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Nutritional value of raw and extruded chickpeas (*Cicer arietinum* L.) for growing chickens

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Abstract

The effects of the inclusion of different concentrations (0, 100, 200 and 300 g kg^{-1}) of raw and extruded chickpeas on performance, digestive organ sizes, and protein and fat digestibilities were studied in one experiment with growing broiler chickens (0 to 21 days of age). Data were analyzed as a 3 x 2 factorial arrangement with three levels of chickpea with or without extrusion. A corn-soybean based diet was used as a positive control. Increasing chickpea content in the diet did not affect weight gain, feed consumption and feed to gain ratio. Relative pancreas and liver weights, and relative lengths of duodenum, jejunum and ceca were significantly ($P<0.05$) increased in response to increasing chickpea concentration in the diet. The inclusion of graded concentrations of chickpea increased ($P<0.05$) the apparent ileal digestibility (AID) of crude protein (CP) and apparent excreta digestibility (AED) of crude fat (CF) only in the case of the intermediate level of chickpea used (200 g kg^{-1}). Extrusion improved weight gain and lowered relative pancreas weight ($P< 0.05$) respect to birds fed raw chickpea-based diets. AID of CP and AED of CF were improved ($P<0.001$) by extrusion. We concluded that the inclusion of up to 300 g kg^{-1} chickpea in chicken diets did not affect performance, and caused a negative effect on the relative weight of some digestive organs.

Additional key words: chick, extrusion, legumes.

Resumen

Valor nutritivo del garbanzo crudo y extrusionado en pollos de aptitud cárnica

Se realizó un experimento con el objeto de estudiar el efecto de la inclusión de distintas concentraciones (0, 100, 200 y 300 g kg^{-1}) de garbanzo crudo y extrusionado sobre los parámetros productivos, el peso y la longitud de los órganos digestivos y la digestibilidad de la proteína y la grasa de pollos broiler (0-21 días de edad). Los datos fueron analizados siguiendo un diseño factorial (3 x 2) con tres concentraciones de garbanzo con o sin extrusión. Se utilizó una dieta basada en maízsoja como control positivo sin garbanzo. La inclusión de cantidades crecientes de garbanzo en la dieta no modificó la ganancia de peso, el consumo de alimento ni el índice de transformación de las aves, pero sí los pesos relativos del páncreas e hígado y las longitudes relativas del duodeno, yeyuno, íleon y ciego que se incrementaron significativamente ($P<0,05$). La digestibilidad aparente ileal (AID) de la proteína bruta (CP) y la digestibilidad aparente fecal (AED) de la grasa bruta (CF) se incrementaron ($P<0,05$) sólo en el caso de la incorporación de 200 g kg^{-1} de garbanzo. La extrusión mejoró la ganancia de peso de las aves, la AID ($P<0,001$) de la CP y la AED de la CF y disminuyó ($P<0,05$) el peso relativo del páncreas. En conclusión, la inclusión de hasta 300 g kg^{-1} de garbanzo no produjo modificaciones en los parámetros productivos de las aves y causó efectos negativos en algunos órganos digestivos.

Palabras clave adicionales: aves, extrusión, leguminosas.

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Abbreviations used: AED (apparent excreta digestibility), AIA (acid insoluble ash), AID (apparent ileal digestibility), AME (apparent metabolisable energy), ANF (antinutritional factors), CF (crude fat), CP (crude protein), DM (dry matter), EC (extruded chickpea), IU (international units), NS (non significant), NSP (non-starch polysaccharides), RC (raw chickpea), SD (standard deviation), SEM (standard error of the mean).

Introduction

Chickpea (*Cicer arietinum* L.) seeds are an important staple food in Southern Europe, North Africa, India and some other areas. It is cultivated mainly as a legume crop, since it is well adapted to semi-arid conditions. Although most chickpeas are currently produced for human consumption, as production increases more chickpeas will be feed grade and available as an alternative source of protein and energy for animal nutrition.

