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Effects of Pine Bark Spent Liquor Prepared by Alkaline Sulfite-Anthraquinone Cooking as a Pellet Binder on Pellet Durability and Performance of Broiler Chicks or Laying Hens

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소나무 수피 알칼리성 아황산염-안트라퀴논 증해폐액이 사료결착제로서 펠렛 내구성과 가금의 생산성에 미치는 영향

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ABSTRACT : Three experiments were conducted to investigate the Pine Bark Spent Liquor(PBSL) inclusion, prepared by alkaline sulfite-anthraquinone cooking, on pellet durability index (PDI) of practical diets and performance of broiler chicks and laying hens. Fourteen treatments with four replications were assigned for PDI test in Experiment 1. Control, 10% Wheat(W10), 20% Wheat(W20), 0.25, 0.50, 1.00, 2.00 and 3.00% PBSL, 0.1, 0.2% commercial pellet binder A(CPB A) or B(CPB B), W10 plus 0.1% CPB A or B were used for PDI test. PDI was measured by PDI tester (Oriental Motors, Japan). The control diet was based on corn and soybean meal with no wheat or pellet binders inclusion. The PDI of the PBSL or other commercial pellet binder treatments were significantly higher than control groups($P<0.05$). It was shown 95.9, 95.9, 95.8, and 95.7 in W10, 0.5% PBSL, 0.2% CPB A or B treatments, respectively. Thus, those treatments were applied to Experiments 2 and 3. In experiment 2, 200 male broiler chicks (Cobb × Cobb) were allocated to the control, W10, PBSL 0.5%, 0.2% CPB A and B with four replications. Starter diets contained 3,169, 3,149 kcal/kg ME and 21% CP, and finisher diets were fed at the level of 3,192, 3,172 kcal/kg ME and 19% CP. Weight gain, feed intake, feed conversion ratio (FCR) were weekly measured for 5 wk and the number of intestinal anaerobes were examined at the end of experiment. The weight gain of chicks fed PBSL was not significantly greater than control groups, but was significant different compared to that of W10 or 0.2% CPB A treatments($P<0.05$). FCR of chicks treated with PBSL or other pellet binders tended to improve compared to that of control. Intestinal anaerobes of all pellet binders was significantly lower than control except W10 treatments. In Experiment 3, 200 Lohmann brown laying hens were placed into wire layer cages. Diets contained 2,720 kcal/kg ME and 18.5% CP. The experimental design was the same as that of Experiment 2. Egg production, feed intake and FCR were measured from 24 to 32 wk. Blood components and egg quality were examined at the end of experiment. There was no significant differences in egg production among treatments. However, the egg weight and feed conversion ratio of hens fed 0.5% PBSL was significantly improved compared the control($P<0.05$). Blood cholesterol of hens fed 0.5% PBSL was significantly lower than control($P<0.05$). The results of these experiments indicated that PBSL could be used as a pellet binder in poultry diets.

(Key words: pellet binder, pellet durability index, pine bark, broiler, laying hens)

INTRODUCTION

Pine wood(*Pinus densiflora* Sieb. et Zucc.) is belong to the most abundant soft wood in Korea and has been used in mechanical pulp and medium density fiber-board(MDF) mills. Most pine bark discharged from these mills is usually disposed of as waste or is burned as an auxiliary fuel. The major limiting factor in utilizing pine bark as a fiber resources is the high polyphenol and low polysaccharide content. However, polyphenols, one of major component of pine barks, can be used as an alternative source of lignin to produce lignosulfonates. After sulfite cooking of the wood, the lignosulfonate obtained from sulfite spent liquor has been used as a pellet binder, dispersant, cement and concrete additives, etc.(FenGel and Wegner, 1984). Therefore, development of a sulfite cooking process, effective in dissolving lignin or related materials in pine bark, is essential for substitution of lignosulfonates and reutilization of pine bark wastes. Recently, alkaline sulfite-anthraquinone(AS-AQ) cooking has been found to be an efficient method for dissolving lignin or its related material from pine bark and the optimal cooking condition have been established(Mun et al., 1997; Mun and Park, 1999).

