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The Effects of Different Levels of Edible Potato (*Solanum tubresum*) Replacing Maize on Performance, Serum Metabolite and Immune System of Broiler Chicks

Research Article

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ABSTRACT

An experiment was conducted to determine the effect of different levels of potato replacing maize seed on performance characteristics and immunes system of broiler chicken in a completely randomized design. A total of 220 broiler chicks were randomly assigned to 5 treatment groups, with 4 replicates of 11 birds each. The chicks in the first group were fed basal diet (control), 2nd and 3rd groups were fed with the cooked potatoes (25 and 35% replacing maize) and 4th and 5th groups were fed raw potatoes (25 and 35% replacing Maize). Two methods were used for preparing the potatoes. In the first method whole potatoes were cooked and then dried in the sun. In the second method the potatoes dried in the sun only. At the end of experiment one bird from each replicate was slaughtered for carcass analysis. There were no significant differences in feed intake, daily feed intake, daily weight gain, feed conversion rate, mortality percentage, carcass percentage, liver percentage and breast, leg, thymus, spleen percentage, concentration of cholesterol, triglyceride, LDL and HDL between treatments (P>0.05). Treatment did however have a significant effect on starter weight gain, starter FCR, pancreas percentage, small intestine, duodenum, jejunum and ileum weight, bursa of fabricius weight percentage and concentration of serum glucose of grower (P<0.05). The use of potato in broiler diets decreased blood cholesterol and consequently reduced abdominal fat pad. According to the results of this experiment, the level of 25% dried potato can replace maize seed without performance reduction of broilers. Replacing maize with potatoes caused a delay in growth rate at higher level.

KEY WORDS broiler, immune system, performance, potatoes, serum metabolites.

INTRODUCTION

A major constraint to poultry production in developing countries is the scarcity and high cost of the components of rations. Maize seed, which usually forms the bulk of such diets, has many other uses and is not readily available for poultry because of its high cost. Furthermore, production of maize in many tropical countries has fallen short of demand because of frequent drought, food, and locust infestation affecting some maize-producing areas. For these reasons, dependence upon maize as the sole source of dietary energy for the poultry industry may be precarious and an alternative is required (Agwunobi, 1999). In poultry industry, the food appropriates a most part of the total cost of meat and egg production. Ayuk and Essien (2009) stated that feed cost makes the highest cost in animal production (70%-80%). Maize and soybean meal are the major components of poultry nutrition in the world.

The scarcity and prohibitive cost of commercial energy sources like maize for poultry rations, has been the maincause of the high cost of poultry products especially in developing countries. The poultry raisers all over the world and particularly those of the developing countries consider use of alternative plants that can be easily grown and yield at least the same per unit area as compared to maize for inclusion in poultry rations. This will subsequently lead to a reduction of the cost of production of poultry meat. Potato readily comes to mind as a promising alternative (Ayuk and Essien, 2009). Potato is generally considered as a high-energy food and is the staple crop of many parts of the world. The cost of production of potato is much lower compared to cereal crops according to economic condition. Potato (fresh basis) contains approximately 20-25% dry matter with 12% crude protein which contains about ½ true proteins.

It contains a reasonably high amount of most amino acids but is limiting in tryptophan and sulphur-containing amino acids (Morrison, 1961). Most studies on potato have indicated that it can be used to partially replace maize in the ration of layers (Bekibele, 1981; Agwunobi, 1993) and broiler chickens (Fetuga and Oluyemi, 1976; Gerspacio *et al*. 1978; Job *et al*. 1979). According to these reports, it could be a good alternative to maize-fed chicken. The overall objectives of this study were to assess the effects of different levels of potato (*Solanum tubresum*) replacing maize seed in broilers' diets on performance, relative organ weight, serum metabolites and humeral immune response.

MATERIALS AND METHODS

All procedures were approved by the Institutional Animal Care and Use Committee of Razi University. A total number of 220 unsexed 1 day-old ROSS 308 broiler chicks were divided between 20 cage pens (battery) in a completely randomized experimental design with five treatments and four replicates of eleven chicks in each.

The temperature was maintained at 32 ± 1 ˚C in the first week and reduced by 2.5 ˚C a week to 21 ˚C. From day 1 until day 4 the lighting schedule was 24 h light. During days 5-42, the dark periods were increased to 1 h. The height of used nipple drinkers were adjusted twice weekly by visual inspection. Chicks were fed diets (starter for 21 days and grower from 22-42 days) based on NRC. The composition of experimental diets is shown in Table 1.

