Jurnal Ilmu Peternakan dan Veteriner Tropis (Journal of Tropical Animal and Veterinary Science), November 2022, hal. 217 – 231 Vol. 12 No. 3
e-ISSN: 2620-9403 p-ISSN: 620-939X

Effect of Transgenic and Non-Transgenic Corn Hybrids on the Performance of Quails and Chicken: A Review

Pengaruh Hibrida Jagung Transgenik dan Non-Transgenik terhadap Performa Puyuh dan Ayam: Review

Joaquin R. V. Torres [1], Joseph F. De La Cruz[1], Himmatul Khasanah[2]*, Listya Purnamasari[2], Desy C. Widianingrum[2]
[1]Department of Basic Veterinary Sciences, College of Veterinary Medicine, University of the Philippines Los Baños, Los Baños – 4031, Philippines
[2]Department of Animal Husbandry, Faculty of Agriculture, University of Jember, Jember - 68121, Indonesia

Article history
Received: Nov 11, 2022;
Accepted: Nov 23, 2022

* Corresponding author:
E-mail: himma@unej.ac.id

DOI:
10.46549/jipvet.v12i3.308

Abstrak

Ayam broiler, layer dan puyuh (*Coturnix japonica*) adalah jenis unggas yang semakin populer untuk dipelihara karena performa yang baik seperti produksi yang cepat, dan kemudahan perawatan, baik untuk penghasil daging dan telur di berbagai negara Asia dan di dunia. Unggas sering dipelihara dengan menggunakan jagung (*Zea mays*) sebagai sumber energi utama dalam ransum. Namun, dalam produksinya, jagung sering menghadapi masalah yang melibatkan hama arthropoda seperti Ngengat Penggerek Jagung Asia (*Ostrinia furnacalis*), dan oleh karena itu, teknologi rekayasa dalam bidang pertanian telah banyak mengembangkan banyak galur jagung transgenik yang telah ditanam dan dibiakkan agar tahan terhadap hama ini. Artikel ini bertujuan untuk mengetahui kinerja jagung transgenik sebagai pakan, keamanan dan kesetaraan gizi pada unggas baik sebagai penghasil daging maupun telur. Hasil review, menunjukkan bahwa di berbagai penelitian, tidak ada perbedaan yang signifikan antara parameter produksi pada ayam pedaging, petelur dan puyuh yang diberi pakan jagung non-transgenik konvensional dan transgenik. Kesamaan ini terlihat pada jenis unggas pedaging dan petelur. Penelitian untuk menganalisis efek jagung transgenik pada parameter komposisi kuning telur, dan komposisi otot ayam pedaging masih perlu dilakukan. Hasil kajian ini juga mengamati bahwa tidak ada gen dan protein transgenik yang tersisa setelah pemotongan unggas di dalam otot dan jaringan, yang menunjukkan bahwa masalah keamanan gen dan protein transgenik tidak ditransfer dari jagung ke produk unggas.

Kata kunci: Broiler; GMO; Kualitas daging; Pakan; Produksi telur

Abstract

Broiler, Layer and Japanese Quail (*Coturnix japonica*) are species of poultry that have become increasingly popular to raise due to their performance such as fast production, and ease of care, either for meat and egg producers in many Asian countries and worldwide. As poultry, they are often raised using corn (*Zea mays*) as the primary energy source in the ration. However, corn often faces problems involving arthropod pests such as the Asian Corn Borer Moth (*Ostrinia furnacalis*), and as such, agricultural engineering technology has developed many strains of transgenic corn that have been grown and bred to be resistant to these pests. This article aimed to determine the transgenic corn performance as feed, safety and nutritional equivalence on poultry (quails and chicken) for meat and egg producer. The review determined that across various studies, there were no significant differences between production parameters in the broiler, layer and quails fed a conventional non-GMO diet and entirely transgenic corn. This similarity was seen in both meat and layer types. Though, research still needs to be done to assess transgenic corn's effects on parameters of yolk composition and breast muscle composition. The study also observed that no transgenic genes and proteins remained after the slaughter of the poultry in the muscle and tissues, indicating the safety concerns of transgenic genes and proteins not being transferred from the corn to poultry.

Keywords: Broiler; Egg production; Feed; GMO; Meat quality

INTRODUCTION

The poultry industry has acquired significance worldwide, and among food animals origin, poultry including broiler, layer and quails produces the most efficient meat and eggs as a source of protein. Generally, poultry farming has committed a foremost part in the livestock sector in some regions of the world including developed and developing countries (Sebho, 2016, Das and Samanta, 2021). To fulfil the feed requirement in the poultry industry, corn (*Zea mays*) is the leading source of energy used, with 2/3 of all maize produced in Europe being used for animal feed (Korwin-Kossakowska *et al.*, 2013) and a staggering 38.7% of the world's global corn production in 2020 being used in animal feed (Buthada, 2022.). This is primarily because corn as grain is fast growing with large yields (Pollak and Salhuana, 2009). It is often used as the standard against which other grains are compared to because it has the highest energy yield among all conventional types of grains used in feed production (Ghazaghi *et al.*, 2019)

However, conventional corn often faces problems involving the Asian Corn Borer (*Ostrinia furnacalis*), a species of the lepidopteran parasite causing significant losses in corn harvests worldwide (Nafus and Schreiner, 2008). As such, bioengineering has produced a transgenic or genetically modified strain of corn known as bt Corn, developed to be resistant to the diseases spread by the insect mentioned above. This resistance is due to the corn possessing a gene from *Bacillus thuriengensis*, which confers the disease resistance to the corn carrying the Cry1Ab Toxin gene (Korwin-Kossakowska *et al.*, 2013). Some varieties of transgenic corn bearing the pest-resistant traits conferred by the Cry1Ab Toxin are BT176, GM MON810, and C0030.3.5 GM Maize and today Genetic Modified Organism (GMO) maize reported to 244 events (GM Crop Events List - GM Approval Database | ISAAA.Org, 2022).

Despite the different names, these varieties of transgenic corn all have the same function: to minimize crop loss due to lepidopteran pests such as the Asian Corn Borer moth. The first use of genetically modified corn was approved in 1996, and since then, its use in feeds, foods, and fuels has only expanded. However, as with most products that have a "Genetically modified" moniker, many still have reservations about their use in the aforementioned fields, citing the possible dangers that they might pose to human and animal health (EFSA, 2006, Bednarek *et al.*, 2013), along with the belief that they do not perform as well as traditional, non-GMO corn. It is the goal of this review to determine whether or not these concerns are unfounded.

The review aimed to determine the nutritional equivalence and safety of transgenic corn compared to non-GMO corn in the quails and chickens performances. The different production parameters commonly associated with both meat type and layer type of quails and chickens, as observed in the various experiments and feeding trials involving the use of GMO corn.

