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Effect of dietary inclusion of quinoa on broiler growth performance

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Abstract

Two experiments were conducted to evaluate the effects of inclusion of Danish grown quinoa seed (*Chenopodium quinoa* Willd.) in feed for broilers containing wheat, rapeseed, peas and soybean meal. The effect of dehulling to remove saponins from quinoa was assessed.

In the first experiment the broilers received mash feed diets from 6 to 36 days of age. Diets containing 100, 200 and 400 g kg^{-1} whole quinoa seed, unprocessed and dehulled, were compared with a control feed. A linear growth depression ($P \leq 0.01$) with increasing inclusion of quinoa was found. As the chickens grew older the growth depression decreased from 1.8 to 0.8% per 10 g kg^{-1} quinoa added. A negligible beneficial effect of dehulling ($P \leq 0.05$) was found only for the first week of the experiment.

In the second experiment the broilers received pelleted diets from 0 to 39 days of age. Diets containing 150 g kg^{-1} unprocessed, 150 g kg^{-1} dehulled quinoa and 50 g kg^{-1} quinoa germ were compared with the control diet. No effect of dehulling was found. A level of 150 g kg^{-1} quinoa reduced liveweight at 20 and 39 days from 627 to 601 g and from 1760 to 1709 g, respectively, and the feed conversion was increased at 20 days of age from 1437 to 1486 g feed kg^{-1} liveweight ($P \leq 0.05$). The performance of broilers receiving 50 g kg^{-1} of a germ fraction from the dehulling was quite as good as the control.

It was concluded that quinoa has potential as broiler feed, but the inclusion should not exceed 150 g kg^{-1} of the diet. © 1997 Elsevier Science B.V.

Keywords: Quinoa grain; Quinoa germ; Broilers; Dehulling; Saponins

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1. Introduction

Quinoa (*Chenopodium quinoa* Willd.) is an annual grain crop, which has been domesticated in the Andes for thousands of years. Currently there is an increasing interest in the crop worldwide, as quinoa is recognised as a valuable, high-quality product for human consumption. Experiments on cultivation practices and breeding techniques have been performed successfully in Denmark (Jacobsen et al., 1994), whilst its prospects as a new crop in European agriculture have been assessed by Risi and Galwey (1984), Jacobsen and Stølen (1993) and Jacobsen et al. (1996).

Quinoa seed contains 120–180 g kg^{-1} crude protein. It has a more balanced amino acid composition than most conventional crops such as cereals, oil seed rape and pulses (Galwey et al., 1990). Nevertheless, the seed coat contains bitter saponins, which adversely affect palatability (Reichert et al., 1986; Ridout et al., 1989). Before human consumption these saponins have to be removed, either by vigorous washing in water or by abrasive dehulling.

Feeding trials have been performed on chickens by Gandarillas (1948), who found no significant difference in performance of chickens fed a balanced diet with 400 g kg^{-1} washed and cooked quinoa seed in comparison with maize. Unprocessed quinoa reduced liveweight gain of chickens, which was also found by Cardozo (1959). Subsequently, Gandarillas et al. (1968) recommended the inclusion of up to 300 g kg^{-1} quinoa in diets for chickens.

Because of its relatively high protein content, making it rich in essential amino acids and its high fat and starch contents, quinoa could become a high quality feedstuff for broiler chickens. The experiments described in this paper studied the effects of inclusion of quinoa in broiler diets.

2. Material and methods

2.1. General

The quinoa seed used in the experimental diets tested here was the variety Olav, previously known as KVL 8401. Seed was harvested from a field experiment grown at the research station of the Royal Veterinary and Agricultural University, located in Taastrup just outside Copenhagen, Denmark.

Two experiments were conducted with commercial male broiler chicks (ASA Chick A/S, Baekke, Denmark), which were floor-reared in commercial chicken houses with 24 h light per day. Experimental chickens were separated from the flock in wire netting pens placed in a row in the centre of the house. Newly hatched chickens were randomly distributed to these pens after removal of weak animals. There was a feeder in each pen, but for the first few days feed was offered from sheets of paper spread on the floor. The chickens had free access to water and feed.