Like other legumes, chickpea seeds contain a variety of antinutritional factors such as protease and amylase inhibitors, lectins, polyphenols and oligosaccharides (Chavan *et al*., 1986; Cerioli *et al*., 1998). In comparison to soybean (*Glycine max* L.), peas (*Pisum sativum* L.) and common beans (*Phaseolus vulgaris* L.), chickpea offers less problems as far as these factors are concerned (Singh, 1988). Little research has been published on the nutritional value of chickpeas for growing chickens. Viveros *et al*. (2001) showed that the inclusion of up to 450 g kg^{-1} of *kabuli* and up to 150 g kg^{-1} of *desi* chickpea seed meal in the diet had a negative effect on the chicken performance.

Attempts to increase the utilization of legumes have employed a wide range of processing techniques such as soaking, autoclaving, pelleting, dry roasting, dehulling, germination, fermentation and recently extrusion cooking (Van der Poel, 1990; Mariscal-Landin *et al*., 2002; Abd El-Hady and Habiba, 2003). The nutritional advantages of extrusion have gained more attention due to its increased industrial use. Extrusion cooking is a technology classified as a high temperature/short time process to produce a wide variety of foods and ingredients. The exposure of feed material to high temperature for short times has the favourable effect of high rates of destruction of microorganisms and heat labile antinutrients. This technology offers numerous advantages including versatility, high productivity, low operating cost, energy efficiency, and high quality of resulting products. The high shear forces may also denature protein and disrupt the food matrix thereby improving the digestibility of nutrients (Milán *et al*., 2000). Modifications of physicochemical and nutritional properties of hard-to-cook beans by extrusion cooking have been reported by Martin Cabrejas *et al*. (1999), and the nutritional quality of extruded kidney bean and its effects on growth and skeletal muscle nitrogen fractions in rats have been studied by Marzo *et al*. (2002). Similarly, the extrusion process counteracts the negative effect produced by the addition of raw kidney bean by the removal of the antinutritional factors (ANF) and by improving the nutrient availability of the seed (Arija *et al*., 2006). The extrusion process also improved the physicochemical and nutritional characteristics of extruded flours from fresh and hardened chickpeas (Milán *et al*., 2000).

There is little information on the effectiveness of extrusion to remove ANF and the degree to which nutrient availability of legumes is affected in chickens diets. The objectives of this study were to study the productive response of growing broiler chicks under practical conditions to different and increasing concentrations of raw chickpea, and to study the extrusion effect on some nutritional parameters of chickpea in chicken diets.

Material and methods

Test product and extrusion

Chickpea seeds (var kabuli*)* cultivated in Navarra (Spain), were added to the diet in either a raw or extruded form. Prior to extrusion the seeds were ground through a hammer mill and sieved to a 0.5-mm diameter particle size. Extrusion of finely ground seeds was performed in a Clextral X-5 model BC 45 twin-screw extruder (F-42100 Firminy, France). The extruder was operated at 100 rpm and the feeder was set to deliver 350 g min^{-1}. Moisture content in the extruder barrel was constant at 250 g kg^{-1} and the extrusion temperature was 150ºC. Samples of raw and extruded chickpeas were analyzed for dry matter (DM), crude protein (CP), ether extract, crude fiber, ash and amino acids.

Birds and diets

One hundred sixty eight newly hatched Cobb 1-d-old broiler chickens were used in a 21-d feeding trial. The chicks were housed in electrically heated batteries brooder placed in a temperature-controlled room with 23 h d^{-1} constant overhead fluorescent lighting. They were randomly distributed and allocated to 28 pens, each pen containing six chicks, to receive seven dietary treatments with four replicates of each treatment. The diets were given in mash form, and water was supplied *ad libitum*. Celite (Celite Corp., Lompoc, CA 93436), a source of acid insoluble ash (AIA), was added at 10 g kg^{-1} to all diets as an indigestible marker. All diets were formulated to meet or exceed the minimum National Research Council (1994) requirements for broiler chickens. At the end of the experimental period, birds were weighed and feed consumption was recorded for feed efficiency computation. All housing and handling procedures were approved by the University Complutense of Madrid Animal Care and Ethics Committee in compliance with the Ministry of Agriculture, Fishery and Food for the Care and Use of Animals for Scientific Purposes (OJ, 1990; BOE, 1996).