Pellet binders have been widely used to improve the diet pellet durability(Pfost, 1964; Pfost and Young, 1973) and the performance of broiler chicks or laying hens(Leeson et al., 1978; Choi et al., 1986; Ibtisan and Sell, 1990). Lignosulfonate, cellulose, hemicellulose, bentonite and collagen protein have been reported as pellet binder for poultry(Shen et al., 1983; Salmon, 1985; Wood, 1987; Tabil et al., 1997).

Lignosulfonate types of pellet binders may especially be effective in a pelleted diet than others(Payne, 1996) because they improve the dietary nutritive value, protein degradability including insoluble nitrogen, and decrease ammonia production in animals (Lawrence, 1983; Windschitl and Stern, 1988; Stanford et al., 1995). They also produce lower serum cholesterol concentration in rats compared with cellulase feeding treatments (Judd et al., 1976) and decrease the cholesterolemic action(Meijer and Beynen, 1990).

Lignin or its related materials in pine bark could be used as an alternative source of lignin to produce lignosulfonates. Mun et al.(1997) reported that pine bark was easily delignified by AS-AQ cooking and resulted in producing approximately 90% delignification. The dissolved materials after cooking of pine bark would be able to play an important role as a pellet binder to improve the pellet quality of practical diets and performance of broiler chicks or laying hens.

Thus, these experiments were conducted to investigate the possible use of pine bark spent liquor(PBSL) as a pellet binder for poultry diets and to compare the effects of PBSL and other commercial pellet binders on the performance of broiler chicks or laying hens.

MATERIALS AND METHODS

1. Preparation of Pine Bark Spent Liquor

Pine bark was obtained from Hansol Paper Mill, Chonju Korea and was air dried and screened to remove sand or small particles. To obtain the spent liquor, 500 hundred grams(oven dry weight; o.d) of pine bark was cooked and then mixed with 30% $Na_2SO_3(Na_2O)$, 7.4% $NaOH(Na_2O)$ and 0.2% AQ according to previous reports (Mun et al., 1997). The liquor to bark ratio was 6:1 for cooking, which was conducted at 180℃ for 3h. The spent liquor was produced and adjusted to pH 7.0 by H_2SO_4. The barl was delignified approximately 89% by this process. The neutralized spent liquor was spray dried at 170℃, 25,000 RPM for 2 h.

2. Experiment 1

Treatments were divided into 14 groups with four replications. Control (no pellet binder), 10% wheat(W10), 20% wheat(W20), 0.25, 0.50, 1.00, 2.00, 3.00% pine bark spent liquor(PBSL), 0.1 or 0.2% commercial pellet binder(CPB) A and B, 0.1% CPB A or B plus W10 treatments were used for pellet diet durability. Binder A belonged to the lignin type of pel-

Table 1. Diet composition of Expt. 1 and Expt. 2

Ingredients	Experiment 1				
	Experiment 2				
	Starter			Finisher	
	Control	W 10	W 20	Control	W 10
Corn	58.95	50.78	42.61	64.32	56.06
Soybean meal (44% CP)	37.48	35.69	33.89	32.12	30.43
Wheat	–	10.00	20.00	–	10.00
DCP	1.73	1.62	1.52	1.77	1.67
Limestone	1.10	1.16	1.23	1.11	1.17
Salt	0.40	0.40	0.40	0.40	0.40
DL−methionine	0.15	0.15	0.15	0.07	0.07
Vitamin premix[1]	0.10	0.10	0.10	0.10	0.10
Mineral premix[2]	0.10	0.10	0.10	0.10	0.10
Total	100	100	100	100	100
Estimated composition					
ME (Kcal/Kg)	3,169	3,149	3,129	3,192	3,172
CP (%)	21.00	21.00	21.00	19.00	19.00
Methionine (%)	0.507	0.507	0.506	0.406	0.405
Lysine (%)	1.239	1.206	1.174	1.096	1.063

[1], Provided per kg of diet : Vitamin A, 10,000 IU; vitamin D_3, 2,200 ICU; vitamin E, 20 IU; riboflavin, 5.6 mg; thiamine, 2.2 mg; pyridoxine, 1.6 mg; vitamin B_{12}, 0.014 mg; niacin, 20 mg; panthothenic acid, 12 mg; folic acid, 1.0 mg; biotin, 0.12 mg; ethoxyquin, 125 mg.

