AMERICAN UNIVERSITY OF BEIRUT

EFFECT OF A DIETARY LIGNOCELLULOSE ON EGG HATCHABILITY AND PERFORMANCE PARAMETERS OF COMMERCIAL BROILER BREEDERS AND ON THEIR PROGENY GROWN TILL MARKET AGE.

by
HAROUT APKAR AKILIAN

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Approved by:

M. T. Farran
Dr. Mohamad T. Farran, Professor — Advisor
Animal and Veterinary Sciences

Dr. Imad Saoud, Professor — Member of Committee
Biology

Dr. Shady Hamadeh, Professor — Member of Committee
Animal and Veterinary Sciences

Nuhad T. Daghir
Dr. Nuhad Daghir, Emeritus Dean — Member of Committee
Dean's Office

Date of thesis/dissertation defense: 01/22/2015

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"Only the unknown frightens men. But once a man has faced the unknown, that terror becomes the known."— Antoine de Saint-Exupéry

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Last but not least, to my wonderful family.To my father, mother and my two sisters for their eternal love and support. No amount of gratitude can express what you mean to me. I am what I am because of you.

AN ABSTRACT OF THE THESIS OF

Harout Apkar Akilian for Master of Science
Major: Poultry Science

Title: Effect of a Dietary Lignocellulose on Egg Hatchability and Performance Parameters of Commercial Broiler Breeders and on Their Progeny Grown Till Market Age.

Two experiments were performed to test the effects of Arbocel®, a dietary lignocellulose, on Ross 308 broiler breeders and their offspring. In the first experiment, 26,000 layers during their post-peak period and 2,600 roosters were placed in 6 poultry houses under commercial settings to investigate the effect of dietary lignocellulose on production and hatching performance. Corn soybean meal rations containing 0.8% wheat bran (control) were formulated to meet the specifications of both laying hen and rooster Ross breeders. Other diets containing 0.8% Arbocel®, were formulated to have the same specifications of the control diets in terms of energy, crude protein and other essential nutrients. Rations were offered to the 33-week old birds in triplicates (averaging 4,330 hens and 430 roosters per house) for a period of 6 months according to breeder recommendations. Total hatching eggs produced per treatment were labeled and set in incubators every 3 days. Hatchability was computed each month on representative samples taken from each house. The t-Test analysis revealed that Arbocel® reduced hen mortality (9.44 vs. 11.39%) and increased the number of hatching eggs/ hen housed (HH) from 105.6 to 109.4. In addition, Arbocel® improved hatchability of sampled eggs by 4.07% ($P<0.05$) and that of total eggs by 2.81%. Taking the latter figure into consideration, Arbocel® resulted in 5.7 more saleable chicks per HH and, with an actual market price of 1.60$/kg Arbocel® and 0.5$/day-old chick, Arbocel® would have resulted in an additional net profit of 2.30$/HH during this 6-month period.

In the second experiment, 1000 male broiler chicks hatched from parents of both treatments of the previous experiment were set in an environmentally controlled house (2000 broilers in total). Both the commercial (0.8% wheat bran) and experimental (0.8% Arbocel®) broiler diets were given to each of the 2 sets of 1000 birds in a 2X2 factorial treatment arrangement, with 5 floor replicates of 100 birds each. The trial's objective was to observe the interactive effect of both feed types coupled with lineage, on overall broiler performance and litter moisture content. Throughout the experiment, a significant difference in litter moisture was observed in samples collected on the 22nd day, with the Arbocel®-fed birds showing 5.59% ($P<0.05$) less moisture than their control birds, whilst on day 33, the difference in moisture levels were strictly numerical, with 2.89% less moisture in litter of Arbocel®-fed birds.

No significant differences were reported amongst all the treatments with regards to percent weights of ready to cook carcass, cut up parts and giblets as well as blood titers sampled for Newcastle Disease Virus, Infectious Bronchitis and Infectious Bursal Disease.

Key Words:Broiler breeders, broilers, dietary lignocellulose,hatchability, saleable chicks, litter moisture.

CONTENTS

LIST OF ILLUSTRATIONS

Figure Page

LIST OF TABLES

LIST OF ABBREVIATIONS

ABW	Average Body Weight
AD	Anno Domini
ADF	Acid Detergent Fiber
ANF	Anti-Nutritional Factor
AREC	Agricultural Research and Education Center
AUB	American University of Beirut
BRST	Percent Breast weight
CP	Crude Protein
CFC	Cumulative Feed Conversion
CMO	Cumulative Mortality
ELISA	Enzyme Linked Immuno Sorbent Assay
FAO	Food and Agricultural Organization
FC	Feed Conversion
FPD	Percent Fat Pad weight
GIT	Gastro-Intestinal Tract
GIZ	Percent Gizzard weight
GLM	General Linear Model
HH	Housed Hen
HRT	Percent Heart weight
IBDV	Infectious Bursal Disease
IBV	Infectious Bronchitis Virus
IBW	Initial Body Weight
IRFC	Insoluble Raw Fiber Concentrate
LDL	Low Level Lipoprotein
LIV	Percent Liver weight
MO	Mortality
NDF	Neutral Detergent Fiber
NDV	Newcastle Disease Virus
NSP	Non-Starch Polysaccharide

RTC	Ready to Cook
SAS	Statistical Analysis System
SPL	Percent Spleen weight
THIG	Percent Thigh weight
%	Percent
/	Per
et al	Et alii (and others)
Kg	Kilogram
Kcal	Kilocalorie
cc	Cubic centimeter
β	Beta

To My Family…

CHAPTER I

INTRODUCTION

In the field of animal nutrition, dietary fibers or non-starch polysaccharides (NSPs) have always been deemed as important ingredients, despite the fact that for monogastric animals, they do not add any nutritional values whatsoever,becausesaid animals don't have the natural enzymes required to break them down. Instead, these fibers express their importance byphysically impacting the general process of digestion, and whether it is a positive or negative impact is highly dependent on the type of fiber used. Generally, NSPs come in two distinct forms, either soluble (in water) or insoluble, where each has its own set of characteristics and composition. Of the two types, the insoluble fiber is more beneficial to animals and possibly more available in nature, considering it is primarily cellulosic and cellulose is one of the most abundant organic productsin the world (plant cell walls).

The Food and Agricultural Organization of the United Nations (FAO) estimates that the world's total cereal harvest of 2014 will be approximately 2,523 million tons, whereas oilcrops were reported reaching 509 million tons by May of 2014. About 10% of total cereal and oil extracted oilseeds will remain as plant residues and other varieties of plant by-products, densely rich in utilizableNSPs.This is important considering global population is increasing rapidly; hence a better management of utilizable food resources is vital to boost a sustainable agriculture for the coming future(Choct, 1997). Alternative feed sources must always be considered to be viable options for the future, considering major ingredients such as corn and soybean are not equally distributed worldwide, and are an economic obstacle to countries that can't afford importing them (Farrell, 2005)

Lignocellulose is a common termdescribing the complex constituted of cellulose, lignin and hemicellulose (Harmsen *et al.*, 2010); hence dietary lignocellulose refers toan edible insoluble fiber source.Its benefits in poultry nutrition have been reported by various scientists.Reduced cannibalism and decreased stress levels were reported amongst layers by El-Lethey *et al.*, (2000), when they were fed diets containing insoluble fiber-rich additives. The same researchers also observed a decrease in feather pecking in stressed hens when fed insoluble fiber-rich additives.Insoluble fibers were also shown to improve digestibility of different types of nutrients. Boguslawska-Tryk (2005) demonstrated an increase in proteolytic activity alongside an increase in pancreatic proteins in Cobb broilers fed Arbocel®(a commercial dietary lignocellulose), while Van Krimpen *et al*., (2007)showed an improvement in thewelfare, egg performance and feed intake of hens in early lay.Improvements in nutrient absorption and body weight gain have also been reported by González-Alvarado *et al.*, (2007) in broilers given fiber-supplemented low fiber diets.