Ingredients and nutrient composition of diets are shown in Tables 1 and 2. Experimental diets were as follows: 1) Control, corn-soybean diet; 2) 100 g kg^{-1} raw chickpea (RC); 3) 200 g kg^{-1} RC; 4) 300 g kg^{-1} RC; 5) 100 g kg^{-1} extruded chickpea (EC); 6) 200 g kg^{-1} EC; and 7) 300 g kg^{-1} EC.

Table 1. Composition (g kg^{-1} as fed) of raw and extruded chickpea seeds (*Cicer arietinum* L.)

Nutrient	Raw chickpea	Extruded chickpea
Moisture	134.0 ± 1.41^a	68.0 ± 1.20^b
AME[1] (kcal kg^{-1})	2587.0 ± 7.07^b	2758.0 ± 8.32^a
Crude protein	200.0 ± 2.10	208.0 ± 1.90
Ether extract	135.0 ± 2.83^a	68.0 ± 1.40^b
Crude fiber	64.0 ± 1.30	65.0 ± 1.20
Ash	35.0 ± 0.50	36.0 ± 0.60
Amino acids		
Aspartic acid	20.4 ± 0.07^b	20.8 ± 0.07^a
Threonine	9.3 ± 0.03	9.4 ± 0.02
Serine	13.6 ± 0.04	13.5 ± 0.05
Glutamic acid	19.4 ± 0.07^b	20.0 ± 0.06^a
Glycine	11.2 ± 0.08^b	11.6 ± 0.06^a
Alanine	10.2 ± 0.03	10.0 ± 0.02
Cystine	2.4 ± 0.03^a	2.1 ± 0.03^b
Valine	11.5 ± 0.03	11.3 ± 0.03
Methionine	2.8 ± 0.07^a	2.5 ± 0.06^b
Isoleucine	9.6 ± 0.03	9.4 ± 0.02
Leucine	19.0 ± 0.06	19.0 ± 0.06
Tyrosine	8.0 ± 0.02	8.1 ± 0.03
Phenylalanine	13.1 ± 0.03^b	13.5 ± 0.07^a
Histidine	2.0 ± 0.01	1.9 ± 0.01
Lysine	15.3 ± 0.03	15.1 ± 0.03
Arginine	12.7 ± 0.02	12.8 ± 0.03
Proline	7.6 ± 0.02	7.7 ± 0.02

[1] AME: apparent metabolisable energy. Calculated value; European table of energy values for poultry feedstuffs (WPSA, 1986). [a,b] Data are means of five determinations ± SD. Row values with different superscripts differ (P<0.05).

Collection of samples and measurements

At 21 days of age, 12 chicks selected at random per treatment were weighed and sacrificed by cervical dislocation. The pancreas, liver and spleen were removed and weighed. Likewise, small intestinal sections (duodenum, jejunum, ileum) and ceca were also removed and length recorded. Ileum was defined as the distance between the yolk stalk and the ileo-caecal junction. The ileum was quickly dissected out and the content expressed by gentle manipulation into a plastic pot in which it was stored at –20ºC. Digesta were pooled from two birds of each replicate within the same treatment. The ileal contents were freeze-dried and ground (1 mm screen) and subsequently analysed for N-Kjeldahl and celite. Clean stainless steel collection trays were placed under each cage and excreta from the birds were collected for 48 h. A sub-sample of excreta was collected in polyethylene bags, weighed, freeze-dried, and subsequently analysed for crude fat.

Chemical analyses

DM, CP, crude fiber, and ash were analysed according to the methods of the AOAC (1995). Ether extract was determined by extraction in petroleum ether following acidification with 4 N HCl solution (Wiseman *et al*., 1992). The AIA contents of diet, excreta and ileal digesta were measured after ashing the samples and treating the ash with boiling 4 M hydrochloric acid (Siriwan *et al*., 1993). Amino acids in the diets were analyzed following AOAC (1995) procedures and separated using a Beckman Model 6300 AA autoanalyzer. Three replicates of all analyses were performed. Tryptophan was not determined.

