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PLASMA LIPID METABOLITES AND LIVER LIPID COMPONENTS IN BROILERS AT 21 DAYS OF AGE IN RESPONSE TO DIETARY DIFFERENT FIBER SOURCES

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SUMMARY

One hundred twenty one-day-old female Ross 308 broilers were used to evaluate the impact of including oat hulls (OH), sugar beet pulp (SBP), and pea hulls (PH) at levels of 2.5, 5.0, and 7.5% in the diet on lipid metabolism of broilers from hatch to 21 d of age. The OH, SBP, and PH contained 0.7, 11.6, and 5.1% soluble fiber and 70.6, 47.4, and 49.6% insoluble fiber, respectively. The control diet contained 1.6% crude fiber (6.9% dietary fiber). The fiber sources were included in the experimental diets at the expense (wt/wt) of the control diet. Each treatment was replicated 6 times (a cage with 2 chicks). At 21 d of age, one chick per replicate was slaughtered and plasma lipid metabolites and liver lipid components were determined. At 21 d of age, the inclusion of fiber in the diet tended to reduce total cholesterol (P = 0.06) and to increase HDL cholesterol (P = 0.06) in plasma and reduced lipid components of the liver including total lipids, triglycerides, and total cholesterol (P<0.05). Type of fiber did not affect total lipids, triglycerides, and LDL cholesterol in the plasma or the relative weight (% of BW) of the liver. Plasma HDL, however, was higher in birds fed OH than in birds fed PH or the control diet with birds fed SBP being intermediate (P<0.01). An increase in the level of fiber in the diet from 0 to 7.5% tended to decrease triglycerides in the liver from 7.37 to 6.00 mg/g across treatments (P = 0.08) but did not affect any of the other traits studied. It is concluded that the inclusion of fiber in the diet modified, in different ways, lipid metabolism in broilers at 21 d of age. Fiber sources differing widely in solubility and physicochemical properties had little impact on these traits. An increase in the level of fiber reduced lipid components in the liver at this age.

Keywords: Broilers, dietary fiber, liver lipid components, plasma Lipid metabolites

INTRODUCTION

It is well known that several dietary fibers decrease serum cholesterol concentrations in human (Anderson *et al.* 1990a,b; Slavin, 2008 and Sarmento and Ticiana, 2013), rats (Kahlon *et al.*, 1993 and Wang *et al.*, 1997) and broilers (Razdan *et al.*, 1997; Yusrizal and Chen, 2003; Viveros *et al.*, 2007 and Zhang *et al.*, 2013). These effects on blood contents might be noted also for liver lipogenesis in broilers (Velasco *et al.*, 2010) and animals (Delzenne *et al.* 2002). Moreover, Anderson *et al.* (1994) reported that dietary soluble fibers such as pectins reduced serum and liver cholesterol , however, insoluble fibers had little effects on these traits. Recently, Brownawell *et al.* (2012) and Slavin (2013) reported that soluble fibers are the most effective in lowering cholesterol concentrations and not all fibers are equal in terms of the types and extent of health benefits they provide.

There is a growing interest in evaluating the effects of fiber inclusion to poultry diets on lipid metabolism (Mohiti-Asli *et al.*, 2012a and b). It has been reported that the inclusion of pectins from sugar beet pulp (SBP) in chicken diets reduced plasma lipid levels and may assist in overcoming high plasma lipid concentrations associated with reduced meal frequency (Pettersson and Aman, 1991; Pettersson and Razdan, 1993 and Razdan and Pettersson, 1994). Moreover, dietary fiber fractions from legume seeds has also been reported to be an important component that might reduce serum cholesterol levels (Uberoi *et al.*, 1992). Pea (*Pisum sativum L.*) fiber was reported as hypocholesterolemic agent that alters postprandial lipaemia and lipoproteins in humans which attributed to long-term metabolic effects (Dubois *et al.*, 1993 and Lairon, 1996) and pea hulls (PH) were considered as an ingredient in broiler diets (Jiménez-Moreno *et al.*, 2011 and Frikha *et al.*, 2013).

The hypothesis of this research was that the inclusion of moderate amounts of fiber into low fiber diets may play a role in lipid metabolism, and its effects may depend on type and level of inclusion of the fiber. In this respect, we hypothesized that increases in soluble fibrous fractions such as pectins from SBP to the diet, which are dispersible in water might affect lipid metabolism in broiler chickens. On the other hand, insoluble fibrous fractions, such as those present in oat hulls (OH), might have no effect on lipid metabolism while, PH that contain mainly cellulose, hemicellulose and low pectin content, might have intermediate effect. Therefore, the aim of this study was to evaluate the effect of increasing levels of 3 fiber sources (OH, SBP and PH) with different physicochemical properties from 1 to 21 d of age on blood and liver lipid metabolism of broilers at 21 d of age.