These parameters are live body weight, feed intake and carcass weight, carcass characteristics and chemical composition, hematologic parameters, serum chemistry, and mortality for meat-type quails. The parameters observed in layer-type quails are the following: hatching and laying rate, egg weight, and egg yolk composition.

RESULTS AND DISCUSSION

Effects of GMO Corn on the Production Parameters of Meat Type Poultry

Live body weight

Live Body weight is an essential parameter in the production of any poultry species, mainly because it is a good indicator of animal health (Castellini *et al.*, 2008). Smaldone *et al.* (2021) reported that live body weight also has a relationship with carcass yield after slaughter, suggesting that higher live body weights often produce better quality meat after slaughter. Quails have increased popularity as a meat source among consumers as well as a broiler, quails have increased popularity as a meat source among consumers, which is considered a commercial product (Hamm and Ang, 1982; Boni *et al*., 2010; Santhi and Kalaikannan, 2017; Zhang *et al*., 2019)

Furthermore, increased body weight also means an increased weight of edible products after slaughter (Murawska, 2017). According to Zhang *et al.* (2021) feeding trial comparing the effects of Cry1Ab Toxin modified corn and conventional corn on the final body weights of Japanese Quail used in the feeding trial, it was observed that there were no significant differences across the body weights of the quails that were fed the control diet, the non-GMO diet, and the GMO diet. This was true for both sex, with the average body weight of males and females quails across all groups being approximately 130 grams at 49 days of age. These results were consistent with studies performed by Liu *et al.* (2017) that utilized 90 ten-day-old quail chicks divided into three groups: one fed a control diet, one provided a non-GMO variant of the corn used; DBN318, and one fed a GMO version of the same corn; C0030.3 rised over 49 days and making it comparatively shorter than the other studies. C0030.3.5 GM Maize was developed in China and possessed many traits in the previous two varieties of transgenic corn. The comparison among MON 810XNK603, RX730, SC1087, SC1140, Asgrow740, Pioneer 34B23 and DEKALB626 as fed ingredient in broiler fed were not significantly different in body live weight, carcass composition (Taylor *et al.*, 2003).

Sartowska *et al.* (2015) found that across ten generations of quail, there were no significant differences in body weight in quails that were fed Bt MON-810 GMO corn and non-GMO corn, with the female quails fed GMO corn having a mean weight of 201.7 grams at 49 days versus the mean weight of those provided non-GMO corn is 201.6 grams. The same was similar in the male quails, with both the GMO-fed and non-GMO-fed groups having a mean weight of 169.0 grams. Their study focused on determining the possible health impact of GMO corn on the quails used in the trial and utilized ten generations of Japanese Quail reared over three years. The Monsanto Company developed GM MON810 corn to create their strain of transgenic corn. However, whereas BT176 is marketed for its herbicide tolerance and insect resistance, GM MON810 is only sold for the latter (*GM Crop Events List - GM Approval Database | ISAAA.Org*, 2019). However, it is more widely approved for use as animal feed in more countries than BT-176.

Korwin-Kossakowska *et al.* (2013) involved multiple generations of quails fed transgenic corn (Bt MON-810) and found that animals had a lower body weight than those fed a GM-Free diet at 15 weeks of age and this difference was not statistically significant. Furthermore, the weights recorded at seven weeks of age were still similar to those recorded by the studies mentioned earlier; male quails fed a GMO corn diet weighed 170.744 grams versus the average weight of 170.229 grams from the male quails fed a non-GMO diet. Interestingly, at the same age, female quails fed a GMO corn diet weighed more than the females fed the non-GMO diet, with an average weight of 210.159 grams from the former and an average weight of 207.442 grams. A study conducted by Flachowsky *et al.* (2007) also found the same results, with the body weights of the quails fed GMO corn (Bt 176) being lower than that of quails fed with only non-GMO corn, with them recording the average weights of those fed a non-GMO diet to be 180.1 grams versus the average values of those fed a GMO diet being 176.9 grams. Finally, Bt 176 was developed by Syngenta to possess traits that not only made it resistant to arthropod pests but also granted it resistance to glufosinate herbicides and antibiotics (Bt176 (176)| GM Approval Database- ISAAA.Org, 2019). Given this information, it can be seen that some studies found that quails-fed transgenic corn showed similar body weight performance.

The live body weight performance of chicken fed by GMO products was reported by Czerwiński (2015) that a broiler feeding GMO corn Mon 810 showed higher feed intake and had no significant effect on body weight gain and feed/gain ratio. Furthermore, Zhang *et al.* (2017) described that broiler feed containing GMO maize and GMO Soybean compared to non-GMO fed to broiler from the first day to 32 days have a similar effect on body weight (days 7, 17, and 32) and overall body weight gain.

Feed intake and carcass weight

A study by Hamrum, (1953) found that the bobwhite quail (*Colinus virginianus*) preferred sweeter-tasting feedstuff. The taste of the feeds still plays a prominent role in the overall feed intake of poultry species. Since feeds are the most important aspect of animal production, due to their direct performance parameters, one must always ensure that the animals are fed the best type of feed available. Fortunately, studies have shown that transgenic corn is virtually identical to conventional corn regarding their nutritional composition, making their tastes a non-issue in the experiments. In their feeding trial of 2 generations of quail, Sartowska *et al.* (2012) found that the average feed intake of the quails was 200 grams of food per bird for both the groups fed only GMO corn and the groups fed only conventional corn. This finding has the same result as Flachowsky *et al.* (2007) observed in their ten generational studies. These same opinions were also reported by Sartowska *et al.* (2015) in their ten generational studies, which found that the average feed intake of all the quails was 220 grams per bird regardless of the type of corn they were being fed. The studies show that quails are just as likely to consume transgenic corn as conventional corn, suggesting that despite their different genetic compositions, they are virtually identical to the quails' performance.

