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EFFECT OF DIETARY LIGNOCELLULOSE ON METABOLIZABLE ENERGY AND NUTRIENT DIGESTIBILITY COEFFICIENTS IN POULTRY DIETS AND ON BROILER PERFORMANCE UNDER COMMERCIAL SETTINGS

by
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AN ABSTRACT OF THE THESIS OF

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Title: Effect of dietary lignocellulose on broiler performance and on nutrient digestibility in roosters

In order to examine and evaluate the effect of Arbocel® (lignocellulose) on the quality of litter, performance and carcass yield of broilers at market age, a field experiment was conducted on 9140 straight run day old chicks of the Cobb 500 strain. Under the ruthless winter conditions of 2012, two poultry houses were chosen to perform the experiment. Each poultry house included two sections containing 2285 birds. Starter, grower and finisher diets containing either 0.8% wheat bran (control) or 0.8% Arbocel® for the first 10 days, 11 – 32 days and 33 – 41 days, were provided to nourish the birds, respectivey. Arbocel® fed birds were examined for litter moisture at 20 days and at market age.Results showed that the litter of Arbocel® fed birds had a 3.8 and 7.2% less moisture ($P<0.05$) than those fed 0.8% wheat bran, at 21 and 40 days of age, respectively. On the other hand, results for final market live weight, feed conversion, yield of ready to cook carcass (RTC) and giblets were equivalent for both groups fed the different treatments, but a minor numerical increase in RTC yield in favor of the Arbocel® treatment was noticed.

A second experiment was conducted on thirty six dubbed Hy-Line roosters aged 55 weeks. A precision feeding digestibility trial was performed on the roosters in order to test for the effect of Arbocel® on true protein digestibility, apparent and true metabolizable energy (AME and TME), AME and TME corrected for endogenous nitrogen loss (AME_n and TME_n), and apparent and true digestibility coefficients of amino acids. The roosters were divided into four equal groups. The broiler finisher diets fed included three treatments, control, control with 0.8% wheat bran, control with 0.8% Arbocel®. The formulation of the diets in the three treatments included the same level of energy (3200 kcal/kg) and crude protein (20%). The nine roosters in each of the 3 groups were independently precision force fed with 30g of each diet, while the 9 remaining roosters from group 4 were independently precision fed with 30 g glucose powder to estimate endogenous and metabolic energy and amino acid losses. Total fecal collection was performed and dried feed and feces samples were tested for gross energy and analyzed for proximate chemical composition and amino acids. The inclusion of Arbocel® in diets did not have any significant effect on energy values of the diet. On the other hand, the protein digestibility and digestibility coefficients of both apparent and true amino acids significantly increased. Arbocel® should be considered a cost effective natural feed additive in poultry ration formulation.

Keywords: Arbocel®, broilers, performance, carcass quality, roosters digestibility, proteins, amino acids

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CHAPTER I

INTRODUCTION

Poultry production sector in developing countries is always faced by an increase in the cost of production due to the increased prices of feed components. Cellulose and fibers are minimally used in poultry nutrition. In addition, the increased litter moisture resulting from the environmental conditions under which the poultry flocks are raised is affecting directly the performance of the birds and subjecting them among others to respiratory disease. Non starch polysaccharide (NSP) known as crude fiber (Wilson and Beyer, 2000) can be divided into soluble NSP and insoluble NSP. Soluble NSP is believed to be poorly digested and also affect the digestion of other feed components. Viscosity of digesta, wet litter and sticky droppings are part of this problem. The addition of enzyme to such feed may increase its nutrient digestibility,metabolizable energy and broiler performance (Farran et al., 2010). Insoluble NSP improve nutrient digestion in poultry (Svihus and Hetland, 2001; Hetland et al., 2005). Pottgüter (2008) recommends the use of fiber for good digestive function of laying hens with positive impacts on the problems of pecking disorder and litter quality. Sarikhan et al. (2010) stated the importance of insoluble fiber on the growth of broiler chickens and on carcass. A natural ligno-cellulose product was recently established; it is known as Arbocel® RC fine and was recently introduced into the Lebanese market. Ligno-cellulose is mentioned on the Positive List of Feed Materials (Reg. No. 12.08.01) of the German Agricultural Society (DLG). Arbocel is mainly a pure α-cellulose in a powdered or fibrous form, and has all the properties of cellulose as previously mentioned.

According to JRS Co. Arbocel® RC fine will not only improve the performance, but also due to its high water binding capacity, it will minimize the wet litter problem in broiler houses. This feed additive contains the following characteristics. First, it will improve performance, and decrease the wetness in the litter due to its binding capacity. In a study done at the Agricultural Research and Education center (AREC) in Lebanon, broilers having 0.8 % lignocelluloses and raised under controlled conditions showed a decrease in litter moisture by 10%, which resulted in drier litter and an increase in ready to cook carcass (RTC) yield by 1.1% as compared to broilers fed control diets in addition to higher protein digestibility (Farran et al., 2013). This study mainly focuses on the possibility of achieving same results under commercial production conditions, in addition to examining the effects of Arbocel® on metabolizable energy values and on the digestibility coefficients of protein and amino acids. Results from such study could help to frame recommendations that will have fruitful bearings on poultry production.

CHAPTER II

LITERATURE REVIEW

A. Dietary Fibers

Dietary fibers are important parts of plant cells that are non-digestible by the enzymes of monogastric animals including poultry (Trowell, 1978). Scientists consider that fibers are polysaccharides and lignin which are part of cell wall (De Vries et al., 1999). The cell wall of the plant is composed from cellulose microfibrils that endow the wall with the needed rigidity. These microfibrils are embedded inside a matrix made of lignin network which is considered a vital supporting paste for other matrix of polysaccharides that include hemicelluloses such as: arabinoxylans, xyloglucans and pectins (Carpita, 1996). When the plant becomes older the cell wall becomes thicker. In other words, the lignin matrix becomes larger in size and upgrades from a secondary to a primary cell wall. Beside, these lignins coat the microfibrils and make them less available for hydrolysis by bacterial enzymes (Gidenne et al 2003).

