

Effect of the use of flaked maize in diets with reduced metabolic energy on performance, egg quality, and serum parameters in layer quails

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SUMMARY

The research was conducted to determine the effects of substituting raw maize with flaked maize in diets containing different levels of metabolic energy on the performance, egg quality, and serum parameters of layer quails. In the experiment, 120 female quails at ten weeks of age were randomly allocated to six treatment groups with four replicates, each consisting of five quails. The quails were fed six diets, with two forms of maize (raw or flaked) and three metabolic energy levels (2750, 2825 or 2900 (control) kcal/kg) during a ten-week trial. Compared with the control group, reducing the metabolic energy level of the diet to 2750 kcal/kg negatively affected egg production ($P < 0,01$), egg mass ($P < 0,01$), feed conversion ratio ($P < 0,01$), and serum cholesterol concentration ($P < 0,05$). Eggshell thickness decreased significantly in the group receiving 2750 kcal/kg metabolic energy in the diet, and the yolk b* value increased significantly ($P < 0,01$). The use of flaked maize in the diets significantly increased egg production ($P < 0,05$), egg mass ($P < 0,05$), eggshell thickness ($P < 0,05$), and yolk L* value ($P < 0,01$) and significantly decreased the feed conversion ratio ($P < 0,05$) and b* value of the yolk ($P < 0,05$). Although the effects of the interactions of the metabolic energy levels and forms of maize on the egg yolk b* value were significant ($P < 0,01$), this effect was not significant for the other parameters. The results indicate that layer quails can be fed diets containing 2825 kcal/kg metabolic energy and that replacement of raw maize with flaked maize in the diet positively affects performance and egg quality.

KEY WORDS: flaked maize, egg quality, metabolizable energy, performance, serum parameters

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INTRODUCTION

Maize, a highly preferred feed ingredient in poultry nutrition, is the grain with the highest metabolic energy (ME) content. Maize can constitute up to 60% of poultry diets and provide approximately 70% of diet energy and 25% of protein. Therefore, it is important to improve the nutritional value and digestibility of maize. One way to improve the digestibility of maize is heat treatment. Heat treatment is generally applied at a temperature above 90°C and aims to improve livestock performance by increasing the digestibility of feeds (Medel et al., 2004; Mateos et al., 2007). Flaking is a process by which grains are cooked with steam and high pressure and then dried by extrusion through a roller. In this way, the starch in the maize is gelatinized and its digestibility increases (Medel et al., 2004). Moreover, heat treatment causes lipids and sugars to be released from the cell wall, and thus their digestibility is increased by exposure to digestive enzymes (Huang, 1992; Vicente et al., 2008). The digestibility of dry matter, organic matter, neutral detergent fibre, starch, and lipids increases with flaking of maize (Gracia et al., 2009). A limited number of studies in the literature have shown that the use of flaked maize in poultry diets positively affects performance (Gonzalez-Alvarado et al., 2007; Gracia et al., 2009; Jimenez-Moreno et al. 2009).

Given the above, we hypothesized that the energy level of the diet can be reduced without any loss in production by increasing the digestibility of maize, which is the main energy source in poultry diets, via flaking. The research was carried out to determine the effect of replacement of raw maize with flaked maize in layer quail diets with different levels of ME on performance, the external and internal quality of eggs, and some serum parameters.

MATERIAL AND METHODS

In the experiment, a total of 120 female Japanese quails at the age of 10 weeks were allocated in equal numbers to six treatment groups with of three ME levels and two forms of maize. Each treatment group comprised four subgroups with five quails in each. During the 10-week experiment, the quails were fed six treatment diets using raw (ground) maize or flaked maize in diets containing 2900 (control (NRC, 1994)), 2825, and 2750 kcal/kg ME (Table 1). The raw materials used in the experiment, including flaked maize (0,70 mm thick), were obtained from local suppliers. A 16-hour lighting programme was used during the experiment, and feed and water were supplied *ad libitum* to the quails.

