



Associations of genetic variations in the OCX-32 gene with egg production traits in Korean native chickens

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ABSTRACT

The present study was undertaken to find out novel single nucleotide polymorphism (SNPs) and to analyze the association between SNPs of *OCX-32* gene and egg production traits, in the four Korean native chicken breeds (Ogol, black, gray, and white). Twenty-one variations (16 SNPs and 5 INDELS) in the intronic region of the *OCX-32* gene were detected, including new 9 variants (1500T>A, 1504A>G, 1658A>G, 1668A>T, 1821A>C, 1234 del A, ins CTT, ins TTC, and 1681 del T) in the chicken population (n=120). Fifteen variations (1346A>G, 1373G>A, 1399T>C, 1446C>G, 1500T>A, 1504A>G, 1522G>A, 1530T>A, 1563G>A, 1668A>T, 1743G>T, 1772T>A, 1821A>C, ins TTC, and ins TCT) showed significant association with egg production ratio, weight and age in the chickens. Conclusively, the result obtained suggested that SNPs and INDELS of the *OCX-32* gene might be useful as genetic markers for egg production traits in breeding program of the Korean native chicken.

Key words: Association, Egg production trait, Korean native chicken, OCX-32, SNP

Korean native chickens (KNC) meat so far has been considered delicious but due to their poor commercial performance it is not being preferred over the broilers (Naha *et al.* 2016). In order to optimize the KNC's indigenous genetic information, the single nucleotide polymorphism (SNP) had been used to isolate economical genes of importance (Xiao *et al.* 2016). Ovocalyxin-32 (*OCX-32*—accession no. NM_204534) has 29 polymorphic sites within exons 2–6 (Fulton *et al.* 2012) associated with shell colour, formation and for antibacterial properties in commercial birds (Takahashi *et al.* 2009). Therefore, the present study was conducted to identify the new polymorphism in intron 1, located between exon 1 and exon 2, of *OCX-32* gene in order demonstrate their possible association with egg production traits in KNC using sequencing method to improve their economical performance for wider acceptability (Wu *et al.* 2016).

MATERIALS AND METHODS

Korean native chickens: Four Korean native female chicken strains (120; including black, gray Ogol and white) of National Institute of Animal Science, Korea were used in this study. The economic traits of chicken, viz. egg production ratio, age at first egg laying, weight of first egg, and egg weight were investigated.

Extraction of genomic DNA: The genomic DNA was extracted from blood of KNC using G-spin™ total DNA extraction mini kit (Intron Biotechnology, Seongnam, Korea). DNA concentration and purity for each DNA sample was assessed using spectrophotometer.

Polymerase chain reaction: We performed DNA sequencing at the intron 1 region which has many SNP in *OCX-32* gene (Gene ID: 395209). The primers that were used to produce amplicon and the predicted PCR product size are shown in Table 1.

Table 1. Primer sequence used for *OCX-32* gene sequencing analyses

| SNP | sequences (5'→3') | Product size (bp) | Annealing temp. (°C) |
|---------------|--|-------------------|----------------------|
| <i>OCX-32</i> | F: TGTTTCTGATGAAG-AGCCAGA R: CTTTGCCACTCTGT-AGGCTGT | 733 | 63 |

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DNA sequencing and genotype analysis: The PCR products were sequenced using BigDye (R) Terminator v3.1 Cycle Sequencing Kit (Applied Biosystems, Foster City, CA, USA) and ABI PRISM 3730XL Analyzer (Applied Biosystems). The 21 SNPs discovered in specific region of OCX-32 gene in KNC population were analyzed to figure out their genotype, respectively.

Statistics: Statistical analysis of variance was accomplished by using the SAS Ver. 9.2 Package with PROC GLM model to evaluate effects of genotypes of each SNPs on economic traits.

$$Y_{ij} = \mu + G_i + Maj_j + \hat{\epsilon}_{ij}$$

where, Y_{ij} , observation for the economic traits; μ , whole average for each trait; G_i , effect of genotype; Maj_j , regression variable for measure age; and $\hat{\epsilon}_{ij}$, random error effect of each observation.