1. Water insoluble polymers:

a. <u>Lignin:</u>

Lignins are the only non-saccharidic polymers of the cell wall. They have a complex branched structure, made of three phenylpropane units (conyferylic, coumarylicandsinapylic acids). Lignin networks are considered as the basic supporting structures for other polymers to be fixed in their right spaces.Moreover, lignins contribute to the cell wall to become more rigid and not easily attacked by bacterial enzymes. Lignin makes up to 5% of dry matter in young plants and 12% in mature grasses (Gidenne et al., 2003).

b. <u>Cellulose:</u>

Cellulose is the main structural polysaccharide forming the cell wall. It is a homopolymer made of chains of glucose units (linked in ß1–4). A total of 8000 to 10000 gulcans is the range for polymerisation. The individual glucan chains are aggregated together by the hydrogen bonding make the microfibrils. This association represents the backbone of the plant. Due to this type of linkage and chemical bonding, cellulose can only be hydrolyzed in strong acid solutions. In legume hulls, cellulose comprises 40 to 50% of dry matter; in forages it reaches 10-30%while in oilseeds or legume seeds it reaches 3–15%. Almost all cereal grains contain small quantities of cellulose (1–5% DM) except for oat where the cellulose comprises 10% (Carpita, 1996; Gidenne et al 2003).

c. <u>Hemicellulose:</u>

Hemicelluloses are made from an arrangement of polysaccharides but with a reduced degree in polymerisation. Xylose represents the major backbone (linked in β1–4), formed from mannose or glucose residues that are capable to make a link through hydrogen bonding with cellulose. The major hemicellulose that forms the cell wall in dicots is known as xyloglucans such as that found in soybean (Huisman et al., 2000). Arabinoxylans is the major hemicellulose in cereals. Highly branched heteropolymers like arabinogalactans are found in soybean, galactomannans or glucomannans in seeds of legumes. Hemicellulose represents 10-25% of dry matter in forages, brans, oilseeds, hulls, pulps and legume seeds, and makes around 12% of dry matter in grains and roots (Gidenne et al 2003).

d. Pectins:

Pectins are made of an association of several polysaccharides composed of a polygalacturonic acid linear backbone branched with neutral sugars (mainly arabinose and galactose). Substances that belong to pectins are components of the primary cell wall especially in dicotyledons. Pectins serve as the sticking agent that links the cells together. Legumes contain 5-10% pectins in their cell walls. In cotyledons of legumes, such as soybean, pea, faba bean and white lupins, total pectins (soluble and insoluble) reach 4–14% of dry matter, (Huisman et al., 2000; Gidenne et al 2003).

2. Water soluble polysaccharides and oligosaccharides:

This group of fibers includes several classes with a degree of polymerisation that ranges between15 to 2000 ß-glucans. (These substances are insoluble in ethanol-water (80:20, v/v)), they are found in low amounts in animal feed. Examples are soluble hemicelluloses such as arabinoxylans in wheat, oat, and barley. Another example is ß-glucans in barley and oat, oligosaccharides such as a-galactosides (in lupin, pea or soya seeds and finally soluble pectins in pulps of fruits or beets.

3. Non-starch polysaccharides (NSP):

Polysaccharides are made from glycosidically linked sugar units and they are found in linear or branched shape. Hexoses, deoxy-hexoses, pentoses and uronic acids are the main components that the sugar units are made from (Englyst and Hudson, 1996; Nalle, 2009). All polysaccharides that do not contain starch are called non-starch polysaccharides (NSP). In more advanced description, the non-starch polysaccharides are divided further into cellulose and non-cellulosic substances. Cellulosic means that NSP contains hemicellulose, β-glucans, pectic elements in addition to inulin, gums and mucilage. These are known as storage polysaccharides (Nalle, 2009).

Based on their solubility and extractability, NSP are divided into soluble and non-soluble. Soluble group includes Hemicellulose, pectins, β-glucans and galactomannangums (Cho *et al*., 1997), while lignin and some hemicelluloses are examples of insoluble fibers (Nalle, 2009).

Soluble NSP is found at a range of 6.8 to 50 g/kg dry matter of faba bean, while in soybean meal it ranges between 63-139g/kg. On the other hand, insoluble NSP ranges between 123.6-227 in fababean and 154-164g/kg in soybean meal (Smits and Annison, 1996; Gdala *et al*., 1997; Knudsen, 1997; Knudsen, 2001; Choct, 2006; Nalle *et al*., 2010).

a. Soluble NSP studies:

Soluble NSP's are viscous in their nature, and it is believed that this viscosity affects the morphology and physiology of the gastrointestinal tract. They are also responsible for the interactions that take place between the intestine and its micro-flora. Other effects include the increase in transportation time inside the intestine, in addition to changes at the level of hormone control and regulation that appear due to the variation in the rate of nutrient absorption (Choct, 2001; Nalle, 2009).

The soluble NSP's increase the viscosity of the gut by reacting with water molecules and binding them to each other to make a network, after that the NSPs react with each other and become caught in the network as stated by Smits and Annison (1996). Due to this viscosity, the interaction between the enzymes and their substrates is reduced (Choct, 1997).

Some nutrients may be captured inside the intestinal cell wall; and digestive enzymes may not have access to these nutrients due to increased viscosity. Soluble NSPs support microorganisms and stimulate their growth, leading to an increase in microbial protein and fat at the terminal ileum. Some NSP can play an unpleasant role by stimulating microbes that are responsible for producing toxins that will negatively affect the gut health and consequently lead to digestive malfunctions (de Lange, 2000). All of these effects can lead to the reduction in nutrient availability due to reduction in nutrient digestion and utilization (Nalle et al., 2009).