The total content of starch and sugar was determined as digestible carbohydrate by a ferricyanide method after enzymatic hydrolysis with glucoamylase and saccharase (Jacobsen, 1981).

All diets were formulated to supply equal amounts of metabolisable energy and essential nutrients. Metabolisable energy was calculated in accordance with the European Economic Community system: the percentages of crude protein, crude fat, starch and sugar were multiplied by the factors 0.155, 0.343, 0.167 and 0.130, respectively, to estimate MJ kg^{-1} feed.

The content of saponins was determined by a haemolytic assay with aescin (Carl Roth Gmbh + Co, Karlsruhe) as external standard. The method was modified from the micromethod published by Gôrski and Jurzysta (1988).

2.2. Dehulling

A small rice scourer, Schule Type 130, was used for dehulling the grain. The bran fraction removed constituted 90 g kg^{-1} of the quinoa seed in Experiment 1, and 140 g kg^{-1} in Experiment 2. The bran was graded by air classification into a coarse fraction, rich in germ, and a light fraction containing most of the saponins. Raw quinoa seed, dehulled seed and germ fraction were all used in the experimental feeds. Table 1 shows the nutrient composition of quinoa fractions compared with wheat and soybean meal.

About 85% of the saponins was removed by the dehulling. The germ fraction and the raw quinoa seed contained equal amounts of saponins while the light fraction of the bran contained about 25 times as much.

2.3. Experiment 1

The nutritional value of raw quinoa seed (diets B, C and D) and dehulled seed (diets E, F and G) was tested in a factorial experiment at 100, 200 and 400 g kg^{-1} inclusion in the diets (Table 2). The control feed (diet A) was a regular broiler feed containing

Table 1
Chemical analysis of quinoa products and other dietary ingredients used for broiler feed

	Quinoa			Wheat	Soybean meal dehulled
	Seed	Dehulled	Germ		
Moisture (g kg^{-1})	141	141	141	150	140
Crude protein (g kg^{-1})	120	112	281	123	479
Crude fat (g kg^{-1})	59	45	146	19	12
Dig. carbohydrates (g kg^{-1})	586	626	332	585	140
Crude fibre (g kg^{-1})	21	17	21	23	34
Ash (g kg^{-1})	25	18	57	16	60
Estimated ME [a] (MJ kg^{-1})	13.8	13.7	14.9	12.3	10.1
Essential amino acids (g kg^{-1} of crude protein)					
Lysine	53	53	52	27	61
Methionine	19	19	20	17	14
Cystine	16	16	17	20	15
Threonine	35	36	33	29	39
Saponins (g aescin kg^{-1})	18	3	18		

[a] ME = 0.155 × Crude protein + 0.343 × Crude fat + 0.167 × Dig. carbohydrates.

Table 2
Composition and determined analysis of diets based on unprocessed and dehulled quinoa seed fed to growing broilers (Experiment 1). The diets were formulated to supply (kg^{-1} of balanced feed): metabolisable energy, 13.55 MJ; Ca, 12.3 g; P, 8.8 g; lysine, 13.3 g; methionine, 0.6 g; cystine, 0.37 g