Calculations and statistical analyses

Apparent ileal digestibility (AID) of CP and apparent excreta digestibility (AED) of CF were calculated using the following formula: 100% - [100% x (AIA concentration in feed / AIA concentration in ileal or excreta content)] x (CP or CF concentrations in ileal or excreta content / CP or CF concentrations in feed). Data were analyzed as a 3 x 2 factorial arrangement with three levels of chickpea with and without extrusion. Data were subjected to ANOVA using the GLM procedures of SAS (SAS Institute, 2001). Treatment 1 was

Table 2. Ingredients and nutrient composition of experimental diets (g kg^{-1} as fed)

Ingredients	Control diet	100 RC [1]	200 RC	300 RC	100 EC [2]	200 EC	300 EC
Corn	515.0	442.3	369.5	296.8	449.7	384.4	319.1
Soybean meal (48% CP [3])	383.4	348.7	314.0	279.3	344.7	305.9	267.1
Raw chickpea	-	100.0	200.0	300.0	-	-	-
Extruded chickpea	-	-	-	-	100.0	200.0	300.0
Sunflower oil	47.9	55.5	63.0	70.6	52.1	56.2	60.4
Dicalcium phosphate	19.3	19.1	18.8	18.6	19.0	18.8	18.5
Calcium carbonate	10.6	10.7	10.8	10.8	10.7	10.8	10.9
NaCl	3.0	3.0	3.0	3.0	3.0	3.0	3.0
DL- Methionine	2.9	3.0	3.1	3.2	3.0	3.0	3.2
Vitamin-mineral premix [4]	5.0	5.0	5.0	5.0	5.0	5.0	5.0
L-Lysine	2.8	2.8	2.7	2.7	2.8	2.8	2.8
Celite [5]	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Analyzed composition							
Crude protein	220.0	226.6	224.3	225.7	225.7	225.0	224.1
Ether extract	66.8	83.9	78.7	105.7	84.0	81.9	87.7
Lysine	15.0	14.3	15.6	15.1	14.0	13.4	13.1
Methionine + cystine	9.8	8.9	8.6	8.8	8.7	8.8	8.7
Ca [6]	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Available P [6]	4.5	4.5	4.5	4.5	4.5	4.5	4.5
AME [6,7] (kcal kg^{-1})	3000	3000	3000	3000	3000	3000	3000

[1] RC: Raw chickpea. [2] EC: Extruded chickpea. [3] CP: Crude protein. [4] Vitamin and mineral mix supplied the following per kilogram of diet: vitamin A, 8,250 IU; cholecalciferol, 1,000 IU; vitamin E, 11 IU; vitamin K, 1.1 mg; vitamin B_{12}, 12.5 mg; riboflavin, 5.5 mg; Ca panthotenate, 11 mg; niacin, 53.3 mg; choline chloride, 1,020 mg; folic acid, 0.75 mg; biotin, 0.25 mg; delaquin, 125 mg; DL-methionine, 500 mg; amprol, 1 g; Mn, 55 mg; Zn, 50 mg; Fe, 80 mg; Cu, 5 mg; Se, 0.1 mg; I, 0.18 mg; NaCl, 2,500 mg. [5] Celite Corp., Lompoc, CA, USA. [6] Calculated values. [7] AME: apparent metabolisable energy.

considered a positive control. The statistical model used was:

$$Y_{ijk} = \mu + C_i + E_j + CE_{ij} + R_k + e_{ijk}$$

where Y_{ijk} is the individual observation, μ is the experimental mean, C_i is the chickpea effect, E_j is the extrusion effect, CE_{ij} is the interaction effect, R_k is the replication effect, and e_{ijk} is the error term. Significant differences among treatment means were determined at $P<0.05$ by Duncan's multiple-range test.

Results

The chemical composition of raw and extruded chickpeas is shown in Table 1. Moisture and ether extract content of EC was lower than that of RC. Apparent metabolizable energy calculated value was higher in EC compared with RC. The concentrations of CP, ash, and crude fiber were similar in both seeds. Aspartic acid, glutamic acid, glycine, and phenylalanine concentrations were higher in EC compared with RC. Methionine and cysteine concentrations were higher in RC than EC.

The performance results of broilers fed graded concentrations of RC and EC are summarized in Table 3. Although values for raw chickpea diets were lower in some cases, the main effect data indicated that the inclusion of graded concentrations of chickpea did not affect the performance of the birds. Extrusion improved weight gain (7%; $P<0.015$).