Treatments were: Control (C), Dried-cooked potato (Dcp 25 and 35% replacing maize) and Dried-raw potato (Drp 25 and 35% replacing maize) in starter and grower diets. Feed and water were available *ad libitum*. The potatoes were cooked at 100 ˚C for 45 minute. Two methods were used for preparing the potatoes. In the first method whole potatoes were cooked and then dried in the sun. In the second method the potatoes dried in the sun only for 2 days in the summer season. Dry matter was 89% by these methods.

Table 1 Composition of feed mixtures (%)

	Potato levels (%)					
	Starter			Grower		
	0%	25%	35%	0%	25%	35%
Ingredients (%)						
Potato	0	15.24	21.33	0	15.98	21.37
Maize	60.97	45.24	39.63	63.94	47.95	41.56
Soybean meal	33.68	33.89	33.60	28.85	28.78	28.76
Soybean oil	0.97	0.97	0.91	3.87	3.02	3.00
DCP	1.73	1.79	1.81	1.54	1.60	1.62
Limestone	1.39	1.36	1.35	1.27	1.24	1.23
Common salt	0.36	0.37	0.37	0.37	0.37	0.37
Vitamin premix[1]	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
DL-methionine	0.20	0.29	0.30	0.17	0.25	0.28
HC-lysine	0.19	0.30	0.20	0.30	0.30	0.30
Calculated analyses						
ME (kcal/kg)	3010	3010	3010	3175	3175	3175
Crude protein (%)	22	22	22	20	20	20
Calcium (%)	1	1	1	0.9	0.9	0.9
Available P (%)	0.5	0.5	0.5	0.45	0.45	0.45
Lysine (%)	1.36	1.44	1.44	1.29	1.25	1.23
Methionine (%)	0.5	0.57	0.57	0.88	0.88	0.83
Met + Cys (%)	0.88	0.93	0.93	0.88	0.88	0.83

[1] Vitamin premix provided 1 kg of diet with: vitamin A: 10800 IU; vitamin D3: 2160 IU; vitamin E: 15 IU; vitamin B6: 8 mg; vitamin B12: 0.08 mg; Pantothenic acid: 10 mg; Niacin: 25 mg; Folic acid: 0.4 mg and Biotin: 5 mg.

[2] Mineral premix provided per kg of diet with: I: 0.35 mg; Se: 0.15 mg; Zn: 40 mg; Cu: 8 mg; Fe: 80 mg and Mn: 5 mg.

Body weights (BW) were recorded on days 0, 21 and 42 of age and feed intake (FI) was measured to calculate feed conversion ratio (FCR) for each feeding period. Mortality ratio was recorded daily and FCR was corrected for mortality by adding body weights to the total pen weight at the end of each period. Blood samples were collected from the brachial vein of four randomly selected chicks per treatment at 21 and 42 days of age and transferred into tubes containing Heparin after providing the blood smear and staining by Giemsa. Differential counting of lymphocytes was done using light microscope.At the end of experiment, from each treatment 4 chicks were randomly selected (1 chick from each pen) and slaughtered by cervical dislocation. The weights of thighs and breast (all without skin), abdominal fat, liver, gallbladder, pancreas, spleen, bursa of fabricius and thymus were measured. Relative organ weights were calculated as organ weight (g/kg BW).

Before evisceration, blood samples (1 chick in each pen) were taken via wing veins of chicks. The blood samples were transferred into tubes and then centrifuged (10 min and 3000 rpm). The sera were removed and stored at -20 ˚C for further analysis. The serum levels of glucose, cholesterol, triglyceride, HDL and LDL were measured with spectrophotometer by using commercial kits (Pars Azmon, Iran). Small intestines of birds were opened immediately after killing and length and empty weight of various sections (Duodenum, Jejunum and Ileum) were measured. Data were analyzed by GLM procedure of SAS (SAS Institute Inc., Cary, NC). Probability values (P<0.05) were taken to indicate statistical significance. The treatment means were compared using Duncan's multiple range test.

RESULTS AND DISCUSSION

The performances of chicks are detailed in Table 2. Daily feed intake and mortality were not statistically affected by dietary inclusion of difference levels of potato replacing maize seed (P>0.05). Daily weight gain and FCR in the starter period of chicks fed on diets including difference level of Dried-raw potato replacing maize were statistically affected by dietary treatment (P<0.05). Chicks fed with Dried-cooked potato at the level of 25% replacing with maize seed showed higher BWG daily and improved FCR when compared with other experimental groups. The data of relative organ weights and intestinal length are summarized in Table 3. The weights of thighs, breast, empty body, carcass, abdominal fat, liver and gallbladder expressed as a percentage of BW were not statistically affected by the dietary treatment (P>0.05).