On the other hand, soluble NSPs are more notorious for their detrimental effects on monogastric animals. They are known for possessinganti-nutritional factors (ANFs) that inhibit proper digestion and even physically alter gut physiology. Smits and Annison(1996) reported that the use of soluble NSPs led to an increase in viscosity of digesta in gut of broilers, which caused a slower passage rate. The increasedtime of residence allowed for bacterial proliferation in the small intestine, which couldbecome pathogenic and even hinder proper digestion. Accordingly, animal nutritionists avoid using large quantities when of soluble NSP when formulating diets for poultry and other monogastric animals.

The present work had two objectives. Firstly, to observe and compare the performance and egg hatchability rates between broiler breeders fed their regular commercial diet supplemented with a commercial dietary lignocellulose (0.8 % Arbocel®RC Fine),and those fed their regular commercial diet (with 0.8% wheat bran)during post-peak period in a commercial setting. Secondly, to assess if the same diets used in the first experiment coupled with the lineages of the breeders' progeny has any interactive effect on the latter's performance, including moisture content oflitter.

CHAPTER II

LITERATURE REVIEW

A. Crude Fibers

Chemical structures of NSPs are quite vast and various methods have been developed to study their components.Crude fiber is the term given to the plant cell walls that have been treated with acid and alkali, removing trace amounts of proteins, pectins and other soluble fibers; thus leaving only the insoluble portion of the NSP (Choct, 1997). The neutral detergent fiber (NDF) measures the insoluble portion of the NSP, which includes celluloses, hemicelluloses and lignin (the latter being the only organic non-carbohydrate component); the acid-detergent fiber (ADF) represents almost exclusively the cellulose and lignin contents (Bach-Knudsen, 2001).

B. General Overview on Cellulose

1. History

Cellulose was first discovered by the French scientist Anselme Payen in 1834, while he was researching different types of wood, and discovered a starch-like substance that can be broken down to into its basic units of glucose (Zugenmaier, 2008). He coined the term "Cellulose" in 1838, since he had obtained his new discovery from the cell walls of plants. However, what was known as cellulose back in the 19th and early 20th centuries is now known in modern times as the cellulose pulp, which is a purified cellulosic material (Zugenmaier, 2008).

2. Structure and Characteristics

Cellulose is one of the most abundant organic compounds found on earth, due to being the primary component of plant cell walls (Arioli *et al.*, 1998). It is a linear unbranched homopolysaccharide (1→4) -β-glucose units and its structure can be seen in the figure 1. The glucose molecules are connected via glucosidic bonds, which make way for the polymer to be arranged in long straight chains (Harmsen *et al.*, 2010). The same researchers also state that celluloseis a relatively hygroscopic material that can absorb up to 8 to14% water under normal atmospheric conditions. Its chemical structure remains the same irrespective of the source it's coming from, and is very insoluble in water and alkali solutions (Choct, 1997).

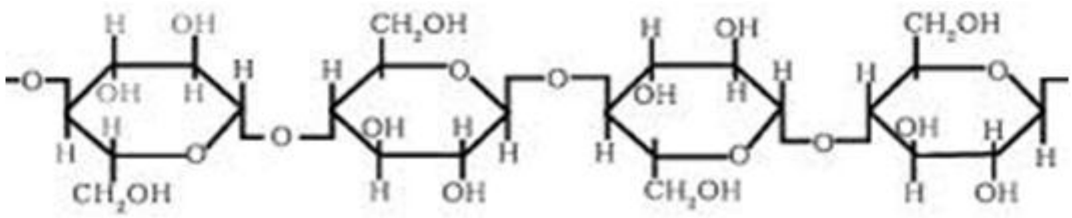

Figure 1: Basic structure of cellulose chain (adopted from npchem.co.jp)

3. Uses

One of the earliest recorded use of cellulose dates back to ancient China during the Han Dynasty, when Ts'ai Lun, an official of the Chinese Imperial court, produced paper sometime around 105 AD, using bast fibers (60-80% cellulose), the inner cell wall of the phloem (Encyclopædia Britannica: papermaking).

However, heavy use of cellulose began around a century ago, upon discovering ideal methods tochemically separate the wood cellulose from lignin (Zugenmaier, 2008). It has been involved in the production of thread-like fiber to produce clothing;celluloid films used by early motion pictures made out of cellulose mixed with camphor andas sustainable forms of insulation. Lignocellulosic biomass has also proven to be an excellent source of biofuel, allowing production of ethanol through fermentation, though the process is a long and expensive one and only recently have some cost-effective processing plants been established (Badger, 2002).

Perhaps the most important use of cellulose though, occurred in its complex lignocellulosic form as a feed ingredient, more commonly labeled as NSPs, and modern science has facilitated in understanding how the latter truly functions in monogastric animals, whereas for ruminant animals they serve as an excellent source of carbohydrates.

C. Non-Starch Polysaccharides

Non-starch polysaccharides and dietary fibers, whether soluble or insoluble, are practically synonymous by definition when mentioned in literature concerning diet and nutrition and are vital ingredients in the daily diets of humans and animals alike.

Structurally, they are complexes of various monosaccharides and depending on the source, have varying degrees of solubility, size and structure (Căpriţă *et al.,* 2010). Different types of NSPs are the result of the varying monosaccharides making up the complex, for example the presence of a large amount of cellulose or a hemicellulose will likely make an NSP an insoluble one, whereas pectins and gums would make it soluble.

Based on these varieties, NSPs can be categorized into three classes, shown in figure 2.

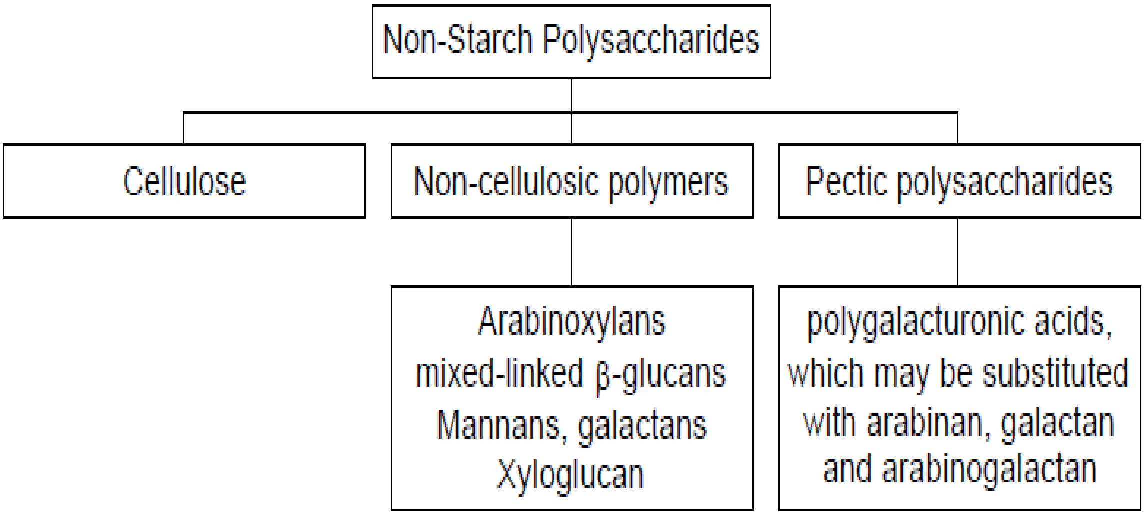

Figure 2: The three groups of NSPs (Adopted from Feed Milling International, June 1997 pp 13-26)

