PERFORMANCE, CARCASS YIELD AND LITTER QUALITY OF BROILER CHICKENS FED DIETS CONTAINING ARBOCEL® FINE

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CERTIFICATION

We certify that this work, "Performance, Carcass Yield and Litter Quality of Broiler Chickens Fed Diets Containing Arbocel® Fine" was carried out by Okehie, Ukachukwu Nathan (Reg. No. 20104884938) in partial fulfillment of the requirement for the award of the degree of M.Sc in Animal Nutrition in the Department of Animal Science and Technology, Federal University of Technology Owerri.

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DEDICATION

This work is dedicated to God.

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ABSTRACT

Arbocel® fine is an insoluble fibre concentrate used outside Nigeria as fibre source in poultry diets. It is high in fibre content and unlike traditional fibre sources, it is free from contaminants and do not consume space in feed formulations. The effect of Arbocel® fine on performance, carcass yield, organ weights, mortality and litter quality of broilers at market age were determined. Arbocel® fine was added to formulated broiler starter and finisher diets at 0.0, 0.6 and 0.8% and fed to 144 day old Marshal Broiler chicks. The chicks were divided into 3 treatment groups of forty eight birds each and assigned to the three treatment diets in a complete randomized design (CRD) experiment replicated 4 times. Each replicate contains twelve birds. Starter and finisher rations were fed to the broilers during 0 – 28 and 29 – 56 days of age, respectively. Results indicated that body weight gain and feed conversion ratio at 28 and 56 day of age were comparable ($P>0.05$) among the three diet groups. Feed intake was higher in bird groups fed diets containing Arbocel® fine, but the values were not significantly ($P>0.05$) different from the control. Inclusion of Arbocel® fine in broiler diets caused significant ($P<0.05$) increase in the cost of feed consumed and feed cost/kg body weight gain as well as reductions in both faecal and litter moisture contents. Ready-to-cook carcass yield slightly increased in the Arbocel® based diet groups but the values were not significantly ($P>0.05$) different from the control. Mortality was significantly ($P<0.05$) reduced in the Arbocel® based diet groups, while organ weights were unaffected by the treatments. The use of 0.6 and 0.8% Arbocel® fine in broiler diets decreased faecal and litter moisture content and increased ready-to-cook carcass yield of broilers, although cost/kg body weight gain were much higher than those on the control.

Keywords: Arbocel® fine, faecal and litter moisture, ready-to-cook carcass yield, insoluble fibre concentrate, broiler.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE
INTRODUCTION

1.1. Background Information

The use of dietary fibre materials in poultry feeds is a common practice in many tropical countries including Nigeria. However, many nutritionists still try to avoid the use of fibre as most fibre sources do not deliver energy for monogastric animals. Many of these fibre sources are by-products of the food manufacturing industries that are preferably used because of their availability and cheap cost, and not that they are potentially best for the animals. Additionally, these traditional fibre sources are often associated with negative attributes like high plate counts, mycotoxin contamination and dilution of the diet in terms of energy (Pietsch, 2012).

In most research conducted on poultry feeding, dietary fibre (DF) has been considered a diluent of the diet (Rougiere and Corre, 2010), with negative connotations in relation to voluntary feed intake and nutrient digestibility (Mateos *et al*., 2002). On the other hand, various studies have shown that the inclusion of moderate amounts of different fibre sources in the diet improves digestive organ development (Gonzalez-Alvarado *et al*., 2007, Hetland *et al*., 2005a, Hetland and Svihus, 2007) and increases HCL, bile acids and enzyme secretion (Svihus, 2011, Hetland *et al*., 2003). These changes might result in improvements in nutrient digestibility (Amerah *et al*. 2009, Sklan *et al*., 2003), gastrointestinal tract (GIT) health (Correa-Matos *et al*. 2003), Kalmendal *et al*, 2011, Miller, 2004, Montagne *et al.,* 2003, Perez *et al*, 2011) and eventually, animal welfare (Aerni *et al*., 2000, van Krimpen *et al*, 2009). In addition, depending on the amount and type of dietary fibre, as well as on the composition of the basal diet, the profile of the existing microbiota in the distal part of the gastro intestinal tract (GIT) might be affected and intestinal absorption of minerals may improve (Amerah *et al*, 2009, Shakouri *et al*, 2006, Roberfoid *et al*, 2002, Coudray *et al*, 2003).

Meanwhile, the main distinctive feature among different fibre sources is their solubility. The ratio of insoluble to soluble fibre (I:S) in a dietary fibre source affect the overall diet utilization and appears to be important in the formulation of diets to provide optimal efficacy (Dhingra *et al.,* 2012). There are some evidence that insoluble fibres such as cellulose and other insoluble non-starch polysaccharide (NSP), lignin, resistant starch, tannins and cuttins have positive effects on selected health and performance related parameters in poultry (Svihus and Hetland, 2001, Hetland *et al*., 2005). Furthermore, there are clear indications that diets high in insoluble fibre prevents cannibalism in laying hens, increases gizzard size, decreases gizzard pH, and improves starch and feed digestibility (Pietsch, 2012).

By contrast a number of investigations have shown a negative effect of soluble fibres on feed utilization in broiler chickens (Bergh, *et al*., 1999). Soluble fibres such as mixed-linked β-glucans in oats or arabinoxylans in wheat caused increased viscosity of the intestinal contents depressed digestibility of protein, starch and fat, and thereby interfere with the absorption of the nutrients (Smiths and Annison, 1996). High viscosity can affect feed intake due to slower passage rate, consequently increasing microbial activity in the small intestine (Choct *et al*., 1996). An increased microbial activity may deconjugate bile salts and alter gut health. In addition, the water-binding capacity of soluble fibres may cause sticky droppings and wet litter problems (Pietsch, 2012).

1.2. Problem Statement

In Nigeria, different fibre sources are used in poultry feed formulations, which have numerous shortcomings. Many of these fibre sources supply more of soluble fibres that show negative effects on feed utilization in broiler chickens (Bergh *et al*., 1999). These fibre sources deliver significant amount of insoluble fibre which are often contaminated with mycotoxins and consume a lot of space in formulation (wheat bran, i.e only delivers 10% fibre) (Pietsch, 2012). A solution might be the use of so called raw fibre concentrates, one of which is Arbocel® and this research was setup to investigate the effect of Arbocel® fine in broiler chicken performance.

1.3. Objectives

The objectives of this study were:

1. To determine the performance of broilers fed diets containing Arbocel® fine till market age.
2. To determine the carcass yield and organ weights.
3. To determine the litter quality
4. To determine the economics of using Arbocel® fine in broiler diets.

1.4. Justification

Arbocel® fine is a raw fibre concentrate with a minimum crude fibre content of 65%, maximum granule size of 8mm and maximum bulk density of 12% (Pietsch, 2012). It is free of mycotoxins, do not consume space in feed formulations, do not bind nutrients, stimulate the intestinal villi, increases enzyme binding capacity (8 – 8 gH_2O/g crude concentrate) (Trautwein *et al*., 2012). Unlike traditional fibre products Arbocel, has a remarkable advantage due to its high hygienic level of production and has proved successful in poultry diets in terms of health status, litter, animal behavior as well as performance and economy (Michard, 2011, Pietsch, 2012, Farran *et al* 2013).

Investigations show that Arbocel® fine is not yet known and used in poultry feeds in Nigeria. There is need to see if the positive effect of Arbocel® fine in other countries can be obtained in Nigeria. This study is designed to determine the usefulness of Arbocel® fine inclusion in broiler chicken diet.

1.5. Scope of the studies

This study covered two phases of broiler production (0 – 28 and 29 – 56 days of age), performance, carcass evaluation, litter/faecal moisture and economics of production.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1. Fibre

Fibre is defined as a nutritionally, chemically and physically heterogeneous material that has no direct nutritive benefit in poultry nutrition and has until now been regarded as ‘useless roughage’ (Michard, 2011, Pottgüter, 2008). It is present in all feed materials and passes into feed formulations more or less unavoidably. Functional fibre, dietary fibre and crude fibre are different words used to describe fibre (Pottgüter 2008). While functional fibre refers to isolated, extracted, or synthetic fibre that has proven health benefits, with several physiological functions (Bersamin and Zidenberg-Cherr, 2004). Dietary fibre is the component or skeletal remains of plants, which is resistant to digestion by endogenous enzymes of animals (Sarikhan *et al*, 2009, Pietsch, 2012). Asp (2004) and, Mertens (2003) stated that dietary fibre is not easy to measure in feeds as it encompasses very diverse polymers with large differences in physicochemical properties, that when included in the diet, result in differences in digestive viscosity, ion exchange capacity, fermentation capability, and bulking effect within the GIT. Establishing a proper definition for dietary fibre has historically been a balance between nutritional significance and the availability of adequate analytical methods, with a clear tendency to adapt the definition to the existing analytical procedures rather than to the physiological effects of the different fibre fractions on the physiology and health of the GIT (Bach Knudsen, 2001, Lupton, 2010). As a result, incongruities between theory and practice have resulted in confusion regarding the effects of dietary fibre on productivity in non-ruminant animals (Montagne *et al.*, 2003, DeVries, 2003, Jiménez-Moreno *et al.,* 2007).

Still more common than the term “dietary fibre” is the term “crude fibre”. Crude fibre is the chemical fraction of matrix insoluble in diluted acids and bases (as determined by proximate analysis using Weender method) (Pottgüter, 2008). According to Pottgüter (2008), crude fibre makes no official contribution to the nutritional value of poultry feed, yet has to be declared as maximum value in many countries. As a rule, crude fibre is not subjected to a minimum requirement in poultry rations and a maximum value is merely designed to ensure that the declaration is not exceeded. While some nutritionists believe that crude fibre is an integral part of the poultry diet, others argue that its inclusion in poultry diets is not necessary. Cellulose and non-starch compounds are typically classified as crude fibre (Wilson and Beyer, 2000). This fraction does not include soluble dietary fibre, like the soluble fraction of hemicellulose, indigestible sugar or resistant starch. Therefore in most cases, the quantity of crude fibre is markedly below the fraction of dietary fibre but the proportion of the two components differs depending on feed ingredients.