RESULTS AND DISCUSSIONS

The OCX-32 gene is composed of 6 exons and located on chromosome 9 in chicken genome (Maxwell *et al.* 2008). A total of 747 SNPs within this gene had been reported in the NCBI SNP database (Gene ID: 395209). The PCR products of high frequency of SNPs were sequenced encompassing 733 bases of intron sequence. Of these 21 variants, 5 SNPs (1500T>A, 1504A>G, 1658A>G, 1668A>T, 1821A>C) and 4 INDELS (1234 del A, ins CTT, ins TTC, 1681 delT) in Korean native chickens were not reported previously (Fig. 1).

The egg production traits were obtained from 120 chickens and were used for the association analysis between 21 polymorphisms. Genotype frequencies of SNPs and INDELS are shown in Tables 2 and 3 respectively. The genotypes in KNC (Gray) group, the 12 SNPs among the 16 polymorphisms, are homologous and equally appeared in "KNC (White)" breed (Table 2).

We observed the association analysis between 16 SNPs within OCX-32 gene and egg production traits (Table 4) and the effects of 5 INDELS on chicken performances in KNC (Table 5). In KNC (Ogol) breed, we observed that it had shown association with EPR ($P < 0.05$), the 7 SNPs (1346A>G, 1373G>A, 1446C>G, 1500T>A, 1504A>G, 1530T>A, 1563G>A) influenced EW ($P < 0.05$) whereas the 1821A>C SNP showed an effect on the AFL ($P < 0.05$) (Table 4).

The results of association analysis between INDELS within OCX-32 gene and egg production traits showed that the ins TCT was associated with EW ($P < 0.05$) in KNC (Black) and the 2 INDELS (ins TTC and ins TCT) were related to AFL ($P < 0.05$) in KNC (White), respectively. The association of INDELS with egg production traits was nonsignificant in KNC (Ogol) and KNC (Gray) (Table 5).

Lee *et al.* (2014) investigated previously the genetic distances between 4 breeds (black, Ogol, red, and white) of KNC using microsatellites markers and observed comparatively near genetic distance between these three breeds of chicken. However, Ogol was reported to have far

Table 2. Genotype frequencies of SNPs on OCX-32 gene in Korean native chickens

| SNP | Genotype | KOC ¹ | KBC ² | KGC ³ | KWC ⁴ |
|---------|----------|------------------|------------------|------------------|------------------|
| 1346A>G | AA | 0.61 | 0.67 | 0 | 0 |
| | GG | 0.39 | 0.33 | 1.00 | 1.00 |
| 1373G>A | GG | 0.61 | 0.67 | 0 | 0 |
| | AA | 0.39 | 0.33 | 1.00 | 1.00 |
| 1399T>C | TT | 0.71 | 0.96 | 0.50 | 0.80 |
| | TC | 0.04 | 0.04 | 0.20 | 0.10 |
| | CC | 0.25 | 0.00 | 0.30 | 0.10 |
| 1446C>G | CC | 0.61 | 0.67 | 0 | 0 |
| | GG | 0.39 | 0.33 | 1.00 | 1.00 |
| 1446T>C | TT | 0.68 | 0.66 | 0.40 | 0.60 |
| | TC | 0.04 | 0.04 | 0.30 | 0.20 |
| | CC | 0.29 | 0.30 | 0.30 | 0.20 |
| 1500T>A | TT | 0.50 | 0.52 | 0 | 0 |
| | TA | 0 | 0.04 | 0 | 0 |
| | AA | 0.50 | 0.44 | 1.00 | 1.00 |
| 1504A>G | AA | 0.61 | 0.67 | 0 | 0 |
| | GG | 0.39 | 0.33 | 1.00 | 1.00 |
| 1522G>A | GG | 1.00 | 1.00 | 0.75 | 0.22 |
| | GA | 0 | 0 | 0.25 | 0.56 |
| | AA | 0 | 0 | 0 | 0.22 |
| 1530T>A | TT | 0.61 | 0.78 | 0 | 0 |
| | AA | 0.39 | 0.22 | 1.00 | 1.00 |
| 1563G>A | GG | 0.61 | 0.67 | 0 | 0 |
| | AA | 0.39 | 0.33 | 1.00 | 1.00 |
| 1658A>G | AA | 1.00 | 0.81 | 1.00 | 1.00 |
| | AG | 0 | 0.04 | 0 | 0 |
| | GG | 0 | 0.15 | 0 | 0 |
| 1668A>T | AA | 0.89 | 0.96 | 1.00 | 1.00 |
| | TT | 0.11 | 0.04 | 0 | 0 |
| 1743G>T | GG | 0.60 | 0.65 | 1.00 | 1.00 |
| | TT | 0.40 | 0.35 | 0 | 0 |
| 1772T>A | TT | 1.00 | 1.00 | 0.50 | 0.10 |
| | AA | 0 | 0 | 0.50 | 0.90 |
| 1802C>T | CC | 0.25 | 0.36 | 0 | 0 |
| | TT | 0.75 | 0.64 | 1.00 | 1.00 |
| 1821A>C | AA | 0.90 | 0.90 | 1.00 | 1.00 |
| | AC | 0 | 0.10 | 0 | 0 |
| | CC | 0.10 | 0 | 0 | 0 |

