Association of TGF-β2 Gene Polymorphism with Growth Rate in Local Chickens

Ali M Sahib*1, Abbas F Al-Khalisy2, Mushtaq T Abdulwahid2

1Department of Veterinary Public Health, College of Veterinary Medicine, University of Kufa, Iraq, 2Department of Veterinary Public Health, College of Veterinary Medicine, University of Baghdad, Iraq

ABSTRACT

Iraqi native chickens have tasty meat and eggs; however, they are characterized by low production efficiency. In fact, phenotypic traits, such as growth rate, are influenced by genes and environmental factors. During health and disease, a variety of cellular processes such as proliferation, differentiation, motility, adhesion, migration, apoptosis, and immune response regulate the TGF-β genes. The enhancement in body weight can be reached through mass selection, whereas feed conversion ratio (FCR) is relatively more difficult to improve. This means, selecting for body weight has been submitted as an effective way of indirectly improving feed conversion ratio. Therefore, the present study attempts to identify associations between productive traits and polymorphism of TGF-β2 gene in local Iraqi chicken. Seventy-five male birds were used in this study. The restriction enzyme Rsal has been used to detect the target region (284 bp) in the TGF-β2 gene. A single nucleotide polymorphism (SNP) was identified at the position 62 in the exon 1 region of TGF-β2 by using PCR-RFLP and DNA sequencing technique. The genotypic frequencies were 46.7, 40, and 13.3% for CC and TC and TT genotypes, respectively. While the allele frequency of C and T were 0.67 and 0.33%, respectively. Generally, during the last period of rearing the best significant (P<0.05) improve in the body weight, weight gain and FCR were recorded in the TT genotype of the TGF-β2 gene. In conclusion, a functional sequence in the genome could be attributed to the mutation. Therefore, genotype of the TGF-β2 gene could be exploited to select the best individual as a parent to the next generations for improving of growth rate in local chickens.

Keywords: chicken, TGF-β2 gene, single nucleotide polymorphism, productive performance

INTRODUCTION

The native domestic breeds of chicken are in danger of extinction in Iraq, as they are in many other parts of the world, so restoration and protection of these potentially important genetic resources would take a lot of focus and effort (1, 2). Native chickens, on the other hand, because of their tasty eggs and meat, as well as their ability to survive a wide range of infectious diseases and high temperatures, play an important role in the socio-economic aspects of smallholder societies (3). One of the most significant challenges in native chicken production is growth. Native chickens in Iraq achieve slaughter weights of 4.5 months or more due to an intensive rearing regime...
(4). This is in stark contrast to broiler chickens (Ross 308 strains), which can weigh up to 1.4 kg in just 28 days (5, 6). The final expression of growth is the product of interactions among genetic, nutritional, and environmental factors (7). The genetic regulation of growth is complex and learning the molecular processes of growth will contribute to more efficient selection for growth in chickens (8). The use of molecular biotechnology in conjunction with an effective selection program would enhance native and local livestock production, adaptability to the climate, and preserve genetic diversity (9). The most efficient approach at improving livestock processing productivity is to use animals that are genetically superior in terms of cumulative genes. Selection based on the genome of animals requires a DNA test that is costly and time-consuming. As a result, increasing our understanding of gene polymorphisms and their relationship to essential economic traits contributed to the discovery of effective alleles and their use as molecular markers in selection programs. Therefore, more research is required before using a single nucleotide polymorphism (SNP) for marker assisted selection, such as expanding the size of the sample population, using multiple species simultaneously and the same maintenance (10). The transforming growth factor subfamily is one of the most important groups of genes involved in the development of growth and fitness traits (11, 12). The chicken transforming growth factor-beta 2 (TGF-β2) is found on chromosome 3 (13, 14). The transforming growth factor-beta 2 is a family of growth factor hormones that regulate the biological activity across a wide range of processes, including morphogenesis (15), development (16), production (17), reproduction (18), and disease resistance (18). Marker assisted selection is a new breeding technique that uses molecular markers to save time and resources by speeding up the breeding process (19). As a consequence, it is important to find and develop new markers that could be used in breeding. Therefore, this research, which aimed to understand the genetic diversity at the genomic level (DNA) rather than at the phenotypic level (measuring traits in birds), would serve as the foundation for selective breeding to help Iraqi chicken production develop.