	Diet						
	A	B	C	D	E	F	G
Ingredients (g kg^{-1})							
Quinoa seed		100.0	200.0	400.0			
Quinoa (dehulled)					100.0	200.0	400.0
Wheat	325.0	225.0	136.0	83.4	225.0	136.0	40.5
Peas	200.0	202.1	200.0		202.1	200.0	42.0
Rapeseed (double-zero, full fat)	150.0	149.9	150.0	150.0	149.9	150.0	150.0
Soybean meal (dehulled, toasted)	184.0	180.0	174.8	249.0	180.0	174.8	249.0
Meat and bone meal (43% crude protein)	60.0	59.9	60.0	60.0	59.9	60.0	60.0
Molasses	10.0	9.9	10.0		9.9	10.0	
Soybean oil	47.5	49.5	46.4	37.5	49.5	46.4	37.5
Calcium carbonate	2.5	3.2	3.2	3.9	3.2	2.8	1.8
Monosodium carbonate	1.5	1.4	1.6	1.5	1.4	1.6	1.5
Sodium chloride	1.0	1.4	1.2	1.2	1.4	1.2	1.2
Dicalcium phosphate	7.5	7.2	6.4	5.1	7.2	7.2	6.6
DL-methionine (400 g kg^{-1})	6.0	5.9	5.6	3.6	5.9	5.6	3.9
Vitamin premix [a]	5.0	5.0	4.8	4.8	5.0	4.8	4.8
Determined analysis [b] (g kg^{-1})							
Crude protein	236	235	227	232	234	226	239
Crude fat	125	127	125	125	127	125	125
N-free extract	427	423	430	422	425	434	414
Crude fibre	39	44	44	41	43	43	43
Ash	58	57	58	56	57	57	57
Moisture	115	115	117	124	114	116	123

[a] Vitamin premix supplied (t^{-1} of feed): vitamin A, 15 million IU; vitamin D_3, 2.5 million IU; α-tocopherol, 30 g; vitamin B_1, 2.2 g; vitamin B_2, 7 g; vitamin B_6, 3.3 g; D-pantothenic acid, 10.8 g; niacin, 53 g; choline chloride, 1 kg; folic acid, 1 g; biotin, 0.1 g; vitamin b_{12}, 20 mg; vitamin K_3, 2.5 g; avoparcin, 15 g; salinomycin-sodium, 60 g; Mn, 100 g; Fe, 62 g; Zn, 64 g; Cu, 25 g; I, 0.4 g; Se, 0.3 g.
[b] The figures for the experimental diets were calculated from proximate analyses on the premixes and on the quinoa ingredients.

wheat, soybean meal, 150 g kg^{-1} double-low rapeseed and 200 g kg^{-1} peas. The Danish feed company DLG formulated and manufactured the control diet and formulated premixes for the experimental diets without adding quinoa seed. All ingredients, except the liquid and the micro ingredients, were ground together on a hammer mill through a 4 mm screen. Proximate analyses were performed on the control feed and the premixes by DLG and were used for calculation of the nutrient contents of the final diets, as shown in Table 2, together with corresponding analyses on the unprocessed and dehulled quinoa used in the diets. Quinoa was added as unground seed and mixed into the diets by hand.

One-day-old male broiler chicks were allocated at random to 21 pens, 1.0 m^2 in size, each containing 25 birds. Seven diets were tested, each in three replicate pens. For the first 5 days all chicks were fed a common chick-starter diet. They were then weighed

and allocated to the respective experimental diets. The total weight of the chicks in each pen and the total feed consumption of each group were measured once a week and the litter quality was assessed until the experiment finished after 36 days. Litter quality was rated from 1 (dry) to 10 (very wet and greasy).

2.4. Experiment 2

The feeding value of three experimental diets containing equal percentages of rapeseed and peas combined with 150 g kg^{-1} raw quinoa seed, 150 g kg^{-1} dehulled quinoa, or 50 g kg^{-1} quinoa germ was examined. The control feed was a regular grower feed containing 120 g kg^{-1} double-low rapeseed and 160 g kg^{-1} peas (Table 3). The diets were manufactured at a pilot plant. All the ingredients, except oil and additives,

Table 3
Composition and determined analysis of diets based on unprocessed and dehulled quinoa seed fed to growing broilers (Experiment 2)