¹KOC, Korean ogol chicken; ²KBC, Korean black chicken; ³KGC, Korean gray chicken; ⁴KWC, Korean white chicken.

Table 3. Genotype frequencies of INDELS on OCX-32 gene in Korean native chickens

| INDEL | Genotype | KOC ¹ | KBC ² | KGC ³ | KWC ⁴ |
|------------|----------|------------------|------------------|------------------|------------------|
| 1234 del A | no del | 0.63 | 0.49 | 0 | 0 |
| | del A | 0.37 | 0.51 | 1.00 | 1.00 |
| ins CTT | no ins | 0.89 | 0.96 | 0.90 | 0.70 |
| | +CTT | 0.11 | 0.04 | 0.10 | 0.30 |
| ins TTC | no ins | 0.89 | 0.89 | 1.00 | 0.70 |
| | +TTC | 0.11 | 0.11 | 0 | 0.30 |
| ins TCT | no ins | 0.82 | 0.81 | 0.90 | 0.30 |
| | +TCT | 0.18 | 0.19 | 0.10 | 0.70 |
| 1681 del T | no del | 0.50 | 0.69 | 0 | 0 |
| | del T | 0.50 | 0.31 | 1.00 | 1.00 |

¹KOC, Korean ogol chicken; ²KBC, Korean black chicken; ³KGC, Korean gray chicken; ⁴KWC, Korean white chicken.

Table 4. Association between SNPs of OCX-32 gene and egg production traits in Korean native chickens

