



Full Length Article

Effects of Insoluble Fiber on Growth Performance, Carcass Traits and Ileum Morphological Parameters on Broiler Chick Males

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ABSTRACT

To determine the effects of insoluble raw fiber concentrate (IRFC) on performance, carcass and ileum morphologic traits, four dietary treatments containing 0, 0.25, 0.50 and 0.75% levels of IRFC with four replicates were fed to 240-days-old Lohmann chick males for 42 days. Weight gain significantly differed in grower (22-42 d) and total of experimental period (0-42 d) and the control group shows a lower weight gain than other groups. Feed conversion rate (FCR) for the control and 0.25% IRFC at the starter and control group for grower and overall of period was greater than other groups. IRFC at the rate of 0.50 and 0.75% produced significantly greater carcass and breast meat than the other groups. Significant differences were observed in intestine and abdominal fat. Use of 0.75% IRFC had lower intestine percentage as compare to other groups. Likewise control group had a higher abdominal fat than other groups, while thigh and liver had no significant differences. Crypt depth did not show differences at day 21 and 42. At day 21 control group had a lower height of villi than others, also control and 0.25% IRFC had a lower villi to crypt ratio (V/C) as compare to 0.50 and 0.75% groups. At day 42, all of IRFC groups had higher villi height and a high V/C ratio than control group. © 2010 Friends Science Publishers

Key Words: Insoluble fiber; Performance; Carcass; Ileum morphology; Broiler

INTRODUCTION

Dietary fiber can be define as components of plants, which are resistant to digestion by endogenous enzymes and consists of non-digestible carbohydrates and lignin that are intrinsic and intact in plants. The functional fiber refers to isolated, extracted, or synthetic fiber that they can provide health benefits, with several physiological functions (Bersamin *et al.*, 2008). Most insoluble fibers are moderately or slowly fermenting, those highly resistant to fermentation include isolated cellulose and lignin. Lignin is a not fermented due to its composition as a phenyl-propane polymer rather than a carbohydrate (Klurfeld, 1999).

Fiber content of diets is mainly more important in ruminants; however there are good results with fiber content in non-ruminants as pigs and poultry (Abo Omar, 2005). Carbohydrates common in poultry diets are starch, sugars, cellulose and other non-starch compounds; cellulose and non-starch compounds typically classified as crude fiber (Wilson & Beyer, 2000). Majority of the insoluble fiber fraction consists of hulls, which reduce the nutrient concentration of the grains but have no antinutritive effect (Scott *et al.*, 1998). Most of the feed ingredients of plant origins contain considerable amounts of non-starch

polysaccharides (NSP), which are mainly insoluble (Bach Knudsen, 1997). Major chemical component important to structure of grains is insoluble fiber, which makes up the main part of the cell wall and has beneficial effects on nutrient digestion (Svihus & Hetland, 2001; Hetland *et al.*, 2005).

Fiber is nutritionally, chemically and physically heterogeneous material, which can be categorized into two major subclasses i.e., viscous and fermentable fiber (soluble) and non-viscous and non-fermentable fiber (insoluble). Both the subclasses have different roles in the digestive and absorptive processes within the gastrointestinal tract. Dietary fiber (DF) content, have an important place in well balanced diets. Differentiation of soluble and insoluble fiber components can help elucidates the physiological effects of fiber (Newman *et al.*, 1992). The physiological and nutritional functions of insoluble NSP's are of practical implications for feed and monogastric animal industries. Insoluble fiber and lignin are usually regarded as nutrient diluents; therefore insoluble fibers do not affect digestion and absorption of nutrients in the intestine (Edwards, 1995). In contrast, soluble fibers usually display antinutritive properties. Soluble fibers increase viscosity and affect negatively nutrient digestion and absorption (Smith &

Annison, 1996) and reducing feed passage rate (Van Der Klis *et al.*, 1993). In addition, fiber sources differ in properties such as particle size, cation exchange capacity (CEC) and water holding capacity (WHC).