In addition, the effects of dietary fibre on poultry physiology and productivity depend on the inclusion level and source of fibre (Jiménez-Moreno *et al.,* 2011, Jørgensen *et al.,* 2003) as well as on the nature of the basal diet (Jiménez-Moreno *et al.*, 2009), the physical structure of the fibre source (Jiménez-Moreno *et al.,* 2010), the feed form (Jiménez-Moreno *et al.,* 2007), and the type and age of the birds (González-Alvarado *et al.,* 2010).

2.2. Classification of Fibre

Fibre is categorized into two major subclasses; soluble (soluble, viscous and fermentable fibre) and insoluble (insoluble, non-viscous and non fermentable fibre) (Pietsch, 2012, Michard, 2011). The ratio of insoluble to soluble fibre (I: S) in a dietary fibre source can affect overall diet utilization and appears to be important in the formulation of diets to provide optimal efficacy (Burhalter *et al.*, 2001). Differentiation of soluble and insoluble fibre components has helped elucidate the physiological effects of crude fibre as the two subclasses have different roles in the digestive/absorptive processes within the gastrointestinal tract (Table 2.1).

To understand the physiological effects, it makes sense to differentiate between soluble-insoluble and highly fermentable – slow/non-fermentable fibre. As a rough overview, it is assumed that in monogastric animals, soluble fibre is highly fermentable whereas insoluble fibre is non-fermentable (Michard, 2011). Non-fermentable fibres show high water binding capacity. This influences gut health in a positive way. It increases the volume of ingesta and this leads to a good saturation effect, especially at higher doses. This effect is beneficial for gestating sows – it promotes gut peristalsis and accelerates colon transit time and thus prevents constipation (Pietsch, 2012).

Fibres that are highly resistant to fermentation include isolated cellulose and lignin. Lignin is not fermented due to its composition as a phenyl propane polymer rather than carbohydrate (Whiteley *et al.*, 1996; Klurfeld, 1999).

2.3. Traditional fibre sources

Most traditional fibre sources are by-products of the food manufacturing industries that are used because of their availability in a particular region and not that they are potentially best for the animals (Pietsch, 2012). The selection of these fibre sources is normally dictated by domestic availability and prevailing market prices. In addition to straw or hulls from cereals or even lignin from wood, major raw materials with high insoluble fibre contents are cereals by-products such as rice or wheat bran, sunflower meal, palm kernel meal, beat pulp, etc.

Table 2.1: Effects of soluble and insoluble fibre

Soluble fibre	Insoluble fibre
• Reduced intestinal passage rate. • Reduces digestion of fat, protein and starch. • Binds nutrients (pectin) • Affects viscosity of the digesta • Mainly fermentable parts •Energy source for monogastric animals •Reduces dry matter of feces contributing to production and sanitary problems.	• Increased intestinal passage rate. • Improves starch digestibility • Stimulation of intestinal villi. Unidentified growth factor. • Accumulate in the gizzard and regulate digesta passage. Poorly fermentable and minimally degraded by the gut microflora. • No energy source for young monogastric • Increases dry matter content of feces • Structural fibre

Source: (Michard, 2011)

These ingredients however, being by-products, are not treated or optimized and might also contain anti-nutritional factors (Pottgüter, 2008). With different raw materials the actual fibre content(Tables 2.2 and 2.3) can therefore range from about 2.1% in a maize-soya based mixture to 6.0 – 12.0% in mixtures based on barley, extracted sunflower meal and cereal by-products such as bran (Pottgüter, 2008). The crude fibre content of any feed is thus related to the energy content of different raw materials and deserves more attention in the formulation of poultry rations (Pottgüter, 2008).

2.4. Crude fibre as part of feed formulation

Sources of crude fiber in poultry diets are the different oilseed meals, which are primarily incorporated into the mixtures to cover the protein requirement. While soybean meal and maize, which are the major feed materials, bring little fiber into the formulation the use of other sources of fibre such as extracted sunflower seed meal, rapeseed meal, DDGS, barley, oats and cereal by-products result in significant amounts of crude fiber in the formulation (table 2.3). The question whether any conclusions are then drawn from this information in terms of modifying feed formulations depends on many factors, such as the availability of fibre carriers as raw material, the cost effectiveness of these raw materials and also the need or desire for targeted intervention by manipulating the crude fiber content of the mixture (Jeroch and Dänicke, 2008).Without the availability and cost effectiveness of suitable raw materials, it may be virtually impossible to achieve a specific crude fiber content in the formulation. In this case an alternative solution would be produced based on lignocellulose for optimizing the crude fiber content, entirely with insoluble NSP (Michard, 2011).

Table 2.2: Content of crude fibre and different NSP fractions in selected feedstuffs in g/kg DM

Feedstuff	Crude fibre	Beta-glucans	Pentosans	Total NSP
Wheat	20 – 34	2 – 15	55 – 95	75 – 106
Rye	22 – 32	5 – 30	75 – 91	107 - 128
Triticale	30	2 – 20	54 – 69	74 – 103
Barley	42 – 93	15 – 107	57 – 70	135 – 172
Oats	80 – 123	30 – 66	55 – 69	120 – 296
Maize	19 – 30	1 – 2	40 – 43	55 – 117
Wheat bran	106 – 136	*	150 – 250	220 – 337
Soybean meal	34 – 99	*	30 – 45	180 – 227
Rapeseed meal	109 - 159	*	*	187
Fodder peas	56 - 72	*	*	156

* No data available

Source: (AWT, 2005)

Table 2.3: Nutrient content of selected feedstuffs (figures at 88% DM)

Feedstuff	Crude protein %	Crude fibre %	Crude starch %	Energy ME MJ/kg
Wheat	12.1	2.6	58.3	12.78
Rye	9.9	2.4	55.6	12.24
Triticale	12.8	2.5	56.3	12.59
Barley	10.9	5.0	52.7	11.43
Oats	10.6	10.2	39.8	10.25
Maize	9.1	2.3	62.0	13.35
Sorghum (Milo)	10.1	2.1	62.0	13.03
Wheat bran	14.1	11.8	13.1	6.17
Soybean meal 48	46.8	4.3	4.0	9.9
Rapeseed meal	34.0	11.5	5.7	8.7
Fodder peas	22.1	5.9	42.1	11.03

Source: (Jeroch and Dänicke 2008)

2.5. Negative effects of Fiber Sources

In modern poultry nutrition, traditional fiber sources are associated with some negative attributes such as energy dilution of the diet, mycotoxins contamination, reduced feed intake and nutrient digestibility (Michard, 2011, Rougière and Carré, 2010, Mateos *et al*., 2002, Janssen and Carré, 1985). Differences in the structure and properties of the existing fiber sources also affect the rate of passage in different ways, digesta pH and volatile fatty acid production in the different segments of the GIT (Montagne *et al.*, 2003, Raninen *et al.,* 2011). Consequently, the effects of dietary fiber on voluntary feed intake, organ size, GIT motility, enzyme production, microbiota growth, and bird behaviour will differ depending on the source of fiber. The excessive use of fiber sources in the diet may also increase viscosity of the intestinal content, with a resultant decrease in bioavailability of vitamin A and utilization of dietary fats, which adversely affects body weight gain and carcass quality. Pietsch, (2012) recommended that limited amounts of such sources of fiber should be used if better performance is to be achieved.

2.6. Improving Fiber Quality

It is important to note that the negative results reported on some type of fibrous sources (soluble fibre) can be eliminated with enzyme supplementation and with feed processing adequately planned to suit the requirement of the specific type and age of bird to be fed (Michard, 2011). With that strategy, when available, feedstuffs that are high in fiber can be used to dilute poultry feed conveniently.

2.7. Lignocellulose – a more effective and efficient fibre supplement

A recently developed fibre source, known as lignocellulose, has proved successful as a non-fermentable fibre supplement for animal nutrition. Lignocellulose is a renewable organic material and is the major structural component of all plants (Dashtban *et al*., 2009; Howard *et al.* 2003). Lignocellulose consists of three major components: cellulose, hemicellulose and lignin. In addition, small amounts of other materials such as ash, proteins and pectin can be found in lignocellulosic residues, in different degrees based on the source (Sanchez, 2009).

Cellulose, the major constituent of all plant material and the most abundant organic molecule on the Earth, is a linear biopolymer of anhydroglucopyranose-molecules, connected by β-1, 4-glycosidic bonds. Coupling of adjacent cellulose chains by hydrogen bonds, hydrophobic interactions and Van der Waal's forces leads to a parallel alignment of crystalline structures known as microfibril (Percival *et al*., 2006).

Hemicelluloses, the second most abundant component of lignocellulosic biomass, are heterogeneous polymers of pentoses (including xylose and arabinose), hexoses (mainly mannose, less glucose and galactose) and sugar acids. Composition of hemicelluloses is very variable in nature and depends on the plant source (Saha, 2000; Saha, 2003).

Lignin, the third main heterogeneous polymer in lignocellulosic residues, generally contains three aromatic alcohols including coniferyl alcohol, sinapyl and *p*-coumaryl. Lignin acts as a barrier for any solutions or enzymes by linking to both hemicelluloses and cellulose and prevents penetration of lignocellulolytic enzymes to the interior lignocellulosic structure. Not surprisingly, lignin is the most recalcitrant component of lignocellulosic material to degrade (Sanchez, 2009; Himmel *et al*., 2007).

Lignocellulose crude fibre source does not have the negative effects of conventional fibre source ingredients mentioned earlier. It has a standardized amount of crude fibre, is mycotoxins free, and has gone through several steps of thermal sanitation during production processes.