Results of the relative organ weights and intestinal length are shown in Table 4. The main effects data showed that increasing amount of chickpea increased rela-

Table 3. Performance of broiler chicks (0 to 21 d) fed raw and extruded chickpea[1]

Diets	Weight gain (g)	Feed consumption (g)	Feed to gain ratio (g:g)
Chickpea (g kg^{-1})			
Control diet	669[a]	904	1.35[b]
100 RC[2]	620[ab]	867	1.40[ab]
200 RC	606[b]	874	1.44[a]
300 RC	626[ab]	877	1.41[ab]
100 EC[3]	667[a]	912	1.37[ab]
200 EC	674[a]	934	1.39[ab]
300 EC	636[ab]	865	1.36[ab]
Pooled SEM	35.50	48.06	0.05
Main effects[4]			
Chickpea			
100	643	889	1.38
200	640	904	1.41
300	631	871	1.38
Processing			
No	617	873	1.42
Yes	659	903	1.37
Source of variation		Probabilities	
Chickpea concentration	NS[5]	NS	NS
Processing	0.015	NS	NS
Processing x concentration	NS	NS	NS

[1] Data are means of four pens of 6 chicks. [2] RC = Raw chickpea. [3] EC = Extruded chickpea. [4] Data were analyzed as a 3 x 2 factorial arrangement, excluding control group. [5] NS = Non significant. [a-b] Means in columns with no common superscript differ significantly (P<0.05).

tive pancreas (up to 10%; P<0.029) and liver weights (up to 3.6; P<0.045) and the relative duodenum (up to 5.6%; P<0.034), jejunum (up to 11.7; P<0.01) and ceca lengths (up to 6.7%; P<0.034). The extrusion of chickpea reduced the relative pancreas weight (17.9%; P<0.001), as compared to raw chickpea diets, to values which were not different from controls. Relative liver weight of birds fed extruded chickpea diets was higher (9%; P<0.05) than those fed control diet. A significant interaction concentration x processing was observed for relative pancreas (P<0.004) and spleen weights (P<0.013), indicating a greater response in the highest chickpea concentration.

The effect of inclusion of graded concentrations of RC diets in broilers on AID of CP and AED of crude fat are reported in Table 5. The main effect data indicated that the inclusion of 300 g kg^{-1} chickpea caused a reduction of the AID of CP (1.5%; P<0.05) and the AED of CF (1.4%; P<0.05) compared to the addition of 200 g kg^{-1} chickpea. Statistical analysis of the data also demonstrated that extrusion (P<0.001) improved the AID of CP and the AED of CF by 2.9 and 2.8 %, respectively. Likewise, a significant interaction (P<0.001) between chickpea concentration and extrusion for AID of CP (P<0.001) and AED of CF was observed.

Discussion

The composition of raw and extruded chickpeas was similar to values presented by Khan *et al.* (1995) and Marzo *et al.* (2002). Extrusion cooking caused a significant decrease in moisture and ether extract contents. This could be due to the high temperature environment inside the screw channel that resulted in evaporation of water and volatile compounds. The release of water at die produced extrudates with lower moisture content than raw flours. These results are similar to those reported by Arija *et al.* (2006) using raw and extruded kidney bean.

The present study also demonstrated that the inclusion of graded concentrations of chickpea in chicken diets did not affect birds performance. These results are in agreement with those reported by Viveros *et al.* (2001) and Farrell *et al.* (1999), who found a negative

Table 4. Relative organ weights and intestinal lengths of broiler chicks (0 to 21 d) fed raw and extruded chickpea[1]