	Control	Quinoa		
		Seed	Dehulled	Germ
Ingredients (g kg^{-1})				
Quinoa seed		150.0		
Quinoa (dehulled)			150.0	
Quinoa germ				50.0
Wheat	439.2	309.9	299.5	421.8
Peas	160.0	160.0	160.0	160.0
Rapeseed (double-zero, full fat)	120.0	120.0	120.0	120.0
Soybean meal (dehulled, toasted)	164.9	156.5	164.8	141.4
Meat and bone meal (43% crude protein)	40.0	40.0	40.0	40.0
Fish meal (70% crude protein)	20.0	20.0	20.0	20.0
Soybean oil	37.9	26.2	28.0	28.9
DL-methionine (500 g kg^{-1})	4.0	3.9	4.0	3.7
Dicalcium phosphate	0.3	0.3	0.5	0.0
Calcium carbonate	6.7	6.8	6.6	7.0
Monosodium carbonate	2.2	1.5	1.7	2.1
Vitamin premix [a]	5.0	5.0	5.0	5.0
Calculated analysis (g kg^{-1})				
Metabolisable energy (MJ kg^{-1})	13.18	13.18	13.19	13.17
Crude protein	225.0	225.0	225.0	225.8
Crude fat	107.9	102.6	102.3	105.7
Starch	325.7	340.2	340.7	331.3
Available phosphorus	4.5	4.5	4.5	4.5
Calcium	10.0	10.0	10.0	10.0
Lysine	12.0	12.4	12.4	12.0
Methionine	5.4	5.5	5.5	5.4
Cystine	3.5	3.5	3.5	3.5

[a] Vitamin premix supplied (t^{-1} of feed): vitamin A, 15 million IU; vitamin D_3, 2.5 million IU; α-tocopherol acetate, 30 g; vitamin B_1, 2.2 g; vitamin B_2, 7 g; vitamin B_6, 3.3 g; D-pantothenic acid, 11 g; niacin, 53 g; choline chloride, 1 kg; folic acid, 1 g; biotin, 0.1 g; vitamin B_{12}, 20 mg; avoparcin, 15 g; salinomycin-sodium, 60 g; Fe, 62 g; Zn, 64 g; Mn, 110 g; Cu, 25 g; I, 0.4 g; Se, 0.3 g.

were ground together through a 2.5 mm sieve in a hammer mill. They were then mixed together with the oil and additives and the diets pelleted through a 5 mm × 35 mm die in a 3 t Matador pellet mill. The outlet pellet temperature reached about 85°C.

One-day-old male broiler chicks were allocated at random to 12 pens, 3.4 m^2 in size, each containing 80 birds. Four diets were tested from 0 to 39 days in each of three replicate pens. The total weight of the chickens and the feed consumption in each pen were measured and the number of dead animals recorded after 7, 20 and 39 days.

2.5. Statistical analysis

In the first experiment the effect of quinoa inclusion in the diets and of the content of quinoa hulls in the diets were assessed by the following regression model

$$Y \text{ variate} = \text{constant} + \text{quinoa} + \text{quinoa hulls}$$

In this model the effect of quinoa hulls was tested having first removed the effect of quinoa. The lack of fit was tested against the variance of replicates. For the Y variate, litter quality, all registrations from 13, 20, 27 and 36 days of age were included in the model together with the independent variable, age of chickens.

The effect of diet in the second experiment was analysed by a two-factorial variance analysis. No effect of pen placement in the chicken house was revealed. Consequently, the standard error of the means (SEM) in Tables 4 and 6 were calculated from the residual mean square in a one-factor analysis of variance. The Ryan–Einot–Gabriel–Welsch multiple F test (Einot and Gabriel, 1975) was used for multiple comparison of the means ($P \leq 0.05$).

Statistical evaluation of mortality was performed by the Kruskal–Wallis test ($P \leq 0.05$) (Quade, 1966).

3. Results

3.1. Experiment 1

The results of the first experiment are summarised in Table 4. The chickens fed quinoa consumed less feed than the control group, and spillage, particularly of quinoa seeds, was observed in pens where the feed contained the most quinoa.

When the experiment started on day 6 after feeding a chick-starter diet to all chickens, there was no significant difference in body weight between the treatment groups. Inclusion of 200 and 400 g kg^{-1} unprocessed quinoa in the diet and of 400 g kg^{-1} dehulled quinoa reduced liveweight gain of the chickens during the experimental period from 6 to 36 days of age. Statistical evaluation by a linear regression model showed a linear depression of the relative weight gain as the inclusion of quinoa was increased (Table 5). The lack of fit from the linear model was not significant at the $P < 0.05$ level for any of the recorded periods. As the chickens grew older the negative effect decreased from 1.8 to 0.8%, per 10 g kg^{-1} quinoa added to the feed, but the effect was still significant at the $P < 0.01$ level for the period from 27 to 36 days of age.

