THE NUTRITIONAL EVALUATION OF DRIED POULTRY WASTE AS A FEED INGREDIENT FOR BROILER CHICKENS

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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ABSTRACT

Studies were carried out to determine the chemical and bacteriological compositions of variously dried poultry waste (DPW), and to evaluate DPW as a feed ingredient for broiler chickens. Poultry waste was collected every three days from caged laying hens, and immediately subjected to: (i) oven drying at 60^oC; (ii) sun drying followed by autoclaving at 1.05 kg/cm^2, 121^oC, for 15 minutes or (iii) solar drying at $50-70^oC$. The differently dried poultry waste showed remarkable similarities in proximate composition, minerals, and amino acid contents, but differed quite significantly in metabolizable energy content, true protein digestibility, and gross protein value. The oven dried waste had a higher metabolizable energy content, true protein digestibility, and gross protein value than the sun dried-autoclaved or the solar dried waste. Most of the bacteria isolated from the dried poultry waste were believed to be normal inhabitants of the chickens' intestinal tract.

The dietary inclusion of 5, 10, and 15% oven dried, sun dried-autoclaved, or the solar dried poultry waste gave no significant differences in growth rate or feed intake of broiler chicks. The 15% level of DPW gave a poorer ($P< 0.05$) feed efficiency than the 5% level, probably due to the lower dietary metabolizable energy content.

In another experiment, lard was included in isonitrogenous diets containing 5, 10, 15 and 20% oven or solar dried poultry waste to make the diets isocaloric with the control diet.

No significant differences were obtained in growth rate or feed intake of broilers, but feed efficiency was depressed at the 20% level of DPW inclusion. The dietary inclusion of up to 20% DPW in broiler diets had no significant effects on carcass yield and meat composition of broilers.

No significant differences were observed in broiler performance, carcass yield, or meat composition of broilers fed diets containing 10% oven or solar dried poultry waste with various dietary energy and protein levels. However, it was cheaper to feed diets with the lowest dietary energy and protein levels.

The inclusion of up to 12% lard in broiler starter diets containing 10% solar dried poultry waste had no significant effects on broiler performance, or calcium and phosphorus utilization, but the 12% level of lard caused a significant reduction in magnesium retention. The diet containing 3% lard gave a significantly higher fat retention than the diet without lard.

From the results of this study, it can be concluded that the oven or solar dried layer waste may be safely included up to 15% of properly balanced diets. Nonetheless, under conditions of this study, the 10% level of poultry waste appeared to be the most economical maximum limit of inclusion in broiler diets.

DEDICATION

This thesis is dedicated to my parents, brothers and sisters, for their support and encouragement.

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1. INTRODUCTION

Proteins of animal origin such as poultry meat and eggs provide a concentrated source of readily assimilable amino acids in suitable proportions for human needs. However, poultry production is greatly affected by the feed costs, which account for about 75% of the total cost of production (Kekeocha, 1984). The high feed costs are partially attributed to the increasing competition between man and animals for similar feed resources. Insufficiency of feed frequently imposes a major constraint on development of animal production in many developing countries. This is particularly the case during the dry season which in certain areas may extend over nine months. The shortage and cost of conventional food ingredients for poultry diets is forcing producers to look for alternative raw materials. Presently a lot of emphasis is being laid on research into the use of agro-industrial by-products and animal wastes which do not offer much competition as food for man and animals.

Poultry waste (excreta) contains nitrogen, calcium, phosphorus, vitamins, and energy that are capable of being utilized when the material is recycled by feeding (NRC, 1983). These nutrients arise from undigested feed, metabolic excretory products and residues from microbial synthesis. A chicken farm with 100,000 layers will provide 12 tons of manure a day, containing about 25% dry matter (Card and Nesheim, 1972). The best method of disposal, if conditions allow, is to spread the manure on cropland. However, poultry waste has also drawn attention as a feed ingredient due to its nutrient composition. Pure poultry droppings can be collected from birds kept in cages, wire floors, or slatted floors. After appropriate heat treatment, poultry waste could be used as a source of nutrients for various classes of poultry. Dried poultry waste (DPW) as described here, refers to air and high temperature dried droppings from laying hens. DPW remains stable for long periods of time (Chang et al., 1974). Nonetheless, DPW has some nutritional limitations, namely:- low metabolizable energy content (600-1800 Kcal/kg), high ash content (25-35 percent), high crude fibre content (10-15 percent), and 5.7-7.1 percent uric acid (Biely et al., 1980). It is therefore necessary to balance dietary formulations carefully when poultry waste is used, to ensure good performance of the flock.

A limited amount of research has been done on the nutritive value of DPW as a feed ingredient for poultry. However, studies on collecting systems and alternative ways of reducing dehydration costs are required. Research aimed at improving uniformity and maintaining the nutritional value of poultry waste is also required. Further work needs to be done on the effect of waste recycling on the health of the animal and on carcass quality.

The objectives of this study were:- (i) to determine the effect of method of processing on the nutritive value and bacteriological content of poultry waste. The processing methods were:- (a) oven drying at 60^{o}C, (b) sun drying followed by autoclaving at 1.05 kg/cm^2, 121^oC for 15 minutes, and (c) solar drying at 50-70^oC; (ii) to study the effects of graded levels of the variously dried poultry waste on broiler performance, carcass yield, and meat composition, and (iii) to identify any nutritional limitations in dried poultry waste and devise ways of improving its nutritive value. In order to fulfil the specified objectives, work reported in section 3 was carried out.

2. LITERATURE REVIEW

2.1 Poultry population in Kenya and the need for alternative poultry feedstuffs

Poultry populations in Kenya during the years 1974-76, 1981, and 1982 were estimated at 16, 17 and 18 million birds respectively (FAO, 1984). According to the Ministry of Agriculture and Livestock Development, Livestock Development Division Annual Report (1984), the poultry population in Kenya was estimated at 15.3 million birds, compared with 1983 population which stood at 19.6 million. The population of broilers and layers was 2.2 million and 1.6 million, respectively. The poultry industry was adversely affected by the shortage of poultry feeds which came about as a result of the drought prevalent throughout 1984, culminating in minimum supply of cereals for inclusion in poultry rations. Although no poultry population estimates were available for the year 1980, a similar situation was experienced due to the drought period during that year. Non-conventional feedstuffs could be very useful in animal feeds during such periods when competition between man and animals for similar feed resources is at a climax.

Abate (1979), Ngige (1981), and Nambi (1981) studied the nutritive values of millets, cocoyam and pigeon peas respectively as potential ingredients in poultry feeds. Although considerable levels of these feedstuffs could be safely included in poultry feeds, production levels of these feedstuffs are not yet adequate to cater for the needs of both man and animals. Therefore there is need to continue searching for less competitive ingredients for poultry. Unlike other commercial feed ingredients, poultry waste is available on the farm. A laying hen produces 30 g of manure per day on dry matter basis (Card and Nesheim, 1972). Therefore Kenya would expect about 17,520 tons of dried poultry waste per year from 1.6 million layers.

2.2 Chemical composition of DPW

Dried poultry waste is variable in composition, even on dry matter basis. The main causes of variability are probably variation in the composition of the feed, age and type of birds to which the diet is fed, collection interval, environmental temperature under which the droppings are kept, and the nature of the dehydrating process (Flegal and Zindel, 1970; Biely et al., 1972; Kubena et al., 1973; Blair, 1974; Biely and Stapleton, 1976; Biely et al., 1980; Kese and Donkor, 1980).

2.2.1 Nitrogen content

Dried poultry waste (DPW) has a high nitrogen content, containing about 25% crude protein, but only half of this is true protein, the other half being non-protein nitrogen (NPN). Uric acid is the major non-protein nitrogenous substance (Biely et al., 1980). The uric acid nitrogen in DPW, which ranges from 30 to 60% of the NPN in DPW is not utilized by poultry (Blair, 1972b; Martindale, 1974). DPW from cockerels from Canada was reported to contain 7.1% uric acid, while that from layers from United Kingdom contained 5.7% uric acid (Biely et al., 1980). The variation in uric acid levels could be due to differences in quality of feed fed to the two types of birds, and to the dehydrating process of poultry waste. Couch (1974) reported a uric acid content of 6.3% for DPW from layers. Most of the variation in crude protein of DPW has been attributed to the NPN, as opposed to the true protein nitrogen which is not too dissimilar (Bhargava and O'neil, 1975).

The true protein content of DPW is similar to that of cereal grains such as barley. Biely et al. (1980) presented a summary of the chemical analysis of DPW from four different sources, namely:- Netherlands, USA, United Kingdom and Canada. Samples from Netherlands, USA, and United Kingdom were obtained from layers, while the sample from Canada was obtained from cockerels. There were remarkable similarities in the composition of all four samples, with the exception of calcium in the sample from Canada (Stapleton and Biely, 1975), which was obtained from four week old cockerels, the other samples being obtained from layers. These remarkable similarities are due to the modifying action of hindgut micro-organisms on non-digested feed. The protein values were fairly similar to those reported for dehydrated layer waste by Wehunt et al. (1960), Lee and Blair (1973), Trakulchang and Balloun (1975), Ichhponani and Lodhi (1976), Blair and Herron (1982) and Reddy et al. (1983).

Manoukas et al. (1964) and Sheppard et al. (1971) showed that the total nitrogen content of DPW was inversely related to the temperature and duration of the drying process.

The protein nitrogen was found to be less variable than non-protein nitrogen. Loss of excreta nitrogen in a forced air oven increased in a stepwise fashion from 4.6 to 10.6% as the drying temperature was increased from 60 to 120°C (Shannon and Brown, 1969). This is in agreement with Parker et al. (1959) who found that 17.6% of the nitrogen in poultry waste was lost when dried at 105°C. Blair (1972b) found that autoclaving poultry manure at 1.10 kg/cm^2 for 30 minutes caused a 20% reduction in uric acid content. Caswell et al. (1975) reported that uric acid nitrogen in broiler litter was lowered significantly by dry heat, alone or in combination with paraformaldehyde (PFA). Autoclaving and PFA addition followed by dry heat lowered the non-protein nitrogen. Ammonia nitrogen was reduced by most of the pasteurizing treatments except autoclaving at 1.05 kg/cm^2 for 10 minutes.

The amino acid levels of DPW compare well with the amino acid levels in a cereal grain like barley (Biely et al., 1980). Fairly similar amino acid levels were reported by Flegal and Zindel (1970), Couch (1974), Ichhponani and Lodhi (1976), El-Boushy and Vink (1977), and Blair and Herron (1982). This confirms the observations made by Manoukas et al. (1964), Sheppard et al. (1971), and Blair, (1974) that protein nitrogen is less variable than non-protein nitrogen. Results of the above workers showed that methionine is the most limiting amino acid in DPW. This is expected because cereals on which most poultry feeds are based are low in methionine. Nonetheless DPW was reported to contain all the other essential amino acids that are normally limiting in conventional feedstuffs (El Boushy and Roodbeen, 1984). This is due to the fact that DPW is a by-product of digestion of compounded feeds.

2.2.2 Ash composition

The ash content of DPW from layers is high (24-35%) and is extremely rich in calcium (7-11%), and phosphorus (2-3%) (Flegal and Zindel, 1970; Blair and Knight, 1973; Couch, 1974; Bhattacharya and Taylor, 1975; Lee and Yang, 1975; Lee and Ling, 1977; El Boushy and Vink, 1977; Blair and Herron, 1982). The high calcium and phosphorus levels in DPW are due to the high content of both minerals in layer feeds. DPW ash also contains considerable levels of potassium, copper, iron, manganese, zinc and magnesium (Biely *et al.*, 1980).

2.2.3 Crude fibre content

Fibre in DPW is fairly high, with a content of 10-15% (Flegal and Zindel, 1970, Blair and Knight, 1973; Couch, 1974; Bhattacharya and Taylor, 1975; Lee and Yang, 1975; El Boushy and Vink, 1977; Blair and Herron, 1982; Reddy *et al.*, 1983). The high crude fibre levels in DPW originate from the feed since poultry cannot digest crude fibre (Kekeocha, 1984). However, a certain amount is necessary in poultry feeds because:- a) crude fibre activates peristaltic movements and enzyme production in the intestine thereby resulting in better digestion. b) The bacteria in the caecum digest cellulose and produce vitamins K and B_{12} which pass out of the intestine in the faeces. These vitamins could be utilized by the chickens when poultry waste is recycled through feeding.

2.2.4 Fat content

The fat content of DPW is generally low, ranging from 2-4% (Flegal and Zindel, 1970; Blair and Knight 1973; Lee and Yang 1975; El Boushy and Vink, 1977; Blair and Herron, 1982). The low fat content in DPW is due to the low fat level in layer feeds.

2.2.5 Metabolizable energy content of DPW

Little information is available regarding the actual metabolizable energy (ME) level of DPW. However, it is safe to say that the ME values for DPW are low since the fat content is low while the fibre, ash and uric acid levels are relatively high. Metabolizable energy is one of the most variable items in DPW, and a lot of energy losses are said to occur during dehydration (Manoukas et al., 1964; Shannon and Brown, 1969). The ME content of DPW has been estimated to range from 792 to 1350 kcal/kg (Pryor and Connor, 1964; Polin et al., 1971; Young and Nesheim, 1972; Shannon, et al., 1973; McNab et al., 1974). However, Blair and Lee (1973) found that the ME content of the DPW varied from 670 to 1270 kcal/kg while Couch (1974) reported an ME value of 660 kcal/kg. Yoshida and Oshii (1965) found that DPW had an ME content of 1840 kcal/kg for chicks, while Blair

(1974) reported an ME value of 850 kcal/kg. Processed poultry waste (PPW) previously dried in a forced air oven and chemically extracted with potassium hydroxide to remove uric acid was reported to have an ME content of 1225 kcal/kg (Coon et al., 1978). Umeda et al. (1974) reported the available energy of DPW by chicks to be 1560 kcal/kg. Most of this variation in metabolizable energy could probably be due to variation in the composition of the feed and to the nature of the dehydration process.

2.3 Effects of DPW containing diets on broiler performance

Fuller (1956) reported dried poultry manure to be as effective as fishmeal in commercial type rations when fed under practical conditions, while Wehunt et al. (1960) reported improved growth rates of chicks when DPW was added to diets suboptimal in protein. This indicates that DPW could be an effective protein supplement in poultry diets. Flegal and Zindel (1970) and Lee and Blair (1973) found that broiler chicks could tolerate 5% DPW in the diets with only a slight effect on feed efficiency (feed:gain). However, feed efficiency was adversely affected when the level of DPW was increased beyond 10%. This adverse effect was attributed to the low metabolizable energy content of DPW, which resulted in increased consumption of diets containing DPW. Similar observations were made by Cenni et al. (1971), Rinehart et al. (1973) and Sloan and Harms (1973). El Boushy and Vink (1977) suggested that uric acid could be toxic at levels beyond 1.07% in the diet. However, Martindale and

Lee (1976) reported increased rates of effective renal plasma flow and increased tubular secretion of uric acid in the hens fed diets containing 20% DPW for a period of one year. Renal hypertrophy was not detected in these birds. This indicates an increased efficiency of uric acid excretion in birds fed diets containing DPW.

Biely and Stapleton (1976) and Blair and Herron (1982), found that chicks fed on 10% DPW in isocaloric and isonitrogenous diets grew and utilized feed as well as those fed the basal diet. McNab et al. (1972) and Bhargava and O'neil (1975) reported that chicks fed diets containing up to 20% DPW in properly balanced diets performed as well as those fed a standard broiler ration.

2.3.1 Effects of DPW containing diets on carcass yield and quality

In feeding a new ingredient such as dehydrated poultry waste, there is need to be concerned about certain possible problems that may arise, including changes in the physiological state of the bird, decreased growth rate, poor feed efficiency, flavour changes in the flesh, or changes in the carcass composition and quality (Cunningham and Lillich, 1975). Rhee et al. (1974) reported non-significant effects of DPW content on dressing percentage, or the composition and organoleptic properties of broiler meat when DPW was included up to 30% of the diet. Similar observations were made by Lee and Yang (1975), Bhargava and O'neil (1975), Kese and Donkor (1980), and Reddy et al. (1983) when DPW was included up to

20% of the diet. However, Ogunmodede and Aninge (1978) found that birds fed diets containing 10 or 15% DPW yielded meat containing more fat and less water than those fed diets containing 5% DPW. This could possibly be attributed to a decrease in dietary protein level as the DPW content in the diets was increased, replacing part of groundnut cake. Cunnigham and Lillich (1975) found no detectable differences in flavour between 0% and 38.2% DPW fed birds. They concluded that under conditions of the study DPW had no noticeable effects on carcass quality, but depressed growth at the highest level.

2.4 Human and animal health aspects of feeding poultry waste to livestock and poultry

According to Fontenot and Webb (1975), and McCaskey and Anthony (1979), no indication has been obtained of harmful effects in humans consuming meat, milk and eggs from animals fed animal waste. The only documented evidence of deleterious effects on animal health was copper toxicity in sheep fed broiler litter containing high levels of copper (Fontenot et al., 1971). This is not a serious problem with other farm animals since they are not as sensitive to high dietary copper.

Potential hazards from recyling animal wastes by feeding include: pathogenic bacteria, moulds, harmful residues of pesticides, medicinal drugs, and heavy metals (National Research Council, NRC, 1983).

2.4.1 Pathogenic organisms

There is no doubt that raw material may contain pathogenic organisms. However, adequate processing renders the waste free of pathogens or with a much reduced profile of organisms capable of causing disease. No disease problems have been reported with poultry wastes in practical diets for beef cattle, dairy cattle or sheep (Drake *et al*., 1965; El-Sabban *et al*., 1970). Even calves, which are well known to be susceptable to digestive upsets, remained healthy when fed diets containing wet cage layer waste (Smith *et al*., 1978). Feedlot cattle also remained healthy when fed diets containing cage layer waste treated with organic acids (Smith *et al*., 1979), and the researchers concluded that potential health problems were no more serious than with conventional feeds. Moreover, under practical conditions, poultry and cattle inoculate themselves many times daily with all the organisms present in the faecal matter. This may provide sufficient immunity to the animal for some of the most common organisms present in the faecal matter (Ichhponani and Lodhi, 1976).

