Effect of processed quinoa on performance traits, small intestinal morphology, and blood parameters of Ross broiler chickens

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Research Article

Keywords: Expanding, Extrusion, Chicken, Processing, Quinoa

Posted Date: October 18th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-932780/v1

Abstract

Restrictions on access to important components of poultry rations such as corn and soybean meal are among the biggest issues in the poultry feed industry. Quinoa with a very high nutritional value can be a good alternative. The present study aimed to investigate the effect of processed quinoa seeds on performance, small intestinal morphology, and blood parameters of Ross broiler chickens. The present experiment was performed with 5 treatments, 4 replications, and 15 chickens per pen in a completely randomized design. Hydrothermal, extrusion, and expansion methods were used to process quinoa seeds. Apart from the control treatment, 15% of quinoa seeds were included in the other treatments. The studied traits were recorded. The general linear model procedure in SAS software was used to compare the means of treatments. The effect of processing methods on body weight, feed conversion ratio, total protein, uric acid, and blood cholesterol, villi height, crypt villi depth, and length to depth ratio of cryogenic villi of jejunum were significant ($P<0.01$). Quinoa processing improved its nutritional properties. In general, extrusion and expansion processing methods were more effective than the hydrothermal method in improving the quality of quinoa.

Introduction

Corn and soybean meal are the most important components of poultry rations. Restriction access to these feed sources is one of the biggest issues in the poultry feed industry. Therefore, it is important to find an alternative feed source. One of these food sources, Quinoa, scientifically known as Chenopodium Quinoa Willd, belongs to the Amaranthaceae family and is classified as a cereal group. This dicotyledonous plant is an annual, alloptraploid, bioactive saline and is distributed all over the world. It has a very high nutritional value. Quinoa seed is the main product of this plant. Quinoa contains an average of 16% protein and 77-70% carbohydrates (Bastidas et al., 2016). About 60% of quinoa seeds contain starch. It has a perfect combination of amino acids (especially lysine, methionine and cysteine). It is rich in minerals (especially calcium, iron, magnesium and zinc) and various vitamins (Vega-Gálvez et al., 2010). The lipid content of quinoa is about 14.5%, of which 89-70% is unsaturated fatty acids. Therefore, it can be a good alternative to oilseeds in the feed (Tang et al., 2015). Other characteristics include high production and drought resistance. Quinoa contains antioxidant compounds. Saponins, phytic acid, tannins, oxalates and trypsin inhibitors are the most important anti-nutritional factors of quinoa (Lopes et al., 2009). Many antioxidant compounds are unstable to heat. Processing neutralizes the effect of anti-nutrients, increases consumption, increases palatability, and ultimately reduces feed waste. The amount of antinutritional activity reduction depends on the temperature, duration of heat application, particle size, and moisture content of the curing method. One of the most common methods for processing feed is thermal methods. The methods of autoclaving, roasting, cracking, micronization, shortwave irradiation, extrusion, expansion, hydrothermal cooking, and steam blowing are among the most important and common (Mateos et al., 2003; Lazaro et al., 2003).

This study aimed to investigate the effect of processed quinoa seeds on performance, small intestine morphology, and blood parameters of Ross broiler chickens.

Materials And Methods

The laboratory part of the present study was performed in the laboratories of Noor Research and Training Institute, Mabna, Oilseed Cultivation Development Laboratory and Atomic Energy Organization of Iran (Tehran, Iran).

Determination of chemical composition of quinoa

Recommended experimental methods were used to determine crude energy (with PARR 1261 calorimeter bomb), percentage of dry matter, ash, crude protein, crude fat, crude fiber, calcium and phosphorus (AOAC, 2002).