Lignocellulose fibre, according to Pietsch, (2012), contains a minimum of 65% crude fibre and therefore, requires lower dietary inclusion rate to increase crude fibre content by 1%.

The chemical properties of the components of lignocellulosics make them a substrate of enormous biotechnological value (Malherbe and Cloete, 2003). Lignocellulosic wastes are produced in large amounts by different industries including forestry, pulp and paper, agriculture, and food, in addition to different wastes from municipal solid waste (MSW), and animal wastes (Table 2.4) (Kim and Dale, 2004; Wen *et al*., 2004). These potentially valuable materials were treated as waste in many countries in the past, and still are today in some developing counties, which raises many environmental concerns (Palacios-Orueta *et al*., 2005; Levine, 1996). Significant efforts, many of which have been successful, have been made to convert these lignocellulosic residues to valuable products such as biofuels, chemicals and animal feed (Howard *et al.,* 2003). Such effort, however, is needed in the livestock industry, in order to generate quality crude fibre for the animals.

In nature, degradation of cellulosic biomass is performed by mixtures of hydrolytic enzymes collectively known as cellulases. The cellulases include endo-acting (endoglucanases) and exo-acting (cellobiohydrolases) enzymes, which act in a synergistic manner in biomass-degrading microbes. Many microorganisms including fungi and bacteria had been found to degrade cellulose and other plant cell wall fibres. By 1976, over 14,000 fungal species capable of degrading cellulose had been isolated, but only a few of them were subjected to in-depth studies (Mandels and Sternberg, 1976). Obviously, fungi contribute significantly to the decay of lignocellulosic residues in nature by producing many different lignocellulolytic enzymes. Most fungal strains produce various enzymes in large amounts which are released in the environment and act in a synergistic manner. The breakdown of lignocellulosic biomass involves the formation of long-chain polysaccharides, mainly cellulose and hemicellulose, and the subsequent hydrolysis of these polysaccharides into their component 5- and 6-carbon chain sugars.

Cellulose in the plant cell wall is not readily available to enzymatic hydrolysis (cellulases) due primarily to; (1) low accessibility of (micro-) crystalline cellulose fibres, which prevents cellulases from working efficiently, and (2) the presence of lignin (mainly) and hemicellulose on the surface of cellulose, which prevents cellulases from accessing the substrate efficiently (Zhang *et al*., 2010). High temperature and acid have been used initially for chemical cellulose degradation and they are still involved in pretreatment of lignocellulosic residues at industrial scales. However, this approach is expensive, slow and inefficient (Rubin, 2008). In addition, the overall yield of the fermentation process will be decreased because this pretreatment releases inhibitors such as weak acids, furan and phenolic compounds (Palmqvist and Hahn-Hägerdal, 2000). Some of these problems could be overcome by applying microorganisms such as fungi. For example, *Thermophilic* fungal species such as *Sporotrichum thermophile* (Bhat and Maheshwari, 1987), *Thermoascus aurantiacus* (Gomes *et al*, 2000) and *Thielavia terrestris* (Gilbert *et al*, 1993) have been proposed as good candidates for bioconversion of lignocellulosic residues to sugars and offer the great potential to be used at industrial scales. Applying thermophilic fungal species at industrial scales also allows energy savings because the costly cooling after steam pre-treatment is avoided and saccharification rates are improved. These fungi have been shown to produce cellulases and to degrade native cellulose; however, the enzyme activity in thermophilic organisms (e.g. *S. thermophile*) is usually low compared to *Mesophilic* fungi such as *T. reesei* (Bhat and Maheshwari, 1987).

Table 2.4: Some of the lignocellulosic residues produced by different industries

Lignocellulosic Wastes	Annual production	Potential contribution to ethanol production (billion litre/year)	References
World Agricultural Wastes[1]	Trillion grams/year (Tg/y)		
Corn stover	203.62	58.6	(Kim and Dale, 2004)
Barley straw	58.45	18.1	(Kim and Dale, 2004)
Oat straw	10.62	2.78	(Kim and Dale, 2004)
Rice straw	731.34	204.6	(Kim and Dale, 2004)
Wheat straw	354.35	103.8	(Kim and Dale, 2004)
Sorghum straw	10.32	2.79	(Kim and Dale, 2004)
Bagasse	180.73	51.3	(Kim and Dale, 2004)
Subtotal	1549.42	442.0	
Municipal Solid Waste (MSW)	Million metric tons (million MT)		
USA (2001)	208	13.7 [2]	(Kalogo *et al*., 2007)
China (1998)	127	8.3 [3]	(Pokhrel *et al*., 2005)
Canada (2002)	30.5	2 [4]	(Statistics Canada, 2005)
Animal Wastes[5]			
In Canada (2001)	177.5		Champagne, 2007
In USA (1995)	160		(Wen *et al*., 2004)

[1] Average values from 1997 to 2001 have been used to calculate world agricultural waste production (Kim and Dale, 2004). [2-4]Potential contribution of MSW in USA, China and Canada in 2001, 1998 and 2002 respectively, assuming a conservative yield of 66 L of ethanol/MT of MSW (Kalogo *et al*., 2007; Pokhrel *et al*., 2005; Statistics Canada, 2005) . [5]The fibre content (including cellulose and hemicellulose of cattle manure, for example, is 52.6%) (dry biomass basis). These sugars can be hydrolyzed and fermented to produce ethanol but the utilization of animal manures is more complicated due to its high protein content (Champagne, 2007; Wen *et al*., 2004).

2.8. Potential Lignocellulose By-products and their Applications

Biomass can be considered as the mass of organic material from any biological material, and by extension, any large mass of biological matter. A wide variety of biomass resources are available (Tables 2.5 and 2.6) on our planet for conversion into by-products. These may include whole plants, plant parts (e.g. seeds, stalks), plant constituents (e.g. starch, lipids, protein and fibre), processing by-products (distiller's grains, corn solubles), materials of marine origin and animal by-products, municipal and industrial wastes (Smith *et al*., 1987). These resources can be used to create new biomaterials and this will require an intimate understanding of the composition of the raw material whether it is whole plant or constituents, so that the desired functional elements can be obtained for bio product production.

Smith *et al*. (1987), Bhat, 2000; Sun and Cheng, (2002), Wong and Saddler (1992a, b), Beauchemin *et al.,* (2001, 2003), Subramaniyan and Prema (2002) and Beg *et al*., (2001) in their separate reviews reported that different lignocellulose by-products in the form of whole plants, plant parts (eg. seeds, stalks), plant constituents (eg. starch, lipids, protein and fibre), processing byproducts (distiller's grains, corn solubles), materials of marine origin and animal byproducts, municipal and industrial wastes can be processed into industrial byproducts.

Bioconversion of lignocellulosic wastes could make a significant contribution to the production of organic chemicals. Over 75% of organic chemicals are produced from five primary base-chemicals: ethylene, propylene, benzene, toluene and xylene which are used to synthesize other organic compounds, which in turn are used to produce various chemical products including polymers and resins (Coombs, 1987).

Table 2.5: Types of lignocellulosic materials and their current uses.

Lignocellulosic material	Residues	Competing use
Grain harvesting Wheat, rice, oats barley and corn	Straw, cobs, stalks, husks,	Animal feed, burnt as fuel,compost, soil conditioner
Processed grains Corn, wheat, rice, soybean	Waste water, bran,	Animal Feed
Fruit and vegetable harvesting	Seeds, peels, husks, stones,rejected whole fruit and juice	Animal and fish feed, some seeds for oil extraction
Fruit and vegetable processing	Seeds, peels, waste water, husks,shells, stones, rejected whole fruitand juice	Animal and fish feed, someseeds for oil extraction
Sugar cane other sugar products	Bagasse	Burnt as fuel
Oils and oilseed plants cotton seeds, olives, soybean etc.	Shells, husks, lint, fibre, sludge, presscake, wastewater	Animal feed, fertilizer, burnt fuel Nuts,
Animal waste	Manure, other waste	Soil conditioners
Forestry-paper and pulp Harvesting of logs	Wood residuals, barks, leaves etc.	Soil conditioners, burnt
Saw-and plywood waste	Woodchips, wood shavings, saw dust	Pulp and paper industries, chipand fibre board
Pulp & paper mills	Fibre waste, sulphite liquor	Reused in pulp and boardindustry as fuel
Lignocellulose waste from communities	Old newspapers, paper, cardboard,old boards, disused furniture	Small percentage recycled,others burnt
Grass	Unutilized grass	Burnt

Source: Howard *et al*, 2003

Table 2.6: Lignocellulose contents of common agricultural residues and wastes.

Lignocellulosic materials	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Hardwood stems	40-55	24-40	18-25
Softwood stems	45-50	25-35	25-35
Nut shells	25-30	25-30	30-40
Corn cobs	45	35	15
Paper	85-99	0	0-15
Wheat straw	30	50	15
Rice straw	32.1	24	18
Sorted refuse	60	20	20
Leaves	15-20	80-85	0
Cotton seeds hairs	80-95	5-20	0
Newspaper	40-55	25-40	18-30
Waste paper from chemical pulps	60-70	10-20	5-10
Primary wastewater solids	8-15	NA	24-29
Fresh bagasse	33.4	30	18.9
Swine waste	6	28	NA
Solid cattle manure	1.6-4.7	1.4-3.3	2.7-5.7
Coastal Bermuda grass	25	35.7	6.4
Switch grass	45	31.4	12.0
S32 rye grass (early leaf)	21.3	15.8	2.7
S32 rye grass (seed setting)	26.7	25.7	7.3
Orchard grass (medium maturity)	32	40	4.7
Grasses (average values for grasses)	25-40	25-50	10-30

NA, data not available.