MATERIALS AND METHODS

Fiber sources and diets:

A batch of OH, a batch of SBP and a batch of PH were obtained from a commercial supplier and grounded using a hammer mill (Model 15303, Fritsch GmbH, Rudolstadt, Germany) fitted with a 2-mm screen and analyzed for chemical composition, physical properties and geometric mean diameter (Table 1). The basal control diet was based on rice, soy protein concentrate and fish meal (Table 2) and contained 3,265 kcal AME_n/kg diet and 6.9% dietary fiber (1.6% crude fiber). The remaining experimental diets were manufactured by diluting (wt/wt) the control diet with 2.5, 5.0 or 7.5% of either OH, SBP or PH. All diets were fed in mash form and met or exceeded the nutritional recommendations of Fundación Española Desarrollo Nutrición Animal (2008) for broilers.

Table 1. Determined chemical composition (%, as-fed basis), geometric mean diameter (GMD ± GSD), water holding capacity (WHC ± SD) and swelling capacity (SWC, mL/g DM) of fiber sources[1]

Item	Oat hulls	Sugar beet pulp	Pea hulls
Chemical analysis			
Gross energy, kcal/kg	4,156	3,678	3,869
Dry matter	93.6	91.4	90.3
Crude protein	3.0	8.9	12.1
Starch	9.2	1.0	8.9
Ether extract	1.4	1.1	1.4
Total ash	3.7	9.2	4.0
Crude fiber	28.3	17.8	39.3
Total dietary fiber	71.3	59.0	57.4
Insoluble dietary fiber	70.6	47.4	49.6
Soluble dietary fiber	0.7	11.6	5.1
Neutral detergent fiber	70.2	34.2	47.0
Acid detergent fiber	33.4	18.0	35.8
Acid detergent lignin	3.7	1.8	1.1
Physical properties			
Screen size, μm			
1,250	31	266	214
630	409	472	543
315	353	152	155
160	150	65	67
80	50	40	17
< 40	7	5	4
GMD ± GSD[2], μm	509 ± 1.9	796 ± 2.1	805 ± 1.9
WHC ± SD, L/kg dry matter	3.93 ± 0.051	10.60 ± 0.080	5.54 ± 0.031
SWC ± SD , mL/g dry matter	2.06 ± 0.350	6.18 ± 0.778	5.45 ± 0.631

[1]Analyzed in triplicate samples. [2]Log normal standard deviation.

Experimental design and husbandry:

All procedures used in this research were approved by the Animal Ethics Committee of the Universidad Politécnica de Madrid and were in compliance with the Spanish guidelines for the care and use of animals in research (Boletín Oficial del Estado, 2007).

The experiment was conducted as a completely randomized design with 10 dietary treatments consisting of a negative control diet with a low fiber content and nine additional diets arranged factorially with 3 sources of fiber (OH, SBP and PH) and three levels of fiber inclusion (2.5, 5.0 and 7.5%). In total, 120 one-day-old female Ross 308 chicks with an initial BW of 47.8 ± 3.3 g were housed in an environmentally controlled room and randomly distributed in groups of two in 60 battery cages (Avícola Grau, Madrid, Spain) equipped with 2 drinker cups and an open trough feeder. Room temperature was kept at 33°C during the first 3 d of life and then, it was reduced gradually according to age until reaching 24°C at d 21. Chicks had free access to feed and water throughout the experiment and received a light program of 23 h light from d 1 to 7 and 18 h light from d 8 to 21.

Laboratory analyses:

Fiber sources and diets were analyzed for total ash using a muffle furnace (method 942.05) and for nitrogen by Dumas (method 968.06) using a LECO analyzer (model FP-528, Leco Corporation, St. Joseph, MI) as described by AOAC International

(2000). Dry matter (DM) was determined by oven-drying (method 6) and ether extract (EE) by Soxhlet fat analysis after 3*N* HCl acid hydrolysis (method 4.b) as described by Boletín Oficial del Estado (1995). Gross energy of all samples was measured with an isoperibol bomb calorimeter (model 356, Parr Instrument Company, Moline, IL). Neutral and acid detergent fiber of the tested fiber sources and experimental diets and acid detergent lignin pH were determined sequentially as described by Van Soest *et al*. (1991) and expressed on an ash-free basis. Starch content of such fiber sources and diets were measured by the amyloglucosidase/α-amylase (method 996.11; AOAC International, 2000). Particle size distribution and geometric mean diameter of the tested fiber sources and the experimental diets were determined in triplicate according to the methodology recommended by the American Society of Agricultural Engineers (1995). Water holding capacity of the tested fiber sources and the experimental diets were determined as indicated by Jiménez-Moreno *et al*. (2009). All the analyses were conducted in triplicate.

Plasma lipid metabolites and liver lipid components:

At the end of the experiment, one chick per cage, were selected at random, slaughtered and used for the studied traits at 21 d of age. Three mL blood samples from these slaughtered chicks were collected in heparinized tubes. Blood samples were centrifuged at 3,000 rpm/min for 10 min. Clear plasma samples were separated into Eppendorf tubes and kept in the deep freezer at -20°C until chemical analyses. In addition, livers were separated from the same slaughtered chicks used for blood samples. Total lipids were extracted and purified from liver samples according to the methodology described by Bligh and Dyer (1959). Briefly, 1 g from homogenized liver sample was collected in a sterile tube containing a mixture of 15 mL chloroform and methanol (2:1; vol/vol) and was shaken. Then, distilled water was used for washing the samples three times (5 mL per each time) followed by centrifugation (2,500 rpm/min for 10 min). The aqueous methanol layer was filtered and the filtered aqueous layer was received in sterilized glass vial that was separated tightly. Then, the chloroform lipid extraction was transferred into a test tube for chemical analyses.