Carcass weight as a parameter is often affected by numerous factors, such as genetic, feed, environment condition, sex age and rising management of the animal (McNaughton *et al.*, 2011, Ahmad *et al.*, 2018, Abou-Kassem *et al.*, 2019, Turgud and Narinç, 2022). Quails, as sexually dimorphic animals, males have much larger carcass weight than females, meaning that their hormonal system causes their bodies to grow at different rates (Sartowska *et al.*, 2015). Carcass weight has been considered to determine the animal's market value after slaughter (Baéza *et al.*, 2022). However, it is not just the external musculature of the animal but also the internal organs such as the heart, gizzard, and liver also play a crucial part in the final carcass weight of the animal as these are also often sold as giblets, which are just as readily consumed as the other parts of the animal (Murawska, 2017). Sartowska *et al.* (2015) found that Japanese quail that were fed a GMO diet (MON-810) had breast muscles and gizzards that were heavier than the quails that were fed non-GMO corn, with the average breast muscle to body weight ratio of birds fed a GMO diet being 18.6% for males and 17.4 % for females, compared to the 17.9% and 16.9% ratios observed from non-GMO fed male and female birds respectively. The difference appears to only exist within those two parameters like the weight to body weight ratio of the heart, gizzard, and liver of the quails used in the experiment were similar regardless of the diet. The ratio of heart weight to body weight in males and female were 0.9% and 0.8%, respectively. The gizzard weight to body weight ratios was similar for males, at an average percentage of 1.4%, while the females fed a non-GMO diet had a slightly decreased ratio of 1.3% versus the 1.4% ratio observed from female birds fed a GMO diet. Finally, the liver weight to body ratio of birds fed a GMO diet was 2.1% and 3.2% for males and females, respectively. Somewhat higher, but not statistically different from the liver to body weight ratios of the group fed a non-GMO diet: 2.04% and 3.14%. Zhang *et al.* (2021) also confirmed that there were no significant differences in organ weight relative to body weight across major organs like the heart and liver. They recorded the average ratio of heart weight to body weight being 0.72-1.28% in males fed a GMO diet, while females of the same group had ratios of 0.57-0.89%. Meanwhile, the results observed from the group providing a non-GMO diet were 0.87-1.07% for males and 0.56-0.62% for females. Liver-to-body weight ratios observed in the group fed a GMO diet were 1.38-1.90% and 1.47-2.21% for males and females, respectively. Meanwhile, the ratios seen in the non-GMO group were 1.29-2.33% and 1.92-2.66 for males and females, respectively. These differences overall are still statistically insignificant.

Other studies on different animals such as chickens and pigs also gave similar results (dela Cruz *et al.*, 2012, Czerwiński *et al.*, 2015). According to Rossi *et al.* (2005) the corn with *Cry*1A(b) gene as feed resulting no difference in average daily weight gain (129.4 and 126.0 g/d), feed intake (63.4 and 61.8 g/d); and feed conversion ratio (1.95 and 2.02) among the transgenic and non-transgenic feed. The transgenic corn of N7070Bt and N7070Bt + Liberty hybrid feed also reported could assist broiler growth with mortality and FCR equivalent to the control using isoline N7070 (non-Bt isoline of N707Obt) and more promising than the price of commercial NC2000 maize without significant difference in chicken carcass yield (Brake *et al.*, 2003). A study by Řehout *et al.* (2009) comparing Bt-maize and non-GMO maize also has a similar result on FCR, carcass and dressing percentage. Zhang *et al.* (2019) reported that the amino acid content of Lysine, Methionine, and Threonine in non-GMO maize was lower than that of GMO maize grains, and the protein content of GMO soybean meal also reported was higher than that of non-GMO soybean meal. The broiler feed intake and feed conversion rate were found significantly greater in broilers fed the non-GMO diet than in the GMO group from days 17 to 32, but body weight gain was reported to be similar in those two types of feed. Feeding transgenic and non-transgenics on chickens was described had no significant difference in feed consumption conversion, slaughter weight, carcass weight, and non-carcass characteristics showed significant differences in spleen weight, liver weight, and heart weight (Řehout *et al.* 2009). Furthermore, the feed containing GMO maize and GMO Soybean compared to non-GMO fed to broiler from the first day to 32 days have a similar effect on feed intake and mortality, but the feed conversion ratio of GMO-fed tends to be lower than conventional maize and soybean meal (Zhang *et al.* 2017).

Carcass Characteristics and Chemical Composition

Carcass characteristics and quality can be determined from various aspects such as physical, chemical, and biological aspects. The physical traits of the GMO corn-fed breast muscle were found to be similar to non-GMO corn such as muscle colour, water-holding capacity, and drip loss on day 1, on the other hand, the pH value and cooking loss were higher in GMO-fed (Zhang *et al.*, 2019). Protein and fat levels in carcass often determine feed conversion efficiency while the animal was alive, with higher values signifying a better FCR (Danek-Majewska *et al.*, 2021). Higher fat depositions also suggest that the animals are eating more than required for muscle development, meaning that the excess nutrients are stored as fat (Nunes *et al.*, 2011). The chemical composition of the breast muscle obtained from GMO-fed quails showed levels of protein and fat that were identified from a nutritional standpoint with the levels of the same parameters obtained from the breast muscles of quails fed a Non-GMO diet: The protein content being 22.9% from males and females fed a GMO corn diet and 2.7% and 22.8% from males and females fed a non-GMO diet respectively. On the other hand, the fat content was recorded to be 2.3% for females of both groups, and 2.1% for males fed a GMO corn diet, slightly lower but still statistically insignificant when compared to the 2.4% observed from males fed a non-GMO diet. The dry matter content was also observed to be similar at 25.9% for both sexes in the non-GMO group, and the males fed a GMO diet, while females fed the GMO diet had a dry matter content of 26% (Sartowska *et al.*, 2015). Taylor *et al.* (2003) and Taylor *et al.* (2007) also reported that the transgenic and non-transgenic corn show similar water moisture, protein and fat in broiler breast and thigh of broiler muscle this might be caused by those diets containing MON 89034 × NK603 were nutritionally equivalent to the diet control or conventional corn when fed to broilers including the protein, vitamin, fat and amino acid composition. Although it did not affect the chemical composition of meat, some reports showed that GMO DNA is not completely degraded during feed processing and digestion in animals. The DNA fragments are still found and detected by molecular methods such as PCR or qPCR in organs and animal tissue (Salisu *et al.*, 2019).

