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Performance of Broiler Chicks Fed Wheat-based Diets Supplemented with Combinations of Non-extruded or Extruded Canola, Flax and Peas

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Abstract: The objective of this study was to determine the potential of various combinations of flax, canola and peas to replace soybean meal in diets fed to broiler chicks and to determine whether the extrusion process is beneficial in improving the nutritive value of these protein sources. A total of 210-day old, male broiler chicks (Ross-308 line) weighing an average of 45.3±0.6 g were randomly assigned to one of seven dietary treatments for a 21-day experiment. There were five birds per pen and six pens per treatment. The control diet was based on wheat and soybean meal while the six experimental diets contained 25% extruded or non-extruded combinations of flax and peas (50:50; Linpro®), canola and peas (50:50; Extrapro®) or canola, flax and peas (25:25:50; Flexipro®), added at the expense of wheat and soybean meal. Chromic oxide (0.35%) was added to all diets as a digestibility marker. Digestibility coefficients for dry matter were significantly ($p<0.05$) lower for the diets containing either extruded or non-extruded Linpro, Extrapro and Flexipro in comparison with the soybean meal diet. Digestibility coefficients for energy and protein followed a similar trend although they were only significantly ($p<0.05$) lower for the non-extruded Linpro and Extrapro diets as well as both extruded and non-extruded Flexipro. These reductions in digestibility are likely a reflection of the higher neutral detergent fibre content of the diets containing Linpro, Extrapro and Flexipro. With the exception of the digestibility coefficient for crude protein for the Flexipro diet, extrusion significantly ($p<0.05$) increased the digestibility coefficients for dry matter, crude protein and gross energy for Linpro, Extrapro and Flexipro. This indicates that in addition to the higher fiber content, there are additional anti-nutritional factors contained in these ingredients reducing digestibility and that these factors appear to be heat labile. With the exception of birds fed raw Linpro, the weight gain of birds fed any of the experimental diets did not differ significantly ($p>0.05$) from that of birds fed soybean meal. Feed intake was also unaffected by dietary treatment. All three products when fed in raw form significantly depressed feed conversion but the depression was overcome by extrusion. In conclusion, extrusion of blends of full-fat flax, canola and peas significantly increased digestibility coefficients for dry matter and energy and resulted in significant improvements in feed conversion compared with non-extruded blends. Use of these products may provide poultry producers with a mechanism to increase the omega-3 fatty acid content of poultry meat thereby catering to the needs of the health conscious consumer.

Key Word: Wheat-based diets, non-extruded, extruded canola, flax, peas

INTRODUCTION

In humans, omega-3 fatty acids are thought to be important for normal growth and development and in decreasing or delaying a number of chronic diseases including cardiovascular disease and hypertension as well as autoimmune, allergic and neurological disorders[1-4]. As a result of these benefits, health authorities in many countries are advising people to increase their consumption of omega-3 fatty acids.

Full-fat canola (rapeseed) and flax (linseed) contain approximately 20-25% crude protein and 40-43% oil[5] . Therefore, they are potentially valuable high-protein, high-energy feedstuffs for use in poultry rations. The oils of these seeds are also rich in α-linolenic acid with canola and flax containing 10-12 and 48-52% α-linolenic acid, respectively[6]. Incorporation of full-fat canola and flax into diets fed to broilers has been shown to significantly increase the incorporation of omega-3 fatty acids into carcass tissues[7-9]. This may make meat from poultry fed flax and canola seed a potential source of omega-3 fatty acids for the human diet.

It can be difficult to incorporate full-fat canola and flax into a diet as the meshed screen on a hammer mill has a tendency to become plugged when processing these products. Handling problems during grinding and storage

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attributed to the high oil content of the flax and canola seeds can be counteracted by mixing these products with other ingredients such as ground peas.

Unfortunately, anti-nutritional factors occur in both canola and flax. Glucosinolates, sinapine and tannins are present in canola seed[10-11] while flax contains mucilage, phytic acid, goitrogens, allergens and anti-pyridoxin[12]. As a consequence, the performance of birds fed full-fat canola and flax may be improved by heating of the seed[13-15].