Nonetheless, animal wastes commonly contain pathogenic organisms (Caswell *et al*., 1975; Knight *et al*., 1977; Smith *et al*., 1978, 1979) and should be processed before being fed. Alexander *et al*. (1968) isolated 10 species of *Clostridium* two species of *Corynebacterium*, three species *Salmonella* and two species of *Mycobacteria* isolates from 44 samples of poultry litter fed to livestock. All 44 samples of litter yielded species of *Bacillus*, *Staphylococcus*, Streptococcus, and members of the Enterobacteriaceae other than Salmonella. These researchers, however, noted that most of the organisms found in poultry litter were normal inhabitants of the intestinal tract of animals.

A number of reports indicate the beneficial effects of heat processing on microbial content of poultry waste. McCaskey and Anthony (1979) pointed out that heat and pelleting and other methods may minimize health hazards. Fontenot et al. (1970) found no adverse effects in sheep fed for 80 days on diets containing up to 75% poultry litter that had been sterilized by dry heat at 150°C for four hours. Caswell et al. (1975) evaluated several methods of processing broiler litter, and found the following to be effective for pasteurization:- i) dry heating at 150°C for 20 minutes; ii) autoclaving at 121°C and 1.05 kg/cm^2 pressure for 10 minutes or longer; iii) dry heating at 150°C at depths of 0.6 or 2.5 cm following addition of 1 to 4 g of paraformaldehyde (PFA) per 100 g of litter; iv) ethylene oxide (ETO) fumigation for a minimum of 30 minutes. Total bacterial counts in broiler litter treated by the above methods were approximately 20,000/g.

Messer et al. (1971) found that four potential pathogens were destroyed by heat (Salmonella typhimurium, Salmonella pullorum, Arizona species, and E. Coli). Arizona species were destroyed by heat at 47.2°C for 30 minutes. S. pullorum survived the temperature but was destroyed by heat at 62.8°C for 30 minutes. On the other hand, 62.8°C for 60 minutes was required for the destruction of S. typhimurium. In the case of E. Coli, 68.3°C for 30 minutes was effective. Blair and Herron (1982) reported that dehydrated broiler litter and layer waste showed low to scant contamination with E. Coli and no Salmonella. In their study, Hacking et al. (1977) did not detect any Salmonella in samples of dried poultry manure; however, the researchers found Coliform bacteria in 26% of the samples, and anaerobic spore formers in 76% of the samples.

Under the California quality control standards for processed waste products, the criteria for effectiveness of pasteurization require not more than 20,000 bacteria/g dried product, and freedom from Salmonellae (Helmer, 1980). In assessing the risk of pathogenic organisms associated with processed waste, it is fair to point out that regular feed ingredients are commonly contaminated. Singh (1974) found that all ingredients tested contained a minimum total microbial count of 12×10^3/g and a mould count of at least 3×10^3/g. Allred et al. (1967) reported that the incidence of Salmonellae in 12,770 samples of feed and feed ingredients was 4.2%. The incidence in animal by-products was 31.07%, 5.23% in poultry feed, 4.72% in fishmeal, 3.13% in swine feed, 2.28% in oilseed meals, and 0.66% in grains.

Mortality among chickens fed diets containing up to 20% DPW was negligible (Biely et al., 1972; Biely, 1974; Stapleton and Biely, 1975; Tanabe et al., 1977). This indicates that the inclusion of low levels of properly dried poultry waste in poultry diets does not pose a health hazard to the chickens. It may be concluded that the health risks from pathogenic organisms associated with feeding of adequately processed animal wastes are probably no greater than those associated with feeding of meat meal tankage, blood meal, poultry by-products meal, hydrolyzed poultry feathers, offal meal, or processed paunch product, all of which are approved for use in feed (NRC, 1983). Biely et al. (1980) noted that information available so far suggests that waste material can be safely and profitably recycled, by feeding, without hazard to animal health.

2.4.2 Mineral hazards

As previously mentioned, DPW is very rich in calcium and phosphorus, both of which are essential in poultry diets. However, there is need to ensure proper mineral balance in DPW containing diets in order to avoid cases of slipped tendons (perosis) resulting from unfavourable calcium:phosphorus ratio (Biely et al., 1972)

Depending upon the source, DPW may contain some heavy minerals which may be harmful to the animal to which DPW is fed. The mineral content of animal wastes could lead to at least two potential problems; toxicity, and accumulation in tissues. Presently, there is no evidence that heavy metal contamination is a serious deterrent to recycling animal wastes through feeding. There is, however, need to collect more information about the mineral content of DPW and its effect on animal health (NRC, 1983). Copper is usually added in trace amounts to layer diets to meet the chickens' requirements. The copper content of DPW from layers has been reported to be less than 100 ppm (Biely et al., 1972; Blair and Knight

1973; Couch, 1974). Therefore inclusion in poultry diets, of low levels of DPW from layers is not likely to cause copper toxicity.

Elements other than copper are probably of much less significance in terms of likely hazards in any recycling systems. Thomas et al. (1972) reported that calcium, phosphorus, sodium, potassium, magnesium, zinc, iron, copper and manganese levels in liver and kidney of sheep fed diets containing 0, 25 and 50% dehydrated poultry waste were within normal range. There is not much information regarding the effect of DPW minerals on toxicity and accumulation in tissues of chickens. However, work done on cattle and sheep shows that residues do not appear to be a demonstrable problem.

2.4.3 Medicinal drug residues and metabolites

Various drugs are used in animal production for medicinal purposes and to improve growth and feed efficiency. Many require a withdrawal period before slaughter to avoid harmful residues in the carcass. However, DPW obtained from layers contains little, if any, drug residues since drugs are not normally included in feed formulations for layers (Couch, 1974). Therefore the use of DPW from layers is not likely to cause a problem of drug residues in the carcass. Helmer (1980) reported that monitoring of processed animal wastes in California has suggested that drug residues have not yet posed a problem.

2.4.4 Mycotoxins

Mycotoxins are metabolites of fungi and are produced by a variety of species. Many have been found in animal feeds due to the presence of fungi. Little research has been done on the occurrence or formation of mycotoxins in animal wastes. Lovett (1972) suggested that poultry litter may be no more of a problem than feed. Blair and Herron (1982) tested dehydrated layer waste for mycotoxins, and were unable to detect aflatoxin, ochratoxin, or zearalenone. Hesseltine (1976) advocated the prevention of mycotoxin formation in foods and feeds rather than detoxification once the toxins have been formed. It would seem sensible to apply the same principle to animal wastes. Since the fungi do not grow on dry substrates, the wastes should be dehydrated rapidly after collection. Rapid dehydration would counteract the effect of *Aspergillus flavus* which does not produce aflatoxins for 48 hours after spore germination under most favourable conditions. Quick collection and rapid efficient dehydration of poultry waste is therefore likely to prevent aflatoxin formation. Hamblin (1980) compiled some work on commercial processing and selling poultry waste as a feed ingredient for livestock and poultry, and concluded that aflatoxin, pesticides, pathogens, and antibiotics were not a problem.

2.5 Economic value of feeding poultry excreta to animals

Very little information is available on the economic value of using dried poultry waste as a feed ingredient in animal diets. Nonetheless, several workers have stressed the need to find alternative ways of reducing dehydration costs involved in drying poultry waste. Smith and Wheeler (1979) studied the nutritional and economic value of animal excreta and concluded that animal excreta products are three to ten times more valuable as protein sources for various classes of ruminant animals than as plant nutrient sources. In both nutritional and economical terms, poultry litter had the highest value and cattle excreta the lowest. Chicken excreta has been reported to be superior over sheep and cow's excreta in replacing up to 15% of maize in diets for starter broiler and pullet replacement chicks and for laying pullets (Oluyemi. et al., 1979).

As previously mentioned, DPW is quite variable in composition, with variation in feed composition and method of waste dehydration being the main factors causing variability. Therefore, it is essential to know its exact composition in order to formulate valid balanced diets. Dehydration costs must be considered when evaluating the economics of using DPW in poultry diets. In the United States, a system of dehydration has been developed by which manure with an original moisture content of 75% can be dried to 9% moisture automatically at a cost of less than $4 per ton for electricity and fuel (Bressler, 1969). Young and Nesheim (1972) found that the use of DPW in poultry diets was economical up to $26.00 a ton. In Africa, however, more effort should be directed towards efficient utilization of solar energy since the sun is a relatively cheap source of energy in the tropics.

3. MATERIALS AND METHODS

3.1 Source and processing of poultry waste

Poultry waste used in the experimental diets was obtained by placing trays underneath the cages of laying hens reared in the Poultry Unit of the Department of Animal Production, Kabete. It was collected every three days, spread out into 2 cm thickness and subjected to three different methods of processing viz: a) oven drying at 60°C (DPW1); b) sun drying followed by autoclaving at 1.05 kg/cm^2, 121°C, for 15 minutes (DPW2); c) solar drying in a simple box type solar drier having a polythene roof (DPW3). The hens from which the waste was collected were fed on layer mash from the same feed company throughout the collection period. Variations in poultry waste composition due to diet composition were therefore minimal. The layer mash was found to contain 90.80% dry matter, 14.75% crude protein, 12.03% ash, 9.84% crude fibre, and had a true metabolizable energy content of 3045 kcal/kg DM. The three day collection interval and the immediate dehydration of poultry waste were intended to reduce nutrient losses that occur in wet manure, and to prevent mould growth. Collection and drying of poultry waste were carried out during the dry season, and consequently there was plenty of sunshine on most days.

The three types of poultry waste were dried to moisture contents below 10%. On average, poultry waste placed in the oven took two days to dry while that placed in the sun or solar drier took three to six days to dry depending upon the environmental temperature. Temperature in the solar drier was approximately 50-70^{0}C on hot days. Extraneous materials such as feathers and spilled feed were carefully removed before milling the dried poultry waste. Milling was done in a Wiley mill* equipped with a 2 mm sieve, prior to mixing in the diets. Dried poultry waste was stored in large polythene bags until the time of use.

3.2 Chemical analyses of DPW and layer mash

Moisture, ash, ether extract, crude fibre, crude protein and nitrogen free extract contents of dried poultry waste and of layer mash fed to layers from which the waste was collected, were determined according to the standard procedures of the Association of Official Analytical Chemists (AOAC, 1984). Calcium, phosphorus, magnesium, copper, and iron in dried poultry waste were also determined according to the procedures of (AOAC, 1984). Calcium and phosphorus solubility in water and in 0.4% HCl were determined according to the method of Watson et al. (1970). True protein in the three differently dried poultry waste was determined according to the method of Ekman et al. (1949), as described in Appendix 1.

3.2.1 Amino acid composition of DPW

Amino acid contents of the oven dried; the sun dried and autoclaved, and the solar dried poultry waste were determined using a single column Biotronic amino acid analyser

*Standard model, No. 3. Wiley Mill, Made in U.S.A. Arthur H. Thomas Co. Philadelphia U.S.A.

LC 2000*, after hydrolysis of the samples with 6N hydrochloric acid at 110°C for 24 hours. Results were expressed in mg/g of the sample.

3.3 True metabolizable energy (TME) content of DPW and layer mash and true protein digestibility of DPW

True metabolizable energy contents of the poultry waste dried in the three different ways, and of layer mash were determined according to the method of Sibbald (1976, as updated, Sibbald, 1981). The methodology of true metabolizable energy determination is described in Appendix 2. TME values determined by the Sibbald procedure are normally higher than the apparent metabolizable energy (AME) values because TME accounts for the endogenous and metabolic energy losses, while AME does not.

True protein digestibility (%) was determined in a similar way as true metabolizable energy. Excreta from the fed and unfed birds, together with samples of test materials were analysed for true protein according to the method of Ekman et al., (1949). The method of calculation was as follows:

$$\text{True protein digestibility \%} = \frac{TP_I - (TP_f - TP_u)}{TP_I} \times 100$$

Where: TP_I = true protein intake (g).

TP_f = true protein voided as excreta by the fed bird (g).

TP_u = true protein voided as excreta by the unfed bird (g).

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*Biotronic Wissenshaftliche Gerate Gmbh
6000 Frankafurt a.m. Borsaigalee 22.

3.4 Bacteriological and aflatoxin examination of DPW

Identification and counting of bacteria in the oven dried; the sun dried autoclaved; and the solar dried types of poultry waste were carried out by direct culture, sub-culture, and biochemical tests according to the procedures described by Cowan (1974).

DPW samples were screened for aflatoxins using the thin layer chromatography (TLC) method applied in Swiss Control Laboratories (1977). Aflatoxins were extracted with methanol/water mixtures. Lipids were separated from the extract by shaking out with petroleum ether. The aflatoxins were shaken out with chloroform, and the chloroform phase was concentrated by evaporation almost to dryness. The residue was transferred to a small flask and the solvent was removed by nitrogen gas. A known volume of solvent (Benzene acetonitrile) was added and a definite amount of the sample and standard solutions were investigated by thin layer chromatography under 365 nm UV light.

3.5 Experiment 1

Gross protein value (GPV) as a method of assessing quality of DPW.

3.5.1 Objective

To establish the relative nutritive values of the oven dried; the sun dried-autoclaved; and the solar dried types of poultry waste in comparison to casein when used as protein supplements to a particular basal ration.

3.5.2 Experimental procedure

The method of Duckworth et al. (1961) was adopted. Day old Shaver "Starbro" broiler type chicks obtained from a commercial hatchery were fed on a commercial broiler starter feed for a period of one week. On the seventh day, one hundred and fifty chicks of approximately similar body weights were selected, and were fed on a depletion diet for two weeks. The depletion diet contained approximately 8% protein of which 6.5% was provided by cereals and the remainder by yeast and dried skimmed milk. The depletion period was designed to assist in standardizing the chicks for the experimental period. Chicks receiving the depletion diet grew slowly, but mortality was negligible (2.67%) and the chicks were otherwise healthy and active.

On the fourteenth day, a representative sample of the chicks was individually weighed and the mean weight determined. One hundred and twenty chicks were selected and divided into twenty groups of six chicks each, ensuring approximately the same initial total body weight for each group. The chicks were placed in electrically heated floor pens allowing a floor area of approximately 0.10 m^2 per chick, and were fed on five experimental diets shown in Table 1. The five diets included a control or cereal diet, which had the same composition as the depletion diet, and four other diets which consisted essentially of the control diet supplemented with 3% protein from casein, the reference protein, or from poultry waste, the test protein. Diets were formulated to contain approximately 1.1% calcium,

Table 1: Composition of diets used in Experiment [1]

	Diets					
	Depletion	Control	Casein	DPW1*	DPW2**	DPW3***
Ingredients	%					
Maize meal	12.30	12.30	12.30	12.30	12.30	12.30
Ground barley	17.60	17.60	17.60	17.60	17.60	17.60
Ground oats	1.69	1.69	1.69	11.18	9.85	9.85
Oatfeed	21.32	21.32	21.32	1.30	4.09	4.09
Wheat bran	17.60	17.60	17.60	17.60	17.60	17.60
Skim milk	1.46	1.46	1.46	1.46	1.46	1.46
Yeast	2.25	2.25	2.25	2.25	2.25	2.25
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin/mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
Dicalcium phosphate	3.06	3.06	2.86	-	-	-
Limestone	0.78	0.78	0.84	-	-	-
Starch	21.49	21.49	17.96	2.71	4.73	5.41
Casein	-	-	3.67	-	-	-
DPW	-	-	-	33.15	29.67	28.99
<u>Chemical analyses</u>						
Dry matter (DM, %)	91.69	91.69	92.52	92.33	92.32	92.27
TME (Kcal/kg DM)	3310.00	3310.00	3344.00	2766.00	2619.00	2737.00
<u>Percent of DM</u>						
Crude protein	9.44	9.44	12.78	16.44	15.88	15.47
True protein	8.54	8.54	11.31	11.71	11.67	11.57
Ash	6.25	6.25	6.10	10.14	10.06	9.26
Ether extract	2.13	2.13	1.53	2.62	2.47	2.56
Crude fibre	10.50	10.50	11.15	11.32	11.21	10.99
Nitrogen free extract	63.37	63.37	60.96	51.81	52.70	53.99

DPW1* is oven dried ($60^{o}C$) poultry waste
DPW2** is sun dried, autoclaved ($1.05\ kg/cm^2$, $121^{o}C$, 15 minutes) poultry waste
DPW3*** is solar dried ($50-70^{o}C$) poultry waste

[1]Vitamin/mineral premix provided the following per kilogram of diet: vitamin A, 10,500 IU; vitamin D_3, 2250 IU; vitamin E, 1.5 IU; vitamin K, 3 mg; riboflavin, 6 mg; pantothenic acid, 7.5 mg; nicotinic acid, 12 mg; choline chloride, 150 mg; vitamin B_{12}, 0.045 mg; iron, 25.5 mg; manganese, 60 mg; copper, 2.4 mg; cobalt, 0.3 mg; zinc, 49.5 mg; iodine, 1.2 mg; BHT, 112.5 mg.

0.72% phosphorus and 10% crude fibre. Dietary formulations for protein in the test diets were based on the true protein values of poultry waste. Calcium and phosphorus levels in poultry waste that were soluble in 0.4% hydrochloric acid were assumed to be available to the chicks. The experiment was conducted in a completely randomized design by random allocation of the replicates to twenty pens. Each diet was fed to four groups of six chicks each. Feed and water were offered *ad libitum*.

3.5.3 Data collection

Records of feed consumption and body weights of chicks per replicate were taken on the 3rd, 7th, 10th and 14th day of the two week test period, the intermediate weighings being designed to make possible corrections for any chicks dying during the period. Weight gain per replicate was calculated as the difference in body weight between two consecutive weighings. Feed consumption was obtained from the difference between feed offered and feed left over at the end of every weighing. Mortality was also recorded.