Determination of performance parameters

The average body weights of the quails were determined by group weighing at the beginning and end of the experiment, and body weight change (BWC) was calculated from these averages. The number of eggs laid was recorded daily, and egg production (EP) was calculated as %. The feeds given to each treatment group were weighed separately, and feed intake (FI) was calculated as g/day/quail by subtracting the remaining feed from the total feed at the end of the experiment. Egg weights (EW) were determined and expressed in g by weighing all eggs collected in the last three days of the experiment. Egg mass (EM) was calculated as g/day/quail by the formula $(EP \times EW)/100$. Feed conversion ratio (FCR) was calculated as g feed/g egg by the formula FI/EM .

Table 1

Experimental diets and calculated nutrient contents

Ingredients, g/kg	ME, kcal/kg		
	2750	2825	2900
Raw or flaked maize	614,5	598,0	58,0
Soybean meal	308,0	311,0	315,0
Sunflower oil	2,0	15,5	29,5
Limestone	56,0	56,0	56,0
Dicalcium phosphate	11,8	11,8	11,8
Salt	3,5	3,5	3,5
Premix ¹	2,5	2,5	2,5
DL methionine	1,7	1,7	1,7
Total	1000,0	1000,0	1000,0
Chemical composition, g/kg			
ME, kcal/kg	2751	2825	2901
Crude protein	200,1	200,0	200,3
Calcium	25,00	25,00	25,00
Available phosphorus	3,51	3,50	3,50
Lysine	10,44	10,48	10,45
Methionine	4,50	4,48	4,47
Methionine + cysteine	8,23	8,21	8,19

¹Premix in 1 kg of diet provides; Mn: 80 mg, Fe: 60 mg, Cu: 5 mg; I, 1 mg, Se: 0,15 mg, Vitamin A: 8,800 IU, Vitamin D₃: 2,200 IU, Vitamin E: 11 mg, Vitamin K₃ 2,5 mg, Nicotinic acid: 44 mg, Cal-D-Pan: 8,8 mg, Riboflavin: 4,4 mg, Thiamine: 2,5 mg, Vitamin B₁₂: 6,6 mg, Folic acid: 1 mg, Biotin: 0,11 mg, Choline: 220 mg

Determination of external egg quality

During the experiment, broken, cracked, and damaged eggs were recorded and calculated as % of total eggs. After determining the weights of all the eggs collected in the last three days of the experiment in air and water, their specific weights were calculated in g/cm³ using the formula EW/(EW – EW in water). Eggshell breaking strength was measured by systematically applying supported pressure to the blunt end of the eggs (Egg Force Reader, Orka Food Technology, Israel). After the eggs were broken on a clean glass table, the eggshells were cleaned of egg residues and then dried for three days at room temperature. Eggshell weights were calculated as % of egg weights. Eggshell thickness was calculated as the average of the values obtained by measuring at three points of the egg (equator, blunt end, and pointed end) using a micrometer (Mitutoyo, 0,01 mm, Japan).

Determination of internal egg quality

The albumen height of the eggs was measured with a height gauge, and the Haugh unit was calculated by the formula $100 \times \log(\text{albumen height} + 7,57 - 1,7 \times \text{EW}^{0,37})$ (Haugh, 1937). Egg yolk colour and L*, a* and b* values were measured using the Roche colour scale and a colorimeter, respectively (Minolta Chroma Meter CR 400 (Minolta Co., Osaka, Japan)) (Romero et al., 2002).

Determination of serum biochemical parameters

At the end of the trial (10th week), 3 ml of blood was taken from one quail selected at random from each subgroup (24 in total, with similar body weights) to determine serum parameters. Blood was centrifuged at 3000 rpm for 5 minutes. The serum was stored at -20°C until analysis. Glucose,

cholesterol, aspartate aminotransferase (AST), creatinine, total protein, albumin, globulin, calcium, and phosphorus concentrations were determined in an autoanalyser using commercial kits (DDS® Spectrophotometric Kits, Diasis Diagnostic Systems Co., İstanbul, Turkey).

Statistical analysis

The data were subjected to analysis of variance based on a 2 (forms of maize) x 3 (levels of ME) factorial design using General Linear Model (Minitab, 2000), followed by Duncan's (Duncan, 1955) multiple comparison test to separate means when a significant effect ($P < 0,05$) was detected.