[2], Provided the mg per kg of diet : Mn 66; Zn, 50; Fe, 44; Cu, 4.0; I, 0.6; Se, 0.16.

let binder and has been widely used by broiler integrators to reduce feed cost. Binder B based on collagen protein belongs to a commercial pellet binder type that is produced from animal soft bone tissue. Pellet durability index(PDI) test of experimental diet was conducted to investigate the evaluation of PBSL or other commercial pellet binders in the quality control laboratory of a local feed mill. All diets were pelleted in a F−3 pelleter(Fuji Paudal Co., Osaka Japan). The PDI tester(Oriental Motor, Japan) was rotated at the speed of 50 RPM for 10 min in each 500g samples. The fines of the sample were screened off and the whole pellet weighed. The percentage of remaining whole pellets was used for PDI that was calculated as the formula of (500−fine) × 100/500.

3. Experiment 2

Two hundred day−old male broiler chicks (Cobb × Cobb) were randomly housed in floor pens. Control, W10, 0.5% PBSL, 0.2% CPB A and B were allocated for 5 wk with four replications. Feed and water were provided *ad libitum* and light was supplied for 24 h. The basal diet was based on corn −soybean meal and all nutrients met NRC(1994) requirement except crude protein and metabolizable energy. Weight gain and feed intake were measured, feed conversion ratio(FCR) were calculated each week. Chicks were sacrificed by decapitation at the end of experiment. Ileal anaerobes were measured in fecal samples from the large intestine feces by the dilution plate method.

4. Experiment 3

Two hundred 23 week old Lohman brown laying hens were assigned to five treatments with four replications. The experimental design was the same that of Experiment 2. Hens were placed in layers cage from 24 to 32 wk. All diets contained 18% CP and 2,720 cal/g ME and provided *ad libitum*. Egg production and feed intake were measured, and the feed conversion ratio(FCR) were calculated from 24 to 32 wk of age. Blood protein, albumin, cholesterol, GOT and egg quality were examined at the end of experiment. The eggshell qualities were measured by FHK(Fujihara, Co. LTD., Japan). Yolk color were measured by Roche color fan(Roche Co., USA). Hens were sacrificed by decapitation at the end of experiment. Blood samples were taken from jugular vein and analyzed by the automatic blood analyzer(Minos, BAT, France).

All data were analyzed by the General Linear Models(GLM) procedure of SAS® (SAS Institute, 1990)

RESULTS AND DISCCUSION

1. Experiment 1

Table 2. Diet composition of Expt. 3

Ingredients	Control	Wheat 10%
Corn	59.04	51.30
Soybean meal	26.16	23.15
Fish meal	1.97	3.28
Wheat	–	10.00
DCP	1.24	1.13
Limestone	10.73	10.30
Salt	0.40	0.38
DL-methionine	0.06	0.06
Mineral premix	0.20	0.20
Vitamin premix	0.20	0.20
Total	100.00	100.00
Estimated composition		
ME (kcal/kg)	2,720	2,720
CP (%)	18.50	18.50
Ca (%)	4.468	4.338
Available P (%)	0.409	0.409
Met+cys (%)	0.701	0.702

[1], Provided per kg of diet: Vitamin A, 10,000IU; vitamin D_3, 2,200IU; vitamin E, 20IU; riboflavin, 5.6mg; thiamine, 2.2mg; pyridoxine, 1.6mg; vitamin B_{12}, 14mg; niacin, 20mg; panthothenic acid, 12mg; follic acid, 1.0mg; biotin, 0.12mg and ethoxyquin, 125mg.

[2], Provided the mg per kg of diet: Mn, 66; Zn, 50; Fe, 44; Cu, 4.0; I, 0.6 and Se, 0.16.

