digestibilities of the various AH diets were comparable to or higher than those of the standard OSU 4 diet, indicating that AH could serve as a source of valuable nutrients for growing rabbits.

The percent CP digestibility was higher ($P<.05$) for the OSU 4 and the 0% AH diets than for the other diets with no differences ($P>.05$) between the OSU 4 and the 0% AH diets. Among the other diets, the percentage of digestible CP was higher ($P<.05$) for the 20% almond hull diet (20% AH) than for the 40% AH and the 60% AH diets with no difference (P>.05) between the two latter diets. The percent digestibility of ADF of the AH containing diets was generally lower (P<.05) than those of OSU 4 and 0% AH diets and it tended to decrease with increasing levels of AH in the diets. The percent ADF digestibility was higher (P<.05) for the 0% AH diet than for the OSU 4 diet. Digestibility of ADF in the experimental diets was generally low (<25%). Low fiber digestibility is typical in rabbits (Cheeke, 1987). The percent GE digestibility was higher (P<.05) for the 0% AH and the 60% AH diets than for the 40% AH diet with no differences (P>.05) among the other diets. However, percent GE digestibility was similar (P>.05) for the 20% AH and 40% AH diets which contained 40% alfalfa meal and 40% AH, respectively. This suggests that the digestible energy values of almond hulls and alfalfa meal for rabbits are similar.

Growth rate was similar among the treatments (Table 3.3) except for the 60% AH group. The reduced ADG and feed intake of the 60% AH animals was probably due to the very hard pellets made from this diet. Pellet hardness increased with increasing levels of AH in the diets, probably due to the high sugar content of AH. Thus, weanling rabbits could be fed up to 40% AH as replacements for alfalfa meal without any adverse effects on their performance characteristics. Table 3.4 shows the results of the percent in vitro dry matter digestion (IVDMD) of alfalfa meal (ALF), wheat mill run (WMR), AH and AH-urea combination (AH-U). The range of IVDMD followed the trend WMR>AH-U>AH=ALF (P<.05). IVDMD for AH and ALF were similar, suggesting similar cecal fermentation potential in rabbits. When comparisons were made between animals of each sex on each experimental diet, no differences ($P > .05$) were observed for any of the parameters tested. Thus, there was no sex effect on the utilization of the various diets.

CONCLUSION

AH were successfully incorporated into the diets of rabbits up to a level of 40% as replacements for ALF without any adverse effects on performance and nutrient digestibility. Although AH could serve as a pellet binder, dietary inclusion at a level of 60% produced pellets that were too hard for weanling rabbits, resulting in adverse effects on feed consumption and other performance characteristics.

Acknowledgement

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Table 3.1. Ingredient composition of the almond hulls experimental diets on as fed basis.

		Almond hulls % composition			
Ingredients	Control	0	20	40	60
Almond Hulls	-	-	20.0	40.0	60.0
Alfalfa meal	54.0	60.0	40.0	20.10	-
Wheat mill run	20.0	23.60	17.30	11.10	4.70
Soybean meal	21.0	10.50	16.50	22.30	28.20
Molasses	3.00	3.00	3.00	3.00	3.00
Vegetable oil	1.20	2.00	2.00	2.00	2.00
Limestone	-	-	0.30	0.50	0.50
Dicalcium phosphate	0.30	0.30	0.30	0.50	1.00
Trace mineral salt**	0.50	0.30	0.30	0.30	0.30
Vitamin premix*	-	0.30	0.30	0.30	0.30

* The vitamin premix supplied the following quantities per kilogram of feed: Vitamin A 3,300 IU; vitamin D 1,100 IU; vitamin E 1.1 IU; vitamin K 0.55 mg; vitamin B_{12} 0.0055 mg; riboflavin 3.3 mg; pantothenic acid 5.5 mg; niacin 22 mg; choline chloride 220 mg; folic acid 0.22 mg; ethoxyquin 64.43 mg.

** Trace mineral premix supplied per kilogram of feed, the following: Calcium 107.5 mg; manganese 60 mg; iron 20 mg; zinc 28 mg; copper 2 mg; iodine 1.2 mg and cobalt 0.205 mg.

Table 3.2. Chemical composition of the experimental diets and the major ingredients.

Diets	Gross energy Kcal/g	Dry matter%	Organic matter%	Crude protein%	Acid deter. Fiber%	Cell wall content%	Cell content%	Ash%
OSU 4	4.40	91.60	83.30	23.40	24.80	39.50	60.50	8.30
0% AH	4.40	92.60	84.50	21.90	23.60	38.60	61.40	8.10
20% AH	4.50	92.20	83.70	21.80	22.90	36.10	63.90	8.50
40% AH	4.50	92.30	83.70	20.60	24.70	35.40	64.60	8.60
60% AH	4.40	92.20	83.20	19.20	24.30	34.80	65.20	9.00
Ingredients								
Almond hulls	-	91.70	82.70	6.30	37.20	43.80	56.20	9.00
Alfalfa	-	92.30	83.20	18.80	34.00	45.70	54.30	9.10
Wheat mill run	-	90.00	84.30	19.60	12.80	42.90	47.10	5.70

Table 3.3. Performance and nutrient digestibility data of rabbits fed various levels of almond hulls (AH).

	Diets % composition				
Parameters	OSU 4	0% AH	20% AH	40% AH	60% AH
Avg initial wt, (g)	971.60	954.30	985.10	979.10	974.50^{NS}
Avg final wt, (g)	2003.10^{b}	1872.90^{ab}	2070.80^{b}	2050.90^{b}	1605.60^{a}
Avg daily gain, (g)	37.00^{b}	33.00^{b}	38.20^{b}	37.20^{b}	22.60^{a}
Avg daily intake, (g)	116.20^{b}	101.50^{b}	117.90^{b}	116.50^{b}	83.70^{a}
Feed conversion eff.	3.10^{a}	3.10^{a}	3.10^{a}	3.20^{a}	3.70^{b}
Nutrient digestibility					
Dry matter%	58.90^{a}	61.50^{b}	59.30^{ab}	58.00^{a}	61.30^{b}
Organic matter%	54.70^{a}	58.00^{b}	54.90^{a}	54.30^{a}	57.90^{b}
Crude protein%	78.00^{c}	76.60^{c}	68.70^{b}	62.60^{a}	63.40^{a}
Acid deter. Fiber%	18.40^{c}	24.10^{d}	15.60^{bc}	14.10^{b}	8.20^{a}
Cell content%	81.80	80.90	80.10	79.90	83.10^{NS}
Gross energy%	59.50^{ab}	60.30^{b}	57.70^{ab}	57.10^{a}	60.50^{b}

^{abc} Means in the same column with different superscripts differ ($P<.05$).

Table 3.4. In-vitro rumen dry matter digestion (%) of alfalfa meal, wheat mill run, almond hull or almond hulls-urea combination

Ingredients	% Dry matter digestion
Alfalfa meal	66.2[b]
Wheat mill run	76.3[d]
Almond hulls	66.5[b]
Almond hulls-urea[a]	69.1[c]

[a] Urea was added to increase the crude protein level of the medium to 20%.

[b,c,d] Means in the same column with different superscripts differ ($P < .05$).

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CHAPTER 4

REPRODUCTIVE AND GROWTH PERFORMANCE OF NEW ZEALAND WHITE RABBITS FED COTTONSEED MEAL BASED DIETS

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ABSTRACT

Two studies were conducted to evaluate the effects of feeding graded levels of cottonseed meal (CSM) on the reproductive and growth performance of does and fryer rabbits. The CSM contained 0.675% and 1.124% free and total gossypol, respectively. Experiment one utilized 64 multiparous rabbit does that were randomly assigned to four treatments containing 0% (control), 5%, 10% and 20% CMS. The experiment was replicated to contain equal numbers of sixteen does. The does were subdivided into two groups of eight, to which two bucks were fed either the same level of CSM-based diet or the control diet were assigned for breeding. The results indicated that the does fed higher levels of cottonseed meal (20%) had the lowest performance with respect to all the reproductive parameters measured, and also had the highest mortality rate (93.75%). However, conception rates, birth weight, stillborn, preweaning mortality and the weaning weights were not significantly different (P>.05) between treatments. Buck performance was not significantly influenced (P>0.01) by the diets. Does fed the 10% CSM based diets outperformed all others in all variables. The second experiment involved fryers weaned from the same experimental does. They were placed in groups of five or one per cage. They were fed the same diets as their dams for a 28 d growth study. Rabbits fed the 20% CSM performed poorest irrespective of whether there were five or one per cage. It was concluded that 20% CSM (0.135% free gossypol in the diet) adversely affected both growth and reproduction, but at least 10% CSM (0.0675% dietary free gossypol) can be used without adverse effects.

INTRODUCTION

Cottonseed meal (CSM) is a widely available protein supplement used in animal feeding. It contains a toxic phenolic compound called gossypol, that can have adverse effects on animal health and performance (Cheeke and Shull 1985). Ruminants are less susceptible to gossypol toxicity than nonruminants because of the binding of free gossypol to soluble proteins in the rumen and the influence of rumen microbes (Reiser and Fu 1962). Since the rabbit cecum contains microorganisms, possibly the same type of microbial detoxification could occur in the cecum of rabbit.

Gossypol has been implicated in impaired reproduction of many animal species of both sexes. In males, the effects of gossypol are both dose- and time- dependent. At effective doses gossypol causes males to become infertile (Randel et al., 1992; Anonymous, 1978). Although females are relatively insensitive to the antifertility effect of gossypol, Randel et al., (1992) and Zirkle et al., (1988) indicated that gossypol seems to disrupt estrous cycles, pregnancy and embryo development in all nonruminant species. The conflicting reports on the sensitivity of rabbits to gossypol suggest that further evaluation of the use of CSM in rabbit diets is necessary. Therefore, the objectives of this study were: (1) to evaluate the reproductive performance of does fed different levels of CSM over a period of time. (2) to determine if fertility of bucks can be affected by the consumption of CSM containing diets. (3) to evaluate the growth performance of weanling rabbits fed different levels of CSM.

MATERIALS AND METHODS

Diets.

The dietary treatments consisted of 0%, 5%, 10% and 20% CSM, with CSM replacing soybean meal on an isonitrogenous basis. All other nutrients were balanced to meet the nutrient requirement of reproducing and growing rabbits (NRC 1977, Cheeke 1987). Tables 4.1 and 4.2 show the dietary composition and the chemical analysis. The diets were mixed and pelleted at a commercial feed mill (Pendelton Grains Growers) and were fed ad libitum to the animals throughout the experimental period.

The does were individually housed in cages measuring (76 x 76 x 61 cm) that were equipped with a nest box, a J-shaped screened metal feeder (25.4 cm long) and an automated waterer located in front of each cage. An additional 12 cages of 76 x 76 x 46 cm with no nest box provision were used for the 8 bucks and the replacement does.

Doe, Buck and Preweaning litter management.

Sixty-four multiparous New Zealand White (NZW) does of varying ages and weights were randomly allotted to each of the four dietary treatments (16 does per treatment). The 16 does were subdivided into two groups of 8 and two mature bucks on each of the dietary treatments were used to breed the does. The subdivisions were designated as (0% x 0%, 0% x 20%, 5% x 0%, 5% x 5%, 10% x 0%, 10% x 10%, 20% x 0%, and 20% x 20%), with the numbers referring to the dietary levels of doe x buck (figure 4.1).

Standard doe management practices were used with a breed back period of 7 days. Does that failed to conceive after ten days were returned to the same buck for rebreeding. Those that were palpated to be pregnant were provided with a wooden nest box lined at the bottom with 3.2mm wire mesh containing laboratory grade wood shavings on the 28^{th} day of pregnancy. At kindling, the live litter size (number of kits born alive and weight) and those born dead were recorded. At 21 days of age, the nest boxes were removed, and the body weight of those still alive were counted, weighed and recorded, and were finally weaned on day 28. Does without a litter, (considered dry) were fed a restricted amount of feed to guard against excessive weight gain.

Animals that died or were culled were replaced immediately, using the replacement criteria of Sanchez et al., (1986). Dead animals were necropsied at the OSU Veterinary Diagnostic Laboratory. Other conditions that resulted in culling and replacement included respiratory disease, pregnancy toxemia, enteric disorder, abortion, endometritis, eye infection, broken back and excessive loss of weight. The nulliparous does kept for replacement were raised on a similar CSM based diet that they were later placed on, and were bred at approximately 5-6 months of age.

Postweaning litter management.

Upon weaning at day 28, the litters were placed into either a group of five or one per cage for the growth study. In the growth experiment the rabbits were continued on the same diet as their dams were fed. Each growth experiment lasted for 28 days, during which beginning weight, ending weight, feed consumption, and mortality were recorded.

Analyses

The standard procedures of AOAC (1984) were used for all proximate analysis. Acid and neutral detergent fiber were determined by methods of Van Soest (1963). The cottonseed meal used in the formulation of the ration was analyzed for gossypol content by the method of Hron et al., (1990). Data were subjected to one way analysis of variance using the GLM methods of SAS (1991). Upon detection of significance, treatment means were separated by the Duncan multiple range method of means comparison (Snedecor and Cochran, 1989).

RESULTS AND DISCUSSION

The diets and their chemical composition are shown in table 4.1 and 4.2 respectively. The nutrient contents were basically the similar across all the dietary treatments. The CSM contained 0.675 % and 1.124 % free and total gossypol respectively which was reflected in the gossypol content of the diets (Table 4.2). Table 4.3 shows the breeding combinations and effects of CSM on the reproductive performance of does.

There were no differences with respect to percent conception rates among treatments. All the other parameters were lower for the groups of does on the dietary combination of 20%x0%, and 20%x20%, CSM based diet, but these were not significantly different (P>.05) from the groups that were on the control diet. The performances of does on 5% and 10% CSM was very comparable and there was no significant difference between the two dietary treatments with respect to all variables measured. There was no observable difference as a result of breeding does to bucks that were either on the same dietary treatment or a control diet indicating that the levels of CSM used did not influence male fertility. Similar observations were made by McNitt et al., (1982).

Table 4.3 shows the preweaning litter performance. No variables were significantly affected by the dietary treatments, except the average weight at day 21 and average weight at weaning. The highest average weight at day 21 was obtained from the 0%*0% combination (451.60 gm), but was not significantly different from the 20%x20% (376.56 gm) and 5%x0% (381.32). The average number of kits born per litter was not significantly different between treatment, but the average number weaned per litter was highest from those on 5%x5%, but was not significantly different from 0%x20%, 5%x0%, 10%x0% and 10%x10%. The lowest number of kits weaned per litter were from those on 0%x0%, 20%x20% and 20%x0% diets which were significantly different from the rest. The possible reason for this observation may be due to the fact that there were fewer number of kits weaned per litter from these groups, hence they had more milk and subsequently, a better performance. The lowest weight at weaning was from the 20%x0%, and was significantly different from the rest of the treatment combinations ($P<.05$). This might have also been related to gossypol toxicity, since the 20% CSM had the higher levels of gossypol.

Table 4.5 shows the effects of CSM on the reproductive performance of the 16 does per treatment irrespective of the buck diet. The number of litters born dead and the average weight at weaning were not ($P>.05$) significantly influenced by the dietary treatments. Other measured parameters were significantly lower ($P<.05$) between the does on the 20% CSM, and the rest of the treatments. Although the number of the litter born alive, weight at birth, number at day 21, and the average weight at weaning were lower on the 20% CSM, but were not significantly different from the control diet. Doe mortality was very high (93.75%) for the group on 20% CSM. Out of the 16 does that were started on the experiment, only one survived to the end of the 12 months' study, the rest including several of the replacements died, apparently of gossypol toxicity. This indicates that the diets containing higher levels of CSM (20%) influenced the performance of the does in all of the measured variables.