Hematologic parameters, serum chemistry and mortality

Blood profile plays a considerable part in determining an animal's health and immune system (Chand *et al.*, 2018). The blood count, haemoglobin concentration, hematocrit level, mean corpuscular volume, mean corpuscular haemoglobin concentration, and platelet count assess its immunologic capabilities via a white blood cell count or dehydration levels via its hematocrit levels (Londok *et al.*, 2018, Alagawany *et al.*, 2020). Serum chemistry parameters such as alkaline phosphatase, alanine aminotransferase, and cholesterol are also three key factors that were observed in the feeding trial (Zhang *et al*, 2021). There were no significant differences among the haematological parameters of quails fed the Cry1Ab-modified Corn compared to those fed with non-modified corn. Of note are the birds' alanine aminotransferase (ALT) and cholesterol values in both groups. Males fed the GMO corn diet were seen to have ALT values of 4.91-4.97 U/L and CHOL values of 4.01-4.05 mmol/L, being statistically insignificant when compared to the values obtained from non-GMO fed quails who had values of 4.59-5.21 U/L and 4.9-5.44 mmol/L for ALT and CHOL respectively (Zhang *et al*, 2021). These results were similar in females for both groups, with the ALT and CHOL levels of females fed a GMO diet being 4.08-5.08 U/L and 2.97-4.19 mmol/L being insignificant from the results obtained from females fed a non-GMO diet of 4.06-6.18 U/L and 4.9-5.44 mmol/L. However, there were significant differences in serum chemistry observed in male quails, with those fed the GMO corn showing higher ALP values but lower CHOL values than those fed non-GMO corns. Males fed a GMO diet had ALP values of 152.63-160.71 U/L, while those fed a non-GMO diet expressed ALP values of 143-151 U/L. These differences were not seen in female quails; however, females fed a GMO diet had average ALP levels of 126.95-181.05 U/L, while those fed a non-GMO diet were seen to have mean ALP values of 136- 156 U/L, making these differences biologically insignificant (Zhang, 2021). Other blood parameters such as blood urea nitrogen, blood creatinine and blood glucose of chicken provided with GMO and non-GMO corn-SBM are also similar in about 2,750-2,25mg/dl, 0,16-0,18 mg/dl and 225-228,75mg/dl, respectively (Zhang *et al.*, 2019) Previous study of Řehout *et al.*, (2009) also found that haematological and biochemical of blood such as haemoglobin level, erythrocyte and leukocyte number, blood protein, γ - glutamyl transferase, alanine aminotransferase and aspartate aminotransferase were similar between control and Bt-maize.

Yassin *et al.* (2009) consider the first-week mortalities vital in poultry production because they become a good indicator of birds' genetic quality and nutritional quality, especially in the feed-ingesting process. In this period, rapid growth occurs, so providing the nutrition needed will affect immunologic responses. Sartowska *et al.* (2015) observed in 10 generations of Japanese Quail raised on a transgenic MON810 corn diet exposed showed similar results in first-week mortalities of the birds fed non-GMO corn. The mortalities recorded during the laying period were similar between both groups, with a below 4% average. The same finding of the Cry1- Ab Toxin in the transgenic corn, which is harmful to arthropod pests, does not affect the quails' performance negatively. Despite public misconceptions, transgenic corn is just as safe to use as feed as conventional corn. The giving poultry with GMO fed including maize, soy, maize soy, and rice found no adverse effect at least on one parameter of health (de Vos and Swanenburg, 2018).

The effect of GMO maize (MON810) and RR Soybean (GTS-40-3-2) in a broiler in Poland resulted in a lower proportion of T helper and T cytotoxic cells in lymphocytes. The spleen weight was found to be higher and apoptotic cells in villi tips increased. Another parameter, tunica mucosa width in the jejunum, showed no significant effect (Czerwinski *et al.*, 2015a; Czerwinski *et al.*, 2015b). Furthermore, BT maize did not affect haematology (Bednarek *et al.*, 2013), serum biochemistry, histopathology, and organ weight (Reichert *et* *al.*, 2012; Li *et al.*, 2015). On the other hand, Rehout *et al.* (2009) reported that GMO maize has no consistent effect on histopathology, serum biochemistry, and organ weight.

Effects of GMO Corn on the Production Parameters of Layer

Hatching and laying rate

Quails, by nature, are more prodigious layers than most breeds of poultry, and their smaller eggs compensate for this. However, the hatching percentage of quails eggs depends on numerous factors such as egg weight and the storage period, with both factors having an inverse relationship with hatch rate (El-Samahy *et al.*, 2017). Sartowska *et al.* (2012) found that quails fed the GMO corn diet used in their experimental trials had a hatch rate of 94%, which was in line with Shanaway (1994), and Szczerbinska *et al.* (2012). The transgenicity of the GMO corn appeared to have had no adverse effects on the hatching rate of the quails used in the experiment, with those quails producing similar results to the quails that were fed a non-GMO diet. The findings of all the studies mean that quails fed a GMO diet are just as fertile and reproductive as those fed a non-GMO diet. This is a good indicator of the lack of adverse effects that transgenic corn has on the overall production levels of layer-type quails.

Transgenic corn-based diet also generally also used in laying hen. Some parameters such as hatching and laying rate can be used as indicator of feed quality. the quality protein maize (QPM) contained opaque-2 gene were used as a diet in laying hen resulting an increased in feeds intake and egg production, and when it compared to commercial maize diet it did not differ significantly. Others parameter also resulting similar performance such as FCR, egg weight, soft and broken egg percentage, haugh unit and yolk colour (Tyagi *et al.*, 2010). Furthermore, the transgenic Bt 176 maize diet also has similar performance with control in term of laying performance such laying intensity, hatched egg, percentage of fertile egg and percentage of hatched living chicken in first to fourth generation (Wang *et al.*, 2013).

Egg weight

Egg weight is not just important in terms of market value, but it also plays a large role in the overall hatchability of the eggs produced. In a study by, (El-Samahy *et al.*, 2017) eggs with a weight larger than 12 grams were found to have the best hatchability compared to eggs of other sizes. However, more giant eggs often require much longer incubation times to hatch weighed between 11-12 grams and were the most successful in producing when considering all factors. The weight of the eggs produced by quails fed with Cry1Ab toxin-expressing GMO corn showed no significant differences when compared to the weight of the eggs produced by quails fed with the non- GMO corn, with eggs obtained from quails fed a GMO diet having an average weight range of 9.79-10.13 grams and those fed a non-GMO diet having eggs whose mean weight had a range of 9.89-10.57 grams (Zhang *et al.*, 2021). These results are in line with the data collected by Korwin-Kossakowska *et al.* (2013), Flachowsky *et al.* (2012), Sartowska *et al.* (2012) and Sartowska *et al.* (2015) found that both GMO and non-GMO-fed animals had average egg weights of 11.6 grams. Similar result with the provision of the transgenic phytase-maize in laying hen also has a no different effect on egg production, egg weight, eggshell and egg mass compared to exogenous phytase (Wang *et al.* 2013; Halle and Flachowsky, 2014). The maize contained the mCry1Ac gene from *Bacillus thuringiensis* strain (BT-799) and the maroACC gene from *Agrobacterium tumefaciens* strain (CC-2) were studied on laying hen performance showed similar findings to control on the egg production, haugh unit and egg component weight of laying hen (Zhong *et al.*, 2016).