The results of Experiment 1 are shown in Table 3. PDI treated all pellet binders were significantly higher than control(P<0.05). It was significantly higher in W20 than W10 treatment(P<0.05). There were no statistical different PDI between 0.1 and 0.2% CPB A, belong to lignosulfonate type. In contrast, it showed significant difference between 0.1 and 0.2% CPB B inclusion treatment(P<0.05). Pine bark spent liquor(PBSL) supplement up to 1% showed significantly higher PDI than control as dietary PBSL inclusion increased(P<0.05). However, the inclusion of 0.5% PBSL was sufficient PDI relative to that of 0.2% CPB A or B. The PDI of W10, 0.5% PBSL, 0.2% CPB A or B was 95.92, 95.92, 95.80, 95.68, respectively. As a result, those treatments were applied to Expt 2 and 3. The PDI between control and pellet binder treatments was different from the previous reports

Table 3. Effects of pine bark spent liquor (PBSL) and other commercial pellet binder (CPB) on pellet durability index (PDI) of broiler diets for Expt. 1

Treatment	PDI
Control	94.00^{g}
Wheat	
10 (W10)	95.92^{c}
20 (W20)	96.20^{b}
PBSL	
0.25	94.88^{f}
0.50	95.92^{c}
1.00	96.50^{a}
2.00	96.52^{a}
3.00	96.67^{a}
CPB A	
0.1	95.68^{d}
0.2	95.80^{cd}
0.1+W10	95.72^{cd}
CPB B	
0.1	95.12^{e}
0.2	95.68^{d}
0.1+W10	95.92^{c}

a–g, Means within column with no common superscripts differ significantly (P<0.05).

(Winowiski, 1988; Briggs et al., 1999) due to the different procedure of pellet diets. However, the results of this experiment indicated that pellet binder supplementation significantly increased the PDI in broiler diets ($P<0.05$).

2. Experiment 2

In previous experiment, W10, 0.5% PBSL, 0.2% CPB A or B treatments exhibited so similar PDI that those treatments were added for the feeding trial of broiler chicks. W10 and CPB A have been used in broiler integrator of feed industry of this country. However, Weight gain of those two treatments were inferior to that of control (Table 4). This may the cause the procedure that control diet was pelleted as the same method of other pellet binder treatments. Weight gain of chicks fed PBSL and CPB B was significantly higher than that of other treatments ($P<0.05$). Chicks fed 0.2% CPB B, control and 0.5% PBSL was significantly different feed intake from other treatments. All pellet binder treatments tended to improve FCR relative to control groups, but was not differ significantly. These results were contrary to the reports that calcium lignosulfate inclusion up to 2.5% did not improve the performance of broiler chicks (Proudfoot and DeWitt, 1976; Proudfoot et al., 1979; Acar et al., 1991). The number of intestinal microflora fed both PBSL and CPB A was significantly reduced ($P<0.05$), but was not shown consisitency. It was decreased in lignosulfonate types of pellet binders due to may be containing phenolic compound or other materials, retarded microbial growth of those pellet binders.

3. Experiment 3

PBSL or commercial pellet binders (CPB) were evaluated in laying hen's diet. Egg production of all treatments was no significance (Table 5). Egg weight of hens fed PBSL or 0.2% CPB B was significantly higher than other treatments ($P<0.05$). The increment of both treatments may due to carbohydrates or protein containing of both pellet binders. Feed intake hens fed PBSL or CPB A was significantly higher than other

Table 4. Effects of PBSL and other commercial pellet binders (CPB) on weight gain (g), feed intake (g), feed conversion ratio (FCR) and intestinal microflora of broiler chicks for Expt. 2

Treatments	Weight gain (g)	Feed intake (g)	Feed/gain	Anaerobes ($\times 10^6$ cfu/g)
Control	1507.9^{ab}	2862.1^{a}	1.916	1.842^{a}
W10	1439.2^{b}	2690.7^{b}	1.880	1.850^{a}
PBSL	1528.9^{a}	2852.4^{a}	1.878	1.417^{b}
CPB A	1443.6^{b}	2703.1^{b}	1.882	1.175^{c}
CPB B	1550.5^{a}	2873.4^{a}	1.866	1.685^{a}
Pooled SE	11.804	8.945	0.014	5.802

$^{a-c}$, Means within column with no common superscripts differ significantly ($P<0.05$).