NSPs, specifically the insoluble ones, were once considered as harmless fillers in the diets of animals not possessing the endogenous enzymes required to break them down.However, further research in the field has opened up many doors that have allowed researchers to see them in a different and positive light.As for the soluble NSPs involved in poultry nutrition, their use is mostly avoided due to their anti-nutritive factors, which have detrimental effects that physiologically affect the gastro-intestinal tract (GIT); thus impeding nutrient absorption, via their physiochemical properties (Căpriţă *et al.,* 2010). According to the work of Smits and Annison (1997) some of these mentioned physiochemical properties include viscosity, water holding capacity and ion binding affinity.

D. Soluble Dietary Fibers

1. Characteristics and benefits of soluble fibers

As previouslymentioned, the various components of NSPs are the determining factors whether the latter is water soluble or insoluble. In the case of soluble dietary fibers, those components could be a combination of any of the pectin, guar gums, arabinoxylans, arabinogalactans and other less important carbohydrate polymers.

Soluble dietary fibers play a very beneficial role in human diets despite the fact that we are monogastrics. Besides their positive physiological mode of actions on the GIT, they also improve and buildup the intestinal microflora; hence acting as a prebiotic (Shawla and Patil, 2009).The different components of soluble NSPs are responsible for an array of benefits to human health. Pectins, guar gum and other soluble fibers, have been known to decrease the levels of low density lipoproteins (LDL-cholesterol) (Haskell *et al.,* 1991, Brown *et al.,* 1999), more commonly known as the "bad cholesterol". Similar results were also reported in rats by Ebihara and Schneeman (1989), accompanied also bya decrease in bile acids; thus shedding light on the possible mechanism of this phenomenon being due to the affinity of certain types of soluble fibers to bile acids;consequently making the body use plasma LDL to produce bile acids.

Additionally, a reduction of blood glucose was observed in diabetic patients given fructo-oligosaccharides (Yamashita *et al.,* 1984), which are inulin-based dietary fibers. Plant fibers and carbohydrates consumed in tandem have led to lower hyperglycemia than just carbohydrates alone (Anderson and Chen, 1979). The basis of such observations is due to increased digesta viscosity and reduced intestinal motility caused by the dissolving of the soluble fibers in the lumen; hence reducing the digestion of glucose (Blackburn and Johnson,1981). Also, in an experiment conducted by Loening-Baucke *et al.,* (2004)it was observed that a significant amount of children suffering from constipation and encopresis were treated by having their diets supplemented with glucomannan, a soluble NSP present in tubers of the Japanese Konjac plant.

2. Anti-nutritional factors in poultry practices

In poultry, ANFs set into motion a variety of mechanisms that substantially hinder the ideal state and function of the GIT, which leads to poorer performances of the birds. When compared to other monogastric animals such as pigs and rats, poultry (especially chicken) were found to be the least capable in fermenting fiber polymers (Jørgensen *et al.*, 1995).

According to Choct (1997), the detrimental effects of soluble NSPs are placed under three separate yet highly interrelated categories, which include viscosity, modification of gut physiology and interaction with the gut microflora. Viscosity is first and foremost expressed by the thickening of digesta, from the dissolving of fibers and forming gels, which results in increased time of its residency inside the small intestine (Gohl and Gohl, 1977). Choct and Annison (1992) documented viscosity of the digesta in broiler chickens consequently leading to the reduction of their feed intake as well as their growth and feed conversion ratio.Sticky droppings are the most common occurrence alongside digesta viscosity in poultry when viscous NSPs are included in the diet (Iji, 1999).

As mentioned earlier, physiological alterations of the gut also persist during significant uses of soluble NSPs. This statement is supported by the experiments performed by Jørgensen *et al.,* (1995) and Iji *et al.,* (2001). The former (Jørgensen *et al.*, 1995) discussed how supplementing diets with pea fiber, oat bran or wheat bran led to the increase of the length of the small intestine, as well as the length and weight of caecum in broiler chickens, while the latter (Iji *et al.,* 2001), further reiterated the previous finding, and also added that diets supplemented with different gums led to different observations, notably, guar gum caused deeper ileal crypts, whereas xanthan gum led to deeper crypts of the jejunal mucosa though the mechanisms of these phenomena are not quite understood.

Poor bird performance and digestion of major nutrients such asstarch, proteins and lipids ensued in adult Rhode Island cockerels fed pectic cell-wall material from white lupin *(Lupinus albus* L.) cotyledon (Carré and Leclercq, 1985). A significant decrease in the digestibility of lipids, starch and proteins was reported in broilers fed diets containing high viscosity carboxymethylcellulose (Smits *et al.*, 1997) and other viscous NSPs (Choct *et al.,* 1996; Józefiak *et al.*, 2003). Similar results were also observed in addition to a poor body weight gain in geese fed a pectin supplemented diet (Hsu *et al.,* 1995).

It is suggested that an increase in gut microflora due to viscosity of digesta also plays a role in reducing the digestibility of the nutrients (Choct *et al.,* 1996; Langhout, 1998), specifically fats since deconjugation of bile acids is likely to occur with elevated gut microbial colonies (Smits and Annison, 1996). Researchers who have published works on the effects of soluble NSPs also state that further experimentations are necessary in understanding the exact mechanics of the ANFs on poultry.

3. Managing ANFs from viscous NSPs in poultry diets

In spite of all the negative outcomes of soluble NSPs mentioned in the previous section, many methods exist in alleviating their presence in poultry diets. Increasing the insoluble fraction of the insoluble to soluble fiber ratio was shown to limit and even decrease the ANFs of the latter (Saki *et al.,* 2011). The authors used cellulose and pectin as insoluble and soluble fiber sources respectively.The most efficient method that is deemed cost effective, involves adding carbohydrate degrading enzymes to diets, such as xylanases and β-glucanases to depolymerize soluble NSPs into smaller polymers (Choct *et al.,* 1995; Meng *et al.,* 2005); thus greatly reducing the effects of ANFs, improving digestion and making nutrients much more accessible for absorption. These enzymes have been shown to also work hand in hand with antibiotics to even further improve nutrient digestibility in diets containing high viscous NSPs (Annison and Choct, 1991). The positive effects of adding antibiotics further provides ground that gut microflora plays a substantial role in holding back successful absorption of nutrients in the gut, however the use of antibiotics in agricultural practices are now practically forbidden under the laws set by the Stockholm Convention in 2001. As for the future, Choct (2006) speculates that new developed enzymes will be able to completely break down NSPs to their basic monomer units, thus highly benefitting the poultry industry since millions of tons of plant residues could be used as source of energy.