**MATERIALS AND METHODS**

**Experimental Birds**

This study was carried out at a poultry farm, College of Veterinary Medicine, University of Baghdad during the period of 9 weeks from 7th March - 6th May 2019. A total of 75 male chicks (Iraqi local) at age 28 days old were brought from the Poultry Research Station, Ministry of Agriculture located at Abu Ghraib, Baghdad, Iraq. All birds were numbered by metal figures fixed on the wing pad and randomly divided into plots. Diet was provided ad libitum (Table 1). The birds were cared for in accordance with animal welfare principles and with ethics committee approval.

**Sample Collection and Laboratory Analysis**

One ml of blood was collected at age 90 days old from the brachial vein of all experimental birds by using disposable syringes. The samples were put in EDTA tubes kept in freezer (-20 °C) for the molecular tests.

A DNA extraction kit was used to obtain DNA from the blood (Favorgen, Taiwan). The primers were supplied from Alpha DNA Canada, as forward 5’- GCC ATA GGT TCA GTG CAA G-3’ and reverse 5’- TGA CAG AAG CTC TCA AGC C-3’ (21-23). The components of PCR reaction were prepared according to the procedure suggested by the manufacturing company (Promega, USA) using 12.5 µL master mix, 1 µL forward primer, 1 µL reverse primer, 3 µL of DNA and 7.5 µL distilled water. The optimum conditions for the gene amplification included initial denaturation at 95 °C for 5 min, followed by 30 cycles of denaturation at 95 °C for 30 sec, annealing at 54 °C for 30 sec, extension at 72 °C for 30 sec, and then final extension at 72 °C for 7 min. The PCR-RFLP assay included digesting the of 20 µL PCR products with 1 µL of RsaI restriction enzyme at 37 °C for 3 h. The restriction patterns were visualized under ultraviolet illumination on a 1.5% agarose gel electrophoresis stained with ethidium bromide. In addition, the 20 µL of PCR products were sent to Macrogen company, Korea, for sequencing.

**Production Traits**

The electronic balance (Guangdong, China) was used to measure live body weight and feed consumption to calculate body weight gain and feed conversion ratio at weekly intervals (24).

**Table 1. Composition of grower diet according to (20)**

| Ingredients                        | Diet (%)                  | 4-10 weeks | 11-13 weeks |
|------------------------------------|---------------------------|------------|-------------|
| Yellow corn                        | 29.6                      | 23.2       |
| Wheat                              | 40                        | 36          |
| Soybean meal (45% CP)              | 13.5                      | 11          |
| Barley                             | 10                        | 23          |
| Protein concentrate for broiler    | 5                         | 0           |
| Protein concentrate for layer      | 0                         | 5           |
| Dicalcium phosphate                | 0.8                       | 0.4         |
| Limestone                          | 0.8                       | 1.1         |
| Salt                               | 0.3                       | 0.3         |
| Total                              | 100                       | 100         |

| Calculated nutritional content     |                           |             |
|------------------------------------|---------------------------|-------------|
| Metabolized energy (kcal/kg)       | 2930.4                    | 2881.35     |
| Crude protein (%)                  | 16.7                      | 15.92       |
| Methionine + Cysteine (%)          | 0.70                      | 0.67        |
| Lysine (%)                         | 0.80                      | 0.78        |
| Fat (%)                            | 2.7                       | 2.56        |
| Fiber (%)                          | 3                         | 3.39        |
| Calcium (%)                        | 0.80                      | 0.82        |
| Available phosphorus               | 0.50                      | 0.33        |
Statistical Analysis

The statistical analysis system (SAS) program was used to investigate the effect of genotype of the TGF-β3 gene on the body weight (25). To compare means, the general linear model procedure and Duncan’s multiple range test were used. In addition, the distribution ratios of the herd and the frequency of the alleles were obtained by chi-square test based on Hardy-Weinberg law (26).