Egg yolk composition

Ricklefs and Smeraski (1983) reported that the hatchability of eggs is often directly linked to the yolk quality and composition of the eggs since it is the yolk that provides nourishment for the growing chick. Generally, healthier females produce yolks that are more nutritious to the growing embryo (Langen *et al.*, 2017). Sartowska *et al.* (2015), found that the chemical composition of the eggs produced by quails fed GMO corn lacked any significant differences from those produced by quails fed non-GMO corn. This was true for parameters such as crude fat, crude protein, dry matter yield, and ash content. Birds given an entirely GMO diet had values of 32.4%, 13.5%, 51.6%, and 1.7% respectively, while those given a non-GMO diet had virtually identical values of 32.2%, 13.4%, 51.4%, and 1.7% respectively. These small statistical differences are indicative of how both diets affect the parameters similarly. Zhang *et al.* (2021) reported similar findings, with their study also determining that the lecithin %, cholesterol %, and Vitamin B2 content of birds fed a GMO diet lacked any significant differences when compared to the results obtained from birds given the non-GMO diet. The results they observed from GMO-fed birds were 746.35-816.45%, 11.22-13.3 ug/100g, and 0.75-0.83 for lecithin %, cholesterol content, and vitamin B2 content, respectively. Compared to the results obtained from non-GMO-fed birds: 747.06-825.34%, 12.93-13.27g/100g, and 0.73-0.79 for the above parameters, the lack of any significant differences is made clear. The yolk is often considered the egg's most nutritious portion due to it being the reservoir of the nutrients passed down from the mother that the chick would need to grow. Therefore, the quality of that the egg yolks of quails fed a transgenic corn diet was no different from the egg yolks of the birds fed a non-GMO corn diet. This further confirms the nutritional equivalence and safety of the transgenic varieties of corn compared to their non-GMO counterparts.

Nutritional equivalence and safety of Transgenic Corn and Conventional Corn

A common argument against using transgenic corn in food animals is the fear that the transgenic proteins found in their genetic makeup could be retained in their meat, eggs, and other food products. These proteins could then possibly cause adverse effects in humans who consume the food products produced by the animals fed these transgenic diets. Multiple studies, however have repeatedly found that these concerns are unfounded, with multiple sources have reported that these transgenic proteins were not passed down from the animals into their eventual food product (Kleter and Kok, 2012). The same applies to the transgenic crops' nutritional quality compared to their non-transgenic counterparts reported that involving Bt-corn in poultry has found that the transgenic bt-corn had no negative effects on the health and immune status of the animals. Kadlec *et al.* (2009) and Rehout *et al.* (2009) also reported similar findings, with them determining that MON810 GM corn had no adverse effects on the hematologic and biochemical indicators in the birds fed with high amounts of the transgenic corn variety. (Korwin-Kossakowska *et al.*, 2013) found that the performance of quails fed GMO corn across all experimental parameters was similar to that of the quails fed a non-GMO corn diet. Though were some differences observed in the egg yolk and breast muscle composition of the birds fed the GMO diet, more research needs to be conducted to determine the cause. Additionally, the study found no negative effects on the final nutritional value of the quails fed GMO corn for consumers. Tests have shown that the risk of GMO ingredient transfer from animal feed to the meat and organs of animals is low, meaning that the poultry animals such as Quail that are fed an entirely GMO diet do not affect their health in any negative way (Zhang *et al.*, 2021). Additionally, Zhang *et al.* (2021) wrote that upon chemical examination of the carcasses of birds fed an entirely GMO diet, there were no traces of the Cry1Ab protein found in their organs and meat. The same is also reported by Korwin-Kossakowska *et al.* (2013) also noted the same findings that transgenic DNA was not detected in the stomach and GIT of the quails; these same DNA fragments also were not detected in both the body tissues and eggs after 12 weeks of feeding with the GMO corn used in their experiment (Bt 176). Flachowsky *et al.* (2007) also observed in their long-term study that 10 generations of Japanese Quail fed a diet of Bt-corn did not adversely affect the immune system of the birds fed the transgenic diet. The nutritional equivalence and overall safety, the various types of transgenic corn used across all of their studies are virtually identical to conventional corn due to them having no significant differences in production parameters for both meat and layer type quails, as well as the absence of their transgenic proteins in the chemical compositions of both the eggs and carcasses of the quails fed the transgenic diets. The studies about maize

e-ISSN: 2620-9403 p-ISSN: 620-939X

transgene identification used molecular analysis on poultry were summarised in Table 1.

Table 1. Detection of corn transgene DNA in chicken digest, blood, tissue and organ using PCR and protein assay

The transgene	Tissue	References
Maize Event CBH 351- derived hybrid (SL): The Cry9C gene and Cry9C protein	Not detected in broiler blood, liver and muscle.	Yonemochi *et al.* (2002)
YieldGard Corn Borer Corn for thev211-bp region of the cry1Ab and 13-bp region of the sh2 coding region	Detected in broiler muscle breast.	Jennings *et al.* (2003)
GM maize cry1a(b) gene cp4epsps gene	Detected in gizzard digesta. Not detected in intestinal digesta 96 hours after feeding Not detected in blood and tissue.	Deaville and Maddison (2005)
Bt176 corn : bla or cry1A(b) fragments	Not detected in organ, meat and egg of laying hen	Aeschbacher *et al.* (2005)
Maize: Cry1A(b) gene and Sh-2	Detected on Maize: Cry1A(b) gene and Sh-2 Low frequency also detected in blood	Rossi *et al.* (2005)
Bt maize: Cry1A (b)	Not detected in liver and kidney.	Řehout *et al.* (2008)
MON 863 Corn: Cry3Bb1 protein	Completely digested and not detected in liver and muscle	Scheideler *et al.* (2008)
Bt corn: 35spromoter sequence, NOS terminator; Corn invertase gene (endogenous)	Detected in crop and gizzard digesta. Not detected in intestine digesta (duodenum, jejunum, ileum), caecum digesta, excreta, and in blood, liver, spleen, and breast muscle.	Świątkiewicz *et al.* (2010)
Bt maize – herbicide tolerance	Partly detected in crop, gizzard and duodenum digesta. Not detected in jejunum, ileum and caeca, excreta, tissues (blood, liver, spleen, lungs) and in eggs of laying hen.	Swiatkiewicz *et al.* (2011)
Phytase transgenic corn: phyA2 gene DNA and protein	Not detected in blood, heart, live, spleen, kidney, breast muscle and egg of laying hen. No protein translocation detected.	Ma *et al.* (2013)
Phytase transgenic corn: phyA2 gene DNA and protein	Not detected in muscle tissues and reproductive organs of laying hens.	Gao *et al.* (2014)
Corn: Transgenic phyA2 and protein	Not detected in ileum and rectum digesta, heart, liver, kidney, and breast or thigh muscles of broiler.	Lu *et al.* (2015)
C0030.3.5 transgenic maize	Not detected in blood, tissues, feces, and eggs of quails No protein translocation detected.	Zhang *et al.* (2021)

CONCLUSIONS

In conclusion, it is evident that transgenic corn is safe to use in poultry such as quails, broiler and laying hen since it is nutritionally equivalent to conventional corn. This is clearly seen in the various discussed performance parameters, all of which showed that the production parameters and product quality for both meat and layer factors were similar between corn GMO and non-GMO diet. Despite these differences, however, all studies did find that the major concern of transgenic DNA fragment retention in the carcasses of the birds fed a transgenic diet are unfounded fears, with the studies finding that there were virtually no traces of any transgenic DNA and protein in key muscle groups and organs of the quail carcasses after slaughter.