Quinoa Seed Processing

In the present study, hydrothermal, extrusion and expansion thermal methods were used to process quinoa seeds. In the hydrothermal method, a 135 kg sample of quinoa seeds was soaked in water (1: 2) in a container and wrapped in aluminum foil. The sample was then placed in an oven at 55 ° C for 25 minutes. The sample was then treated with acetate buffer (pH = 5.5) and kept at the same temperature for 12 hours. The sample was taken out of the oven and washed several times with distilled water to bring the pH to the pre-process state. Finally, the sample was dried in an oven at 80° C for 3 hours. After drying, the grains (at 10% moisture) were ground (Fredlund et al. 1997). The extrusion method was performed at 155±2° C for 15 seconds using a single-screw extruder (single shaft) at a speed of 450 rpm and a diameter of 10 cm. The final step also involved drying and grinding quinoa seeds (Mirghelenj et al. 2013). The expansion process was performed using the wet expansion method at 125° C for 15 seconds using the Amandos Cal single conditioner expander (Heger et al. 2016).

Place and time of the farming experiment

This research was conducted in the spring of 1399 in the research farm of Islamic Azad University, Qaemshahr branch. The breeding saloon was well prepared. The floor and walls of the hall were completely washed. Drinking and eating utensils were washed and disinfected before the chickens arrived. Room temperature and humidity were adjusted based on Ross 308 strain breeding guide tables. The room temperature was adjusted to about 32° C in the first week of rearing and the temperature was gradually reduced to 23-24° C. The humidity of the hall was about 55-65% during the breeding period.

Chickens and experimental treatments

Three hundred Ross 308 broilers were weighed and randomly distributed in experimental pens. 15 chickens were placed in each pen. The dimensions of each pen were 1*2 square centimeters. Rations were formulated based on the nutritional needs of Ross 308 strain and UFFDA software. All rations were isocaloric and isonitrogenous. Chickens were fed experimental rations from 1 to 42 days of age during the initial 3 periods (1 to 11 days), growth (12 to 22 days), and final (23 to 42 days) using the powdered feed. Experimental treatments included the first treatment which contained a basic ration without quinoa.

The second treatment contained 15% of unprocessed quinoa seeds. The third, fourth, and fifth treatments contained 15% of quinoa seeds processed by hydrothermal, extrusion, and expansion methods, respectively. The composition of rations is presented in Table 1.

Table 1. Components and nutrient composition of rations (%)

Feed	*Starter*	*(1-10 day)*	*Grower*	*(11-24 days)*	*Finisher*	*(25-42 days)*
components	Control	Contains quinoa	Control	Contains quinoa	Control	Contains quinoa
Corn	55.47	436.99	56.38	43.56	61.20	48.53
Quinoa seed	0	15	0	15	0	15
Soybean meal	36.53	30.13	37.69	35.63	32.64	30.29
Oil	0.90	1.20	2.04	2.21	2.73	2.91
Corn gluten	3.00	5.57	0	0	0	0
Di-calcium phosphate	1.77	1.64	1.69	1.52	1.48	1.32
Calcium carbonate	0.94	0.96	0.90	0.91	0.83	0.84
Mineral vitamin premix*	0.500	0.500	0.500	0.500	0.500	0.500
Methionine	0.28	0.23	0.25	0.17	0.19	0.17
Lysine	0.20	0.27	0.10	0.05	0.01	0
Threonine	0.08	0.10	0.03	0.03	0	0.02
Salt	0.25	0.25	0.25	0.25	0.25	0.25
Sodium Bicarbonate	0.17	0.17	0.17	0.17	0.17	0.17
Metabolic energy (kcal / kg)	2850	2850	2950	2950	3050	3050
Crude protein(%)	22.5	22.5	21.0	21.0	19.0	19.0
Lysine (ileal digestibility)	1.24	1.24	1.17	1.17	0.98	0.98
Methionine + cysteine (ileal digestibility)	0.92	0.92	0.85	0.85	0.74	0.74
Threonine (ileal digestibility)	0.84	0.84	0.76	0.76	0.66	0.66
Calcium (%)	0.90	0.90	0.87	0.87	0.78	0.78
Available phosphorus (%)	0.45	0.45	0.44	0.44	0.39	0.39

*Vitamin premix supplied per kilogram contains 4400000 units of vitamin A, 72000 units of vitamin D, 14400 mg of vitamin E, 2000 mg of vitamin K, 640 mg of cobalamin, 612 mg of thiamine, 3000 mg Riboflavin, 4896 mg pantothenic acid, 12160 mg niacin, 612 mg pyridoxine, 2000 mg biotin and 260 g choline chloride. The provided mineral premix contains 64.5 grams of manganese, 100 grams of iron, 8 grams of copper, 640 milligrams of iodine, 190 milligrams of cobalt and 8 grams of selenium per kilogram.