The LD_{50} of gossypol for rabbits is between 350 and 600 milligrams/kilogram of body weight (Randel et al). Higher levels of free gossypol are also known to depress intake and impair the ability of does to adequately support their kits, and in poultry, they are known to depress hatchability and egg production (Johnston and Berrio, 1985, Fitzsimmons et.al., 1989). Other studies have suggested that gossypol may have no effect on females (Nomier and Abou-Donia 1985), but Zirkle et. al. (1988), reported that embryos cultured in higher doses of gossypol acetic acid degenerated, suggesting that it may have a direct action on embryos. Randel et. al. (1992) also indicated that gossypol may have direct effects on developing embryos. In males, it has been reported that up to 99.9% antifertility efficacy was achieved in human subjects that received a 20 mg/day gossypol based pill for six months with their sperm showing decreased motility and malformed spermatozoa (Anonymous 1978). Chang et al., (1980) also indicated that rabbits fed 10mg/kg of body weight gossypol acetic acid for 15 weeks had lower sperm numbers and the gossypol caused immotile, curved and detached head and tail of spermatozoa in rats and hamsters. Randel et al., (1992) has reported similar observations in their review. Thus it appears that high levels of gossypol were responsible for the poor performance of the does fed diets containing higher levels of CSM.

The result of the growth trials either in group or individual cages is presented in table 4.6. The initial weights of the fryers on each of the dietary treatments were significantly ($P<.05$) different because all of the weaned rabbits were used without an attempt to equalize their body weights, a reflection in the overall net gain of the rabbits in both studies. Group survival was highest from the 5% CSM based diet. Out of the 38 groups of five fryers per cage placed on the 5% CSM, 25 groups survived without any mortality.

Mortality was highest in the fryers on the 20% CSM diets in both trials (group and individual) being 32% and 34% respectively. This may be associated with the higher free gossypol levels (0.135%) in the 20% CSM which was higher that the FDA recommended dietary level of 0.04% for nonruminants. Several other reports have indicated that high levels of gossypol are known to cause mortalities in various species of animals (Akanbi 1984, Balogun et. al., 1990). Waldroup, and Goodner (1973) indicated that increasing levels of gossypol are shown to correlate with increased mortality. However, mortality of fryer rabbits is not uncommon. One of the known causes implicated in mortality of young rabbits is enteritis, particularly if the diet contains high sources of starch, because such diets are known to allow the bacterium *Clostridium spiroforme* to proliferate, leading to diarrhea or enteritis (Sinkovics et al., 1980). Haschek et al., (1989) indicated that in non-ruminants, gossypol is absorbed from the gastrointestinal tract and transported to the kidney, muscle, and other tissues causing toxicity and mortality problems. It is not clear why mortality in the control diet was as high as in the group on the 10% CSM diet, but it may be associated with enteritis which is one of the main cause of mortality in rabbit production (Cheeke et al., 1987 and Grobner et al., 1985).

Table 4.6. shows the effects of CSM on average daily feed intake, average weight gain and feed efficiency in the two growth studies (grouped and individual). Figure

4.2. shows the comparative effects of CSM on fryers in groups of five per cage or one per cage. In both trials, the fryers on the 20% CSM diet showed a significantly poorer performance ($P<.05$) from the others. Although the daily intake of free gossypol with the 10% and 20% CSM based diets was high, it did not influence the average daily feed intake of the individually caged fryers. High levels of gossypol in diets of different species of animals may result in depression of feed intake (Ofojekwu and Ejike 1984).

CONCLUSION.

The effect of CSM on the reproductive and growth performance of does and fryer rabbits was studied for a period of twelve months. The does were individually caged and fed graded levels of CSM diets and bred to bucks that were either on the same levels of CSM or control diet. The fryers were weaned from the experimental does and continued on the same level of CSM for a 28 day growth study. They were placed either in a group of five or one per cage. The results indicated that performance of does fed higher levels of CSM diets significantly decreased with respect to all the variables measured, but there was no apparent influence of CSM on male fertility. Fryer performance in both growth studies also indicated that poor performance was correlated to higher CSM levels. Thus it can be concluded that does and fryer rabbits can be fed diets containing up to 10% CSM without adverse effects on doe and fryer performance.

Table 4.1 Composition of the experimental diets containing cottonseed meal (CSM) fed to fryer and doe rabbits as fed.

	Control diet		Cottonseed meal diets		
Ingredient	Doe diet	Fryer diet	5 % CSM	10 % CSM	20 % CSM
Suncured alfalfa	54.00	56.50	54.00	54.00	54.00
Wheat mill run	21.00	37.00	21.00	21.00	21.00
Soybean meal	20.00	- -	15.00	10.00	0.00
Cottonseed meal	- -	- -	5.00	10.00	20.00
Molasses	3.00	3.00	3.00	3.00	3.00
Corn	1.25	- -	1.25	1.25	1.25
Trace mineral salt**	0.50	0.50	0.50	0.50	0.50
Dicalcium phosphate	0.25	0.25	0.25	0.25	0.25
Bentonite*		1.25			
Copper sulfate*		.100			
Meat meal*		.82			

* Only added to the fryer diet.

** Trace mineral premix supplied per kilogram of feed, the following: Calcium 107.5 mg; manganese 60 mg; iron 20 mg; zinc 28 mg; copper 2 mg; iodine 1.2 mg and cobalt 0.205 mg.

Table 4.2. Chemical composition of cottonseed meal and the experimental diets.

Parameters	CSM[1]	Fryer Diet	Doe Diet	5 % CSM	10 % CSM	20 % CSM
DEnergy, Kcal/kg	- -	2300.00	2844.27	2842.86	2810.74	2737.28
Dry matter, %	89.77	89.73	88.63	90.98	87.86	88.79
Crude protein, %	41.25	16.00	18.59	19.70	18.31	18.37
Neutral deter. fiber, %	- -	41.24	38.14	35.94	35.60	37.24
Acid deter. fiber, %	15.83	22.89	21.04	22.60	22.84	23.38
Fat, %	1.50	2.89	2.71	2.65	1.69	2.47
Ash, %	6.80	7.72	7.64	7.42	7.86	7.86
[2]Gossypol free, %	0.675	- -	--	0.034	0.068	0.135
Total, %	1.124	- -	--	0.057	0.1124	0.225

[1] Calculated value.

[2] Analyzed by Hron, R. J. of USDA Mid South Area Southern Regional Research Center, New Orleans Louisiana 70179.

Table 4.3 Preweaning performance of litters from NZW does fed graded levels of cotton seed meal.

Breeding combination	Parameters					
Doe x Buck	Number of times bred*	Parity*	%Conception^{NS}	Number born alive*	Number at day 21**	Number weaned**
0% x 0%	5.50 ± 0.46^{a}	3.63 ± 0.38^{ab}	68.33 ± 7.73	17.62 ± 2.16^{c}	13.63 ± 2.17^{cd}	12.63 ± 2.28^{c}
0% x 20%	6.00 ± 0.27^{a}	4.13 ± 0.55^{ab}	71.73 ± 11.07	32.50 ± 6.22^{abc}	24.75±4.08^{abcd}	24.00 ± 3.89^{abc}
5% x 5%	5.38 ± 0.38^{a}	4.38 ± 0.32^{a}	84.10 ± 7.36	32.63 ± 5.08^{abc}	26.75±3.65^{ab}	25.62 ± 3.36^{ab}
5% x 5%	5.62 ± 0.52^{a}	4.50 ± 0.65^{a}	79.10 ± 8.27	37.88 ± 8.13^{ab}	31.38 ± 6.76^{a}	30.00 ± 6.36^{a}
10% x 0%	4.71±0.42^{a}	3.86±0.46^{ab}	82.14±7.37	29.86±4.25^{abc}	25.86±3.28^{abc}	25.28±3.16^{ab}
10% x 10%	5.63 ± 0.32^{a}	5.13 ± 0.35^{a}	90.92 ± 3.60	43.25 ± 3.51^{a}	34.38 ± 3.96^{a}	33.88 ± 3.89^{a}
20% x 0%	3.38 ± 0.59^{b}	2.63 ± 0.63^{b}	75.00 ± 12.19	22.71 ± 2.77bc	16.86±1.87^{bcd}	16.43 ± 1.91^{bc}
20% x 20%	3.14 ± 0.55^{b}	2.57 ± 0.48^{b}	82.14 ± 7.37	16.71 ± 4.48^{c}	12.43 ± 4.62^{d}	12.29 ± 4.59^{c}

^{abcd} Means within a column with a different superscripts are different * (P<0.01) and ** (P<0.02). ^{NS} Means within a column without a superscript are not significant (P>0.05). Means and standard errors are based on eight observations.

Table 4.4. Effects of CSM containing diets on reproductive performance of NZW does

Breeding combination		Parameter					
Doe x Buck	Number of does	Average wt at birth (g)	Average wt at day 21 (g)*	Average wt at weaning (g)**	Number born dead	%Preweaning mortality	% Weaned at day 28[NS]
0% x 0%	8	51.69 ± 5.38	451.60 ± 32.07[a]	938.83 ± 80.17[ab]	6.50 ± 2.52	32.06 ± 7.54	67.93 ± 7.54
0% x 20%	8	49.18 ± 3.83	370.37 ± 25.30[b]	928.81 ± 35.36[ab]	5.63 ± 2.99	20.41 ± 6.24	79.59 ± 6.23
5% x 0%	8	58.29 ± 2.94	381 ± 22.39[ab]	927.38 ± 35.00[ab]	6.00 ± 2.28	18.45 ± 3.90	81.55 ± 3.90
5% x 5%	8	55.90 ± 2.99	338.20 ± 15.82[b]	930.05 ± 59.58[ab]	6.38 ± 2.84	18.81 ± 7.15	81.19 ± 7.15
10% x 0%	8	60.38 ± 1.66	371.31 ± 11.63[b]	991.99 ± 71.17[a]	1.43 ± 0.61	12.09 ± 5.69	87.90 ± 5.69
10% x 10%	8	60.10 ± 2.26	336.62 ± 17.20[b]	922.36 ± 43.12[ab]	4.88 ± 1.39	22.95 ± 4.95	77.05 ± 4.94
20% x 0%	8	56.10 ± 2.79	322.58 ± 29.28[b]	803.43 ± 33.53[c]	6.86 ± 3.84	24.74 ± 6.48	75.26 ± 6.48
20% x 20%	8	53.38 ± 4.71	376.56 ± 38.10[ab]	909.23 ± 52.68[ab]	2.57 ± 0.48	25.99 ± 11.15	74.00 ± 11.15

[ab] Means within a column with a different superscript are different * ($P<0.01$) and ** ($P<0.05$)

[NS] Means without superscripts are not different ($P>0.05$). Means and standard errors are based on eight observations.

Table 4.5 Reproductive performance of NZW does fed graded levels CSM diets

Parameter	Control Diet	5 % CSM	10 % CSM	20 % CSM
Times bred	5.75 ± 0.26^{a}	5.50 ± 0.32^{a}	5.20 ± 0.28^{a}	3.27 ± 0.39^{b*}
No. of Parity	3.88 ± 0.33^{a}	4.43 ± 0.35^{a}	4.53 ± 0.32^{a}	2.60 ± 0.39^{b*}
No. at day 21	19.19 ± 2.65^{b}	29.06 ± 3.76^{a}	30.40 ± 2.76^{a}	14.64 ± 2.47^{b**}
Avg. wt at day 21, (g)	410.98 ± 22.34^{a}	359.89 ± 14.38^{b}	352.80 ± 11.29^{b}	349.57 ± 24.27^{b**}
Number weaned	18.31 ± 2.63^{b}	27.81 ± 3.52^{a}	29.87 ± 2.71^{a}	14.36 ± 2.46^{b***}
Ave. Weaned wt., (g)	933.82±42.35	928.71 ± 33.38	954.85 ± 39.94	856.33 ± 33.39^{NS}
Percent weaned	73.76 ± 4.96	81.37 ± 3.94	82.11 ± 3.88	74.63 ± 6.20^{NS}
Preweaning mort., %	26.93 ± 1.93	21.10 ± 1.66	19.28 ±1.57	27.17 ± 1.60^{NS}
No. of does	16.00	16.00	16.00	16.00

^{ab} Means within the same row with a different superscript are significant * ($P<0.01$), ** ($P<0.02$) and *** ($P<0.05$).

^{NS} Means within a row without a superscript are not significant ($P>0.05$). Means and standard error are based on sixteen observations.

Table 4.6. Effects of cottonseed meal on performance of groups and individually-fed fryer rabbits

Parameter	Control	5% CSM	10% CSM	20% CSM
*Initial wt. (g)	1010.47±14.67^{a}	939.61±13.12^{c}	975.68±16.78^{b}	912.25±22.59^{d}
*Net gain (g)	984.52±17.53^{ab}	1025.25±10.24^{a}	947.98±12.79^{b}	823.83±21.42^{c}
*Avg. Daily gain (g)	35.16±0.63^{ab}	36.62±0.37^{a}	33.86±0.46^{b}	29.42±0.77^{c}
**Initial wt. (g)	1056.58±21.26^{a}	982.20±13.56^{c}	1015.05±24.22^{b}	872.63±19.55^{d}
**Net gain (g)	1005.00±25.89^{a}	1016.60±11.93^{a}	982.21±13.30^{a}	814.20±31.51^{b}
**Ave. Daily gain (g)	35.89±0.92^{a}	36.31±0.43^{a}	35.08±0.48^{a}	29.08±1.13^{b}
**Ave. Daily feed (g)	131.16±3.87^{b}	140.60±1.57^{a}	135.42±1.88^{ab}	117.74±3.45^{c}
**Feed / gain	3.66±0.06^{c}	3.91±0.05^{b}	3.93±0.09^{ab}	4.13±0.11^{a}
Group survival	8/26	25/38	17/38	6/19
% Group survival	30.77	65.79	44.74	31.58
Mortality	36/93	14/171	55/143	32/63
% Mortality	38.71	8.19	38.46	50.79

* Calculations based on individual rabbits that survived within a group.

** Calculation based only on groups that had no mortality.

^{abc} Means within a column with a different superscript are different ($P<0.05$).