| SNP | Genotype | KOC ¹ | | | | KBC ² | | | | KGC ³ | | | | KWC ⁴ | | | |
|---------|-----------------------|------------------------|-------------------------|-----------------------|------------------------|------------------------|------------|--------|------------------------|------------------------|-----------------------|--------|----------|------------------|------------|--------|---|
| | | EPR ⁵ (%) | AFE ⁶ (days) | EW ⁷ (g) | | EPR (%) | AFE (days) | EW (g) | | EPR (%) | AFE (days) | EW (g) | | EPR (%) | AFE (days) | EW (g) | |
| 1346A>G | AA | 72.4±1.8 ^a | 152.0±2.9 | 53.4±0.6 ^a | 64.7±2.5 | 136.1±1.7 | 55.0±0.6 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| | GG | 81.1±2.6 ^b | 145.9±4.0 | 50.4±1.3 ^b | 72.2±5.2 | 136.2±4.0 | 57.2±1.4 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| 1373G>A | GG | 72.4±1.8 ^a | 152.0±2.9 | 53.4±0.6 ^a | 64.7±2.5 | 136.1±1.7 | 55.0±0.6 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| | AA | 81.4±2.6 ^b | 145.9±4.0 | 50.4±1.3 ^b | 72.2±5.2 | 136.2±4.0 | 57.2±1.4 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| 1399T>C | TT | 73.4±2.0 | 151.7±2.9 | 53.0 | 68.2±2.3 ^a | 135.4±1.6 ^a | 55.6±0.6 | - | 58.1±4.6 | 143.6±2.8 ^a | 49.0±1.2 | - | 68.2±5.6 | 158.3±1.9 | 49.2±0.6 | - | - |
| | TC | 77.8 | 144.0 | 50.3 | 42.5 ^b | 157.0 ^b | 59.0 | - | 76.7±0.8 | 174.5±6.9 ^b | 46.9±0.7 | - | 45.2 | 135.0 | 50.3 | - | - |
| 1446C>G | CC | 82.4±2.4 | 144.4±4.0 | 50.3±1.3 | - | - | - | - | 61.7±4.1 | 139.3±6.2 ^a | 48.6±0.7 | - | 53.5 | 143.0 | - | - | - |
| | CC | 72.4±1.8 ^a | 152.0±2.9 | 53.4±0.6 ^a | 64.7±2.5 | 136.1±1.7 | 55.0±0.6 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| 1466T>C | GG | 81.1±2.6 ^b | 145.9±4.0 | 50.4±1.3 ^b | 72.2±5.2 | 136.2±4.0 | 57.2±1.4 | - | 59.3±5.3 | 159.5±3.5 | 51.4±1.1 | - | 77.7±5.8 | 156.7±2.3 | 48.5±0.6 | - | - |
| | TT | 82.4±2.4 | 144.4±4.0 | 50.3±1.3 | 64.7±2.5 | 136.1±1.7 | 55.0±0.6 | - | 58.7±4.3 | 135.7±4.6 | 46.3±0.1 | - | 39.9±2.4 | 146.0±4.9 | 50.3 | - | - |
| 1500T>A | TC | 77.8 | 144.0 | 50.3 | 73.0 | 133.0 | 60.2 | - | 72.0±3.7 | 146.7±5.0 | 46.7±0.3 | - | 49.1±2.0 | 156.0±5.8 | 53.5 | - | - |
| | CC | 73.4±2.0 | 151.7±2.9 | 53.0 | 64.7±2.5 | 136.6±4.5 | 56.7±1.5 | - | 65.8±2.6 | 135.9±2.0 | 54.7±0.6 | - | - | - | - | - | - |
| 1500T>A | TT | 72.4±1.8 ^a | 152.0±2.9 | 53.4±0.6 ^a | 65.8±2.6 | 135.9±2.0 | 54.7±0.6 | - | 78.0 | 143.0 | 58.0 | - | - | - | - | - | - |
| | TA | - | - | - | 78.0 | 143.0 | 58.0 | - | 65.8±2.6 | 135.9±3.1 | 57.1±1.2 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| 1504A>G | AA | 81.1±2.6 ^b | 145.9±4.0 | 50.4±1.3 ^b | 65.8±2.6 | 135.9±3.1 | 57.1±1.2 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| | AA | 72.4±1.8 ^a | 152.0±2.9 | 53.4±0.6 ^a | 64.7±2.5 | 136.1±1.7 | 55.0±0.6 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| 1522G>A | GG | 81.1±2.6 ^b | 145.9±4.0 | 50.4±1.3 ^b | 72.2±5.2 | 136.2±4.0 | 57.2±1.4 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| | GG | 74.8±1.7 | 149.8±2.2 | 52.5±0.7 | 65.8±2.6 | 136.7±1.6 | 55.7±0.6 | - | 62.6±4.0 | 153.7±4.8 | 46.9±0.3 ^a | - | 49.4±1.9 | 139.0±1.8 | 50.3 | - | - |