In general, high levels of soluble NSP in poultry diets have been associated with poor digestibility of feed constituents and may cause sticky droppings and wet litter problems (Farran et al., 2010).

It is a well-known fact that inefficiently digested NSP including arabinoxylans and pectin (Campbell and Bedford, 1992) are part of the poultry diet. These substances chemically react creating a cross link between these molecules making them non-digestible by the bird (Adams and Pough, 1993).

Due to this fact, the chicken will increase its water intake which in turn allows the harmful microbial fermentation to take place, increasing moisture in the feces and resulting in severe diarrhea (Fengler and Marquard, 1988; Dunn, 1996).

The anti-nutritive effects of soluble NSP, on digestibility and health represent a main issue for researchers (Dohms et al. 2006). Consequently, poultry farmers must be very careful in deciding on the use of grain-rich diets especially wheat barley and rye, since they contain a high concentration of soluble NSPs. In addition soluble NSPs trap the highly digestible nutrients in the cell walls making them unavailable for the animal and so the animal growth will be hindered. (Dohms et al. 2006; Anjum et al. 2005)

Several enzymes are produced by the chicken and are responsible for proper digestion including amylases to digest starch, proteases to digest protein and lipases to digest fats. On the other hand, the chicken cannot produce enzymes that are responsible for the digestion of fibers.

In order to address this problem a multi-enzyme supplement can be added with the feed which can lower digesta viscosity and improve the performance of chicks.

A study was conducted by Choct and Hughes (1995) to test the non-starch polysaccharide degrading enzyme (NSPDE) efficiency in feed digestion and the conclusion behind this study was as follow:

1- Feed utilization was improved during the starter phase
2- Effects on weight gain, dressing percentage and weights of organs, except liver weight, were found to be non-significant.
3- NSPDE improved feed intake

Despite the negative consequences of soluble NSP's, poultry farmers can still benefit from this product simply by adding proper enzymes as part of the meal such as β-glucanases and xylanases. The addition of enzymes will allow a depolymerization action to take place in the NSP's, the fact that reduces the anti-nutritive factors and lead to better digestibility.

It is believed that fibers contribute to keeping a healthy gastro intestinal tract by minimizing digestive disturbances with a reduced need to use antibiotics (Mateos et al., 2002; Montagne et al., 2003). Birds start consuming litter when fiber is not sufficient in their diets and this is very obvious in layers that tend to consume litter containing wood shavings, paper and feathers. Hetland et al. (2005) indicated that the paucity in fiber is an indicator of absence of structural components in the diet (Hetland et al., 2005).

Enzymatic additives in degrading the soluble NSP in poultry feed:

Wheat, as a good source of energy, is used in poultry diets; this type of grain contains around 8.3 to 9.3% non-starch polysaccharides (Slominski et al., 2000). The problem with NSP is due to the fact that it has an anti-nutritive factor which increases the digesta viscosity due to water-soluble and viscous arabinoxylans, which itself reduces the digestion of nutrients. In addition NSP physically traps the wheat starch and protein by cell wall polysaccharides (Theander et al., 1989; Bedford and Autio, 1996; Wiseman et al., 2000). Canola meal and peas along with soybean meal (SBM) are commonly used due to their high value protein, but they also contain a high content of NSP which hold a negative effect on nutrient digestion (Bell and Keith, 1987; Longstaff and McNab, 1987; Dale, 1996). Canola meal contains around 17.9% NSP (Slominski and Campell, 1990), 14.5% is recorded in soybean meal (Huisman et al., 1998), and 14.2% in peas (Igbasanet al., 1997). Non-starch polysaccharides available in wheat, soybean meal, canola meal, peas and barley were subjected in vitro to cellulase, pectinase, xylanase, glucanase, galactanase, and mannanase or their blends at 45°C and pH 5.2. The NSP was more degraded when a combination of enzymes were used. The percentages of degradation of NSP varied according to their sources. For example wheat NSP had a percentage degradation of 37%, 36 % for canola, 26 % for soybean and 28% for peas. Another trial was conducted by Larbier et al. (2003) done on 2-wk (5 to 18 d of age) broiler chickens to test for growth performance and nutrient digestibility; enzymes were used in 4 mixtures. All combinations had positive results concerning weight gain, feed-to-gain ratio, AMEn, apparent ileal digestibility of starch and protein, and apparent total tract digestibility of NSP in birds fed wheat; wheat screening, SBM, canola meal, and peas based diet. The most compound arrangement of enzymes had the best result regarding ileal protein digestibility and feed-to-gain ratio. These results are linked to the fact that the enzymes contributed in the elimination of nutrient encapsulating effect of the cell wall polysaccharide and to a small percent of reduction in viscosity of digesta. In another experiment performed on roosters the combination of the enzymes improved NSP digestibility from 11.1 to 30.1%(Larbier et al., 2003).