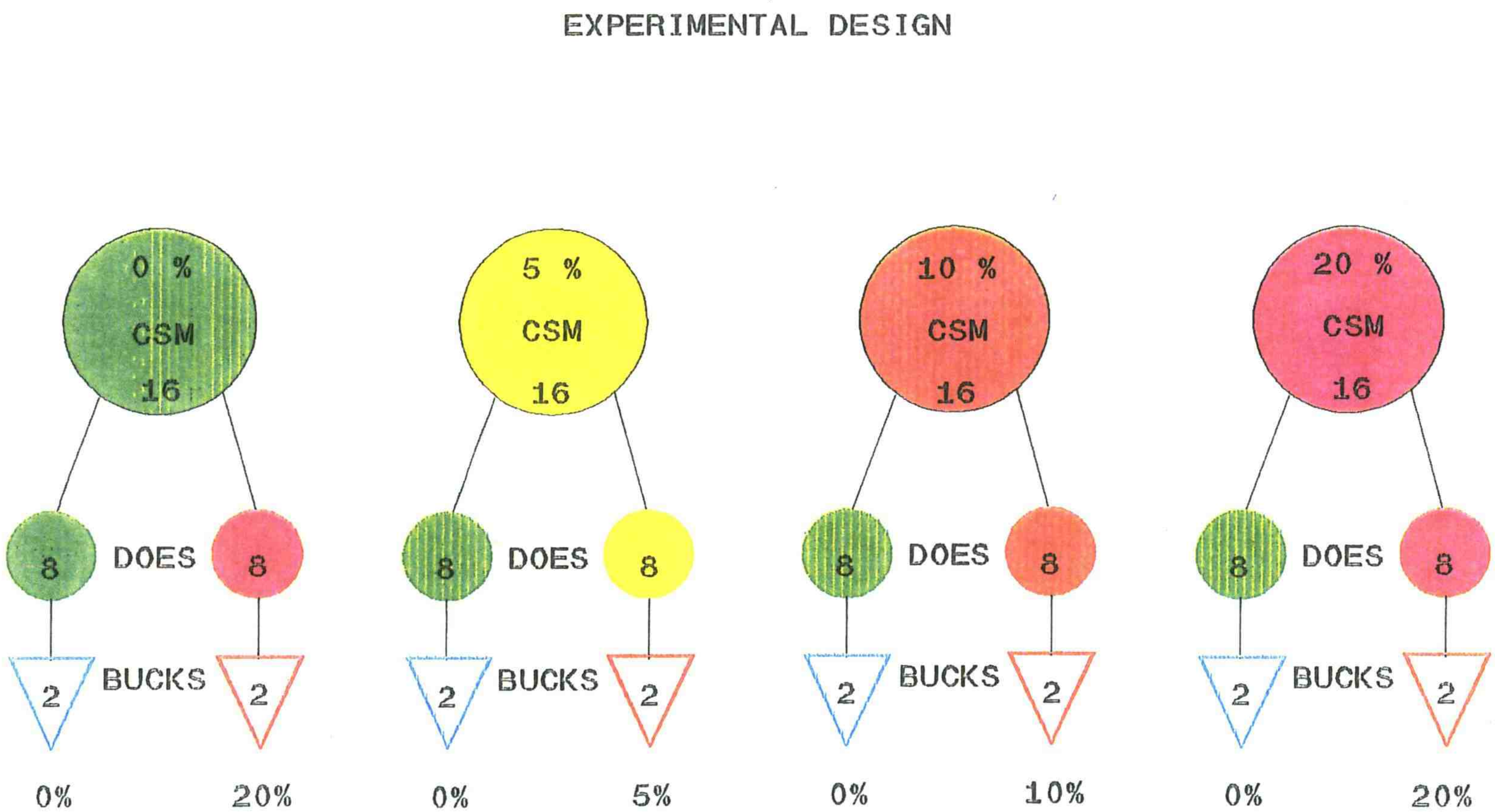

Figure 4.1. Experimental design for does fed cotton seed meal diets

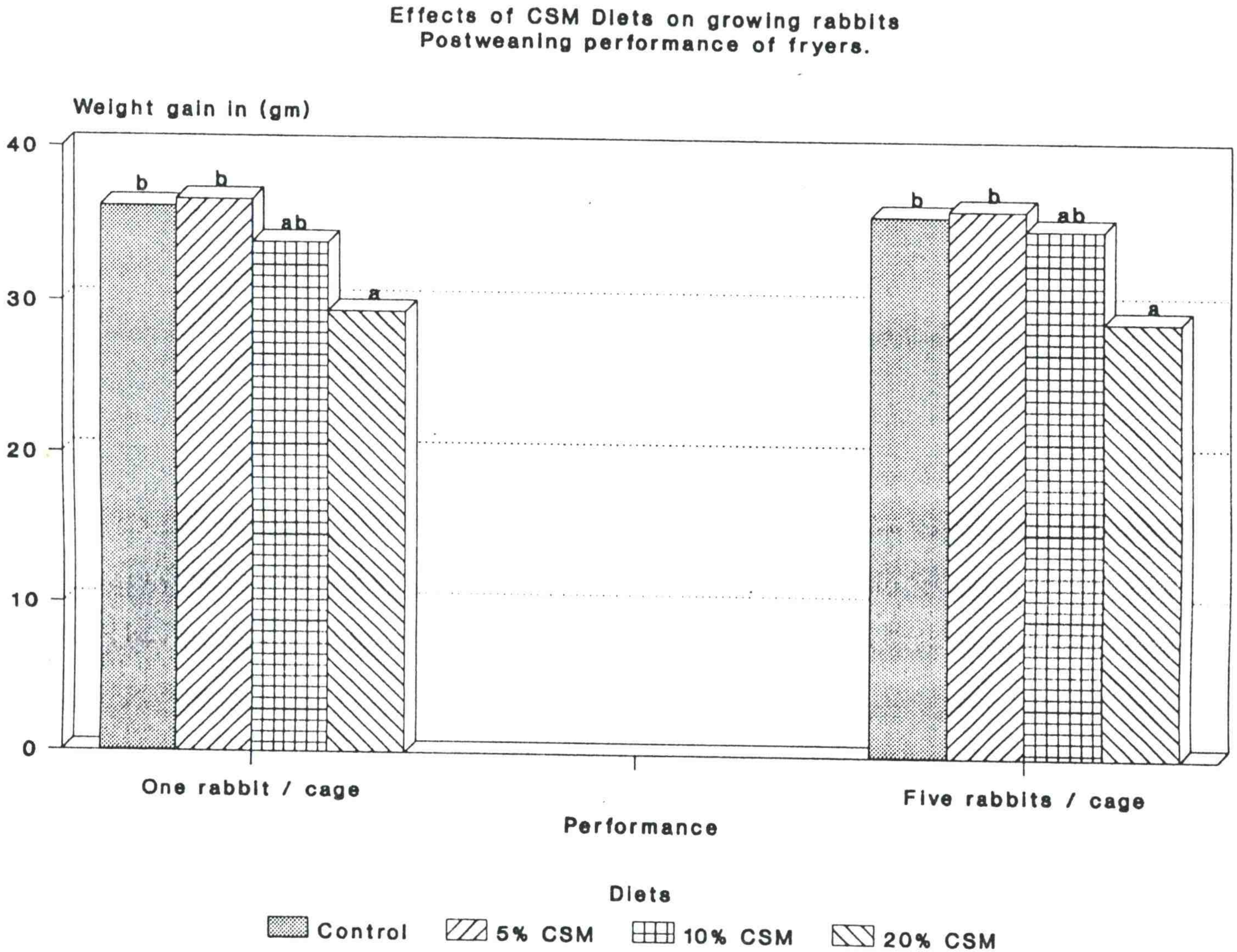

Figure 4.2. Comparative performance of fryer rabbits fed CSM based diets in individual or a group of five per cage

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PART TWO: FEED ADDITIVES

CHAPTER 5

EFFECTS OF ALLZYME (ß-GLUCANASE) ON COMPARATIVE PERFORMANCE OF GROWING RABBITS, BROILER CHICKS AND LAYING PULLETS FED ß-GLUCAN CONTAINING GRAINS (BARLEY, TRITICALE AND RYE)

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ABSTRACT

Three experiments were conducted to evaluate the effects of a commercial enzyme product (Allzyme BG) on the utilization of diets containing rye, triticale and low- and high- glucan barley grains in rabbits and broiler chicks. The grains were ground and used at 40% of the diet for the rabbits and at 100% substitution for corn in the broiler experiments. The high (7.5%) and low (3.5%) glucan barley also were used in layer hen experiment at 100% substitutional level. The enzyme preparation (Allzyme BG) was added at 2.2 kg per ton of feed. For the rabbits, the average daily feed intake, average daily gain and feed efficiency were very similar within all the grains. No adverse effects of feeding the grains to the fryer rabbits were observed, neither was there any response to enzyme supplementation, indicating that dietary ß-glucan has no adverse effects on weanling rabbits. Supplementation with ß-glucanase significantly improved ADF digestibility for the high glucan barley based diets, but had no effect on the digestibility of other nutrients. In the broiler experiment, growth rate and feed conversion were reduced when the four grains were fed. Supplementation with ß-glucanase markedly improved the performance of the broiler chicks. With layers, birds fed diets containing unsupplemented high glucan barley lost over 150 gm of body weight, and had only 32% egg production in a two-week period. In all parameters evaluated with layers, the enzyme supplemented groups showed an improvement over the unsupplemented diets. Poultry fed diets with the feed grains containing ß-glucan responded to supplementation of ß-glucanase, whereas there was no response in weanling rabbits.

INTRODUCTION

Certain cereal grains, such as barley, rye and triticale, contain viscous water-soluble gums (ß-glucans), pectins and other poorly digested polyssacharide fractions, which adversely affect their utilization by poultry and swine (Cheeke 1991). The ß-glucans are part of the hemicellulose component of the plants cell structure. They contain a polymerized ß-glucose linked together by a chemical bond known as $(1\rightarrow3)(1\rightarrow4)$ ß-D-glucan that is different from the $\alpha\rightarrow1\rightarrow4$ and α-$1\rightarrow6$ bonds. The ß-D-glucans are viscous, hygroscopic, and gummy. These substances are particularly important in poultry nutrition, causing reduced bird performance and wet litter problems and can also impair nutrient absorption and cause pasty vent in chicks. The viscous substances prevent the formation of micelles, thus inhibiting the absorption of fat and other nutrients (Edney et al., 1989; Gohl et al., 1978; Hasselman et al., 1981, 1982; Petterson et al., 1988; Rotter et al., 1989a).

These deleterious effects can be overcome by either soaking or steeping the grain in water and or by addition of ß-glucanase. The soaking or steeping process is believed to activate the ß-glucanase enzyme already present in barley seeds, hence reducing the glucan effects. The dietary addition of ß-glucanase aids the animal in digestion of the grains and improves their utilization especially in nonruminants (Petterson et al., 1990, Rotter et al., 1989a, Cheeke 1987, Campbell and Classen 1989).

Several reports have indicated that grains like barley, rye and triticale contain some poorly digested carbohydrates, which reduce the value of these grains for swine and poultry. However, the effects of ß-glucans in grains and responses to enzyme supplementation have not been studied in rabbits. Cheeke (1987) speculated that the ß-glucans might increase enteritis by promoting excess cecal microbial growth. Thus the objectives of this study were to compare the responses of weanling rabbits and broiler chicks to diets containing barley, rye and triticale with or without ß-glucanase supplementation and to evaluate the effects of feeding 100% high and low glucan barley with or without ß-glucanase on fecal moisture and egg production in layers.

MATERIALS AND METHODS

The grains used were commercial sources of triticale (cv. Flora), rye, and low (3.50%) and high (7.50%) ßeta-glucan-containing barley that was grown at Washington State University. The Allzyme ß-glucanase was donated by Alltech Inc. Biotechnology Center, Nicholasville, Kentucky.

Diets

The grains used for the formulation of the diets were ground through a 2 mm Wiley mill. In all experiments, the diets were divided into two equal parts, one part being supplemented with Allzyme BG (ß-glucanase) at 2.2 kg per tonne according to the recommended specification and the other part without Allzyme BG supplementation.

Eight diets with 40% grain were formulated from the four grains for the rabbits and designated with the symbols + or - for with or without enzyme supplementation, respectively. The rabbit diets were pelleted and the poultry diets were fed in mash form. For the broilers and layers, the grains were used to replace 100% of the corn in the control diet. Diets were formulated to meet the NRC requirements for rabbits (NRC 1977) and poultry (NRC 1984). The diets are shown in tables 5.1a, 5.1b, 5.1c.

Rabbit experiment

Ninety 4-5 week old New Zealand White rabbits of both sexes were weighed, ear-tagged and randomly assigned to the nine dietary treatments with ten rabbits per treatment. They were housed in an open sided conventional rabbit house. Each animal was placed in an individual cage measuring 30 x 76 x 46 cm and equipped with an automatic waterer which provided free choice water throughout the experimental period. Each cage also had a "J" type galvanized metal feeder with a screen bottom in which the feed was placed for ad libitum feeding. The health of the animals was monitored on a daily basis, particularly for fecal consistency and evidence of enteritis. Feed consumption and weight gain were recorded during the experimental period and used to calculate feed efficiency, average daily gain and average daily feed intake (table 5.1f).

On day 21 of the experiment, five animals from each of the treatments were randomly selected and wire fecal collection screens were placed underneath their cages. The feces were collected on a daily basis for seven days, placed in labeled plastic zip-lock bags and kept at -4 °C for further analysis. The collected feces were dried at 60 °C in a conventional oven for 72 h, air equilibrated for 48 h and along with a 100 grams from each of the experimental diets, were ground to pass through a 1 mm mesh Wiley mill. The ground samples (diets and feces) were analyzed for nutrient composition and the results used to determined nutrient digestibility (table 5.1g).

All proximate analysis, dry matter (DM), crude protein (CP), ether extract (EE), and ash, were carried out according to the procedures of AOAC (1984). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were done according to the procedures of Van Soest (1963) and gross energy (GE) was determined using a Parr adiabatic bomb calorimeter. At the end of the experimental period, all the animals were weighed to determine net weight gain and the total feed given to each animal during the experimental period was recorded, and used to calculate average feed intake and feed efficiency (table 5.1f).

Broiler experiment

The broiler hatching eggs were obtained from Keith Smith Farms, Hot Spring, Arkansas via Jenks Hatchery, Tangent, Oregon. They were incubated and hatched in incubators at the OSU poultry unit. After hatching, the birds were feather sexed and wing banded, and placed on the broiler starter ration for a one week pre-experimental period. One hundred, one-week old, Peterson x Hubbard broiler strain chicks of equal sexes (five male and five females) were randomly assigned to ten dietary treatments with ten birds per treatment. The birds were housed in electrically heated, ventilated wooden pens (1.22 m x 2.44 m/pen), with a bird density of .69 m^2 / bird. The floor pens were covered with wood shavings litter (5.1 cm deep). An infrared heat lamp was used as the heat source for the 28 day experimental period. Artificial lighting (5.8 lux) was provided throughout the experimental period. The incidences of pasted vents, or sticky feces, were monitored, and mortality rates recorded on a daily basis throughout the experimental period. Total feed consumption and body weight gain were also recorded at the end of the experimental period. The data were used to calculate average daily gain, daily feed intake and feed efficiency (table 5.2b).

Layer experiment

A 2-week preliminary experiment was conducted to investigate the supplementation of Allzyme BG (ß-glucanase) in the high or low ß-glucan barley on the fecal moisture content, egg production and change in weight for pullet layers. Fifty, 60-week old Dekalb XL Short Comb White Leghorn (SCWL) laying pullets were weighed at the initiation of the experiment and randomly assigned to the five dietary treatments with ten layers per treatment. The layers were placed in stair-step individual cages (20.3 cm x 45.7 cm x 40.6 cm x 48.3 cm) that provided an area of

700 cm^2 per layer. The experiment was carried out in an enclosed windowless, positive pressure, mechanically ventilated house using standard management practice. Artificial lighting (5.8 lux) was provided at 14 h/day (0400 - 1800 h). The experimental diets were provided in mash form and fed ad libitum, while water was provided in continuous troughs at intermittent period of 15 minutes / 2h per day during the light periods. On the eighth day of the experiment, metal trays were covered with aluminum foil and placed on a long wooden 1.8 x .6 meters boards, which were suspended underneath the cages for total fecal collection for seven days. The collected feces were placed in labeled plastic bags and stored at -4 °c for analysis. The fecal samples were weighed and then dried in a conventional oven at 60 °C for 72 h, air equilibrated for 48 h and used to calculate moisture content. During the experimental period, feed consumption and egg production were recorded for each of the dietary treatments. At the end of the experiment, the layers were weighed to determine the change in body weights (table 5.3).

Data from all the experiments were treated as a complete randomized design and subjected to one way analysis of variance using general linear models (GLM) of Statistical Analysis Systems (SAS, 1991). Means were separated by Duncan's method of multiple range comparison.

RESULTS AND DISCUSSION

Rabbit experiment

The results of the chemical composition of the major dietary ingredients and dietary compositions are presented in tables (5.1b) and (5.1c), respectively. Despite some slight variation in the protein content of the major ingredients, all nutrients were balanced to meet the minimum requirements of the growing rabbit. ADF values were slightly lower (13%) in unsupplemented rye- and up to 22% in the control diet (OSU #64). According to Cheeke (1987), a minimum of 21% ADF should be included in the diets of all classes of rabbits because lower levels are associated with cecal-colonic hypomotility and could result in diarrhea. Although 2 rabbits died from the group on enzyme supplemented rye, and 1 from of the unsupplemented high glucan barley and supplemented low glucan barley, respectively (table 5.1f), this mortality incidence cannot be conclusively associated with lower fiber levels.