Table 4
Performance of broilers fed whole quinoa seed and dehulled seed—Experiment 1

	Control	Raw quinoa seed ($g\ kg^{-1}$)			Dehulled quinoa seed ($g\ kg^{-1}$)			SEM
		100	200	400	100	200	400	
Feed consumption, days 6–36 (g per chicken)	2374	2297	2003	1645	2265	2043	1583	
Liveweight, 6 days (g per chicken)	86a	87a	84a	84a	83a	88a	88a	±1.8
Liveweight gain, days 6–36 (g per chicken)	1323a	1247ab	1065bc	765d	1232ab	1079abc	875dc	±56.6
Feed conversion, days 6–36 (g feed g^{-1} gain)	1.79	1.84	1.88	2.15	1.84	1.89	1.81	
Litter rating [a]	4.3	4.9	4.8	5.5	4.7	4.9	5.2	
Mortality (%)	6.7	5.3	2.7	2.7	2.7	6.7	2.7	

[a] Litter quality was rated from 1 (dry) to 10 (very wet and greasy). Mean of registrations from each pen after 13, 20, 27 and 36 days.
Means within a row followed by different letters are significantly different ($P < 0.05$).

About 85% of the saponins in quinoa was removed by dehulling. During the first week those chickens fed dehulled quinoa gained significantly more weight than those on diets containing equal amounts of raw quinoa (Table 5). The positive effect of dehulling was small compared with the negative effect of quinoa—4% compared with 18% at 100 g kg^{-1} inclusion of quinoa. From the second week onwards the effect was not significant and the chickens apparently became accustomed to the bitter taste of the saponins.

Table 5
The effect of the inclusion of quinoa and quinoa hulls in the diets on the relative liveweight gain [a]

Period (days)	Intercept [a]	Regression coefficients		SEE [b]	Lack of fit
		Quinoa [a]	Hulls [a]		$F(4,14)$
6–13	140.5 ± 3.7 ***	-181 ± 17 ***	-43 ± 17 *	9.7	2.69 NS
13–20	130.6 ± 3.8 ***	-145 ± 18 ***	-16 ± 18 NS	10.1	2.30 NS
20–27	126.3 ± 4.5 ***	-117 ± 21 ***	-30 ± 21 NS	11.8	0.34 NS
27–36	117.0 ± 4.7 ***	-80 ± 22 **	-10 ± 22 NS	12.5	0.51 NS
6–36	126.3 ± 4.5 ***	-117 ± 21 ***	-30 ± 21 NS	11.8	0.27 NS
Litter rating [c]	-1.0 ± 0.2 ***	1.8 ± 0.5 ***	0.8 ± 0.5 NS	0.57	1.13 NS

[a] Liveweight gain, intercept and SEE are expressed in terms of a percentage of mean liveweight gain for the period in question, quinoa is expressed in kilograms per kilogram of diet and hulls in an arbitrary unit, 1 and 0 in unprocessed and dehulled quinoa, respectively, and consequently 0, 0.1, 0.2, 0.4 for the diets including the corresponding amounts of unprocessed quinoa (kg kg^{-1}).
[b] Standard error of estimation.
[c] The model included age of the chickens (13, 20, 27 and 36 days) which was significant ($P \leq 0.001$) with the regression coefficient 0.228 ± 0.7 and the degrees of freedom for the lack of fit was $F(24,56)$.
*** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$; NS not significant.

A statistical evaluation of the feed consumption and the feed conversion ratio was not possible because only the total feed consumption in all three pens of each group was recorded.

Average mortality tended to be lower for chickens fed quinoa than for the control group. During the course of the experiment the litter became progressively wetter and greasier in all pens. It was impaired by increasing levels of quinoa in the diet, and dehulling had no significant effect.