E. Insoluble Dietary Fibers

1. Characteristics of insoluble dietary fibers

Insoluble dietary fibers or NSPs primarily contain cellulose and sometimes non-cellulosic but insoluble carbohydrates such as hemicelluloses and lignin.They are not very well known for having detrimental effects on the health of monogastrics. In fact Davis and Briggs (1947) determined that cellulose up to 15% levels had significant growth promoting factor in New Hampshire chicks, and only mild growth inhibiting effects when used between 20 and 50% levels. Siri *et al.*, (1992) reported that a 20% supplementation of cellulose had no damaging effects on growing Leghorn chicks.

Working in a complete opposite way of its soluble counterparts, major properties of insoluble fibers include their ability to increase the rate of passage of digesta in the GIT, as well as retain and absorb water (Kirwan *et al.*, 1974; Stephen and Cummings, 1979). Feed passage rate is considered as being a very important factor in the performance, health and nutrient digestibility in birds (Svihus *et al.*, 2002).However, successful manifestations of the insoluble fiber properties are a function of the fibers' particle size (Kirwan *et al.*, 1974; Heller *et al.*, 1980; Amerah *et al.*, 2009) and will further be discussed in detail in the 3rd subheading of this section.

2. Benefits of insoluble fibers in humans

The properties of insoluble NSPs have been proven to be very beneficial for humans.Diverticular disease; an inflammation of the large bowel in adult men is one example of an illness that was highly speculated to be due to deficiency of dietary fibers in the diet (Painter and Burkitt, 1971). As a matter of fact, Aldoori *et al.*, (1998) demonstrated how an increase in insoluble fibers, especially cellulose, was directly associated with the reduction of this particular disorder. The water holding capacity of insoluble fibers allows water to be trapped in the stool, thus keeping it soft and allowing normal motility of the gut (Stephen and Cummings, 1979), which proves to be essential in maintaining ideal function and regularity of the GIT (Anderson *et al.*, 1994). The contrast between the two types of fibers has been outlined by Spiller *et al.*, (1980), where cellulose had caused a significant reduction of digesta transit time and improved the fecal weight during excretion, whereas pectins had slowed down the rate of excreta transit time as well as resulted in lower fecal weight.

Other studies involving the benefits of insoluble fibers in human health include thatof Heller*et al.*, (1980) and of Lairon *et al.*, (2005). The work of Heller and his co-authors discussed the use of coarse bran supplementation on feed to promote greater colonic health, while the latter group of researchers reported thatan inverse correlation was observed between the increasesin dietary fiber, especially the non-soluble kind, with the decrease of cardiovascular disease risks.

Last but not least, another major benefit provided by dietary fibers in humans is the reduction of cancer of the large bowel, where intake of diets high in fiber such as vegetables and whole grains, greatly reduced colorectal cancer mortality (Jansen *et al.*, 1999). According to Burkitt (1971), low prevalence of rectum cancer in Africans was most likely due to their diets rich in fiber, and that the reduction of transit time of the digesta was a possible explanation for this particular occurrence.

3. Different sources of insoluble fibers discussed in literature

This section will focus on an array of researches conducted in poultry growout practices highlighting the use of diverse insoluble fiber sources and their positive effects. For a considerable amount of time, the use of insoluble fibers in the diets of monogastrics was simply considered as diluents, holding no nutritional values whatsoever (Hetland *et al.*, 2004).

In 2000, El Lethey *et al.* tested the effects of feed form (mash and pellets) and forage materialson feather pecking and overall stress in layers. It was concluded that layers deprived of straw had lower egg production than those with access to it, though feed form played no part in this. Additionally, heterophil/lymphocyte ratio; a reliable indicator of stress in poultry, was much higher in straw-deprived birds, but significantly lower in layers with access to straw and pelleted feed, but not mash.

Hetland *et al.,* (2005) further reiterated the findings of El Lethey *et al* (2000), that layers fed diets low or lacking in insoluble fiber started to eat feathers or litter such as wood shavings (rich in insoluble fibers), to compensate for the lack of structurally coarse components in their feed, whereas the group of laying hens who were fed diets containing coarse oat hulls displayed no such behavior.

Hetland *et al.,* (2003) had already underlined the importance of these coarse components, stating that they stimulate the gizzard much more than finer ingredients and this stimulation leads to an increase in gizzard weight and of total bile acids within it, which plays a considerable role in improving absorption of nutrients. Ileal starch was considerably better digested in broilers given oat hulls and layers given wood shavings, when both types of birds were offered wheat-based diets. In fact, Oat is a type of cereal grain that, because of its hull, is rich in insoluble fibers (Bach-Knudsen, 1997). The presence of coarse oat hulls in broiler diets showed effects very similar to that of other insoluble fiber sources, where feed passage time was decreased and better nutrient absorption and higher feed intake were observed (Hetland and Svihus, 2001).Finer oat hulls failed to have any effect on speeding up the rate of passage of the digesta.

Crude protein is another macronutrient that was better absorbed by broiler breeders fed diets including 3% cellulose. Additionally, the diet caused lower abdominal fat weight and increased fertilization of eggs among various positive observations made by Mohiti-Asli *et al.,*(2012).Furthermore, Farran *et al.,* (2013) in addition to decreased litter moisture, also observed a significant increase in protein digestion in Ross 308 broilers fed lignocellulose-supplemented diets. Similar results were obtained regarding apparent and true digestibility of crude protein, as well as amino acids in Cobb broilers fed lignocellulose-supplemented diets (Farran, unpublished data). Regarding improved protein digestion, this can most likely be explained via experiments by Boguslawska-Tryk (2005), where she associated the implementation of Arbocel®BWW-40 (a commercial insoluble fiber) in Cobb diets, with the increase in proteolytic activity of the pancreas, as well asin pancreatic enzymes trypsin and chymotrypsin which suggests an improved digestion of proteins. In a more recent experiment conducted by Lim Jr. *et al.*, (2013), insoluble rich fiber concentrate (IRFC) at 0.8% inclusion in diets given to 19-week old DeKalb layers yielded a significant increase in egg production as well as improved feed utilization.

Other sources of insoluble fibers included the sawdust of the tree species *Daniellia ogea,* where it was given to Anak broilers in an experiment performed by Oke and Oke (2007). Broilers fed diets containing 8%/Kg of this sawdust showed a significant increase in weight gain, feed intake and weights of their carcassand cut-up parts when compared to broilers fed fiber-free control diet, as well as diets containing fiber levels less than 8%/Kg, or much higher levels than 8%/Kg (suggesting nutrient dilution).

As mentioned earlier, insoluble fibers such as cellulose exert beneficial effects by reducing detrimentalANFs of feed ingredients rich in soluble NSPs. An example of such an ingredient is wheat. Wheat is rich in protein and starch but the presence of soluble NSPs leads to poor digestion of starch (Choct *et al.,* 1999).However, it was shown that when cellulose was added to wheat-based dietspre-pelleting, starch absorption was significantly increased in broilers (Svihus and Hetland, 2001).

The present manuscript describes experiments performed to examine the economic significance of supplementing insolubledietary fibers in poultry diets on a commercial level based on previously published works involving small scale practices, as well as extending our knowledge on how lignocellulose can improve the performances of both breeders and their progeny.

CHAPTER III

MATERIALS & METHODS

A. General Procedure

Experimental protocols in the present work were according to the guidelines and regulations set by the Institutional Animal Care and Use of the American University of Beirut (AUB).