RESULTS AND DISCUSSION

DNA Extraction

The DNA extracted was very efficient and showed sharp bands on the agarose gel (Figure 1).

PCR Assay

Polymerase chain reaction (PCR) amplified a partial region of the TGF-β2 gene, which showed a molecular weight of 284 bp (Figure 2). The present results agree with other authors (21-23).

PCR-RFLP Assay

The PCR products were subjected to restriction digestion using the Rsal enzyme (GT/AC) to detect SNP T>C in the TGF-β2 gene’s first exon and it was able to cut at this position only when the SNP was present (when T was transformed to C). The following fragment sizing patterns were observed by agarose gel electrophoresis (Figure 3)

1. Wild type CC: No cleavage of the whole 284 bp segment by Rsal.
2. Heterozygous TC: Rsal cut the sequence to show three fragments in agarose gel electrophoresis (284 bp, 184 bp and 100 bp).
3. Homozygous TT: Rsal cut the sequence to show two fragments in agarose gel electrophoresis (184 bp and 100 bp)

The current result agrees with other researchers (21-23).

Figure 3. Rsal restriction fragment patterns of TGF-β2 by PCR-RFLP on 1.5% agarose gel. M= 100 bp ladder; TT, TC, CC = genotype

Sequencing

The genotypes CC, TC and TT of the TGF-β2 gene were observed in local chicken. At the same time, in exon 1, a T/C transition mutation was discovered at location 62 bp (Figure 4).

The substitution of thymine (T) by cytosine (C) in chickens resulted in a change in the Rsal restriction site sequences, which were changed from GT|AC to GC|AC, preventing the Rsal enzyme from recognizing its restriction site (21-23).

Distribution of Genotype and Allele Frequency

Table 2 shows different genotypes of the TGF-β2 gene encoding region due to different genetic bundles resulting from enzymatic digestion. The genotypes were CC, TC and TT, and their distribution ratios were 46.7, 40 and 13.3%, respectively. Moreover, the differences between these percentages were highly significant (P<0.01). According to Hardy-Weinberg law, allele frequencies were 0.67 and 0.33 for both C and T, respectively. The chi-square analysis revealed that the association of Rsal allelic pattern with strain is significant. This difference can be due to factors, such as cross breeding between populations, gene flow across boundaries and different sample numbers used. Cross breeding leads to increased heterozygosity among...
populations and sub-populations (27). Gene flow across boundaries introduces new unique alleles in a population, leading to an increase in heterozygosity for the whole population (27). It was reported that chickens had two alleles (T and C) and three genotype variants (TT, CT, and CC) for the TGF-β2 gene (21). Polymorphic Indonesian chickens with two alleles (T and C) and three genotypes (TT, CT, and CC) were seen by (23). At the same time, the T allele had a higher prevalence than the C allele in Indonesian chickens owing to inbreeding and vigorous selection of the TGF-β2 gene.

Effect of the TGF-β2 Gene on the Body Weight

The results of Table 3 show no significant differences among the three genotypes of the TGF-β2 gene in weekly body weight of males in the fourth, fifth, sixth, seventh, eighth, ninth and tenth week. While there were significant differences (P<0.05) in body weight in week eleven, twelve and thirteen by TT genotype that was dominant on the other genotypes 1003, 1191, and 1304 g, followed by TC genotype 954, 1139, and 1246 g, then CC genotype 918, 1077, and 1176 g, respectively. These values reflect how diverse the indigenous chickens in Iraq are within their ecotypes. The increment of body weight may be related to genotype.

In reality, the number and size of an organ's or tissue's cells and extracellular components determine its size. The number and size of muscular cells are determined by a number of factors, both directly and indirectly. Steroids, TGF-β, and myostatin are the three primary hormones that regulate muscle development in livestock (28).