Diets	Relative weight (g/100 g body weight)			Relative length (cm/100 g body weight)			
	Pancreas	Liver	Spleen	Duodenum	Jejunum	Ileum	Ceca
Chickpea (g kg^{-1})							
Control diet	0.27[c]	2.30[c]	0.085[d]	3.32[b]	7.32[d]	7.47	1.83
100 RC[2]	0.30 [bc]	2.58 [ab]	0.070[ab]	3.48[ab]	7.75[bcd]	7.69	1.87
200 RC	0.33[b]	2.44[bc]	0.068[ab]	3.53[ab]	8.21[bc]	8.19	1.92
300 RC	0.37[a]	2.68[a]	0.088[a]	3.62[a]	8.88[a]	8.22	1.90
100 EC[3]	0.28[c]	2.47[b]	0.074[ab]	3.31[b]	7.60[cd]	7.49	1.73
200 EC	0.30[bc]	2.51[ab]	0.073[ab]	3.53 [ab]	8.19[bc]	8.01	1.92
300 EC	0.27[c]	2.56[ab]	0.065[b]	3.57[a]	8.27[b]	7.87	1.84
Pooled SEM	0.04	0.20	0.02	0.27	0.72	1.25	0.17
Main effects[4]							
Chickpea							
100	0.29	2.53	0.072	3.40	7.67	7.59	1.80
200	0.31	2.47	0.071	3.53	8.20	8.10	1.92
300	0.32	2.62	0.077	3.59	8.57	8.05	1.87
Processing							
No	0.33	2.57	0.076	3.54	8.28	8.04	1.89
Yes	0.28	2.51	0.071	3.47	8.02	7.79	1.83
Source of variation				Probabilities			
Chickpea concentration	0.029	0.045	NS	0.034	0.01	NS	0.034
Processing	0.001	NS[5]	NS	NS	NS	NS	NS
Processing x concentration	0.004	NS	0.013	NS	NS	NS	NS

[1] Data are means of four pens of 3 chicks. [2] RC = Raw chickpea. [3] EC = Extruded chickpea. [4] Data were analyzed as a 3 x 2 factorial arrangement, excluding control group. [5] NS = Non significant. [a-d] Means in columns with no common superscript differ significantly ($P<0.05$).

effect when chickpea was included up to 360 g kg^{-1} in the diet. However, Johnson and Eason (1990) did not observe differences in performance of birds fed with 200 g chickpea kg^{-1}. These discrepancies could be due to the presence of certain amounts of antinutritional factors in the seed, which can vary considerably among batches of the same legume. Saini *et al*. (1992) observed a large variation in concentrations of trypsin and chymotrypsin inhibitors of chickpea grown in Australia, which were influenced by the location and year of cultivation. Singh and Jambunathan (1981) also showed that trypsin inhibitor activity of two varieties of chickpea varied considerably among different genotypes.

Although the inclusion of graded concentration of chickpea did not cause growth depression, the relative pancreas weight was increased in the birds fed the higher concentration of chickpea. This result agree with previously reported data in rats (Cavallé de Moya *et al*., 2003) and chickens (Rubio *et al*., 1990; Viveros *et al*., 2001; Brenes *et al*., 2002; Arija *et al*., 2006) with the use of faba bean, chickpea, and lupin seed in the diets. The enlargement in the pancreas is usually linked to the presence of trypsin inhibitors and lectins in the legume seeds. This fact has frequently been observed in rats (Grant *et al*., 1995; Cavallé de Moya, 2003) fed kidney bean, and chicks (Huisman *et al*., 1990; Rubio *et al*., 1990) fed diets containing legumes. Miller *et al*. (1991) and Miller and Holmes (1992) demonstrated that birds fed on kabuli chickpea had greater pancreas weight. Farrell *et al*. (1999) also observed a linear increase (although not significant) in pancreas weight when the rate of chickpea was increased. Inactivation of free trypsin in the gut stimulates the release of cholecystokinin from neuroendocrine cells in the intestine, thereby initiating hypersecretion of pancreatic digestive enzymes and subsequent enlargement of the pancreas (Grant *et al*., 1999; Cavallé de Moya *et al*., 2003). In the case of the liver, the observed increase in the relative weight could be related to the nutritional status of the chickens fed chickpea. The mobilization of body reserves to meet

Table 5. Apparent digestibility of protein and fat in broiler chicks (0 to 21 d) fed raw and extruded chickpea[1]