The biochemical analyses were conducted at the laboratory of biochemistry, Cairo University Research Park (CURP), Giza, Egypt. Total lipids were reacted with vanillin in the presence of sulfuric and phosphoric acid to produce complex color which was measured by spectrophotometer (Spectronic Helios Gamma UV-Vis, Serial no.: UVG-160414, wavelength range: 190-1100nm, Thermo Fisher Scientific, England) at 530 nm according to the method described by Knight *et al.* (1972). Triglycerides were determined colorimetrically according to Fossati and Prencipe (1982) for plasma samples and to Schettler and Nussel (1975) for lipids extracted from the liver samples. Cholesterol was determined in plasma and extracted total lipids from liver samples according to Allain *et al.* (1974). Heparin and sodium citrate were used selectively to precipitate all lipoproteins except the low density lipoprotein (LDL) fractions in plasma which were present in the supernatant (Steinberg, 1981). Also, phosphotungstic acid and magnesium ions were used selectively for precipitating all lipoproteins except the high density lipoprotein (HDL) fractions in plasma which were present in the supernatant (Lopes-Virella *et al.*, 1977). Then, the LDL- and HDL-cholesterol were determined in the supernatant using the same method described for total cholesterol.

Statistical analyses:

All data were analyzed as a completely randomized design with 10 treatments using the GLM procedure of SAS (SAS Institute, 2004). Adequate contrasts were performed to study the linear and quadratic responses of the different variables to increase levels (0, 2.5, 5.0 and 7.5%) of each of the three fiber sources. The effects of source and level of fiber inclusion and the interaction were studied. Also, the effects of fiber levels within each fiber source were studied. The experimental unit was the cage for BW and the slaughter chick for all the other traits. Results in tables are presented as least-square means. Differences were considered significant at $P < 0.05$ and tendencies at $0.10 < P < 0.05$. Significant differences between means were separated by a least square differences using protected t-test.

RESULTS

Experimental diets and chicken husbandry:

Total soluble dietary fiber was higher in SBP (11.6%) than those presented in OH (0.7%) and in PH (5.1%) being intermediate (Table 1). As expected, an increase in the level of dietary fiber, each fiber source reduced crude protein and starch content and increased neutral detergent fiber content of the diet (Table 3). Geometric mean diameter values were higher for all treatments diets (by 13.8-20.5% for OH, 26.4-30.1% for SBP, and 38.4-47.2% for PH) than for the control diet (458 μm ± 1.83 log normal standard deviation).

No mortality was observed during the experimental period for all treatments. Also, dietary fiber sources with different levels of inclusion did not affect live BW or liver relative weight (Table 4).

Plasma lipid metabolites and liver lipid components:

Results in Table (4) indicated that the inclusion of fiber in broiler diets from hatching to 21 d of age tended to reduce total cholesterol ($P = 0.06$) and to increase HDL cholesterol ($P = 0.06$) in plasma. Moreover, lipid components of the liver including total lipids, triacylglycerides, and total cholesterol were reduced ($P<0.05$) in response to dietary fiber.

Table 2. Ingredient composition and calculated analysis of the experimental diets from hatch to 21 d of age (%, as-fed basis unless otherwise indicated)

		Oat hulls			Sugar beet pulp			Pea hulls		
Item	**Control**	**2.5**	**5.0**	**7.5**	**2.5**	**5.0**	**7.5**	**2.5**	**5.0**	**7.5**
Ingredient										
Rice	59.75	58.25	56.75	55.27	58.25	56.75	55.27	58.25	56.75	55.27
Soy protein concentrate, 53% CP	24.00	23.40	22.80	22.20	23.40	22.80	22.20	23.40	22.80	22.20
Fish meal, 72% CP	7.60	7.41	7.22	7.03	7.41	7.22	7.03	7.41	7.22	7.03
Soy oil	5.00	4.87	4.75	4.62	4.87	4.75	4.62	4.87	4.75	4.62
Limestone	1.15	1.12	1.09	1.06	1.12	1.09	1.06	1.12	1.09	1.06
Fiber source	-	2.50	5.00	7.50	2.50	5.00	7.50	2.50	5.00	7.50
Dicalcium phosphate	1.50	1.47	1.43	1.39	1.47	1.43	1.39	1.47	1.43	1.39
Sodium chloride	0.30	0.29	0.29	0.28	0.29	0.29	0.28	0.29	0.29	0.28
DL-Methionine, 99%	0.20	0.20	0.19	0.19	0.20	0.19	0.19	0.20	0.19	0.19
Vitamin and mineral premix[1]	0.50	0.49	0.48	0.46	0.49	0.48	0.46	0.49	0.48	0.46
Calculated analysis[2]										
AME_n (kcal/kg)	3,265	3,179	3,107	3,038	3,191	3,134	3,074	3,213	3,160	3,107
CP	22.00	21.50	21.00	20.50	21.50	21.00	20.50	21.50	21.00	20.50
Crude fiber	1.61	2.30	2.91	3.61	2.01	2.44	2.83	2.56	3.50	4.44
Digestible Lysine	1.25	1.21	1.18	1.15	1.22	1.19	1.16	1.22	1.20	1.18
Digestible Methionine	0.58	0.56	0.55	0.53	0.56	0.55	0.53	0.56	0.55	0.53
Digestible Methionine + Cystine	0.90	0.87	0.85	0.83	0.87	0.85	0.83	0.88	0.87	0.85
Digestible Threonine	0.81	0.78	0.77	0.75	0.79	0.77	0.75	0.79	0.77	0.76
Calcium	1.07	1.05	1.02	1.00	1.07	1.07	1.06	1.04	1.02	1.00
Available phosphorus	0.41	0.41	0.40	0.39	0.41	0.40	0.39	0.41	0.40	0.39