REFERENCE

Abou-Kassem DE, El-Kholy MS, Alagawany M, Laudadio V and Tufarelli V. 2019. Age and sex-related differences in performance, carcass traits, hemato–biochemical parameters, and meat quality in Japanese quails. *Poultry science*, *98*(4): 1684-1691.

Aeschbacher K, Messikommer R, Meile L and Wenk C. 2005. Bt176 corn in poultry nutrition: physiological characteristics and fate of recombinant plant DNA in chickens. *Poultry Science*, *84*(3): 385-394.

Ahmad S, Mehmood S, Javed K, Mahmud A, Usman M, Rehman A, Ishaq HM, Hussain, H and Ghayas A. 2018. Different selection strategies for the improvement of the growth performance and carcass traits of Japanese quails. *Brazilian Journal of Poultry Science*, *20*: 497-506.

Alagawany M, Nasr M, Al-Abdullatif A, Alhotan RA, Azzam MM and Reda FM. 2020. Impact of dietary cold-pressed chia oil on growth, blood chemistry, haematology, immunity and antioxidant status of growing Japanese quail. *Italian Journal of Animal Science*, *19*(1): 896-904.

Anastasio A. 2021. The Influence of Broilers' Body Weight on the Efficiency of Electrical Stunning and Meat Quality under Field Conditions. *Animals*, 11(5): 1362. https://doi.org/10.3390/ani11051362

Baéza E, Guillier L and Petracci M. 2021. Production factors affecting poultry carcass and meat quality attributes. *Animal*, 100331.

Bednarek D, Dudek K, Kwiatek K, Świątkiewicz M, Świątkiewicz S and Strzetelski J. 2013. Effect of a diet composed of genetically modified feed components on the selected immune parameters in pigs, cattle, and poultry. *Bulletin of the Veterinary Institute in Pulawy*, *57*: 209-2017.

Bhutada G. 2021. From feed to fuel: This is how corn is used around the world. [online] https://www.weforum.org. Available at: https://www.weforum.org/agenda/2021/06 /corn-industries- sustainability-food prices#:~:text=Corn%20has%20a%20number%20of, key%20component%20of%20livestock%27s%20diet. [29 Maret 2022]

Boni I, Nurul H and Noryati I. 2010. Comparison of meat quality characteristics between young and spent quails. *Int Food Res J*, *17*(3): 661-6.

Brake J, Faust MA and Stein J. 2003. Evaluation of transgenic event BT11 hybrid corn in broiler chickens. *Poultry Science*, 82(4): 551559. https://doi.org/10.1093/ps/82.4.551

Castellini C, Berri C, Le Bihan-Duval E and Martino G. 2008. Qualitative attributes and consumer perception of organic and free-range poultry meat. *World's Poultry Science Journal*, *64*(4): 500-512.

Chand N, Naz S, Rehman Z and Khan RU. 2018. Blood biochemical profile of four fast-growing broiler strains under high ambient temperature. Applied Biological Chemistry, 61(3): 273-279. DOI: https://doi.org/10.1007/s13765-018-0358-4

Czerwiński J, Bogacki M, Jalali BM, Konieczka P and Smulikowska S. 2015a. The use of genetically modified Roundup Ready soybean meal and genetically modified MON 810 maize in broiler chicken diets. Part 1. Effects on performance and blood lymphocyte subpopulations. *Journal of Animal and Feed Sciences*, 24(2): 134-143.

Czerwinski J, Slupecka-Ziemilska M, Wolinski J, Barszcz M, Konieczka P and Smulikowska S. 2015b. The use of genetically modified Roundup Ready soybean meal and genetically modified MON 810 maize in broiler chicken diets. Part 2. Functional status of the small intestine. *J. Anim. Feed Sci*, *24*(2): 144-152.

Danek-Majewska A, Kwiecień M, Winiarska-Mieczan A, Haliniarz M and Bielak A. 2021. Raw Chickpea (Cicer arietinum L.) as a Substitute of Soybean Meal in Compound Feed for Broiler Chickens:

Effects on Growth Performance, Lipid Metabolism, Fatty Acid Profile, Antioxidant Status, and Dietary Value of Muscles. *Animals*, 11(12): 3367.

Das PK and Samanta I. 2021. Role of backyard poultry in south-east Asian countries: Post COVID-19 perspective. *World's Poultry Science Journal*, 77(2): 415-426.

de Vos CJ and Swanenburg M. 2018. Health effects of feeding genetically modified (GM) crops to livestock animals: A review. *Food and Chemical Toxicology*, *117*: 3-12.

Deaville ER and Maddison BC. 2005. Detection of transgenic and endogenous plant DNA fragments in the blood, tissues, and digesta of broilers. *Journal of Agricultural and Food Chemistry*, *53*(26): 10268-10275.

Dela Cruz J, Acda S, Josephine C and Nelia C. 2012. Effects of different corn hybrids on performance parameters, carcass yield and organoleptic characteristics of broilers. *Philippine Journal of Veterinary and Animal Science*, 38(1): 2333.

EFSA. 2004. Guidance document of the scientific panel on genetically modified organisms for the risk assessment of genetically modified plants and derived food and feed. The EFSA Journal 99:1

El-Samahy R, El-Sayiad G, Abou-Kassem D and Ashour E. 2017. Pre-hatch performance of Japanese quail egg weight categories incubated after several storage periods. Zagazig *Journal of Agricultural Research*, 44(2), 563570. https://doi.org/10.21608/zjar.2017.53873

Flachowsky G, Chesson A and Aulrich K. 2005. Animal nutrition with feeds from genetically modified plants. *Archives of Animal Nutrition*, 59(1): 140. https://doi.org/10.1080/17450390512331342368

Flachowsky G, Schafft H and Meyer U. 2012. Animal feeding studies for nutritional and safety assessments of feeds from genetically modified plants: a review. *Journal für Verbraucherschutz und Lebensmittelsicherheit.* 7:179-194

Flachowsky G, Halle I and Aulrich K. 2005. Long term feeding of bt-corn a ten-generation study with Quails. *Archives of Animal Nutrition*, 59(6): 449-451. https://doi.org/10.1080/17450390500353549

Gaines AM, Allee GL and Ratliff BW. 2011. Nutritional evaluation of Bt (Mon810) and roundup ready corn compared with commercial hybrids in broilers. *Poultry Science Journal*, 80, 51.