Rabbits fed the control diet had higher ($P<.05$) average daily feed intake (145 gm) than rabbits fed the grain diets with or without enzyme supplementation. But the average daily gain (ADG) of 42 gm in the same group was not different ($P>.0$) from the rest of the dietary treatments. Animals are known to adjust their feed intake in order to meet their energy requirements. Because the control diet had higher fiber (22%) than the rest, it may contain less energy per gram of feed, thus higher intake would be required to meet the energy requirement of the growing rabbits (table

5.1d).

Inclusion of the grains gave numerical reductions in the ADG with the grain based diets, but were not significantly different (P>.05) between the grains except for the unsupplemented triticale- diet. Feed efficiencies for rye, low ß-glucan barley and triticale with or without the allzyme supplementation were better (P<.05) than the control. But the feed efficiencies for the rabbits fed high glucan barley-containing diets that were not significantly different (P<.05) from the control. The lack of response of rabbits to the dietary ß-glucanase suggests that there may be adequate microbial ß-glucanase produced in the cecum.

The digestibility of dry matter, energy and ether extract were (table 5.1g) were significantly (P<.05) higher with the grain diets than for the high alfalfa control diet. Within the grains, the digestibility of dry matter and energy were slightly higher (P<.05) with rye and triticale than with low and high ß-glucan containing barley. No significant differences (P>.05) were observed between the barleys with respect to dry matter, and energy digestibility. Crude protein digestibility (70%) was significantly better (P<.05) from the supplemented triticale diet than from the unsupplemented rye diet. Digestibility of acid detergent fiber (ADF) was significantly (P<.05) lower in the unsupplemented high glucan barley. Neutral detergent fiber (NDF) digestibility were better (P<.05) for all the grains. Graham et al, (1986), indicated that enzyme supplementation did not significantly influence apparent digestibility of nutrients in swine, and concluded that ß- glucanase has limited value for barley based diets fed to swine.

Broiler experiment

The chemical analysis result of the chicks experimental diets is presented in table (5.2a). There was basically no difference within the grains as a result of ß-glucanase supplementation. Although there were variations in the nutrient composition of the grains, all the diets met the minimum requirements for broiler chickens (NRC 1984).

The results from the broiler chicks experiment (table 5.2b) were much different from those of the rabbit experiment. Supllementation of ß-glucanase improved the average daily gain for the broiler chicks fed high glucan barley, low glucan barley and the triticale, but it did not influence the dietary treatment containing rye grains. The overall improvement as a result of supplementation was between 9% - 15% over the unsupplemented diets. There was also improvement of 3.5% - 19.8% in the feed conversion as a result of supplementation with greatest improvements in the rye diet and lowest in the triticale. Although the feed conversion efficiencies with the grains as compared to the corn were improved by addition of Allzyme, they were still 4.4% - 20.2% poorer than the corn diet. These results agree with Campbell and Classen 1989, in which they suggested that supplementation with ß-glucanase improved the overall performance of chickens . This infers that these alternative grains, even with enzyme supplementation, could replace corn in the least cost diet formulation only if their costs were substantially less than corn, because of their lower metabolizable energy.

Laying hen experiment

The chemical composition of the layer diet shows that energy level was similar between the corn-based and the low glucan barley-based diets, but was significantly different ($P<.05$) from the high glucan-containing diets. This might be due to differences in the nutrient composition of the two major ingredients, low and high glucan barley (table 5.1c). Despite the variation, all nutrients in the diets met the minimum requirements for layers, except gross energy which was between 1% to 5% deficient in corn and the unsupplemented high glucan barley.

The response of layers to enzyme supplementation was more dramatic than for either the rabbits or the broiler chick experiment (table 5.3). Although all layers fed the barley-based diets lost body weight, the loss was more dramatic (155 g) in the high glucan barley. This was significantly ($P<.01$) different from the layers fed the supplemented high and unsupplemented low glucan barleys. The addition of Allzyme markedly reduced the weight loss with both the high and the low glucan barley diets. Egg production, daily feed consummed per layer, and feed conversion followed the same trend, where supplementation exhibited superiority over unsupplemented high and low glucan barley (figure 5.1.). Campbell and Classen

(1989) indicated that feeding barley-containing diets to layers increases the moisture content of the feces resulting in dirty eggs, but such a problem was not observed in this experiment. Mature layers have less need for high energy feedstuffs than broiler chicks. Thus a lower energy feedstuff like barley may be a more useful ingredient for layers than broilers. However, feeding barley to layers from 20 to 40 weeks of age when the layers have higher requirements for energy and feed consumption is increased to meet both egg production and body tissues demands. During this period, layers cannot consume enough of the low energy barley feed, therefore, weight loss may occur as was observed in this trial. Coon et al., 1988 reported that feeding layers from 20 to 36 weeks of age varying levels of barley did not affect egg production; however, the reduction of the metabolizable energy, crude protein, lysine and methionine in the diets of the same layers from 36 to 64 weeks of age resulted in decreased egg production, egg weights and body weights. The use of barley in layer diets can be beneficial for regulating egg size and minimizing body weight gains in post peak layers, if barley is priced low enough to offset the resulting increased feed consumption and lower feed utilization rates (Coon et al., 1988).

CONCLUSION

Supplementation of ß-glucanase did not influence the growth performance of weanling rabbits, but inclusion of the ß-glucan containing-grains improved efficiency of feed conversion in rabbits. Broiler chicks on diets without added Allzyme BG had lower growth rate and poor feed conversion efficiency, but those on Allzyme BG supplemented diets had markedly improved performance. Supplementation of ß-glucanase improved the performance of the laying hens. The following conclusions were made:

1. Compared to performance of rabbits fed a high alfalfa diet, growth rate of rabbits was not increased when barley, rye or triticale was incorporated into the diet but feed conversion was improved by inclusion of grain.

2. No adverse effect of glucan-containing grains on performance or health of weanling rabbits was observed; no response to supplementation of grain-containing diets with β-glucanase (Allzyme BG) was observed in rabbits indicating that dietary β-glucans are not deleterious to rabbits.

3. Broiler chicks had lower growth rate and feed conversion when fed β-glucan-containing grains as compared to a corn-based control diet; but supplementation with β-glucanase markedly improved performance of chicks fed barley, rye and triticale-containing diets.

4. All the layers fed the barley-based diets without supplementation lost significant weight, and had lower egg production.

5. Dietary ß-glucans are not deleterious to rabbits, thus Allzyme BG supplementation only influenced the performance of broiler chicks and layers, but not that of rabbits.

Table 5.1a. Composition of the rabbit experimental diets on as fed basis

	% Composition	
Ingredient	Control (OSU64)	Grains
Dehydrated alfalfa	56.50	32.00
Grains	-	40.00
Wheat mill run	37.00	10.00
Soybean meal	-	12.00
Molasses	3.00	3.00
Bentonite	1.25	-
Meat Meal	0.82	-
Vegetable oil	-	1.25
Dicalcium Phosphate	-	1.00
Salt	.50	.50
Vitamin premix*		.25

ßeta Glucanase added at the recommended rate of 2.2g/kg of feed.

* The vitamin premix supplied the following quantities per kilogram of feed: Vitamin A 3,300 IU; vitamin D 1,100 IU; vitamin E 1.1 IU; vitamin K 0.55 mg; vitamin B_{12} 0.0055 mg; riboflavin 3.3 mg; pantothenic acid 5.5 mg; niacin 22 mg; choline chloride 220 mg; folic acid 0.22 mg; ethoxyquin 64.43 mg.

Table 5.1b. Composition of the broiler chicks experimental diets

Ingredient	Percent composition
Grains[1]	59.00
Soybean meal (47.5%)	32.50
Meat and bone meal	5.00
Fat	2.00
Ground limestone	0.52
Monocalcium phosphate	0.35
Salt	0.25
Vitamin premix[2]	0.20
DL- Methionine (98%)	0.13
Trace mineral premix[3]	0.05
Amprol-25[4]	0.05
Bacifern[5]	0.05

[1]Grains were rye, triticale, and low and high glucan barley.

[2] The vitamin premix supplied the following quantities per kilogram of feed: Vitamin A 3,300 IU; vitamin D 1,100 IU; vitamin E 1.1 IU; vitamin K 0.55 mg; vitamin B_{12} 0.0055 mg; riboflavin 3.3 mg; pantothenic acid 5.5 mg; niacin 22 mg; choline chloride 220 mg; folic acid 0.22 mg; ethoxyquin 64.43 mg.

[3] Trace mineral premix supplied per kilogram of feed, the following: Calcium 107.5mg; manganese 60mg; iron 20mg; zinc 28mg; copper 2mg; iodine 1.2mg and cobalt 0.205mg.

[4] Gratuitously provided by MSD Agvet Division of Merck and Co. Rahway, NJ.

[5] Gratuitously provided by Pitman - Moore, Inc. Mundelin, Il. 60060

Table 5.1c. Composition of laying pullets experimental diet

Ingredients	% Composition
Grains	71.30
Corn	3.00
Soybean meal (47.50%)	19.00
Limestone	4.15
Oyster shell	3.30
Monodicalcium phosphate	1.70
Salt	0.25
Vitamin premix[1]	0.20
Trace mineral premix[2]	0.05
DL-Methionine	0.05

[1] The vitamin premix supplied the following quantities per kilogram of feed: Vitamin A 3,300 IU; vitamin D 1,100 IU; vitamin E 1.1 IU; vitamin K 0.55 mg; vitamin B_{12} 0.0055 mg; riboflavin 3.3 mg; pantothenic acid 5.5 mg; niacin 22 mg; choline chloride 220 mg; folic acid 0.22 mg; ethoxyquin 64.43 mg.

[2] Trace mineral premix supplied per kilogram of feed, the following: Calcium 107.5 mg; manganese 60 mg; iron 20 mg; zinc 28 mg; copper 2 mg; iodine 1.2 mg and cobalt 0.205 mg.

Table 5.1d Chemical composition of major ingredients used in the experimental diets

			Nutrient composition%				
Ingredient.	GE Kcal/kg	Dry matter %	Neutral detergent fiber %	Acid detergent fiber%	Crude protein %	Fat %	Ash %
High ßG Barley	3454.2	88.8	28.7	10.6	10.4	2.07	2.43
Low ßG Barley	3481.5	88.5	35.6	8.63	11.7	1.74	2.72
Rye	3282.4	86.9	19.8	3.42	8.29	1.60	2.15
Triticale	3290.7	87.3	19.9	4.04	9.33	1.58	1.99
Soybean meal	3768.8	88.5	15.4	8.98	47.2	1.32	6.57
Wheat mill run	3508.4	86.7	37.3	10.2	17.8	4.47	4.66
Dehyd. Alfalfa.	3445.1	88.7	38.6	28.3	17.4	2.18	10.7

High ßG barley contained 7.5% ßeta glucan; Low ßG barley contained 3.5% ßeta glucan.

Table 5.1e Chemical composition of the rabbit experimental diets

	Nutrient composition%						
Diets	GE Kcal/kg	Dry matter%	Neutral detergent fiber%	Acid detergent fiber%	Crude protein%	Fat%	Ash%
Control (OSU64)	3548.2	88.9	35.2	21.8	14.8	2.42	7.63
High ßG Barley+	3517.5	88.0	29.1	15.7	16.0	3.78	7.10
High ßG Barley-	3527.6	87.9	29.8	14.6	15.8	3.47	7.31
Low ßG Barley+	3491.3	87.9	30.1	16.9	15.7	2.95	7.66
Low ßG Barley-	3591.7	88.6	30.0	16.4	15.4	3.28	8.01
Rye+	3478.6	87.2	25.0	13.1	14.8	3.28	6.89
Rye-	3490.7	87.5	26.2	14.6	14.5	3.74	7.42
Triticale+	3436.3	87.3	26.6	14.5	15.1	3.66	7.79
Triticale-	3494.1	87.5	25.7	13.9	14.0	2.98	7.05

+, with added Allzyme ßG; -, without of added Allzyme ßG.

Table 5.1f. Performance of weanling rabbits fed grain-based diets with or without Allzyme (BG) supplementation

	Parameters					
Diets	Initial wt. (g)	Avg feed intake (g)	Avg daily wt. gain (g)	Feed/gain	Mort.[2]	Mort.%
Control (OSU64)	791.10 ±26.3[a,1]	145.39 ±3.58[a]	42.01 ±1.20[a]	3.47 ±. 04[a]	-	-
High ßG Barley+	715.10 ±35.2[ab]	118.72 ±6.39[b]	39.04 ±1.47[ab]	3.04 ±0.15[ab]	-	-
High ßG Barley-	715.30 ±38.2[ab]	112.00 ±3.41[b]	38.14 ±3.20[ab]	3.12 ±0.31[ab]	1	10
Low ßG Barley+	704.80 ±35.3[ab]	117.49 ±8.29[b]	41.06 ±2.07[a]	2.87 ±0.13[b]	1	10
Low ßG Barley-	705.50 ±33.2[ab]	120.47 ±4.47[b]	41.18 ±2.03[a]	2.95 ±0.07[b]	-	-
Rye+	698.90 ±36.4[b]	107.18 ±6.39[b]	37.47 ±1.42[ab]	2.88 ±0.18[b]	-	-
Rye-	752.00 ±37.6[ab]	111.88 ±6.67[b]	39.63 ±1.54[ab]	2.81 ±0.10[b]	2	20
Triticale+	682.40 ±31.2[b]	104.14 ±2.92[b]	35.41 ±0.93[b]	2.95 ±0.06[b]	-	-
Triticale-	717.40 ±27.4[ab]	110.90 ±4.11[b]	39.39 ±1.18[ab]	2.82 ±0.07[b]	-	-

[ab] Any means within a column with the same superscripts are not significantly different at ($P<.05$).

[1] Means and standard error based on ten observations. [2] Number of dead animals from a group of ten.

+, with added Allzyme ßG; -, without of added Allzyme ßG.

Table 5.1g. Percent nutrient digestibilities by weanling rabbits fed barley, rye and triticale grain-based diets.

	Nutrients %					
Diets	Energy %**	Dry Matter %**	Crude protein %**	Acid detergent fiber %*	Neutral detergent fiber %**	Fat %**
Control (OSU64)	50.16 ±0.5^{d1}	52.20 ±.44^{d}	66.56 ±.69^{ab}	8.78 ±.85^{ab}	3.43 ±.89^{b}	47.51 ±2.05^{c}
High ßG Barley+	61.25 ±.72^{c}	63.25 ±.65^{c}	66.65 ±.46^{ab}	9.70 ±1.85^{a}	17.45 ±1.34^{a}	75.68 ±0.89^{a}
High ßG Barley-	61.52 .87±^{c}	63.03 ±.72^{c}	68.34 ±.34^{a}	0.07 ±1.07^{c}	17.39 ±.77^{a}	72.62 ±2.14^{ab}
Low ßG Barley+	60.38 ±.73^{c}	62.09 ±.50^{c}	67.72 ±2.36^{ab}	4.95±2.20^{abc}	18.99 ±1.78^{a}	70.37 ±3.49^{ab}
Low ßG Barley-	61.67 ±.50^{c}	62.69 ±.46^{bc}	66.19 ±.91^{ab}	6.52 ±1.85^{ab}	17.92 ±1.10^{a}	70.16 ±2.31^{ab}
Rye+	66.02 ±.58^{a}	67.42 ±.61^{a}	66.84 ±.78^{ab}	5.04±1.88^{abc}	18.32 ±1.66^{a}	76.17 ±.57^{ab}
Rye-	63.83 ±.33^{b}	65.56 ±.39^{b}	62.85 ±1.37^{b}	2.89 ±2.47^{bc}	18.55 ±2.07^{a}	74.69 ±2.26
Triticale+	64.17 ±.93^{ab}	65.93 ±.83^{ab}	69.47 ±1.79^{a}	7.62 ±1.38^{ab}	15.67 ±1.28^{a}	77.36 ±1.29^{a}
Triticale-	65.98 ±.35^{a}	67.23 ±.39^{ab}	66.86 ±1.01^{ab}	7.39 ±1.69^{ab}	17.99 ±1.30^{a}	76.90 ±1.24^{ab}

^{ab} Means within the same column with a different superscript are significantly different

** ($P<.01$) and *($P<.02$). [1] Means and standard error based on five observations.

+, with added Allzyme ßG; -, without of added Allzyme ßG.