RESULTS AND DISCUSSION

Performance

The effects of replacing raw maize with flaked maize in diets containing different levels of ME on the performance parameters of layer quails are shown in Table 2.

As a main factor, the diet ME level did not statistically affect BWC, EW or FI, while it significantly affected EP, EM, and FCR ($P < 0,01$). The reduction of the ME level to 2750 kcal/kg in layer quail diets significantly decreased EP relative to the control group (2900 kcal/kg ME). Similarly, Lotfi et al. (2018) reported that lowering the ME level to 2750 kcal/kg negatively affected EP in quails. On the other hand, our results are in contrast with those of Elangovan et al. (2004) and Barreto et al. (2007), who found that reducing the ME level to 2700 or 2500 kcal/kg in quail diets did not affect EP. As in the case of EP, the reduction in the diet ME level also caused a decrease in EM. Compared to the control group, this decrement was significant in the group receiving a diet with 2750 kcal/kg ME ($P < 0,01$). Similarly, Lotfi et al. (2018) reported that EM was significantly reduced in quails fed diets with 2750 kcal/kg ME relative to 2960 kcal/kg ME. The researchers found that EM levels decreased significantly in quails fed a diet containing 2750 kcal/kg ME compared to 2960 and 3050 kcal/kg ME. These reports are in agreement with the results of the present study. In contrast, research conducted by Freitas et al. (2005) and Mouro et al. (2008) demonstrated that the diet ME level (from 2500 to 2900 kcal/kg) did not affect EM in quails. Barreto et al. (2007), on the other hand, found that EM levels decreased with a gradual increase in the ME level from 2650 kcal/kg to 3050 kcal/kg ME in layer quail diets. In our experiment, FCR worsened with the reduction of the diet ME level, and this effect was highly significant in the 2750 kcal/kg ME group compared to the control group (2900 kcal/kg ME) ($P < 0,01$). These results are in line with the reports of Elangovan et al. (2004), Mouro et al. (2008), and Lotfi et al. (2018). In contrast, Barreto et al. (2007) claimed that FCR was improved by reducing the ME level (from 3050 to 2650 kcal/kg) in layer quail diets. However, Freitas et al. (2005) reported that changing the diet ME level (from 2585 to 2885 kcal/kg) did not affect feed efficiency in laying quails.

While substituting raw maize with flaked maize in the diet did not affect the BWC, EW, or FI parameters, EP, EM, and FCR improved significantly with the use of flaked maize in the diet ($P < 0,05$). Maize is the main energy source for poultry, with its high content of starch and lipids and low cellulose content. The steam, pressure, and heat applied to the grain in the flaking process cause gelatinization of the starch in maize (Medel et al., 2004). Additionally, lipids and sugars are released from cellulose and can be digested by poultry (Jimenez-Moreno et al., 2009). Therefore, flaking of maize allows the energy and other nutrients required for optimum EP to be better utilized by quails. Flaking of maize did not significantly affect FI, but it increased EP, resulting in a significant improvement in EM and FCR, which are parameters directly related to EP. Similarly, Murakami et

al. (2008) reported that heat-treated (extruded) diets improved EP and EM in layer quails compared to the control group. In that study, FCR was not affected by the treatments, as FI also increased with the extrusion process. In some studies, however, the use of heat-treated maize in broiler diets has been reported to improve FCR (Çolak and Cufadar 2018; Puntigam et al., 2018; Massuquetto et al., 2020).

In our experiment, there was no statistical effect of the interactions between diet ME levels and maize forms on performance parameters. The results in Table 2 indicate that EM and FCR show a tendency to improve with the use of flaked maize use at each energy level, but the differences are not statistically significant.