Gao C, Ma Q, Zhao L, Zhang J and Ji C. 2014. Effect of dietary phytase transgenic corn on physiological characteristics and the fate of recombinant plant DNA in laying hens. *Asian-Australasian Journal of Animal Sciences*, *27*(1): 77.

Ghazaghi M, Hassanabadi A and Mehri M. 2019. Pre-cecal phosphorus digestibility for corn, wheat, soybean meal, and corn gluten meal in growing Japanese quails from 28 to 32 d of age. *Animal Nutrition*, *5*(2): 148-151.

Halle I and Flachowsky G. 2014. A four-generation feeding study with genetically modified (Bt) maize in laying hens. *Journal of Animal and Feed Sciences*, 23: 58-63

Hamm D and Ang CYW. 1982. Nutrient composition of quail meat from three sources. *Journal of Food Science*, *47*(5): 1613-1614.

Hamrum CL. 1953. Experiments on the senses of taste and smell in the bob-white quail (*Colinus virginianus virginianus*). *American Midland Naturalist*, 49(3): 872. https://doi.org/10.2307/2485214

Hedawy KAA and Wassel FAA. 2005. Studies on some bacterial agent causing mortalities in quail farms in kena province. *Assiut Veterinary Medical Journal*, 51, 105 .

Huss D, Poynter G and Lansford R. 2008. Japanese quail (*Coturnix japonica*) as a laboratory animal model. *Lab Animal*, 37:513-519.

ISAAA. 2019. Event name: BT176 (176). Bt176 (176) GM Approval Database ISAAA. [online]. Available at: from:https://www.isaaa.org/gmapprovaldatabase/event/default.asp?EventID=127 [5 April 2022]

ISAAA. 2022. Maize (Zea mays L.) GM Events (244 Events). [online]. Available at: https://www.isaaa.org/gmapprovaldatabase/crop/default.asp?CropID=6&Crop=Maize. [27 Juni 2022].

Jennings JC, Albee LD, Kolwyck DC, Surber JB, Taylor ML, Hartnell GF, Liretta FP and Glenn KC. 2003. Attempts to detect transgenic and endogenous plant DNA and transgenic protein in muscle from broilers fed YieldGard Corn Borer Corn. *Poultry Science*, *82*(3): 371-380.

Kadlec J, Rehout V, Citek J, Hanusova L, Hosnedlova B. 2009. The influence of GM Bt maize MON 810 and RR soya in feed mixtures upon slaughter, haematological and biochemical indicators of broiler chickens. *Journal of Agrobiology*, 26(1): 51-55.

Kleter GA and Kok EJ. 2012. Safety of genetically modified (GM) crop ingredients in animal feed. *Animal Feed Contamination*, 467-486. https://doi.org/10.1533/9780857093615.5.467

Korwin-Kossakowska A, Sartowska-Zygowska K, Linkiewicz A, Tomczyk G, Prusak B and Sender G. 2013. Evaluation of the effect of genetically modified RR soya bean and Bt MON 810 maize in the diet of Japanese quail on chosen aspects of their productivity and retention of transgenic DNA in tissues. *Archives Animal Breeding*, 56 (1): 1-12.

Langen EM, von Engelhardt N and Goerlich-Jansson VC. 2017. Social environment during egg laying: Changes in plasma hormones with no consequences for yolk hormones or fecundity in female Japanese quail, Coturnix japonica. *Plos One*, 12(5), e0176146. https://doi.org/10.1371/journal.pone.0176146

Li Y and Wang TY. 2017. Germplasm enhancement in maize: advances and prospects. *Journal of Maize Sciences*, *25*(3): 11-18.

Li Z, Gao Y, Zhang M, Feng J and Xiong Y. 2015. Effects of a diet containing genetically modified rice expressing the Cry 1 Ab/1 Ac protein (Bacillus thuringiensis toxin) on broiler chickens. *Archives of animal nutrition*, *69*(6): 487-498.

Liu Y, Zhang D, Yu C, Wang C and Bian H. 2017. A 90 d subchronic feeding study of CP4-EPSPS transgenic glyphosate herbicide-resistant soybean (Glycine max) ZZ-J9331 in quails (Coturnix japonica). *Journal of Agricultural Biotechnology*, *25*(3): 451-460.

Lu L, Guo J, Li S, Li A, Zhang L, Liu Z and Luo X. 2015. Influence of phytase transgenic corn on the intestinal microflora and the fate of transgenic DNA and protein in digesta and tissues of broilers. *Plos one*, *10*(11), e0143408.

Ma Q, Gao C, Zhang J, Zhao L, Hao W and Ji C. 2013. Detection of transgenic and endogenous plant DNA fragments and proteins in the digesta, blood, tissues, and eggs of laying hens fed with phytase transgenic corn. *PLoS One*, *8*(4), e61138.

McNaughton J, Roberts M, Rice D, Smith B, Hinds M, Delaney B, Iiams C, Sauber T. 2011. Comparison of broiler performance and carcass yields when fed transgenic maize grain containing event DP-Ø9814Ø-6 and processed fractions from transgenic soybeans containing event DP-356Ø43. *Poultry science*, *90*(8): 1701-1711.

Murawska D. 2017. The effect of age on growth performance and carcass quality parameters in different poultry species. *Poultry Science*, 33-50.

Nafus DM and Schreiner IH. 1991. Review of the biology and control of the Asian corn borer, Ostrinia furnacalis (Lep:

Pyralidae). *International Journal of Pest Management*, *37*(1): 41-56.

Nunes BDN, Ramos SB, Savegnago RP, Ledur MC, Nones K, Klein CH and Munari DP. 2011. Genetic parameters for body weight, carcass chemical composition and yield in a broiler-layer cross developed for QTL mapping. *Genetics and Molecular Biology*, *34*, 429-434. https://doi.org/10.1590/s1415-47572011005000019

Řehout V, Hanusová L, Kadlec J, Čítek J and Hosnedlová B. 2008. Detection of DNA fragments from roundup ready soya and Bt maize in organs of broilers. J Agrobiol. 25(1):141–4.

Řehout, V., Kadlec, J., Čítek, J., Hradecká, E., Hanusová, L., Hosnedlova, B., and Lád, F. (2009). The influence of genetically modified Bt maize MON 810 in feed mixtures on slaughter, haematological and biochemical indices of broiler chickens. *Journal of Animal and Feed Sciences*, *18*(3): 490-498.

