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# Does selection index application for highly heritable traits need revisiting – A comprehensive study with bodyweight and shank length in Vanaraja male line chicken

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ABSTRACT

Selection index (SI) is one of the best methods for estimating the breeding value of an animal combining all sources of information on the animal and its relatives. In the present study, the SI was constructed utilizing the five generations data of Vanaraja male line (PD-1) for body weight (BW-6) and shank length (SL-6) at 6 weeks of age with variance, covariance estimates and heritability of both the traits. The SI was employed on three generations data on simulation basis and the selection parameters were estimated and compared with the mass selection (MS) actually practiced in the population. The least squares mean of SL-6, the primary trait of selection increased from 76.63±0.002 (G-I) to 82.85 ±0.002 mm (G-II), and subsequently reduced to 80.17±001 mm (G-III). The BW-6 also followed similar trend. Generation had significant effect on both SL-6 and BW-6. The heritability estimates for SL-6 and BW-6 were moderate with 0.21 to 0.28 for SL-6 and 0.22 to 0.27 for BW-6. The two traits exhibited high degree of positive association with 0.87 to 0.92 correlation coefficient. The economic value estimated for weight and shank length was 1:8.95. Thus, the selection index constructed was I= 0.2260*BW6, g + 0.7717*SL6, mm. Selection differential was higher in SI method on pooled basis compared to MS in all three generations for the primary trait, SL-6. The response to selection and selection intensity was also higher in SI method compared to MS. A similar trend was observed for BW-6 with respect to selection differential and response to selection. The study concluded that SI was superior to mass selection based on the results in Vanaraja male line chicken.

**Keywords:** Selection, Selection differential, Selection index, Shank length, Response

Modern chicken breeds are a result of evolution in terms of natural selection followed by artificial selection with advanced quantitative genetic principles for improving productivity for various commercial objectives (Siegal and Dunnigton 1997, Tallentire *et al.* 2016). The theory of selection indices has been introduced more than 60 years ago and is highly developed with the availability of advanced computing facilities but the application in practical breeding has not been extensive due to the difficulties in the derivation of economic values and paucity of information on trait relationships (Ogbu and Nwosu 2017). The selection index (S1) has been the choice of selection in poultry breeding as multiple traits with multiple sources of information are targeted at a time in a breeding program in the recent past. The Osborn index is the popular method for improving egg production in poultry (Osborne 1957) and is being extensively used for genetic improvement in commercial poultry breeding programs (Johari *et al.* 1991, Rajkumar *et al.* 2020, 2021a).

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The SI is a total score that includes all the advantages and disadvantages of an animal for the selected traits which were under consideration for improvement. The weightage given to each trait depends on its relative economic value, the heritability of the character and genetic correlation between characters. The index is the best estimate of an animal's breeding value. The only disadvantage of SI is that the traits vary in importance from time to time, and the index built at one time will not be applicable for all times (Lin 1978), hence, it needs to be constructed and modified from time to time. However, a theoretical simulation study by Villanueva (1990) reported that two trait selection indices can be applied to further generations without necessarily adjusting the index for changing parameters. In the present study too, a two trait SI was used for estimating breeding value.

Generally, index selection is practised for a low heritable trait for estimating the optimum breeding value of the individual. The index is considered not useful for highly heritable traits as the maximum response was expected from mass selection (MS) for the target trait. The SI constructed based on six generations of data on shank length (SL-6) and body weight (BW-6) at six weeks of age of the PD-1 chicken population was compared with the mass selection that is used for selection in three consecutive generations (S-11 to S-13) in a theoretical simulation study. The comparative merits and demerits of the mass selection (MS) and selection index (SI) were analysed in the present study.

## MATERIALS AND METHODS

*Experimental population and management:* The Vanaraja male line (PD-1) was derived from a mediocre Red Cornish population (Ayyagari 2008) which was under selection for higher 6 week shank length since last fourteen generations. The PD-1 is the male parent line (Rajkumar *et al*. 2021b) for production of *Vanaraja*, a popular dual-purpose rural chicken variety in India (Rajkumar *et al.* 2021c).

Chicks were hatched in 3 to 4 hatches in each generation in a pedigreed mating with 50 sires and 250 dams, each sire mated to five dams (1:5). In each generation, about 3000 healthy chicks were produced, wing banded and reared under deep litter management. Standard brooding, feeding and management practices were followed uniformly in all the generations. The chicks were fed *ad lib.* with broiler starter ration (2900 kcal ME, 22.0% CP) up to 6 weeks of age and provided clean drinking water round the clock through automated drinkers. The chicks were vaccinated against marek's disease (MD), Newcastle disease (ND), infectious bursal disease (IBD) and fowl pox (FP) on 1$^{st}$, 5$^{th}$, 14$^{th}$ and 21$^{st}$ day, respectively. Body weight and shank length data were recorded at six weeks of age. At the end of the six weeks, 450 females and 200 males were selected in each generation based on higher six week shank length, the primary trait of selection in PD-1.