The first experiment was performed to assess the effects of Arbocel®, a dietary lignocellulose, on Ross 308 broiler breeders. A regular commercial diet supplemented with 0.8% Arbocel® was fed to broiler breeders having reached their post-peak production period. Various parameters such as mortality and egg hatchability were observed and compared to post-peak broiler breeders who were fed strictly the commercial diet (mixed with 0.8% levels of wheat bran). This experiment took place in poultry houses, in a commercial setting, at Tanmia Farms in the Bekaa region.

The second experiment was performed at the Agricultural Research and Education Center (AREC) of the American University of Beirut, situated in the Bekaa region. Male offspring from the 2 experimental sets of broiler breeders used in the first experiment were used, with each set of males split into 2 subsets. Each subset was fed either the regular commercial diet with 0.8% wheat bran, or the 0.8% Arbocel® supplemented commercial starter and finisher diets. All four subsets (treatments) were then compared amongst themselves for various parameters to underline any changes in their performance.

B. Analysis of Arbocel®

Table 1 represents the analytical composition of Arbocel®RC Fine, provided by Berghof Analytik and IGV Institute.

Table 1: Analytical Composition of Arbocel® RC Fine.
Values are as reported by Farran *et al.,* (2013).

Characteristics	**Rate**
Humidity	5.70%
Neutral Detergent Fiber (NDF)	88.80%
Acid Detergent Fiber (ADF)	70.50%
Acid Detergent Lignin (ADL)	24.30%
Insoluble Dietary Fiber (IDF)	88.80%
Soluble Dietary Fiber	ND
Crude Cellulose	67.90%
Crude Protein	0.30%
Lipids	0.50%
Water Retention	600-700%

ND: Not Detected

C. Experiment 1

For this experiment, 26,000 layers in their post-peak period (33 weeks of age) and 2,600 roosters of Ross 308 parent strains were used in a complete randomized design in a span of 6 months, to test the effects of Arbocel® on production and hatching performance of broiler breeders. All birds were reared by Tanmia Farms, following guidelines set by the Ross 308 broiler breeder manual prior to reaching their post-peak stage.The birds were distributed in 6 adjacent commercial poultry houses (averaging

4,330 hens and 430 roosters/ house). The houses were all equipped with laying nests, automatic drinkers and separate feeders for males and females. Corn soybean meal rations were formulated (table 2), to meet the specifications of parent breeders provided by the Ross Company. The rations were either mixed with 0.8% wheat bran and fed to birds in the control treatment in 3 houses, or with 0.8% Arbocel® for the experimental treatment, used in the remaining 3 houses. Both diets were formulated to have the same specifications in terms of energy, crude protein, amino acids and other essential nutrients; hence all diets used in the 2 treatments are isocaloric and isonitrogenous. All birds followed a light schedule (~15 hours) and were fed daily at the amounts set by the breeder manual. Water was provided*ad libitum*.

Egg production was recorded daily and graded into different categories; undersized, oversized, cracked and soiled eggs were all discarded. On a monthly basis, the eggs were counted in each category and hatching eggs from each replicate were labeled and set apart in a collective incubator for 18 days and then moved to a hatcher for 3 days. On the 10^{th} day, eggs were subjected to candling to determine fertilization and dead-in-shell eggs were not taken into consideration. The number of sampled eggs picked from each house is given in table 3. The day old chicks were counted, graded and percent hatchability was compared using the t-Test. Remaining data was analyzed using the General Linear Model (GLM) and means were separated using Duncan's multiple range test (SAS, V. 9.2, Rockville, MD 20850, United States).

Table 2: Feed Composition of the First Experiments' Diets in Kilograms per Ton

Ingredients	Control Male	Arbocel® Male	Control Female	Arbocel® Female
Yellow Corn	678	681	649.5	634.5
Soybean 48%CP	150	154	255	257
Wheat Bran	140	125	8	-
Arbocel®RC Fine	-	8	-	8
Limestone	20	20	73	73
Salt	3	3	3.2	3.2
DL Methionine	-	-	0.3	0.3
Vit& Min Mix*	3	3	3	3
Mono Calcium Phosphate	6	6	6	6
Soybean Oil	-	-	10	15
Calculated Composition				
ME (kg/kcal)	2850	2850	2900	2900
CP (%)	15	15	17.5	17.5
Methionine + Cysteine (%)	0.50	0.50	0.60	0.60
Lysine (%)	0.88	0.88	0.90	0.90

*Provided per kilogram diet for males and females: Vitamin A (retinyl acetate), 11000 IU, Vitamin D3 3500 IU, Vitamin E (DL-α-tocopheryl acetate), 100 IU, Vitamin K (Menadione) 5mg, Thiamin (B1) 3mg, Riboflavin (B2) 12mg, Nicotinic Acid, 55mg, Pantothenic Acid, 15mg, Pyridoxine (B6) 4mg, Biotin 0.25mg, Folic Acid 0.25mg, Vitamin B12 0.03mg, Choline, 1000mg, Cu (copper sulfate) 10mg, I (potassium iodide) 2mg , Fe (ferrous sulfate monohydrate) 50 mg, Mn (manganous oxide) 120 mg, Se (sodium selenite) 0.3 mg, Zn (zinc oxide) 110 mg.

Table 3: Number of Sampled Eggs/Month/House.

Houses 1 to 3 Represent the Experimental Arbocel® Trial and 4 to 6 the Control Group

		Number of Sampled Eggs					
Treatment	**House**	**1st month**	**2nd month**	**3rd month**	**4th month**	**5th month**	**6th month**
Arbocel®	1	576	864	864	432	432	432
	2	432	864	864	432	432	432
	3	432	864	864	432	432	432
Control	4	576	864	864	432	432	432
	5	432	864	864	432	432	432
	6	432	864	864	432	432	432

Amount of sampled eggs collected from each treatment were equal for every month throughout completion of the experiment. These values represented the number of eggs used in evaluating hatchability and infertile eggs percentages, though total population of eggs produced throughout the entirety of this experiment were also subject to hatchability and fertility evaluations and will be discussed in the results and discussion section of this manuscript.

D. Experiment 2

One thousand day-old male chicks from each of the Arbocel®-fed and the control parent breeders of the previous experiment were collected and transported to AREC. They were placed in an environmentally controlled house equipped with an extra heavy duty heater to keep the temperature in check depending on the experiments' requirements, considering the onset of the trial was November 30th, and harsh cold weather persisted in the Bekaa region.

The chicks were raised in 20 floor pens, with 100 chicks per pen. The experimental design was that of a 2x2 factorial arrangement. The main factors were lineage (Arbocel® or control fed parents) and Arbocel® and control feeding to progeny. In other words, chicks originating from parents fed the control diet were fed both the control and the Arbocel® diets, and the same treatments were applied to chicks coming from the Arbocel® fed parents. Each treatment was replicated 5 times with 100 birds per replicate. Feed and water were provided *ad libitum*. The composition of the isonitrogenous and isocaloric starter and finisher rations containing 0.8% wheat bran or Arbocel® are given in table 4.

During the experiment, representative litter samples, feed consumption and weight of birds were collected at 22 and 33 days of age. The litters were dried and analyzed for moisture content and feed conversion values were computed. Antibody titers for Newcastle Disease Virus (NDV), Gumboro (IBDV), and Infectious Bronchitis (IBV) were determined in sera samples using enzyme-linked-immuno-sorbent-assay (ELISA), in day-old chicks and at the ages 22 and 33 days. The blood samples were collected from 2 birds chosen at random from each pen.