Howard *et al*, 2003

2.9. Lignocellulose as a Physiological Requirement in Poultry

From the nutritionist's point of view and from the view of animal welfare, the formulation of a diet should fulfill the animal's physiological demand rather than try to compensate physiological imbalance with supplements (Neufeld, 2009). This shows why chickens appear to have a desire for structural components and thus, will search for coarse and insoluble materials (Michard, 2011). In a situation where the diet has a low fibre content, litter material used as bedding in floor systems may be an alternative source for structural components, thus the birds can show abnormal behaviour, including litter consumption and feather pecking (Hetland *et al.*, 2005b). Michard (2011) suggested that although correct intake of energy, amino-acids and trace elements is important, more attention should be paid to dietary insoluble fibre not only in layer nutrition but also for breeders and broilers fed without antibiotic growth promoters. According to the author, insoluble fibers have positive effects on intestinal microflora and intestinal health including poultry.

2.10. Application of Lignocellulose in Broilers

It has commonly been accepted that an increase in dietary fibre reduces feed intake in poultry. However, different authors have demonstrated that the inclusion of moderate amounts of insoluble dietary fibre does not affect voluntary feed intake in broilers (González-Alvarado *et al*, 2007; Jiménez-Moreno *et al.*, 2011; Jiménez-Moreno *et al.*, 2009), growing turkeys (Sklan, 2003), or laying hens (Pérez-Bonilla, 2011). In fact, research conducted with diets that included up to 5% of a source of insoluble fibre has shown an increase in AMEn intake with increased levels of fibre in the diet (Jiménez-Moreno *et al.*, 2011). González- Alvarado *et al.* (2007) studied the effects of the inclusion of 3% OH (hydroxide) or soybean hulls in a control diet based on corn that contained 2.5% crude fibre or a control diet based on rice that contained 1.5% crude fibre. According to them, from 1 to 4 d of age, the inclusion of a fibre source reduced average daily feed intake without affecting average daily gain; consequently, feed conversion ratio was improved with fibre inclusion. Moreover, from 1 to 21 d of age, dietary fibre inclusion did not affect average daily feed intake but improved average daily gain and feed conversion ratio.

González-Alvarado *et al*. (2010) reported that the inclusion in the diet of 3% SBP (sugar beet pulp), a source of soluble dietary fibre, reduced the average daily feed intake from 25 to 42 d of age as compared with a diet containing 3% OH. However, no negative effects of SBP inclusion were observed during the first 10 day of life. The authors reported that inclusion of OH improved average daily gain and feed conversion ratio, whereas the yield of primal parts (breast and leg quarters) was not affected. In addition, Pettersson and Razdan (1993) reported that the inclusion of 2.3% SBP in the diet increased average daily feed intake and average daily gain in broilers at 14 and 21 d of age. However, a further increase to 4.6 or 9.2% SBP hindered these traits.

It is probable, however, that the level and type of dietary fibre, as well as the age of the bird, modify the response of broilers with respect to feed intake (Mateos *et al*, 2012).Therefore, the beneficial effects of fibre inclusion on the growth performance of broilers were related to improved nutrient digestibility rather than to changes in the metabolic pathways (Mateos *et al*, 2012).

Reports by Jiménez-Moreno *et al.* (2007) showed that dilution of the diets with increasing levels of the fibre sources did not affect any of the growth performance variables studied; in fact, AMEn efficiency was improved with fibre inclusion. However, Shelton *et al* (2003) and Plavnik *et al.* (1997) reported that modern broilers have a high capacity for feed consumption, and they might accept higher dilutions of the diet than generally expected.

Moreover, modern broiler strains fed high-energy pelleted diets might overconsume the feed, resulting, in some cases, in poor feed efficiency and excess carcass fat (Latshaw, 2008; Svihus, 2011). The high capacity of some fibre sources, such as SBP, to retain water increases the bulk of the digesta, producing satiety in those broilers fed to appetite.

However, Svihus (2011) suggested that the hyperphagia frequently reported in *ad libitum* fed birds selected for high growth rates might be related to underdeveloped gizzards, a consequence of the poor structure of the feeds and the lack of sufficient structural components such as dietary fibre. An excess of feed intake, as occurs in these birds, usually results in poorer feed efficiency than expected. Dietary fibre might cause physical constraints in gizzard volume, resulting in an improvement in feed efficiency without affecting the growth rate.

According to Scheideler (1998) Dietary fibre from oats alone improved weight gain and feed gain compared to the flaxseed or flaxseed with oat diets. Dietary fibre from both sources increased gizzard size and viscosity of gut contents compared to the corn/soy control. Performance in the laying period (18-38 weeks) indicated no significant change in performance due to dietary fibre inclusion in pullet rations (Scheideler, 1998).

It has frequently been reported that when structural dietary components, such as fibre sources, are added to poultry diets, the pH of the gizzard contents decreases by a magnitude in the range of 0.2 to 1.2 units (Svihus, 2011; Jiménez-Moreno *et al*.,2009, 2011; González-Alvarado *et al*., 2008). Hetland *et al* (2005a) reported that coarse fibre structures were shown to accumulate in the gizzard. Coarse insoluble fibre increases the gizzard size, decreases the PH in the gizzard and it improves the starch and feed digestibility.

Sarikhan *et al*, (2009) reported that levels of total protein, albumin, amylase, lipase and phosphorous were not affected much by dietary treatments at day 42 when insoluble fibre was incorporated into broiler diets. Triglyceride, HDL (high density lipids) and VLDL (volatile low density lipids) levels were affected ($p<0.01$) by different levels of IRFC (insoluble raw fibre concentrates) in diet and there were lower levels in triglyceride and VLDL and higher levels in HDL in 0.50 and 0.75 dietary groups than control and 0.25 group. Also cholesterol and LDL (low density lipids) levels in 0.75 group were significantly lower ($p<0.01$) as compared to control group. Levels of total protein, albumin, amylase, lipase and phosphorous were not affected by dietary treatments but Calcium in 0.50 group was higher than controls.

2.11. Application of Lignocellulose in Layers.

Hetland *et al*. (2005b) reported a 60% increase in gizzard weights and gizzard contents in hens fed low-fibre diets with access to wood shavings as compared with hens kept in cages. Hartini *et al.,* (2002) reported that mortality was reduced with the inclusion of fibre in the diets of laying hen based on wheat that contained 2.9% CF. Hetland and Choct (2003) reported that coarse insoluble fibre is difficult to grind and consequently increases the gizzard size. Coarse insoluble fibre stays a longer time in the gizzard. Feeds having a low coarse insoluble fibre provoke feather consumption.

According to Steenfeldt, (2012) high fibre diets prolong the passage of feed, which makes the birds to experience less hunger than when commercially fed, thus leading to heavier gizzard.

2.12. Application of lignocellulose in pigs

The effects of dietary fibre on GIT health were more noticeable in weaner pigs (Dunkley *et al.,* 2007, McHan and Shotts, 1993. Correa-Matos *et al.* (2003) observed that fermentable dietary fibre reduced the severity of *Salmonella typhimurium* infection in piglets.

2.13. Lignocellulose as a Defense Mechanism

Dietary fibre has a protective effect against a range of metabolic problems and diseases in humans, including the control of insidious problems such as constipation, obesity, type II diabetes, colon cancer, serum glucose levels, and cardiovascular diseases (Miller Jones, 2004). Dietary fibre might also help protect the mucosa of the GIT, reducing the incidence of ulcers and colitis, as well as chronic inflammation of the digestive mucosa. As such, dietary fibre might help act as a barrier against infection and, to a certain extent, might suppress the growth of *Clostridium difficile* in different species (May *et al.,* 1994; Frankel *el at.*, 1994; Horner *et al.,* 2000). Consequently, most human nutritionists recommend an increase in the daily consumption of dietary fibre to reduce the incidence of these diseases in Western populations (Miller Jones, 2004; Blackwood *et al.,* 2000; McBurney, 2010; Dunkley *et al,* 2007).

In contrast to humans, in whom the interest in adding fibre to the diet is based on long-term benefits, the benefits of dietary fibre on the physiology of non-ruminant animals are more elusive. The inclusion of fibre in the diet was shown to enhance intestinal function and modify the composition and quantity of the gut microflora population in the GIT of poultry and pigs, both *in vitro* (Dunkley *et al,* 2007; McHan and Shotts. 1993) and *in vivo* (Correa-Matos *et al*, 2003; Shakouri *et al.,* 2006; Jiménez-Moreno *et al.,* 2011; van der Meulen *et al.,* 2010).

Jiménez- Moreno *et al*. (1996) recorded that *Lactobacillus* counts in the crop increased with the inclusion of SBP (soy bean pulp), but not with the inclusion of OH (oat hulls). However, no effects of dietary fibre on *Lactobacillus* counts were detected in the ceca. On the other hand, the counts of *C. perfringens* and *Enterobacteriaceae* in the ceca decreased significantly with OH inclusion but were not affected by SBP.

According to Mateos*,* (2011), solubility, viscosity, and fermentation capability are 3 key physicochemical properties of fibre sources that affect microflora diversity and colony counts in the GIT. In this respect, Shakouri *et al.* (2006) reported an increase in *Enterobacteriaceae* counts in the ceca in response to an increase in intestinal viscosity caused by inclusion in the diet of 3% methylated citrus pectin.

Jørgensen *et al.* (2003) observed that an increase in dietary fibre (pea fibre, wheat bran, and oat bran) to 37.5% increased the concentration and amount of organic acids excreted as well as H_2 production from fermentation processes, indicating that microbial activity was increased.