*Data and traits studied*: The data on growth performance, shank length (SL-6) and body weight (BW-6) of PD-1 line at six weeks of age were collected over the five generations (S-7 to S-11) and utilized for the construction SI and the data for three generations (S-11 to S-13) were utilized for comparative study between mass and index selection methods. In each generation, BW-6 was measured to 0.1 g accuracy using digital balance while SL-6 was measured to the nearest of 0.01 mm accuracy using digital Vernier calipers.

*Statistical analysis*: The data collected on 6688 birds representing three generations were analyzed using least squares technique (Harvey 1990) with a computer package and the hatch corrected data were utilized for estimating the genetic parameters by variance component analysis (King and Henderson 1954). Selection differential (S), response to selection (R), selection intensity (I) were estimated using standard methods (Snedecor and Cochran 1994).

*Construction of selection index*: Variance and covariance components were estimated utilizing the five generations data of PD-1 for body weight (BW-6) and shank length (SL-6) at 6 weeks of age by REML fitting an animal model (Meyer 2007). The data generated on 13,338 birds produced from 50 sires and 250 dams in each generation was analyzed using REML fitting in animal model. The data was rationalized for both body weight and shank length. The variance and covariance estimate and heritability of both the traits estimated over the five generations data were utilized for the construction of index along with economic weightage. Spearman rank correlation between SI and MS was estimated using SPSS 16.0 software.

## RESULTS AND DISCUSSION

Body weight and shank length are the important economic traits in poultry, particularly in backyard poultry with high heritability and high degree of association between them. Mass selection and index selection are the two popularly used methods of selection for the improvement of the economic traits in livestock and poultry (Osborne 1957). The construction of SI and its merits for estimation of breeding value of individual birds in comparison with MS were discussed comprehensively.

The least squares means, heritability ($h^2$) and genetic correlation coefficient ($r_g$) for SL-6 and BW-6 are presented in Table 1. Generation had significant effect (P≤0.05) on both SL-6 and BW-6. The significant effect of generations on body weight and shank length in chicken were reported by many authors similar to the present findings (Rajkumar *et al.* 2020, 2021a, b, Prince *et al.* 2020). The primary trait of selection, SL-6 increased from 76.63±0.002 (G-I) to 82.85 ±0.002 mm (G-II), subsequently reduced to 80.17±001 mm. The body weight also followed similar trend with increase in G-II and reduced in next generation. The variations in shank length and body weight were common in a biological system which were attributable to the feeding, climatic and management practices followed in each generation. The average shank length of 77.44 mm at six weeks of age was observed in the same population during the earlier generations (Rajkumar *et al.* 2021b). The higher shank length estimates in the present study in later generations was attributed to the selection as the population was under selection for higher shank length for the last 14 generations. Linear positive trend with respect to SL-6

Table 1. Least squares mean, heritability and correlation coefficients for SL-6 and BW-6 in PD-1 chicken line

| Gen. | SL-6, mm | | BW-6, g | | $r_g$ (SL-6 & BW6) | n |
|---|---|---|---|---|---|---|
| | Mean* | $h^2$ | Mean* | $h^2$ | | |
| G-1 | 76.63±0.002 [c] | 0.28±0.07 | 668.67±0.04 [c] | 0.27±0.05 | 0.87 | 2182 |
| G-II | 82.85±0.002[a] | 0.25±0.09 | 814.63±0.03 [a] | 0.26±0.07 | 0.92 | 2376 |
| G-III | 80.17±0.001 [b] | 0.21±0.03 | 747.56±0.08 [b] | 0.22±0.08 | 0.89 | 2130 |

*Mean with different superscripts with in the column differ significantly (P≤0.05).