Gross protein value per replicate was calculated as follows:-

$$\text{Gross protein value (GPV)} = \frac{\text{Weight gain/g of supplementary protein in test diet (g)}}{\text{Weight gain/g of supplementary protein in casein diet (g)}} \times 100$$

$$\text{Weight gain/g of supplementary protein} = \frac{\text{Extra weight gain (g)*}}{\text{Food eaten/chick (g)}} \times \frac{100}{\text{\% supplemetary protein}^{+}}$$

*Extra weight gain = Weight gain/chick of test group - weight gain/chick of corresponding control group

+% supplementary protein = True protein content of test diet by analysis - true protein content of control diet by analysis.

The gross protein value for each type of DPW was calculated as the mean result from the four replicates used per diet.

3.5.4 Chemical analyses of experiment 1 diets

Proximate composition of the experimental diets were determined according to the standard procedures (AOAC, 1984). True metabolizable energy (TME) contents were determined according to the method of Sibbald (1981).

3.5.5. Statistical analysis

Gross protein values were subjected to analysis of variance, and means compared using Tukey's test (Steel and Torrie, 1980).

3.6 Experiment 2

Effects of feeding graded levels of variously dried poultry waste on broiler chick performance.

3.6.1 Objectives

Results of the chemical analyses of DPW, and the gross protein values obtained in Experiment 1 showed that dried poultry waste contained some nutrients useful to poultry. Therefore, Experiment 2 was designed to determine effects of DPW inclusion in practical broiler starter diets on: (a), growth rate of broilers, (b) feed intake and conversion efficiency, (c) hepatic GOT and GPT activities, and (d) tibia ash.

3.6.2 Experimental procedure

Poultry waste collected and processed as described in 3.1 was included in broiler starter diets at levels of 5, 10, and 15%. The increasing levels of DPW replaced some of the meat and bone meal and maize meal in the diets. Every additional 5% DPW replaced 1% meat and bone meal in the diets. This was based on the fact that the protein content of meat and bone meal is about five times the true protein content of DPW. The dietary protein and energy contents were within the levels recommended for broiler starter chicks by Scott et al. (1976). However, both energy and protein levels decreased slightly with the increasing levels of DPW in the diets because no attempt was made to make the diets isocaloric or isonitrogenous.

Day old Shaver "Starbro" broiler type chicks obtained from a commercial hatchery were used in the experiment. They were fed on a commercial broiler starter feed for one day. On the second day, two hundred and sixteen chicks of approximately uniform weights were selected, weighed, and randomly allocated to nine experimental diets. Each diet was fed to four groups of six chicks each. The chicks were placed in electrically heated floor pens, allowing a floor area of approximately 0.10 m^2 per chick, and were fed on diets shown in Table 2 for a period of four weeks. The experiment was conducted in a completely randomized design. Feed and water were offered ad libitum.

Table 2: Composition of diets used in Experiment 2

Type of DPW	Oven dried (DPW1)			Sun dried, autoclaved (DPW2)			Solar dried (DPW3)		
Diets	1	2	3	4	5	6	7	8	9
Level of DPW (%)	5	10	15	5	10	15	5	10	15
Ingredients	%								
Maize meal	56.55	54.55	50.55	56.55	54.55	50.55	56.55	54.55	50.55
Lard	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Sunflower seed meal	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
Blood meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
DPW	5.00	10.00	15.00	5.00	10.00	15.00	5.00	10.00	15.00
Fish meal	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Meat and bone meal	8.00	7.00	6.00	8.00	7.00	6.00	8.00	7.00	6.00
Wheat bran	2.00	-	-	2.00	-	-	2.00	-	-
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin/mineral premix[1]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Chemical analyses									
Dry matter (DM %)	91.32	91.29	91.47	91.16	91.12	91.12	90.79	90.95	91.40
TME (Kcal/kg DM)	3939.00	3672.00	3624.00	3900.00	3896.00	3859.00	3790.00	3748.00	3524.00
Percent of DM									
Crude protein	25.05	23.78	23.49	24.33	24.02	23.47	24.68	24.08	23.16
Ash	7.84	8.47	8.54	7.38	7.46	7.74	8.50	8.93	9.32
Ether extract	7.57	7.38	7.11	7.57	7.51	7.32	7.89	7.45	7.63
Crude fibre	7.73	7.80	8.20	7.34	7.53	8.81	7.54	8.03	8.53
Nitrogen free extract	43.13	43.86	44.13	44.54	44.60	43.78	42.18	42.46	42.76

[1] Vitamin/mineral provided the same levels of minerals and vitamins as given in Table 1 footnote.

3.6.3 Data collection

Records of feed consumption and body weight of chicks per replicate were taken every week until 30 days of age. Body weight gain per week was obtained as the difference in body weights per replicate between consecutive weeks. Mean body weight gain per treatment was calculated as a mean of the four replicates. Weekly feed consumption per replicate was obtained from the difference between feed offered and left over at the end of every week. Mean feed consumption per treatment was calculated as a mean of the four replicates. Feed efficiency was calculated as a ratio of feed consumption to body weight gain. Mortality was also recorded. Mortality rate was calculated as the number of dead chicks expressed as a percentage of the total number of chicks on the experiment. GOT and GPT activities in the liver were determined from two randomly selected chicks aged two days, according to the method of Reitman and Frankel (1957). This was carried out before chicks were fed on the experimental diets. Similar enzyme determinations were carried out from one chick per dietary treatment at the end of the 2nd, 3rd, and 4th week of the experiment, as described in 3.6.3.1.

The left and right tibiae were obtained from one chick per treatment at the end of the 1st week of the experiment, and from chicks used for liver GOT and GPT determinations at the end of the 2nd, 3rd and 4th week of the experiment. The tibiae were boiled in water for six minutes to remove the flesh. They were then dried in the oven, and later extracted in diethyl ether to remove fat. The fat free tibiae were again dried in the oven at 105^{o}C, cooled and the dried weights recorded. The dried bones were ashed in a muffle furnace at 600^{o}C, and percentage tibia ash determined according to the method of A O A C (1984).

The procedure given in 3.5.4 was followed for chemical analyses of the diets. Data were subjected to analysis of variance, and means compared using the f-test (Steel and Torrie 1980).

3.6.3.1 Description of GOT and GPT determinations

The enzymes GOT and GPT catalyse the transfer of α-amino groups from specific amino acids to α-ketoglutaric acid to yield glutamic acid and oxaloacetic acid or pyruvic acid as shown below:

$$\text{Aspartic acid} + \alpha\text{-ketoglutaric acid} \xrightarrow{\text{GOT}} \text{oxaloacetic acid} + \text{glutamic acid}$$

$$\text{Alanine} + \alpha\text{-ketoglutaric acid} \xrightarrow{\text{GPT}} \text{pyruvic acid} + \text{glutamic acid.}$$

In some recent books, GOT is called Aspartate aminotransferase, while GPT is called Alanine aminotransferase. Unfortunately, they both have the same acronym (AAT) so that the older nomenclature with the acronyms GOT and GPT is often retained (Ottaway and Apps, 1984). The oxaloacetic or pyruvic acid formed in the above reactions is reacted with 2, 4 dinitrophenylhydrazine. The absorbance of the resultant colour of phenylhydrazones is measured at a wavelength of 505 nm (Reitman and Frankel, 1957).

The chicks selected for liver GOT and GPT determinations were killed by cervical dislocation. The livers were immediately excised, blotted dry, wrapped in aluminium foils covered with ice, and stored in a refrigerator until the time of analysis. At the time of analysis, the liver was cut into small pieces, after which one gram was weighed and finely ground using a small mortar and pestle. 9 mls of 0.25 M sucrose solution was added to the liver in the mortar and thoroughly mixed to form a homogenate. 5 ml of the homogenate was transferred into 5 ml tubes and centrifuged at a relative centrifugal force of 1300 x g for 30 minutes to obtain the supernatant. Before measurement of GOT and GPT activities in the liver, standard curves for the two enzymes were prepared.

The GOT standard curve was prepared as follows: 0.2 ml of distilled water was added to each of six test tubes. This was followed by additions of 1.0, 0.9, 0.8, 0.7, 0.6 and 0.5 ml of aspartate α-ketoglutarate, and then 0.0, 0.1, 0.2, 0.3, 0.4 and 0.5 ml of pyruvate to each of the six tubes respectively. 1 ml of 2, 4 dinitrophenylhydrazine was added to each tube, mixed, and left to stand for 20 minutes at room temperature. 10 ml of 0.4 N sodium hydroxide solution was added to each of the tubes, mixed, and left to stand for 5 minutes. Absorbance for each tube contents was read on a Beckman uv Spectrophotometer set at 505 nm, using 1 cm cuvettes. Water was used as reference. A standard curve was plotted for Absorbance against GOT activities (SF units/ml), and is presented in Figure 1. The GPT standard shown in Figure 2 was similarly determined. The only variation was alanine α-ketoglutarate being used instead of aspartate α-ketoglutarate.

Figure 1: Standard curve for GOT activity

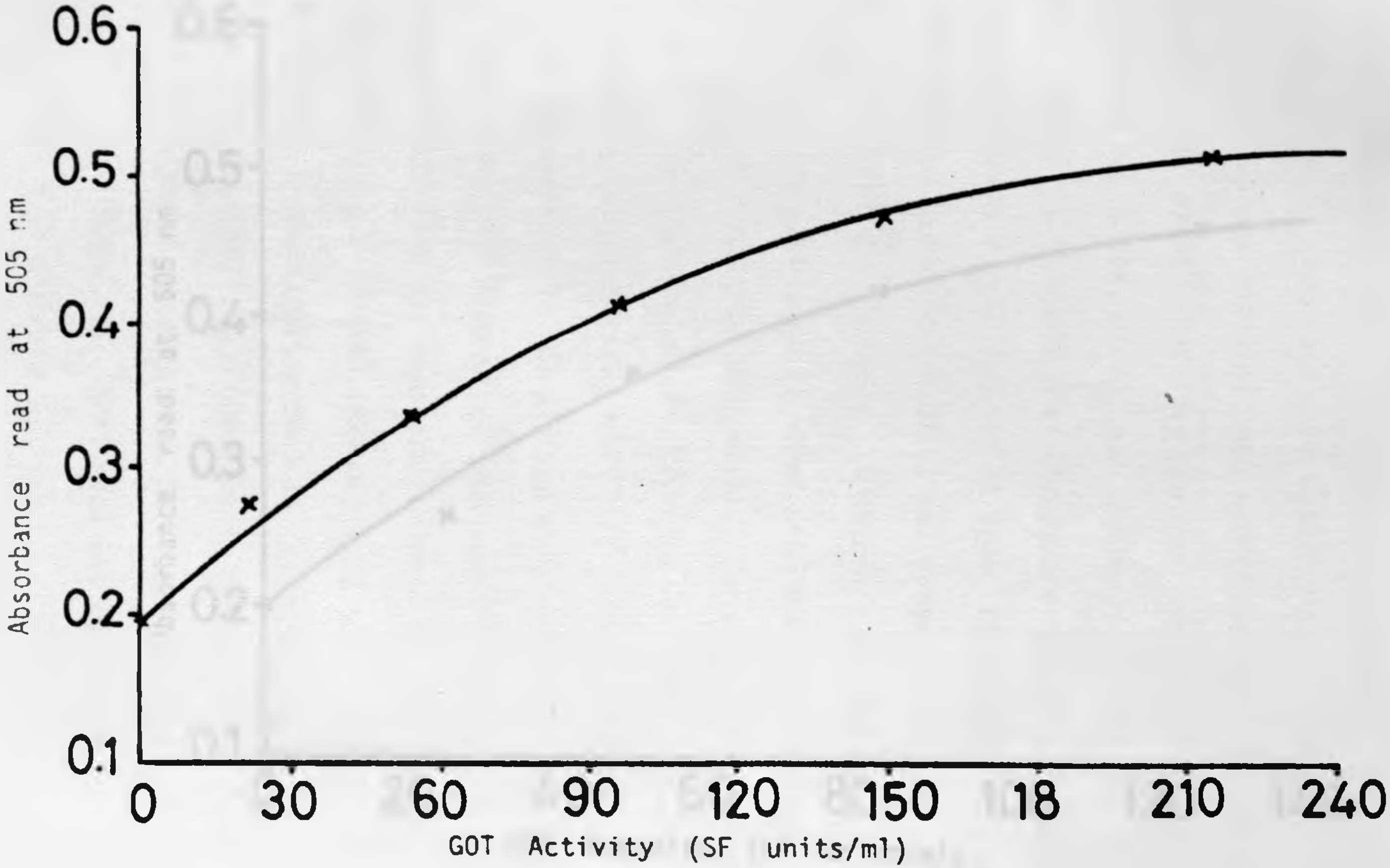
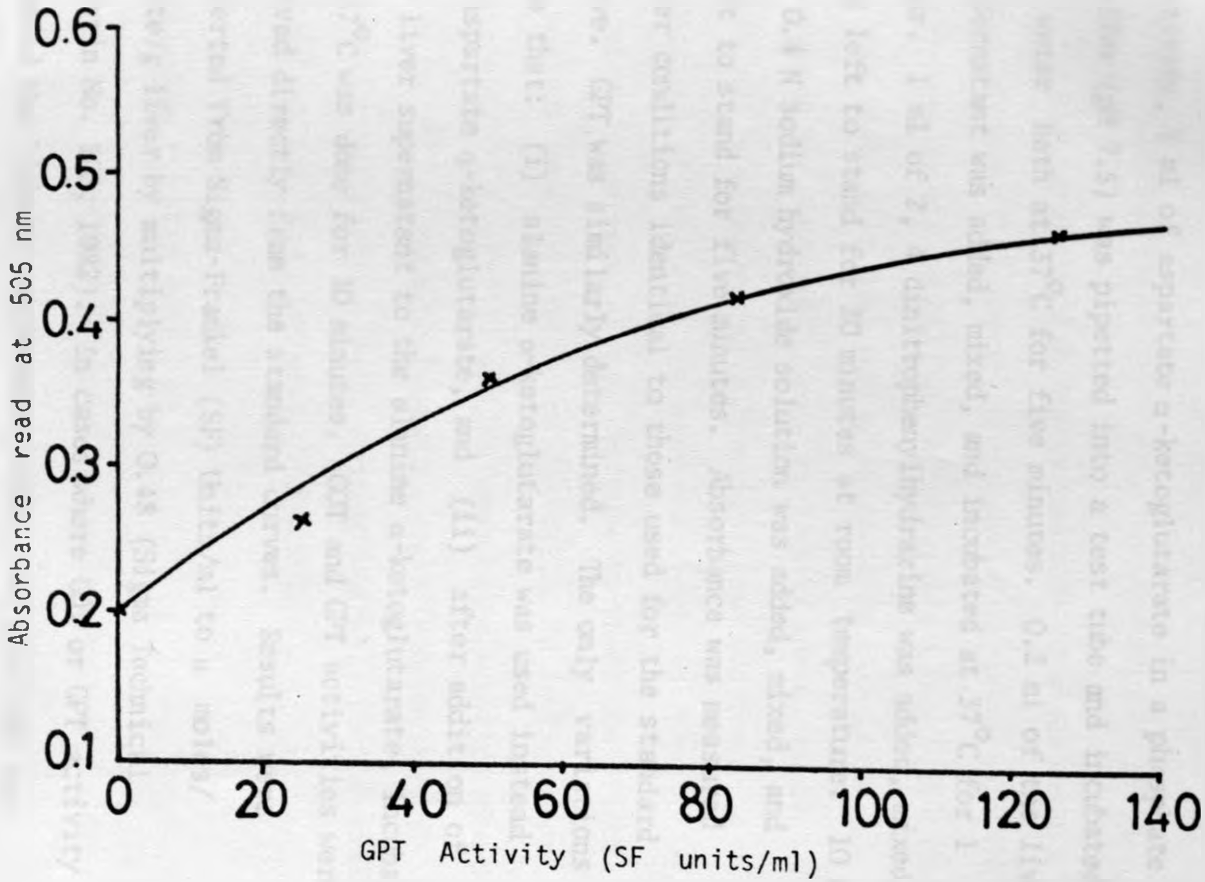


Figure 2: Standard curve for GPT activity



Enzyme determinations in the liver supernatant were carried out within a maximum of two days after obtaining the livers from the chicks in order to avoid activity losses. GOT and GPT measurements were based on the reactions mentioned above. In determining hepatic GOT activity, 1 ml of aspartate α-ketoglutarate in a phosphate buffer (pH 7.5) was pipetted into a test tube and incubated in a water bath at $37^{O}C$ for five minutes. 0.2 ml of the liver supernatant was added, mixed, and incubated at $37^{O}C$ for 1 hour. 1 ml of 2, 4 dinitrophenylhydrazine was added, mixed, and left to stand for 20 minutes at room temperature. 10 ml of 0.4 N sodium hydroxide solution was added, mixed, and left to stand for five minutes. Absorbance was measured under conditions identical to those used for the standard curve. GPT was similarly determined. The only variations were that: (i) alanine α-ketoglutarate was used instead of aspartate α-ketoglutarate, and (ii) after addition of the liver supernatant to the alanine α-ketoglutarate, incubation at $37^{O}C$ was done for 30 minutes. GOT and GPT activities were derived directly from the standard curves. Results were converted from Sigma-Frankel (SF) Units/ml to μ moles/minute/g liver by multiplying by 0.48 (Sigma Technical Bulletin No. 505, 1982). In cases where GOT or GPT activity exceeded the highest calibration point, the specimen was diluted 5 fold with saline. The assay was then repeated and the results multiplied by 5.

3.7 Experiment 3

Effects of fat supplementation to broiler diets containing oven or solar dried poultry waste.