| 1522G>A | GA | - | - | - | - | - | - | - | 62.9±5.7 | 136.0±4.5 | 51.1±2.0 ^b | - | 56.0±7.3 | 158.6±3.0 | 50.2±0.8 | - | - |
| | AA | - | - | - | - | - | - | - | 62.9±5.7 | 136.0±4.5 | 51.1±2.0 ^b | - | 88.5±0.3 | 157.7±1.6 | 47.9±0.9 | - | - |
| 1530T>A | TT | 72.4±1.8 ^a | 152.0±2.9 | 53.4±0.6 ^a | 73.9±6.6 | 136.6±1.7 | 55.2±0.5 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| | AA | 81.1±2.6 ^b | 145.9±4.0 | 50.4±1.3 ^b | 65.3±2.4 | 134.5±5.0 | 57.4±1.8 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| 1563G>A | AA | 72.4±1.8 ^a | 152.0±2.9 | 53.4±0.6 ^a | 64.7±2.5 | 136.1±1.7 | 55.0±0.6 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| | GG | 81.1±2.6 ^b | 145.9±4.0 | 50.4±1.3 ^b | 72.2±5.2 | 136.2±4.0 | 57.2±1.4 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| 1658A>G | AA | 81.1±2.6 ^b | 145.9±4.0 | 50.4±1.3 ^b | 72.2±5.2 | 136.2±4.0 | 57.2±1.4 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| | AA | 74.8±1.7 | 149.8±2.2 | 52.5±0.7 | 64.7±2.5 | 136.1±1.7 | 55.0±0.6 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| 1668A>T | AG | - | - | - | 73.0 | 133.0 | 60.2 | - | 64.7±2.5 | 136.6±4.5 | 56.7±1.5 | - | - | - | - | - | - |
| | GG | - | - | - | 64.7±2.5 | 136.6±4.5 | 56.7±1.5 | - | 67.5±2.5 | 136.4±1.7 | 55.7±0.7 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| 1743G>T | AA | 77.5±1.5 ^a | 148.2±2.4 | 52.0±0.7 | 67.5±2.5 | 136.4±1.7 | 55.7±0.7 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| | TT | 61.6±3.7 ^b | 161.6±3.7 | 54.1±1.2 | 59.6 | 129.0 | 57.0 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| 1772T>A | GG | 71.6±1.9 ^a | 151.8±2.7 | 53.3±0.6 | 60.8±3.4 | 138.2±1.7 | 54.5±0.6 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| | TT | 79.6±2.8 ^b | 146.8±3.7 | 51.2±1.4 | 71.4±5.8 | 135.8±4.5 | 57.3±1.6 | - | 60.2±4.6 | 146.4±3.2 | 46.6±0.3 ^a | - | 53.5 | 143.0 | - | - | - |
| 1802C>T | TT | 74.8±1.7 | 149.8±2.2 | 52.5±0.7 | 65.8±2.6 | 136.7±1.6 | 55.7±0.6 | - | 65.7±3.4 | 150.6±6.5 | 50.2±1.0 ^b | - | 65.6±5.1 | 155.7±2.2 | 49.4±0.6 | - | - |
| | AA | - | - | - | - | - | - | - | 71.4±5.8 | 135.8±4.5 | 57.3±1.6 | - | - | - | - | - | - |
| 1821A>C | CC | 77.7±2.7 | 147.8±3.0 | 52.1±1.2 | 71.4±5.8 | 135.8±4.5 | 57.3±1.6 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| | TT | 67.6±4.6 | 152.0±7.3 | 52.9±1.1 | 60.8±3.4 | 138.2±1.7 | 54.5±0.6 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| 1821A>C | AA | 76.5±1.6 ^a | 148.1±2.2 ^a | 52.1±0.7 | 68.0±2.4 ^b | 136.2±1.8 | 55.8±0.6 | - | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | - | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 | - | - |
| | AC | - | - | - | 52.2±15.3 ^b | 138.3±2.6 | 55.4±2.7 | - | 52.2±15.3 ^b | 138.3±2.6 | 55.4±2.7 | - | - | - | - | - | - |
| CC | 58.2±2.8 ^b | 169.5±0.5 ^b | 54.7±1.9 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