Soybean meal is the most commonly used source of supplementary protein for poultry production and it is generally a consistent, high quality product[16]. However, as transportation costs for feed increase, poultry producers will have to maximize the use of locally produced feedstuffs. Therefore, it is important that alternative sources of supplementary protein be developed. A series of products have recently been developed for use in the poultry industry in which various combinations of flax, canola and peas are mixed and extruded. The objective of the following experiment was to determine the potential of these products to replace soybean meal in diets fed to broiler chicks and to determine whether the extrusion process is beneficial in improving the nutritive value of mixtures of flax, canola and peas.

MATERIALS AND METHODS

Acquisition of ingredients: The protein sources tested during this experiment are recently developed, commercially available products marketed under the brand names of Linpro®, Extrapro® and Flexipro® (Oleet Processing Ltd., Regina, Saskatchewan). Linpro is an extruded product produced using a combination (50:50) of full-fat flax and peas, Extrapro is an extruded blend (50:50) of full-fat canola seed and peas while Flexipro consists of approximately 25% full-fat canola, 25% full-fat flax and 50% peas.

In order to produce the final product, the appropriate amount of peas were ground, mixed with the various high oil products and then the mixtures were extruded for 5-10 sec using an Instapro Extruder (Instapro Inc., Des Moines, Iowa) at a temperature of 120-135°C. The non-extruded mixtures were diverted from the production line immediately before extrusion and thus contained the same raw materials as the extruded products. The soybean meal used was obtained from a local feed processor. A chemical analysis of the protein sources is shown in Table 1.

Growth trial: A total of 210-day old, male broiler chicks (Ross-308 line; Lilydale Hatchery, Wynyard, Saskatchewan) weighing an average of 45.3±0.6 g were randomly assigned to one of seven dietary treatments. The control diet was based on wheat and soybean meal while the six experimental diets contained 25% of extruded or non-extruded Linpro, Extrapro or Flexipro, added at the expense of wheat and soybean meal (Table 2). All diets were supplemented with sufficient vitamins and minerals to meet or exceed the levels recommended by the NRC[17]. The experiment diets were provided in mash form (3 mm screen) and the experiment was conducted over a 21-day period.

The chicks were housed in raised-floor battery cages (83.8 x 45.7 x 25.4 cm; Jamesway Manufacturing Co., Ft. Atkinson, WI, USA) with mesh grate floors overtop of fecal collection trays. There were five birds per pen and six replicate pens per treatment. Feed and water were available ad libitum throughout the experiment. The battery brooder was maintained at a temperature of 35°C for the first week with the temperature gradually reduced to 29°C by the end of second week. Incandescent lighting was provided continuously during the experiment.

Broilers were weighed individually at the start (day 1) and end of the experiment (day 21) as well as at weekly intervals. Weighed amounts of feed were added as required with a single weigh back at the conclusion of the experiment to allow for the calculation of feed consumption and feed conversion on a pen basis.

Digestibility determination: Chromic oxide (0.35%) was added to all diets as a digestibility marker and was fed throughout the experimental period. During the final two days of the experiment (morning and afternoon), clean feces (free from feathers and feed) were collected from plastic liners placed in the fecal collection trays underneath each pen of birds. The fecal samples from the four collections were pooled and then frozen for storage. Prior to analysis, the samples were dried in a forced oven dryer at 55°C for 72 h, followed by fine grinding. The digestibility coefficients for dry matter, crude protein and energy were determined using the equations for the indicator method described by Schneider and Flatt[18].

Chemical analysis: Samples of the experimental diets and feces were analysed according to the methods of the Association of Official Analytical Chemists[19] (Table 3). Analys.s were conducted for moisture (AOAC method 930.15), crude protein (AOAC method 984.13), ash (AOAC method 942.05) and ether extract (AOAC method 920.39). Neutral detergent fibre was analysed using the method of Van Soest *et al.*[20]. The calcium and phosphorus content of the experimental rations were determined using the nitric-perchloric acid digestion method of Zasoski and Burau[21] with calcium determined on a Perkin-Elmer Model

4000 Atomic Absorption Spectrophotometer (AOAC method 968.08) and total phosphorus determined colorimetrically (Pharmacia LKB Ultrospec III) using a molybdovanadate reagent (AOAC method 965.17). An adiabatic oxygen bomb calorimeter (Parr; Moline, Illinois) was used to determine gross energy. Chromic oxide was determined by the method of Fenton and Fenton[22] .