Due to the fact that wheat and soybean contain soluble non-starch polysaccharides (NSP), it is recommended to add enzymes that help in reducing the adverse effects of these anti-nutritional factors and improve the performance of laying hens (Nasi and Lyons,1988; Jeroch, 1991; Pan et al., 1998; Da¨nicke et al.,1999; Jaroni et al., 1999a, b). Following this recommendation, a study was performed on laying hens in order to test for the effect of supplying enzymes QuatrazymeHP that contained both xylanase and β-glucanases with wheat/barley- or maize/soybean meal-based diets. The experiment aims to test the performance of layers when these enzymes are supplied with the diet. Two experiments were done, the first included supplementation of Quatrazyme HP for 28weeks old 90 ISA Brown laying hens, where the layers were fed wheat/barley basal diet, another group was provided with the same diet but without supplementation of Quartazyme HP. In the second experiment, Quartazyme HP was supplied to 66 ISA Brown laying hens at 45 weeks of age fed maize/soybean meal basal diet; also a same group was given the same diet but Quartazyme HP was excluded. For both experiments egg production, egg weight, egg mass, feed conversion ratio and change in body weight were documented. Results showed that enzyme supplementation improved feed conversion ratio. A gain of 86g was recorded in birds supplemented the enzymes, while a decrease of 103g was recorded for the birds that did not get any enzyme with the diet. Egg production, egg weight or egg mass of birds having maize/soybean meal diet were not affected by enzyme supplementation.

Xylanase and β-glucanase reduced the in vitro viscosity of wheat, barley, maize and soybean meal. This effect was greater for wheat and barley than for maize and soybean meal. It was concluded that addition of enzymes such as (xylanase and β-glucanases) improves the efficiency of meals fed to laying hens. (Rodehutscord.,&Timmler., 2001)

Reducing intestinal viscosity has been identified as one of the major motives of NSP-hydrolysing enzyme supplementation (Bedford and Morgan, 1996, Jeroch et al.,1995). A study was performed Montagne et al.(2003) on pekin ducks to test the effect of adding xylanase to the feed. Four enzyme blends were used. The ducks were supplemented with pelleted diets at starter and finisher stages. Wheat, rye and triticale were part of the diets. Five blends of enzymes were used and all arrangements contained 1,4-beta-xylanase. Ileal digesta viscosity was significantly reduced; however, the ducks having 45% rye in their diet had higher viscosity in their digesta compared to birds having their diets more based on triticale and wheat although enzyme supplementation took place. The difference in digesta viscosity was not reflected on growth or feed conversion. At an age of 21 days the body weight of the ducks was improved and this was due to enzyme supplementation, also it was stated that the feed intake was increased with enzyme supplies. Concerning rye, the study revealed that enzyme effect does not increase with an increase in the rate of soluble NSP. Xylanase addition to the diets aids a lot in decreasing the viscosity in the digesta of ducks having wheat, rye and triticale in their diets, but the effect on growth and feed conversion is mild.

b. Insoluble NSP studies:

Some scientists claim that insoluble NSP may have some negative effects on the performance of poultry.These negative effects include decrease in time that digesta takes to be transmitted in the digestive system. Insoluble NSP increase the gut mobility and when it comes to nutrient digestion insoluble NSP can act as a barrier (Choct, 2004). However, it was reported that insoluble NSP has trace effects on poultry performance if given at the appropriate rate which ranges between 64 and 73g/kg (Jorgensen *et al*., 1995).

On the other hand, insoluble NSP was reported to have beneficial effects on poultry performance (Svihus and Hetland, 2001, and Hetland et al., 2005). Elevated levels of insoluble fiber in the diet may shorten the residence time of digesta and has the ability to hold a high amount of water and maintain the mobility of the gut (Stephen and Cumming, 1979).

However, Jorgensen et al. (1995) mentioned that insoluble NSP will have minor effects on poultry performance if given at a rate of 64 to 73 g/kg. Insoluble NSP in the form of wood shavings (40g/kg), cellulose powder at 100g/kg (Svihus and Hetland, 2001), and oat hulls at 100g/kg (Rogel *et al.*, 1987; Hetland and Svihus, 2001; Hetland *et al.*, 2003), was provided to broilers at a high level but no significant effects were recorded on digesta retention, time ,and nutrient digestibilities (Hetland et al., 2003).

Nevertheless, stressed layers fed insoluble fiber had their feather pecking reduced (El-Lethey et al., 2005).Also chicken having insoluble fiber in their rations had a better immune response as an indicator of less stress (El-Letheyet al., 2005). Rogel *et al.* (1987) added that starch and feed containing fiber will stay for longer time in the upper gastro intestinal part which makes them more available for digestion. Many studies done showed that including insoluble fiber in the chicken's diet increased body weight at 4, 5 and 6 weeks of age (Madrigal *et al.,* 2002).

However, studies proved that the retention time for digesta and nutrient digestibility in broilers were not affected by the addition of insoluble NSP at high levels with different forms (wood shavings, fine cellulose powder and oat hulls) (Hetland*et al.,* 2003).

Insoluble fibers containing lignin and cellulose are slowly fermented; lignin is a phenyl-propane polymer so it is not a carbohydrate and thus is not fermented (Klurfeld, 1999). Cellulose and non-starch compounds are carbohydrates that are classified as crude fiber (Wilson & Beyer, 2000). Insoluble fibers do not have negative anti- nutritive effect (Scott et al., 1998). Almost all poultry feeds or diets contain non-starch polysaccharides (NSP) which are insoluble fibers and are part of cell walls and these components hold positive effects regarding the digestion of nutrients (Svihus & Hetland, 2001; Hetland et al., 2005). Insoluble fiber affects the movement of digesta in the intestine and may enhance some enzymes to have good access to their substrates by forming a spongy structure in the digesta, as a result, the surface of the digesta will be more exposed and available for the enzyme (Choct, 2001). In addition to that, insoluble fibers have an effect on the villi height in GI tract, the issue that will make absorption and retention of nutrients better and resulting in better carcass growth and yield at the end. Weight gain (WG), feed conversion (FC) and growth were increased as well due to insoluble fiber supplementation. Regarding breast meat and carcass percent, a positive significant result was also recorded. (Jin *et al.,* 1994; Klurfeld, 1999, Awad *et al.,* 2008; Dohms et al. 2006).