3.7.1 Objectives

True metabolizable energy contents of experiment 2 diets revealed that energy in the diets decreased with the increasing levels of DPW, which necessitates supplementation of such diets with high energy ingredients like lard. In feeding a new ingredient such as poultry waste, it is important to consider not only weight gain and feed efficiency of broilers, but also their carcass composition. Therefore Experiment 3 was designed to study the effects of various levels of lard supplementation to broiler diets containing 0, 5, 10, 15, and 20% oven or solar dried poultry waste on (i) growth performance, (ii) feed intake and conversion efficiency, (iii) dressed weight, (iv) abdominal fat pad weight, and (v) meat composition.

3.7.2 Experimental procedure

Nine approximately isonitrogenous isocaloric broiler starter and finisher diets were formulated to contain 0, 5, 10, 15 and 20% oven or solar dried poultry waste which were collected and dried as described in 3.1. Various amounts of lard were included in the diets to bring the energy to approximately the same level in all diets (2915 Kcal AMEn/kg) of starter diets, and 2945 Kcal AMEn/kg of finisher diets).

The starter and finisher diets were formulated to contain approximately 21.60% and 18.40% crude protein respectively. The composition of the diets used is shown in Tables 3 and 4.

Day old Shaver "Starbro" broiler type chicks obtained from a commercial hatchery were fed on commercial broiler starter feed for a period of three days. On the fourth day, two hundred and sixteen chicks of approximately uniform weights were selected, weighed, and randomly allocated to nine dietary treatments. Each diet had four replicates of six chicks each. The chicks were placed in electrically heated floor pens, and were fed on broiler starter diets up to 28 days of age, and on finisher diets till 53 days of age. The experiment was conducted in a completely randomized design. Feed and water were offered ad-libitum.

3.7.3 Data collection

Records of body weights and feed consumption of chicks per replicate were taken every week until 53 days of age. Mean body weight gain, feed consumption, and feed efficiency per treatment were determined according to the procedure described in 3.6.3. Mortality was also recorded, and one of the dead chicks was immediately subjected to a post-mortem examination to establish the cause of death.

At 53 days of age, one broiler of the same sex was randomly selected from each treatment replicate and slaughtered. Dressed weights of the slaughtered broilers were recorded. The abdominal fat pad from each of slaughtered broilers was carefully removed and weighed.

Table 3: Composition of starter diets used in Experiment 3

Type of DPW		Oven dried poultry waste				Solar dried poultry waste			
Diets	1	2	3	4	5	6	7	8	9
Level of DPW (%)	0	5	10	15	20	5	10	15	20
Ingredients	%								
Maize meal	64.05	58.55	51.55	44.55	36.10	57.90	50.43	42.85	33.70
Lard	-	1.65	3.75	5.90	8.45	2.30	4.97	7.70	10.95
Sunflower seed meal	16.00	17.35	19.25	21.10	23.00	17.35	19.15	21.00	22.90
DPW	-	5.00	10.00	15.00	20.00	5.00	10.00	15.00	20.00
Wheat bran	4.00	2.00	1.00	-	-	2.00	1.00	-	-
Fish meal	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Meat and bone meal	7.50	7.00	6.00	5.00	4.00	7.00	6.00	5.00	4.00
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin/mineral premix[1]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Chemical analyses									
Dry matter (DM %)	89.72	90.07	90.45	91.30	90.88	90.02	90.07	90.07	90.62
TME (Kcal/kg DM)	3761.00	3630.00	3641.00	3662.00	3764.00	3589.00	3615.00	3716.00	3839.00
Percent of DM									
Crude protein	24.52	24.02	24.46	23.99	23.70	24.42	23.98	24.20	24.11
Ash	6.51	7.12	7.62	8.11	9.18	6.85	7.73	7.83	8.43
Ether extract	6.43	7.71	9.15	10.66	11.15	6.97	8.82	10.87	12.82
Crude fibre	5.88	6.45	8.70	10.26	11.06	8.16	9.22	9.95	10.11
Nitrogen free extract	46.38	44.77	40.52	38.28	35.79	43.62	40.32	37.22	35.15

[1] Vitamin/mineral premix provided the same levels of minerals and vitamins as given in Table 1 footnote.

Table 4: Composition of finisher diets used in Experiment 3

Type of DPW		Oven dried poultry waste				Solar dried poultry waste			
Diets	1	2	3	4	5	6	7	8	9
Level of DPW (%)	0	5	10	15	20	5	10	15	20
Ingredients	%								
Maize meal	69.35	63.45	57.20	50.80	44.00	62.80	56.15	49.20	41.70
Lard	-	1.80	3.70	5.65	7.70	2.45	4.90	7.45	10.15
Sunflower seed meal	15.50	16.80	18.75	20.70	22.35	16.80	18.70	20.60	22.20
DPW	-	5.00	10.00	15.00	20.00	5.00	10.00	15.00	20.00
Wheat bran	5.70	4.00	2.40	0.90	-	4.00	2.30	0.80	-
Fish meal	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Meat and bone meal	5.00	4.50	3.50	2.50	1.50	4.50	3.50	2.50	1.50
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vit./mineral premix[1]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Chemical analyses									
Dry matter (DM,%)	89.90	90.08	90.90	90.85	90.44	89.64	90.87	91.02	91.54
TME (Kcal/kg DM)	3707.00	3718.00	3787.00	3771.00	3678.00	3579.00	3667.00	3759.00	3769.00
Percent of DM									
Crude protein	20.63	20.45	21.03	20.47	20.27	20.94	19.89	20.18	20.66
Ash	5.11	6.26	6.46	7.47	8.14	6.17	6.42	7.10	7.68
Ether extract	5.15	5.97	7.13	10.18	12.17	7.54	9.71	10.82	13.03
Crude fibre	8.29	8.24	9.08	9.54	10.57	8.53	9.11	9.57	10.09
Nitrogen free extract	50.72	49.16	47.20	43.19	39.29	46.46	45.74	43.35	40.08

[1]Vitamin/mineral premix provided the same levels of minerals and vitamins as given in Table 1 footnote.

The abdominal fat that was removed and weighed was the fat that sorrounded the gizzard and lay between the abdominal muscles and the intestines. Thigh meat from the dressed broilers was removed from the bones, cut into small pieces, and thoroughly minced in a blender. Samples of the minced meat from each broiler were then analysed for water, crude protein, and crude fat according to the standard procedures (AOAC, 1984). Proximate composition and TME contents of the diets were determined as mentioned in 3.5.4. Maize meal used in the diets was screened for aflatoxins as described in 3.4. Data were analysed statistically as given in 3.5.5.

3.8 Experiment 4

Effect of dietary energy and protein levels of DPW containing diets, on broiler performance.

3.8.1 Objective

Energy and protein sources are the most expensive items in poultry rations and should be economically used through formulation of the best utilizable diets. Results of Experiment 3 showed that broiler chicks fed lard supplemented diets containing 5, 10, and 15% oven or solar dried poultry waste performed as well as those fed the control diet containing no poultry waste and no lard. However lard is an expensive energy source and is rather difficult to mix uniformly in feed when included at levels beyond 5-6%. Therefore Experiment 4 was designed to identify the most efficiently utilized energy and protein levels in diets containing 10% oven or solar dried poultry waste and less than 6% lard. The level of DPW was limited to 10% to avoid the use of uneconomically high levels of lard in diets containing 15% DPW.

3.8.2 Experimental procedure

Poultry waste collected and dried in the oven or solar drier as described in 3.1 was included at a level of 10% in broiler starter diets formulated to contain 2750, 2860 and 2970 Kcal. AMEn/kg, and 20.80, 21.70, and 22.50% crude protein respectively. Finisher diets were formulated to contain the same energy levels but with crude protein contents of 18.20, 19.20 and 20.00% respectively. These protein and energy levels were designed to meet the requirements of broiler chickens (Scott *et al.*, 1976). The compositions of the starter and finisher diets used in Experiment 4 are presented in Tables 5 and 6 respectively.

One hundred and fourty four day old Shaver "Starbro" broiler chicks were obtained from a commercial hatchery. The chicks were weighed and divided into twenty four groups of six chicks each. Four groups of six chicks were allocated to each of the six dietary treatments. The chicks were raised in identical electrically heated floor pens allowing a floor area of approximately 0.10 m^2 per chick. The chicks were brooded for 28 days. Feed and water were offered *ad libitum* throughout the experimental period of 54 days. Starter diets were fed for the first 28 days, and finisher diets for 26 days.

3.8.3 Data collection

Weekly body weights, feed consumption, and mortality per replicate were recorded. At the end of the experiment at 54 days of age, one male broiler was randomly selected from each treatment replicate and weighed individually. The selected broilers were slaughtered and their dressed weights were recorded. Thigh meat was carefully removed from each of the slaughtered broilers, minced in a blender and analysed for water, fat and protein contents as in 3.7.3. Data were analysed statistically as indicated in 3.5.5.

Table 5: Composition of starter diets used in Experiment 4

Type of DPW	Oven dried poultry waste			Solar dried poultry waste		
Level of DPW (%)	10.00	10.00	10.00	10.00	10.00	10.00
Level of energy and protein	Low	Medium	High	Low	Medium	High
Ingredients	------------------	------------------	%	------------------	------------------	------------------
Maize meal	56.50	50.40	44.50	59.00	52.90	47.00
Maize gluten meal	0.70	2.05	3.40	1.00	2.35	3.70
Lard	0.20	2.95	5.70	0.30	3.05	5.80
Sunflower seed meal	16.20	18.20	20.00	16.10	18.10	19.90
DPW	10.00	10.00	10.00	10.00	10.00	10.00
Wheat bran	2.80	2.80	2.80	-	-	-
Fish meal	8.00	8.00	8.00	8.00	8.00	8.00
Meat and bone meal	5.00	5.00	5.00	5.00	5.00	5.00
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin/mineral premix[1]	0.30	0.30	0.30	0.30	0.30	0.30
Chemical analyses						
Dry matter (DM, %)	92.24	92.52	92.74	91.83	92.34	92.58
TME (Kcal/kg DM)	3628.00	3702.00	3824.00	3568.00	3688.00	3748.00
Percent of DM						
Crude protein	22.91	23.50	23.73	22.96	23.32	23.88
Ash	7.43	7.61	7.69	7.47	7.46	7.51
Ether extract	7.59	9.78	12.28	9.04	10.18	12.84
Crude fibre	7.14	7.53	7.68	7.44	7.57	7.79
Nitrogen free extract	47.17	44.10	41.36	44.92	43.81	40.56

[1] Vitamin/mineral premix provided the following per kilogram of diet:- vitamin A, 12,000 IU; vitamin D_3, 2,400 IU; vitamin E, 9.6 IU; vitamin K, 2.4 mg; vitamin B_2, 7.2 mg; vitamin B_{12}, 0.012 mg; folic acid, 1.2 mg; copper, 16.8 mg; nicotinic acid, 36 mg; pantothenic acid, 12 mg; cobalt, 1.2 mg; iodine, 2.4 mg; iron, 28.8 mg; manganese, 80.4 mg; zinc, 80.4 mg; selenium, 0.12 mg: BHT, 144 mg.
Choline chloride was included at a rate of 0.70 g per kilogram of feed.

Table 6: Composition of finisher diets used in Experiment 4

Type of DPW	Oven dried poultry waste			Solar dried poulry waste		
Level of DPW (%)	10.00	10.00	10.00	10.00	10.00	10.00
Level of energy and protein	Low	Medium	High	Low	Medium	High
Ingredients			%			
Maize meal	59.20	53.65	48.10	61.70	56.15	50.60
Maize gluten meal	1.90	2.70	3.70	2.00	2.80	3.80
Lard	0.20	2.95	5.70	0.30	3.05	5.80
Sunflower seed meal	16.50	18.50	20.50	16.40	18.40	20.40
DPW	10.00	10.00	10.00	10.00	10.00	10.00
Wheat bran	4.34	4.34	4.14	1.74	1.74	1.54
Fish meal	4.00	4.00	4.00	4.00	4.00	4.00
Meat and bone meal	3.00	3.00	3.00	3.00	3.00	3.00
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin/mineral premix[1]	0.30	0.30	0.30	0.30	0.30	0.30
Lysine HCl	0.26	0.26	0.26	0.26	0.26	0.26
Chemical analyses						
Dry matter (DM, %)	89.94	90.29	90.59	90.53	90.49	90.96
TME (Kcal/kg, DM)	3573.00	3687.00	3805.00	3494.00	3619.00	3773.00
Percent of DM						
Crude protein	20.47	21.59	22.14	19.93	20.83	21.83
Ash	6.45	6.49	6.59	5.99	6.38	6.23
Ether extract	6.95	10.69	12.89	6.51	10.34	12.82
Crude fibre	8.38	8.64	9.32	8.68	9.03	8.84
Nitrogen free extract	47.69	42.88	39.65	49.42	43.91	41.24

[1]Vitamin/mineral premix provided the same levels of minerals and vitamins as given in Table 5 footnote.

3.9 Experiment 5

Effects of dietary fat levels on performance and mineral retention of broiler chicks.

3.9.1 Objectives

Although no statistically significant differences in body weight gains and feed efficiency were observed between treatment groups in Experiment 4, broilers fed the diets with medium energy and protein levels resulted in slightly better growth rates than the rest of the diets. The broiler chicks fed the diets with high energy and protein levels did not perform as well as would have been expected. This relatively poor performance could be attributed to interactions of dietary components. Considerable evidence indicate that addition of fat to poultry diets interferes with mineral metabolism, thereby reducing calcium retention and in some cases bone ash and calcium contents. Experiment 5 was designed to determine the effects of widely varying dietary levels of fat, energy, and protein on calcium, phosphorus, magnesium and fat utilization of broiler chicks from day old to 28 days of age.

3.9.2 Experimental procedure

Lard was included at levels of 0, 1.5, 3.0, and 12.0% of diets containing 10% solar dried poultry waste. The diets were formulated to have a constant nitrogen corrected apparent metabolizable energy (Kcal/kg) to percentage crude protein ratio (132:1). Calculated AMEn in the diets ranged from 2635 Kcal/kg in the diet containing 0% lard to 3191 Kcal/kg in the diet containing 12.0% lard, while calculated crude protein ranged from 19.93% to 24.13%. The diets used in Experiment 5 are shown in Table 7. Seventy two day old Shaver "Starbro" broiler chicks obtained from a commercial hatchery were used in the experiment. Three replicate groups of six chicks each were allotted to each of the four diets. The experiment was conducted in a completely randomized design. The chicks were placed in an electrically heated brooder, allowing a floor area of approximately 0.10 m^2 per chick. Feed and water were provided ad libitum throughout the four week experimental period.

3.9.3 Data collection

Weekly body weights, feed intake, and mortality were recorded up to 28 days of age. Mean body weight gain, feed intake, and feed efficiency per dietary treatment were obtained as described in 3.6.3. Total excreta per treatment replicate was collected for a 72 hour period between the 24th and 27th day of the experiment. Feed intake during this period was recorded. The excreta samples were dried in the oven at 60°C and the dry weights were recorded. The dried excreta and feed samples were finely ground in a laboratory mill and analysed for fat, calcium, phosphorus and magnesium, according to the standard procedures (AOAC, 1984). Apparent nutrient retention was calculated as follows:

$$\text{Apparent nutrient retention (\%)} = \frac{\text{Wt. of nutrient ingested} - \text{Wt. of nutrient in excreta}}{\text{Weight of nutrient ingested}} \times 100$$

Faecal soap was determined through two stages of ether extraction as described by Atteh and Leeson (1985). The first extraction to remove neutral fat and fatty acids was

Table 7: Composition of diets used in experiment 5

Level of DPW3***	10.00	10.00	10.00	10.00
Level of lard (%)	0.00	1.50	3.00	12.00
Ingredients	-------------------	%	-------------------	
Maize meal	56.50	51.40	52.10	33.93
Maize gluten meal	-	-	3.00	5.50
Lard	-	1.50	3.00	12.00
Sunflower seed meal	14.80	14.50	17.96	25.90
DPW3	10.00	10.00	10.00	10.00
Wheat bran	6.10	10.00	1.30	-
Fish meal	7.00	7.00	7.00	7.00
Meat and bone meal	5.00	5.00	5.00	5.00
Vitamin/mineral premix[1]	0.30	0.30	0.30	0.30
Salt	0.30	0.30	0.30	0.30
Lysine HCl	-	-	0.04	0.07
Chemical analyses				
Dry matter (DM, %)	90.25	90.76	91.76	92.64
TME (Kcal/kg DM)	3313.00	3433.00	3645.00	3976.00
Percent of DM				
Crude protein	22.17	21.99	23.32	25.52
Ash	7.40	7.44	7.75	7.34
Calcium	1.44	1.49	1.53	1.30
Phosphorus	1.04	1.04	1.04	1.01
Magnesium	0.30	0.28	0.28	0.30
Ether extract	6.66	8.46	10.00	18.71
Crude fibre	8.81	9.44	9.96	10.25
Nitrogen free extract	45.21	43.43	40.74	30.82

***DPW3 is solar dried (50-70^{o}C) poultry waste

[1] Vitamin/mineral premix supplied the same levels of minerals and vitamins as given in Table 5 footnote.

carried out according to the standard procedures (AOAC, 1984). Thimbles containing the residues of the first extraction were placed in 25% hydrochloric acid (specific gravity 1.13) for two hours at room temperature. This was done to liberate fatty acids present as soap. The thimbles were then dried in the oven at 60°C for 24 hours, and the process of ether extraction repeated to give an estimate of fatty acids released from faecal soap. Samples of feed were subjected to similar two stage ether extraction to act as standards. At the end of the experiment at 28 days of age, one chick was randomly selected from each treatment replicate and killed to obtain the tibiae. Tibiae ash contents were determined as described in 3.6.3. Data were analysed statistically as given in 3.5.5