Table 4: Feed Composition of the Second Experiments' Diets in Kilograms per Ton

	Starter Diets		Finisher Diets	
Ingredients (%)	**Control**	**Arbocel®**	**Control**	**Arbocel®**
Corn	526.5	520.4	611.7	605.7
Soybean Meal (48% CP)	377.3	381.0	300.2	303.8
Arbocel® RC Fine	----	8	----	8
Wheat Bran	8	----	8	----
Sunflower Oil	47.4	50	38.4	40.9
Salt	4.5	4.5	4.4	4.4
Limestone	11.8	11.7	11.7	11.7
Dicalcium Phosphate	17.9	18.0	18.5	18.6
DL-Methionine	2.9	2.9	2.5	2.5
L-lysine. HCl	0.2	0.1	0.9	0.9
Vit. & Trace Min. Premix[2]	3	3	3	3
Coccidiostat[1]	0.63	0.63	0.63	0.63
Calculated Composition				
ME (kcal/kg)	3200	3200	3200	3200
CP (%)	23	23	20	20
Methionine + Cysteine (%)	1	1	0.88	0.88
Lysine (%)	1.25	1.25	1.1	1.1

[1]Starter diets contained the coccidiostat Maxiban at 0.0625% as recommended by ELANCO.
[2]Provided per kilogram diet: vitamin A, 12,500 IU (retinyl acetate); cholecalciferol, 2500 IU; vitamin E, 30 IU (DL-α-tocopheryl acetate); vitamin K_3, 3 mg; thiamin, 2 mg; riboflavin, 6 mg; niacin, 30 mg; pantothenic acid, 10 mg; vitamin B_6, 5 mg; vitamin B_{12}, 0.02 mg; folic acid, 1 mg; biotin, 0.05 mg; choline, 300 mg; vitamin C, 100 mg; butyrated hydroxytoluene, 125 mg; Mn (manganous oxide), 96 mg; Zn (zinc oxide), 80 mg; Fe (ferrous sulfate monohydrate), 82 mg; Cu (copper sulfate), 8 mg; I (potassium iodide), 2.4 mg; Co (cobalt sulfate), 0.8 mg; Se (sodium selenite), 0.014 mg.

Also, it is important to mention that blood samples were withdrawn on the first day at the hatchery from birds belonging to the two lineages treatment. Thusresults expressedmaternal antibody titers in the day-old chicks.

At the end of the trial, 5 birds representing the average live weight of a pen were selected, leg banded and processed at the processing laboratory at AREC. Weights of Ready to Cook carcasses (RTC), livers, spleens, hearts, gizzards and abdominal fat pads were recorded, as well as breast muscles and thighs. All analyses were performed using the General Linear Model and means were separated using Duncan's multiple range test (SAS, V. 9.2).

E. Vaccination Program

The vaccination program used in the second experiment is given in table 5, along with their dosages and administration routes.

Table 5: Vaccination Program Implemented in the Second Experiment

Age (Days)	**Vaccine**	**Administration Route**	**Dosage**
7	AI-H9/Oil-ND	Subcutaneously	0.5 cc
10	IB-491/Biovac ND Clone	Eye Drop	2 Drops (1 per eye)
15	Biovac ND Clone	Intramuscular	0.5 cc
23	ND	Eye Drop	1 Drop

Vaccines for avian influenza H9 strain (AI-H9) and Newcastle disease (oil emulsion) were well mixed and given to all the birds on day 7 of age. Three days following the first vaccination (day 10), vaccine against Infectious Bronchitis of 4-91 serotype (IB-491) was well mixed with a booster Biovac Newcastle Disease (ND) and given to all the birds. Same booster was given again after five days and then on day 33.

CHAPTER IV

RESULTS & DISCUSSION

A. First Experiment

1. Performance and Productivity of Breeders

One week prior to the start of the first experiment, egg production and hatching proportion per housed hen were assessed for the control birds and those that were to be fed the Arbocel® diet and no distinguishable differences were observed between the two groups.Various egg types and mortality percentages were recorded and analyzed from the onset of the trial up until its conclusion 6 months later and results arepresented in table 6.

Table 6: Average Number of Eggs Produced per Housed Hen (HH) and Cumulative Hen Mortality (%) for Control and Arbocel® Treatments During the Six Month Experimental Period.

	Treatment		**SEM[1]**
Number of Eggs per HH	**Control**	**Arbocel®**	
Total	111.8	114.8	1.52
Hatching	105.6	109.4	1.56
Table	3.6	3.4	0.16
Large	0.6	0.6	0.05
Cracked	1.3	0.9	0.21
Discarded	1.0	0.9	0.06
Cumulative Hen Mortality (%)	11.4	9.4	1.31

[1.] Pooled standard error of means

The differences between the two treatments seem to be strictly numerical, with the most evident ones being the percent mortality of the females, where it was higher for the control treatment at 11.4% as compared to the experimental treatment's 9.44% and the hatching eggs per HH at 109.4 for the Arbocel® treatment versus the control's 105.6. %.

The previous statement is in agreement with results obtained by of Lim Jr. *et al.*, (2013), where they reported a significant increase in egg production by 3.43% in layers fed IRFC. Inchaoren and Maneechote (2013) further supported these findings when they reported a 2.56% increase in hen-day egg production in hens fed white rice hull (as source of insoluble fiber) at 6% replacement to corn, when compared to hens fed the control diet.

Average infertile eggs and hatchability percentages of the monthly sampled eggs throughout the entire duration of the trial and their values are represented in table 7.

Table 7: Percent Hatchability and Infertile Eggs Sampled from Hens Fed Control and Arbocel® Diets Over the Six Months Trial.

		1st month	**2nd month**	**3rd month**	**4th month**	**5th month**	**6th month**
Hatchability (%)	**Arbocel®**	77.1[a]	77.7[a]	76.9[a]	71.1[a]	66.3[a]	62.0[a]
	Control	73.0[b]	71.8[b]	74.2[b]	66.7[b]	62.9[b]	58.0[b]
	SEM[1]	1.03	0.90	0.60	1.40	0.66	0.78
Infertile eggs (%)	**Arbocel®**	0.63	0.57[b]	0.44[b]	0.29[b]	0.33	0.21
	Control	0.72	0.63[a]	0.65[a]	0.46[a]	0.35	0.20
	SEM[1]	0.089	0.023	0.035	0.024	0.011	0.013

[ab,] Within a column, for each criterion, averages with no common superscripts are significantly different ($P < 0.05$).

[1.] Pooled standard error of mean

A significant difference was observed in egg hatchability during every month of the trial, with the Arbocel® treatment yielding better results. Arbocel® improved hatchability of sampled eggs by 4.07% ($P<0.05$), with the greatest individual difference being observed during the second month, where hatch proportion of eggs of fowl fed the Arbocel® was 5.9% more than control, whereas the least significant difference was seen during the third month at 2.7%. As for changes in infertile egg percentages, the experimental group resulted in lower infertile eggs than control, with values decreasing in tandem with increasing values found in the hatchability percentages. On the first month, an insignificant difference was observed followed by a significant difference from the second month up to the fourth (highest being 0.21% and the lowest 0.06%) all the while favoring Arbocel® group, and afterwards decreased to negligible differences for the remainder of the trial. This phenomenon, along with the numerical increase of total egg production shown in table 6, is in accordance with the findings of Mohiti-Asli *et al.*, (2012), where they reported an increase in egg fertility rate in broiler breeders fed dietary inulin or cellulose at a rate of 3%. The positive results obtained from the present experiment are most likely because of positive effects of dietary lignocellulose on digestion, whereby improving its process allowed forbetter digestibility of nutrients.