[1]Provided the following (per kg of diet): vitamin A (transretinyl acetate), 10,000 IU; vitamin D3, (cholecalciferol), 2,000 UI; vitamin E (all-*rac*-tocopherol acetate), 20 IU; vitamin K (bisulphate menadione complex), 3 mg; riboflavin, 5 mg; pantothenic acid (D-calcium pantothenate), 10 mg; nicotinic acid, 30 mg; pyridoxine (pyridoxine·HCl), 3 mg; thiamin (thiamin-mononitrate), 1 mg; vitamin B_{12} (cyanocobalamine), 12 µg; D-biotin, 0.15 mg; choline (choline chloride), 300 mg; folic acid, 0.5 mg; Se (Na_2SeO_3), 0.1 mg; I (KI), 2.0 mg; Cu ($CuSO_4 \cdot 5H_2O$), 10 mg; Fe ($FeSO_4 \cdot 7H_2O$), 30 mg; Zn (ZnO), 100 mg; Mn ($MnSO_4 \cdot H_2O$), 100 mg; and ethoxyquin, 110 mg.
[2]According to Fundación Española Desarrollo Nutrición Animal (2008).

Table 3. Determined chemical composition (%, as-fed basis) and geometric mean diameter (GMD ± GSD[1], *μ*m) of the experimental diets from hatch to 21 d of age[2]

		Oat hulls			Sugar beet pulp			Pea hulls		
Item	**Control**	**2.5**	**5.0**	**7.5**	**2.5**	**5.0**	**7.5**	**2.5**	**5.0**	**7.5**
Chemical analysis										
Gross energy (kcal/kg)	4,080	4,070	4,065	4,048	4,075	4,022	4,010	4,027	4,039	4,063
Dry matter	89.9	90.0	89.8	89.7	89.9	89.9	89.9	90.3	90.2	90.0
Crude protein	22.1	21.2	21.1	20.7	21.5	21.2	20.8	21.7	21.5	21.2
Starch	43.7	42.8	41.7	40.7	42.6	41.4	40.3	42.7	41.5	40.5
Ether extract	5.68	5.28	4.96	4.71	5.65	5.46	5.41	5.55	5.26	5.21
Total ash	7.89	7.89	7.90	7.61	8.20	8.10	7.91	8.09	8.10	7.91
Crude fiber	1.63	2.30	2.92	3.53	2.02	2.44	2.81	2.50	3.47	4.33
Total dietary fiber	6.93	8.50	10.12	11.73	8.22	9.54	10.81	8.12	9.32	10.51
Insoluble dietary fiber	4.77	5.89	7.61	9.33	5.29	6.41	7.53	5.89	7.01	8.13
Soluble dietary fiber	2.16	2.61	2.51	2.40	2.93	3.13	3.28	2.23	2.31	2.38
Neutral detergent fiber	4.18	5.12	7.09	9.43	4.89	5.34	6.82	4.78	5.99	7.14
Acid detergent fiber	1.96	2.26	2.63	3.79	1.30	1.92	2.17	2.55	3.03	3.77
Physical properties										
Screen size (*μ*m)										
1,250	65.1	65.3	51.6	60.5	100.3	74.8	80.3	68.3	79.6	96.6
630	190.8	237.6	281.7	305.3	285.5	273.8	306.2	480.8	381.7	376.8
315	464.2	572.8	563.1	516.0	503.2	630.1	567.3	430.6	506.1	490.3
160	270.5	123.1	103.4	118.2	111.0	21.3	46.2	20.1	32.4	36.3
80	9.2	1.2	0.2	0.0	0.0	0.0	0.0	0.2	0.2	0.0
< 40	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GMD	458.0	521.0	542.0	552.0	579.0	589.0	596.0	674.0	634.0	646.0
GSD	1.83	1.67	1.62	1.65	1.77	1.63	1.64	1.57	1.62	1.65

[1]Log normal standard deviation.
[2]Analyzed in triplicate samples.