Table 5. A comparison of PBSL prepared by alkaline sulfite-anthraquinone cooking and other commercial pellet binders (CPB) on performance of laying hen for Expt. 3

Treatments	Egg production (%)	Egg weight (g)	Feed intake (g)	Feed intake/egg
Control	95.44	57.47^{bc}	124.94^{c}	2.312^{ab}
W10	96.21	56.39^{bc}	127.97^{a}	2.336^{a}
PBSL	95.66	58.10^{a}	126.72^{b}	2.258^{bc}
CPB A	96.21	56.21^{c}	123.58^{d}	2.261^{bc}
CPB B	95.78	57.70^{b}	122.94^{d}	2.250^{c}
Pooled SE	0.278	0.075	0.175	0.009

$^{a-c}$. Means within column with no common superscripts differ significantly ($P<0.05$).

treatments(P<0.05). PBSL contained sodium salts may have a role to increase feed intake. PBSL, CPB A and B treatements exhibited significantly improved FCR compared to other groups(P<0.05).

The results of blood components are shown in Table 6. It was no significance except cholesterol. The blood protein of hens fed PBSL or CPB B tended to be higher than that of other treatments, but was not significantly different. The GOT fed pellet binders seemed to be higher than control, but was no significance between treatments. Blood cholesterol of hens fed control was significantly increased compared to that of other treatments(P<0.05). However, it was significantly decreased with PBSL inclusion (P<0.05). The results of this experiment was the similar trend to the reports that cholestrolemic effects of lignin types pellet binder would be lower than control groups in rats(Judd et al., 1976; Meijer and Beynen, 1990).

The egg qualities of hens fed PBSL or other commercial pellet binders were shown in Table 7. Eggshell breaking strength, Haugh unit and yolk index were no significance of all treatments. Eggshell breaking strength was no consistency, whereas hens fed PBSL tended to improve Haugh unit than other treatments. Lignosulfonates types of pellet binders treatments also showed significantly higher yolk color compared to that of control groups(P<0.05). It seemed to the cause of PBSL contained xanthophyll or other color that influence the yolk color.

In conclusion, the results of Expt 1 indicated that 0.5% PBSL supplementation had equal pellet binding ability to 0.2% other commercial pellet binders, but significantly higher PDI than control groups in broiler diets. The broiler chicks fed 0.5% PBSL showed sufficient to weight gain and FCR of 0.2% other commercial pellet binder treatments in Expt. Hens fed 0.5% PBSL inclusion tended to improve egg production and FCR, but was not significantly different. PBSL supplements increased egg weight and feed intake significantly(P<0.05). Hens fed PBSL decreased blood cholesterol significantly compared to that of control(P<0.05). The yolk color of hens fed PBSL was

Table 6. A comparison of blood components of laying hens fed PBSL or commercial pellet binders (CPB) for Expt. 3

Treatments	Protein (%)	Albumin	Glucose	GOT	Cholesterol
	(%)	(g/dl)	(mg/dl)	(U/L)	(mg/dl)
Control	7.00	2.49	176.27	158.25	252.90[a]
W 10	6.81	2.59	187.58	162.50	192.63[b]
PBSL	7.49	2.44	188.99	170.75	192.10[b]
CPB A	6.97	2.57	191.37	171.00	174.33[b]
CPB B	7.10	2.41	181.63	185.24	177.03[b]
Pooled SE	0.110	0.028	2.763	3.574	8.460

[a,b], Means within column with no common superscripts differ significantly (P<0.05).