The inclusion of an insoluble fibre source, such as OH, in the diet, improved gizzard functionality and might mechanically activate the mucosal surface, increasing GIT motility and reducing the chances of bacteria, such as *C. perfringens*, adhering to the mucosal surface in the distal part of the GIT (Kalmendal *et al.,* 2011). Insoluble dietary fibre has a more abrasive action, scraping mucin from the mucosa as it passes along the GIT (Montagne *et al.,* 2003; Leterme *et al.,* 1998) and increasing endogenous losses. In addition, dietary fibre ingestion might modify the composition of the mucins and, consequently, alter the profile of commensal and pathogenic bacteria capable of adhering to the mucus layer. Dietary fibre that leads to more acid mucin appears to increase the potential of mucus to resist the attack of bacterial enzymes

(Rhodes, 1989), favoring the elimination of pathogens (Montagne *et al.,* 2003). In this respect, Novoa-Garrido *et al.* (2006) reported that the incidence of mucosal gizzard lesions was highly correlated (r = 32%) with *C. perfringens* counts. In addition, Kalmendal *et al.* (2011) reported that the inclusion in the diet of high levels of sunflower meal, an insoluble source of dietary fibre, was associated with significant decreases in colony counts of *Clostridium* spp. Perez *et al*. (2011) reported that the inclusion of DDGS in broiler diets increased cecal bacterial diversity and resulted in intestinal health benefits in broilers.

2.14. Lignocellulolytic effect on feather pecking/mortality

Feather pecking and cannibalism are important welfare problems in poultry, especially under non-cage production systems and when birds are not beaked (Hartini *et al.,* 2002; E l-Lethey *et al.,* 2000). According to field observations by Mateos (2011), laying hen mortality, under commercial conditions, is lower when birds are fed diets that contain a high level of dietary fibre (e.g., inclusion of barley and sunflower meal) than when they are exclusively fed diets based on corn and high-protein soybean meal.

Van Krimpen *et al*. (2009) in their report, observed a reduction in feather damage in floor-reared hens with an increased consumption of insoluble non-starch polysaccharides. The incidence of feather pecking is inversely related to the time spent by the bird in other exploratory activities, such as feeding, drinking, and foraging. Consequently, nutritional factors that increase the duration of time spent in feeding may reduce the incidence of pecking behaviour. In addition, dietary fibre increases the feeling of satiety thus reduces feather pecking. The appetite for additional fibre and the time spent in pecking litter depends in part on the crude fibre content of the basal diet. Consistent with this information, there is a tendency for a higher incidence of feather pecking and cannibalism in birds fed low-fibre diets in pellet form than in birds fed high-fibre diets as mash (Aerni *et al.,* 2000; Hartini *et al.,* 2002).

Aerni *et al* (2000) concluded that hens with no access to litter should be fed with finely milled feed, and that litter becomes indispensable when feed is presented in pellet form. When egg production is in cages, presentation of the feed in crumb form increases the risks of feather pecking. Dilution of the feed obliges hens to increase the volume and quantity of feed intake and so to increase feed consumption times. This leads to an improvement in plumage and a reduction in actual feather pecking. This could explain the reduction in mortality observed in certain trials using diluted diets (table 2.7) (Balnave and Robinson, 2000). The report showed "that hens fed roughage had better plumage due to a lower rate of feather pecking.

Van Krimpen*,* (1995) concluded in reviewing nutritional factors affecting feather pecking, "a low energy diet seems to reduce feather pecking behaviour and to improve plumage condition". Mortalities observed in the 2 experiments carried out by Hartini *et al* (2002) are shown in table 2.8. The hens were housed in cages, subjected to high light intensity, not debeaked, and aged 70 weeks in experiment 1 and 54 weeks in experiment 2.

2.15. Lignocellulolytic effect on litter quality

Hafez (2012) enumerated a number of important functions of litter as absorbing moisture, promoting dryness by increasing the surface area of the house floor, diluting faecal material and protecting the birds from the cooling effect of the ground. However, poor litter can affect beside other many factors the birds' health and can result in increasing condemnation rates, downgrades and subsequently the efficiency of the production. The author suggested that for effective poultry production, proper maintenance of litter is as important as required feed, water, lightning, ventilation and hygiene, as well as disease control program. If these are not properly done very high bacterial loads and unsanitary growing conditions may result in producing odour, insect problems, soiled feathers, foot pad lesions and breast blisters and incidentally prevalence of coccidiosis (Pietsch, 2012). Butcher and Miles (2009) reviewed litter quality as one of the key factors in poultry production and thus needed proper attention.

Table 2.7: Effect of feed energy dilution on mortality.

Energy, kcal	Volume of feed ingested, ml	Mortality, %
2920	140	7.29[b]
2727	160	4.69[ab]
2535	219	1.04[a]

Source: Balnave and Robinson (2000)

Table 2.8: Effect of fibre type on the mortality of hens of which half un-debeaked.

Type of diet	Mortality in %	
	17-20 wks.	21 to 24 wks.
Standard feed (corn)	13.2[b]	28.9[b]
Insoluble fibre (mill run)	3.9[a]	14.3[a]
Soluble fibre (barley)	5.8[a]	15.9[a]
Soluble fibre (barley) + enzyme	4.1[a]	17.8[a]

Source: Hartini *et al* (2002)

2.16. Effects of excess fibre

It is generally accepted that fibres may improve intestinal digestion by reducing the number of goblet cells present on the villous structures in the small intestines, and hence reduce the amount of goblet mucin which acts as a luminal barrier against absorption (Pietsch, 2012). This, however, may not always be the case, especially with fibre sources of high molecular weight or those having high methoxyl contents such as citrus pomace, apple pomace, tomato pomace, etc.

Accordings to Pietsch, (2012) excess feeding of such fibre sources may lead to enlargement of the intestinal villi arising from physical stimulation of villous growth similar to that observed with ruminants fed on high fibre diets, where rumen papillae are also enlarged through the physical action of fibres. The increased size of the villi is often coupled with about two-fold increase in goblet cell numbers which adversely affects absorption. The excessive use of such fibre sources in the diet may also increase viscosity of the intestinal content, with a resulting decrease in bioavailability of vitamin A and utilization of dietary fats, which adversely affects body weight gain and carcass quality (Pietsch, 2012).

2.17. Arbocel® fine in poultry nutrition

Arbocel ® is an insoluble fibre source which is HPC (high performance concrete) fibrillated (new and innovative milling technology). Arbocel is classified based on physical structure and texture. The types include Arbocel® R (powdered), Arbocel® RC (compacted) and Arbocel® RC Fine (compacted fine).

Arbocel® is made available worldwide by JRS at any quantity with regards to the following attributes: longstanding years of experience in the production and processing of fibres, customerspecialized types, market strength due to worldwide market leadership and 22 production plants in Europe and Overseas (JRS, 2009).

Unlike traditional fiber sources, there is no mycotoxin risk associated with Arbocel, it is free of bark and delivers 65% crude fibre according to the Weender analysis (JRS, 2009). Arbocel is won from selected, untreated and carefully dried native timber and produced by J. Rettenmaier and Söhne (JRS), Germany by milling and fibrillation with standard properties (Table 2.9), that meets EU regulatory requirements, having no used aids and supplementary products, no critical substance, no remarks on specific analytical problems, but require usual precautionary measures when working with all combustible materials containing dusty particles. J. Rettenmaier and Söhne GmbH + Co KG is registered as feed material manufacturer under the EC Feed Hygiene Regulation (183/2005), Germany and is certified according to the QS (Qualität und Sicherheit) quality assurance scheme (QS-ID: 4031735751574) (JRS, 2009).

Arbocel fine is characterized by a very high water binding capacity and by an optimum microbiological status. According to JRS (2009), it is listed in the Positive List of Feed Materials (Reg. No. 12.08.01) of the German Agricultural Society (DLG). Arbocel ® RC Lignocellulose is used in feedstuffs mainly for raw fibre enrichment and for its expansion and swelling capacity at inclusion rates between 0.5 and 0.6%, depending on the application.

Farm experience as well as University trials has shown that the use of about 0.8% Arbocel will have a significant positive effect on health and performance related parameters (Pietsch, 2012). It has been demonstrated on University level that Arbocel reduces the humidity in litter of broilers and layers (Pietsch, 2012, Hafez 2012). Stenfeldt (2012) demonstrated that the insoluble fibre source Arbocel has a positive impact on feather pecking in layers. According to the author, the presence of insoluble fibre appears indispensable, causing an increase in gizzard size, improved starch digestibility and limiting feather pecking. Farran (2012) recorded a positive effect on carcass yield when broilers were fed Arbocel®, a lignocellulose, which resulted in additional profit to broiler processors and thus considered Arbocel® as a cost effective natural feed additive in poultry ration formulation. The author also recorded no effect on the metabolizable energy (AME and TME) of birds fed Arbocel®, but had an increment in the protein digestibility and the digestibility coefficients of both apparent and true amino acids. The improved protein digestibility has an impact on the performance. This has been demonstrated for broilers and for layers (Pietsch, 2012).

2.18. Mode of action of Arbocel®

Arbocel acts in different ways to improve performance. In other to increase laying percentage there is improved protein digestion, which leads to a better laying performance.

To improve the feed intake in early lay; there is high swelling capacity of Arbocel®, which results in an enlarged gizzard, it also leads to a longer retention time of the digesta in the gizzard and a sufficient feed intake at the beginning of the laying stage is ensured

Mode of action to improve litter quality: Arbocel® has a very high water binding capacity (800 %), binds water in the upper part of the intestinal tract, releases water in the lower part of the intestinal tract by osmotic pressure and facilitates the re-absorption of water in the lower part of the intestinal tract. Arbocel® fibre reduces the digesta viscosity by accelerating transit period, reduces colonization of harmful bacteria, reduces excretion of endotoxins, reduces humidity in the litter and improves litter quality.