The ratio of insoluble to soluble fiber (I/S) in a DF source can affect overall diet utilization and appears to be important in the formulation of diets to provide optimal efficacy (Burhalter *et al.*, 2001). Recent reports with young pigs have shown that diets very low in fiber impair nutrient digestibility and growth (Mateos *et al.*, 2006). The inclusion of moderate amounts of fiber in low fiber diets might improve chick performance at early ages by reducing gizzard pH and improving the utilization of nutrients. Therefore young broiler chicks require a minimal amount of fiber in diets. The influence of fiber content in diets on voluntary feed intake and total tract apparent retention of nutrients in broilers is the subject of debate (Moran, 2006). Some researchers have indicated that an adequate type and amount of fiber might improve gastro intestinal tract (GIT) adaptation of poultry to current productive systems and reduce digestive disturbances without antibiotic use in feed (Mateos *et al.*, 2002; Montagne *et al.*, 2003). Birds have an appetite for fiber and when it did not provide in a minimum amounts in diet, they have an increased consumption of litter. Besides when laying hens feeding low fiber diets, they have a tendency for ingestion of litter that contains wood shavings, paper and feathers. This indicates a need for structural components in response to the lack of fiber in the poultry diets (Hetland *et al.*, 2005).

Insoluble fiber can affect the gut transit time of digesta, gut motility of epithelium and may improve the ability of endogenous enzymes to successful access to their related substrates (Choct, 2001). It seems that insoluble fiber can make a spongy form in digesta and it make easy to penetrate enzymes into digesta. Therefore the surface of substrate to enzyme action will be greatly increased. Insoluble fiber can affect the villi height in gastrointestinal tract by simulation effect and affect villi to crypt ratio, leading to better absorption and retention of nutrients and ultimately better growth and carcass yield of birds. The objective of this study was to determine the influence of supplementing insoluble fiber on the growth and morphological characteristics of chick males.

MATERIALS AND METHODS

Birds and diets: Total of 240 one-day-old Lohmann broiler males chicks were individually weighed and randomly allocated to the four treatment groups with four replications of 15 birds per replication. Chicks were grouped based on the following levels of insoluble raw fiber concentrate (IRFC) in diets: (1) control diet (no IRFC), (2) 0.25% IRFC, (3) 0.50% IRFC and (4) 0.75% IRFC. Experimental diets were formulated according NRC (1994) recommendations, with the same ratio of ME:CP in all diets (Table I). Chicks were under uniform management conditions. They had free

access to feed and water and light provided according 23 h light and 1 h dark throughout the experimental period. Birds fed experimental diets for starter (0-21 d) and grower (22-42 d) periods.

Growth performance: Body weight gain and feed intake were measured weekly and feed conversion rate (FCR) were used to determine the growth performance at the end of starter, grower and overall of experimental period (0-42 d).

Carcass traits: At the end of experiment, final body weight was taken then 2 birds from each pen (each bird as a replicate), were randomly selected and tagged, then birds were fasted (no limitation of water access) for 8 h on day 42. Birds were weighed and slaughtered by serving both of the right and left carotid artery and jugular vein in a single cut and bled for 180s. After slaughter, carcass weight measured on the chilled carcass after removal of feather, head, lungs, GIT, liver, kidney, abdominal fat, dissected and collected. Carcass (CAP), breast meat (BMP), thigh (TP), intestine (IP), liver (LP) and abdominal fat (AFP) calculated as the percentage of fasted live body weight.

Ileum morphological parameters: One bird selected randomly from each pen at day 21 and 42 and then killed by cervical dislocation after 8 h fasting with water access. Then small intestine (defined as the segment between gizzard & ileo-secal junction) removed immediately from abdominal cavity without any press on its tissue. Fragments of approximately 1 cm were collected from ileum (5 cm) after Meckel's diverticulum and fixed in 10% saline formalin (900 mL of distilled water, 100 mL of 40% formaldehyde & 7.6 g of NaCl), the fragments were dehydrated by transferring in the series of alcohols with increasing concentrations, then placed in to the toluene to clearing and embedded in paraffin. Sections were cut (10 cuts with 6 μ m thickness) from the waxed tissue on a rotary microtome (Microtec CUT 4060) and were cleared wrinkles by floating on warm water with 50-55°C prior to mounting Mayer's adhesive coated slides. Sections were stained using hematoxylin-eosin method. Images of samples by light microscopy obtained using an image analyzer (Moticam 480-SONY) under 40x magnification and analyzed using Motic Images Plus v.2.0 software (Motic China Group, 1999-2004) to villi height and crypt depth measurements. Values in Table IV are means of 10 adjacent villi and crypts; only vertically oriented villi and crypts measured (Fig. 1).