Table 5.2a. Chemical composition of the broiler chicks experimental diets

	Nutrients						
Diet	GE Kcal/kg	Dry matter%	Neutral detergent fiber%	Acid detergent fiber%	Crude protein%	Ash%	Fat %
High ßG Barley+	2934.1	94.9	19.5	6.96	25.1	6.87	4.6
High ßG Barley-	2934.9	94.9	20.2	6.58	24.3	7.07	4.2
Low ßG Barley+	2970.7	95.5	25.8	8.02	25.7	7.24	3.9
Low ßG Barley-	2968.1	95.4	27.0	7.69	23.9	6.75	4.1
Rye+	2814.7	94.1	14.6	4.07	23.9	6.36	3.8
Rye-	2828.4	94.5	15.7	4.54	23.8	6.79	3.9
Triticale+	2817.0	94.0	14.6	5.61	24.5	6.19	4.0
Triticale-	2826.3	94.3	13.3	4.11	24.2	6.37	4.4
Control+	2874.0	93.9	13.2	3.86	22.8	5.89	4.9
Control-	2873.6	93.9	15.0	4.15	22.4	6.15	4.8

+, with added Allzyme ßG; -, without added Allzyme ßG.

Table 5.2b. Performance of broiler chicks fed barley, rye and triticale grains with or without Allzyme BG supplementation.

			Parameters					
Diets	Initial wt. (g)	Total gain (kg)	Average daily gain (g)	% Increase in daily gain with Allzyme ßG	Avg daily feed intake	Feed/gain	%Improvt. with Allzyme ßG	Difference between control in Feed/gain
Control+	143.70±3.4^{NS}	1.38 ± 0.07^{ab}	48.82 ± 2.5^{ab}	-	89.48	1.87 ± 0.09^{ab}	-	-
Control-	144.00±2.9	1.43 ± 0.06^{a}	50.94 ± 2.3^{a}	-	91.56	1.83 ± 0.09^{a}	-	-
High ßG Barley+	150.90±1.9	1.31 ± 0.04^{abc}	46.83 ± 1.5^{abc}	10.60	92.63	1.99 ± 0.06^{ab}	10.8	8.70
High ßG barley-	150.20±2.9	1.19 ± 0.05^{cd}	42.38 ± 1.5^{cd}	-	92.76	2.23 ± 0.09^{ab}	-	-
Low ßG barley+	146.40±3.1	1.41 ± 0.06^{a}	50.70 ± 2.1^{a}	19.40	100.22	2.03 ± 0.09^{ab}	8.60	10.90
Low ßG Barley-	145.90±2.8	1.19 ± 0.04^{cd}	42.50 ± 1.5^{cd}	-	93.33	2.22 ± 1.60^{ab}	-	-
Rye+	145.90±4.8	1.20 ± 0.05^{cd}	42.90 ± 1.7^{cd}	11.70	93.12	2.20 ± 0.08^{ab}	19.80	20.20
Rye-	149.10±3.5	1.08 ± 0.08^{d}	38.40 ± 3.0^{d}	-	95.78	2.74 ± 0.37^{c}	-	-
Triticale+	145.10±4.8	1.35 ± 0.04^{ab}	48.10 ± 1.4^{ab}	9.30	91.30	1.91 ± 0.05^{ab}	3.50	4.40
Triticale-	144.90±3.2	1.23 ± 0.05^{c}	44.00 ± 1.8^{c}	-	86.10	1.98 ± 0.09^{ab}	-	

Means within the same column with a different superscript are significantly different ($P<.05$). +, -, = with or without supplementation.

Table 5.3. Performance of laying pullets fed high and low ß-glucan barley with or without Allzyme BG supplementation

Parameter	Control	High ßG barley	High ßG barley+ Enz.	Low ßG barley	Low ßG barley +Enz.
Initial weight (Kg).	$1.80 \pm .08$	$1.81 \pm .06$	$1.81 \pm .06$	$1.78 \pm .06$	$1.79 \pm .05^{NS}$
Weight gain (gm).	13.63 ± 24.5^{a}	-154.6 ± 60.6^{b}	-49.98 ± 27.5^{a}	-50.00 ± 29.1^{a}	-13.13 ± 15.5^{a}
Total feed intake (gm).	20136.00^{a}	10977.00^{e}	15500.00^{d}	15545.00^{c}	15591.00^{b}
Total eggs produced.	115.00	42.00	103.00	100.00	106.00
% Egg production.	88.46	32.31	79.23	76.92	81.54
Feed/hen day (gm).	154.89	84.41	119.20	119.58	119.93
Dozen eggs produced.	9.58	3.50	8.58	8.33	8.83
Feed/dozen (Kg).	2.10	3.14	1.81	1.87	1.77
% Fecal moisture.	78.85	81.85	81.56	77.14	75.45
% Fecal dry matter.	21.15	18.68	18.45	22.86	24.58

^{a,b,c,d,e} Means in a row with the same superscript are significantly different ($P < .05$).

Means and standard error based on ten observations

Performance of laying pullets fed high and low glucan barley with or without Allzyme (BG) supplementation

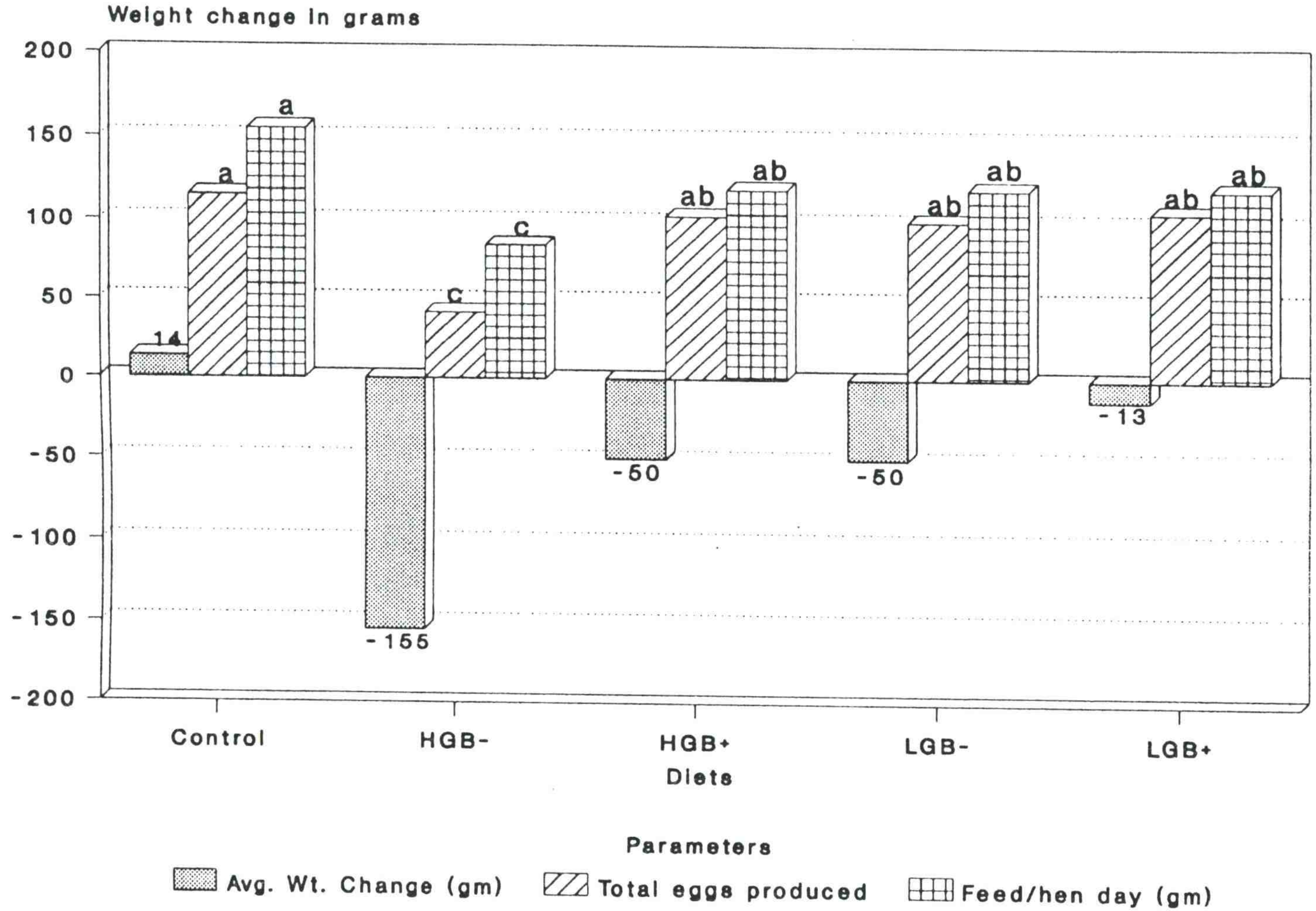

Figure 5.1. Effect of Allzyme BG supplementation on weight gain, feed intake, and egg production of laying pullets fed high and low ß-glucan containing barley diets

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PART THREE: FEED PROCESSING METHODS

CHAPTER 6

EFFECTS OF AMMONIATION OF WHEAT MILL RUN ON PERFORMANCE AND NUTRIENT DIGESTIBILITY IN FRYER RABBITS

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ABSTRACT

The effect of ammoniation of wheat mill run (WMR) on the performance and nutrient digestibility of growing rabbits was studied. Forty 4-5 week old weanling rabbits were assigned to five dietary treatments with 8 rabbits on each. The diets were formulated using either ammoniated or untreated WMR at 50% and 25% levels of substitution. The ammoniated WMR was obtained by dissolving 3g of urea and .25g of raw soybean in 10 mls of water per 100 g of the WMR and incubating the mixture in a tightly sealed plastic bag for 28 days before mixing the diets. The experiment lasted for 28 days, during which feces and urine were collected in the last week of the study for digestibility and nitrogen retention determination. The results indicated that neither the overall performance nor the nutrient digestibility were significantly influenced as a result of ammonia treatment. The group fed 25% untreated WMR had the highest average daily gain and NDF digestibility. Those on treated 50% WMR had the lowest average daily gain, daily feed intake and percent nitrogen retention. Feed efficiency was best for the group on untreated 50% WMR and poorest with those on the control diet. Ammoniation did not significantly influence the nutrient composition and digestibility. The digestibility of ADF was negative for all WMR-containing diets. It was concluded that ammoniation of WMR does not improve its feeding value for rabbits.

INTRODUCTION

Fibrous feedstuffs are important in the maintenance of digestive transit, normal gut function, formation of hard feces and prevention of enteritis in rabbits. Although straw and other fibrous materials are poorly digested by non-ruminants, the successful effects of ammoniated straw in ruminants (Harrera-Saldana et al., 1983, Ibrahim et al., 1985, Llamas-Lamas and Combs 1990, Tiwari et al., 1990) producing feed of high nutritive value has led to research in the possibility of feeding rabbits ammoniated fibrous feeds (Lebas and Leplace 1977; Hodgson 1975; Uden and Van Soest 1982; Fayek et al., 1989). The objective of this experiment was to determine if ammoniation of WMR would increase its utilization in the diets of weanling rabbits and also evaluate the performance and nutrient digestibility in growing rabbits.

MATERIALS AND METHODS

Diets

A standard fryer rabbit ration (OSU7) was used as a base diet with which the treated and untreated wheat mill run (WMR) were substituted at 50% and 25% levels. Treated WMR was obtained by dissolving 3 gm of urea in 10 mls of water per 100 g of the WMR and adding .25 gm of raw soybean as a source of urease. The solution was thoroughly mixed with the WRM and incubated in a tightly sealed plastic bag for 28 days before formulating the diets. After incubation, the contents were removed and allowed to aerate for 24 h to reduce the ammonia odor, and along with the unammoniated WMR portion, were used to formulate the experimental diets. Table 6.1 shows the composition of the standard fryer diet, the experimental diets at various substitutional levels and the chemical analysis of the diets.

Animals

Forty 4-5 week old New Zealand White (NZW) weanling rabbits were ear-tagged, weighed and randomly assigned to the five dietary treatments with 8 rabbits per treatment. Each animal was placed in an individual cage measuring 30 X 76 X 46 cm. Each cage was equipped with an automatic watering device and a "J" shaped galvanized metal feeder with a screen bottom. The diets were measured and fed to the animals ad libitum for an experimental period of 28 days, during which feed intake, weight gain, mortality and any incidence of enteritits were recorded.

After three weeks, 1 mm fine wire mesh screens designed to collect the entire fecal output were placed underneath the cages of all the experimental animals. A 50 gallon plastic bag was fastened under the screen to collect the urine. The collected urine was removed from the bags on a daily basis and placed in labelled plastic bottles containing 5 ml of H_2SO_4 to prevent putrefaction. Both the feces and urine were removed and frozen at -4 °C for further analysis.

At the end of the 28 days, final weight gain of each animal and the total feed intake were recorded and the results were used to calculate the daily weight gain, daily feed intake, and feed to gain ratio. The feces were later dried at 60 °C in a conventional oven for 72 h and air equilibrated for 48 h and ground to pass through a 1 mm screen in a Wiley mill and used for digestibility determinations (table 6.3).

Analyses

Chemical analysis were done using the standard procedures of AOAC (1984), while acid detergent fiber (ADF) and neutral detergent fiber (NDF) were done by the methods of Van Soest (1963). The data were subjected to the GLM procedures of SAS (1991) for analysis of variance and Duncan's method of means separation was used to separate the means that were significant.

RESULTS AND DISCUSSION

Table 6.1 shows the chemical composition of diets. There were no differences in the nutrient composition of all the diets, except that ADF and NDF which were slightly higher in some of the diets. Figure 6.1 shows the animal performance data. The group on diet 4 (25% untreated WMR) had the highest average daily gain 42.3 g, but it was not significantly different from the those on diet 5 (control) which had 38.5 g. The rabbits on treatment 1 (50% treated WMR) had the lowest average daily gain of 29 g) which was significantly ($P<0.01$) different from the rest of the treatments. Average daily feed intake followed the same pattern. The lower average weight gain of the rabbits fed diet 1 might have been due to residual ammonia in the diet which could have reduced voluntary intake. The lower feed intake in addition to lower levels of crude protein in the diet might have resulted in amino acid deficiency, thus protein synthesis to promote adequate growth was not achieved. NRC (1977) and Cheeke (1987) indicated that a growing rabbit needs at least 15% crude protein to perform well, however, none of the diets had levels of crude protein higher than 15%. This result is in agreement with that of Copping, et al., (1988) who stated that rabbits fed a low protein diet supplemented with urea had a reduced feed intake which subsequently resulted in lower gain. The group on diet 2 (50% untreated WMR) had the best feed to gain ratio (F/G) of 2.97, and there was no difference between the rest of the dietary treatments.

Digestibility of nutrients

Dry matter (DM) and ADF digestibility were not significantly influenced as a result of ammonia treatment. Crude protein digestibility was highest among all nutrients. Diet 2 (untreated 50% WMR) had the highest value (79.4) but was not significantly (P>0.05) different from diet 3 (25% treated) and 4 (25% untreated), but was significantly different from 1 (50% treated and 5 (control). The high crude protein digestibility values obtained in this study may be due to the fact that rabbits practice cecotrophy, which tends to permit further digestion of the nutrients. Mathius et al., (1988) indicated that addition of nitrogen or increasing the crude protein level in diets of rabbits tends to increase the digestibility of nitrogen. A similar observation has also been reported by Makkar and Singh (1987). The NDF digestibility was lowest with diet 3 (4.6 ± 3.38), but was not significantly (P>0.05) different from diet 5 and 2, while diet 4 had the highest value (28.59 ± 6.08) but was different (P> 0.05) from 1 and 2. ADF values were negative, with no pattern to suggest dietary effect or otherwise. The negative value associated with ADF digestibility is not uncommon. Tor-Agbidye et al., (1990) reported similar values when graded levels of buckwheat were fed to fryer rabbits. The possible reasons for negative values in the digestibility of ADF have been theorized and explained (Cheeke 1983; Fayek et al., 1989). Urine was collected for urinary nitrogen analyses, but because of very high variability in the urinary nitrogen values, the data were not used.