Length and weight of different intestinal sections were increased by dietary inclusion of Dried-raw potato (P<0.05). The length of jejunum in Dcp 25% treatment and the weights of small intestine, jejunum and ileum in Drp 25% and Drp 35% treatments were significantly higher than control group (P<0.05). The relative weights of pancreas in Drp 25% and Drp 35% treatments were higher comparing with other experimental groups (P<0.05). Dietary treatments had no significant effect on weights of cecum (P>0.05); however, cecum weights tended to be higher in dried-raw levels of potato. The length of small intestine, duodenum and ileum did not statistically differ among treatments (P>0.05).

The effects of dietary treatments on serum metabolite contents are shown in Table 4. Serum glucose, cholesterol, triglyceride, HDL and LDL were not affected by dietary treatment in 21 days (P>0.05), but content of glucose were significantly affected by dietary treatment in grower period (P<0.05). The content of glucose in Dcp35% treatment was higher and in Dcp25%, Drp25% and Drp35% treatments was lower comparing with control group (P<0.05). Dried-raw potato treatments caused a decrease (not significant) in cholesterol, HDL and LDL levels when potato percentage increased in grower period (P>0.05).

The effects of dietary treatments on the white blood cells count, relative weights of thymus, bursa of fabricius and spleen are shown in Table 5. The relative weight of spleen and thymus did not statistically differ among the treatments groups (P>0.05). Relative weights of bursa were however affected by dietary treatment (P<0.05). Treatment did not affect the counts of lymphocytes, heterophils, monocytes, basophils and eosinophils at 21 and 42 days of age (P >0.05).

Daily feed intake of chicks and mortality percentages were not affected by dietary treatments throughout the experiment. These results are in an agreement with those of Whittemore *et al*. (1975) and Agwunobi (1999) who reported that the dietary treatment using potatoes did not have any significant effect on daily feed intake and mortality in starter and grower rearing periods. The similarity in feed intake in the treatments reveals the isocaloric nature of the diets, as the feed intake of birds is usually regulated by the energy content of diets.

The birds fed on the potato diets continually passed wet droppings in both the starting and grower periods. This laxative effect increased with the rate of substitution. It appears that the laxative effect of the potato diets adversely affected feed efficiency and weight gain.

Daily weight gain and FCR in starter period of chicks fed on diets were statistically affected by dietary treatment.

Table 2 Performance traits of broiler chickens fed on potato-included diets in different rearing periods

	Treatments						
Variables	**Control**	**Dcp 25%**	**Dcp 35%**	**Drp 25%**	**Drp 35%**	**SEM**	**P-value**
Feed intake (g/chick /d)							
0-21	40.88	41.66	40.43	40.42	41.25	0.322	NS
21-42	96.76	94.04	91.32	88.93	95.79	1.066	NS
0-42	67.81	66.94	65.12	63.80	66.95	0.575	NS
Weight gain (g/chick/d)							
0-21	17.47[a]	18.20[a]	16.20[ab]	13.77[b]	13.95[b]	0.578	*
21-42	44.12	37.69	38.47	35.94	37.70	1.280	NS
0-42	30.31	27.61	27.01	24.46	25.09	0.767	NS
FCR (g.food/g.chick)							
0-21	2.07[b]	2.04[b]	2.19[ab]	2.54[a]	2.53[a]	0.101	*
21-42	2.20	2.26	2.15	2.24	2.54	0.072	NS
0-42	2.15	2.36	2.31	2.48	2.56	0.065	NS
Mortality (%)							
0-21	1.13	0.56	0.56	0.56	1.70	0.417	NS
21-42	0.00	0.00	0.00	0.58	0.61	0.164	NS
0-42	1.13	0.56	0.56	1.13	2.27	0.534	NS

Dcp 25% and 35%: dried-cooked potato 25% and 35% replacing maize.
Drp 25% and 35%: dried-raw potato 25% and 35% replacing maize.
NS: non significant and SEM: standard error of the means.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).