Table 4. Effect of different fiber sources[1] and levels of inclusion in broiler diets on BW, relative liver weight, plasma lipid metabolites, and liver lipid components at 21 d of age

Item	BW (g)	Liver weight (g/100 g BW)	Total lipids		Triacylglycerides		Total cholesterol		LDL-cholesterol (mg/dL)	HDL-cholesterol (mg/dL)	HDL:Total cholesterol ratio	HDL:LDL cholesterol ratio
			In plasma (mg/dL)	In liver (mg/g)	In plasma (mg/dL)	In liver (mg/g)	In plasma (mg/dL)	In liver (mg/g)				
Treatment												
Control	967	3.015	233.9	35.7^{a}	18.61^{a}	7.37^{a}	161.4^{a}	2.66^{a}	70.3	44.9^{c}	0.28^{c}	0.69
2.5% OH	942	2.963	226.5	32.7^{ab}	17.65^{ab}	6.60^{ab}	156.9^{ab}	2.28^{abc}	68.8	59.6^{ab}	0.38^{ab}	0.90
5.0% OH	934	2.953	223.7	30.4^{ab}	17.52^{ab}	6.28^{ab}	150.7^{ab}	2.11^{bc}	66.3	61.0^{a}	0.41^{a}	0.97
7.5% OH	922	2.923	222.9	29.6^{b}	17.38^{ab}	5.90^{b}	149.1^{ab}	2.05^{bc}	64.6	61.2^{a}	0.41^{a}	0.98
2.5% SBP	931	2.983	222.6	31.8^{ab}	17.75^{ab}	7.06^{ab}	154.0^{ab}	2.47^{b}	68.0	48.5^{bc}	0.32^{bc}	0.75
5.0% SBP	924	2.972	220.1	30.3^{b}	17.35^{ab}	6.38^{ab}	152.4^{ab}	2.39^{abc}	65.3	53.5^{abc}	0.36^{abc}	0.93
7.5% SBP	920	2.962	218.1	29.6^{b}	16.56^{b}	6.01^{b}	151.9^{ab}	2.33^{abc}	64.5	54.7^{abc}	0.36^{abc}	0.89
2.5% PH	932	2.978	231.4	33.1^{ab}	18.36^{ab}	6.79^{ab}	152.3^{ab}	2.31^{abc}	68.6	45.5^{c}	0.30^{bc}	0.71
5.0% PH	922	2.968	229.7	31.3^{ab}	17.93^{ab}	6.43^{ab}	144.4^{b}	2.14^{bc}	64.9	46.6^{c}	0.33^{abc}	0.74
7.5% PH	917	2.952	216.3	30.7^{ab}	17.52^{ab}	6.10^{b}	142.6^{b}	1.95^{c}	63.8	51.8^{abc}	0.37^{abc}	0.85
SEM (n=6)[2]	25.4	0.1225	9.84	1.92	0.710	0.436	5.48	0.182	6.15	4.27	0.031	0.120
Fiber source												
OH	932	2.947	224.3	30.9	17.63	6.26	152.2	2.15	66.6	60.6^{a}	0.40^{a}	0.95
SBP	925	2.972	220.3	30.5	17.22	6.49	152.8	2.39	65.9	52.2^{ab}	0.34^{ab}	0.85
PH	924	2.966	225.8	31.7	17.94	6.44	146.5	2.13	65.8	48.0^{b}	0.33^{b}	0.76
Fiber level (%)												
0.0	967	3.015	233.9	35.7^{x}	18.61^{x}	7.37^{x}	161.4^{x}	2.66^{x}	70.3	44.9^{y}	0.28^{y}	0.69
2.5	935	2.975	226.8	32.5^{xy}	17.92^{xy}	6.82^{xy}	154.4^{xy}	2.35^{xy}	68.5	51.2^{xy}	0.33^{y}	0.78
5.0	927	2.964	224.5	30.6^{y}	17.60^{xy}	6.36^{xy}	149.2^{y}	2.21^{y}	65.5	53.7^{xy}	0.36^{xy}	0.89
7.5	920	2.946	219.1	29.9^{y}	17.16^{y}	6.00^{y}	147.9^{y}	2.11^{y}	64.3	55.9^{x}	0.38^{x}	0.90
	----------						*Probability*	----------				
General model	0.9706	1.0000	0.9553	0.4589	0.7588	0.3440	0.4497	0.2376	0.9985	0.0387	0.0591	0.5783
Contrasts												
Control vs. all	0.1649	0.6977	0.3187	0.0243	0.1668	0.0397	0.0641	0.0279	0.5219	0.0604	0.0248	0.1865
Fiber source	0.9105	0.9687	0.7793	0.7598	0.4667	0.7979	0.3026	0.1512	0.9860	0.0025	0.0195	0.1756
Fiber level	0.7769	0.9610	0.6186	0.2428	0.4186	0.0844	0.3093	0.2709	0.6941	0.4120	0.1836	0.4419
Linear												
Fiber level	0.1207	0.6369	0.1878	0.0068	0.0695	0.0052	0.0226	0.0081	0.3439	0.0243	0.0056	0.0862
OH level	0.2354	0.6248	0.4193	0.0192	0.2344	0.0193	0.0833	0.0184	0.4807	0.0115	0.0042	0.0822
SBP level	0.2197	0.7681	0.2622	0.0237	0.0445	0.0189	0.2257	0.1890	0.4699	0.0797	0.0568	0.1524
PH level	0.1911	0.7313	0.2208	0.0528	0.2501	0.0383	0.0115	0.0069	0.4037	0.2620	0.0553	0.3456

[1]OH = Oat hulls, SBP = Sugar beet pulp and PH = Pea hulls.

[2]Standard error of the mean (*n* = number of observations).