Diets	Protein digestibility (%)	Fat digestibility (%)
Chickpea (g kg^{-1})		
Control diet	85.8[c]	86.8[ab]
100 RC[2]	86.4[bc]	85.6[b]
200 RC	84.9[c]	85.6[b]
300 RC	83.1[d]	82.8[c]
100 EC[3]	85.5[c]	85.8[b]
200 EC	88.7[a]	87.6[a]
300 EC	87.8[ab]	88.0[a]
Pooled SEM	1.10	1.22
Main effects[4]		
Chickpea		
100	85.9	85.7
200	86.8	86.6
300	85.5	85.4
Processing		
No	84.8	84.7
Yes	87.3	87.1
Source of variation	Probabilities	
Chickpea concentration	0.05	0.05
Processing	0.001	0.001
Processing x concentration	0.001	0.001

[1] Data are means of four pens of 2 chicks. [2] RC = Raw chickpea. [3] EC = Extruded chickpea. [4] Data were analyzed as a 3 x 2 factorial arrangement, excluding control group. [a-d] Means in columns with no common superscript differ significantly (P<0.05).

the needs of the rapidly growing tissues might increase the liver´s activity, thus causing hypertrophy. Viveros *et al*. (2001) and Arija *et al*. (2006) also observed an increase in the relative weight of the liver in birds fed chickpea and kidney bean, respectively. Changes in liver weight have also been observed in rats due to an increase in amino acid degrading enzymes and a decrease of protein synthesis (Rubio, 2000).

The increase in the relative duodenum, jejunum and ceca lengths of birds fed on chickpea could be attributed, at least to some extent, to the presence of high levels of complex carbohydrates, including resistant starch, oligosaccharides, and non-starch polysaccharides (NSP) present in this seed (Rossi *et al*., 1984; Champ *et al*., 1986; Garcia Alonso *et al*., 1998). Alonso *et al*. (2000) and Brenes *et al*. (2003) determined, by *in vivo* and *in vitro* procedures, low starch, oligosaccharides, and NSP digestibilities in several legume seeds (faba bean, kidney bean, and lupin seed). In experiments with rats, Ikegami *et al*. (1990) showed that the addition of indigestible polysaccharides to the diet caused enlargement of the digestive organs.

Data also demonstrated a significant reduction in the AID of CP and AED of CF in birds fed the highest chickpea concentration. Similar results have been published in previous studies with faba beans, peas and chickpeas, suggesting that their lower nutritional value is due to the antinutritional factors present in the seed, particularly trypsin inhibitors (Huisman *et al*., 1990; Grosjean *et al*., 1992). The presence of trypsin and chymotrypsin inhibitors in chickpea seeds could be at least partially responsible, since they can inhibit digestive enzymes (Bressani and Elias, 1988; Viveros *et al*., 2001). Rubio *et al*. (1995) and Cavallé de Moya *et al*. (2003) also attributed this effect in rats to an excessive secretion of endogenous nitrogen by the use of legumes.

Extrusion improved significantly weight gain and relative pancreas weight. This beneficial effect could be attributed to the reduction or inactivation of the trypsin, chymotrypsin and α-amylase inhibitors by the extrusion process. Earlier experiments (Savage and Thompson, 1993; Savage *et al*., 1995) showed the possibility of reducing the effect of the ANF by various cooking and processing methods. Extrusion has been shown to be very effective in destroying lectins, protease inhibitors and α-amylase inhibiting enzymes (Marzo *et al*., 2002; Abd El-Hady and Habiba, 2003; Arija *et al*., 2006). Moreover, due to the presence of shear forces and high-energy input, proteins are more easily accessible for enzyme attack during the extrusion process (Camire, 1991). Extrusion is also known to gelatinize starch, which would improve the conditions for efficient digestion of protein in the small intestine of pigs (Bengala–Freire *et al*., 1991), chicks (Arija *et al*., 2006) and in *in vitro* conditions (Alonso *et al*., 2000). Martin-Cabrejas *et al*. (1999) also showed increased solubilization of insoluble fiber by the extrusion processing of common bean.

In conclusion, the use of chickpea in chicken diets up to 300 g kg^{-1} did not affect performance, and caused an increase in the size of some digestive organs. Extrusion improved weight gain, protein and fat digestibilities, and counteracted the negative effect of raw chickpea feeding on pancreas size.

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