Although it has been suggested that growing rabbits are more efficient in the utilization of urea than adult rabbits, (Coppings et.al., 1988), King (1971) indicated that young rabbits have a lower capacity to utilize the nitrogen derived from urea in the synthesis of the body protein. This study did not observe any particular benefits of feeding ammoniated WMR to the rabbits irrespective of the dietary levels of the WMR. Similar observations have been reported by Abou- Ashour and Ahmed (1986).

CONCLUSION

The effect of feeding growing rabbits either treated or untreated WMR substituted at 50% and 25% levels, was investigated using forty fryer rabbits of 4-weeks old. It was observed that urea treated and untreated wheat mill run incorporated into the diets of growing rabbits, did not improve either the general performance nor the nutrient digestibility. However, it was observed that inclusion of up to 50% treated or untreated wheat mill run in the diets of fryer rabbits did not have adverse effects on nutrient digestibility, although growth performance may be affected with treated WMR. Mortality was very low with only one rabbit from each group except those on the 25% treated WMR died during the experimental period. Thus it could be concluded that only up to 25% treated wheat mill run should be included in the diets of growing rabbits. Further studies could however, be conducted to investigate this type of treatment also on adult rabbits and may include biochemical parameters such as blood and tissue ammonia levels to fully assess the beneficials effects of ammoniaton in growing rabbits.

Table 6.1. Composition and chemical analyses of the experimental diets containing ammoniated and untreated wheat mill run

Ingredient	50% Treated	50% Untreated	25% Treated	25% Untreated	Control
Alfalfa					74.00
Wheat mill run	50.00	50.00	25.00	25.00	21.00
Molasses					3.00
Canola oil					1.25
Salt					.50
Dicalcium					.25
Copper sulfate					.10
DL-Methionine					.20
Chemical Analyses					
Dry matter, %	89.90	90.36	90.11	90.06	91.21
Crude Protein, %	13.76	14.29	13.61	13.51	13.02
Neutral deter. Fiber, %	50.35	47.23	42.06	59.24	44.71
Acid deter. Fiber, %	20.52	17.41	22.91	22.38	25.92
Ash, %	9.99	9.06	9.58	9.49	9.28

Performance of fryer rabbits fed ammoniated and unammoniated wheat mill run

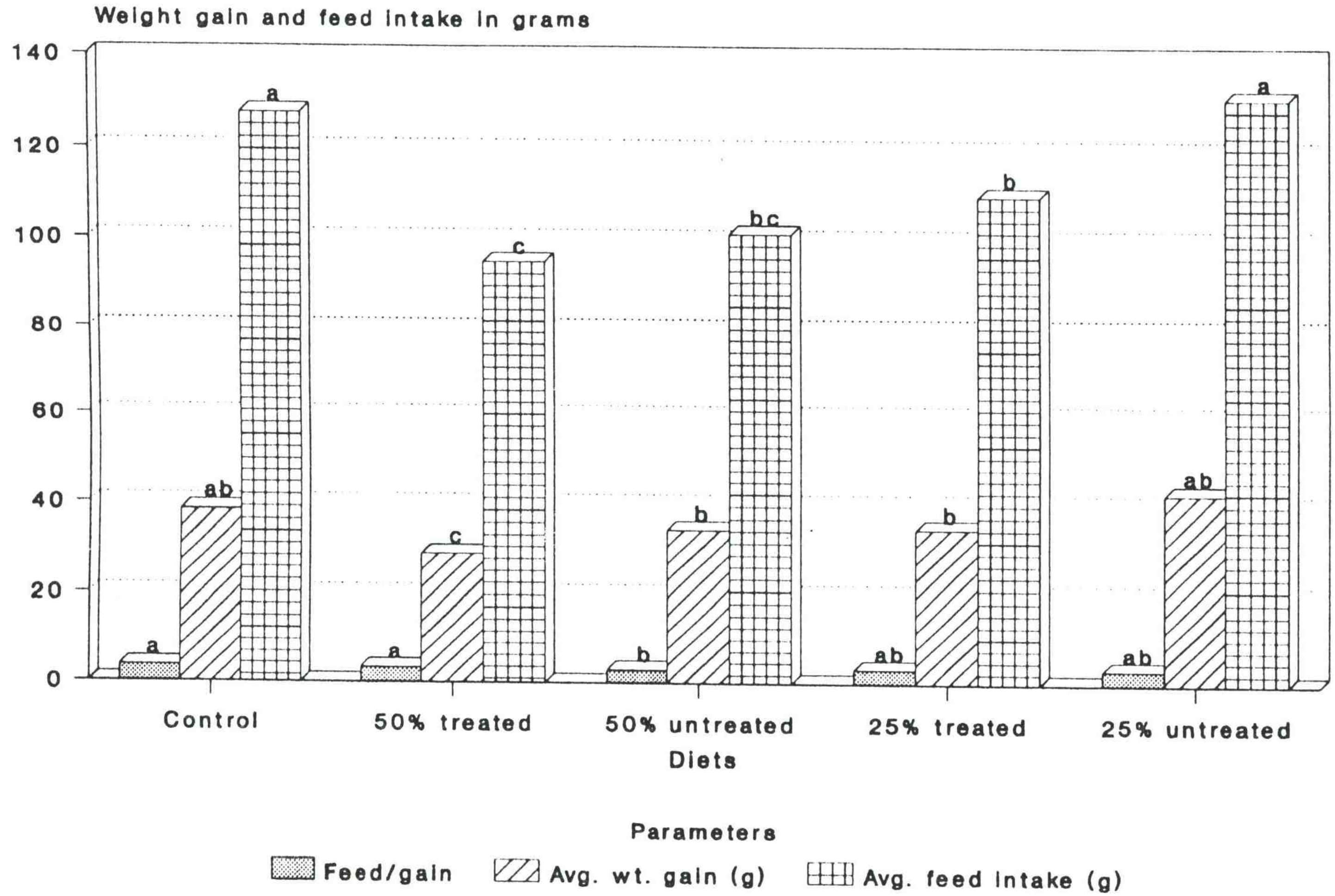

Figure 6.1. Effects of ammoniated and unammoniated wheat mill run on weight gain, feed intake and feed conversion in fryer rabbits.

Table 6.2. Performance and nutrient digestibility of fryer rabbits fed ammoniated and unammoniated wheat mill run

Parameter	50% Treated	50% Untreated	25% Treated	25% Untreated	Control
Initial weight, (g)	928.63 ± 44.36	879.25 ± 41.48	886.25 ± 32.75	886.25 ± 51.78	862.00 ± 39.92^{Ns}
Average daily weight gain, (g)	28.88 ± 1.60^{c}	34.33 ± 2.53^{b}	34.57 ± 1.85^{b}	42.28 ± 2.14^{a}	38.46 ± 1.93^{ab}
Average daily feed intake, (g)	94.79 ± 3.16^{c}	101.08 ± 6.56^{bc}	109.43 ± 5.15^{b}	130.96 ± 5.41^{a}	127.64 ± 4.79^{a}
Feed / gain ratio	3.32 ± 0.13^{a}	2.97 ± 0.08^{b}	3.19 ± 0.12^{ab}	3.12 ± 0.11^{ab}	3.71 ± 0.46^{a}
Nutrient digestibility					
Dry matter, %	59.73 ± 0.66	61.04 ± 0.42	57.38 ± 1.05	56.73 ± 2.40	57.15 ± 2.29^{NS}
Crude protein, %	75.21 ± 0.70^{b}	79.35 ± 0.57^{a}	76.21 ± 0.68^{ab}	76.88 ± 1.24^{ab}	75.76 ± 1.54^{b}
Neutral deter. fiber, %	23.73 ± 3.37^{ab}	19.59 ± 3.3^{abc}	4.59 ± 3.38^{c}	28.59 ± 6.08^{a}	9.22 ± 5.58^{bc}
Acid detergent fiber, %	-15.74 ± 5.10	-27.18 ± 5.37	-16.86 ± 4.33	-24.67 ± 11.2	-11.21 ± 7.22^{NS}

^{abc} Means within a row with a different superscript are significant ($P<0.05$).

^{NS} Not significant at ($P>0.05$).

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CHAPTER 7

EFFECTS OF AMMONIATION OF VARIOUS TOXIN-CONTAINING FEEDSTUFFS ON THE PERFORMANCE OF BROILER CHICKS.

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ABSTRACT

The effects of ammoniating various toxin-containing seeds and forages on nutrient composition and performance of broiler chicks were evaluated. All the feedstuffs were ground and ammoniated by adding 3 g of urea in 10 mls of water and .25 g of soybean meal as a urease source per 100 g of the test materials. The ammoniated materials were tightly sealed in plastic bags for 28 days, after which they were incorporated into a standard broiler starter diets at various percentages between 0% to 20%. The unammoniated test materials, were also incorporated from 0% -20% in the experimental diets. Ten 7-day old broiler chicks (Peterson X Hubbard) were assigned to each of the dietary treatments and fed the experimental diets for 28 days. Feed and water were supplied ad-libitum throughout the experimental period. Ammoniation increased the nitrogen content of all the test materials, but other nutrients were either slightly increased, decreased or unaffected. Chicks fed the ammoniated tansy ragwort, meadow foam, pinto beans, radish seeds and bracken fern based diets had significantly ($P<.05$) better gains compared to the diets with the same level of the untreated plant materials. Those on the untreated kidney beans, whole cottonseed, cottonseed meal, 0% (-) endophyte free and 66% endophyte infected tall fescue and 3% jimsonweed seeds had slightly better weight gain than their counter parts on similar but ammoniated diets. The groups on both treated and untreated 66% endophyte infected tall fescue diets had the best weight gain among all the dietary treatments. Those on both treated and untreated whole cottonseed and 5% tansy ragwort had the worst weight gains. Feed intake, efficiency and mortality were not significantly affected. It was concluded that ammoniation increased the nitrogen content of some of the feedstuffs, and reduced the toxicity of some toxin-containing feedstuffs.

INTRODUCTION

Apart from improvement in the quality of straw and other low quality roughage, ammoniation has been reported to be beneficial as a means of detoxification of certain toxic constituents of plants and / or by-products. Bell et al., (1984), reported that the glucosinolate content of mustard and other brassicca meals was reduced up to 80% by ammonia treatment. Norred and Morrissey (1983) indicated that rats fed aflatoxin contaminated corn had chronic signs of aflatoxin toxicosis such as increased mortality, liver neoplasia, decreased hematocrit and hemoglobin, but those signs were absent in the groups fed ammoniated aflatoxin-contaminated corn. Schroeder et al., (1985) reported similar observations. Park et al., (1988) reviewed the literature on the decontamination of aflatoxin and indicated that ammoniation is one of the most effective detoxification procedures.

Sanderson et al., (1985) observed that ammoniation of sweet clover prevented the formation of dicourmarol and hence prevented the bleeding disease associated with feeding moldy sweet clover hay. Ammoniation of endophyte-infected tall fescue hay increased serum prolactin concentrations and prevented signs of heat stress (eg elevated rectal temperature) in steers fed hay (Kerr et al., 1990). Thus ammoniation of fescue hay and straw may be a practical method of preventing tall fescue toxicosis. These reports on the effectiveness of ammoniation in the detoxification of a variety of natural toxins prompted us to evaluate this procedure with a number of feedstuffs and poisonous plants that contain various natural toxins. Thus the objective of this study was to evaluate the effect of ammoniation as a feed processing method on improving the palatability, acceptability, and / or detoxification of toxic constituents of some by-products, seeds and forages containing different classes of toxicants. The classes of toxicants used and the plant containing them are listed in table 7.1.

MATERIALS AND METHODS.

Diets.

The diets were formulated with ammoniated or unammoniated test materials under different classes of toxicants (table 7.1). A known quantity of the test materials (leaves, forages and seeds) were obtained and subdivided into two equal parts of desired quantity and one of the parts ammoniated by dissolving 3 g feed grade urea in 10 mls of water and .25 g of raw soybean as urease source per 100 g of the test material to release ammonia. The solution was stirred to ensure a homogenous mixture, after which it was mixed with one portion of the test materials and incubated in tightly sealed plastic bags. After 28 days, the bags were opened and allowed to aerate for 24 h to reduce the ammonia odor. Both the ammoniated and the unammoniated portions of the test materials were used at various levels (0% to 20%) to substitute the broiler starter mash diet (table 7.2) to formulate the experimental diets (table 7.3).

Birds and Housing.

The hatching eggs were obtained from Keith Smith Farms, Hot Spring, Arkansas via Jenks Hatchery, Tangent, Oregon. They were incubated and hatched in incubators at the OSU poultry unit. After hatching and feather sexing, the chicks were placed on the broiler starter diet for a one week pre-experimental period. Ten, one-week old Peterson x Hubbard broiler chicks (five of each sex) were randomly assigned to each of the dietary treatments (table 7.3). The birds were individually wing banded, weighed and housed in an electrically heated, ventilated broiler house with wood shavings as litter. Bird density was .69 m^2 / bird and the temperature was maintained between 18 - 24 °C (65 - 75 °F) for twenty four hours a day, and feed and water were provided ad-libitum for 28 d. During the experimental period, the birds were monitored on a daily basis for toxicity signs associated with the various toxicants, and mortality rates recorded. The dead birds were taken to the Veterinary Diagnostic Laboratory for diagnosis. At the end of the 28 d period, total feed consumption and final body weight of each of the birds were recorded. The results were used to calculate average daily gain, daily feed intake and feed efficiency (table 7.6).

The data were treated as a completely randomized design and the means were analyzed by a one-way analysis of variance using GLM in SAS (SAS Institute, 1991), and the significant treatment means were separated by Duncan's multiple range method of means comparison (Snedecor and Cochran, 1989).

RESULTS AND DISCUSSION

Effects of Ammoniation on nutrient composition

Table 7.4 shows the nutrient composition of the treated and untreated feed ingredient incorproated in the broiler diets. The dry matter content of the treated test materials was slightly lower than the untreated due to the 10% water used to dissolve the urea and raw soybean. The nitrogen contents of all the ammoniated materials were increased, with the highest as much as 32% in the luecaena leaves, and the lowest (7.0%) in the raw soybean. Also there was a slight increase in the composition of the acid detergent fiber (ADF) in all of the treated materials, except the datura seeds and whole cottonseed which had lower ADF values. The contents of neutral detergent fiber (NDF), ash and fat were not consistent with any form of treatment.

The dry matter content of the diets containing the treated test material was slightly lower in most of the diets (table 7.5). However, the dry matter contents of the treated 2.5% tansy ragwort, 3% datura seeds and St. Johnswort were slightly higher than their untreated counter parts. Most of the diets containing the treated test materials had slightly lower values of nitrogen compared to their untreated counter parts. This suggests that the increase in the nitrogen content of the test materials as a result of ammoniation did no influence the nitrogen content of the diets. The seed-based test materials had less nitrogen increase than the (fibrous) forage materials. Apart from nitrogen content, ammoniation did not seem to influence the content of other nutrients of the experimental diets. Keith and Bell (1984) indicated that ammoniation did not increase content of other nutrients in ammoniated canola meal. They also stated that ammoniation can increase the nitrogen content of canola meal, but such nitrogen is of limited benefit to the animals because it is poorly utilized. Sundstól and Owen (1984) reported similar observations and stated that, if ammoniation is properly done, it can increase nitrogen values of treated materials.