4. RESULTS AND DISCUSSION

4.1 Chemical composition of dried poultry waste (DPW)

The proximate, true protein, minerals, and true metabolizable energy contents of the oven dried, the sun dried and autoclaved, and the solar dried types of poultry waste are shown in Table 8. Calcium and phosphorus solubility in water and in 0.4% HCl, and the true protein digestibility of the oven dried, the sun dried-autoclaved, and the solar dried poultry waste are presented in the same table. The three differently dried types of poultry waste showed little variation in true protein and proximate composition. However, the waste differed quite significantly in the true metabolizable energy content and true protein digestibility. The energy content of the oven dried poultry waste was over twice that of the solar dried poultry waste. Differences in energy values of the three differently dried poultry waste confirm an earlier finding of Shannon and Brown (1969) that the loss of energy increased with decreasing temperature and with increasing duration of the drying process. Although temperatures in the forced air oven and in the solar drier were approximately the same (60^{o}C and 50-70^{o}C), poultry waste placed in the solar dried took a longer time to dry due to inefficient air circulation and moisture accumulation in the solar drier. Some of the starch and sugars in the poultry waste possibly dissolved in the moisture formed in the solar drier, and were utilized by the bacteria present

Table 8: Chemical composition of dried poultry waste (dry matter basis)

	Type of dried poultry waste (DPW		
	DPW1*	DPW2**	DPW3***
Dry matter, %	92.16	92.37	93.10
Ash, %	28.75	28.99	26.69
Crude protein, %	21.76	17.55	22.59
True protein	9.82	10.95	11.13
Crude fibre, %	15.95	15.29	15.56
Ether extract, %	2.94	3.85	3.06
Nitrogen free extract %	22.76	26.69	25.11
Calcium, %	7.27	7.15	7.31
Ca soluble in 0.4% HCl, %	3.91	3.57	4.19
Ca soluble in water, %	0.71	0.76	0.75
Phosphorus, %	2.65	2.50	2.42
P soluble in 0.4% HCl, %	2.12	1.84	1.94
P soluble in water, %	1.05	0.78	0.97
Magnesium, %	1.25	1.28	1.05
Copper, ppm	48.00	43.00	45.00
Iron, ppm	1200.00	1300.00	1400.00
True metabolizable energy, Kcal/kg, DM	1152.00	624.00	506.00
True protein digestibility, %	76.08	62.64	51.14

*Oven dried (60°C) poultry waste

**Sun dried, autoclaved (1.05 kg/cm^2, 121°C, 15 minutes) poultry waste

***Solar dried (50-70°C) poultry waste

in the waste, thereby reducing the final energy content of the dried product. The energy content of the oven dried poultry waste (1152 kcal/kg) is in agreement with the finding of Pryor and Connor (1964) who showed that chicken faeces had metabolizable energy of approximately 30% of the feed from which it originated (3045 kcal/kg). The slightly higher energy value of the sun dried-autoclaved waste in comparison to that of the solar dried poultry waste could be attributed to a reduction in uric acid, and an increase in available carbohydrate as a result of the autoclaving process (Blair, 1972a, 1974).

The true protein digestibility of the oven dried poultry waste was 24.94% higher than that of the solar dried poultry waste. The protein digestibility value of the solar dried poultry waste (51.14%) was fairly similar to that reported by Yoshida and Oshii (1965) for air dried excreta (53%). The relatively lower true protein digestibility of the solar dried, and the sun dried-autoclaved poultry waste could be due to the detrimental effect of extensive heating on protein quality. Extensive heating can result in impairment of protein quality by the Maillard or browning reaction (Maynard et al., 1979). In this reaction, free amino groups of the peptide chain react with the aldehyde group of reducing sugars such as glucose or lactose to yield an amino-sugar complex that is no longer available to the animal.

The crude protein content of the oven dried; the sun dried-autoclaved, and the solar dried poultry waste were lower than those reported for dehydrated layer waste by

Flegal and Zindel (1970), Blair and Knight (1973), Blair (1974), Bhargava and O'neil (1975), Ichhponani and Lodhi (1976), El Boushy and Vink (1977), and Muller (1982). The relatively lower crude protein contents of the three differently dried poultry waste used in this study could be attributed to:- i) the rather low crude protein content (14.75%) of layer mash fed to hens from which the excreta was collected, and (ii) the methods used in drying the waste were slow. Total nitrogen content of dried poultry waste was reported to be inversely related to the temperature and duration of the drying process (Parker et al., 1959; Sheppard et al., 1971).

The remarkable similarity in the true protein contents of the three differently dried poultry waste material is in agreement with the observation made by Manoukas et al. (1964), Sheppard et al. (1971), Blair (1974), and Bhargava and O'neil (1975), that protein nitrogen was less variable than non-protein nitrogen. The true protein contents of the oven dried; the sun dried-autoclaved; and the solar dried poultry waste were 45.13, 62.39, and 49.27% of the crude protein contents in the three samples, respectively. These results are in agreement with the findings of Biely et al. (1980) and Muller (1982) that true protein is about 50% of crude protein in DPW. The non-protein nitrogen contents (crude protein - true protein) of the oven dried, the sun dried-autoclaved; and the solar dried poultry waste were 11.94, 6.60, and 11.46%, respectively. The relatively lower crude protein and non-protein nitrogen contents of the sun dried-autoclaved poultry waste confirm earlier findings of Blair (1972a) and Caswell _et al._ (1975) that autoclaving causes a reduction in non-protein nitrogen content of poultry manure.

The three differently dried poultry waste samples contained high percentages of ash, calcium, and phosphorus. The major and trace mineral contents of poultry manure consist of the endogenous fraction and the fraction of the diet which is not absorbed (Maynard _et al._, 1979). The high crude fibre levels in dried poultry waste are expected since poultry do not efficiently utilize fibre (Fontenot _et al._, 1983), although its presence in feeds is essential to aid digestion (Kekeocha, 1984). The high ash and crude fibre levels partly explain the low metabolizable energy content of DPW.

Calcium solubility of the oven dried; the sun dried-autoclaved and the solar dried poultry waste in 0.4% HCl (soluble calcium expressed as a percentage of total calcium) were found to be 53.78, 49.93, and 57.32% respectively, while phosphorus solubility of the three poultry waste samples were 80.00, 73.60, and 80.17% respectively. Calcium solubility of the oven dried; the sun dried-autoclaved; and the solar dried poultry waste in water were found to be 9.77, 10.63, and 10.26% respectively, while phosphorus solubility of the three poultry waste samples in water were 39.62, 31.20, and 40.08% respectively. The relatively higher solubility of calcium and phosphorus in 0.4% HCl compared to that in water is not surprising because of the ability of acids to combine with bases. These results showed that method of drying had no significant effect on calcium and phosphorus solubility in 0.4% HCl or water. Loosli (1972) observed that feed processing had little influence on calcium availability. A positive, but inconsistent correlation between mineral solubility in 0.4% HCl and availability to chicks was reported by Gillis et al. (1948) and Watson et al. (1970). There is little information on the availability of calcium and phosphorus in dried poultry waste. However, Parker et al. (1959) showed that 88% of the phosphorus is available, while Blair (1974) and Cuca (1984) indicated that calcium and phosphorus in dried poultry waste are highly available for poultry. McNab et al. (1974) reported that at least 45.3% of the calcium and 46.2% of the phosphorus in dried poultry manure were digested by laying hens. The relatively higher solubility of phosphorus in both water and 0.4% HCl possibly indicates that the DPW phosphorus is more available than calcium. The absorption of calcium and phosphorus is dependent upon their solubility at the point of contact with the absorbing membranes (Maynard et al., 1979).

4.1.1 Amino acid composition of DPW

Amino acid composition of the oven dried; the sun dried-autoclaved; and the solar dried types of poultry waste are presented in Table 9. The remarkable similarity in amino acid composition of the three differently dried poultry waste confirms earlier observations by Manoukas

Table 9: Amino acid composition of dried poultry waste

Amino acid (mg/ g)	DPW1*	DPW2**	DPW3***
Alanine	9.23	7.78	10.15
Arginine	2.19	2.21	2.51
Aspartic acid	5.33	5.20	5.80
Cystine	6.98	7.43	8.26
Glutamic acid	5.96	5.78	7.64
Glycine	1.49	1.70	1.55
Histidine	1.21	1.18	1.47
Isoleucine	1.79	1.76	2.76
Leucine	2.90	2.89	3.85
Lysine	2.63	2.41	3.17
Methionine	1.26	1.06	1.68
Phenylalanine	1.83	1.77	2.52
Serine	1.84	1.99	2.14
Threonine	2.07	2.15	2.63
Tyrosine	3.33	3.34	4.12
Valine	2.39	2.38	3.28

* DPW1 is oven dried (60^{o}C) poultry waste.

** DPW2 is sun dried-autoclaved (1.05 kg/cm^2, 121^{o}C, 15 minutes) poultry waste.

***DPW3 is solar dried (50-70^{o}C) poultry waste.

et al. (1964), Sheppard et al. (1971), Blair (1974) and Bhargava and O'neil (1975) that protein nitrogen is less variable than non-protein nitrogen. The slightly lower amino acid levels in the oven dried poultry waste could be attributed to a limited destruction of amino acids during oven drying (Dale et al., 1985). The amino acid composition of the three differently dried poultry waste were lower than those reported by Flegal and Zindel (1970), Blair and Knight (1973), Couch (1974), El Boushy and Vink (1977), and Blair and Herron (1982). The amino acid composition of the dried poultry waste could reflect that of feed fed to layers from which the waste was collected. Although the amino acid composition of layer mash was not determined, the crude protein content of 14.75% is less than 16.0-17.70% which is recommended for laying hens by Blair et al. (1983).

4.2 Bacteriological and aflatoxin composition of DPW

Results of the direct culture determination of the bacteriological composition of dried poultry waste are shown in Table 10. Culture in selenite broth showed that none of the three types of dried poultry waste was contaminated with Salmonella spp. Further examination by subculture and biochemical tests to classify the bacteria in dried poultry waste revealed the presence of Staphylococcus epidermidis, Streptococcus faecalis, and Escherichia coli in the oven dried, the sun dried-autoclaved, and the solar dried poultry waste. Citrobacter freundii was detected in the oven dried and the sun dried-autoclaved samples, while poor growths of Clostridium welchii were observed in the sun dried-autoclaved, and the solar dried poultry waste. These results showed that the three types of dried poultry waste were not completely sterile. However, complete sterility of animal feeds is almost impossible as observed by Singh (1974) who found that all ingredients tested contained a minimum total microbial count of 12 x 10^3/g, and a mouldcount of at least 3 x 10^3/g. The bacterial counts in the three types of dried poultry waste showed that method of processing had a significant effect on the number of bacteria. The relatively smaller number of bacteria in the sun dried autoclaved poultry waste could be attributed to the effect of autoclaving in destroying bacteria (Caswell et al., 1975). Solar drying of poultry waste was not as effective as oven drying or autoclaving, in destroying bacteria. This could be due

Table 10: Bacteriological composition of dried poultry waste

Sample type	Total bacteria/g sample	Bacteria type and number/g
Oven dried at $60^{o}C$ (DPW1)	1.44×10^7	Staphylococcus spp., 1.12×10^7 Non-lactose fermenters, 3.2×10^6 Streptococcus spp., 1.12×10^4
Sun-dried and autoclaved at 1.05 kg/cm², $121^{o}C$, for 15 min. (DPW2)	2.64×10^5	Non-lactose fermenters, 2.56×10^5 E. Coli, 8×10^3
Solar dried at $50\text{-}70^{o}C$ (DPW3)	7.28×10^7	E. coli, 1.04×10^7 Non-lactose fermenters, 5.2×10^7 Anthracoides, 3.2×10^6 Streptococcus spp., 7.2×10^7

to the temperature flactuations and poor air circulation inside the solar drier which led to the slow drying of the sample, and to possible multiplication of the existing bacteria. The presence of Staphylococcus epidermidis, Streptococcus faecalis, and Escherichia coli in each of the three differently dried poultry waste samples showed that oven drying at 60°C; sun drying (24-29°C) followed by autoclaving at 1.05 kg/cm^2, 121°C, for 15 minutes; or solar drying at 50-70°C were not adequate to get rid of these bacteria. The 2 cm thickness to which the poultry waste was spread in drying, possibly did not allow thorough penetration of heat to get rid of these bacteria. Nonetheless, most of these bacteria are normal inhabitants of the intestinal tract of animals (Gwilym, 1957; Jawetz et al., 1972). Poor growths of Clostridium welchii observed in the sun dried-autoclaved, and the solar dried types of poultry waste could be due to the inconsistent drying temperatures which probably encouraged putrefaction. The absence of Salmonellae in the dried poultry waste samples is not surprising because the waste was collected from healthy hens, and if any Salmonellae had been present in the fresh excreta, they would have been destroyed during the drying process. Although in some cases, the temperatures used for drying the poultry waste were less than the 62.8°C recommended by Messer et al. (1971) for destroying S. pullorum and S. typhimurium, the durations for drying were much longer than 60 minutes and could adequately destroy any Salmonellae present.

Thin layer chromatography examination of the oven dried, the sun dried-autoclaved, and the solar dried poultry waste showed no aflatoxin contamination. This is in agreement with

Hesseltine (1976) who reported that rapid dehydration would counteract the effects of Aspergillus flavus, and that fungi do not grow on dry substrates.

4.3 Experiment 1

4.3.1 Chemical analyses of the diets

Results of the chemical analyses of the diets used in experiment 1 were presented in Table 1. The true protein content of the depletion and control diet was 8.54%, while that of the test diets ranged from 11.31 to 11.71%. These values were close to those prescribed by Heiman et al. (1939) and Duckworth et al. (1961) (8% and 11% respectively), in the determination of gross protein values of protein supplements. Crude fibre contents of the diets (10.50-11.32%) were achieved through the use of oatfeed. Diets were made nearly isofibrous. The true metabolizable energy content of the control diet and that of the casein diet were approximately 700 kcal/kg DM higher than the energy content of the diets containing poultry waste. This is because no attempt was made to make the diets isocaloric. Although Duckworth et al. (1961) did not specify the level of dietary metabolizable energy to be used in the gross protein value determination, chickens can to a certain extent adjust their feed intake to meet their energy requirements (Scott et al., 1976). The energy content of the diet containing the oven dried poultry waste was slightly higher than that of the diets containing the sun dried-autoclaved or the solar dried poultry waste. This is a reflection of the differences in energy content of the vario··sly dried poultry waste, since the other ingredients were approximately the same for the three diets.

4.3.2. Chick performance and gross protein values (GPV) of dried poultry waste

Mean feed consumption, and body weight gain of chicks fed experiment 1 diets between three and five weeks of age are presented in Table 11. The gross protein values of the differently dried poultry waste are shown in the same table. Chicks grew slowly due to the low dietary protein contents (8.54% true protein in the control diet, and 11.31-11.71% true protein in the test diets). However, the chicks were quite healthy and active. Mortality was 0.83%. The only chick which died at the age of four weeks had been feeding on the diet containing the solar dried poultry waste. The low feed intake by chicks fed the cereal (control) diet could be due to the high dietary energy level. The diet containing casein gave the highest feed intake of all diets although it had the highest metabolizable energy content. This indicates that protein quality and quantity, being the most limiting factors in these diets, influenced feed intake. Low dietary protein has been reported to increase feed intake (NRC, 1984). Body weight gains of the chicks also showed a similar trend to that of feed intake in that the casein diet resulted in the highest weight gains, while the control diet gave the lowest weight gains. The extra weight gains resulting from the casein or the dried poultry waste containing diets, over the control diet are due to the supplementary protein from these sources. Although chicks fed the diet

Table 11: Average feed consumption, weight gain per chick, and gross protein values (GPV) of DPW

Kind of diet	Avg. true protein in diets (%)	Avg. supplementary protein in diets (%)	Avg. body wt. at 3 weeks (g)	Avg. body weight at 5 weeks (g)	Avg. wt. gain (g)	Avg. wt. gain over control (g)	Avg. feed intake (g)	Avg. supplementary protein intake (g)	GPV[1] (%)
Cereal (control)	8.54	–	156±4	237±8	81	0	452±12	0	–
Cereal + casein	11.31	2.77	156±4	383±8	227	146	687±19	19	100.00
Cereal + DPW1*	11.71	3.17	152±2	323±6	171	90	648±16	21	$56.88^{a}\pm2.35$
Cereal + DPW2**	11.67	3.13	161±4	296±9	135	54	583±25	18	$38.82^{b}\pm2.82$
Cereal + DPW3***	11.57	3.03	154±4	269±4	115	34	521±9	16	$28.16^{b}\pm3.48$

[1] Mean of four observations ± standard error of the mean

* Oven dried poultry waste

** Sun dried autoclaved poultry waste

***Solar dried poultry waste

[a,b] Means within a column bearing different superscripts are significantly different ($P<0.05$)

containing casein or the differently dried poultry waste had approximately the same supplementary protein intake, these chicks gave different weight gains because of the differences in protein quality of casein and dried poultry waste.

The oven dried; the sun dried-autoclaved; and the solar dried types of poultry waste had gross protein values of 56.88, 38.82, 28.16% respectively, as compared to casein which was given an arbitrary value of 100%. The GPV of the oven dried poultry waste was significantly higher than that of the sun dried-autoclaved, or the solar dried poultry waste. The differences in GPV of the variously dried poultry waste could be attributed to the differences in protein digestibility values of the three samples of poultry waste. Both the GPV and the true protein digestibility values of the three types of poultry waste showed similar sequences. This is an indication of a positive relationship between the protein digestibility and the gross protein values of dried poultry waste. The oven dried poultry waste gave the highest GPV despite its slightly lower amino acid content compared to the sun dried-autoclaved or the solar dried poultry waste. This suggests that the GPV was not directly related to the amino acid content of DPW. GPV measures the value of a protein concentrate as a supplement to a basal ration of mixed cereals (Carpenter et al., 1952; Duckworth et al., 1961; Yoshida, 1976). Therefore it may be concluded that the oven dried poultry waste provided a better protein supplement to the basal ration, than the sun dried-autoclaved or the solar dried poultry waste. However, DPW would not necessarily have the same GPV if a different basal mixture was used.