Table 7. Effects of PBSL or other commercial pellet binders on egg quality of laying hen for Expt. 3

Treatments	Eggshell breaking strength(kg/cm^2)	Yolk color	Haugh unit	Yolk index[1]
Control	3.959	6.071[c]	76.47	0.497
W 10	4.079	6.667[ab]	77.67	0.487
PBSL	4.069	7.000[a]	72.32	0.503
CPB A	3.952	7.000[a]	79.05	0.480
CPB B	4.150	6.429[bc]	72.94	0.468
Pooled SE	0.098	0.089	1.131	0.005

[1], Yolk height/Yolk width.

[a,b,c], Means within column with no common superscripts differ significantly (P<0.05).

significantly higher than control groups. Hence, PBSL would be able to use as a pellet binders in poultry diets and have a feeding effect on performance of broiler chicks or laying hens

적 요

소나무 수피로부터 alkaline sulfite-anthraquinone cooking을 통하여 생산된 Pine Bark Spent Liquor (PBSL)의 펠렛 내구성(Pellet durability index(PDI))과 사료결착제로서 가능성을 구명하기 위하여 육계와 산란계 사료에 첨가 · 급여하였다. 실험 1에서는 실용계 사료인 대조구, 소맥 10%와(W10), 20% 첨가구(W20), PBSL 0.25, 0.50, 1.00, 2.00, 3.00% 첨가구, 두 종류의 시판용 사료결착제 0.1, 0.2%(CPB A와 CPB B), W10 + 0.1% CPB A or B로 14개 처리구를 4반복으로 하여 펠렛 내구성 조사를 시행하였다. PDI는 PDI tester(Oriental motors, Japan)로 측정하였다. 실험 2에서는 1일령 육계 수컷 200수를 무첨가구인 대조구외에 실험 1에서 최적으로 판단되는 처리구인 W10, PBSL 0.5%, 0.2% CPB A and B의 5개 처리구를 4반복으로 배치하여 시행하였다. 기초사료는 사육전기에 3,169와 3,149kcal/kg ME와 21% CP를 급여하였고, 사육후기에는 3,192와 3,172 kcal/kg ME와 19% CP사료를 급여하였다. 증체량, 사료섭취량, 사료요구율은 주간별로 5주간 측정하였으며 실험 종료시에 장내 혐기적인 미생물 수를 조사하였다. 실험 3에서 24주령 로만 갈색계 450수를 이용하여 처리구는 실험 2와 동일하게 8주간 시행하였다. 처리구당 반복은 18수씩 5반복으로 90수 전체 450수를 이용하였다. 사료는 대사에너지 2,720 kcal/kg와 CP는 18.5%로 하였다. 처리구당 산란율, 난중, 사료섭취량, 사료요구율, 계란의 품질을 주간별로 조사하였으며, 실험종료시에 혈액의 성상을 조사하였다. 실험 1에서 PBSL 0.5%, W10 0.5%, CPB A, B 0.2% 처리구의 PDI는 95.9, 95.9, 95.8, and 95.7로서 대조구에 비하여 현저하게 높았다(P<0.05). 그러므로 이러한 결과는 실험 2와 3에 적용하였다. 실험 2에서 PBSL 처리구의 증체량은 대조구와 통계적인 차이는 없었지만W10과 CPB A와는 현저하게 차이가 있었다(P<0.05). 사료요구율은 PBSL이나 다른 사료결착제 처리구에서 대조구에 비하여 개선되는 경향을 보였다. W10을 제외한 사료결착제 처리구에서 장내 혐기성 미생물 수는 대조구에 비하여 현저하게 낮았다(P<0.05). 실험 3에서, 모든 처리구간에 산란율은 차이가 없었으며, 난중과 사료요구율은 0.5% PBSL 처리구에서 대조구에 비하여 현저하게 개선되었다(P<0.05). 혈중 콜레스테롤도 펠렛사료결착제 처리구에서 대조구에 비하여 현저하게 낮았다(P<0.05). 본 연구의 결과 PBSL은 가금용 사료에 0.5%를 첨가하였을 때 펠렛 결착제로서 가능함을 시사한다.

(색인어 : 펠렛 결착제, 펠렛결착도, 소나무수피, 육계, 산란계)

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