Statistical analysis: Experimental data subjected to one-way-ANOVA using the GLM procedure of SAS (SAS Institute, 2003) and significant differences compared by Duncan's multiple range tests. All of statement of differences were based on significant at $p < 0.05$.

RESULTS AND DISCUSSION

Growth and performance: Supplementing broiler diets with insoluble fiber did not affect FI at the end of starter (21 d), grower (42 d) and overall of experimental period (0-42 d).

Table I: Composition of experimental diets

Ingredient and composition	Starter (0-21 d)				Grower (22-42 d)			
					(%)			
Ground yellow corn	63.85	63.70	63.74	63.49	69.36	69.26	69.12	68.93
Soybean meal (48% CP)	27.00	27.00	26.86	26.90	24.75	24.58	24.47	24.40
Fish meal, menhaden (60% CP)	6.00	5.9	6.00	5.95	2.86	2.88	2.88	2.90
DCP	1.00	1.00	0.82	0.84	0.80	0.80	0.80	0.80
Oyster shell	1.20	1.20	1.13	1.12	1.32	1.32	1.32	1.32
Sodium chloride	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Vitamin premix ¹	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Mineral premix ²	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DL-methionine	0.20	0.20	0.20	0.20	0.10	0.10	0.10	0.10
L-lysineHCL	0.00	0.00	0.00	0.00	0.06	0.06	0.06	0.05
Coccidiostats	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
IRFC ³	0.00	0.25	0.50	0.75	0.00	0.25	0.50	0.75
<i>Calculated analysis</i>								
ME, kcal/kg	2910	2900	2900	2895	2960	2950	2940	2935
CP (N × 6.25)	20.91	20.84	20.84	20.81	18.50	18.43	18.37	18.34
ME/CP	139.1	139.1	139.1	139.1	160.0	160.0	160.0	160.0
Crude fiber	3.34	3.51	3.69	3.84	3.28	3.45	3.62	3.79
Ether extract	3.21	3.19	3.20	3.19	3.10	3.10	3.09	3.09
Lysine	1.16	1.16	1.16	1.16	1.02	1.02	1.01	1.00
TSAA	0.90	0.90	0.90	0.90	0.73	0.73	0.72	0.72
Calcium	1.07	1.06	1.00	1.00	0.9	0.9	0.9	0.9
Available phosphorus	0.48	0.48	0.45	0.45	0.36	0.36	0.36	0.36
Ca/AP	2.22	2.21	2.22	2.22	2.50	2.50	2.50	2.50

1 The vitamin premix supplied the following per kilogram of complete feed: vitamin A, 4,500 IU (retinyl acetate); cholecalciferol, 1,000 IU; vitamin E, 25 IU (dl-a-tocopheryl acetate); vitamin B12, 0.02 mg; menadione, 1.5 mg; riboflavin, 3 mg; thiamine, 1.5 mg; pantothenic acid, 5 mg; niacin, 20 mg; choline, 150 mg; folic acid, 0.5 mg; biotin, 0.5 mg; pyridoxine, 2.5 mg

2 The mineral premix supplied the following per kilogram of complete feed: manganese (MnSO₄·H₂O), 60 g; zinc (ZnO), 40 mg; iron (FeSO₄·7H₂O), 80 mg; copper (CuSO₄·5H₂O), 8 mg; selenium (Na₂SeO₃), 0.2 mg; iodine (Iodized NaCl), 0.8 mg; cobalt (CoCl₂), 0.4 mg