The transforming growth factor-beta is part of a broad family of multifunctional growth factors that play a pivotal role in all tissues of the body for embryo and adult (11, 29, 30). The profile of polypeptides from the TGF-β family includes stimulation or inhibition of proliferation, differentiation, motility, adhesion, migration, apoptosis and immune response of epithelial, endothelial, hematopoietic, neural and mesenchymal cells (31-33). These functions participate in the control of normal tissue homeostasis or pathological conditions (34-36). Therefore, the TGF-β genes influence many different cell types, such as myogenesis, chondrogenesis, osteogenesis, hematopoiesis, epithelial cell differentiation, and adipogenesis (37-41).

At stage 10 days of embryo development, chicken TGF-β2 mRNA was found in cells from all three germ layers (42, 43), implying that it plays a significant role in the development of many tissues. The TGF-β genes are expressed in a variety of locations in the early avian embryo, and they may play a role in phenotypic transformation, matrix deposition, and cell proliferation (44). The TGF-β genes can act as a stimulator for satellite cell proliferation and differentiation, resulting in myofibrillar hypertrophy and muscle tissue regeneration (45). Expression of TGF-β is decreased in the transitional chondrocytes of chicks with tibial dyschondroplasia, but TGF-β expression is increased where the lesion is being healed (46).
The TGF-β2 mRNA was identified in cultured chicken embryo cardiac myocytes as well as in developing chicken embryo heart and muscles (43, 47). Also, TGF-β2 is prevalent in the tissues that make up the skeleton, where it aids in bone growth regulation, and in the intricate lattice that exists in the spaces between cells (the extracellular matrix) (48-50).

Du et al. (2013) (11) observed that TGF-β2 polymorphism was related to skeletal traits. (51) revealed a significant association of TGF-β2 with body weight and explained its role in bone resorption and remodeling. The study of (16) showed that TGF-β2 may play an important role in fetal myoblast proliferation in chicken leg muscles.

The results of this study agreed with other authors (30, 52, 53).

**Effect of the TGF-β2 gene on Weight Gain**

Table 4 shows non-significant differences among the three genotypes of the TGF-β2 gene in weekly weight gain of males in the fifth, sixth, seventh, eighth, ninth and tenth week. While, there were significant differences in weight gain in the eleven, twelve, thirteen week and total by TT genotype that was dominant on the other genotypes 244.50, 188, 113 and 942.50 g, followed by TC genotype 193.26, 184.84, 107.56 and 880.76 g, then CC genotype 160.03, 158.48 99.94 and 814.88 g, respectively.

The improvement occurred in total weight gains may be related to genotype. The significant differences in body weight between the various genotypes of the TGF-β2 gene led to the presence of differences between the various genotypes in the trait of body weight gain. The current results agree with (30).

**Effect of the TGF-β2 gene on Feed Intake**

Data obtained from this study are presented in Table 5. Genotypes of the TGF-β2 gene had no significant difference in feed intake at the sixth, tenth week and total. But there were significant differences in feed intake in the fifth, seventh, eighth, ninth, eleven, twelve and thirteen week.

There was no significant difference observed in the total feed intake, which may support the hypothesis that local chickens exhibit decreased feed intake, meaning that heritability value for feed intake in chicken is low (54).

**Effect of the TGF-β2 gene on feed conversion ratio**

Generally, Table 6 shows non-significant differences among the three genotypes of the TGF-β2 gene in weekly feed conversion ratio (FCR) in the fifth, sixth, seventh, eighth, and tenth week. While there were significant differences in FCR in the ninth, eleven, twelve, thirteen week and final.

Feed conversion ratio is one of the economic important parameters in poultry production because it includes feed consumption and weight gain (17, 55, 56). Therefore, any
improvement of FCR may be resulted from improvement in body weight gain during the period of study (Table 4).

The results obtained in this study support the broad effects of the TGF-β2 gene on growth and development. At the same time, gene polymorphism may be used as a candidate of quantitative trait loci to improve productivity in local chickens.