[a-c]Means for treatment or fiber source within the same column with different superscripts differ significantly ($P < 0.05$).

[x-y]Means for fiber level effect within the same column with different superscripts had linear effect at $P < 0.05$.

Type of fiber did not affect total lipids, triacylglycerides, or LDL cholesterol in the plasma or the relative weight (% BW) of the liver. Plasma HDL, however, was higher in birds fed OH than in birds fed PH or the control diet with birds fed SBP being intermediate ($P < 0.01$). An increase in the level of fiber in the diet from 0 to 7.5% tended to decrease triglycerides in the liver from 7.37 to 6.00 mg/g across treatments ($P = 0.08$) but did not affect any of the other traits studied. Linear reduction was observed for liver lipids components in response to dietary fiber levels ($P < 0.01$). The same trend was observed for total cholesterol in plasma ($P < 0.05$). In addition, plasma HDL-cholesterol was linearly increased by dietary fiber levels ($P < 0.05$). However, no quadratic effects were observed for all traits.

HDL-cholesterol was increased in chickens fed 2.5% OH or more but not by dietary, neither SBP nor PH (Figure 1). Liver lipids components were reduced in chickens fed diets containing 7.5% OH comparing with those fed the control diet with chickens fed diets containing either 2.5 or 5% OH being intermediate (Figure 1). The same trend was observed by dietary PH for liver triglycerides and total cholesterol. Also, dietary 5% or more SBP reduced liver total lipids and triglycerides comparing with non-dietary SBP with dietary 2.5% SBP being intermediate.

DISCUSSION

Experimental diets and chicken husbandry:

Results of the current trial indicated that dietary fiber sources differing in solubility and physicochemical properties did not affect live BW and liver relative weight (%BW). These results are consistent with data of Jiménez-Moreno *et al.* (2011) for PH and with the results obtained by Jiménez-Moreno *et al.* (2013) for OH or SBP for broilers from 1 to 18 d of age fed the same levels of fiber inclusion studied in the current trial. In the same context, Jiménez-Moreno *et al.* (2009 & 2010) reported that 2.5 and 5.0% OH, rice hulls or sunflower hulls could be included in low fiber diets for broilers from 1 to 21 d of age without impairing broiler performance. Pettersson and Razdan (1993) observed that broilers fed a diet that contained 2.3% SBP had higher BW and better feed conversion ratio from 1 to 21 d of age than broilers fed the control diet. However, when the level of SBP was increased to 4.6 and 9.2% in broiler diets growth performance was impaired. An excess of fiber could cause a significant distension of the GIT with a concomitant increase in maintenance requirements of the birds, as demonstrated by Hansen *et al.* (1992) in rats and Jørgensen *et al.* (1996) in pigs. This discrepancy in the results might be explained by the high pectin content of the SBP that increased water holding or to the differences in the physicochemical characteristics of the fiber sources used which might affect gut motility, microbiota growth and voluntary FI of the birds. Thus, bulk and weight of the fresh excreta might be increased as reported by Jørgensen *et al.* (1996) who observed an increase in moisture content of the excreta as the level of pea fiber (an ingredient with a high pectin content) increased but not when oat bran was used. Jiménez-Moreno *et al.* (2011) reported that the inclusion of PH in the diet improved energy efficiency in broilers from 1 to 18 d of age which is in agreement with results of González-Alvarado *et al.* (2010) in broilers from 1 to 42 d of age fed diets containing 3.0% OH or SBP and suggests that the beneficial effects of dietary fiber on growth performance of broilers were due primarily to an increase in diet digestibility which resulted in more nutrients available for growth.

Plasma lipid metabolites and liver lipid components:

Dietary fiber reduced plasma total cholesterol and liver lipid components and increased plasma HDL cholesterol in broilers at 21 d of age, supporting the hypothesis of hypolipidaemic effects of dietary fiber that was suggested by Trowell (1972) and proofed by several publications in poultry, animals, and humans (Anderson *et al.* 1991b; Anderson *et al.* 1994; Razdan *et al.*, 1997; Viveros *et al.*, 2007; Zhang *et al.*, 2009 and Crowe1 *et al.*, 2012). However, dietary fiber sources differ in solubility and physicochemical properties did not affect the most of lipid metabolism in either plasma or liver. It has been reported that dietary soluble fibers reduced serum and liver cholesterol however, insoluble fibers had little effects on these traits (Anderson *et al.*, 1994 and Slavin, 2013). On the other hand, Sarikhan *et al.* (2009) found that broilers fed diets supplemented with insoluble fibers up to 0.75% from 1 to 42 d of age did not affect serum lipids metabolites at 21 d of age. However, they observed that triglycerides, total cholesterol, and LDL-cholesterol were reduced and HDL-cholesterol was increased in response to dietary insoluble fibers up to 0.75% at 42 d of age. In the same respect, Kahlon *et al.* (1993) reported that dietary oat fiber or its fractions lowered elevated plasma cholesterol, LDL-cholesterol, and triglycerides in Hamsters. The same trend was observed in men by Anderson *et al.* (1984 and 1991a). The discrepancy among the authors is not known. However, it might be explained, at least in part, by the differences in species, age and duration of fiber inclusion in the diet as factors affecting broilers responding to dietary lower-cholesterol agents. Meluzzi *et al.* (1992) reported that age, sex, strain and sampling season varying blood constituents in broilers. In addition, Chau and Cheung (1999) suggesting that the cholesterol-lowering effects of the insoluble dietary fibers might be caused by the indirect influences on lowering the intestinal absorption of cholesterol by the variation among fibers in physicochemical properties.