3 IRFC: Insoluble raw fiber concentrate is a commercial product of JRS Co. (Germany) with this composition, DM: 93.9%, crude fiber 72.5%, ADF: 86.5%, ADL: 0.6%, NDF: 90.5%, crude protein (n × 6.25): 1.1%, crude fat 0.2%, NFE: 19.8%, crude ash 0.3%, sugar: <0.1%, crude starch: <0.1%

Table II: Growth performance of chickens fed different levels of IRFC

Diet	Growth Performance								
	AFI			AWG			FCR		
	21 d	42 d	0-42 d	21 d	42 d	0-42 d	21 d	42 d	0-42 d
				(g/b)			NU		
0.00% IRFC	1057.3	2958.8	4016.1	581.5	1333.4 ^b	1914.9 ^b	1.81 ^a	2.21 ^a	2.1 ^a
0.25% IRFC	1049.4	3036.7	4086.0	595.8	1488.0 ^a	2083.8 ^a	1.75 ^a	2.03 ^b	1.96 ^b
0.50% IRFC	1033.0	2997.2	4030.2	615.2	1458.1 ^a	2073.3 ^a	1.67 ^b	2.05 ^b	1.94 ^b
0.75% IRFC	1029.9	3125.7	4155.6	617.5	1529.4 ^a	2146.9 ^a	1.66 ^b	2.04 ^b	1.93 ^b
CV%	2.40	2.27	1.96	3.31	2.53	2.21	2.13	1.26	0.65s
SEM ²	7.06	25.21	25.70	6.64	23.84	28.12	0.02	0.02	0.02
Pvalue	NS	NS	NS	NS	0.001	0.001	0.003	<0.0001	<0.0001

AFI= Average feed intake, AWG= Average weight gain, FCR= Feed conversion rate

g/b= grams per bird, NU= no unit

CV: Coefficient of variance, SEM: Standard error of the mean, based on pooled estimate of variance, Pvalue: Probability value

a,b: Means followed by different letters within columns are different by Duncan's multiple range test in 0.05 significance level

At day 21 did not observed difference between dietary treatments in WG trait. Insoluble fiber increased ($p < 0.01$) WG and all of IRFC groups had a higher growth than control group. FCR improved ($p < 0.01$) by levels of insoluble fiber in diets at day 21, day 42 and overall of period. At day 21, 0.50 and 0.75% IRFC groups had a lower FCR than control and 0.25% IRFC groups. At day 42 and overall of period, all IRFC dietary groups had better FCR than control group (Table II). These findings are confirmed by the research of Rogel *et al.* (1987) that the fiber sources inclusion in broiler diets increase the ileal digestibility of starch and diets rich in fiber remain in the upper gastro intestinal tract longer and might be digested more

completely, because of increase peristalsis and production of hydrochloric acid and other digestive enzymes. Other studies show that broilers fed a high fiber diets had an increased body weight gain at 4, 5 and 6 weeks of age (Madrigal *et al.*, 2002).

Addition of indigestible nutrients like cellulose and lignin to broiler diets increase weight gain from 7-21 days of age and improve productive traits and FCR in broilers (Gonzalez-Alvarado *et al.*, 2007). Santos *et al.* (2006) indicated that turkeys fed the diet supplemented with wood fiber showed improved FCR from 1 to 28 d of age than those not supplemented.