### Table 5. Relationship of genotypes of the TGF-β2 gene with feed intake (g). Mean ± standard error

| Feed Intake | CC (No. =35) | TC (No. =30) | TT (No. =10) |
|-------------|--------------|--------------|--------------|
| Week5       | 62 ± 1.60 a  | 57 ± 1.10 a  | 64 ± 0.35 b  |
| Week6       | 103 ± 2.45 a | 102 ± 2.60 a | 97 ± 2.35 a  |
| Week7       | 236 ± 2.50 b | 232 ± 1.45 ab| 224 ± 1.60 b |
| Week8       | 349 ± 1.00 b | 334 ± 3.45 a | 340 ± 0.55 b |
| Week9       | 435 ± 1.75 b | 454 ± 2.90 b | 447 ± 1.95 b |
| Week10      | 562 ± 2.05 c | 551 ± 4.90 a | 569 ± 4.90 b |
| Week11      | 683 ± 2.00 c | 673 ± 2.55 a | 657 ± 1.50 a |
| Week12      | 784 ± 3.90 a | 766 ± 3.05 a | 793 ± 4.50 b |
| Week13      | 874 ± 2.25 a | 894 ± 3.85 a | 905 ± 4.50 b |
| Total       | 4087 ± 8.50 a| 4063 ± 14.9 a| 4094 ± 7.40 a|

Significant variations at P<0.05 are denoted by small separate letters in the same row.

### Table 6. Relationship of genotypes of the TGF-β2 gene with feed conversion ratio (FCR, g/g). Mean ± standard error

| FCR at     | CC (No. =35) | TC (No. =30) | TT (No. =10) |
|------------|--------------|--------------|--------------|
| Week5      | 4.103 ± 0.018 a | 3.577 ± 0.091 a | 3.904 ± 0.489 a |
| Week6      | 4.602 ± 0.286 a | 4.682 ± 0.109 a | 4.160 ± 0.278 a |
| Week7      | 5.222 ± 0.118 a | 5.258 ± 0.092 a | 5.200 ± 0.013 a |
| Week8      | 4.778 ± 0.038 a | 4.580 ± 0.186 a | 4.515 ± 0.043 a |
| Week9      | 4.072 ± 0.007 a | 4.215 ± 0.001 b | 4.213 ± 0.017 a |
| Week10     | 4.191 ± 0.055 a | 4.153 ± 0.012 a | 4.278 ± 0.001 a |
| Week11     | 4.267 ± 0.034 a | 3.482 ± 0.003 ab | 2.685 ± 0.521 a |
| Week12     | 4.947 ± 0.118 a | 4.144 ± 0.011 a | 4.215 ± 0.028 b |
| Week13     | 8.742 ± 0.122 a | 8.313 ± 0.074 b | 8.004 ± 0.025 a |
| Final      | 5.015 ± 0.034 ab | 4.613 ± 0.026 ab | 4.343 ± 0.213 a |

Significant variations at P<0.05 are denoted by small separate letters in the same row.

### ACKNOWLEDGEMENTS

The authors would like to express their gratitude to all of the workers at the Department of Veterinary Public Health, College of Veterinary Medicine, University of Baghdad, Iraq, for their continued support, advice, effort, and encouragement.

### CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

### REFERENCES

1. Yacoub HA, Fathi MM. Phylogenetic analysis using d-loop marker of mtDNA of Saudi native chicken strains. Mitochond. DNA. 2013; 24: 538–551.
2. Yacoub HA, Fathi MM, Sadek MA. Using cytochrome b gene of mtDNA as a DNA barcoding marker in chicken strains, Mitochond. DNA. 2015; 26: 217–223.
3. Fathi MIC, Motawei MI, Abou-Emera OK, El-Zarei MF. Evaluation of genetic diversity of Saudi native chicken populations using microsatellite markers. Poult Sci. 2017; 96(3): 530–536.
4. FAO. Local chicken genetic resources and production systems in Indonesia. Prepared by Muladno. GCP/RAS/228/GER Working Paper. 2008; No. 6. Rome.
5. Zuidhof MJ, Schneider BL, Carney VL, Korver DR, Robinson FE. Growth, efficiency, and yield of commercial broilers from 1957, 1978, and 2005. Poult Sci. 2014; 93:2970–2982.
6. Abdulwahid MT. Effect of injection hatching eggs with Newcastle disease vaccine and different doses of vitamin E on some productive traits and immune response of broilers. Iraqi J. Vet. Med. 2015; 39(2): 98–107.
7. Scanes CG, Harvey S, Marsh JA, King DB. Hormones and growth in poultry. Poult Sci. 1981; 60(2): 197–201.
8. Deeb N, Lamont SJ. Genetic architecture of growth and body composition in unique chicken population. Journal Hered. 2002; 93: 107–118.
9. Naqvi AN. Applications of molecular genetic technologies in livestock production: Potentials for developing countries. Adv. Biol. Res. 2007; 1: 72–84.
10. Du X, Chen C, Yuan Z, Zhang L, Chen X, Wang Y, et al. Genetic polymorphisms of Mc4R and IGF2 gene association with feed conversion efficiency traits in beef cattle. Pak. Vet. J. 2013; 33(4): 418-422.
11. Li H, Deeb N, Zhou H, Mitchell A, Ashwell C, Lamont SJ. Chicken quantitative trait loci for growth and body composition associated with transforming growth factor-β genes. Poult Sci. 2003; 82: 347–356.
12. Enayati B, Rahimi-Mianji G. Genomic growth hormone, growth hormone receptor and transforming growth factor b-3 gene
polymorphism in breeder hens of Mazandaran native fowls. Afr. J. Biotechnol. 2009; 8(14): 3154-3159.
13. Abasht B, Dekkers JC, Lamont SJ. Review of quantitative trait loci identified in the chicken. Poul Sci. 2006; 85: 2079–2096.
14. Wang SZ, Hu XX, Wang ZP, Li XC, Wang QG, Wang YX, et al. Quantitative trait loci associated with body weight and abdominal fat traits on chicken chromosomes 3, 5 and 7. Genet. Mol. Res. 2012; 11: 956–965.
15. Lorda-Diez CI, Montero JA, Garcia-Porrero JA, Hurle JM. TGF-β2 and 3 are coexpressed with their extracellular regulator Ltbp1in the early limb bud and modulate mesodermal outgrowth and BMP signaling in chicken embryos. BMC Dev. Biol. 2010; 10(1): 69.
16. Lu Y, Chen S, Yang N. Expression and methylation of FGF2, TGF-β and their downstream mediators during different developmental stages of leg muscles in chicken. PLoS ONE. 2013; 8(11): e70945.
17. Jin S, Chen S, Li H, Lu Y, Zhang D, Ji C, et al. Polymorphisms in the transforming growth factor β3 gene and their associations with feed efficiency in chickens. Poul Sci. 2013; 92(7): 1745–1749.
18. Gu L, Sun C, Gong Y, Yu M, Li S. Novel copy number variation of the TGFβ3 gene is associated with TGFβ3 gene expression and duration of fertility traits in hens. PLoS ONE. 2017; 12(3): e0173696.
19. Lu SX, Wu CX. Research and application of animal genetic marker-assisted selection. Yi Chuan. 2002; 24:359-362.
20. National research council (NRC). Nutrient requirements of poultry. 9th ed. National academy press. Washington. D.C, USA; 1994.
21. Malek M, Lamont SJ. Association of INOS, TRAIL, TGF-β2, TGF-β3, and Igl genes with response to Salmonella enteritidis in poultry. Genet. Sel. Evol. 2003; 35(Suppl 1): S99–S111.
22. Tohkki R, Idris I, Panandam JM, Bejo MH. The effects of polymorphisms in IL-2, IFN-γ, TGF-β2, IgL, TLR-4, MD-2, and INOS genes on resistance to Salmonella Enteritidis in indigenous chickens. Avian Pathol. 2012; 41(6): 605-612.
23. Mubsinin M, Ulupi N, Gunawan A, Wibawan IWT, Sumantri C. Genetic and their downstream effect on feed efficiency in chickens. Poult Sci. 2017; 85(2): 362.
24. Al-zubaidie SSA. Poultry management. 1st edition. College of Agriculture. Basra University; 1986.
25. Cary N. Statistical analysis system, User’s guide. Statistical Version. 9. SAS. Inst. Inc. USA: 2012.
26. Edwards AWF. GH Hardy (1908) and hardy-weinberg equilibrium. Genetics J. 2008;179(3): 1143-1150.
27. Keambou TC, Hakob BA, Ommeh S, Bembide C, Ngono EP, Manjeli Y, et al. Genetic diversity of the Cameroon indigenous chicken ecotypes. Int. J. Poult. Sci. 2014; 13(5): 279.
28. Dayton WR, White ME. Cellular and molecular regulation of muscle growth and development in meat animals. J. Anim. Sci. 2008; 86: 217-225.
29. Wu MY, Hill CS. TGF-β superfamily signaling in embryonic development and homeostasis. Dev. Cell. 2009; 16: 329-343.