STATISTICAL ANALYSIS

All data were analysed as a one-way ANOVA using the General Linear Models procedure of the Statistical Analysis System Institute, Inc.[23] . Significant differences between means were determined by Student Neuman Keuls' multiple range test with the 5% level set as the level of significance.

RESULTS AND DISCUSSION

The chemical analysis of the basic ingredients used in formulating the diets is shown in Table 1. The nutrient contents of the wheat and soybean meal used to formulate the diets were similar to industry standards for these ingredients[17] with the exception of the protein content of the wheat, which was higher than that typically reported (17.2 vs. 14.1%). The Linpro, Extrapro and Flexipro used in the present trial contained approximately 21% crude protein and 23% ether extract. These values are roughly intermediate to the chemical composition of peas[17] vs. full-fat flax and canola seed [24] and are within the range of analysis that would be expected for a 50:50 blend of these ingredients. Extrusion tended to reduce the moisture and neutral detergent fibre content of the feed while increasing crude protein and ether extract.

The chemical analysis of the diets fed are presented in Table 3. The crude protein content of all the diets was similar while the ether extract and neutral detergent fiber content of the soybean meal diet was lower than the other diets reflecting the chemical composition of the basic ingredients used in formulating the diets.

Digestibility coefficients for dry matter were significantly ($p<0.05$) lower for the diets containing either extruded or non-extruded Linpro, Extrapro and Flexipro in comparison with the soybean meal diet (Table 4). Digestibility coefficients for crude protein and energy followed a similar trend although digestibility coefficients were significantly lower ($p<0.05$) for the non-extruded diets only. The reductions in digestibility are likely a reflection of the higher neutral detergent fibre content of the diets containing Linpro, Extrapro and Flexipro. Fiber is not very digestible by poultry[25] and its presence impairs the digestibility of energy and other nutrients contained in the grain[26] . It is thought that dietary fibre reduces nutrient digestibility due to its physiochemical properties, leading to a more rapid rate of passage, thus limiting the amount of time available for nutrient breakdown[27] .

With the exception of the digestibility coefficient for crude protein for the Flexipro diet, extrusion significantly ($p<0.05$) increased the digestibility coefficients for dry matter, crude protein and gross energy for Linpro, Extrapro and Flexipro. This indicates that in addition to the higher fiber content, there are additional anti-nutritional factors contained in these ingredients reducing digestibility and that these factors appear to be heat labile.

The performance of broilers fed diets containing the extruded and non-extruded protein sources is shown in Table 5. The weight gain and feed conversion of broilers fed the soybean meal diet was significantly ($p<0.05$) better than the non-extruded Linpro diet. Raw-untreated flax seed has been reported to significantly reduce broiler performance[6,8,28] . The decrease in performance with diets containing raw flaxseed has been suggested to be due to the presence of antinutritional factors such as mucilage[20] , cyanogenic glycosides[30], allergens[31] and vitamin B_6 antaogonists[32]. Heat treatments such as boiling, wet autoclaving and dry autoclaving have been shown to at least partially detoxify the antinutritional factors in flaxseed and thereby improve broiler performance[14,15]. It would therefore appear that the heat generated in the extrusion process used in the production of Linpro significantly improves the nutritional value of whole-flax seed for poultry.

The weight gain of broilers fed Extrapro, regardless if extruded or non-extruded, was not significantly different from that of boilers fed soybean meal, supporting the findings of Leeson *et al.*[33] and Shen *et al.*[13]. In contrast, Summers *et al.*[34] reported that broilers fed diets containing 17.5 and 35% canola seed did not perform as well as broilers fed soybean meal containing diets.

The feed conversion of broilers fed non-extruded Extrapro was significantly ($p<0.05$) poorer that that of broilers fed soybean meal. This supports the findings of Shen *et al.*[13] (1983) and Summers *et al.* [34]. Extrusion improved feed conversion by 9.6% compared with the non-extruded product. This finding conflicts with that of Lee *et al.*[6] and Leeson[33] who reported little benefit of heat treatment of canola seed. However, Shen *et al.*[13] reported improvements of a similar magnitude to those of the current study using steam crumbling of canola seed.