Gonzalez-Alvarado *et al.* (2007) reported that fiber

Table III: Carcass traits of chickens fed different levels of IRFC

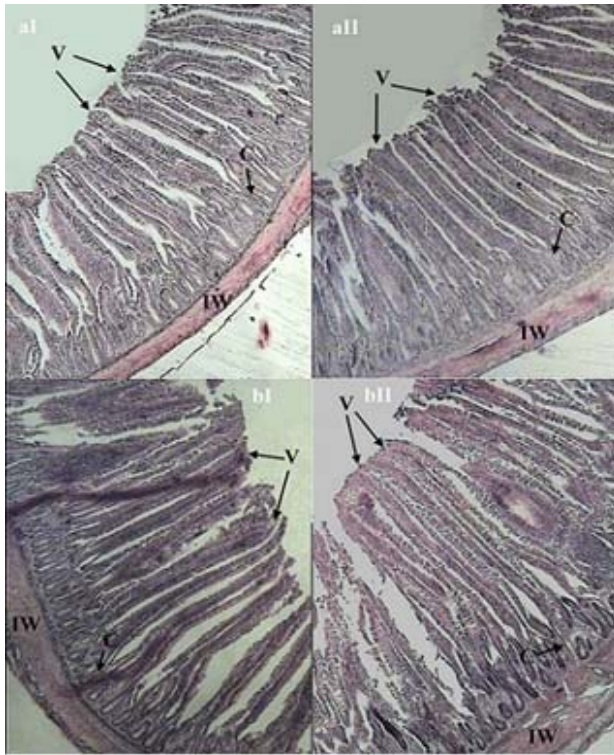
Diet	Carcass Traits					
	CAP	BMP	TP	IP	AFP	LP
	(%)					
0.00% IRFC	67.28 ^b	27.12 ^b	30.12	3.96 ^{ab}	2.23 ^a	2.00
0.25% IRFC	68.93 ^{ab}	28.29 ^{ab}	30.20	4.20 ^a	1.72 ^b	1.91
0.50% IRFC	71.15 ^a	30.60 ^a	30.17	3.71 ^{bc}	1.85 ^b	1.80
0.75% IRFC	71.17 ^a	30.17 ^a	30.78	3.41 ^c	1.50 ^b	1.85
CV%	3.57	6.56	2.72	7.26	16.43	9.26
SEM	0.58	0.46	0.16	0.08	0.07	0.03
Pvalue	0.036	0.016	NS	<0.001	0.003	NS

CAP: Carcass percent, BMP: Breast meat percent, TP: Thighs percent, IP: Intestines percent, AFP: Abdominal fat percent, LP: liver percent
Carcass traits are as a percentage of fasted body live weight before slaughter

CV: Coefficient of variance, SEM: Standard error of the mean, based on pooled estimate of variance, Pvalue: Probability value

a,b: Means followed by different letters within columns are different by Duncan's multiple range test in 0.05 significance level

Fig. 1: Sections of ileum (40x) from 21 (a) and 42 (b) day old broiler chicks fed the control diet (I) and the diet supplemented with IRFC (II). (IW) intestinal wall, (V) villi, (C) crypt



inclusion improved body weight gain and feed conversion from 1 to 21 days of age. Jimenez-Moreno *et al.* (2009) indicated that fiber inclusion improved body weight gain and FCR, therefore the inclusion of moderate amounts of fiber in diets may improve performance and nutrient digestibility in young chicks. Hetland and Svihus (2001) and Tabook *et al.* (2006) observed high feed intake and no effects on performances when insoluble fiber was included

at moderate levels in broiler diets. Mourao *et al.* (2008) observed that dehydrated pasture as an insoluble fiber source increased FCR, reducing growth without influence on feed intake.

Carcass traits: Carcass percent and breast meat percent in 0.50 and 0.75% IRFC was significantly influenced ($p < 0.05$) by dietary insoluble fiber and it was higher in compare with control group. TP and LP did not affected by dietary levels of insoluble fiber. IP affected significantly ($p < 0.01$) by dietary treatments and 0.75% IRFC group obtained lower IP in compare with other groups, also AFP affected significantly ($p < 0.01$) by insoluble fiber and caused that resulted lower AFP in all of groups consumed IRFC than control group (Table III).

Shahin and Abdelazim (2005) indicated that birds fed a high fiber diets had lower carcass weight than birds fed low fiber diets, this result is contrast with our results and this differences may be is in related of fiber source and amounts of fiber in diet. Furthermore, they confirmed that broilers fed high amounts of fiber in diet had a higher relative muscle and lower relative fat percent in compare with chicks fed low levels of fiber.

Shahin and Abdelazim (2006) concluded that the carcass fat of broiler have a considerable reduction using high fiber diets. Bartov and Plavnik (1998) found that relative abdominal fat pad weight increased significantly by increasing energy to protein ratio that it causes using low fiber amounts in diet.