Through years, research prevailed that insoluble NSPs hold positive effects on the digestive performance of the mono-gastric animal. Insoluble NSPs provide stability to the digestive tract, improve the digestibility of fat and starch and reduce digestive disorders. insoluble NSPs had also positive effects on feather picking in layers and reduced the occurrence of sticky droppings (Dohms et al., 2006; Choct et al., 2005)

Litter used in poultry is considered a source of insoluble fiber for the birds. The amount of intake of litter that contains insoluble fiber was directly related to the amount of fibers found in the diet. For example birds having wheat in their diet consumed more litter while those fed oat consumed less litter, this is because oat contains more fiber and thus the consumption of litter decreased. Insoluble fibers affect gizzard performance positively in poultry. Fiber is not easily grinded compared to other nutrients in the gizzard. In addition, the production of bile acid in the gizzard is increased due to insoluble fiber (Dohms et al., 2006).

4. Arbocel:

It is a pure fibrillated ligno-cellulose, a cellulosic fiber, which does not contain mycotoxins and bark. Fibrillation of the arbocel is dependent on a technology called HPCfibrillation. Arbocel carries approximately 25% lignin. It is also defined as natural cellulose fibers, which are used as thickeners to reinforce fiber as an absorbent and diluent or as a carrier or filler in most manifold application fields. Arbocel is a pure α-cellulose in a powdered or fibrinous form, and has all the properties of cellulose as previously mentioned. According to JRS Co. Arbocel® RC fine will not only improve the performance, but also due to its high water binding capacity, minimize the wet litter problem in broiler houses.

Impact of including Arbocel® in broilers diets

In a study conducted by (Farran et al.; 2013), results showed that weight gain, feed conversion value and mortality rate of broilers fed the Arbocel® RC fine were comparable to those fed the control diet throughout the trial. Litter was 10% drier for the Arbocel® treated group at market age as well. Ready to cook carcass yield was increased whereas abdominal fat was decreased. The final conclusion from the study stated that Arbocel improved the quality of litter by reducing its moisture, increased the yield of ready to cook carcasses at market age, and decreased accumulation of abdominal fat. Processing operations (evisceration, cleaning and handling) become easier in broiler processing plants and higher income can be generated from higher RTC weight (3.8 US cent/bird). However, weight gain and feed conversion values were not significantly improved in this trial.

c. Broiler Digestibility trial:

A study conducted by (Slominski et al., 2000) on Arbocel at Kasetsart University (Germany) proved that the gizzard increased in weight for two reasons: first, the fact that Arbocel swells inside the gizzard and causes it to swell, second the Arbocel® leads to increased retention time of the feed inside the gizzard. Consequently, the egg laying was improvedas the feed intake if utilization are enhanced.

In the same study, the Arbocel improved protein digestion, and resulted in better egg laying performance by 2%. This was also reflected in a study done in Australia in Tynoong North Farm and the farmer was able to make extra profits that reached extra 4 300 € with 25000 layers (Svihus & Hetland, 2001).

The effect of Arbocel on litter quality had always been a target for investigation. Bad quality litter having extra moisture is a serious problem to farmers since it represents a main cause for many health problems on the birds including foot pad lesions, breast blisters, dirty eggs, necrotic enteritis and others. Thus, there is a need to improve the litter quality by reducing its moisture (Farran et al., 2013).

A study was done in Australia in 2011 at La Trobe University byYokhana (2014) and the results showed that Arbocel reduced litter moisture in layers fed Arbocel compared to controls deprived of Arbocel (39.45% vs 45.17%, respectively). Consequently, it binds the water in the upper intestine and releases it in the lower part, due to osmosis. This will speed up the reabsorption of the water in the lower part of the intestinal digestive tract.

A digestibility trial was done at Kopen Hagen Fur by J. Rettenmaier & Söhne (2001), to test the effect of feeding Arbocel on crude protein, crude fat, and crude carbohydrate digestibility in poultry.Arbocel was used at different percentages (1.5, 1 and 0.5 %) in the diet fed to birds. It was concluded that the inclusion of 1.5 % Arbocel in the diet had a very good positive effect on fat digestibility while no effect was recorded regarding protein and carbohydrate digestibility. When the birds were fed 1% Arbocel in the diet, no significant difference on the digestibility of the three components was observed. On the other hand, a 0.5% Arbocel® inclusion in the diet had a slightly negative effect on the digestibility of carbohydrates, protein and fat (Nurlailiwati, Universität Hohenheim, 2000).

Feeding Arbocel® to chickens reduced feather pecking from 10.8% in the controls, to 2.9% when Arbocel® was fed at a ratioof 1.5%. In addition, a study conducted in year 2000 revealed that Arbocel® positively influenced feather conditions in the head, neck and chest of birds.

CHAPTER III

MATERIAL AND METHODS

A. Broiler field trial:

Two nearby poultry houses located in south Lebanon were chosen to perform the broiler experiment. A total of 9140 straight run day-old Cobb 500 broiler chicks were selected and divided between the 2 poultry houses. Each poultry house was separated into two equal divisions using a one meter high poultry wire mesh. Each division contained 2285 chicks that were raised on the floor. Starter, grower and finisher corn soybean meal basal diets (control) containing 0.8% wheat bran were prepared to meet or somewhat exceed the requirement of broiler chicks (NRC, 1994). Wheat bran was included in the formulation of the control rations, whereas Arbocel® RC fine at 0.8% was included as a supplement in the other diets. Both diets for the same age/period were cosiderd isonitrogenous and isocaloric (Table 1).