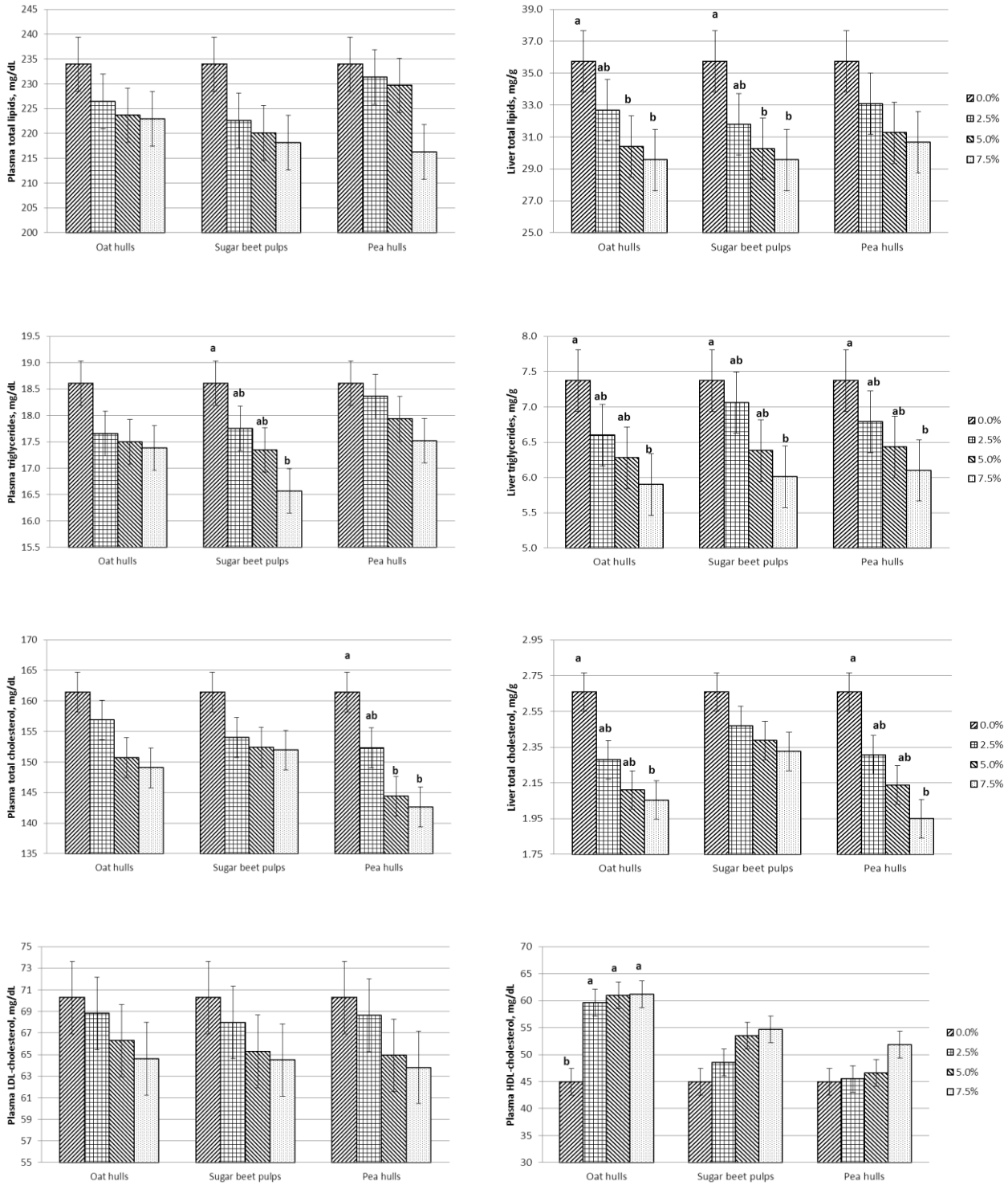

Figure 1. Effect of different levels inclusion of each fiber source in broiler diets on lipid metabolism traits in plasma and liver at 21 d of age. Columns within each fiber source with different superscripts differ significantly ($P < 0.05$)