Table 3 Carcass yield and intestinal parameters of broiler chickens

	Treatments						
Variables	**Control**	**Dcp 25%**	**Dcp 35%**	**Drp 25%**	**Drp 35%**	**SEM**	**P-value**
Breast (%)	21.82	23.97	22.52	20.60	22.37	0.521	Ns
Thigh (%)	18.54	18.16	17.87	18.26	18.47	0.298	Ns
Empty body (%)	61.10	62.72	58.81	59.89	62.28	0.875	Ns
Carcass (%)	71.07	78.64	77.62	78.15	79.93	1.098	Ns
Abdominal fat (%)	1.44	1.19	1.13	1.19	1.07	0.066	Ns
Liver (%)	2.49	2.61	2.44	2.83	2.95	0.131	Ns
Pancreas (%)	0.25[c]	0.26[bc]	0.25[c]	0.34[a]	0.30[ab]	0.011	**
Gallbladder (%)	0.07	0.05	0.06	0.09	0.07	0.006	Ns
Small intestine weight (%)	2.90[bc]	2.58[c]	3.41[ab]	3.62[a]	3.61[a]	0.128	*
Duodenum weight (%)	0.60[ab]	0.51[b]	0.72[a]	0.65[ab]	0.71[a]	0.026	*
Jejunum weight (%)	1.18[b]	1.15[b]	1.50[a]	1.57[a]	1.52[a]	0.057	*
Ileum weight (%)	1.12[ab]	0.91[b]	1.17[ab]	1.39[a]	1.37[a]	0.054	**
Cecum weight (%)	0.43	0.38	0.49	0.51	0.48	0.023	Ns
Small intestine length (mm)	1867.00	1855.25	1783.25	1950.00	1917.50	21.876	Ns
Duodenum length mm)	283.25	290.25	270.00	280.00	291.25	3.804	Ns
Jejunum length (mm)	792.75[bc]	783.25[bc]	728.25[c]	907.50[a]	858.75[ab]	18.267	**
Ileum length (mm)	790.00	781.75	785.00	762.50	767.50	7.013	Ns

Dcp 25% and 35%: dried-cooked potato 25% and 35% replacing maize.
Drp 25% and 35%: dried-raw potato 25% and 35% replacing maize.
NS: non significant and SEM: standard error of the means.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).

Daily BWG in the groups Dcp 25% were numerically better than other treatments. Other studies of Ayuk and Essien (2009) using 50% potato in diet or utilize 40% potato in ration and Turner *et al.* (1976) and Agwunobi (1999), using 36% in starter and 45% in finisher period, and Tamir and Tsega (2009) by using of 200/1000 kg potato in diet all indicated that applied potato replacing maize in diets of broilers did not have any significant effect on daily BWG and FCR.

Some stadies, reported that the replacement of maize with oven-dried and sun-dried sweet potato meal, caused a reduction in body weight gain and nutrient utilization of birds in the sweet potato meal compared with the maize-based control diets. The slight but consistent reduction in growth rate as sweet potato root replaced maize may have been due to the presence of unidentified inhibitors of digestive and / or metabolic processes as suggested by Gerspacio (1978). The gradual decrease in live weight gain with increasing content of potato meal indicates that potato has some nutritional deficiencies when compared to maize grain. It contains a reasonably high amount of most amino acids but is limiting in tryptophan and sulphur-containing amino acids (methionine and cysteine). Dietary treatments had no significant effect on the relative weights of thighs, breast, empty body, carcass, abdominal fat, liver and gallbladder. The relative weights of pancreas in Drp 25% and Drp 35% treatments were affected by dietary treatment.

The results of this experiment are in agreement with other reports, in growth rate (Gerspacio *et al.* 1978), and weights of liver and pancreas (Panigrahi *et al.* 1996) and weights of thighs, breast, liver and abdominal fat (Agwunobi, 1999), who reported no observed statistical effect in these factors when chicks were fed on diets included potato in broiler. Greater pancreas may be due to presence of inhibitor factor (solanine and solanidine) in potato which forced the pancreas to high activity.

However, the higher abdominal fat associated with maize diets has implications for human health. High intakes of animal fats may result in elevated blood cholesterol, causing atherosclerosis and heart failure (American Medical Association, 1972). Hence, potato may be a good substitute for maize when carcass quality is considered.

Length and weight of intestinal sections were increased by dietary Dried-raw potato compared with the control. The length of jejunum in Drp 25% treatment and the weights of small intestine, duodenum, jejunum and ileum in Drp 25% and Drp 35% treatments were significantly higher than in the control group. The results of this experiment are in opposite of Agwunobi (1999), this author had obtained an insignificant reduction in weight of intestinal section by the use of potato in ration.