Table 2

Effects of the use of flaked maize in diets with different ME levels on performance in layer quails

ME, kcal/kg	Form of maize	BWC, g	EP, %	EW, g	EM, g/d/quail	FI, g/d/quail	FCR, g feed/g egg
2750		8,06	80,29 ^B	12,61	10,15 ^B	34,49	3,45 ^A
2825		12,95	86,06 ^{AB}	12,89	11,08 ^{AB}	34,16	3,10 ^{AB}
2900		7,38	91,54 ^A	12,90	11,81 ^A	33,78	2,89 ^B
SEM		3,868	1,992	0,232	0,332	0,431	0,104
	Raw	8,78	83,27 ^b	12,71	10,59 ^b	34,17	3,28 ^a
	Flake	10,14	88,67 ^a	12,89	11,43 ^a	34,11	3,00 ^b
	SEM	3,199	1,898	0,186	0,309	0,356	0,100
2750	Raw	7,88	75,35	12,36	9,33	34,12	3,72
2750	Flake	8,25	85,24	12,87	10,97	34,85	3,18
2825	Raw	17,33	82,43	13,19	10,87	34,75	3,22
2825	Flake	8,58	89,70	12,60	11,29	33,57	2,97
2900	Raw	1,15	92,03	12,59	11,58	33,64	2,91
2900	Flake	13,60	91,06	13,21	12,03	33,92	2,83
SEM		5,038	2,174	0,298	0,401	0,564	0,117
Probabilities, P≤							
ME		0,544	0,002	0,591	0,006	0,532	0,002
Form		0,762	0,026	0,489	0,035	0,913	0,024
Interactions		0,174	0,143	0,131	0,323	0,296	0,288

BWC: Body weight change, EP: Egg production, EW: Egg weight, EM: Egg mass, FI: Feed intake, FCR: Feed conversion ratio. SEM: Standard error of means.

^{A, B}: within a column, values not sharing a common letter are statistically different; P < 0,01

^{a, b}: within a column, values not sharing a common letter are statistically different; P < 0,05

Egg external quality

The effects of substituting raw maize with flaked maize in diets containing different levels of ME on the external quality of the eggs of layer quails are shown in Table 3.

Table 3

Effects of the use of flaked maize in diets containing of different levels ME on the external quality of layer quail eggs

ME, kcal/kg	Form of maize	Cracked eggs, %	Specific weight, g/cm ³	Eggshell breaking strength, kg	Eggshell weight, % of EW	Eggshell thickness, µm
2750		1,99	1,069	1,47	8,26	187 ^B
2825		1,01	1,070	1,51	8,42	196 ^A
2900		0,16	1,068	1,41	8,04	195 ^A
SEM		0,472	0,0010	0,063	0,145	1,9
	Raw	1,04	1,068	1,46	8,10	190 ^b
	Flake	1,07	1,069	1,46	8,39	196 ^a
	SEM	0,508	0,0008	0,052	0,118	1,8
2750	Raw	1,88	1,068	1,45	8,07	184
2750	Flake	2,11	1,069	1,50	8,45	190
2825	Raw	1,23	1,070	1,58	8,43	195
2825	Flaked	0,78	1,069	1,44	8,41	198
2900	Raw	0,00	1,065	1,36	7,79	192
2900	Flaked	0,32	1,070	1,46	8,39	199
SEM		0,693	0,0013	0,090	0,185	2,3
Probabilities, P≤						
ME		0,136	0,374	0,558	0,190	0,004
Form		0,963	0,123	1,000	0,088	0,021
Interactions		0,88	0,221	0,415	0,389	0,760

SEM: Standard error of means^{A, B}: within a column, values not sharing a common letter are statistically different; P < 0,01^{a, b}: within a column, values not sharing a common letter are statistically different; P < 0,05

Neither the diet ME level nor the form of maize, as the main factors, nor their interactions affected cracked egg %, specific weight, eggshell breaking strength, or eggshell weight, but eggshell thickness was significantly affected by both the dietary ME level and the form of maize, as the main factors (P < 0,01 and P < 0,05, respectively).

Eggshell thickness decreased considerably with the reduction of the diet ME level from 2900 kcal/kg to 2750 kcal/kg ME (P < 0,01). This is in agreement with research by Elangovan et al. (2004), who reported that when the diet ME level was lowered to 2700 kcal/kg, eggshell thickness in layer quails decreased. Similar results were obtained by Lotfi et al. (2018). In laying hens, however, Junqueira et al. (2006), Wu et al. (2008), and Koreleski and Swiątkiewicz (2009) claimed that the diet ME level did not affect eggshell thickness.