Both poultry houses contained only one entrance and birds that were located near this entrance were fed with Arbocel® containing diets; this decision was chosen by the grower due to logistic reasons. Till a period of 10 days 2 starter diets were provided each to the day-old chicks with 2 replicates per treatment and 2285 birds per replicate. After that, grower diets were supplied to the birds until they reached an age of 32 days, followed by the finisher rations till the birds reached a market weight of 2kg per broiler at an age of 41 days. Feeds and water were provided *adlibitum* whereas light was provided for 23 hours per day.Vaccination program was based on the normal practices applied by the farmer who was responsible for managing those specific houses. Mortality was taken and weight recorded as it occured. At the end of the experiment, data regarding cumulative mortality rate, feed consumption, weight gain, and feed conversion values were gathered. Any abnormalities in the birds were monitored throughout the experimental stage. Regarding moisture data determination, litter samples were taken from each division at 20 days and at market age. Ninty broilers were randomly selected from each section at market age, and were slaughtered by severing the Jugular vein, scalded, de-feathered, and eviscerated at the farm affiliated processing plant. Viscera, head and neck were removed and ready to cook (RTC) carcasses were weighed. In addition weight of liver and heart were recorded together and the weight of gizzard was recorded.

Table 1: Composition of broiler diets used in the field trial

	Starter		Grower		Finisher	
	Control	**Arbocel®**	**Control**	**Arbocel®**	**Control**	**Arbocel®**
Corn	54.65	54.65	59.63	59.63	59.04	59.04
SBM 48	37.38	37.38	31.75	31.75	31.40	31.40
Methionine	0.27	0.27	0.28	0.28	0.26	0.26
Threonine	0.02	0.02	0.05	0.05	0.04	0.04
Lysine	0.15	0.15	0.19	0.19	0.15	0.15
Dical	2.20	2.20	2.12	2.12	1.96	1.96
Limestone	1.23	1.23	1.20	1.20	1.05	1.05
Salt	0.23	0.23	0.21	0.21	0.23	0.23
Na Bicarb	0.15	0.15	0.15	0.15	0.15	0.15
Soybean Oil	2.59	2.59	3.32	3.32	4.60	4.60
Vitamin and Mineral Mix	0.27	0.27	0.27	0.27	0.27	0.27
Wheat bran/ Arbocel®*	0.80	0.80	0.80	0.80	0.80	0.80
Coccidiostat	0.05	0.05	0.05	0.05	0.05	0.05
Calculated Analysis						
ME (kcal/kg)	3060		3154		3260	
CP (%)	22.9		20.6		20.4	
Lysine (%)	1.35		1.22		1.18	
Methionine (%)	0.61		0.59		0.56	
TSA	0.99		0.93		0.90	

*Wheat bran was used in the control diet while Arbocel® was used in the experimental diet

B. True digestibility trial:

Healthy thirty six dubbed Hy-line roosters aged 55 weeks were purchased from a local commercial farm. Each rooster was put individually in a separate metabolism cage for 2 weeks, as an adaptation period, and then the roosters were divided into 4 groups of 9 birds each. The roosters were offered male breeder standard corn-SBM diet with water *ad libitum* and 16 hours of lighting period per day.

Three broiler finisher diets were used during this experiment and they all contained the same levels of Metabolizable Energy (ME) and Crude Protein (CP) in addition to all needed nutrients and all diets met the broiler’s requirements throughout the finisher period. These diets are:

- Control
- Control + 0.8% wheat bran
- Control + 0.8% Arbocel (Table 2)

Table 2: Composition of experimental diets in the digestibility trial

Ingredients (%)	**Control**	**Control + WB**	**Control + Arbocel^{R} RC**
Corn	62.176	61.172	60.566
Soybean Meal (48% CP)	30.091	30.017	30.375
Arbocel^{R} RC fine	-	-	0.800
Wheat bran	-	0.800	-
Sunflower oil	3.558	3.838	4.085
Salt	0.443	0.443	0.444
Limestone	1.71	1.172	1.166
Dicalcium Phosphate	1.856	1.851	1.862
DL- Methionine	0.250	0.250	0.251
L-Lysine HCL	0.094	0.094	0.088
Vitamin & Mineral Mix	0.300	0.300	0.300
Coccidiostat	0.0625	0.0625	0.0625
Calculated Analysis			
ME (Kcal/Kg)	3200	3200	3200
CP (%)	20.0	20.0	20.0
TSA (%)	0.88	0.88	0.88
Lysine (%)	1.10	1.10	1.10

In match with Sibbald (1986), the feed was removed 2 days before the test diet was provided in precision. The birds were intubated (force feeding), 40 ml of aqueous glucose solution (50% wt/vol) at 8 and 24 hours after feed withdrawal (McNab and Blair, 1988).

The feed in the 3 diets was grinded to a size of 2 mm. For precision feeding each bird, from the 9 birds of each group was individually intubated with 30g from each diet. However, each bird from group 4 was individually precision fed 30g of glucose powder in order to have an estimate of the endogenous and metabolic energy and amino acid losses. Water was provided adlibitum and each bird was intubated with 50 ml of water 32 h after precision feeding.

The excreta from each rooster was collected in clean plastic plate, 48 hours after feeding, then dried and ground. Then proximate chemical composition, gross energy and amino acid profile of diets and feces were determined. Additionally, True protein digestibility coefficient, apparent metabolizable energy (AME) and AME corrected for nitrogen balance (AME_n), true metabolizable energy (TME), and TME corrected for nitrogen balance (TME_n), and apparent and true amino acid digestibility coefficients have been calculated.

It is worth noting that both trials were granted the approval of the Institutional Animal care and Use Committee (IACUC) of the American university of Beirut.

Data were collected and means compared using the T test procedure of SAS, (1992).

CHAPTER IV

RESULTS AND DISCUSSION

A. Broiler trial:

Table 3 represents the results obtained from the Broiler field experiment. Although the Arbocel® fed group was raised under the previously mentioned conditions, the results showed no difference in terms of body weight at 20 days and 41 days. Body weight and feed conversion values at 20 and 41 days along with the mortality rate of broilers at market age were not significantly different between the two dietary treatments. Similarly, the ready to cook carcass yield and the yield of liver anf heart and gizzard in percentage of live weight of birds were comparable for both treatments.