30. El-Tahawy WS, Abdel-Rahman MM. Molecular, sequencing and bioinformatics of insulin-like growth factor 1 (IGF-1) gene and transforming growth factor β2 gene associations with growth traits in three strains of chicken. Preprints J. 2020; 1-22.
31. Carlson CM, Turpin EA, Moser LA, O’Brien KB, Cline TD, Jones JC, et al. Transforming growth factor-β: activation by neuraminidase and role in highly pathogenic H5N1 influenza pathogenesis. PLoS Pathogens. 2010; 6(10): e1001136.
32. Zhang P. Mechanisms and regulation of transforming growth factor superfamily mediated gene expression [dissertation]. Michigan, USA: University of Michigan; 2012.
33. Cooley JR, Yatskievych TA, Antin PB. Embryonic expression of the transforming growth factor beta ligand and receptor genes in chicken. Dev. Dyn. 2014; 243: 497-508.
34. Javelaud D, Mauvel A. Mammalian transforming growth-factor-betas: Smad signaling and physio-pathological roles. I. J. B. C. B. 2007; 36 (7): 1161-1165.
35. Pioniatowski LA, Wójcieszewicz P, Gasiuk R, Szukiewicz D. Transforming growth factor beta family: insight into the role of growth factors in regulation of fracture healing biology and potential clinical applications. Mediat. Inflamm. 2015; 1-17.
36. Teixeira AF, Dijke PT, Zhu H. On-target anti-TGF-β therapies are not succeeding in clinical cancer treatments: what are remaining challenges. Front. Cell Dev. Biol. 2020; 8(605): 1-18.
37. Massague J, Cheifetz S, Endo T, Nadal-Ginard B. Type beta transforming growth factor is an inhibitor of myogenic differentiation. Proc. Natl. Acad. Sci. USA. 1986; 83: 8206-8210.
38. Roberts AB, Sporn MB. The transforming growth factor-beta. In: Peptide growth factors and their receptors I. Springer, New York, NY; 1991. P. 419-472.
39. Burt DW, Law AS. Evolution of the transforming growth factor-beta superfamily. Progr. Growth Factor Res. 1994; 5:99-118.
40. Roark EF, Greer K. Transforming growth factor-beta and bone morphogenetic protein-2 act by distinct mechanisms to promote chick limb cartilage differentiation in vitro. Dev. Dyn. 1994; 200: 103-116.
41. Wall NA, Hogan BL. TGF-beta related genes in development. Curr. Opin. Genet. Dev. 1994; 4: 517-522.
42. Jakowlew SB, Giment G, Tuan RS, Sporn MB, Roberts AB. Pattern of expression of transforming growth factor-beta 4 mRNA and protein in the developing chicken embryo. Dev. Dyn. 1992; 195: 276-289.
43. Jakowlew SB, Giment G, Tuan RS, Sporn MB, Roberts AB. Expression of transforming growth factor-beta2a and beta 3 mRNAs and proteins in the developing chicken embryo. Differentiation J. 1994; 55: 105-118.
44. Sanders EJ, Wride MA. Roles for growth and differentiation factors in avian embryonic development. Poult Sci. 1997; 76: 111-117.
45. Saxena VK, Sachdev AK, Gopal R, Pramod AB. Roles of important candidate genes on broiler meat quality. World’s Poult. Sci. J. 2009; 65: 37-50.
46. Loveridge N, Farquharson C, Hesketh JE, Jakowlew SB, Whitehead CC, Thorp BH. The control of chondrocyte differentiation during endochondral bone growth in vivo: Changes in TGF-beta and the proto-oncogene c-myc. J. Cell Sci. 1993; 105: 949-956.
47. Jakowlew SB, Dillard PJ, Winokur TS, Flankers KC, Sporn MB, Roberts AB. Expression of transforming growth factor-betas 1-4 in chicken embryo chondrocytes and myocytes. Dev. Biol. 1991; 143: 135-148.
48. Joyce ME, Jinguishi S, Bolander ME. Transforming growth factor-β in the regulation of fracture repair. Orthop Clin North Am. 1990; 21(1): 199-209.
49. Tsiridis E, Upadhyay N, Giannoudis P. Molecular aspects of fracture healing: which are the important molecules. Injury J. 2007; 38(1): S11-S25.
50. Xu X, Zheng L, Yuan Q, Zhen G, Crane JL, Zhou X, et al. Transforming growth factor-β in stem cells and tissue homeostasis. Bone Res. 2018; 6: 1-31.
51. Bennett AK, Hester PY, Spurlock DM. Relationships of transforming growth factor–β2 single nucleotide polymorphism and messenger ribonucleic acid abundance with bone and production traits in chickens. Poult Sci. 2007; 86: 829-834.
52. Tang S, Ou J, Sun D, Zhang Y, Xu G, Zhang Y. A novel 62-bp indel mutation in the promoter region of transforming growth factor-beta 2 (TGFβ2) gene is associated with body weight in chickens. Anim. Genet. 2011; 42(1): 108-112.
53. Chen S, An J, Lian L, Qu L, Zheng J, Xu G, et al. Polymorphisms in AKT3, Figf, PRKAG3, and TGF-β genes are associated with myofiber characteristics in chickens. Poult Sci. 2013; 92: 325-330.
54. Moreira GCM, Poleti MD, Pértille F, Boschiero C, Aserm ASM, Godoy TF, et al.Unraveling genomic associations with feed efficiency and body weight traits in chickens through an integrative approach. BMC genetics. 2019; 20(1): 1-14.
55. Al-Khalisy AFS. The effect of using cod liver oil to broilers diet on some production and physiological traits. Al-Anbar Vet J. Vet. Sci. 2011; 4(2): 195-200.
علاقة تعدد المظاهر الوراثية لجين عامل النمو المحول بيتا 2 مع معدل النمو في الدجاج المحلي