Economically, these differences are of a significantimportance. Poultryindustries nowadays aim to improve and make more profit in innovative ways under the confines of ethics and safe practice, and the method of insoluble fiber is a sustainable one. This experiment sets a good example, considering it is the first time the effects of dietary lignocellulose are being assessed on a commercial setting. The following table (table8) provides various compiled results of all the objectives of interest for this experiment.

Table 8: Differences of Hatching Eggs per HH, Hatchability of Total Eggs and Number of Chicks Hatched per HH between the Two Treatments

	Control	Arbocel®	Difference
Hatching Eggs in 6 months/HH (Breeder Farm Data)	105.6	109.4	+ 3.8 eggs
Hatchability of Total Eggs (% as per hatchery data)	68.7	71.5	+ 2.81%
Number of Chicks Hatched/Hen Housed	72.6	78.3	+ 5.7 chicks

Hatchability of total eggs was increased by 2.81%, favoring the Arbocel® treatment. The improved hatchability resulted in an additional 5.7 saleable chicks per housed hen, whereas egg production per HH got increased by 3.8%. Taking the hatchability value of total eggs (2.81%) into consideration, and knowing that the market price of a day-old chick stands at 0.5$, and that of Arbocel® at 1.60$/kg, a net profit of 2.30$/ HH was obtained from calculations. However, if the value of improved hatchability of sampled eggs (4.07%) was to be used in the same calculations, much higher profit per HH is to be expected.

Lastly, the effect of Arbocel® on other parameters such as egg weight and hen and rooster body weights was investigated. No significant differences were reported in any of the said parameters throughout the entire duration of the experiment.

B. Second Experiment

1. General Performance Parameters

At the start of the second experiment, 2000 chicks were weighed in bulks of hundreds before being distributed in to the floor pens. The recorded weights showed no significant differences in initial body weight (IBW) between the chicks hatched from the control and Arbocel® parents. This phenomenon was to be expected,considering no significant egg weight differences from the two breeder treatments were observed. The rationale behind this result or lack thereof couldmost likelybe due to the fact that dietary lignocellulose is not a digestible nutrient for monogastrics; hence it cannot be passed from mother to embryo and have its effects expressed on the chicks post hatch. Displayed results in table 9 show a similar trend of insignificant differences observedalong the entirety of the experiment, concerning average body weight, feed conversion and mortality by the age of 22 days (ABW22, FC22 and MO22, respectively), as well as the cumulative FC (CFC), cumulative MO (CMO) and ABW33 by the termination date of the experimentat 33 days.

Table 9: Initial and Average Body Weights (IBW and ABW), Feed Conversion Ratios (FC), Cumulative FC (CFC) and Mortality (MO) Rates at 22 and 33 days (CMO).

		IBW	ABW22	FC22	MO22	ABW33	CFC	CMO
Lineage	**Arbocel®**	47.0	752.4	1.79	1.8	1805.4	1.73	8.8
	Control	47.3	779.6	1.70	1.0	1866.1	1.71	6.2
	Average	47.2	766.0	1.75	1.4	1835.8	1.72	7.5
Diets	**Arbocel®**	47.5	775.1	1.73	1.3	1848.5	1.74	7.7
	Control	46.9	756.8	1.77	1.5	1823.0	1.75	7.3
	Average	47.2	766.0	1.75	1.4	1835.8	1.75	7.5
SEM[1]		0.36	12.10	0.033	0.48	24.08	0.022	0.88

[1.] Pooled standard error of mean

Results found in table 9 suggest that neither lineage, dietary lignocellulose nor the interaction between them had any effect on the body weights, feed conversion or mortality. This is not in accordance with results found in the experiment of Sarikhan *et al.,* (2010), where broilers fed an insoluble fiber rich concentrate at levels of 0.5% and 0.75% displayed a larger body weight and an improved feed conversion compared to broilers fed the control diets containing 0% of this supplement. On the other hand, the results obtained are in full agreement with that of Farran *et al.,* (2013) where no significant differences were observed in the body weights and feed conversions of male Ross 308 broilers fed the control and the Arbocel® experimental diets.

2. Analyzed Sera Titers

The effect of Arbocel® on the immune system was also investigated via analyzing the blood titers of the 4 treatments for Newcastle Disease Virus (NDV), Infectious Bronchitis (IBDV) and Infectious Bursal Disease (IBV). Blood sampling was performed on days 1, 22 and 33. The blood withdrawn on the first day was strictly between the two treatments of chick types as it was conducted at the hatchery and not yet implemented in the experimental design.

The average titer results of day-old chicks can be seen in the next table (table 10). Maternal titers were only numerically higher than the titers of chicks coming from Arbocel®-fed parents for all three diseases tested in the experiment, where for IBV it was 2615 as opposed to 2124, for IBDV 5399 against 3613 and for NDV 2194 versus 803.

Table 10: Average Antibody Titers of Day Old Chicks for IBV, IBDV and NDV

Parents	IBV	IBDV	NDV
Control	2615	5399	2194
Arbocel	2124	3613	803
SEM[1]	321.9	830.6	739.1

[1.] Pooled standard error of mean

The ELISA analysis of blood sera titers of broilers fed the Arbocel® or control diets at 22 and 33 days of age for the same three diseasesare displayed in table 11.

Table 11: Average Antibody Titers for Infectious Bronchitis Virus (IBV), Infectious Bursal Disease Virus (IBDV) and Newcastle Disease Virus (NDV) at 22 and 33 days.

		IBV d.22	IBV d.33	IBDV d.22	IBDV d.33	NDV d.22	NDV d.33
Lineage	**Arbocel®**	478.2	581.4	195.7	507.8	1.6	300.3
	Control	265.3	810.4	222.9	466.1	3.7	1031.8
	Average	371.8	695.9	209.3	487.0	2.7	666.1
Diets	**Arbocel®**	249.5	343.2	213.5	444.4	4.2	774.6
	Control	494	1048.6	205.1	529.5	1	557.4
	Average	371.8	695.9	209.3	487.0	2.6	666
SEM[1]		280.53	313.14	41.53	75.15	1.22	402.64

[1.] Pooled standard error of mean

The results of table 11show that neither lineage, dietary lignocellulose nor the interaction between the two affected the immunity of the birds, as the blood titers were all comparable amongst each other at all ages. The titers against IBV, IBDV and NDV increased for all treatments from day 22 to day 33, which is a classical pattern in vaccinated birds. However, lack of consistent homogeneity of titers in birds, specifically for IBV and NDV at day 33 resulted in non-significant differences between treatments, as reported by Little and Hill (1978). Low NDV titers observed on day 22 (8 days post-booster) indicates low immunogenicity of the used vaccines; results that are in accordance with previous literature (Barbour *et al.,* 2013; Sa'idu and Abdu, 2008; Chong *et al.,* 2010; Hossein *et al.,* 2010). Low immunogenicity of said vaccines is further reflected in sera titers at 33 days of age, where the high variability in titers among replicates resulted in non-significant differences between treatments (Barbour *et al.,*2013).