Table 3: Live weight, feed conversion (FC), litter moisture and ready to cook carcass yield (RTC), as percentage of live body weight of Cobb 500 broilers raised in a commercial farm and fed 0.8% Arbocel® RC fine till market age.

	20 Days		**41 Days**				**Carcass and Giblet Yield (% of Live Weight)**		
Treatment	**Body Weight (g)**	**Litter Moisture (%)**	**Body Weight (g)**	**FC (g feed/g gain)**	**Mortality (%)**	**Litter Moisture (%)**	**RTC (%)**	**Liver + heart (%)**	**Gizzard (%)**
Control	514	45.6^{a}	2083	1.950	3.28	48.9^{a}	73.3	3.08	2.06
Arbocel® RC fine	508	41.8^{b}	2043	1.954	2.80	41.7^{b}	73.7	3.01	2.06
SEM[1]	9.2	0.63	0.02	0.0091	0.284	0.74	0.23	0.032	0.009

[1] Pooled standard error of means

[a,b] Means with different superscripts are significant different ($p < 0.05$)

The current performance results differ from those of Sariklanet al. (2010) who showed a significant benefit of feeding lignocellulose on growth and feed efficiency of Lohman chickens from 1 to 42 days.. Although the use of different strains (Lohman in their study vs Cobb in the current study) may apparently explain the discrepancy of results, it is hard to believe that those highly selected commercial strains respond differently to feeding Arbocel.

The ready to cook carcass yield in the current study was comparable between both dietary treatments, but was improved significantly in the lignocellulose fed group as indicated by Sarikhan et al. (2010) who obtained a significantly improved 3.89 point of carcass yield with the use of 0.75% dietary ligno-cellulose. These improvements could be explained by an increase of nutrient digestibility resulting from lignocellulose feeding.

The litter moisture of the Arbocel® fed group showed a significant reduction ($P <0.05$) in comparison with the control group by 3.8 and 7.1% at 20 and 41 days (end of the trial), respectively. These lower values in poultry litter as compared to the 10% decrease that was observed previously in both cage and floor trials (Farran et al., 2013), may be explained by the conditions of birds that were subjected to (gusty wind and heavy rain) at the entrance of the poultry house. These results are in agreement with those of Rezei et al. (2008) who obtained significant reduction in litter moisture at 4 weeks of age with the use of purified cellulose (75% against 67% of cellulose for the product tested here). Similarly, Pottguetter (2008) recommends the use of insoluble fiber to reduce the moisture content of litter. Another explanation for decreasing litter moisture may come from lower water consumption in birds fed a diet rich in insoluble fiber as suggested by Nielson et al. (2011). This parameter would imply that a better use of water in diets rich in fiber have an impact on the moisture content of feces. Further studies are needed to clarify the mechanisms.A note that should be kept in mind is that the birds having Arbocel$^{®}$ in their diet were positioned at the entrance of the poultry house and they were subjected to opposing cold weather conditions compared to the control group that were not subjected to these conditions. Consequently, it is believed that those conditions were partially responsible for not having results comparable to those cited in the literature.

B. True Digestibility trial:

In reference to table 4, AME, AME_n, TME, and TME_n were not affected by Dietary Arbocel$^{®}$ at a level of 0.8%. However, the digestibility of proteins was positively affected and it had a 6% increase in Arbocel fed birds ($P< 0.05$) compared to the birds fed the control diet or even the 0.8% wheat bran. In the same manner, Arbocel$^{®}$ caused an increase of 6% for both apparent and true amino acid digestibility coefficients (Tables 5 and 6). In addition Arbocel$^{®}$ positive impact was also observed on digestibility coefficient of all essential amino acids.

Table 4: Apparent and True Metabolizable Energy (AME and TME) and those corrected for nitrogen balance (AME$_n$ and TME$_n$) along with the True Protein Digestibility (TCP) for the three diets used in the rooster digestibility trial.

Treatment	AME (Kcal/kg)	AME$_n$ (Kcal/kg)	TME (Kcal/kg)	TME$_n$ (Kcal/kg)	TCP (%)
Control	3035	3232	3769	3619	54.3^{b}
Control+WB	3049	3245	3788	3627	54.0^{b}
Control + Arbocel®	3056	3254	3795	3641	60.3^{a}
SEM[1]	51.2	41.3	51.2	41.3	1.32

[a,b] Means in the same column with no common superscripts differ significantly ($p < 0.05$).

[1] Pooled standard error of means

Table 5: Apparent Dietary Amino Acid Digestibility Coefficients (%) for the diets used in the rooster digestibility trial

Treatment	Asp	Thr	Ser	Glu	Pro	Ala	Cys	Val	Met
Control	72.8^{b}	58.8^{ab}	61.4	78.3^{b}	69.6	65.4^{b}	48.5	63.5^{b}	80.8^{b}
Control+WB	72.1^{b}	58.8^{b}	60.1	78.0^{b}	70.3	66.1^{b}	48.5	62.6^{b}	81.1^{b}
Control + Arbocel®	78.5^{a}	65.7^{a}	66.4	82.6^{a}	73.3	72.6^{a}	54.6	71.0^{a}	87.6^{a}
SEM[1]	1.43	2.6	2.1	1.14	1.61	1.81	2.93	2.36	1.17