Study traits

Performance traits

At the end of each week, the chickens were weighed 4 hours after stopping the feed with a digital scale to the nearest 10 g. Feed intake, body weight and feed conversion ratio were recorded.

Blood biochemical parameters

At 42 days of age, three birds were selected from each experimental unit and blood samples were taken through the Jugular vein. After separating the serum from the blood clot, the resulting serum samples were centrifuged at 4000 rpm for 15 minutes. The content of uric acid, total protein, cholesterol, and triglyceride in serum samples was determined using the CHOD-PAP enzymatic method and with the commercial kit of Pars Azmoun Company and Biochemistry Company.

The morphology of the jejunum

The small intestine was spread out next to a graduated ruler. Sections 1.5 cm long were separated from the middle of all three parts of the small intestine (Bradley et al. 1994).

Statistical Analysis

The present experiment was performed with 5 treatments and 4 repeats in a completely randomized design. The general linear model (GLM) procedure in SAS software (2001) was used to compare the means of treatments. The statistical model used was as follows:

$y_{ij}= \mu+ T_j+ e_{ij}$

where yij is the value of each observation, μ is mean effect, Ti is effect of treatments, and eij is residual effects.

Result

Chemical composition of quinoa sedes

The results related to the qualitative characteristics of raw quinoa seeds are presented in Table 2. Based on this information, quinoa seeds used in the present study contained 15.4% crude protein, 7.66% fat, 3.7% ash and 6.7% crude fiber.

Table 2. Chemical compounds of unprocessed quinoa seeds

Chemical Compounds	Dry matter (%)	Gross energy (Kcal)	Crude protein (%)	Fat (%)	Ash (%)	Crude fiber (%)	Calcium (%)	Phosphorus (%)
	89.93	3585	15.36	7.66	3.70	6.70	0.30	0.40

Performance traits

Bodyweight

As shown in Table 3, the effect of treatments in all rearing periods on mean body weight is significant (P <0.01). The highest body weight was mostly observed in all rearing periods in the treatments treated by extrusion and expansion methods. Also, in general, the lowest body weight was related to the unprocessed treatment. The highest body weight was observed during the whole period in the treatment treated by the extrusion method. The lowest body weight was obtained in the hydrothermal processing method.

Table 3. The effect of different quinoa processing methods on the body weight of broiler chickens

Rations		Body	weight (gr)	
	Starter	Grower	Finisher	Whole period
Basic ration (without quinoa)	436.53^{a}	803.56^{a}	1229.18^{a}	2469.28^{a}
Ration containing unprocessed quinoa sedes	347.50^{c}	694.93^{c}	1047.37^{d}	2089.79^{c}
Ration containing quinoa seeds processed by hydrothermal method	386.83^{b}	745.64^{b}	1108.64^{c}	2241.12^{b}
Ration containing quinoa seeds processed by extrusion method	417.21^{a}	804.13^{a}	1190.82^{ab}	2412.15^{ab}
Ration containing quinoa seeds processed by expansion method	430.46^{a}	794.53^{a}	1159.50^{bc}	2384.94^{b}
SEM	9.20	12.00	18.51	37.77
P.value	0.00	0.00	0.00	0.00

^{abc} In each column, the means with non-common letters are significantly different from each other (P <0.05). SEM = Standard error of mean. P.value = Probability of value.

Feed intake

As shown in Table 4, there was no significant difference in feed intake between different treatments in any of the rearing periods (P> 0.05). In other words, the effect of different processing methods on feed consumption was not significant (P> 0.05).