Calculations of GPV were based on the true protein contents of the diets. However, the role played by the non-protein nitrogen should not be disregarded. Although it is commonly felt that non-protein nitrogen is of little significance in the nutrition of birds, there is ample evidence indicating that under carefully defined conditions, non-protein nitrogen supplied in form of urea or ammonium salts can be utilized in lieu of non-essential amino acids (Featherston et al., 1962; McGinnis, 1967; and Blair, 1972b). With the exception of uric acid which has been described as useless to poultry (Bare et al., 1964; Blair, 1974; Martindale, 1974; Biely et al., 1980 and Fontenot et al., 1983), the rest of the non-protein nitrogen components such as ammonium nitrogen and urea in dried poultry waste probably provided non-essential amino acids to the chicks. McNab et al. (1974) reported a true protein digestibility value of 90.5% for total nitrogen in the sample of DPW while that of true protein was 64.2%. From these digestibility values, it appears that some non-protein nitrogen is apparently absorbed.

4.4 Experiment 2

4.4.1 Chemical analyses of the diets

The results of the chemical analyses of diets used in experiment 2 were shown in Table 2.

Crude protein, ether extract, and true metabolizable energy contents of the diets decreased slightly as the level of dried poultry waste were increased from 5 to 15%. This is because the DPW was of lower protein, ether extract and metabolizable energy contents than those of maize meal, meat and bone meal and wheat bran which were partially replaced with DPW. Crude fibre and ash contents in the diets increased with the increasing levels of dried poultry waste, due to the relatively high ash and crude fibre levels in DPW.

4.4.2 Broiler chick performance

The effects of feeding graded levels of the oven dried, the sun dried-autoclaved, and the solar dried poultry waste on broiler chick performance are shown in Table 12. No sign-ficant differences were observed in body weight gain or feed intake of chicks fed the different diets. At 30 days of age, broiler chicks fed diets containing 5%, 10%, and 15% oven dried poultry waste weighed an average of 696 g, 706 g, and 667 g, respectively; those fed diets containing 5%, 10%, and 15% sun dried-autoclaved poultry waste weighed 670, 660, and 659 g, while those fed diets containing 5%, 10%, and 15% solar dried poultry waste weighed 696 g, 653 g and 651 g, respectively. These body weights are within the range prescribed by NRC (1971) which states that broiler chicks of mixed sexes should weigh 550 to 750 g between 3.7 and 4.7 weeks of age. Mean body weight gain of chicks decreased, while feed intake increased with the increasing level of dried poultry waste in the diets. As a result of this trend, feed efficiency became poorer with the increasing level of DPW in the diets. No significant differences were observed in feed efficiency of chicks fed the diets containing 5% or 10% oven dried, sun dried-autoclaved or solar dried poultry waste. However, the mean feed efficiency of chicks fed diets containing 15% dried poultry waste was depressed by 9.63% and 5.29% respectively, compared to that of chicks fed the diets containing 5% or 10%

Table 12: Effect of level and type of DPW on growth rate, feed intake, and feed efficiency of broiler chicks from 2 to 30 days of age

Level of DPW	DPW1*	DPW2**	DPW3***	Mean
	Mean body weight gain (g)			
5%	654[1]	628	654	645[2]
10%	664	618	611	631
15%	625	617	609	617
Mean	648	621	625	
	Mean feed intake (g)			
5%	1361	1425	1439	1408
10%	1454	1403	1441	1433
15%	1431	1469	1520	1473
Mean	1415	1432	1467	
	Mean feed efficiency (feed:gain)			
5%	2.08	2.27	2.20	2.18[a]
10%	2.19	2.27	2.36	2.27[ab]
15%	2.29	2.38	2.50	2.39[b]
Mean	2.19[a]	2.31[ab]	2.35[b]	

* Oven dried poultry waste

** Sun dried-autoclaved poultry waste

***Solar dried poultry waste

[1] Each value is the average of four replicate pens of six chicks each.

[2] Standard errors of the means were: 23 for gain; 34 for feed intake; and 0.08 for feed efficiency.

[a,b] Means for feed efficiency bearing different superscripts in a row or column are significantly different ($P<0.05$).

dried poultry waste. The mean feed efficiency of chicks fed diets containing the solar dried poultry waste was significantly poorer ($P<0.05$) than that of chicks fed diets containing the oven dried poultry waste.

The significant decline in feed efficiency as the level of dried poultry waste in the diets was increased beyond 10% could be attributed to the low energy content of DPW which caused a decrease in the dietary energy contents. Similar observations were made by Flegal and Zindel (1970), Cenni et al. (1971), Lee and Blair (1973), Rinehart et al. (1973), and Sloan and Harms (1973). However, the increasing levels of dried poultry waste in the diets also resulted in higher ash and crude fibre contents, which could also affect feed efficiency. The diets containing the oven dried poultry waste gave the best overall body weight gain and feed efficiency of chicks. This could be attributed to the relatively higher energy level and true protein digestibility of the oven dried poultry waste compared to the sun dried-autoclaved or the solar dried poultry waste.

Mortality for the whole experiment was 6.94%. Chicks fed the diets containing 5% or 10% oven dried poultry waste, or 15% sun dried autoclaved poultry waste survived throughout the experimental period. Chicks fed diets containing the solar dried poultry waste had the highest mortality rate of 3.70%. Most of the deaths occurred during the third week of the experiment. Although the solar dried poultry waste gave the highest number of bacteria, it is not safe, at this stage, to conclude that the method of drying had a direct effect on mortality of chicks. The number and type of bacteria in the solar dried poultry waste did not differ much from that in the oven dried poultry waste, and most of the bacteria isolated in the dried poultry waste were believed to be normal inhabitants of the intestinal tract (Jawetz et al., 1972). On individual diet basis, highest mortality (2.31%) came from chicks fed the diet containing 10% sun dried-autoclaved poultry waste, even though this type of poultry waste had the least number of bacteria.

4.4.3 Effect of level and type of DPW and age of broiler chicks on hepatic GOT and GPT activities

Mean hepatic GOT and GPT activities in broiler chicks aged two days were found to be 159, and 27 μ moles/min/g liver, respectively. Mean hepatic GOT and GPT activities between 16 and 30 days of age of broiler chicks fed diets containing 5%, 10%, and 15% oven dried, sun dried-autoclaved or solar dried poultry waste are presented in Table 13. No significant differences were observed in mean hepatic GOT or GPT activity of chicks fed the different diets. In all cases, however, GOT activity was considerably higher than GPT activity. Significant differences were observed in GOT and GPT activities determined at different ages of chicks (Figures 3 and 4). GOT activity at 23 days of age was significantly higher ($P<0.05$) than at 16 or 30 days of age, while GPT activity at 30 days of age was significantly lower ($P< 0.05$) than at 16 or 23 days of age. Bell and Freeman (1971) also reported an age-dependant decrease in GPT activity in pullets.

Table 13: Effect of level and type of DPW on mean hepatic GOT and GPT activities of broiler chicks between 16 and 30 days of age

	Mean GOT activity (μ moles/min/g liver			
	Type of DPW			
Level of DPW	DPW1*	DPW2**	DPW3***	Mean
5%	38.72[1]	42.24	36.32	39.09[2]
10%	30.56	42.72	38.08	37.12
15%	32.16	37.76	42.08	37.33
Mean	33.81	40.91	38.83	

	Mean GPT activity (μ mole/min/g liver)			
	Type of DPW			
Level of DPW	DPW1*	DPW2**	DPW3***	Mean
5%	11.07	10.72	10.38	10.72
10%	9.57	10.08	14.26	11.30
15%	7.94	9.09	11.15	9.39
Mean	9.53	9.96	11.93	

* Oven dried poultry waste

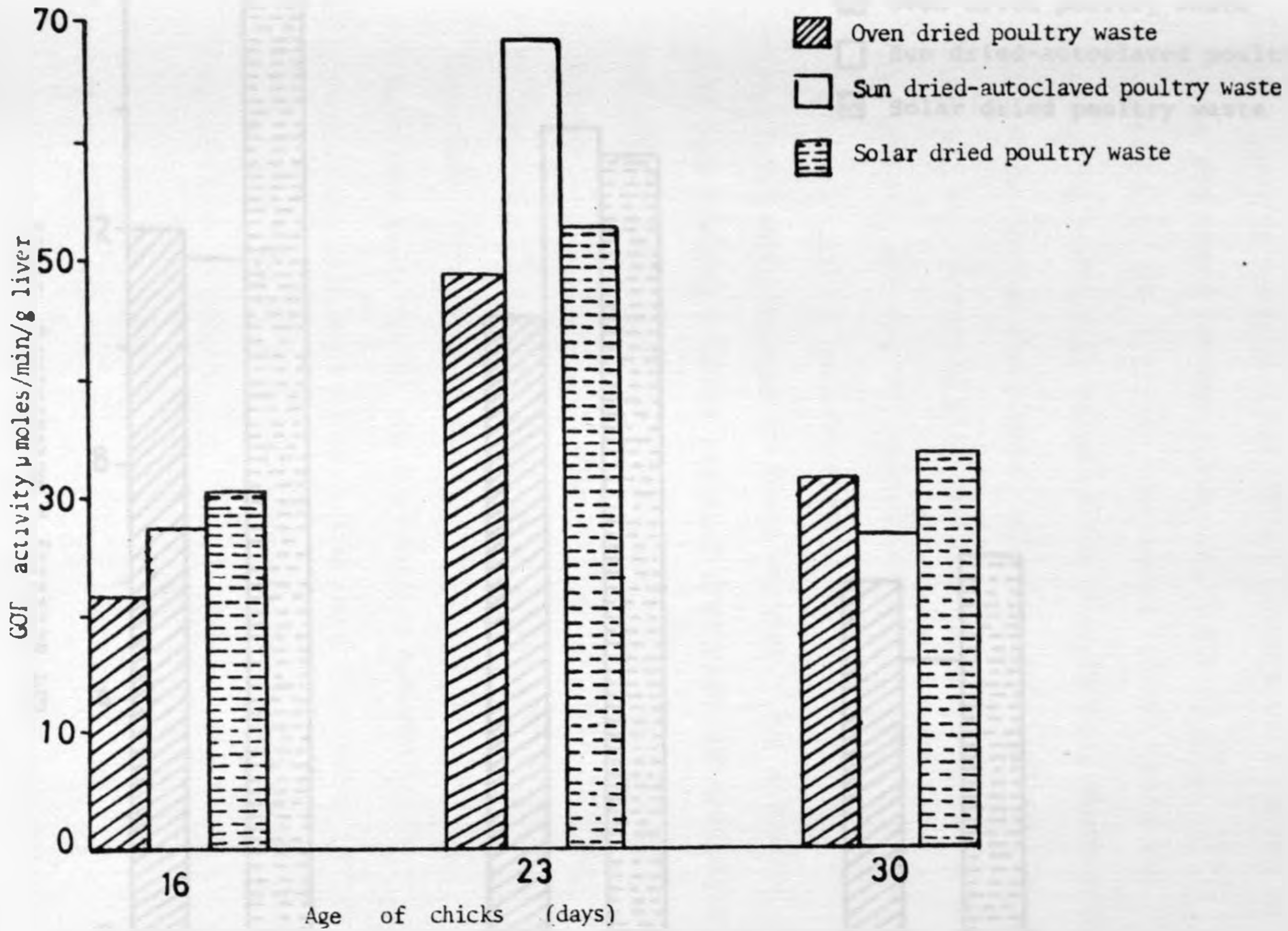
** Sun dried autoclaved poultry waste

***Solar dried poultry waste

[1]Each value is the average of three observations.

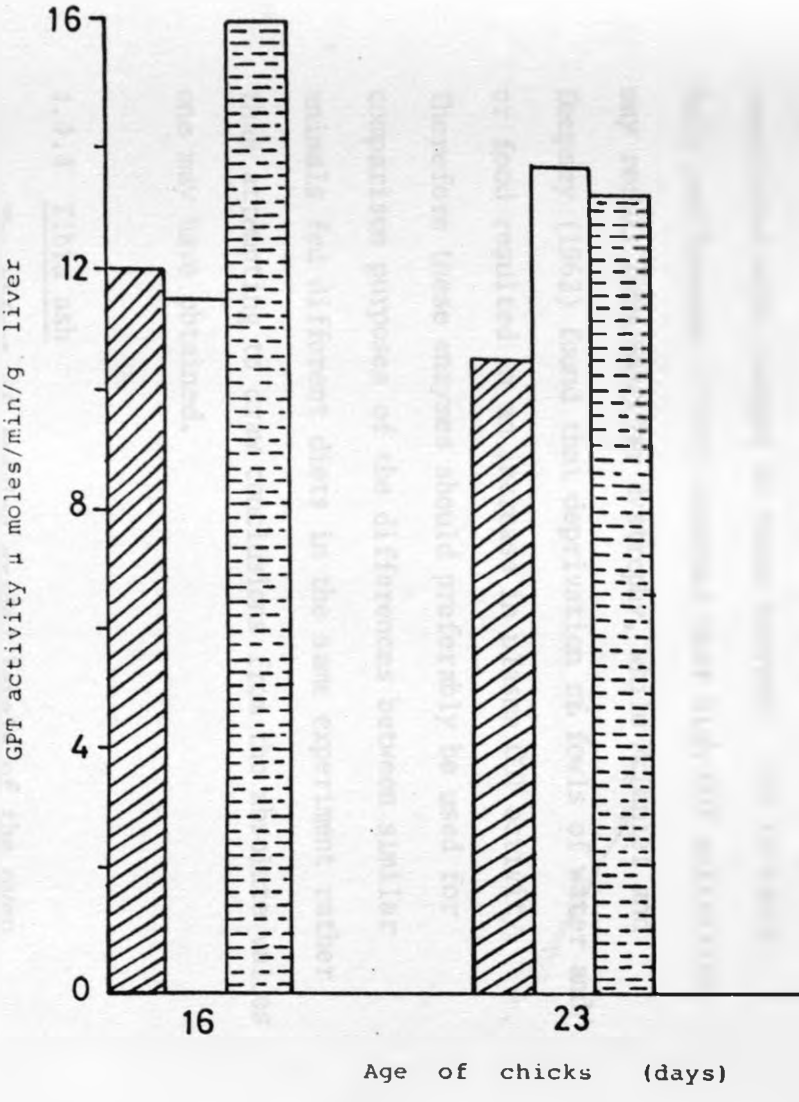
[2]Standard errors of the means were: 4.16 for GOT; and 2.24 for GPT.

Figure 3: Effect of age on hepatic GOT activity of broiler chicks fed diets containg DPW

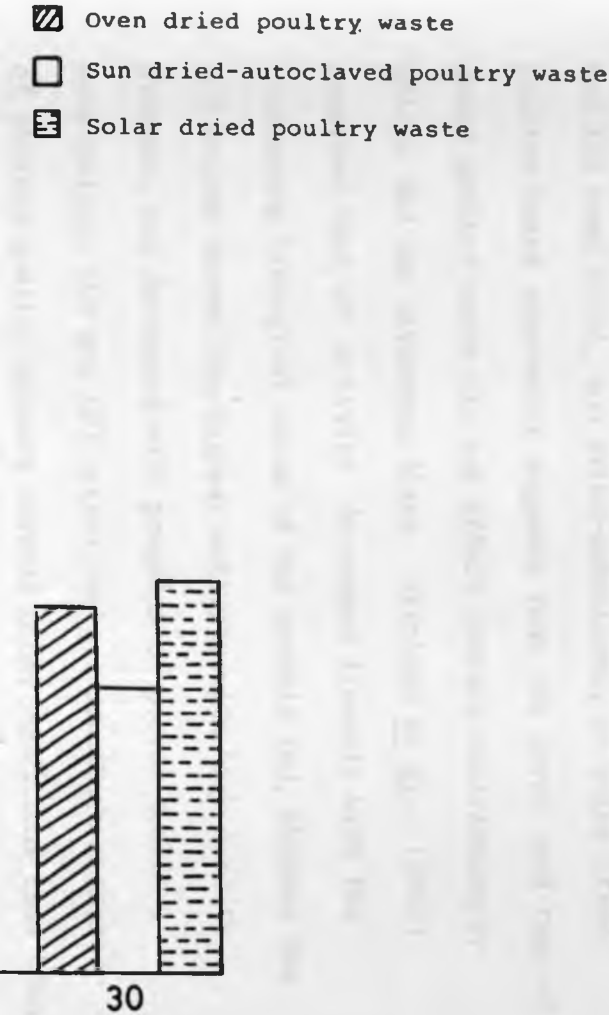


- 70 -

Figure 4: Effect of age on hepatic GPT activity of



broiler chicks fed diets containing DPW



The lack of significant differences in mean hepatic GOT or GPT activities of chicks fed diets containing 5%, 10% and 15% oven dried, sun dried-autoclaved, or solar dried poultry waste apparently suggests that the level and type of dried poultry waste did not affect protein utilization by chicks fed the different diets. Wirthgen et al. (1967) reported that GPT activity decreased linearly with the increasing biological value of the protein fed, whereas the GOT enzyme showed the highest activity with high quality protein, and decreased with proteins of poorer quality. Nonetheless, GOT and GPT activities are sensitive measures of protein quality because several other conditions have been associated with changes in these enzymes. For instance, Bell and Freeman (1971) reported that high GOT activities may result from muscular dystrophy, while McDaniel and Dempsey (1962) found that deprivation of fowls of water and/or food resulted in an increase in plasma GOT activity. Therefore these enzymes should preferably be used for comparison purposes of the differences between similar animals fed different diets in the same experiment rather than attempting to draw conclusions from the absolute values one may have obtained.