Treatment	Ile	Leu	Tyr	Phe	Lys	His	Arg	Trp	EAA[*]
Control	68.3^{b}	73.4^{b}	67.0^{b}	73.2^{b}	76.5^{b}	76.3^{b}	77.1^{b}	81.1^{ab}	72.9^{b}
Control+WB	67.3^{b}	73.2^{b}	66.5^{b}	72.5^{b}	74.3^{b}	75.9^{b}	76.5^{b}	79.8^{b}	71.8^{b}
Control + Arbocel®	75.0^{a}	78.5^{a}	73.4^{a}	78.4^{a}	81.9^{a}	81.6^{a}	81.6^{a}	83.9^{a}	78.5^{a}
SEM	1.87	1.59	1.87	1.61	1.32	1.6	1.32	1.21	1.6

[ab] Means in the same column with no common superscripts differ significantly ($p < 0.05$)

[*] Essential amino acids

[1] Pooled standaed error of means

Table 6: True Dietary Amino Acid Digestibility Coefficients (%) for the diets used in the rooster digestibility trial

Treatment	**Asp**	**Thr**	**Ser**	**Glu**	**Pro**	**Ala**	**Cys**	**Val**	**Met**
Control	85.7^{b}	85.0^{a}	86.7	88.0^{b}	86.8	83.6^{b}	90.5	84.9^{b}	89.7^{b}
Control+WB	86.0^{b}	85.2^{b}	86.6	88.5^{b}	88.0	84.9^{b}	87.7	86.0^{ab}	90.4^{b}
Control + Arbocel®	91.5^{a}	92.3^{a}	90.8	92.5^{a}	90.8	90.9^{a}	90.5	92.4^{a}	94.9^{a}
SEM[1]	1.43	2.6	2.1	1.14	1.61	1.81	2.93	2.36	1.17

Treatment	**Ile**	**Leu**	**Tyr**	**Phe**	**Lys**	**His**	**Arg**	**Trp**	**EAA**[*]
Control	85.4^{b}	86.8^{b}	89.2^{b}	87.4^{b}	86.0^{b}	86.8^{b}	89.5^{b}	90.2^{ab}	87.2^{b}
Control+WB	86.0^{b}	87.2^{b}	89.9^{b}	87.7^{b}	85.9^{b}	86.9^{b}	90.2^{b}	89.0^{b}	87.2^{b}
Control + Arbocel®	92.1^{a}	92.1^{a}	96.2^{a}	92.8^{a}	91.7^{a}	92.1^{a}	94.5^{a}	93.6^{a}	$93.o^{a}$
SEM	1.87	1.59	1.87	1.61	1.32	1.6	1.32	1.21	1.6

[ab] Means in the same column with no common superscripts differ significantly ($p < 0.05$)
[*] Essential amino acids
[1] Pooled standaed error of means

This improvement in digestibility could be caused by the increase of enzymatic activity and enlargement of the digestive tract of birds fed dietary Arbocel lignocellulose as demonstrated in a previous trial conducted in Austria at the school of life science in Trobe University on Hy-line Brown pullets(Yokhana et al., 2016). A total of 36 eight week old pullets were upheld and divided into 3 groups, each containing 12 pullets. Each group was provided with a different ration, control containing commercial layer ration, mixed fiber (MF) containing the control ration + 1.5% soluble/insoluble fiber (Opticell) and insoluble fiber (IF) having control ration + 1.5% Arbocel®.

Pullets were raised till they reached an age of 16 weeks, then all birds were slaughtered and weight of the internal organs was recorded. Internal organs included proventriculus, pancreas and small intestine which include the jejunum and ileum. In addition to that, enzymatic activity was also measured. Enzymes tested included (pepsin, pancreatic general proteolytic, and trypsin intestinal di-aminopeptidases.

Results showed that pullets fed insoluble fiber (Arbocel) for 8 weeks had a heavier weight than pullets fed control diet. With respect to the weights of internal organs, the gizzard and small intestines of pullets having IF (Arbocel)were larger in weight than pullets having control diet also the liver and intestine were also heavier than pullets fed the isoluble/soluble (MF, Opticell). On the other hand the weight of proventriculus and pancreas were not affected in either MF and IF. Activity of pepsin was increased in IF pullets, also pancreatic general proteolytic and trypsin activities were greater compared to CO and MF this is related to the increased enzymatic production in the tissues of the organs. MF had a greater intestinal di-peptidase activity compared to CO. The activity of intestinal di-peptidase was higher in MF and IF in comparison to CO. The addition of Arbocel® to the diet of pullets increased the weight of the upper digestive tract organs and the total activity of the enzymes responsible for protein digestion. Due to these improvements, the digestibility and utilization of dietary proteins was improved and thus the weight gain was also improved.

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

Based on the results obtained from Experiments 1 (Broiler trial) and 2 (Digestibility trial), the following conclusions can be made:

- Arbocel® lignocellulose inclusion in broiler diets did not affect the birds' performance and carcass quality.
- Dietary Arbocel® decreased the moisture content of the litter, specifically at late rearing stages. This achievement is of primordial importance to reduce the likelihood of disease occurrence, control ammonia levels and reduce carcass condemnations.
- The inclusion of Arbocel® in roosters' diet didn't affect the energy values of the diets.
- Dietary Arbocel® improved protein digestibility and the coefficients of apparent and true digestibility of amino acids for roosters.

For the above reasons, Arbocel should be considered a cost effective natural feed additive in poultry ration formulation. Its inclusion in the diets of poultry would reduce the intervention with antibiotics, as the litter moisture content and ammonia release will be reduced. It is worth noting that additional benefits will be also obtained from having lower frequency of birds with carcass condemnation at the market age.

Moreover, increasing the digestibility of proteins and amino acids, following the use of Arbocel® in poultry diets, will have a marked impact on the cost of production, knowing that feed constitutes around 70% of the total production cost in poultry farms. Consequently, reduced feed costs will increase the profitability and production efficiency of poultry farms.

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