Table 2.9.Physical and Chemical Properties of Arbocel® Fine

Parameter	Property
Colour	yellowish
Structure	granules
Granule size	max. 8 mm
Fibre length	200µm – 300 µm
Bulk density	400 g/l – 530 g/l
Humidity	max. 12%
Crude fibre content	min. 65%
Acid detergent lignin (ADL)	min. 20%
Residue on ignition (850 ºC, 4h)	approx. 0.5%
pH value	5.5 +/- 1
Water binding capacity	450% - 650%

Source: JRS (2009)

CHAPTER THREE

MATERIALS AND METHODS

3.1. Experimental Site

The research was carried out at the Teaching and Research farm of the School of Agriculture and Agricultural Technology, Federal University of Technology Owerri, Nigeria, West Africa between latitude $4^0 4^1$ and $6^0 3^1$N and longitude $6^0 15^1$ and $8^0 15^1$E with mean annual rainfall, temperature and relative humidity of 250mm, 26.5-27^{0}C and 70-80%, respectively (Adeyemi, 2011). The research was conducted between the months December and February.

3.2. Experimental Material

Arbocel® fine was made available by Dr. Manfred Pietsch of J. Rettenmaier and Söhne (JRS) from Germany. J. Rettenmaier and Söhne GmbH + Co KG is registered as feed material manufacturer under the EC Feed Hygiene Regulation (183/2005) and is certified according to the QS quality assurance scheme (QS-ID: 4031735751574). The material was received and stored in a cool environment.

3.3. Experimental Diets

Three experimental starter and finisher broiler diets were formulated, such that the diets contained 0, 0.6 and 0.8% Arbocel®, respectively, partially replacing wheat offal in the diets. Other ingredients used in the formulation of the diets were procured from Fidelity Agro Industry, Owerri, Imo State. The ingredient compositions of the diets are shown in Table 3.1.

Table 3.1: Composition of starter and finisher diets

	Starter Inclusion Levels			Finisher Inclusion Levels		
Ingredient (%)	**0%**	**0.6%**	**0.8%**	**0%**	**0.6%**	**0.8%**
Maize	50.00	50.00	50.00	58.00	58.00	58.00
Soy bean meal	15.00	15.00	15.00	16.00	16.00	16.00
Spent grain	13.00	13.00	13.00	10.00	10.00	10.00
PKC	4.00	4.00	4.00	3.00	3.00	3.00
Arbocel	---	0.60	0.80	---	0.60	0.80
Wheat offal	3.00	2.40	2.20	2.50	1.90	1.70
Fish meal	8.00	8.00	8.00	4.50	4.50	4.50
Blood meal	3.00	3.00	3.00	2.00	2.00	2.00
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00
Oyster shell	1.00	1.00	1.00	1.00	1.00	1.00
Lysine	0.25	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25	0.25
Vit. Premix*	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis						
Crude protein	23.27	23.24	23.17	20.33	20.24	20.21
Crude fibre	4.73	5.17	5.06	4.88	4.77	4.44
Crude ash	4.05	4.01	4.00	3.35	3.31	3.30
Calcium	1.44	1.44	1.44	1.33	1.32	1.32
Phosphorus	0.92	0.91	0.91	0.84	0.83	0.83
Lysine	1.10	1.10	1.10	0.88	0.88	0.88
Methionine	0.40	0.40	0.40	0.30	0.30	0.30
Energy (kcal/kg)	2867.28	2859.74	2857.23	2928.05	2920.51	2918.00

* To provide the following per kg of feed: vitamin A, 12,000 iu; vitamin D_3, 2,500 iu; vitamin E, 8mg; vitamin K_3, 2 mg; vitamin B_1, 23 mg; vitamin B_2, 5 mg; vitamin B_6, 4 mg; vitamin B_{12} 8 mg, Niacin, 15 mg; pantothenic acid, 6 mg; folic acid, 4 mg; Manganese, 8 mg; zinc, 0.05 mg; iron, 20 mg; copper, 3 mg; iodine, 1.2 mg; selenium, 0.16 mg; cobalt, 2 mg.

3.4. Experimental Birds and Design

One hundred and forty four (144) day old mixed sex Marshal Strain broilers from Amazing farms in Owerri were used for the experiment. The birds were housed in 12 pens measuring 1.5m x 1.5m, inside a dwarf walled building, guarded with wire mesh to prevent predators, and black polythene to control wind and temperature for the first 2 weeks of brooding. The pens were covered with wood shavings as the litter material and provided with feeders and waterers. Stoves and lanterns were used to provide heat and light, respectively.

Three groups of birds containing forty-eight birds each were randomly assigned to each of the three experimental diets in a complete randomized design (CRD) replicated 4 times. Each replicate contained 12 birds each. Feed and water were provided to the birds *ad libitum*. The birds were fed starter diets from 1 – 28 day of age and finisher diets from 29 – 56 day of age respectively. The birds were vaccinated against New Castle Disease Virus and Infectious Bursal (Gumboro) disease. Mortality was recorded as it occurred. The experiment lasted for 56 days.

3.5. Data Collection and Analysis

The birds were weighed on arrival and weekly thereafter. Daily feed intakes were recorded by subtracting the quantity of feed that remained from the quantity given. Weekly weight gains were obtained from the differences between the weights of two successive weeks. Feed conversion ratios were obtained from the quotient of the feed intakes and the weight gains. Litter and faecal samples were collected from all pens at 28 and 56 days of age and analyzed for humidity according to the method described by AOAC (1999).

At 56- day of the experiment, two birds each, a male and a female, representing the average pen weights, were selected from each pen and processed. The selected birds were starved of feed but not water for 18hours, slaughtered by severing the jugular veins and eviscerated. The internal organs and the carcass weights were weighed individually. Weights of the abdominal fat, heart, full and empty gizzard, spleen, pancreas, liver and carcass were recorded and later expressed as percentages of live weight.

The data generated were statistically analyzed using analysis of variance and means were separated using the R-cran programme of R Core Team (2014).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Performance of Starter Broilers

Data on the performance of starter broilers fed diets containing Arbocel® fine are shown in Table 4.1. There were no significant ($P > 0.05$) differences in weight gain, feed intake and feed conversion ratio among groups fed diets containing Arbocel® fine and the control. Compared with the control diet, the parameters measured were not affected in birds fed diets containing Arbocel® fine.

Diets containing Arbocel® fine at the two levels of inclusion, caused 6.55 and 7.72% reductions in faecal moisture that were not significant when compared with the control (70.51%). Values for mortality were not significantly ($P > 0.05$) different.

Cost of feed consumed and cost of feed per kg body weight gain were significantly ($P<0.05$) higher in 0.8% the group fed diets containing Arbocel® fine than the control.

4.2. Performance of Broiler Finishers

Data on the performance of finisher broilers fed diets containing Arbocel® fine are presented in Table 4.2. Again, there were no significant ($P>0.05$) differences in weight gain, feed intake and feed conversion ratio of the broilers fed diets containing Arbocel® fine, when compared with the control.

Table 4.1: Performance of Starter Broilers Fed Diets Containing Arbocel® fine

Parameter	Dietary Inclusion Levels (%) of Arbocel ® Fine			
	0.00	**0.60**	**0.80**	**SEM**
Initial body weight (g)	37.615	38.99	39.65	1.31
Final body weight (g)	683.59	691.65	678.53	28.97
Body weight gain (g)	645.97	652.66	638.88	29.60
Feed intake (g)	1645.95	1654.65	1674.36	48.60
Feed conversion ratio	2.56	2.54	2.64	0.21
Cost of feed consumed (₦/kg)	150.31^{b}	165.53^{ab}	172.38^{a}	4.88
Cost of feed/kg body weight gain (₦)	233.95^{b}	254.09^{ab}	271.40^{a}	9.97
Faecal Moisture Content (%)	70.51	65.89	65.07	2.86
Mortality (%)	13.94	3.85	3.85	1.99

^{ab} means within rows with different superscripts are significantly different ($P < 0.05$)

Inclusion of Arbocel® fine in broiler finisher diets at 0.6 and 0.8% caused 6.45 and 6.24%, reductions in faecal moisture, respectively. The values were significantly ($P<0.05$) lower when compared with the control (75.82%). Litter moisture were also lower in the groups diets containing Arbocel® fine groups, but the values were not significantly different from the control (24.54%).

Birds fed diets containing 0.6 and 0.8% Arbocel® fine recorded a significantly ($P < 0.05$) higher feed cost and cost of feed per kg body weight gained than the control. Values for mortality were not significantly ($P > 0.05$) different.

4.3. Cumulative Performance of the Experimental Birds.

Data on the cumulative performance of the experimental birds are shown on Table 4.3. There was no significant ($P > 0.05$) difference among the experimental birds fed diets containing Arbocel® fine in body weight gains, feed intake and feed conversion ratio. Weekly weight, feed intake and feed conversion ratio (figures 4.1, 4.2 and 4.3) show a very similar trend among the different treatment groups.

Cost of feed consumed were similar among the treatments while feed cost per kg body weight gain significantly ($P < 0.05$) increased when Arbocel® fine was included at 0.8%.

Both faecal and litter moisture of birds fed diets containing 0.6 and 0.8% Arbocel® fine were reduced, relative to the control group, but only the faecal moisture values were significantly ($P < 0.05$) different when compared with the control. Values for mortality were significantly ($P<0.05$) higher in the control than the groups fed diets containing Arbocel® fine.

4.4. Carcass and Internal Organs of the Experimental Birds

Data on carcass and internal organ weights of the experimental birds are shown in Table 4.4. There were no significant differences in the carcass and organ weights of birds fed diets containing Arbocel® fine and the control. Weights of the pancreas, gizzard and heart were lighter in chickens fed diets containing Arbocel® fine than in control, while weights of the liver were heavier in birds fed the diet containing 0.8% Arbocel® fine but not with diet containing 0.6% Arbocel® fine. Ready-to-cook carcass yield were slightly higher in the groups containing Arbocel® fine diet groups but the values were not significantly ($P>0.05$) different from the control.