¹KOC, Korean ogol chicken; ²KBC, Korean black chicken; ³KGC, Korean gray chicken; ⁴KWC, Korean white chicken. ⁵EPR, egg production ratio; ⁶AFE, age at first egg; ⁷EW, egg weight; abc: mean values without a common superscripts are significantly different (P<0.05).

Table 5. Association between INDELs of *OCX-32* gene and egg production traits in Korean native chickens

| INDEL | Genotype | KOC ¹ | | | KBC ² | | | KGC ³ | | | KWC ⁴ | | |
|-----------|----------|----------------------|-------------------------|---------------------|------------------|------------|-----------------------|------------------|------------|----------|------------------|------------------------|----------|
| | | EPR ⁵ (%) | AFE ⁶ (days) | EW ⁷ (g) | EPR (%) | AFE (days) | EW (g) | EPR (%) | AFE (days) | EW (g) | EPR (%) | AFE (days) | EW (g) |
| 1234del A | no del | 74.3±1.5 | 149.7±2.7 | 53.2±0.7 | 65.8±2.4 | 136.2±1.8 | 55.0±0.6 | - | - | - | - | - | - |
| | del A | 75.4±3.2 | 150.0±3.6 | 51.7±1.1 | 72.2±3.6 | 136.2±2.8 | 57.2±0.9 | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 |
| insCTT | no ins | 74.85±1.8 | 150.8±2.5 | 52.61±0.6 | 66.5±2.4 | 136.0±1.8 | 55.9±0.6 | 50.0 | 154.0 | 46.0 | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 |
| | +CTT | 75.2±8.4 | 143.7±5.3 | 50.9±3.0 | 86.3 | 139.0 | 52.6 | 64.4±3.1 | 147.9±4.0 | 48.7±0.7 | - | - | - |
| insTTC | no ins | 75.8±1.9 | 151.0±2.5 | 52.3±0.7 | 65.8±2.6 | 136.8±1.8 | 55.8±0.6 | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | 68.2±5.6 | 159.1±1.9 ^a | 49.6±0.6 |
| | +TTC | 76.1±2.2 | 138.0±3.5 | 51.3±2.4 | 78.2±1.0 | 130.7±4.7 | 55.9±2.8 | - | - | - | 55.6±8.0 | 143.3±3.4 ^b | 48.6±0.8 |
| insTCT | no ins | 74.3±1.6 | 148.6±2.5 | 52.5±0.7 | 67.5±2.4 | 135.5±1.5 | 55.0±0.6 ^a | 50.0 | 154.0 | 46.0 | 55.6±8.0 | 143.3±3.4 ^a | 48.6±0.8 |
| | +TCT | 82.5±5.5 | 154.2±6.6 | 50.8±1.9 | 65.8±8.4 | 139.0±6.7 | 59.3±1.0 ^b | 64.4±3.1 | 147.9±4.0 | 48.7±0.7 | 68.2±5.6 | 159.1±1.9 ^b | 49.6±0.6 |
| 1681del T | no del | 74.3±1.4 | 149.7±2.7 | 53.2±0.7 | 65.8±2.4 | 136.2±1.8 | 55.0±0.6 | - | - | - | - | - | - |
| | del T | 75.4±3.2 | 150.0±3.6 | 51.7±1.1 | 72.2±3.6 | 136.2±2.8 | 57.2±0.9 | 62.9±2.9 | 148.5±3.6 | 48.4±0.6 | 64.4±4.7 | 154.4±2.1 | 49.4±0.6 |

¹KOC, Korean ogol chicken; ²KBC, Korean black chicken; ³KGC, Korean gray chicken; ⁴KWC, Korean white chicken. ⁵EPR, egg production ratio; ⁶AFE, age at first egg; ⁷EW, egg weight; ^{abc}mean values without a common superscripts are significantly different (P<0.05).

