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Effects of adapted quality protein maize on broiler performance

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A B S T R A C T

Quality protein maize (QPM) has high contents of the essential amino acids lysine and tryptophan. The substitution of standard maize (SM) with QPM in feeds can be profitable due to improved livestock performance and decreased use of costly dietary lysine supplementation and protein ingredients. Herein, effects of QPM adapted to temperate climate on broiler performance were tested. A feeding experiment was performed on control (fed with SM) and treatment (fed with QPM) broilers. Each feeding trial of 42 days' duration was carried out in three phases – starter (1–14), grower (15–35) and finisher (36–42). Diets for each growth phase were formulated based on the biochemical analysis of maize kernels. At the end of each growth phase, feed intake (FI), body weight gain (BWG), average daily gain (ADG) and feed conversion ratio (FCR) were calculated. In the first experiment, SM was completely replaced with QPM in treatment group diets. The results indicated better FCR in the treatment group for grower (1.51:1.56) and finisher (1.56:1.61) phases. In the second experiment, QPM content was increased and the soybean component decreased by 3%. This time, FCR improvement was even better but in all three phases – 1.16:1.33 for starters, 1.28:1.36 for growers and 1.30:1.46 for finishers. These results indicate a significant financial reduction in the cost of feed as the price of soybean is usually two to four times higher than the price of maize. Overall, it can be concluded that using adapted QPM in broiler diets can be profitable for both feed industry and broiler producers.

Keywords: broilers, feed conversion ratio, lysine, soybean, quality protein maize

И З В О Д

Кукуруз високог квалитета протеина (*Quality protein maize – QPM*) сматра се супериорним у односу на стандардни кукуруз (*standard maize – SM*) као компоненту сточне хране, јер побољшава перформансе животиња и смањује употребу синтетског лизина. Циљ овог рада је био испитивање нутритивних и финансијских ефеката *QPM* оброка у исхрани бројлера. Експерименти исхране су изведени на контролној (храњеној *SM*-ом) и огледној (храњеној *QPM*-ом) групи бројлера. Експеримент је трајао укупно 42 дана и састојао се од три фазе – стартер (1–14. дан), гровер (15–35. дан) и финишер (36–42. дан). Смеше хране за сваку фазу су формулисане на основу биохемијске анализе зрна *SM* и *QPM* кукуруза. Унос хране (*FI*), прираст (*BWG*), просечан дневни прираст (*ADG*) и степен конверзије хране (*FCR*) израчунати су на крају сваке фазе. Изведена су два огледа. У првом, *SM* је у потпуности замењен *QPM*-ом у оброцима за огледне пилиће. Пошто су резултати показали боље вредности за *FCR* код огледних пилића у гровер (1.51:1.56) и финишер (1.56:1.61) фазама, у другом огледу садржај *QPM*-а је повећан а соје смањен за 3%. Степен конверзије хране у овом огледу је био још нижи, и то у све три фазе – 1.16:1.33 у стартер, 1.28:1.36 у гровер и 1.30:1.46 у финишер фази. Ови резултати указују на значајну финансијску уштеду, пошто је цена соје два до четири пута већа од цене кукуруза. Може се закључити да употреба адаптираног *QPM* кукуруза у исхрани бројлера има предности како за индустрију сточне хране тако и за произвођаче бројлера.

Кључне речи: бројлери, степен конверзије хране, лизин, соја, *QPM*

1. Introduction

Quality protein maize (QPM) is high lysine and tryptophan maize developed through conventional breeding programmes at the International Maize and Wheat Improvement Centre, Mexico. Increasing requirements for nutritionally enhanced food and feed led to QPM adaptation to temperate regions, although this process was frequently hampered by the retained exotic germplasm (Worral et al., 2015; Kostadinovic et al., 2016; Carena and Dong, 2017). Besides double the amount of lysine and tryptophan compared to standard maize (SM), the quality of QPM protein is 90% similar to milk due to the nitrogen balance index comparable with milk (Jilo, 2021). Although QPM was primarily developed for human consumption, it can be beneficial for use in feeds, especially in developed countries where 78% of total maize production is used for feed (Sofi et al., 2009).