3. Moisture Analysis in Broiler Litters

Having a dry litter is imperative in maintaining ideal health conditions of the birds. The moister the litter, the more ammonia gas is released in the air which in turn is toxic, proliferation of bacteria also persists leading to various diseases (Miles and Butcher, 1995). Another issue is footpad dermatitis (lesions of ventral footpads of chicken), caused by wet litter combined (Pietsch, 2013).

Insoluble dietary fibers are known for causing dryer poultry litter due to their water retention abilities (Pottgüter, 2008). On that basis, it was expected from Arbocel® to provide similar results. Litter samples were collected on the 22nd and 33rd days, from 5 different spots in each of the 20 floors pens and were then weighed. After drying, the samples were weighed again and their moisture contents determined.The results are shown in table 12 and interaction is not taken into account for this part of the experiment as this factor is directly affected by the diet.

Table 12: Litter Moisture Content Sampled at Days 22 and 33

Treatment	Litter moisture day 22	Litter moisture day 33
Arbocel®	32.9[a]	46.0
Control	38.5[b]	48.9
SEM[1]	1.64	1.27

[ab,] Within a column, averages with no common superscripts are significantly different (P < 0.05)

[1.] Pooled standard error of means

A significant difference of 5.59%(P<0.05) moisture contentwas observed at day 22; whereas only a numerical difference of 2.89% in favor of Arbocel® was reported on the last day (33rd day). These results suggest that the inclusion of Arbocel® plays a substantial role in decreasing moisture content in litter. These findings are in agreement with that of Rezaei *et al.,*(2011) where he reported a significant decrease in litter moisture content of Ross 308 broilers fed diets that included levels of 0.5% micronized insoluble fibers. They are also more recently in agreement with the findings of Farran *et al.,* (2013), where they demonstrated a significant decrease in litter moisture with male broilers fed diets supplemented with 0.8% Arbocel®RC Fine dietary lignocellulose. However, a difference of 3% appearing on the 33rd day was not enough to report any significance. Harsh cold weather conditions persisting around the time may have been the reason for elevated moisture content in litter of 33rd day when compared to samples taken on the 22nd day and could be an explanation for a lack of significant reduction in litter moisture content for Arbocel® treatment.

4. Broiler Performances Post Slaughter

For the last part of the second experiment, 5 birds representing the average live weight of each of the 20 floor pens (100 birds in total), were slaughtered and eviscerated with their carcasses (ready to cook) weighed alongside their cut up parts (breasts and thighs), giblets (including hearts, gizzards and lungs), spleens and fat pads. The weights of each of these parameters were then computed as percent body weight and their values are represented in table 13.

Table 13. Percent ready to cook carcass (RTC), gizzard (GIZ), liver (LIV), heart (HRT), spleen (SPL), fat pad (FPD), breast (BRST) and thigh (THIG) of broilers fed Arbocel® and control diets for 33 days, and originating from parents fed either control or Arbocel® rations.

		RTC	GIZ	LIV	HRT	SPL	FPD	BRST	THIG
Lineage	**Arbocel®**	71.2	1.68	2.31	0.63	0.12	0.82	19.8	27.3
	Control	71.6	1.67	2.21	0.60	0.14	0.87	19.8	27.7
	Average	71.4	1.68	2.26	0.62	0.13	0.85	19.8	27.5
Diets	**Arbocel®**	71.2	1.64	2.23	0.60	0.13	0.83	20.1	27.3
	Control	71.6	1.72	2.29	0.62	0.13	0.85	19.5	27.9
	Average	71.4	1.68	2.26	0.62	0.13	0.84	19.8	27.6
SEM[1]		0.52	0.034	0.036	0.015	0.005	0.056	0.32	0.19

[1.] Pooled standard error of mean

No significant differences were observed from either of the individual factors of parents or diets or from their interaction. Results of some of these parameters, specifically that of the RTCs and fat pads, contradict to those of Farran *et al,* (2013) who had previously reported that inclusion of the same Arbocel® RC Fine in broiler diets had yielded higher percentages of ready to cook carcasses and lower fat pads in Ross 308 broilers when comparedto their control counterparts. However in this experiment we observe a negligible numerical difference of lower FPDs in the experimental trial alongside as well as comparable RTC weights between the different groups.A possible explanation for such values could be the duration of the experiment, as it lasted in total 32days (the 33rd day was not taken into account as it was termination day) and mean live weight of birds were in the range of 1,8 Kgwhereas in the experiment of Farran *et al,*. (2013), the broilers were slaughtered on the 38th day; hence 37 days old, and represented a mean live weight of 2 Kg.

CHAPTER V

CONCLUSION & RECOMMENDATION

The need to implement dietary lignocellulose on a commercial scale experiment was backed by many researchers who have determined that low levels of this ingredient generally yielded positive results on smaller experimental scales, and barely represented any adverse effects.

The purpose of the first experiment was to observe the impact of Arbocel®, a dietary lignocellulose, supplemented at a 0.8% level to a commercial diet, on the hatchability and fertility rates of eggs laid by broiler breeders during their post peak period. The experiment returned excellent results, with significant differences showing in both fertility and hatchability rates for the experimental breeder trial as opposed to control. Also a numerical improvement in reducing mortality was observed, again favoring the experimental group. In addition, no significant differences were reported between control and experimental groups concerning the body weights of males, females as well as that of the eggs.

The second experimentwas designed to further study the benefits of the same lignocellulose on the performance of offspring of both groups used in the first experiment, including litter moisture content. Whether an interactive effect between the lineage and lignocellulose existed or not was the primary objective to observe, and the results proved that it did not. The results showed comparable differences between the two trials in terms of RTC, giblet, spleen and fat pad weights, and suggested the dietary lignocellulose used did not improve broiler performance any further than the usual commercial diets used in regular practice. On the other hand, the inclusion of Arbocel®

has proved to be effective in reducing moisture content in the litter, as results showed a significant difference between the two trials, with the experimental group showing a lower moisture rate than its control counterpart on the 22^{nd} day, and a numerical difference on the 33^{rd}.

From the two experiments conducted, several conclusions were drawn. Arbocel® dietary lignocellulose at 0.8% supplementation greatly improved fertility and hatchability of sampled eggs in breeders during their post-peak period as the improved performances resulted in 5.7 more saleable chicks per housed hen, greatly increasing income and profit in large breeder practices. In addition, the same levels of supplementation of this fiber in commercial broiler diets significantly reduced moisture content in the litter of broilers; though it did not impact their performance in any other way, be it on the immunological level involving sera titers to IBV, IBDV and NDV, or at the level of post-slaughter parameters such as RTC, giblets, spleens and fat pads. However, other experiments involving Arbocel® have shown contradictory outcome in the latter parameters, demonstrating favorable results; hence, further experimentations hold a high potential in determining the positive aspects of Arbocel® in broilers.

All the gathered data from both experiments, especially the first, greatly encourage the supplementation of commercial diets with Arbocel® at 0.8% level to improve the performance and quality of life of the breeders all the while increasing profits in a very sustainable and cost-effective manner. As for the broilers, it is recommended in order to substantially reduce moisture in the litter, all the while holding the promise of improving other performance parameters with additional experiments.

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