It is important to point out that the Linpro, Extrapro and Flexipro products contained not only flax and canola seed but also peas. As a result, the improved performance

Table 1: Chemical composition of ingredients used to determine the effects of extrusion on the nutritive value of blends of canola, flax and peas

	Wheat	SBM	Raw linpro[2]	Extruded linpro	Raw extrapro[3]	Extruded extrapro	Raw flexipro[4]	Extruded flexipro
Moisture	10.86	9.93	10.82	6.63	10.53	5.69	10.67	6.50
Crude protein	17.17	44.86	20.27	22.56	20.99	20.97	20.63	22.16
Ash	1.84	6.94	3.41	3.97	3.94	3.67	3.67	3.58
Ether extract	1.60	1.33	21.30	25.44	23.70	23.87	22.50	23.23
Neutral detergent fibre	13.15	7.56	16.31	12.92	17.57	11.69	16.94	11.94

[1]Linpro is a 50:50 combination of whole flax and peas
[2]Extrapro is a 50:50 combination of whole canola seed and peas
[3]Flexipro is a 25:25:50 combination f whole flax, whole canola seed and peas

Table 2: Formulation of diets used to determine the effects of extrusion on the nutritive value of blends of canola, flax and peas

	SBM	Raw linpro	Extruded linpro	Raw extrapro	Extruded extrapro	Raw flexipro	Extruded flexipro
Wheat	60.36	43.63	43.63	43.84	43.84	43.74	43.74
Soybean meal	32.42	25.69	25.69	25.85	25.85	25.75	25.75
Raw or extruded linpro[2]	0.00	25.00	25.00	0.00	0.00	0.00	0.00
Raw or extruded extrapro[3]	0.00	0.00	0.00	25.00	25.00	0.00	0.00
Raw or extruded flexipro[4]	0.00	0.00	0.00	0.00	0.00	25.00	25.00
Canola Oil	2.90	1.37	1.37	1.11	1.11	1.24	1.24
Dicalcium Phosphate	1.67	1.62	1.62	1.62	1.62	1.62	1.62
Limestone	1.08	1.09	1.09	1.03	1.03	1.07	1.07
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Vitamin-mineral premix[1]	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Chromic oxide	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Choline	0.08	0.08	0.08	0.08	0.08	0.08	0.08

[1]Supplied per kilogram of diet: 11,000 IU vitamin A (retinyl acetate + retinyl palmitate), 2,200 IU vitamin D_3, 30 IU vitamin E (dl-α-topheryl acetate), 2 mg menadione, 1.5 mg thiamine, 6 mg riboflavin, 60 mg niacin, 4 mg pyridoxine, 0.02 mg vitamin B_{12}, 10 mg pantothenic acid, 6 mg folic acid, 0.15 mg biotin, 0.625 mg ethoxyquin, 500 mg calcium carbonate, 80 mg iron, 80 mg manganese, 10 mg copper, 0.8 mg iodine, 0.3 mg selenium
[2]Linpro is a 50:50 combination of whole flax and peas.
[3]Extrapro is a 50:50 combination of whole canola seed and peas.
[4]Flexipro is a 25:25:50 combination of whole flax, whole canola seed and peas

Table 3: Chemical analysis of diets used to determine the effects of extrusion on the nutritive value of blends of canola, flax and peas

	SBM	Raw linpro[2]	Extruded linpro	Raw extrapro[3]	Extruded extrapro	Raw flexipro[4]	Extruded flexipro
Moisture	11.54	11.23	10.45	11.36	10.23	11.27	10.00
Ash	6.03	6.05	6.33	6.01	6.13	5.97	6.13
Crude protein	24.90	23.91	25.16	24.49	24.53	24.34	24.91
Ether extract	4.53	7.99	9.08	7.72	8.21	7.90	8.03
Neutral detergent fibre	10.44	15.65	14.27	14.21	13.33	15.28	14.20
Calcium	0.95	0.96	0.98	0.98	0.88	0.95	0.97
Phosphorus	0.78	0.79	0.81	0.79	0.78	0.77	0.79