4.4.4 Tibia ash

The effect of feeding graded levels of the oven dried, the sun dried-autoclaved, and the solar dried poultry waste on tibia ash content of broiler chicks between 9 and 30 days of age is presented in Table 14. No significant

Table 14: Effect of dietary level and type of DPW on tibia ash content of broiler chicks between 9 and 30 days of age

	Mean tibia ash content (%)			
	Type of DPW			
Level of DPW	DPW1*	DPW2**	DPW3***	Mean
5%	48.03[1]	48.44	49.72	48.73[2]
10%	48.18	49.01	48.48	48.56
15%	50.28	48.54	51.00	49.94
Mean	48.83	48.66	49.73	

* Oven dried poultry waste

** Sun dried autoclaved poultry waste

***Solar dried poultry waste

[1]Each value is the average of four observations.

[2]Standard error of the means was 1.05.

differences were observed in percentage tibia ash content of broiler chicks fed diets containing various levels of the differently dried poultry waste. This possibly indicates that the level and type of dried poultry waste did not affect bone mineralization. Increases in the level of dried poultry waste resulted in slight increases in both calcium and phosphorus in the diets. However, the calcium: phosphorus ratio remained within the range recommended by Scott et al. (1976). Calculated calcium:phosphorus ratio in the diets ranged from 1.83:1 for the diet containing 5% oven dried poultry waste to 1.94:1 for the diet containing 15% solar dried poultry waste. Lameness among chicks on the experiment was negligible (0.46%). The only chick that was noted to have a lame leg at the age of two weeks was feeding on the diet containing 15% solar dried poultry waste. Leg abnormality at such an early age could be due to injury rather than dietary origin.

4.5 Experiment 3

4.5.1 Chemical analyses of the diets

The chemical analyses presented in Tables 3 and 4 showed that the diets containing 0% or levels of up to 20% oven or solar dried poultry waste were approximately isonitrogenous. This was made possible through proper adjustments of meat and bone meal, sunflower seed meal, and wheat bran with the increasing levels of poultry waste in the diets. Increasing DPW resulted in increased ash and crude fibre contents in the diets. Ether extract content increased with the increasing levels of lard in the diets. The true metabolizable energy values in the starter diets ranged from 3589 to 3839 kcal/kg DM. Although the diets were formulated to be isocaloric, this was not achieved. The TME values in starter diets containing 15% or 20% solar dried poultry waste were 127-250 kcal/kg DM higher than the diet containing 5% solar dried poultry waste. The differences in dietary energy levels could be attributed to the effects of diet composition on fat utilization by poultry (Sibbald and Kramer 1980). The differences could also be due to the interaction of fat to make the energy of other dietary components more available (Sibbald and Price, 1977). Several workers (Touchburn and Naber, 1966; Jensen et al., 1970; Horani and Sell, 1977; and Mateos and Sell, 1981) observed that the generally recognized metabolizable energy values of feed grade fat underestimates fat's true energy contribution to practical rations. The true metabolizable energy content of the diets containing the oven dried poultry waste were more uniform than those of the diets containing the solar dried poultry waste. This is probably due to the constant drying temperature and good air circulation in the oven which gave a more uniform product than the solar dried waste which was affected by temperature flactuations and poor air circulation.

4.5.2 Broiler performance

The effect of level of oven or solar dried poultry waste on broiler performance is shown in Table 15. No significant differences were observed in body weight gain or feed intake of broilers fed the different diets. However, the diets containing 20% oven or solar dried poultry waste gave significantly poorer ($P < 0.05$) feed efficiencies than the diet without poultry waste. The lack of significant differences in broiler performance between broiler chicks fed diets containing 0% to 15% oven or solar dried poultry waste indicates that with proper adjustments of energy and protein to meet the broilers' requirements, the oven or solar dried poultry waste can be safely included up to 15% of broiler diets.

Feed efficiencies of chicks fed diets containing 20% oven or solar dried poultry waste were depressed by 10.29% and 9.56% respectively, compared to that of chicks fed the diet without poultry waste. The chicks fed the diets containing 20% oven or solar dried poultry waste had a relatively higher feed intake compared to the rest of the diets. Although feed intake is normally associated with inadequate dietary energy (Farrel and Cumming, 1973;

Table 15: Effect of level of oven or solar dried poultry waste on broiler performance from 4 to 53 days of age

Dietary treatment	Mean body weight gain (g)	Mean feed intake (g)	Feed efficiency (feed:gain)
0% DPW	1499	4078	2.72[a]
5% DPW1*	1457	4137	2.84[ab]
10% DPW1	1485	4107	2.77[ab]
15% DPW1	1562	4299	2.75[ab]
20% DPW1	1429	4291	3.00[b]
5% DPW3***	1497	4266	2.85[ab]
10% DPW3	1493	4178	2.80[ab]
15% DPW3	1405	4171	2.97[ab]
20% DPW3	1496	4461	2.98[b]
SE[1]	39	84	0.05

*Oven dried (60°C) poultry waste

***Solar dried (50-70°C) poultry waste

[a,b]Means in a column with different superscripts are significantly different ($P < 0.05$).

[1]Standard error of means.

Velu and Baker, 1974; NRC, 1984), TME levels revealed that energy was not limiting in the diets containing 20% oven or solar dried poultry waste. Therefore, the poor feed efficiency of chickens fed the two diets was probably due to wider calorie to protein ratios. Disproportionate increases in energy in relation to other nutrients have been reported to adversely affect chicken performance (Morris, 1969). The poor feed conversion efficiency of the diets containing the high level of dried poultry waste could also be due to the effect of the crude fibre and uric acid present in DPW. The starter diets containing 20% oven or solar dried poultry waste had crude fibre contents of 11.06% and 10.11% respectively, while the diet without poultry waste contained 5.88% crude fibre. The crude fibre contents in the finisher diets also increased with the increasing levels of DPW in the diets. Low levels of crude fibre (3-5%) are essential in poultry diets to aid digestion (Titus and Fritz, 1971; Kekeocha, 1984). Often the crude fibre level of 3-5% is exceeded because most of the common poultry feedstuffs contain considerable levels of crude fibre. High dietary fibre levels have been reported to cause increased feed intake and reduced weight gain of chickens (Moran and Evans, 1977; Bayer et al., 1978). It has also been shown that crude fibre increases endogenous losses of amino acids and reduces availability of dietary amino acids (Parsons, 1985). Increased endogenous amino acid losses result mainly from sloughing of intestinal mucosal cells and elevated mucous production. Crude fibre may reduce availability of dietary amino acids by forming gels around the amino acids and by interfering with digestive enzymes. In some cases, however, feed may contain as much as 10-12% crude fibre without having any markedly detrimental effect on production (Titus and Fritz, 1971). Chickens can tolerate higher levels of cellulose and hemicellulose fibres than lignin.

Blair (1972b) reported that uric acid nitrogen content in DPW ranged between 30 and 60% of the NPN. El-Boushy and Vink (1977) suggested that uric acid could be toxic beyond 1.07% in the diet, while Bare et al. (1964) proposed that uric acid depresses growth by acting as an irritant and thus interfering with the absorption of nutrients from the intestinal tract. However, Lee and Blair (1972) reported no growth depression when uric acid was added to diets containing crystalline amino acids, while Martindale and Lee (1976) reported an increased efficiency of uric acid excretion in birds fed diets containing DPW. More research is needed into the effect of dietary uric acid on chicken performance.

The relatively poor feed efficiencies of chickens fed the diets containing 20% DPW supplemented with lard could further be explained by the interaction of fat with minerals such as calcium, and magnesium. Such an interaction which occurs at high levels of dietary saturated fats and calcium, has been reported to cause decreased utilization of energy, fat and calcium (Atteh and Leeson, 1985).

Total mortality of broiler chicks fed experiment 3 diets during the seven week experimental period was 8.80%. The occurrence of mortality did not appear to be related to dietary treatment. Postmortem of one of the chicks fed the diet containing 15% solar dried poultry waste revealed a water belly which was suspected to be due to mycotoxicosis. The yellow maize used in the diets possibly had traces of mould growths which were not detected before the maize was included in the diets. This probably caused the suspected mycotoxicosis. However, analysis of maize for aflatoxins, using the thin layer chromatography, showed that contamination was negligible.

4.5.3 Carcass yield, abdominal fat pad weight and meat composition of broilers fed experiment 3 diets

The effect of level of oven or solar dried poultry waste on carcass yield, abdominal fat pad weight, and meat composition is shown in Table 16. No significant differences were observed in percentage dressed weight, abdominal fat pad weight, or thigh meat protein and fat contents of broilers fed the different diets. The remarkable similarities in carcass yield, abdominal fat pad weight and meat composition of broilers fed the diet without poultry waste or levels up to 20% DPW are in agreement with the findings of Bhargava and O'neil (1975), Lee and Yang (1975), Rhee *et al.* (1974), Kese and Donkor (1980), and Reddy *et al.* (1983) that the inclusion of the DPW in properly balanced diets had no significant effect on carcass yield and composition. Yoshida *et al.* (1962) showed that carcass fat and water contents remained constant as long as the energy:protein ratio remained constant. Griffiths *et al.* (1977) and Summers and Leeson

Table 16: Effect of level of oven or solar dried poultry waste on carcass yield, abdominal fat pad weight and meat composition

Experimental diets	Mean dressed weight (%)	Abdominal fat pad weight (%)	Meat water content (%)	Meat protein content (%)	Meat fat content (%)
0% DPW	76.61	2.43	72.34[a]	17.23	5.80
5% DPW1*	72.72	2.33	71.86[a]	17.25	5.16
10% DPW1	70.79	2.24	72.97[ab]	17.23	6.35
15% DPW1	72.74	2.29	72.91[ab]	16.45	6.39
20% DPW1	68.41	2.04	75.05[b]	16.87	5.14
5% DPW3***	71.61	2.61	71.04[a]	16.70	8.00
10% DPW3	72.99	2.26	71.94[a]	16.55	6.60
15% DPW3	70.90	2.39	71.70[a]	16.76	6.74
20% DPW3	69.69	2.34	71.89[a]	16.40	5.84
SE[1]	2.41	0.18	0.53	0.36	0.66

*Oven dried (60°C) poultry waste

***Solar dried (50-70°C) poultry waste

[1]Standard error of means

[a,b]Means in a column with different superscripts are significantly different (P<0.05).

(1979) reported that abdominal fat pad of broilers was not significantly influenced by the metabolizable energy content of the diet, but decreased with the decreasing calorie: protein ratio. The true metabolizable energy to crude protein ratio in the starter diets ranged from 149:1 to 159:1, while that in the finisher diets ranged from 171:1 to 184:1. These differences in calorie:protein ratio were not large enough to affect carcass yield and meat composition. The relatively high water content and low fat content of broilers fed the diet containing 20% oven dried poultry waste could probably be due to the interaction of dietary fat with other dietary components such as calcium, which possibly reduced fat retention by broilers. Broilers fed this diet also had a relatively lower abdominal fat pad weight compared to the rest of the diets.

4.6 Experiment 4

4.6.1 Chemical analyses of the diets

The chemical analyses presented in Tables 5 and 6 showed that the four diets were nearly similar in crude protein, ash and crude fibre contents. The crude protein levels were within the recommended protein requirements for broilers (Scott et al., 1976). The ether extract content in the starter diets ranged between 7.59% and 12.84%, while that in the finisher diets ranged between 6.95% and 12.89% due to the various levels of lard included in the diets to attain the required energy levels. The true metabolizable energy contents in the diets containing the oven dried poultry waste were slightly higher than those of the diets containing the solar dried poultry waste. This can be attributed to the relatively higher availability of energy in the oven dried poultry waste in comparison to that of the solar dried poultry waste.

4.6.2 Broiler performance

The effect on broiler performance of various dietary levels of energy and protein in diets containing 10% oven or solar dried poultry waste is shown in Table 17. The non-significant difference in growth rate, feed intake, and feed efficiency of broilers fed the different diets is in agreement with the observations made by Hill and Dansky (1954), Vondell and Ringrose (1958), Bartov et al. (1974), and Pesti (1982) that broiler performance will not vary with different energy concentrations (provided that

Table 17: Effect of dietary levels of energy and protein in diets containing 10% DPW, on broiler performance from day old to 54 days of age

Dietary treatments	Mean body weight gain (g)	Mean feed intake (g)	Mean feed efficiency (feed:gain)
10% DPW1* (Low ME, CP)	1682	4627	2.75
10% DPW1 (Medium ME, CP)	1750	4950	2.83
10% DPW1 (High ME, CP)	1668	4764	2.86
10% DPW3*** (Low ME, CP)	1624	4638	2.86
10% DPW3 (Medium ME, CP)	1744	4816	2.76
10% DPW3 (High ME, CP)	1698	4996	2.94
SE[1]	60	120	0.11

*Oven dried poultry waste

***Solar dried poultry waste

[1]Standard error of means

the energy:protein ratio is kept constant), because of the birds' ability to adjust the weight of food eaten to keep metabolizable energy intake reasonably constant. The diets used in experiment 4 were not exactly in a constant true metabolizable energy:crude protein ratio (155:1 to 161:1 in the starter diets, and 171:1 to 175:1 in the finisher diets). However, the differences in the calorie to protein ratio were not large enough to cause significant changes in broiler performance. Nonetheless, the diets containing 10% oven or solar dried poultry waste with medium dietary levels of energy and protein (3702 or 3688 kcal TME/kg DM, 23.50% or 23.32% crude protein in the starter diets, and 3687 or 3619 kcal TME/kg DM, 21.59% or 20.83% crude protein in the finisher diets) gave slightly better growth rates than the rest of the diets. The relatively better performance of broilers fed the two diets could possibly be due to a better balance of nutrients in these diets. Morris (1969) indicated that when the energy content of a poultry diet is increased, corresponding increases in the proportion of most other nutrients should be done. However, due to the large number of nutrients required in poultry diets, it is not always possible to balance out each specific nutrient in relation to energy. This causes the minor differences observed in the performance of broilers fed diets with a constant or approximately constant energy: protein ratio.

Feed intake by broilers fed the diets containing the solar dried poultry waste increased slightly with the increasing levels of energy and protein in the diets.

This trend was probably caused by the reduction in bulk density of the feed and the improvement in feed palatability due to the various levels of lard included in the diets. Total mortality of broilers throughout the 54 day experimental period was 3.47%. This low mortality shows that the dietary inclusion of 10% oven or solar dried poultry waste in broiler diets is not detrimental to broilers.

The apparent profit obtained from feeding experiment 4 diets to broilers is shown in Appendix 3. However, the exact net profit per broiler would be slightly less than what is given in Appendix 3 because labour, transport, and other minor miscellaneous costs were not included in the calculation. From the economic point of view, the diets with the lowest levels of energy and protein were relatively cheaper than the rest of the diets. The increased costs in the diets containing higher levels of energy and protein were mainly due to the high cost of lard.

4.6.3 Carcass yield and meat composition of broilers fed experiment 4 diets

The carcass yield and meat composition are shown in Table 18. Results showed no significant differences in dressed weight or meat composition of broilers fed the different diets. This showed that the dietary energy and protein levels had little influence on carcass yield and composition of edible meat. Similar observations were made by Summers *et al.* (1985). However, several earlier workers (Fraps, 1943; Danoldson *et al.*, 1956; Newell *et al.*, 1956; Rand *et al.*, 1957; Spring and Wilkinson, 1957;

Table 18: Effect of dietary levels of energy and protein in diets containing 10% DPW, on carcass yield and meat composition of broilers

Dietary treatments	Dressed weight (%)	Meat water content (%)	Meat protein content (%)	Meat fat content (%)
10% DPW1* (Low ME, CP)	71.11	73.20	17.97	7.51
" " (Medium ME, CP)	71.55	72.46	18.45	8.02
" " (High ME, CP)	72.94	71.39	18.08	7.76
10% DPW3*** (Low ME, CP)	72.59	71.52	18.41	7.86
" " (Medium ME, CP)	72.03	71.55	17.48	7.58
" " (High ME, CP)	75.66	73.78	17.30	7.60
SE[1]	1.66	0.89	0.46	0.82

* Oven dried poultry waste

***Solar dried poultry waste

[1]Standard error of means

Sibbald *et al.*, 1961; Carew *et al.*, 1964; Essary and Dawson, 1965; Summers *et al.*, 1965; Kubena *et al.*, 1972; Mbugua, 1983) reported that specific changes in either dietary protein, fat, or energy levels produced changes in the total body composition of chickens. Therefore it appears that variations in dietary energy and protein levels of experiment 4 diets were probably too narrow to cause any significant changes in carcass yield and composition.

4.7 Experiment 5

4.7.1 Chemical analyses of the diets

The chemical analysis presented in Table 7 showed that the four diets were approximately similar in ash, calcium, phosphorus, and magnesium contents. The ether extract content in the diets ranged from 6.66% in the diet without lard, to 18.71% in the diet containing 12% lard. Protein content in the diets ranged between 21.99 and 25.52%, while true metabolizable energy content ranged from 3313 to 3976 kcal/kg DM. The TME:CP ratio in the diets ranged from 149:1 to 156:1. Inspite of the wide variation in protein content in the diets, the protein levels were within the recommended requirements for broiler chicks (Scott et al., 1976). Crude fibre increased slightly with the increasing levels of sunflower seed meal included in the diets to attain the required protein levels. Nitrogen free extract decreased with the increasing level of lard in the diets.