In the current trial, plasma total cholesterol and liver components were linearly reduced and plasma HDL-cholesterol was linearly increased ($P < 0.05$) in response to dietary fiber levels up to 7.5%. The hypocholesterolemic effects of dietary fibers with different levels may be attributed to one or more of the following mechanisms: 1] the modification of bile acid absorption and metabolism by binding them with cholesterol (Hargis, 1988; Topping, 1991; Esmail, 2012), 2] the interference with lipid absorption and metabolism (Hargis, 1988; Topping, 1991; Wang *et al*., 1992; Hashish and Abd El-Samee, 2012), 3] the production of short-chain fatty acids from fermentation of fiber in the colon that interfere with cholesterol synthesis (Gallaher *et al.*, 1993; Anderson *et al*. 1994; Lopez *et al*., 1999 and Hashish and Abd El-Samee, 2012 and Slavin, 2013), 4] the inhibition of cholesterol biosynthesis due to suppressing the enzymatic activity of HMG-CoA reductase by the bioactive anti-nutritive factors present in fibers (Burger *et al.*, 1984; Qureshi *et al.*, 1991; Esmail, 2012 and Hashish and Abd El-Samee, 2012), 5] the alterations in the concentrations of or sensitivity to insulin or other hormones (Anderson *et al*. 1994 and Hashish and Abd El-Samee, 2012), 6] the shortening of intestinal transit time to increase fecal sterol excretion (Hargis, 1988; Slavin and Feirtag, 2011 and Hashish and Abd El-Samee, 2012).

It is concluded that the inclusion of fiber in the diet modified in different ways lipid metabolism in broilers at 21 d of age but that fiber sources differing widely in solubility and physicochemical properties had little impact on these traits. However, the hypolipidaemic effects of fiber was accumulated in the liver as noted by the reduction in lipid components in the liver at this age. In general, dietary fibers might play an important role in lipid metabolism as hypolipidaemic agent in broiler chickens.

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مكونات التمثيل الغذائي للدهون في بلازما وكبد كتاكيت التسمين علي عمر 21 يوم كإستجابة للتغذية علي مصادر مختلفة من الألياف

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تم استخدام عدد 120 كتكوت أنثي من النوع روص 308 عمر يوم بهدف تقييم أثر إضافة قشر الشوفان (OH)، ومصاصة قصب السكر (SBP)، و قشر البسلة (PH) بمستويات 2.5 و 5.0 و 7.5٪ لعلائق كتاكيت التسمين حتي 21 يوم من العمر علي التمثيل الغذائي للدهون. بالتحليل الكيميائي لمصادر الألياف المختلفة OH، SBP، PH تبين إحتوائها علي 0.7، 11.6، 5.1% من الألياف القابلة للذوبان وعلي 70.6، 47.4، 49.6٪ من الألياف غير القابلة للذوبان، على التوالي. إحتوت عليقة المقارنة المستخدمة علي 3265 كيلو سعر حراري/كجم عليقة، 22.1٪ بروتين، 1.3٪ ليسين مهضوم، وكانت نسبة الألياف الخام بها 1.6٪ (بما يعادل 6.9٪ من الألياف المأكولة). تم إحلال مصادر الألياف المختلفة OH، SBP، PH في العلائق التجريبية المختلفة بالنسب سالفة الذكر (2.5 و 5.0 و 7.5٪) على أساس (وزن/وزن) من عليقة الكنترول. تم تكرار كل معاملة من المعاملات العشر 6 مرات (بمعدل قفص لكل كتكوتين). تم ذبح كتكوت واحد من كل مكرر علي 21 يوم من العمر، وتم تقدير نواتج تمثيل الدهون في البلازما و مكونات التمثيل الغذائي للدهون المختلفة في الكبد. أشارت النتائج إلي أنه علي 21 يوم من العمر، أدي وجود الألياف في العليقة إلي تقليل الكوليسترول الكلي وزيادة الكولسترول علي الكثافة (HDL) في البلازما بمعدلات تميل إلي المعنوية ($P = 0.06$)، كما أدى إلي خفض مكونات الدهون في الكبد معنوياً بما في ذلك الدهون الكلية والدهون الثلاثية والكولسترول الكلي ($P < 0.05$). لم يؤثر نوع الألياف المستخدم معنوياً علي مستويات الدهون الكلية والدهون الثلاثية والكولسترول منخفض الكثافة (LDL) في البلازما أو علي وزن الكبد بالنسبة لوزن الجسم. بينما كان مستوي الكولسترول علي الكثافة (HDL) في الطيور المغذاه علي قشور الشوفان OH أعلى مقارنةً بمستواه في كل من الطيور المغذاه علي قشور البسلة PH أو عليقة المقارنة وكان مستواه في الطيور المغذاه علي مصاصة القصب SBP متوسطاً بين تلك المجموعات ($P < 0.01$). أكدت النتائج علي أن زيادة مستوى الألياف في العليقة من صفر إلي 7.5٪ بين المعاملات المختلفة أدي إلي خفض الدهون الثلاثية في الكبد بمعدل يتراوح بين 6.00 و 7.37 ملجم/جم ($P = 0.08$) ولكن لم يؤثر على أي من الصفات الأخرى التي شملتها الدراسة. خلصت الدراسة إلى أن وجود الألياف في علائق التسمين تؤثر بطرق مختلفة علي خفض معدلات التمثيل الغذائي للدهون علي 21 يوم من العمر، إلا أنه عند مقارنة مصادر الألياف المختلفة التي أستخدمت والتي تباينت في قدرتها علي الذوبان وكذلك في خصائصها الشكلية والكيميائية كان تأثيرها متقارب على هذه الصفات. كما لوحظ أن زيادة مستوى الألياف بالمعدلات سالفة الذكر (من صفر إلي 7.5%) في علائق كتاكيت التسمين أدي إلي خفض مكونات التمثيل الغذائي للدهون في الكبد علي نفس العمر.