[1]Results are the mean of analyses conducted in duplicate.
[2]Linpro is a 50:50 combination of whole flax and peas.
[3]Extrapro is a 50:50 combination of whole canola seed and peas.
[4]Flexipro is a 25:25:50 combination of whole flax, whole canola seed and peas

Table 4: Rffects of ectrusion on nutrient digestibility and retention in diets containing blends of canola, flax and peas fed to broiler chicks

	SBM	Raw linpro[3]	Extruded linpro	Raw extrapro[4]	Extruded extrapro	Raw flexipro[5]	Extruded flexipro	SEM
Dry Matter (%)	62.2^{a}	51.7^{c}	58.6^{b}	53.2^{c}	57.3^{b}	47.5^{d}	49.8^{cd}	1.16
Energy (%)	67.5^{a}	54.1^{b}	64.6^{a}	55.6^{b}	63.7^{a}	50.1^{c}	55.6^{b}	1.25
Nitrogen retention (%)	51.0^{a}	42.9^{b}	52.8^{a}	44.2^{b}	49.9^{a}	38.0^{b}	39.6^{b}	1.77

[1]Standard error of the mean
[2]Within row, means followed by same or no letter (s) do not differ ($p<0.05$)
[3]Linpro is a 50:50 combination of whole flax and peas.
[4]Extrapro is a 50:50 combination of whole canola seed and peas.
[5]Flexipro is a 25:25:50 combination of whole flax, whole canola seed and peas

Table 5: Effects of extrusion on the performance of broiler chicks fed diets containing blends of canola, flax and peas (0-21 days)

	SBM	Raw linpro[3]	Extruded linpro	Raw extrapro[4]	Extruded extrapro	Raw flexipro[5]	Extruded flexipro	SEM
Weight Gain (g)	812^{a}	663^{b}	723^{ab}	701^{ab}	764^{ab}	723^{ab}	761^{ab}	28.8
Feed Intake (g)	1120	1109	1057	1085	1068	1150	1051	40.7
Feed Conversion	1.38^{d}	1.68^{a}	1.46^{cd}	1.55^{bc}	1.40^{d}	1.59^{ab}	1.38^{d}	0.03

[1]Standard error of the mean
[2]Within row, means followed by same or no letter (s) do not differ ($p<0.05$)
[3]Linpro is a 50:50 combination of whole flax and peas.
[4]Extrapro is a 50:50 combination of whole canola seed and peas.
[5]Flexipro is a 25:25:50 combination of whole flax, whole canola seed and peas

of broilers fed the extruded compared with the non-extruded products could just as likely be due to the effects of extrusion on the pea component of the diet. The inclusion of raw peas in the diet of broiler chickens has been reported to have a negative effect on growth rate[35,36]. This negative effect is generally attributed to the presence of various antinutritional factors in peas including protease inhibitors[37] and tannins[38] . Again, heat treatments including micronization[39] and autoclaving[40] have been shown to improve the nutritive value of peas for poultry. Extrusion heating, as used in the present experiment, has been shown to significantly reduce the level of anti-nutritional factors in peas[41] .

Although the potential to incorporate omega-3 fatty acids into carcass tissues may be sufficient justification to recommend the use of Linpro, Extrapro and Flexipro in poultry diets, there may be additional advantages to their use. It is possible that the use of these high-fat products could play a role in reducing dust levels in poultry barns as Chiba *et al.*[42] reported significant reductions in aerial dust levels in livestock facilities, which fed diets containing additional lipid. Theprepackaged fat in the products may also be of benefit to poultry producers who mix their own feed, and who may not have sufficient production volume to justify keeping a heated fat tank at their feed mixing facility.

CONCLUSIONS

The extrusion of blends of full-fat flax, canola and peas significantly increased digestibility coefficients for dry matter and energy and resulted in significant improvements in feed conversion compared with non-extruded blends. Use of these products may provide poultry producers with a mechanism to increase the omega-3 fatty acid content of poultry meat thereby catering to the needs of the health conscious consumer.

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