Table 4. The effect of different quinoa processing methods on the feed intake of broiler chickens

Rations		Feed	intake (gr)	
	Starter	Grower	Finisher	Whole period
Basic ration (without quinoa)	505.92	1198.83	2735.05	4439.80
Ration containing unprocessed quinoa sedes	459.03	1192.18	2657.80	4309.02
Ration containing quinoa seeds processed by hydrothermal method	490.65	12.04.20	2726.92	4421.77
Ration containing quinoa seeds processed by extrusion method	486.83	1180.10	2711.41	4386.35
Ration containing quinoa seeds processed by expansion method	503.03	1179.29	2716.03	4396.34
SEM	6.08	6.53	23.74	23.39
P.value	0.21	0.25	0.19	0.18

[abc] In each column, the means with non-common letters are significantly different from each other (P <0.05). SEM = Standard error of mean. P.value = Probability of value.

Feed conversion ratio

Based on the results of Table 5, it can be seen that the effect of different treatments on feed conversion ratio was significant in all rearing periods (P <0.01). Quinoa processing has been effective in improving feed conversion ratio (P <0.01). In general, the highest and lowest improvements in feed conversion ratio were obtained by extrusion and hydrothermal methods, respectively.

Table 5. The effect of different quinoa processing methods on the feed conversion ratio of broiler chickens

Rations		Feed	intake (gr)	
	Starter	Grower	Finisher	Whole period
Basic ration (without quinoa)	1.16[b]	1.29[c]	2.34[c]	1.80[c]
Ration containing unprocessed quinoa sedes	1.32[a]	1.71[a]	2.53[a]	2.06[a]
Ration containing quinoa seeds processed by hydrothermal method	1.27[a]	1.61[b]	2.46[a]	1.97[ab]
Ration containing quinoa seeds processed by extrusion method	1.17[b]	1.47[c]	2.27[bc]	1.82[c]
Ration containing quinoa seeds processed by expansion method	1.17[b]	1.48[c]	2.34[ab]	1.84[bc]
SEM	0.02	0.02	0.03	0.03
P.value	0.00	0.00	0.00	0.00

[abc] In each column, the means with non-common letters are significantly different from each other (P <0.05). SEM = Standard error of mean. P.value = Probability of value.

Blood biochemical parameters

Based on the results of Table 6, it can be seen that the effect of different treatments was significant on the total protein, uric acid, and blood cholesterol of broilers (P <0.05). No difference in triglyceride content was observed between different treatments (P> 0.05). The highest and lowest blood protein levels were obtained by extrusion and hydrothermal processing methods, respectively. The highest amount of cholesterol was obtained by the extrusion method.

Table 6. The effect of different methods of quinoa processing on blood parameters of broiler chickens

Rations	Total protein (mg/dl)	Uric acid (mg/dl)	Cholesterol (mg/dl)	Triglyceride (mg/dl)
Basic ration (without quinoa)	5.26^{ab}	4.19^{c}	222.54^{a}	172.74
Ration containing unprocessed quinoa sedes	4.73^{b}	4.81^{a}	165.27^{b}	155.37
Ration containing quinoa seeds processed by hydrothermal method	5.07^{b}	4.57^{ab}	172.89^{b}	163.81
Ration containing quinoa seeds processed by extrusion method	5.67^{a}	4.26^{bc}	184.46^{b}	152.33
Ration containing quinoa seeds processed by expansion method	5.08^{b}	4.41^{bc}	177.00^{b}	160.05
SEM	0.10	0.07	6.41	4.31
P.value	0.03	0.04	0.02	0.07

^{abc} In each column, the means with non-common letters are significantly different from each other (P <0.05). SEM = Standard error of mean. P.value = Probability of value.

The morphology of the jejunum

The results of the study of the characteristics of the villi of the jejunum at 42 days of age are presented in Table 7. The effect of experimental treatments was significant on all studied indices including villi height, crypt depth, and the ratio of villi height to crypt depth (P <0.05). The highest villi length was observed in the extrusion treatment. The highest and lowest ratios of villi length to crypt depth were observed in extrusion and hydrothermal processing methods, respectively (P <0.05).