Effects of Ammoniation on broiler performance

Ammoniation significantly increased the daily feed intake of the chicks fed the endophyte infected tall fescue, radish seeds, 6% datura seeds, vetch seeds, luecaena leaves, and raw soybean, but caused a decreased feed intake for the groups on 3% datura seeds, endophyte-free fescue seeds and bracken fern over their counter parts on the untreated test materials (table 7.6). The highest average feed intake (98.7 g) was from the groups on the diets containing treated St. Johnswort, which was 17% higher than their counter part on the diets containing untreated St. Johnswort, but was not significantly ($P<.05$) different from kidney beans, pinto beans, endophyte infected tall fescue, black locust, raw soybean and the control. The lowest average feed intake (26.5 g) was for the group on treated whole cottonseed which was 32% lower and significantly ($P<.05$) different from those on the untreated whole cottonseed (39.1 g). The feed intake of the broilers on both levels of tansy ragwort and crotalaria seeds were significantly lower than the rest of the groups regardless of treatment. Since animals eat to satisfy their energy requirements, it would appear that the feed intake of broilers on most of the treated and untreated test materials of the diets was high enough and comparable to the control to support growth, except those on all levels of tansy ragwort, crotalaria and whole cottonseed. The groups on these test materials had significantly lower ($P<.05$) average feed intake than those on the control. In general, there was no definite pattern for feed intake associated with any particular toxin-containing test materials.

The average daily gains of the broiler chicks on diets containing treated 2.5% tansy ragwort, 6% datura seeds, radish seeds, meadowfoam, black locust, pinto beans and bracken fern were improved as a result of ammoniation compared to their counterparts on the untreated test materials. This suggests that perhaps ammoniation detoxified the toxic constituents of these materials, hence improved the performance of the chicks fed those test materials as compared to their counter parts that had diets containing untreated materials. But the performance of the chicks on ammoniated 3% datura seeds, endophyte-free tall fescue seeds, cottonseed meal and soybean meal was depressed as compared to their counter parts on the unammoniated test materials. This may not be necessarily a result of ammoniation, but due to the toxic constituents of the toxicants in the seeds and forages. Ammoniation did not influence the performance of the groups on 5% tansy ragwort, 0.2% and 0.1% crotalaria, endophyte infected tall fescue, kohlrabi, whole cottonseed, St. johnswort, vetch seeds, luecaena leaves, and kidney beans. The performance of chicks on all of those dietary treatments was similar between treated and untreated test materials. The performance of chicks on all levels of datura seeds, endophyte-free and endophyte infected tall fescue, cottonseed meal, and treated radish seeds were similar to control and significantly higher (P<.05) than the rest of the treatments. The difference in daily gains between the chicks on diets containing treated and untreated test materials were as high as 53% in meadowfoam and as low as 12% in the pinto beans.

The broilers on diets containing untreated 3% datura seeds and cottonseed meal gained more higher (P<.05) than their counter parts on the diets containing the treated materials. The endophyte infected tall fescue seeds had the best average daily gains of 51.6 g and 50.1 g in the treated and untreated, respectively, and were higher than the control group (45.04 g). Chicks on both treated and untreated 5% tansy ragwort, .2% crotalaria, whole cottonseed, and luecaena leaves had the lowest average daily gain among all the dietary treatments. This was followed by 5% tansy (15.29 g and 15.10 g) and then luecaena leaves (18.84 g and 18.89 g) treated and untreated respectively.

Although average daily feed intakes of chicks on some of the diets were very comparable to the control, the intakes were not linearly related to the average daily gain. This might be associated with toxic constituents of the test materials in the diets. Fenwick et al., (1984) indicated that ammoniation is sometimes an insufficient method to effectively prevent the effects of some toxicants, hence toxicity effect may occur with consequences manifested in the performances of the animals fed diets containing such ammoniated test materials. Keith and Bell (1984) reported that weight gain and feed intake were not significantly different between a group of rats fed ammoniated or unammoniated canola meal containing glucosinolates. They concluded that although ammoniation was effective in reducing the glucosinolate concentration in the canola meals, it can also decrease the absorption of lysine. By the same reasoning, it is possible that the poor performance of the broilers on some of the diets containing ammoniated materials might be associated with effect of ammoniation on lysine.

Treatment did not seem to have much effect on the efficiency of feed utilization, however, the chicks on the diet containing treated 6% datura had the best overall feed efficiency (1.78) which was significantly ($P<.05$) different from those on the diet containing untreated 6% datura seeds (2.16). The improvement in feed efficiency associated with the chicks on the diet containing treated datura seeds, meadowfoam and bracken fern, is an indication that perhaps the toxic constituent of these test materials was lowered or destroyed as a result of ammoniation. Toxic constituents of datura (jimsonweed) seeds have been implicated in poisoning of livestock exposed to contaminated grains containing jimsonweed. Diets containing up to 3% of jimsonweed have been reported to depress performance of broilers (Day and Dilworth, 1984; Crawford and Friedman, 1990). Gumbmann et al., (1989) also indicted that concentration of jimsonweed above .5% can result in adverse physiological changes in rats.

The poorest efficiency of feed utilization was for the group of chicks on diets containing treated and untreated luecaena leaves (4.98 vs 3.91), respectively. This poor efficiency of feed utilization may be due to the presence of mimosine as well as dilution of the energy level by the inclusion of the 20% forage in the diets. Luecaena leaves contain mimosine, a toxic amino acid that inhibits the growth of broiler chicks (D'Mello and Thomas, 1978; D'Mello et al., 1987). Tangendjaja et al., (1990) reported that leucaena leaf meal at dietary level of 20%, 40% and 60% inhibited the growth of rabbits.

Three chicks died on diets containing untreated cottonseed meal. The mortality incidence associated with the cottonseed meal diet is due to gossypol, the toxic constituent of cottonseed meal. The fact that broilers chicks on treated cottonseed meal had no incidence of mortality, is an indication that the ammoniation was effective in destroying the toxic constituents and gossypol in cottonseed meal. Higher levels of gossypol tend to be correlated with high mortality rates (Waldroup et al., 1973; Vohra et al., 1974, and Balogun et al., 1990).

Mortality and the signs of thiamin deficiency for the groups of chicks on the untreated bracken fern were halted when the chicks were injected with vitamin B complex (thiamin). Prior to the treatment, 2 of the chicks on the diet containing untreated bracken died, but all the treated chicks recovered. Bracken fern (*Pteridium aquilinum L Kuhn*) contains a thiaminase enzyme which can induce thiamin (Vitamin B_1) deficiency particularly in non-ruminants. Due to lack of microbes non-ruminants do not synthesize enough of the vitamin B_1 through the natural process. Thus when thiamin deficiency occurs, deficiency symptoms like anorexia, gait disturbance, staggering, lack of coordination, weak and fast pulse, exhaustion, muscular spasm, and backward inflection of the neck can occur, leading to death (Fenwick, 1988 and Ushijima et al., 1983). The thiamine deficiency symptoms were observed in most of the chicks on the untreated bracken fern based diet.

It is not clear why one chick died from the group on treated 3% jimsonweed, since ammoniation was expected to inhibit the effect of atropine alkaloid found in jimsonweed. The alkaloid can cause problems with the central nervous systems and depress the performance of the animals. Day and Dilworth (1984) reported that dietary levels of 3 and 6% jimsonweed drastically depressed performance of young broilers. Flunker et al., (1987) indicated that more than 3% of jimsonweed seed would be required to depressed performance in broilers. Other effects of jimsonweed seeds reported include depressed weight gain and increased liver and testicular weights (Dugan et al., 1989 and Crawford and Freidman, 1990). Mortality cases occurred on some of the diets containing both treated and untreated test materials that may not be related to dietary treatments.

The performance of the broiler chicks fed these toxicant-containing diets was not influenced by any particular group of toxicants. The various classes of toxicants used in this study are known to exert adverse physiological, biological and economic effects on different species of livestock. James et. al., (1992) indicated that natural toxins can cause adverse effects on the reproductive performance in livestock by causing abortions, emaciation and subsequent abnormal mating, birth defects and increasing the time between parturition and rebreeding.

Pyrrolizidine alkaloids (PA) are hepatoxic to many animals and are responsible for losses of large numbers of livestock when plants containing them are ingested by the livestock (Cheeke and Shull, 1985; Cheeke, 1988; and Deyo and Kerkvliet, 1990). Hooper and Scalan, (1977) indicated that mortality and decrease in weight gain occurred in pigs and chickens fed varying levels of *Crotalaria retusa* seeds. Apart from being hepatoxic, crotalaria seeds can cause damage to pulmonary and renal organs. They can also cause birth defects (malformations) and fetal death (Johnston and Smart 1983). Goeger et al., (1982) reported that feeding tansy ragwort to lactating and kid goats resulted in mortality with obvious signs of alkaloid toxicosis. Cheeke (1984) indicated that cattle and horses are more susceptible to alkaloid toxicosis than goats, sheep and other non-ruminant herbivores (rabbits, gerbils, guinea pigs,and hamsters). It has also been indicated that the concentration of alkaloids in tall fescue is related to the infestation of the plant by the endophytic fungus (*Epichlore typhia*). This endophytic fungus can cause decreased performance of exposed livestock, particularly cattle and sheep (Cheeke and Shull 1985). Porter and Thompson (1992) indicated that the endophyte can produce ergot peptide alkaloids which cause fescue toxicosis with signs like decreased prolactin, increased body temperature and restricted blood flow to internal organs. Ammoniation has been reported to be effective in lowering the toxic constituents of plants. However, Keith and Bell (1984) did not observe any significant differences in weight gain and feed intake as a result of ammoniation of canola meal containing glucosinolates. They concluded that although the ammoniation process can be effective in reducing the glucosinolate concentration in the canola meals, the method has an adverse effect on protein quality, particularly lysine availability, and thereby can decrease the nutritional value of the meal.

CONCLUSIONS

A number of toxicant-containing forages and seeds were ammoniated to determine the effects of such a feed processing method on the performance of broiler chickens. Ammoniation significantly increased the nitrogen content of fibrous (forage) test materials, but there was only a slight nitrogen increase in some of the seed-based test materials. Other nutrients were only slightly increased or decreased as a result of ammoniation. Although the average daily gains of broiler chicks on some of the diets containing ammoniated test materials were improved, this was not consistent and not related to any particular group of toxicants. Some of the dietary treatments containing both ammoniated and unammoniated test materials had little or no effect on the performance of the broiler chicks; rather the toxic constituents of the particular test material appeared to have a more direct correlation with performance. The chicks on diets containing untreated kidney beans, whole cottonseed, cottonseed meal, endophyte-free and endophyte infected tall fescue, and 3% jimsonweed seeds had better weight gains than their counter parts on the diets containing the same treated test materials. The group of chicks fed diets containing endophyte free (E-) tall fescue seeds had the best overall weight gain. The 3% jimsonweed seed and cottonseed meal-fed birds gained more than the chicks on the control diet. The chicks on diets containing whole cottonseed and 5% tansy ragwort had the lowest weight gains. Ammoniation significantly increased the feed intake of the groups on endophyte infected tall fescue, radish seeds, 6% datura seeds, vetch seeds, luecaena leaves, and raw soybean, but caused a decreased feed intake for the groups on 3% datura seeds, endophyte-free fescue seeds and bracken fern over their counter parts on the untreated test materials. Ammoniation was effective in reducing the toxicity of some plant materials such as datura seeds, radish seeds, meadowfoam and pinto beans, which was reflected in the performance of the chicks fed the diets containing the test materials. But the performance of the chicks on ammoniated 3% datura seeds, endophyte-free tall fescue seeds, cottonseed meal and soybean meal was depressed, compared to their counter parts on the unammoniated test materials.

It was concluded that ammoniation reduced the toxicity of seeds like datura, radish, meadowfoam and pinto beans, and forages like black locust but had little or no effect on the performance of broiler chicks fed diets containing 5% tansy ragwort, crotalaria seeds, endophyte infected tall fescue, kohlrabi seeds, whole cottonseeds, St. johnswort, vetch seeds, leucaena leaves, and kidney beans. Generally, improvement or decrease associated with ammoniation had no specific pattern. Thus ammoniation could be a feed processing method to detoxify some toxin-containing seeds and forages, but is not a general procedure for destruction of natural toxicants.

Table 7.1. Different classes of toxin-containing seeds and forages used in the experimental diets

Class of Toxicant	Forage or seeds	Botanical Name
Alkaloids	Tansy ragwort	*Senecio jacobaea*
	Crotalaria	*Crotalaria spectabilis*
	Jimsonweed	*Datura stramonium*
	Fescue seeds	*Festuca arundinacae*
Glucosinolates	Radish seeds	*Raphanus sativus*
	Kohlrabi	*Brassica oleracea*
	Meadowfoam	*Limnanthes alba*
Phenolics	Cottonseed meal	*Gossypium hirsutum*
	Whole cottonseed	*Gossypium hirsutum*
	Black locust	*Robinia pseudoacacia*
	St. Johnswort	*Hypericum perforatum*
Toxic Amino acids	Vetch seeds	*Vicia sativa*
	Leucaena leaves	*Leucaena leucocephala*
Lectin	Kidney beans	*Phaseolus vulgaris*
	Pinto beans	*Phaseolus vulgaris*
Cyanogen	Bracken fern	*Pteridium aquilinum*
Trypsin inhibitor	Raw soybeans	*Glycine max*

Table 7.2. Composition of the conventional broiler starter diet (1704)

Ingredients	Percent composition
Yellow corn	59.00
Soybean meal (47.5%)	32.50
Meat and bone meal	5.00
Animal fat	2.00
Ground limestone	0.52
Monocalcium phosphate	0.32
Salt	0.25
Vitamin premix[1]	0.20
DL-Methionine (98%)	0.13
Trace mineral premix[2]	0.05
Amprol-25[3]	0.05
Bacifern[4]	0.05

[1] The vitamin premix supplied the following quantities per kilogram of feed: Vitamin A 3,300y IU; vitamin D 1,100 IU; vitamin E 1.1 IU; vitamin K 0.55 mg; vitamin B_{12} 0.0055 mg; riboflavin 3.3 mg; pantothenic acid 5.5 mg; niacin 22 mg; choline chloride 220 mg; folic acid 0.22 mg; ethoxyquin 64.43 mg.

[2]Trace mineral premix supplied per kilogram of feed, the following: Calcium 107.5 mg; manganese 60 mg; iron 20 mg; zinc 28 mg; copper 2 mg; iodine 1.2 mg and cobalt 0.205 mg.

[3] Gratuitously provided by MSD Agvet Division of Merek and Co., Rahway, NJ.

[4] Gratuitously provided by Pitman - Moore, Inc., Mudellin Il. 60060.

Table 7.3. Composition of experimental diets with ammoniated or unammoniated test materials.

Class of toxicant	Test materials	% Substitution	% Broiler ration	Birds/treatment
Alkaloids	Tansy ragwort	5.00	95.00	10
	Tansy ragwort	2.50	97.50	10
	Crotalaria seeds	0.20	99.80	10
	Crotalaria seeds	0.10	99.10	10
	Datura seeds	6.00	94.00	10
	Datura seeds	3.00	97.00	10
	Fescue seeds E-	20.00	80.00	10
	Fescue seeds E+	20.00	80.00	10
Glucosinolates	Radish seeds	20.00	80.00	10
	Kohlrabi seeds	20.00	80.00	10
	Meadow foam seeds	20.00	80.00	10
Phenolics	Cottonseed meal	20.00	80.00	10
	Whole cottonseed	20.00	80.00	10
	Black locust	20.00	80.00	10
	St. Johnswort	5.00	95.00	10
Toxic Amino Acids	Vetch seeds	20.00	80.00	10
	Leucaena leaves	20.00	80.00	10
Lectins	Kidney beans	20.00	80.00	10
	Pinto beans	20.00	80.00	10
Cyanogen	Bracken fern	20.00	80.00	10
Trypsin inhibitor	Raw soybean	20.00	80.00	10

+ - Endophyte infected and endophyte free tall fescue seeds.