Intensive work in broiler selection over the last half century has led to great changes in broiler performance and carcass characteristics, with proper nutrition as a major non-genetic factor responsible for the success of poultry meat production (Dosković et al., 2019). The evaluation of the effects of dietary QPM on broilers showed improved livestock performance and decreased use of costly lysine supplementation and protein ingredients. The nutritional performance of

three QPM hybrids was compared with standard maize in a feeding trial with broilers in the work of Prandini et al. (2011). The inclusion of QPM resulted in a higher body weight gain (BWG) and a higher average daily gain (ADG) throughout the experimental period. The authors stated that this was caused by a higher feed conversion ratio (FCR) of the diets containing QPM rather than a higher feed intake (FI) by broilers. Moreover, the effect of different percentages of QPM in a diet was evaluated. Onimisi et al. (2009) evaluated the impact of the replacement of standard maize with QPM in broiler diets on growth parameters. Six diets were formulated by replacing SM with QPM at 0, 25, 50, 75 and 100%, respectively (T_1–T_5), while T_6 was a SM based diet balanced with synthetic lysine. At the starter phase, BWG and FCR were improved with increased QPM content in the diet, though a statistically significant improvement was obtained only at 100% QPM. The best performance was observed in the diet supplemented with synthetic lysine. However, at the finisher phase, T_4–T_6 were significantly better compared to the other treatments. These improvements in weight gains were primarily attributed to the higher lysine content in the diet, since lysine is one of the most critical and limiting amino acids in maize and broiler performance, and is crucial in protein synthesis for the growth of tissues. Higher levels of QPM in the diet also increased the tryptophan content, causing a higher concentration of available niacin. The lower leucine to isoleucine ratio in QPM may also have contributed to the better performance observed in the QPM diet by reducing the preponderance of leucine and boosting the production of niacin. Mushipe et al. (2017) examined the effects of graded substitution of standard maize with QPM (0, 25, 50, 75 and 100%) on the performance of broiler chicken. BWG and ADG, as well as an improvement in the economy of feed utilization, were the highest in birds fed with 75% and 100% QPM diets. Despite their high feed intake, birds fed with 100% QPM diet were the most efficient feed utilizers. Overall, feed with QPM was consumed less per unit mass of product (broiler meat), leading to a reduction in the price of broiler meat production.

The Maize Research Institute Zemun Polje has developed a programme on creating QPM hybrids adapted to temperate climate aimed for broiler feed (Ignjatovic Micic et al., 2020). This is the first such programme in Serbia. The aim of the research presented herein was to test the nutritional and financial effects of adapted hybrid ZPQPM13 in broiler diets with QPM meal. Positive results would lead to a novel formula (product) for feed and poultry industries competitive on the markets worldwide.

2. Materials and methods

2.1. Materials

ZPQPM13, a QPM hybrid adapted to growth conditions in temperate regions, was developed by crossing two QPM lines. The first one was ZPL5 commercial line, converted to QPM through marker assisted breeding, and the second was GS-6 line, with 50% tropical and 50% temperate germplasm. This hybrid fulfilled all QPM criteria: high grain yield (at the level of standard commercial hybrids), hard endosperm (over 90%), high tryptophan content (over 0.075%), high protein content (over 10%), good quality index (tryptophan to protein ratio), as well as the tryptophan content stability over diverse environmental conditions (Table 1). The significance of the differences between the measured traits in 2017 and 2018 for QPM and SM hybrids is presented in Ignjatovic-Micic et al. (2020).

Table 1.
Average results (over years and locations) of ZPQPM13 hybrid analyses for traits important for QPM

ZPQPM13 hybrid traits	Average (2017 and 2018)
Grain yield (t ha^{-1})	9.145
Hard endosperm percentage (%)	93.32
Tryptophan content (%)	0.083
Protein content (%)	11.81
Quality index	0.70