Table 4.2: Performance of Finisher Broilers Fed Diets Containing Arbocel® Fine

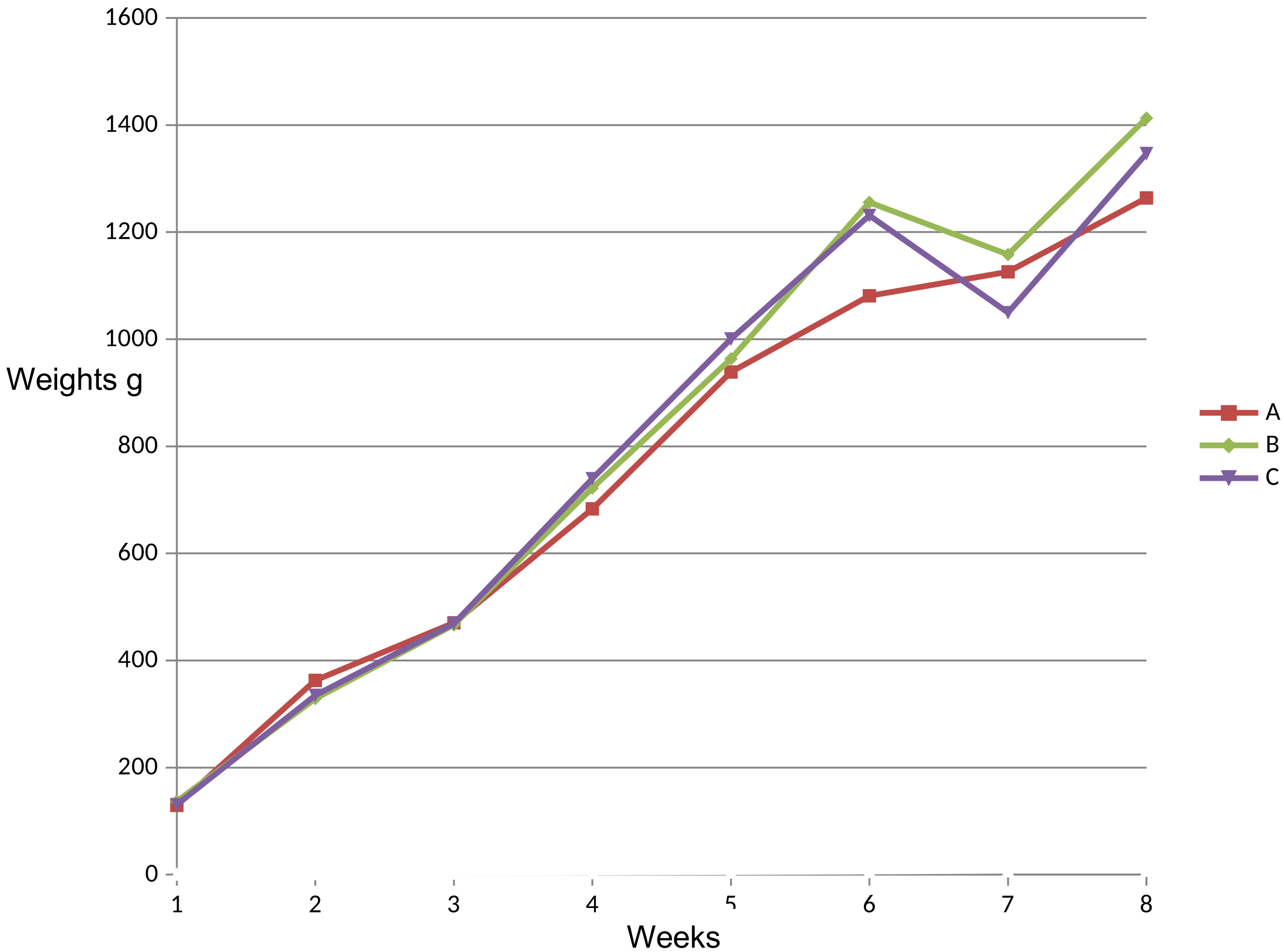
	Dietary Inclusion levels % Arbocel® fine			
Parameter	**0.00**	**0.60**	**0.80**	**SEM**
Final body weight (g)	2291.59	2147.25	2200.53	67.09
Body weight gain (g)	1608.00	1455.60	1522.00	50.60
Total Feed intake (g)	4409.50	4791.17	4628.78	118.79
Feed conversion ration	2.74	3.29	3.04	0.13
Cost of feed consumed/kg (₦/kg)	395.22^{b}	471.21^{a}	468.71^{a}	11.64
Cost of feed/kg body weight gain (₦)	246.03^{b}	325.32^{a}	309.21^{a}	12.59
Faecal Moisture Content (%)	75.82^{a}	70.93^{b}	71.09^{b}	0.84
Litter Moisture Content (%)	24.54	23.24	21.99	1.92
Mortality (%)	11.12	6.09	4.01	3.20

^{ab} means within rows with different superscripts are significantly different ($P < 0.05$)

Table 4.3: Cumulative performance of broilers fed diets containing Arbocel® fine

	Dietary Inclusion levels (%) of Arbocel® fine			
Parameter	**0.00**	**0.60**	**0.80**	**SEM**
Initial body weight (g)	37.62	38.99	39.65	1.31
Final body weight (g)	2291.59	2147.25	2200.53	67.09
Total Body Weight gain (g)	2253.97	2108.26	2160.88	67.69
Total Feed intake (g)	6055.45	6445.82	6303.14	140.92
Feed conversion ration	2.69	3.06	2.92	0.09
Cost of feed consumed (₦)	545.53	636.74	641.09	39.70
Cost of feed/kg body weight gain (₦)	479.98^{b}	579.41^{ab}	580.61^{a}	27.49
Carcass weight (%)	70.85	70.92	71.15	0.78
Returns @ N1000/kg carcass wt (₦)	1623.66	1522.83	1565.60	44.96
Faecal Moisture Content (%)	75.82^{a}	70.93^{b}	71.09^{b}	0.84
Litter Moisture Content (%)	24.54	23.24	21.99	1.92
Mortality (%)	24.04^{a}	9.78^{b}	7.69^{b}	3.10

^{ab} means within rows with different superscripts are significantly different ($P < 0.05$)

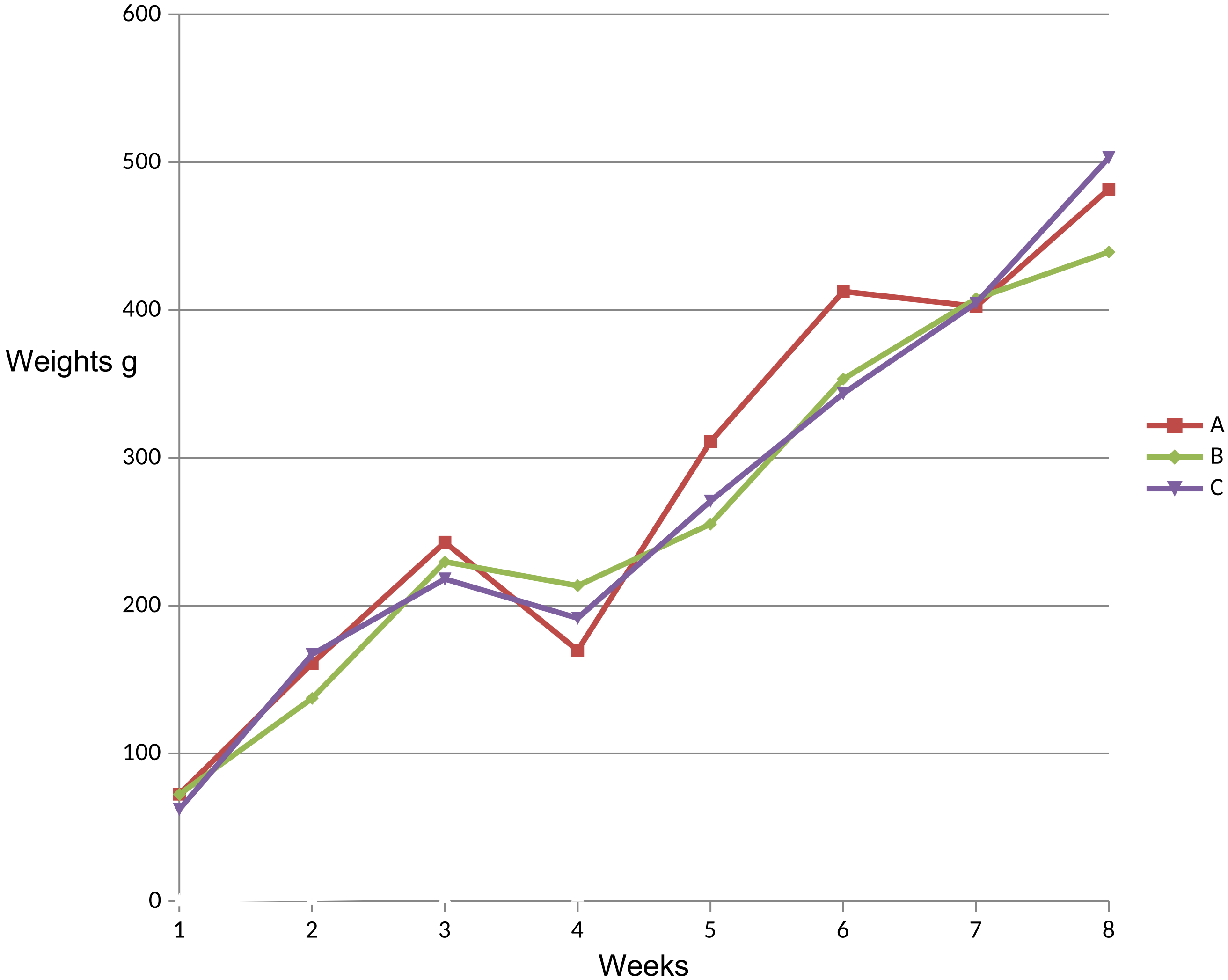


A represents 0.0% (control)