Table 7.4. Percent nutrient composition of the test materials used in the experimental diets

	Dry matter		Crude protein		Acid deter. Fiber		Neutral deter. Fiber		Ash		Fat	
Test material	**Treated**	**Untreated**	**Treated**	**Untreated**	**Treated**	**Untreated**	**Treated**	**Untreated**	**Treated**	**Untreated**	**Treated**	**Untreated**
Datura seeds	92.73	94.23	24.14	17.56	49.37	51.46	68.73	76.14	3.27	3.18	18.29	15.12
Fescue seeds E-	90.27	90.56	19.58	11.75	17.53	13.31	38.18	48.80	5.78	5.58	2.73	0.87
Fescue seeds E+	90.66	91.46	22.05	13.36	16.54	15.61	35.51	46.72	6.48	5.92	1.31	1.06
Radish seeds	89.42	94.37	37.72	28.87	20.42	17.89	26.80	24.34	4.11	4.20	39.97	42.89
Kohlrabi seeds	89.14	93.39	34.07	26.13	29.78	24.47	37.55	33.41	4.71	4.88	35.28	36.37
Meadow foam	87.81	92.24	29.52	17.87	33.05	26.06	53.65	68.58	8.33	7.62	19.33	18.60
Cottonseed meal	85.70	91.24	48.13	41.29	20.08	19.82	30.53	30.12	7.30	7.69	2.86	4.04
Whole cottonseed	89.63	94.08	33.54	25.13	32.49	32.81	43.80	35.54	3.97	4.62	18.77	22.00
Black locust	85.70	91.27	27.83	21.05	34.21	23.45	50.85	46.36	7.78	8.02	1.39	3.19
St. Johnswort	91.63	92.47	22.70	13.81	26.58	21.52	38.72	41.89	4.58	5.23	4.84	4.64
Vetch seeds	85.74	88.65	36.55	28.82	9.51	9.45	43.35	35.12	4.16	4.68	22.22	24.36
Luecaena leaves	92.20	94.98	31.23	21.24	25.70	24.83	43.93*	44.60	8.28	8.06	3.82	3.23
Kidney beans	86.26	90.82	33.29	25.45	7.62	5.39	36.70	33.02	4.04	4.84	1.61	1.41
Pinto beans	86.33	90.47	30.12	21.70	6.91	5.47	38.16	33.41	3.98	4.98	2.06	1.15
Bracken fern	90.04	90.52	26.93	16.91	39.92	30.88	59.08	66.13	7.90	7.87	1.62	2.08
Raw soybean	87.39	91.11	39.07	36.40	8.58	8.40	17.83	12.57	4.92	5.23	24.10	20.55

Table 7.5. Percent nutrient composition of the experimental diets on dry matter basis

		Dry matter		Crude protein		Acid deter. Fiber		Neutral deter. Fiber		Ash		Fat	
Diet	%	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated
Tansy ragwort	5	90.91	91.34	22.30	21.46	5.04	5.78	16.92	16.70	6.82	6.80	5.29	5.09
Tansy ragwort	2.5	91.51	91.04	20.45	20.96	5.24	5.91	19.63	16.61	7.19	6.39	6.03	5.20
Crotalaria	0.2	90.83	91.021	22.02	20.98	5.37	4.47	15.52	12.09	5.89	6.66	4.14	5.14
Crotalaria	0.1	90.93	91.36	22.24	20.93	6.20	5.51	17.73	14.83	6.20	6.80	4.83	6.27
Datura seeds	6	91.99	93.03	25.38	24.68	7.06	6.37	19.17	18.43	6.23	6.28	6.22	6.11
Datura seeds	3	93.33	92.87	23.90	25.76	5.31	5.44	16.18	18.82	6.56	6.48	5.20	5.61
Fescue seeds E-	20	92.05	92.80	24.34	22.69	5.42	5.24	21.54	23.27	6.24	6.16	4.70	4.48
Fescue seeds E+	20	92.49	92.82	23.86	22.79	6.11	6.41	23.27	23.35	6.28	6.29	3.95	4.26
Radish	20	89.72	90.15	22.78	22.16	9.08	10.19	19.61	23.07	5.77	5.50	- -	- -
Kohlrabi seeds	20	89.59	90.16	22.12	25.12	10.43	10.83	23.78	22.02	5.66	5.88	- -	- -
Meadow foam	20	92.81	93.38	25.59	23.48	8.24	8.00	23.61	26.76	6.59	6.51	9.46	9.24
Cottonseed meal	20	88.96	89.68	25.66	24.62	9.59	9.44	22.78	24.32	6.42	6.26	- -	- -
Whole cottonseed	20	89.33	90.43	21.30	21.26	10.72	14.56	23.87	28.09	6.15	5.79	- -	- -
Black locust	20	88.55	89.55	21.46	19.66	12.64	12.39	28.28	16.29	6.40	6.41	- -	- -
St. Johnswort	5	92.73	92.39	25.06	25.56	6.04	4.76	16.06	25.79	6.44	6.34	4.34	4.66
Vetch seeds	20	88.39	88.92	23.10	21.97	5.79	7.15	26.21	25.79	5.88	6.00	- -	- -
Leucaena leaves	20	92.45	93.18	25.31	24.86	8.08	8.28	24.60	21.87	6.75	7.12	4.71	5.04
Kidney beans	20	89.44	89.75	22.33	21.51	6.87	8.21	23.90	23.32	5.82	5.66	- -	- -
Pinto beans	20	88.82	88.96	22.01	20.89	7.01	6.43	24.55	26.28	6.02	5.84	- -	- -
Bracken fern	20	92.10	93.09	25.62	23.64	10.78	8.06	27.40	26.99	6.71	6.53	3.84	4.42
Raw soybean	20	89.52	89.97	23.82	23.25	9.10	10.21	23.36	18.70	5.39	5.91	- -	- -
Control	- -	- -	89.49	- -	25.96	- -	6.30	- -	20.66	- -	5.93	- -	5.32

Table 7.6. Performance of broiler chicks fed ammoniated and unammoniated toxic-containing seeds and forages

Diet	%	Initial weight (g) Treated	Initial weight (g) Untreated	Avg. daily wt. gain (g) Treated	Avg. daily wt. gain (g) Untreated	Daily feed intake (g) Treated	Daily feed intake (g) Untreated	Feed/gain Treated	Feed/gain Untreated	Mortality N/10 Treated	Mortality N/10 Untreated
Tansy ragwort	5	144.74±2.9	145.55±3.9	15.29 ± 1.4^{a}	15.10 ± 1.2^{a}	43.18	40.95	3.07±0.3	2.89±0.3	-	-
Tansy ragwort	2.5	145.32±3.3	145.81±4.2	30.79 ± 2.0^{a}	24.35 ± 1.4^{b}	59.62	53.76	2.01±0.1	2.27±0.1	1	1
Crotalaria seeds	0.2	144.93±3.2	144.77±2.9	16.06 ± 1.6^{a}	15.24 ± 1.4^{b}	34.05	31.37	2.33±0.2	2.20±0.2	-	1
Crotalaria seeds	0.1	145.28±4.1	145.23±4.2	26.34 ± 1.6^{b}	24.29 ± 2.4^{b}	52.56	52.13	2.07±0.1	2.36±0.2	-	-
Datura seeds	6	144.05±4.7	143.35±4.0	48.70 ± 1.6^{a}	42.62 ± 3.4^{b}	86.04	82.12	1.78±0.1	2.16±0.3	-	-
Datura seeds	3	139.16±5.1	139.81±4.3	46.48 ± 2.2^{b}	50.33 ± 2.7^{a}	83.95	89.29	1.84±0.1	1.83±0.1	1	-
Fescue seeds E-	20	143.96±3.6	145.96±3.9	42.90 ± 4.2^{b}	49.85 ± 1.3^{a}	85.91	94.55	2.34±0.4	1.91±0.0	-	-
Fescue seeds E+	20	149.50±5.3	149.80±3.8	51.64 ± 2.6^{a}	50.07 ± 2.4^{a}	96.06	93.54	1.90±0.1	1.90±0.1	1	-
Radish seeds	20	150.10±3.2	151.40±2.5	45.77 ± 2.0^{a}	22.52 ± 2.1^{b}	89.79	54.36	2.00±0.1	2.94±0.7	-	-
Kohlrabi seeds	20	148.70±3.1	148.80±3.8	40.50 ± 2.2^{a}	41.57 ± 1.7^{a}	82.07	82.86	2.09±0.1	2.02±0.1	-	-
Meadow foam	20	146.87±5.9	144.87±5.7	34.64 ± 1.9^{a}	16.29 ± 1.7^{b}	79.58	67.47	2.37±0.1	4.64±0.6	-	-
Cottonseed Meal	20	150.30±2.1	149.70±3.2	45.74 ± 1.7^{b}	49.12 ± 1.6^{a}	91.61	90.20	2.03±0.1	1.85±0.1	-	3
Whole cottonseed	20	148.70±2.0	149.70±3.2	10.24 ± 0.8^{a}	12.56 ± 1.0^{a}	26.46	39.11	2.77±0.3	3.31±0.3	-	-
Black locust	20	148.90±3.2	149.80±2.5	33.03 ± 1.2^{a}	29.80 ± 1.4^{b}	91.54	86.36	2.81±0.1	2.95±0.1	-	-
St. Johnswort	5	137.25±8.6	140.27±8.6	44.70 ± 1.5^{a}	42.35 ± 1.6^{a}	98.66	82.34	2.23±0.1	1.97±0.1	1	-
Vetch seeds	20	149.80±2.6	149.30±3.4	37.92 ± 1.5^{a}	34.68 ± 3.2^{b}	80.54	60.07	2.15±0.1	2.10±0.2	-	1
Luecaena leaves	20	146.03±3.1	147.38±4.0	18.84 ± 1.7^{a}	18.89 ± 1.4^{a}	81.82	69.50	4.98±0.8	3.91±0.4	-	-
Kidney beans	20	149.30±3.5	148.50±3.1	32.13 ± 1.5^{ab}	35.42 ± 0.9^{a}	92.86	91.25	2.94±0.1	2.59±0.1	-	-
Pinto beans	20	151.10±3.1	150.40±2.6	41.38 ± 1.6^{a}	36.40 ± 1.8^{b}	91.07	92.75	2.22±0.1	2.61±0.2	1	-
Bracken fern	20	144.57±3.8	143.51±4.5	33.63 ± 1.5^{a}	27.03 ± 2.6^{b}	86.54	92.44	2.61±0.1	3.69±0.4	-	2
Raw soybean	20	148.20±2.9	148.80±2.7	36.96 ± 1.2^{b}	40.67 ± 1.5^{ab}	92.57	85.75	2.53±0.1	2.13±0.1	-	-
Control	- -	- -	150.90±2.6	- -	45.04±1.6	- -	88.79	- -	1.99±0.1	-	-

^{ab} Means within a row with different superscripts are significantly different (P<.01). ^{NS} Not significant (P>.05).

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SUMMARY AND SUGGESTIONS

There is an abundance of alternative feedstuffs for livestock production, particularly in the developing nations. But due to the fact that some of them are not easily digested and some contain toxins, there is the need to explore all the possible avenues for improving the utilization of these abundant feedstuffs. Thus the objective of this study was to nutritionally evaluate the use of buckwheat, almond hulls, cottonseed meal, ß-glucanase and ammoniation on the performance of rabbits, brioler chicks and laying pullets.

The study was divided into three main sections. Section one dealt with utilization of buckwheat, almond hulls, and cottonseed meal at graded levels in the diets of rabbits. In study one and two, graded levels of buckwheat grain and almond hulls were utilized in the diets of growing rabbits as sources of energy. Feed intake, weight gain, feed conversion ratio and nutrient digestibilities were evaluated. It was observed that the performance of the rabbits was not significantly affected from inclusion of any of the dietary levels of buckwheat and almond hulls, except for levels above 40% in the almond hull-based diets. Nutrient digestibility was not significantly affected, except that the digestibility of acid detergent fiber was negative in all diets containing buckwheat grain. There were no deleterious effects on nutrient digestibility from the almond hull diets. It was concluded that up to 60% buckwheat and 40% almond hulls could be used in the diets of growing rabbits without adverse effects on performance and nutrient digestibility.

In study three of section one, graded levels of cottonseed meal were utilized in the diets of rabbit does and weanling rabbits over a prolonged period of time. The higher levels of cottonseed meal (20%) significantly affected all the reproductive parameters evaluated, except the performance of bucks. Similar trends were observed with the performance of the weanling rabbits. Therefore it was concluded that at least 10% CSM with 0.068% free gossypol could be fed to both does and fryers without adverse effects on their reproductive and growth performance.

In section two of the study, the effects of Allzyme (ß-glucanase) was evaluated by feeding diet containing high and low barley, triticale and rye to fryer rabbits, broiler chicks and laying pullets. Supplementation with Allzyme BG to the four feedstuffs had no beneficial effects on the performance of rabbits, except it improved the digestibility of acid detergent fiber; however supplementation significantly improved the performance of broilers and laying hens. It was concluded that ß-glucanase supplementation was more beneficial to poultry than rabbits.

In section three of the study, ammoniation was employed to evaluate the effect of such a method in improving the utilization of wheat mill run and toxin-containing seeds and forages on the performance of fryer rabbits and broiler chicks. The test materials were ammoniated with urea and a urease source (raw soybean) and used to formulate the diets of the animals. Treated wheat mill run had no advantage on performance and nutrient digestibility of fryer rabbits, except an increase in the nitrogen content of the treated wheat mill run. However, in the toxin-containing seeds and forages, ammoniation not only increased the nitrogen content of the test materials but also detoxified some toxicants and significantly improved the performance of broiler chicks, but had little or no effect on other types of toxic containing seeds and forages. It was concluded that ammoniation can be an effective feed processing method to detoxify toxicants in some types of seeds and forages, but will be of little or no benefit on other types of toxin-containing seeds and forages.

Suggestions for further studies

1. In livestock production, cost is an important factor, hence it will be advisable to examine studies of this nature with cost analysis to determine the profitability of utilizing such by-products.

2. It is also be reasonable to look at the biochemical changes associated with feeding of gossypol more thoroughly. This would help to determine the extent of liver damage and other reproductive consequences of gossypol on both male and female rabbits.

3. Higher levels of Allzyme (ß-glucanase) might be investigated, particularly with the high glucan containing grains to determine if Allzyme at higher levels might be more beneficial to the rabbits, and improve the performance of layers.

4. Use of anhydrous ammonia instead of the urea-urease procedure should also be evaluated with toxin-containing materials, to fully assess the effects of ammoniation.

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Appendix 1. The overall reproductive performance of NZW does fed CSM containing diets.

Parameter	Control	5 % CSM	10 % CSM	20 % CSM
Times bred	92.00	88.00	78.00	49.00
No. of parity	62.00	71.00	68.00	39.00
% Conception	67.39	80.68	87.18	79.59
Total born alive	401.00	564.00	555.00	276.00
Total born dead	97.00	99.00	49.00	205.00
No. at day 21	307.00	465.00	456.00	205.00
% mortality at day 21	23.44	17.55	17.83	25.72
Total weaned	293.00	445.00	448.00	201.00
Total weight (kg)	273.61	413.28	427.77	172.12
Percent weaned	73.76	81.37	82.11	74.63
Total mortality	108.00	119.00	107.00	75.00
Mortality %	26.93	21.09	19.28	27.17
Culled does no/16	4.00	3.00	1.00	2.00
Doe mortality no/16	5.00	2.00	4.00	15.00
% Doe mortality*	31.25	12.50	25.00	93.75
Buck mortality & culls	0.00	0.00	1.00	6.00

* Percentage of doe mortality based on the original number from the start of experiment. Total number based on 16 observations.