4.7.2 Effect of dietary fat level on broiler performance

The effect on broiler performance of graded levels of fat in diets containing 10% solar dried poultry waste, is shown in Table 19. The non-significant differences in growth rate, feed intake, and feed efficiency confirms that within a certain range of energy and protein, broiler performance will not vary with different energy concentrations provided that the energy:protein ratio is kept approximately

Table 19: Effect on broiler performance, of graded levels of fat in diets containing 10% solar dried poultry waste

Dietary treatments	Mean body weight gain (g)	Mean feed intake (g)	Mean feed efficiency (feed:gain)
10% DPW3*** + 0% lard	560	1211	2.16
" + 1.5% lard	558	1213	2.17
" + 3.0% lard	577	1262	2.19
" + 12.0% lard	589	1158	1.97
SE[1]	40	69	0.08

***Solar dried (50-70°C) poultry waste

[1]Standard error of means

constant. Nonetheless, body weight gain and feed efficiency improved slightly with the increase in nutrient density. This is in agreement with the observation made by Yacowitz and Chamberlain (1954), Arscott and Santher (1958), Rand _et al._ (1958), Carew _et al._ (1964), Schaible (1970), De Groote _et al._ (1971), Waldroup _et al._ (1976), Griffiths _et al._ (1977), Pesti (1982), and Harms (1986) that fat supplementation improves feed efficiency. However, it is apparent that increases in growth rate and feed efficiency obtained with the diet containing 12% lard are not sufficient to warrant the higher cost of the concentrated diet. Results of this experiment also showed that solar dried poultry waste can be used up to 10% of broiler starter diets without fat supplementation. Total mortality throughout the four week experimental period was 2.78%. The two chicks died during the first week of the experiment as a result of injury in the cage.

4.7.3 Effect of dietary fat level on fat and mineral utilization by broiler chicks

The effect of dietary fat level on fat and mineral utilization by broiler chicks is shown in Table 20. The significant decrease in magnesium retention as the level of lard in the diets was increased above 3% is in agreement with Griffith _et al._ (1961), Sibbald and Price (1977), and Atteh and Leeson (1985) who indicated that dietary fat especially the saturated type interferes with mineral retention. Other factors may exist that affect utilization of high levels of lard supplementation to poultry diets,

Table 20: Effect of dietary fat level on fat and mineral utilization by broiler chicks

Dietary treatments	Faecal soaps[1] (%)	Fat retention (%)	Calcium retention (%)	Magnesium retention (%)	Phosphorus retention (%)	Tibia ash (%)	Tibia calcium (%)	Tibia magnesium (%)	Tibia phosphorus (%)
10% DPW3 + 0% lard	38.67	66.68^{a}	45.28	43.74^{a}	47.92	48.55	42.54	0.82	15.06
10% DPW3 + 1.5% lard	40.37	71.10^{ab}	49.20	44.67^{a}	48.94	48.58	38.59	0.57	16.16
10% DPW3 + 3.0% lard	38.18	78.03^{b}	51.63	41.34^{a}	50.80	47.35	37.58	0.65	16.61
10% DPW + 12% lard	42.95	73.36^{ab}	41.49	28.47^{b}	38.83	46.22	37.32	0.66	16.95
SE[2]	1.45	2.10	3.30	2.34	3.52	1.44	1.16	0.05	0.54

a,b Means within the same column with different superscripts are significantly different ($P<0.05$)

[1] Faecal ether extract 2 as a proportion of Extracts 1 and 2.

[2] Standard error of means

but reduction in magnesium retention appears to be important. The lack of significant differences in calcium retention between treatment groups is in agreement with Whitehead et al. (1972) who noted that the decrease in calcium retention, due to addition of fat in the diets, is less at lower dietary calcium levels than at higher levels. The calcium, phosphorus, and magnesium contents were approximately the same in experiment 5 diets. Therefore, it is not surprising that no significant differences were observed in calcium and phosphorus retention, tibia ash and mineral content, and faecal soap contents between treatment groups.

Fat retention of the diet containing 3% lard was significantly higher ($P < 0.05$) than that of the lard-free diet. The diet containing 3% lard (10.00% ether extract) gave the highest fat, calcium and phosphorus retention and the least faecal soap content of all diets used in the experiment. There is no established optimum level of fat inclusion in broiler diets. Edward Jr. (1969) suggested that a level of 6-8% total fat in broiler rations gives the most desirable overall results, while Rand et al. (1958) observed that best overall performance was obtained when fat contributed between 20 and 38% of the total metabolizable energy content of the diet. Nonetheless, the utilization of fat by poultry is affected by diet composition (Mateos and Sell, 1980; Sibbald and Kramer, 1980; Fuller and Dale, 1982), and by the calorie:protein ratio (Sibbald, et al., 1961; Kubena et al., 1972; Horani and Sell, 1977; Nakhata, 1980).

Results of experiment 5 showed that the level of lard included in diets containing 10% solar dried poultry waste should preferably be limited to 3% in order to avoid the reduction in magnesium retention which occurs at higher levels of fat supplementation.

5. GENERAL DISCUSSION

There has been much attention drawn to the possible use of poultry waste as one of the potential alternative feedstuffs for livestock and poultry. This is because of its availability, low cost, and nutritive value. Poultry waste is generally of two types, with or without litter material. Waste without litter material is the one most suitable for feeding to chickens because poultry cannot tolerate the high crude fibre levels present in the litter material. Dried poultry waste is variable in composition due to the composition of the feed, age and type of birds to which the diet is fed, collection interval, environmental temperature under which the droppings are kept, and the nature of the dehydrating process (Flegal and Zindel, 1970; Kubena et al., 1973; Biely et al., 1980; Kese and Donkor, 1980). In this study, layer waste was used in preference to broiler waste because it is more uniform in composition, since laying hens are normally fed on one type of feed, whereas broilers are fed on starter and then finisher diets. Besides, laying hens being older birds, are less efficient in feed utilization than broilers.

Results of the chemical analyses of the oven dried ($60^{o}C$), the sun dried-autoclaved ($1.05\ kg/cm^2$, $121^{o}C$, 15 minutes), and the solar dried ($50-70^{o}C$) poultry waste used in the study showed that the method of processing had no significant effects on proximate, true protein, amino acids, and mineral composition of dried poultry waste, but had a considerable effect on the metabolizable energy, protein digestibility, and gross protein values of the dried waste. The oven dried poultry waste had relatively higher metabolizable energy, protein digestibility, and gross protein values than the sun dried-autoclaved, or the solar dried waste. This suggests a need to dry the fresh waste rapidly in order to maintain the protein quality and to prevent excessive energy losses. A lot of energy losses are said to occur during dehydration (Manoukas et al., 1964; Shannon and Brown, 1969). Oven drying is expensive due to the high cost of electricity. Solar energy is a relatively cheaper source of energy in the tropics. Therefore, a more efficient solar drier with adequate air circulation should be devised for rapid drying of the poultry waste.

Layer waste is rich in nitrogen (protein and non-protein), ash, calcium, phosphorus, and crude fibre. Nutrients in poultry waste arise from undigested feed, endogenous and metabolic excretory products, and residues of microbial synthesis (NRC, 1983). The hen is only about 55% efficient in utilization of dietary protein (Scott et al., 1976). Consequently, a considerable amount of the protein nitrogen in the waste originates from the feed. Nearly 50% of the nitrogen in poultry waste is non-protein nitrogen. Chickens do not efficiently utilize non-protein nitrogen. Therefore, the true protein content of dried poultry waste should be used in the formulation of chicken diets. The high calcium content of layer waste originates mainly from the feed since a high level of this mineral is used in layer feeds for egg shell formation. Calcium and phosphorus in dried poultry waste appear to be highly available to the chickens. This was shown by the high solubility of the two minerals in 0.4% HCl. The solubility in 0.4% HCl of calcium in the differently dried poultry waste used in this study was 49.93 - 57.32%, while that of phosphorus was 73.60 - 80.17%. Blair (1974) and Cuca (1984) also reported that calcium and phosphorus in dried poultry manure were highly available to poultry. Parker (1959) showed that 88% of the phosphorus in dried poultry waste is available, while McNab et al. (1974) reported that at least 45.3% of the calcium and 46.2% of the phosphorus in dried poultry manure were digested by laying hens. Therefore, the contribution of the two minerals by dried poultry waste should be considered when the waste is used as a feed ingredient. The magnesium, copper, and iron contents of dried poultry waste used in this study were fairly similar to those reported by Blair (1974) for dehydrated layer waste. The levels of the three minerals were low, and are not likely to have any adverse effects on the health of chickens if dried poultry waste is used in properly balanced diets. Fontenot et al. (1971) reported a problem of excess copper in sheep fed diets containing dried poultry waste.

This was due to the high copper content of the dried poultry waste used by the researchers, and the high sensitivity of sheep to copper toxicity. The mineral content of animal wastes will vary with the amount added to the diet of the host animal. Therefore, it would be of advantage to know the chemical composition of the feed fed to the chickens from which the waste is collected.

Fresh poultry waste may contain pathogenic organisms if obtained from diseased birds. However, adequate processing renders the waste free of pathogens or with a much reduced profile of organisms capable of causing disease (Caswell et al., 1975). Most of the bacteria isolated in dried poultry waste used in this study were believed to be normal inhabitants of the chickens' intestinal tract, and were not hazardous to the chickens to which the waste was fed. Waste should be collected from disease-free chickens in order to avoid the risks of disease transmission through recycling by feeding.

Feed intake records of broilers used in this study showed that there was no problem of acceptability of diets containing up to 20% oven or solar dried poultry waste. Broilers fed diets containing the dried waste looked healthy and active. Mortality was generally low (less than 10% in each of the five feeding experiments). No symptoms of calcium or phosphorus deficiencies were observed in broilers fed diets containing the dried waste. This confirms that most of the calcium and phosphorus that were soluble in 0.4% HCl were available to the chickens. The inclusion of up to 20% dried poultry waste in properly balanced broiler diets had no adverse effects on carcass yield and quality. Similar findings were reported by Bhargava and O'neil (1975), and Reddy _et al_. (1983). Carcass composition is mainly affected by the calorie to protein ratio in the diets (Yoshida _et al_., 1962). Therefore, the protein and energy sources in diets formulated to contain dried poultry waste should be properly adjusted to obtain the recommended calorie:protein ratio.

The low metabolizable energy content is one of the limiting factors in the use of dried poultry waste in chicken rations. Flegal and Zindel (1970) and Lee and Blair (1973) showed that dietary levels of dried poultry waste beyond 10% have an adverse effect on the growth performance and feed efficiency of broilers. In this study, however, the supplementation of diets containing dried poultry waste with lard to obtain the recommended energy levels, showed that the oven or solar dried poultry waste could be included up to 15% of the diet without adverse effects on broiler performance. High energy ingredients such as lard are currently expensive. Therefore the level of dried poultry waste to be included in broiler diets should preferably be limited to 10% unless other cheaper oils are found. Besides, dried poultry waste is rather high in crude fibre and minerals, and excess levels of these two components in the diet can be avoided through the limitation of the level of dried poultry waste included in broiler diets to 10%.

6. CONCLUSIONS

The following conclusions can be made from the results of the study:

1. Waste obtained from laying hens at three day intervals and dried in the oven at 60°C, or sun dried and autoclaved at 1.05 kg/cm^2, 121°C, for 15 minutes, or solar dried at 50-70°C, does not differ significantly in proximate, true protein, minerals and amino acid composition, but differs quite considerably in metabolizable energy and bacteriological contents. Oven drying of poultry waste causes less energy losses than sun drying and autoclaving, or solar drying. Autoclaving the sun dried poultry waste at 1.05 kg/cm^2, 121°C for 15 minutes is more efficient in reducing the number of bacteria than oven drying at 60°C or solar drying at 50-70°C of the fresh waste.

2. Rapid drying of poultry waste soon after collection prevents aflatoxin formation in the waste.

3. The oven dried poultry waste has a higher protein digestibility and a higher gross protein value than the sun dried-autoclaved, or the solar dried poultry waste.

4. Dietary inclusions of up to 10% oven dried, sun dried-autoclaved or solar dried poultry waste, to partially replace maize meal, meat and bone meal, and wheat bran in broiler starter diets, have no adverse effects on broiler chick performance.

5. With proper adjustments of dietary energy and protein to meet the recommended broiler requirements, the oven dried and the solar dried poultry waste can be included at levels up to 15% of broiler starter and finisher diets without adverse effects on growth rate, feed intake, feed efficiency, carcass yield and meat composition of broilers.

6. Use of lard to attain the required energy levels in diets containing dried poultry waste reduces feed dustiness, improves palatability, and results in improved broiler performance. However, inclusion of lard at levels beyond 3% in diets containing 10% solar dried poultry waste reduces magnesium retention and is rather uneconomical.

7. Finally it can be concluded that a level of 10% oven or solar dried poultry waste is the most appropriate maximum level that can be included in broiler diets without the necessity of high levels of lard to meet the broilers' energy requirement.

7. SCOPE FOR FURTHER WORK

More work needs to be conducted into the use of solar energy for fast dehydration of poultry waste with minimum nutrient losses. Work should be done on the total elimination of the possibility of disease transmission through waste recycling. Risks that may arise from medicinal drug residues and metabolites, mycotoxins, and mineral elements should be investigated further, and if necessary, withdrawal periods to ensure freedom from residues should be recommended. Methods should be devised to break down uric acid to nitrogen that can be utilized by chickens. Studies should be carried out on the improvement of amino acids in dried poultry waste by grading it up with micro-organisms, housefly larvae, or earth worms. Research is needed on the availability to chickens of mineral elements in dried poultry waste. The overall economic benefits of feeding poultry wastes to chickens should be determined.

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9. APPENDICES

Appendix 1: True protein analysis in DPW

One gram of dried finely ground poultry waste was weighed into a 250 ml glass beaker, and wetted with a few ml of ethanol to aid dispersion. To this was added 50 ml distilled water, 40 ml of a boric acid/sodium hydroxide buffer solution with a pH of about 8.0, and 10 ml of 0.1 M potassium permanganate solution to oxidise the uric acid to break-down products with greater solubility. The beaker was placed in a water bath at a temperature of $50^{o}C \pm 0.5^{o}C$ and stirred mechanically for 35 minutes. Immediately after this, 25 ml of 0.16 M uranyl acetate solution was added to precipitate the true protein. The sample was boiled up and left overnight to cool and allow the precipitate to settle. The following day, the sample was filtered through a rapid filter paper (Whatman 91, 15 cm), and the residue was washed with 250 ml of 1% uranyl acetate solution at room temperature. The filter paper with residue were then transferred to a 500 ml kjeldahl flask and digested with sulphuric acid, using a selenium tablet as a catalyst, after which the nitrogen content was determined according to the standard procedure (AOAC, 1984).

Appendix 2: True metabolizable energy determination in DPW and layer mash

The oven dried, the sun dried-autoclaved, and the solar dried poultry waste were each mixed with an equal amount of ground maize. Eighteen adult cockerels (over six months of age) were fasted for 24 hours. Three fasted cockerels were each force-fed 30 g of ground maize, maize plus each type of dried poultry waste, or layer mash alone. Maize was used as a carrier to reduce dustiness of DPW. The purpose of force feeding (precision feeding) was to ensure that a known quantity of a feedstuff entered the alimentary canal of a bird at a known time. The procedure avoids the need to recover waste feed, prevents feed selection and eliminates variation in intake among birds. The force-feeding devices consisted of a stainless steel funnel and an aluminium plunger. The steel funnel used was 40 cm long, and had an external diameter of 1.3 cm and an internal diameter of 1.1 cm. The plunger consisted of a 1 cm diameter aluminium rod to which a 3.0 cm diameter spherical knob was attached. A plastic sleeve was rivetted to the rod to prevent the plunger from projecting more than 0.5 cm beyond the end of the funnel. Force feeding was carried out by inserting the stem of the funnel through the opened beak of the cockerel, and moving it down the oesophagus into the crop. Feed was poured into the funnel and pushed down into the crop using a plunger. After feeding, the funnel was removed with a rotary action, pressure being applied to the oesophagus with the left hand to dislodge feed particles adhering to the stem of the funnel. Each cockerel was placed in a wire cage over an excreta collection tray and the time was recorded. Water was provided *ad libitum*. Three cockerels were not fed and served as the negative control for the measurement of metabolic plus endogenous energy. The excreta voided during the 24 hours after placing the cockerels in cages was collected, dried in the oven at 60°C, and allowed to cool and equilibrate with the atmospheric moisture. Weight of the dried excreta from each cockerel was recorded. Samples of test materials, and excreta from the fed and unfed birds were assayed for gross energy using an adiabatic oxygen bomb calorimeter. Calculation was done as follows:-

$$\text{TME (Kcal/kg DM)} = \frac{\text{EI} - (\text{EEf} - \text{EEu})}{\text{Feed DM input (kg)}}$$

Where EI = the gross energy input (kilocalories)

EEf = the energy voided as excreta by the fed birds (kilocalories)

EEu = the energy voided as excreta by the unfed birds (kilocalories)

Since DPW was fed with an equal amount of maize, TME of DPW was calculated as follows:-

TME of DPW (kcal/kg DM) = 2 (TME of maize + DPW) - TME of maize

The above method of calculation was based on the finding of Sibbald (1977) that the true metabolizable energy values of feedingstuffs are approximately additive.

Appendix 3: Apparent profit[1] per broiler fed Experiment 4 diets from day old to 54 days of age

	Experimental diets					
	1	2	3	4	5	6
Level of DPW	10% DPW1*	10% DPW1	10% DPW1	10% DPW3***	10% DPW3	10% DPW3
Level of ME, CP	Low	Medium	High	Low	Medium	High
Cost/day old chick (Kshs.)	6.70	6.70	6.70	6.70	6.70	6.70
Feed cost/broiler (Kshs.)	14.64	18.22	19.98	14.95	18.00	21.25
Total cost (Kshs.)	21.34	24.92	26.68	21.65	24.70	27.95
Broiler weight at 54 days (g)	1722	1790	1708	1664	1784	1738
Value[2]/broiler (Kshs.)	29.27	30.43	29.04	28.29	30.33	29.55
Apparent profit/broiler (Kshs.)	7.93	5.51	2.36	6.64	5.63	1.60

[1]Apparent profit = Cost of broiler at marketing – (Cost of a day old broiler chick + Cost of feed consumed per broiler).

[2]Each broiler was valued at KShs. 17.00 per kilogram live weight at 54 days of age.