B represents 0.6%

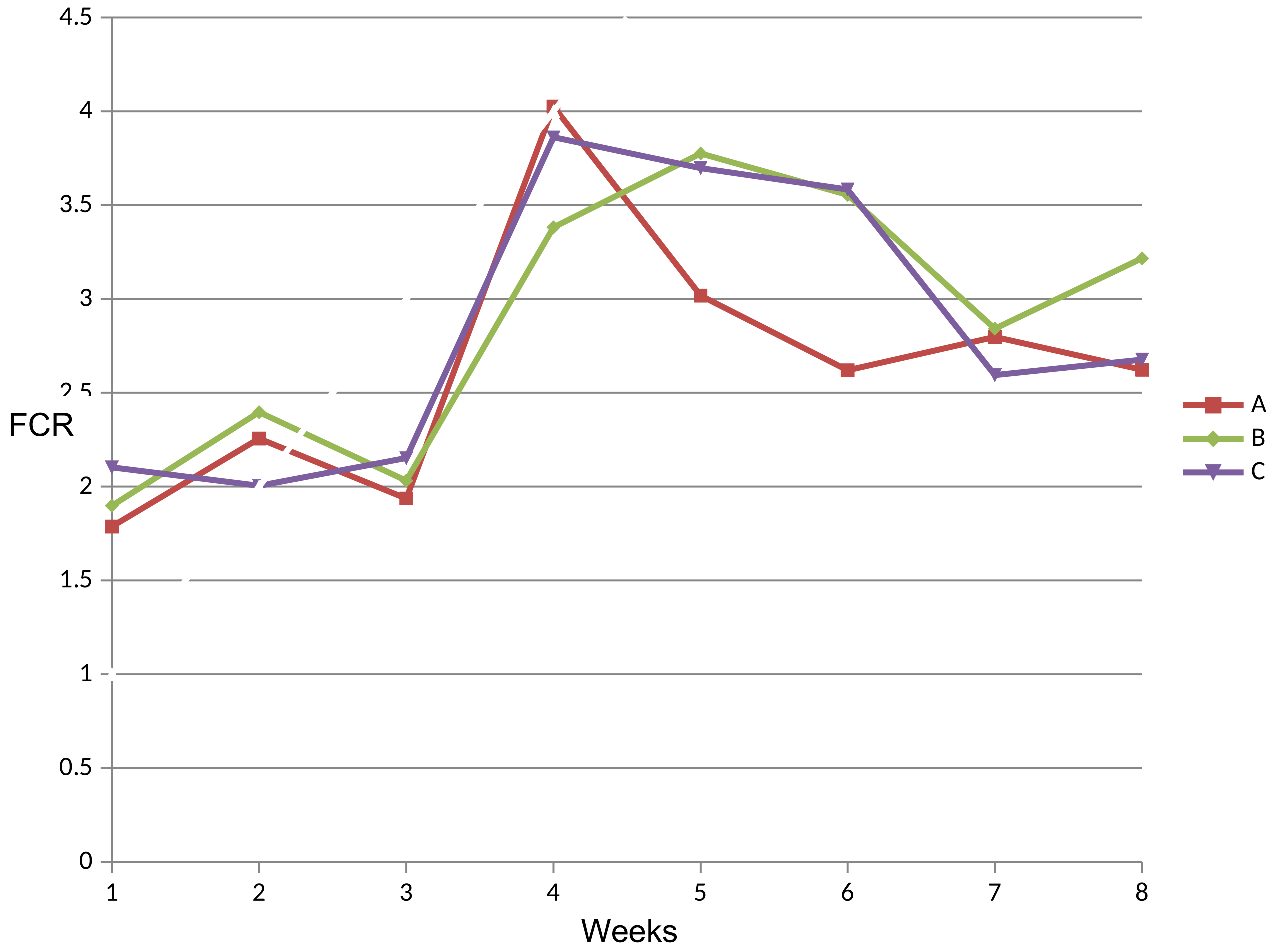
C represents 0.8%

Fig 4.1. Weekly Feed Intake of broilers fed diets containing Arbocel® fine



A represents 0.0% (control)
B represents 0.6%
C represents 0.8%

Fig 4.2. Weekly Weight Gain of broilers fed diets containing Arbocel® fine



A represents 0.0% (control)
B represents 0.6%
C represents 0.8%

Fig 4.3. Weekly Feed Conversion Ratio of broilers fed diets containing Arbocel® fine

Table 4.4: Carcass and internal organs weights of broilers fed diets containing Arbocel® fine

Treatment	RTC Carcass (%)	Fat pad (%)	Liver (%)	Full Gizzard (%)	Empty Gizzard (%)	Heart (%)	Spleen (%)	Pancreas (%)
Control	70.29	1.85	1.88	3.31	2.44	0.47	0.09	0.30
0.6 Arbocel® RC fine	70.92	1.89	1.81	3.00	2.14	0.46	0.10	0.24
0.8 Arbocel® RC fine	71.27	2.05	2.03	3.22	2.28	0.43	0.10	0.23
SEM	0.81	0.16	0.13	0.13	0.12	0.04	0.01	0.03

4.5. Discussion

Insoluble fibers play an important role in animal production and human health by changing the microbial ecosystem in the gut (Rolfe, 2000). Studies by Hetland and Svihus (2001) and Hetland *et al.* (2002) indicated that performance did not decrease when insoluble fiber was included in moderate levels in broilers or layers diets despite reduced concentration in the diets.

Arbocel fine is an insoluble fiber concentrate, containing 65% insoluble fiber (JRS,2009). It is presently used as feed additive in poultry diets in different parts of the world including Germany, Lebanon, Thailand, Australia etc. (Pietsch,2012). This is supported by the report of Farran (2012) in which the inclusion of Arbocel® lignocellulose at 0.8% in broiler diets did not negatively affect the weight gain and feed conversion ratio. Meanwhile, there are no reports in literature on the use of Arbocel fine in poultry diets in Nigeria. It was a major objective of this experiment therefore, to ascertain whether the beneficial effects of Arbocel fine observed in poultry in other countries could be reproduced in Nigeria.

In the present study, weight gain and feed conversion values were not significantly ($P>0.05$) improved as was indicated in trials performed in other countries (Farran, 2012). This similarity in performance tends to show that Arbocel® fine is not region specific. Figure 4.1 and 4.3 shows the comparable weight and feed conversion ratio of the birds fed the treatment diets.

Arbocel improved the overall feed intake without any improvement in feed conversion ratio. Steenfeldt (2012) reported similar high feed consumption when broilers were fed different insoluble and soluble fiber sources. Improvement in feed intake are likely to occur because of improved digestibility producing faster rates of passage of digesta through the digestive tract but not due to reduced nutrient concentration(Rogel *et al.*1987a, b) since the composition diets remains similar and meets the NRC requirements for broiler chickens.

Both faeces and litter material were drier in birds fed Arbocel® fine diets at 28 day of age and at market age than the control. The reductions in fecal moisture were 6.45 and 6.24% lower for 0.6 and 0.8% Arbocel at market age, respectively. The result agrees with the report by Farran (2012), who recorded a 10% reduction in litter moisture of finisher broilers fed 0.8% Arbocel diet. This tends to show that Arbocel was able to regulate the rate of digestion by increasing water and nutrient absorption, and thus minimize the rate of excretion of moisture via the feces.

Mortality was very low in birds fed Arbocel® fine diets and higher in birds fed control diet. The cause of the deaths was not determined and the factors responsible for the reduction in the Arbocel® fine group are not known. However, Hetland *et al.* (2004) reported that feed dilution by addition of fiber in the diet contributes to reduced mortality via pecking and cannibalism in laying hens as the birds will spend more time eating and drawing the attention of the birds away from peaking and cannibalism which may not be the case here.

Ready to cook (RTC) carcass yield were higher in Arbocel® RC Fine diet groups although the values were not significantly different when compared with the control. Farran (2012) reported a significant increase in carcass yield when broilers were fed 0.8% Arbocel® Fine. The non-significant but higher carcass yield tend to show that Arbocel in broiler diets had positive effect on carcass yield. This may be attributed to higher protein digestibility coefficient in birds fed Arbocel RC Fine (Farran, 2011).

The liver, gizzard, heart, spleen, pancreas and fat pad were not significantly affected by the treatments. The result is in agreement with the findings of Farran, (2012), except for the significantly lower fat pad recorded by broilers fed 0.8% Arbocel® fine diet. This tends to show that the effect of Arbocel® fine addition on organ weight did not differ from the control.

Cost of feed consumed and feed cost/kg gain were significantly higher in birds fed Arbocel® fine diets than the control. The higher values obtained may be attributed to the increased feed intake of birds fed Arbocel® fine diets and the higher costs of the Arbocel® fine feeds, since Arbocel® fine is an imported product. Contrary to this finding, Farran (2012) recorded positive effect on the cost benefit, when Arbocel® fine was included in the diets of broilers at 0.8%. This positive effect could be achieved in Nigeria if this product is produced locally or imported in large quantity.

CONCLUSION

The current results on Arbocel® fine supplementation at 0.6 and 0.8% in broiler diets showed improved quality of litter.

Weight gains and feed conversion ratios were not significantly improved in the trial as was indicated in the trials performed in other countries. Ready to cook (RTC) carcass yield were increased in the two Arbocel® fine diet groups. Inclusion of Arbocel® fine in the diets caused an increase in feed cost/kg gain contrary to reports from trials performed in other countries.

RECOMMENDATION

Further research is, however, recommended to ascertain the effect of different fiber sources used in poultry diets in Nigeria, on performance, litter quality and economics of production so as to determine the possibility or otherwise of adopting Arbocel as a dietary fiber source in the country.

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