2.2. Experimental design

A total of 400 day-old Ross 308 broiler chicks were divided in two groups – control (C) and treatment (T), with 200 chicks in each group. The broilers were housed groupwise randomly in deep litter system with sawdust as bedding at a housing density of 10 birds/m^2. The temperature was maintained at 34°C for the first 7 days and then gradually reduced to around 26°C by 21 days of age, after which broilers were maintained at room temperature. Lighting was provided for 24 hours. Chickens were vaccinated against infectious bursal disease, infectious bronchitis and Newcastle disease between days 12 and 21. The birds had *ad libitum* access to their respective diets and clean drinking water. The only difference between control and treatment diets was in the maize component – control diets contained standard maize and treatment diets contained QPM13 maize. All the experimental diets contained metabolizable energy at 3150, 3200 and 3250 kcal/kg and crude protein at 23, 19 and 18 g/100 g respectively in starter, grower and finisher phases. The ingredient and nutrient composition of the diet is presented in Table 2. Each feeding trial of 42 days' duration was carried out in three phases–starter (1–14 days), grower (15–35 days) and finisher (36–42 days), with corresponding diets.

First experiment (E1): The first group was a control group, in which chicken diets contained standard maize. The second group was a treatment group, in which standard maize in diets was completely replaced with QPM.

Second experiment (E2): The first group was a control group, in which chicken diets contained standard maize. The second group was a treatment group, in which standard maize in diets was completely replaced with QPM, but with the QPM component increased and the soybean component decreased by 3% compared to E1.

Both experiments were performed in two replicates. Body weight was measured on days 1, 7, 14 (starter phase), 35 (end of the grower phase) and 42 (end of the finisher phase). At the end of each growth phase, FI, BWG, ADG and FCR were calculated. The t-test (Microsoft Excel) was used to determine the significance of differences between the results obtained with two dietary treatments.

Table 2.
Ingredients and nutrient composition of experimental diets for broilers

Ingredient (%)	Control			Treatment		
	Starter	Grower	Finisher	Starter	Grower	Finisher
Standard maize	51	60	63	0	0	0
QPM	0	0	0	51	60	63
Soybean cake	37	15	10	37	15	10
Soybean grit	5	18	20	5	18	20
Yeast	3	3	3	3	3	3
Vit and Min. premix	4	4	4	4	4	4
Nutrient content (%)						
ME (kcal/kg)	3150	3200	3250	3150	3200	3250
Protein	23	19	18	23	19	18
Lysine	1.2	1.2	1	1.2	1.2	1
Methionine	0.5	0.5	0.5	0.5	0.5	0.5
Meth + Cyst	0.8	0.8	0.7	0.8	0.8	0.7
Threonine	0.79	0.79	0.7	0.79	0.79	0.7
Tryptophan	0.2	0.2	0.18	0.2	0.2	0.18
Calcium	0.8	0.8	0.8	0.8	0.8	0.8
Available phosphorus	0.33	0.33	0.33	0.33	0.33	0.33

3. Results and discussions

Adapted QPM hybrid ZPQPM13 was identified as a QPM hybrid with the potential to substitute costly synthetic lysine or soybean components in broiler diets (Ignjatovic-Micic et al, 2020). Two feeding trials were performed with the aim to test the nutritional and financial advantages of this QPM hybrid in broiler feeds.

In the first trial, treatment feed differed from control in that standard maize was substituted with QPM, and that led to a lower FCR for the treatment group at the end of grower (1.51 for treatment and 1.56 for control) and finisher (1.56 for treatment and 1.61 for control) phases, indicating better conversion of feed containing QPM (Table 3).

Table 3.
Results of the first feeding trial

Trait	Starter phase				Grower phase				Finisher phase			
	C	T	%	SL	C	T	%	SL	C	T	%	SL
weight (g)	461.62	450.84	-2.34	ns	2056.81	2053.87	-0.14	ns	2672.47	2634.05	-1.44	ns
FI (g/chick)	545.25	591.90	8.56	**	3039.72	2942.80	-3.19	**	4103.23	3918.30	-4.51	**
FCR	1.20	1.34	11.55	**	1.56	1.51	-2.99	*	1.61	1.56	-2.88	**
BWG (g)	419.21	409.34	-2.36	ns	2014.40	2012.37	-0.10	ns	2630.06	2592.55	-1.43	ns
ADG (g/day)	29.94	29.24	-2.36	ns	57.55	57.50	-0.10	ns	62.62	61.73	-1.43	ns