Eggshell thickness significantly improved with the replacement of raw maize with flaked maize in layer quail diets (P < 0,01). Hafeez et al. (2015) found that eggshell thickness in laying hens was not affected by the use of mash, pellets, and expander feeds. Similar results were also reported by Murakami et al. (2008). Hafeez et al. (2016) found that expansion of feeds did not affect ileal mineral absorption, concluding that there was no effect on the stability of the eggshell and that the differences were due to chance.

Internal egg quality

The effects of the treatments on Haugh unit and L*, a* and b* values of the yolk are presented in Table 4.

Table 4

Effects of the use of flaked maize in diets with different ME levels on the internal quality of layer quail eggs

ME, kcal/kg	Form of maize	Haugh unit	L*	a*	b*
2750		64,95	51,45	-0,80	26,69 ^A
2825		63,36	50,59	-0,58	23,14 ^B
2900		65,58	51,31	-0,42	22,61 ^B
SEM		0,641	0,384	0,101	0,666
	Raw	64,97	50,52 ^B	-0,56	24,62 ^a
	Flaked	64,29	51,72 ^A	-0,64	23,67 ^b
	SEM	0,585	0,278	0,099	0,703
2750	Raw	65,17	51,30	-0,68	29,21 ^A
2750	Flaked	64,74	51,61	-0,93	24,17 ^B
2825	Raw	64,07	49,86	-0,58	23,59 ^B
2825	Flaked	62,65	51,31	-0,58	22,69 ^{BC}
2900	Raw	65,68	50,40	-0,43	21,06 ^C
2900	Flaked	65,48	52,23	-0,40	24,16 ^B
SEM		0,916	0,442	0,147	0,418
Probabilities,					
P ≤					
ME		0,093	0,148	0,081	<0,001
Form		0,404	0,004	0,582	0,002
Interactions		0,806	0,243	0,656	<0,001

SEM: Standard error of means

^{A, B}: within a column, values not sharing a common letter are statistically different; P < 0,01

^{a, b}: within a column, values not sharing a common letter are statistically different; P < 0,05

While the effect of diet ME level as a main factor was highly significant for yolk b* value (P < 0,01), its effect was not significant for other internal egg quality parameters. The b* value in the group fed a diet with 2750 kcal/kg ME was significantly higher than in the groups receiving 2825 and 2900 kcal/kg ME. The decrease in yolk b* value may be due to the difference in the amount of maize used in the treatment diets.

Although the form of maize as a main factor had no significant effect on Haugh unit or the yolk a* value, its effect was significant for L* (P < 0,01) and b* (P < 0,05) values. Compared to raw maize, the L* value of yolk increased significantly with the use of flaked maize in the diet, whereas the yolk b* value decreased significantly. Heat treatment reduces the b* value of maize by approximately 50% by decreasing the total carotenoid content and especially the xanthophyll content of the maize (Puntigam et al., 2018). The most likely reason for the decrease in the yolk b* value in the group with flaked maize is the loss of carotenoid compounds in the maize due to heat treatment.

In the experiment, there was no statistical effect of the interaction between diet ME level and the form of maize on internal egg quality parameters, except the yolk b* value (P < 0,01). Egg yolk b* value was found to be significantly higher in the interaction group whose diet contained 2750 kcal/kg ME and raw maize compared to the other groups, while in the interaction group whose diet contained

2900 kcal/kg ME and raw maize it was significantly lower than in the other groups, except the group whose diet contained 2825 kcal/kg ME and flaked maize ($P < 0,01$).