علي مهدي صاحب 1، عباس فوزي الخالصي 2، و مشتاق طالب عبد الواحد 2

فرع الصحة العامة البيطرية، كلية الطب البيطري، جامعة الكوفة، العراق. فرع الصحة العامة البيطرية، كلية الطب البيطري، جامعة بغداد، العراق

الخلاصة

يعتبر الدجاج المحلي في العراق مصدراً للحم والبيض ذات الطعم المرغوب. إلا أنه، ذو كفاءة إنتاجية منخفضة. في الواقع، تتأثر الصفات المظهرية مثل معدل نمو الجسم بالعوامل الوراثية (الجينات) والعوامل البيئية. تنظم جينات عامل النمو المحول بيتا عددًا من العمليات الخلوية مثل الانتشار والتمايز والحركة والانصاف والاتصال والاستجابة المضادة أثناء حالة الصحة والمرض. إذ أن زيادة وزن الجسم يمكن الحصول عليها من خلال الادخار المستمر، في حين يصعب تحفيز كفاءة تحويل الغذاء. هذا يعني أن الادخار لوزن الجسم يعد طريقة غير مباشرة للتحسين كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة كفاءة K

الكلمات المفتاحية: الدجاج، جين عامل النمو المحول نوع بيتا 2، تعدد أشكال النوكليوتيدات المفرد، الادخار الانتاجي