Abdominal fat, carcass fat and total body fat yields were greatly depressed by feeding birds with high fiber diets and lead to less abdominal fat depots (Shahin & Abdelazim, 2006). Santos *et al.* (2006) reported that pullets fed the diet containing wood shavings (as an insoluble fiber source) had lower relative small intestinal weights at day 28 than those fed other diets, however jejunum and total small intestine weights were lower for turkeys fed diets supplemented with wood shavings.

At the other side Mourao *et al.* (2008) reported that birds fed diets containing insoluble fiber resulted in a lighter carcasses with lower levels of abdominal fat pad in compared with control. Its might to possible that the effect of dietary insoluble fiber (insoluble non-starch polysaccharides) in the size of digestive organs is less clear (Taylor & Jones, 2001; Wu & Ravindran, 2004; Mourao *et al.*, 2008).

Ileum morphological parameters: Table IV is containing ileum morphological parameters. Villi height affected significantly ($p < 0.01$) by insoluble fiber in diets at days 21 and 42. At day 21, 0.75% IRFC group in compare with control and 0.25% IRFC groups had a higher villi height. At day 42, it observed that all of groups fed insoluble fiber had higher villi height than control treatment. Crypt depth did not influenced by dietary treatments at days 21 and 42. Ratio of villi to crypt (V/C) influenced ($p < 0.05$) by different levels of insoluble fiber in diet. Results indicated that 0.75 and 0.50% IRFC groups in compare with control group at

Table IV: Intestine morphologic parameters of chickens fed different levels of IRFC

Diet	Intestine morphologic parameters						
	Villi height		Crypt depth (μm)	V/C			
	d 21	d 42		d 21	d 42	d 21	d 42
0.00% IRFC	710.57 ^c	999.40 ^b	205.90	236.46	3.49 ^b	NU	4.29 ^b
0.25% IRFC	765.97 ^b	1131.83 ^a	196.99	222.95	3.96 ^{ab}		5.15 ^a
0.50% IRFC	814.72 ^{ab}	1163.59 ^a	197.22	219.31	4.17 ^a		5.40 ^a
0.75% IRFC	832.74 ^a	1102.22 ^a	203.27	203.53	4.22 ^a		5.58 ^a
CV%	3.47	3.09	6.06	7.06	6.65		8.29
SEM	15.78	20.37	3.21	5.43	0.10		0.18
Pvalue	0.002	0.002	NS	NS	0.034		0.025

V/C: Villi to crypt ratio

μ = micron, NU= no unit

CV: Coefficient of variance, SEM: Standard error of the mean, based on pooled estimate of variance, Pvalue: Probability value

a,b: Means followed by different letters within columns are different by Duncan's multiple range test in 0.05 significance level

day 21 and all of IRFC groups than control group at day 42 had a high ratio of V/C. Yamauchi and Isshiki (1991) and BiYu and Chiou (1996) found that broiler chicks developed larger intestinal villi with high dietary fiber levels, resulting in faster growth rates. The present of coarse and simulator compounds in diets like large particle size parts and also fibers can affect gastro-intestinal tract by increasing villi height and crypt depth in gastro intestinal tract (Jin *et al.*, 1994; Klurfeld, 1999; Dhalke *et al.*, 2003). It is demonstrated that adding 10% fiber to diet for 2 weeks increase cell proliferation in the villi of gastro intestinal tract, also adding cellulose to the low fiber diets increase DNA synthesis and cell multiplication in gastro intestinal tract (Jin *et al.*, 1994; Klurfeld, 1999).

The intestinal mucosal architecture can reveal useful information on the intestinal function. Increasing villi height suggests an increased surface area for greater absorption of available nutrients (Awad *et al.*, 2008). Also increase in villi to crypt ratio is related to an increase in digestion and absorption (Montagne *et al.*, 2003; Silva *et al.*, 2009).

CONCLUSION

Use of insoluble fiber in commercial broiler chicks enhances meat production. Insoluble fiber improves the intestine morphological parameters and result best performance due to completing digestion and absorption process, allowing the bird to exploit maximum potential to growth. Thus provision of insoluble fiber in the diets has can improve the broilers performance.

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