Table 4 Serum metabolites levels of broiler chickens fed on potato- included diets in different rearing periods

	Treatments						
Variables	**Control**	**Dcp 25%**	**Dcp 35%**	**Drp 25%**	**Drp 35%**	**SEM**	**P-value**
21-d							
Glucose (mg/dL)	218.25	220.25	213.25	191.25	211.00	8.841	Ns
Cholesterol (mg/dL)	136.25	115.00	109.25	114.00	116.50	14.585	Ns
Triglyceride (mg/dL)	109.25	98.00	83.75	80.00	99.50	37.133	Ns
HDL (mg/dL)	94.75	78.75	75.50	85.75	79.00	17.161	Ns
LDL (mg/dL)	19.00	16.50	17.00	13.25	16.00	41.233	Ns
42-d							
Glucose (mg/dL)	215.25^b	191.50b^c	247.50^a	181.00^c	167.25^c	7.607	**
Cholesterol (mg/dL)	107.00	100.25	117.00	109.75	98.75	2.887	Ns
Triglyceride (mg/dL)	75.50	82.00	94.25	78.00	66.75	6.049	Ns
HDL (mg/dL)	78.50	66.25	78.75	78.25	76.25	2.483	Ns
LDL (mg/dL)	13.00	17.25	21.50	16.75	9.75	1.381	Ns

Dcp 25% and 35%: dried-cooked potato 25% and 35% replacing maize.
Drp 25% and 35%: dried-raw potato 25% and 35% replacing maize.
NS: non significant and SEM: standard error of the means.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).

Table 5 Percentage myeloid, mononuclear cells and lymphoid organ relative weights of broiler chickens

	Treatment						
Variables (%)	**Control**	**Dcp 25%**	**Dcp 35%**	**Drp 25%**	**Drp 35%**	**SEM**	**P-value**
Thymus	0.31	0.28	0.14	0.32	0.33	0.028	Ns
Bursa of fabricius	0.22^b	0.21^b	0.12^c	0.20^b	0.29^a	0.014	*
Spleen	0.09	0.09	0.08	0.10	0.10	0.091	Ns
21 day							
Lymphocyte	65.25	64.25	64.00	66.25	66.00	0.529	Ns
Heterophil	31.25	31.50	33.25	31.25	31.00	0.554	Ns
Monocyte	0.50	1.00	0.25	0.50	0.50	0.135	Ns
Basophil	2.25	2.25	2.00	1.25	1.75	0.161	Ns
Eosinophil	0.75	1.00	0.50	0.75	0.75	0.160	Ns
42 day							
Lymphocyte	41.25	42.25	39.50	40.00	42.00	0.619	Ns
Heterophil	51.75	52.00	53.00	53.25	52.25	0.373	Ns
Monocyte	3.25	3.00	3.50	3.50	2.75	0.304	Ns
Basophil	1.50	0.75	1.25	1.00	0.75	0.185	Ns
Eosinophil	2.25	2.00	2.75	2.25	2.25	0.206	Ns

Dcp 25% and 35%: dried-cooked potato 25% and 35% replacing maize.
Drp 25% and 35%: dried-raw potato 25% and 35% replacing maize.
NS: non significant and SEM: standard error of the means.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).

One reason for the differences of the various results with my study may be associated with the length of rearing period. Serum level of glucose, cholesterol, triglyceride, HDL and LDL were not affected by dietary treatment in the starter phase, but content of glucose was significantly affected by dietary treatment in grower period. The content of glucose in Dcp 35% treatment and Dcp 25%, Drp 25%, Drp 35% treatment was higher and lower respectively. It seem that increase density of glucose were associated with starch digestion and absorption in the jejunum. Increase of glucose in Dcp 35% may be due to by passing of starch which is gelatinized by the thermal processing. When the starch is absorbed in the hind gut, it can cause a delay in response to the insulin release and this factor may increase the glucose of chicks fed by Dcp 35%. The relative weight of spleen and thymus did not statistically differ among the treatments. Also dietary treatment did not affect the counts of lymphocytes, heterophils, monocytes, basophils and eosinophils at 21 and 42 days of age. But relative weights of bursa were significantly affected by dietary treatment. The reason for the decrease and increase significant effect of Dcp35% and Drp35% respectively on bursa of broiler is unknown. Similarly, Ayuk and Essien (2009) observed that absolute counts of leucocyte in broilers were not affected by different level of potato replacing maize. The proportional counts of lymphocytes, heterophils, monocytes, basophils and eosinophils were within the ranges stipulated in the literature for domestic poultry (Schalm *et al.* 1975; Oyewale, 1987; Simaraks *et al.* 2004; Islam *et al.* 2004).

CONCLUSION

It is concluded that dried potato can replace up to 25% of maize seed in broiler diets, without any significant decrease in performance and growth rate. The quality of the carcass improved because of a decreased in blood cholesterol and lower abdominal fat content. At higher rates of substitution the laxative effect increased and adversely affected the feed conversion efficiency, growth rate and carcass weights.

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