Reichert M, Kozaczyński W, Karpińska TA, Bocian Ł, Jasik A, Kycko A, Świątkiewicz M, Świątkiewicz S, Furgał-Dierżuk I, Arczewska-Włosek A, Strzetelski J and Kwiatek K. 2012. Histopathology of internal organs of farm animals fed genetically modified corn and soybean meal. *Bull Vet Inst Pulawy*, *56*, 617-22.

Rossi F, Morlacchini M, Fusconi G, Pietri A, Mazza R, Piva G. 2005. Effect of Bt corn on broiler growth performance and fate of feed derived DNA in digestive tract. Poultry Sci 84, 1022-1033 SAS/STAT (2010) Inc., Cary, NC, USA

Salisu IB, Amin AB, Ali Q, Tijjani A and Ibrahim AA. 2019. Digestive fate of transgenic DNA and protein in livestock tissues fed genetically modified feed ingredients: A review. *Nigerian Journal of Animal Production*, *46*(2): 8-21.

Santhi D and Kalaikannan A. 2017. Japanese quail (Coturnix coturnix japonica) meat: characteristics and value addition. *World's poultry science journal*, *73*(2):337-344.

Sartowska K, Korwin-Kossakowska A, Sender G, Jozwik A and Prokopiuk M. 2012. The impact of genetically modified plants in the diet of Japanese quails on performance traits and the nutritional value of meat and eggs preliminary results. *Archiv fur Geflugelkunde*, 76, 140-144.

Sartowska KE, Korwin-Kossakowska A and Sender G. 2015. Genetically modified crops in a 10-generation feeding trial on Japanese quails performance and body composition. *Poultry Science,* 94(12), 2909-2916. https://doi.org/10.3382/ps/pev271

Scheideler SE, Hileman RE, Weber T, Robeson L and Hartnell GF. 2008. The in vivo digestive fate of the Cry3Bb1 protein in laying hens fed diets containing MON 863 corn. Poultry science, 87(6), 1089-1097.

Sebho HK. 2016. Exotic chicken status, production performance and constraints in Ethiopia: a review. *Asian Journal of Poultry Science*, 10(1), 30-39.

Shanaway M. 1994. Quail Production Systems a review; Food and Agriculture Organization of the United Nations, Rome. ISBN 9251033846.

Smaldone G, Capezzuto S, Ambrosio RL, Peruzy MF, Marrone R, Peres G and Anastasio A. 2021. The influence stunning and meat quality under field conditions. *Animals,* 11(5), 1362. https://doi.org/10.3390/ani11051362

Swiatkiewicz S, Koreleski J, Arczewska-Wlosek A, Swiatkiewicz M, Twardowska M, Markowski J and Kwiatek K. 2011. Detection of transgenic DNA from Bt maize and herbicide tolerant soybean meal in tissues, eggs and digestive tract content of laying hens fed diets containing genetically modified plants. *Annals of Animal Science*, *11*(3).

Świątkiewicz S, Twardowska M, Markowski J, Mazur M, Sieradzki Z and Kwiatek K. 2010. Fate of transgenic DNA from Bt corn and Roundup Ready soybean meal in broilers fed GMO feed. *Bulletin of the Veterinary Institute in Pulawy*, *54*, 237-42.

Swiatkiewicz S and Arczewska A. 2011. Prospects for the use of genetically modified crops with improved nutritional properties as feed materials in Poultry Nutrition. *World's Poultry Science Journal*, 67(4), 631642. https://doi.org/10.1017/s0043933911000729

Swiatkiewicz S, Swiatkiewicz M, Arczewska-Wlosek A and Jozefiak D. 2014. Genetically modified feeds and their effect on the metabolic parameters of food-producing animals: A review of recent studies. *Animal Feed Science and Technology*, 198, 119. https://doi.org/10.1016/j.anifeedsci.2014.09.009

Taylor ML, Hartnell GF, Riordan SG, Nemeth, MA, Karunanandaa K, George B and Astwood JD. 2003. Comparison of broiler performance when fed diets containing grain from Roundup Ready (NK603), yieldgard x roundup ready (Mon810 X NK603), non-transgenic control, or Commercial Corn. *Poultry Science*, 82(3), 443453. https://doi.org/10.1093/ps/82.3.443

Taylor M, Lucas D, Nemeth M, Davis S and Hartnell G. 2007. Comparison of broiler performance and carcass parameters when fed diets containing combined trait insect-protected and glyphosate-tolerant corn (mon 89034 × NK603), control, or conventional reference corn. Poultry Science, 86(9), 19881994. https://doi.org/10.1093/ps/86.9.1988

Turgud FK and Narinç D. 2022. Influences of Dietary Supplementation with Maca (Lepidium meyenii) on Performance, Parameters of Growth Curve and Carcass Characteristics in Japanese Quail. *Animals*, *12*(3), 318.

Tyagi PK, Shrivastav AK, Mandal AB, Tyagi PK and Elangovan AV. 2010. The feeding value of quality protein maize is similar to commercial maize for egg production and quality traits in laying hens. *Indian Journal of Poultry Science*, *45*(2), 217-219.

Wang S, Tang CH, Zhang JM and Wang XQ. 2013. The effect of dietary supplementation with phytase transgenic maize and different concentrations of non-phytate phosphorus on the performance of laying hens. *British poultry science*, *54*(4), 466-470.

Yassin H, Velthuis AGJ, Boerjan M and van Riel J. 2009. Field study on broilers' first-week mortality. *Poultry Science*, 88(4), 798804. https://doi.org/10.3382/ps.2008-00292

Yonemochi C, Fujisaki H, Harada C, Kusama T and Hanazumi M. 2002. Evaluation of transgenic event CBH 351 (StarLink) corn in broiler chicks. Anim Sci J. 73(3):221–8.

Zhang L, Shen W, Fang Z and Liu B. 2021. Effects of genetically modified maize expressing Cry1Ab and EPSPS proteins on Japanese quail. *Poultry Science*, 100(2), 10681075. https://doi.org/10.1016/j.psj.2020.11.014

Zhang S, Ao X and Kim IH. 2019. Effects of non-genetically and genetically modified organism (maize-soybean) diet on growth performance, nutrient digestibility, carcass weight, and meat quality of broiler chicken. *Asian-Australasian Journal of Animal Sciences*, *32*(6), 849.

Zhong RQ, Chen L, Gao LX, Zhang LL, Yao B, Yang XG and Zhang HF. 2016. Effects of feeding transgenic corn with mCry1Ac or maroACC gene to laying hens for 12 weeks on growth, egg quality and organ health. *animal*, *10*(8), 1280-1287.