Serum parameters

The effects of substituting raw maize with flaked maize in diets with different ME levels on serum biochemical parameters in layer quails are presented in Table 5. Neither diet ME level nor maize form, as the main factors, nor their interactions statistically affected serum parameters other than the serum cholesterol level of laying quails ($P < 0,05$). The serum cholesterol level was not affected by the maize form or the interaction between the main factors, but the serum cholesterol level of the group receiving 2750 kcal/kg ME in the diet was found to be significantly higher than in the group receiving 2900 kcal/kg ME in the diet ($P < 0,05$). These results differ from those reported by Park and Kim (2016) and by Saleh et al. (2020), who reported that serum cholesterol decreased with decreasing diet energy level, while Majdolhosseini et al. (2019) and Hu et al. (2019) reported that serum cholesterol concentration was not affected by dietary ME level. The use of sources of polyunsaturated fatty acids such as sunflower oil in the diet causes a decrease in the cholesterol concentration in the serum (Velasco et al., 2010). In the present study, to reduce the dietary ME level to 2750 kcal/kg, the amount of oil used in the diet was 2,0 g/kg. Therefore, the reason for the high serum cholesterol level in quails fed diets containing 2750 kcal/kg ME is that the amount of sunflower oil (2,0 g/kg) used in this experimental diet was approximately 1/15 and 1/8 of the amount used in the diets containing 2900 and 2825 kcal/kg ME (29,5 and 15,5 g/kg, respectively).

Table 5

Effects of the use of flaked maize in diets with different ME levels on serum biochemical parameters in layer quails

ME, kcal/kg	Form of maize	Glucose, mg/dL	Cholesterol, mg/dL	AST, U/L	Creatinine, mg/dL	Total protein, g/Dl	Albumin, g/dL	Globulin, g/dL	Ca, mg/dL	P, mg/dL
2750		324	256 ^a	224	0,344	5,23	1,41	3,81	22,69	5,80
2825		317	231 ^{ab}	227	0,358	5,00	1,55	3,45	21,89	5,64
2900		343	221 ^b	232	0,350	4,94	1,41	3,53	19,30	5,56
SEM		8,9	8,6	10,5	0,0074	0,202	0,050	0,174	1,024	0,575
	Raw	328	239	223	0,357	5,21	1,48	3,73	22,07	5,82
	Flake	329	233	233	0,344	4,90	1,44	3,46	20,52	5,52
	SEM	8,0	8,3	8,5	0,006	0,162	0,044	0,144	0,899	0,449
2750	Raw	317	255	216	0,360	5,50	1,43	4,08	23,28	5,03
2750	Flake	331	256	232	0,328	4,95	1,40	3,55	22,10	6,58
2825	Raw	314	242	215	0,355	5,13	1,58	3,55	21,73	6,18
2825	Flake	321	219	239	0,360	4,88	1,53	3,35	22,05	5,10
2900	Raw	353	219	237	0,355	5,00	1,43	3,58	21,20	6,25
2900	Flake	334	223	226	0,345	4,88	1,40	3,48	17,40	4,88
SEM		11,8	12,3	14,3	0,0099	0,290	0,074	0,245	1,338	0,725
Probabilities, P _≤										
ME		0,171	0,045	0,882	0,414	0,611	0,138	0,356	0,074	0,955
Form		0,941	0,598	0,451	0,148	0,225	0,595	0,209	0,205	0,651
Interactions		0,454	0,532	0,512	0,204	0,771	0,982	0,696	0,371	0,160

AST: Aspartate aminotransferase, **Ca:** Calcium, **P:** Phosphorus, **SEM:** Standard error of means.^{A, B}: within a column, values not sharing a common letter are statistically different; P < 0,01^{a, b}: within a column, values not sharing a common letter are statistically different; P < 0,05

CONCLUSIONS

The results of the research indicate that the use of 2750 kcal/kg ME in the diet negatively affected EP, EM, FCR, and serum cholesterol, but 2825 kcal/kg ME did not affect these parameters. Compared to other ME levels, the use of 2750 ME in the diet decreased eggshell thickness and increased the yolk b* value. With the substitution of raw maize with flaked maize in layer quail diets, EP, EM, FCR, and eggshell thickness improved, and the egg yolk L* value increased, but the b* value decreased. Therefore, it was determined that 2825 kcal/kg ME provides sufficient energy in layer quail diets without negatively affecting performance or egg quality, and the use of flaked maize in the diet positively affects performance and egg quality.

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