Table 7. The effect of different methods of quinoa processing on the morphological characteristics of the jejunum

Rations	Villi height (μm)	crypt depth (μm)	the ratio of villi height to crypt depth
Basic ration (without quinoa)	1050.04^{a}	168.45^{bc}	6.23^{ab}
Ration containing unprocessed quinoa sedes	936.80^{b}	193.85^{a}	4.84^{d}
Ration containing quinoa seeds processed by hydrothermal method	987.32^{ab}	179.99^{b}	5.49^{c}
Ration containing quinoa seeds processed by extrusion method	1065.79^{a}	159.66^{c}	6.67^{a}
Ration containing quinoa seeds processed by expansion method	1036.97^{a}	175.61^{b}	5.90^{bc}
SEM	16.55	3.40	0.18
P.value	0.02	0.02	0.03

^{abc} In each column, the means with non-common letters are significantly different from each other ($P < 0.05$). SEM = Standard error of mean. P.value = Probability of value.

Discussion

Processed quinoa compounds

Crude protein content in different varieties of quinoa in the range from 13.7 to 16.7, fat from 5.5 to 14.5, ash from 1.4 to 3.8, crude fiber from 2.6 to 10.5, and humidity has been reported from 9.57 to 11.71%, which is consistent with the results of the present study (Ogungbenle et al., 2003; Maidala et al., 2013). Processing resulted in a slight increase in the moisture content of quinoa seeds, which appears to be due to water uptake during processing. The optimum moisture content for oilseeds is less than 12%.

Performance traits

Body weight

Weight gain is one of the most important factors in assessing the performance of broiler flocks. It has been reported that with increasing the amount of quinoa in the ration, growth performance decreases linearly, which is consistent with the results of the present study (Olukosi et al., 2019). The presence of anti-nutritional factors is one of the most important reasons for the decline in performance traits. One of the most important anti-nutritional substances in quinoa seeds is trypsin. Trypsin inhibits the digestion of dietary protein and leads to severe weight loss in monogastric animals. In a study of broilers, it was reported that quinoa processing could reduce the negative impact of anti-nutritional agents (Olukosi et al., 2019). In another study, it was reported that quinoa seed extract, due to its high content of antioxidants and phenolic compounds, led to improved growth performance and reduced feed conversion ratio. With processing, the digestibility of nutrients in quinoa increases, and body weight increases (Eassawy et al., 2019).

Feed intake

Based on the results of the present study, it has been observed that the use of quinoa reduces the amount of feed consumed by chickens. The presence of phytic acid in quinoa seeds leads to a decrease in calcium absorption and thus reduces feed intake (Eassawy et al., 2016). The use of high levels of oilseeds has led to an increase in feed density, which is manifested by a decrease in feed intake. Anti-nutrients such as trypsin in the treatment of unprocessed quinoa in the present study may be another reason for reducing the feed intake of broilers. Decreased appetite while taking trypsin inhibitors may be due to impaired hepatic metabolism due to liver tissue damage (Pacheco-Dominguez et al., 2011).

Feed conversion ratio

The feed conversion ratio is affected by weight gain and feed intake. In the present study, with the replacement of quinoa seeds, body weight did not show a suitable increase in the amount of feed consumed. Therefore, the feed conversion ratio increased. The increase in feed conversion ratio in the group receiving unprocessed quinoa may be due to reduced feed efficiency. Because the antinutrient factors in quinoa seeds affect the feed conversion ratio (Nahavandinejad et al., 2014; Masey O'Neill et al., 2018). The observed improvement in feed conversion ratios in chickens fed processed quinoa seeds is largely due to the positive effect of the processing method on the elimination of anti-nutritional compounds as well as the improvement of nutrient digestibility. According to the results presented in the present study, it was reported that the use of 10, 20, and 30% levels of unprocessed quinoa seeds led to an increase of 14, 12, and 28% in the feed efficiency of broilers (Eassawy et al., 2016).). The feed conversion ratio in the hydrothermal method was higher compared to the extrusion and expansion methods. Part of the inadequate conversion ratio in the hydrothermal group may be due to the reduced nutritional value of quinoa as a result of germination. Another factor influencing the increase in oral conversion ratio in the hydrothermal method may be the high amount of trypsin. This anti-nutrient increases the oral conversion ratio by affecting the small intestinal mucosa, reducing protein digestibility, and inhibiting lipid uptake (Eassawy et al., 2016).