3.2. Experiment 2

The results are summarised in Table 6. No significant differences in feed consumption were found between the four diets. At 20 days of age, weight and feed conversion were impaired ($P \leq 0.05$) for the group fed 150 g kg^{-1} dehulled quinoa compared with the control. No other significant differences were found between the four groups. By comparison of the mean performance of the groups receiving 150 g kg^{-1} raw and dehulled quinoa with the control, a significantly lower liveweight ($P \leq 0.01$ and $P = 0.05$, respectively) at 20 and 39 days of age was found and impaired feed conversion ($P \leq 0.05$) at 20 days of age.

On average, the two quinoa groups consumed 0.7% more feed per kilogram gain in 39 days than the control group, but only the difference at 20 days was significant at the $P = 0.05$ level.

Table 6
Performance of broilers fed diets with quinoa—Experiment 2

	Control	Quinoa seed (150 g kg^{-1})			Quinoa germ (50 g kg^{-1})	SEM
		Raw	Dehulled	Mean		
Feed consumption (g per bird)						
Days 0–7	127a	133a	129a	131	127a	±1
Days 0–20	900a	889a	896a	892	896a	±11
Days 0–39	3145a	3087a	3065a	3076	3160a	±33
Liveweight (g per bird)						
Days 7	153a	150a	150a	150	150a	±2
Days 20	627a	608ab	593b	601 * *	625a	±6
Days 39	1760ab	1711b	1708b	1709	1776a	±16
Feed conversion (g feed kg^{-1} liveweight)						
Days 0–20	1437a	1463a	1510b	1486	1434a	±14
Days 0–39	1787ab	1804b	1794ab	1799	1779a	±6
Mortality (%)						
Days 0–7	2.1a	2.1a	1.7a		1.7a	±0.4
Days 0–20	2.1a	2.1a	2.5a		2.9a	±0.5
Days 0–39	3.8a	3.3a	5.8b		4.2ab	±0.5

Values within a row followed by the same letter are not significantly different ($P < 0.05$).
Asterisks indicate that values are significantly different from the control group at $P < 0.05$ and $P < 0.01$, respectively.

The mortality at 39 days among the chickens fed 150 g kg^{-1} dehulled quinoa was significantly higher than that of the control group and the group fed raw quinoa grain.

Feed consumption, weight gain and feed conversion of the chickens fed 50 g kg^{-1} quinoa germ in the diet tended to be better than those of the control group, though none of the differences were significant at the $P = 0.05$ level.

4. Discussion

Based on the chemical analyses the nutritional value of quinoa for broilers is better than that of wheat and maize (Table 1). However, in the first experiment, inclusion of whole quinoa seed in mash feed, at levels of 100–400 g kg^{-1}, resulted in a significantly linear depression in the growth of chickens (Table 5). Removing most of the bitter tasting saponins by dehulling only improved the liveweight gain slightly for chickens in the period 6–13 days. Thus, the growth depression was apparently caused mainly by factors other than the bitter tasting compounds in the hulls.

In the second experiment with pelleted feed, incorporation of 150 g kg^{-1} quinoa seed resulted in performance comparable to that of the control group and no beneficial effect was found by removing about 85% of the saponins by dehulling.

Previous results showed that inclusion of 400 g kg^{-1} washed or cooked quinoa had a positive or neutral effect on liveweight gain, while unprocessed quinoa seed reduced weight gain, compared with a control feed (Gandarillas, 1948; Cardozo, 1959). If washing or cooking of the seed is more effective in removing the growth depressing factors in quinoa than dehulling, the discrepancy with the present study might be partly explained.

When used for human consumption, quinoa seeds are dehulled. A germ fraction prepared by air classification of the fines from dehulling is a valuable feed, comparable in nutritive value to maize gluten. Chickens fed 50 g kg^{-1} quinoa germ had liveweight gains and feed conversion rates similar to those of the control group. The results of the present work show that up to 150 g kg^{-1} unprocessed or dehulled quinoa seed could be included in pelleted broiler feed. It appears that poultry may adapt to the bitter taste of saponins after a short adjustment period and utilise the nutrients in quinoa effectively.

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