C – control group, T – treatment group, SL – significance level, * – $p<0.05$, ** – $p<0.01$, ns – not significant, FI – feed intake, FCR – feed conversion ratio, BWG – body weight gain, ADG – average daily gain

In the second trial, broilers in the treatment group were fed with feed that contained 3% more QPM and 3% less soybean meal (cake). This gave even better results in comparison with the first trial. In the treatment group, FCR was significantly improved ($p<0.01$) and this time in all three phases – starter (1.16 vs. 1.33), grower (1.28 vs. 1.36) and finisher (1.30 vs. 1.46), i.e. 13.44%, 6.25% and 10.85%, respectively. These findings confirmed the results of the first trial and further improved the effects of ZPQPM13 on feed conversion. The results of the second feeding trial are given in Table 4.

Table 4.
Results of the second feeding trial

Trait	Starter phase				Grower phase				Finisher phase			
	C	T	%	SL	C	T	%	SL	C	T	%	SL
weight (g)	455.28	483.84	6.27	**	1971.02	1961.07	-0.50	ns	2737.55	2644.63	-3.39	**
FI (g/chick)	591.90	545.25	-7.88	**	2621.23	2443.10	-6.80	**	3939.20	3397.48	-13.75	**
FCR	1.33	1.16	-13.44	**	1.36	1.28	-6.25	**	1.46	1.30	-10.85	**
BWG (g)	407.08	435.24	6.92	**	1922.82	1912.47	-0.54	ns	2689.35	2596.03	-3.47	**
ADG (g/day)	29.08	31.09	6.92	**	54.94	54.64	-0.54	ns	64.03	61.81	-3.47	**

C – control group, T – treatment group, SL – significance level, * – $p<0.05$, ** – $p<0.01$, ns – not significant, FI – feed intake, FCR – feed conversion ratio, BWG – body weight gain, ADG – average daily gain

In addition to FCR, different feeding trials with QPM in broiler diets indicated that body weight gain is one of the main improved features. However, except at the end of the starter phase, no improvements were found in the BWG and ADG of the treatment broilers in this research. Similarly, in Prakash et al. (2021), BWG was not improved, while FCR was significantly improved in broilers fed with APQH9 QPM hybrid diet. On the contrary, Panda et al. (2010) and Nartey et al. (2018) reported significant improvements in BWG and FCR only in the finisher broilers fed QPM diets, whereas in Khan et al. (2020) these improvements were noted in the grower and finisher broilers.

Besides being the main energy source, the results of the second trial confirmed that QPM could also be the source of protein and lysine, as it decreases the percentage of protein (e.g. soybean meal) in diets and the need for synthetic lysine supplementation. Thus, this indicates a significant financial reduction in feed, as the price of soybean is usually up to four times higher than the price of maize. Similarly, in Khan et al. (2020), soybean meal was reduced by 3.47% in QPM diets compared to SM diets, leading to 14.2% more profit. An economic analysis for broiler production in Kenya, conducted by De Groote et al. (2010), showed an increase in the small-scale farmers' profits by using the QPM. They reported reduced costs by 5.24% for starter feed and by 5.05% for finisher feed. The cost-reducing effects of QPM in the poultry feed industry were also assessed in Nepal (Thapa et al., 2021), suggesting that the industry can minimize the average feed cost by 1.5%. As pointed out by these authors, the feed industry could benefit sustainably from the use of QPM with a strong linkage between feed industry and maize value chain actors. Therefore, it can be concluded that both feed and broiler producers, as well as the seed companies, could profit through reduced costs, improved FCR and new value-added products launched.

4. Conclusions

The lower FCR for the treatment group confirmed better conversion of feed containing QPM. In order to further investigate nutritional benefits, the effects of ZPQPM13 on meat quality will be examined in the future. This research indicates significant financial benefits of using QPM in feed, compared to standard maize. Even though the final weight was 3.5% higher in control broilers, the comparison of meat and feed prices confirmed significant financial benefits of using QPM, as the price of soybean is usually up to four times higher than the price of maize. Furthermore, feed intake by broilers fed with ZPQPM13 was reduced, indicating cost savings for broiler producers.

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Declaration of competing interests

The authors declare no conflict of interest.

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