Blood biochemical parameters

In the present study, the use of quinoa seeds reduced cholesterol. According to the present study, the inhibitory effects of quinoa seeds on cholesterol accumulation have been reported (Navruz-Varli and Sanlier, 2016). Cholesterol accumulation is reduced by using quinoa seeds. Because polyphenols bind to cholesterol particles and prevent the accumulation of particles. The use of unprocessed quinoa led to a decrease in total plasma protein, which could be due to a decrease in the available phosphorus content in the feed (Underwood and Suttle, 2001). The decreased total protein is associated with decreased dietary phosphorus content (due to reduced hepatic protein synthesis as a result of poor liver function and malabsorption of nutrients in the small intestine). The establishment of the phytate-protein complex in the poultry gastrointestinal tract is effective on digestibility and protein absorption. Quinoa seed processing can compensate for part of the reduction in total protein by removing some of the trypsin and phytic acid. Improving dietary protein digestibility and proper amino acid balance have been reported to reduce serum uric acid (Dehghani-Tafti and Jahanian, 2016).

The morphology of the jejunum

The antinutrient compounds of quinoa seeds have the greatest impact on the morphology and microbiology of the intestine. Anti-nutritional compounds such as trypsin inhibitors lead to abnormal microflora, thinner mucus, delayed maturation of intestinal absorption cells (enterocytes), and shortening of intestinal villi and crepes. The hydrothermal method has little effect on the antinutritional compounds in quinoa seeds, especially trypsin. Thus, the intestinal epithelial cells are constantly changing (Fasina et al., 2006). In the present study, the increase in crypt depth in the hydrothermal method could be due to the increased destruction and atrophy of the lining cells of the villi tip. This degradation is due to the negative effect of tannins and protein inhibitors deep in the crypt to build and replace them with atrophic cells. An increase in the number of goblet cells has been reported in chickens fed high levels of trypsin inhibitors (Feng et al., 2007). Excessive secretion of endogenous proteins and an increase in the number of mucin-secreting goblet cells leads to the destruction of the intestinal epithelium, reduction of villi height, and destruction of microvilli (Rocha et al., 2014). These results are consistent with the results presented in the present study. Reduction of antinutrient compounds in quinoa seeds due to processing improves the morphological characteristics of broiler chickens. Consumption of processed quinoa seeds is expected to increase the production of volatile fatty acids. Volatile fatty acids act as the main source of energy for intestinal villi. On the other hand, considering the accelerating effect of volatile fatty acids on the maturation of distal intestinal villi, it is not expected that replacing processed quinoa seeds will increase the length of intestinal villi (Rocha et al., 2014).

Applying optimal processing methods reduces the content of antinutritional in quinoa seeds. The improvement of quinoa grain quality indices by applying the extrusion method is more than other methods. Quinoa seeds reduce blood cholesterol levels due to the content of antinutrient components. Feeding with quinoa seeds processed by extrusion, expansion and hydrothermal methods leads to better performance in poultry. In general, extrusion and expansion methods performance was better than others.

Declarations

Acknowledgments

The authors thank all those who contributed to the present study.

Funding

Not applicable.

Conflict of interest /Competing interests

The authors declare no competing interests.

Ethics approval

The experimental method was approved by the national committee for ethics in biomedical research of Iran.

Consent to participate

All the authors give consent for participation.

Consent to publication

All the authors give consent for publication.

Availability of data and material (data transparency)

All data generated and analyzed during this study are included in this published article.

Code availability

Not applicable.

Author' contribution

All the authors contributed to the study conception and design. Data collection was done by Negin Zeyghami. Data analysis and manuscript preparation were performed by Mohammad Ali Jafari and Mehrdad Irani. All the authors edited, read, and approved the final manuscript.

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