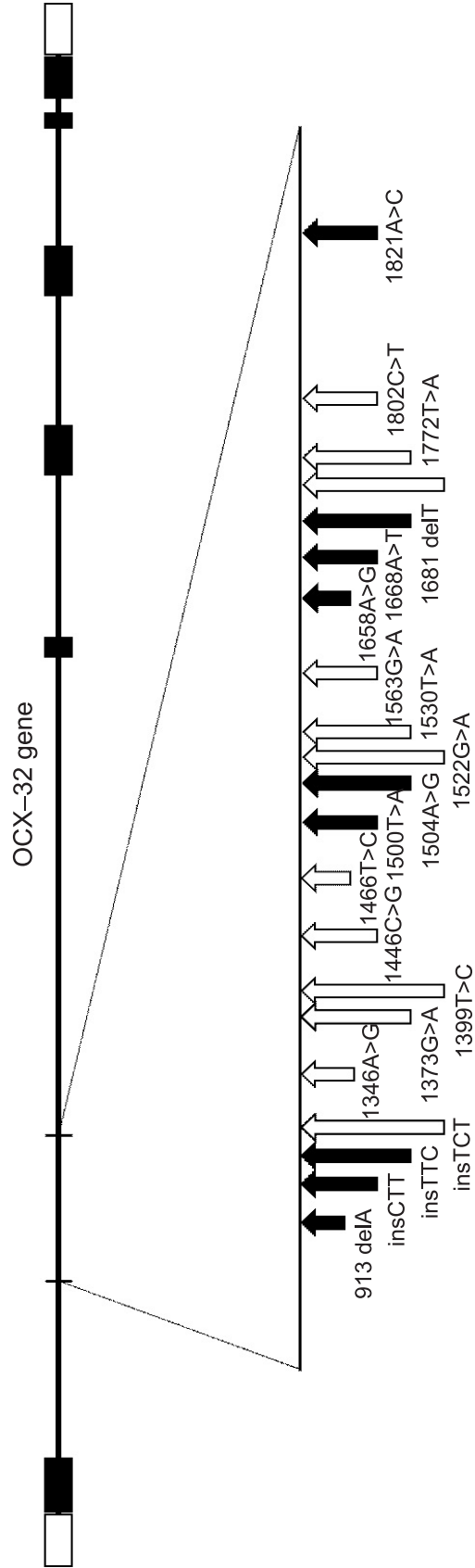


Fig. 1. Identification of sequence polymorphism in *OCX-32* (GeneBank accession no. NM_204535). Coding exons are marked by shaded blocks and 5' and 3' UTR by white blocks. The red positions are novel SNPs.

genetic distance when compared with other breeds. Takahashi *et al.* (2009) also reported that the quantitative traits loci (QTL) within 9 chromosome of chicken genome were associated with egg production quality such as formation of egg shell and egg weight. Similarly, Lee *et al.* (2014) further confirmed that the expression of OCX-32 gene influences the formation of eggshell using cDNA microarray in Taiwanese county chickens. Uemoto *et al.* (2009) reported the significant association between the SNPs (c.494A>C and c.267T>G) and found them located in exon 2 and exon 4 of the OCX-32 gene which was found to be in corroboration with our present findings. On the other hand, Uemoto *et al.* (2009) reported egg production traits (egg production ratio, yellowness and frequencies of meat spot) in total of 272 F2 resource populations by crossing White Leghorn (WL) males and Rhode Island Red (RIR) females.

All the above reports suggested that the OCX-32 gene is a potential gene to be framed as molecular marker associated with egg production and could further be used for breed selection in commercial laying chicken.

In the present study, the new genetic variations were found in the OCX-32 gene in the KNCs including Korean Ogol chicken and this was further verified based on the statistical data that they influence egg production traits in chickens. Conclusively, it was found that SNPs in OCX-32 gene were associated with egg production traits and newly found SNPs and INDELS within this gene could become a suitable marker to improve egg production performance in Korean native chickens.

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