Table 2. Expected genetic gains using the selection index in shank length and body weight

| Selection intensity | Proportion selected (%) | BW-6, g | SL-6, mm |
|---|---|---|---|
| 0.798 | 50 | 17.55 | 0.68 |
| 0.966 | 40 | 21.25 | 0.83 |
| 1.159 | 30 | 25.50 | 0.99 |
| 1.400 | 20 | 30.80 | 1.20 |

was maintained in the populations with some exceptions over the years. Lower body weight and shank length at six weeks of age were reported in different chicken populations (Rajkumar *et al.* 2017, 2021a, d, e, Haunshi *et al.* 2021). Higher body weights and lower shank length were reported in PB-2 broiler parent line at five weeks of age (Prince *et al.* 2020). Higher body weight at six weeks was reported in broiler pure lines and crossbred (Rajkumar *et al*. 2011) than the present findings. The variations in body weight and shank length were attributable primarily to the breed characteristics as differential growth is common in different chicken breeds. The heritability estimates for SL-6 and BW-6 were moderate with 0.21 to 0.28 for shank length and 0.22 to 0.27 for body weight at six weeks of age. The body weight and shank length exhibited high degree of positive association with 0.87 to 0.92 correlation coefficient (Table 1). Similar heritability and correlation coefficients were observed in PD-1 chicken (Rajkumar *et al.* 2016, 2020a), in Dahlem Red (Rajkumar *et al.* 2021a), in rural parent line (Rajkumar *et al.* 2021b). Higher $h^2$ estimates for body weights in Ghagus chicken breed were documented (Haunshi *et al.* 2022) compared to the present findings. The observed variations in genetic parameters might be due to the degree of variability in the population and various genetic and non-genetic factors affecting the populations.

The selection index was formulated using the variance, covariance and heritability of BW-6 and SL-6 with five generations of data. The genetic and phenotypic variance for BW-6 was 2566.28 and 13298.4, respectively and that for SL-6 was 5.42 and 32.25, respectively. The covariance between the traits was 93.98 for BW-6 and 520.06 for SL-6. The cumulative $h^2$ for BW-6 and SL-6 was 0.20 and 0.17, respectively, over the five generations. The economic value for each trait was given based on the market value of ₹120/ kg of chicken meat. The average BW-6 and SL-6 were 692.88±1.00 g and 77.44±0.05 mm, respectively, based on the five generations data (Rajkumar *et al*. 2020). The economic value estimated was ₹0.12/g for body weight and ₹1.074/mm shank length. The final weightage for body weight and shank length was 1:8.95. Thus, the selection index constructed was:

$$I = 0.2260 \times BW6, g + 0.7717 \times SL6, mm$$

The expected genetic gains utilizing the above index at different selection intensities are detailed in Table 2. The accuracy of the selection index is dependent on the number of traits, relative economic weightage of traits, precision and magnitude of the genetic and phenotypic parameter estimates and selection intensity (Jeyaruben *et al.* 1995).

This index was employed, and the selection parameters were estimated and compared with the mass selection that is practiced in the population. Selection differential was

Table 3. Selection differential (mm) and response to selection (mm) for shank length at six weeks of age, the primary trait in PD-1 chicken line

| Generation | Male | | Female | | Pooled | |
|---|---|---|---|---|---|---|
| | Mass selection | Selection index | Mass selection | Selection index | Mass selection | Selection index |
| *Selection differential* | | | | | | |
| G-1 | 9.60 | 10.21 | 6.10 | 7.11 | 7.85 | 8.66 |
| G-II | 5.67 | 7.69 | 4.14 | 6.14 | 4.91 | 6.92 |
| G-III | 7.08 | 7.96 | 3.44 | 6.23 | 5.26 | 6.96 |
| *Response to selection* | | | | | | |
| G-1 | 2.69 | 2.86 | 1.71 | 1.99 | 2.19 | 2.43 |
| G-II | 1.42 | 1.92 | 1.04 | 1.54 | 1.23 | 1.73 |
| G-III | 1.56 | 1.69 | 0.76 | 1.37 | 1.12 | 1.53 |

Table 4. Selection differential (mm) and response to selection (mm) for body weight at six weeks of age in PD-1 chicken line

| Generation | Male | | Female | | Pooled | |
|---|---|---|---|---|---|---|
| | Mass selection | Selection index | Mass selection | Selection index | Mass selection | Selection index |
| *Selection differential* | | | | | | |
| G-1 | 185.95 | 257.80 | 110.18 | 159.87 | 148.06 | 208.84 |
| G-II | 129.57 | 242.41 | 87.70 | 162.34 | 108.63 | 202.38 |
| G-III | 164.84 | 459.43 | 77.52 | 210.53 | 121.18 | 334.98 |
| *Response to selection* | | | | | | |
| G-1 | 50.21 | 69.61 | 29.75 | 43.17 | 39.98 | 56.39 |
| G-II | 33.69 | 63.03 | 22.80 | 42.21 | 28.24 | 52.62 |
| G-III | 34.62 | 96.48 | 16.28 | 44.21 | 25.44 | 70.36 |

Table 5. Selection Intensity for SL-6 and BW-6 using both methods of selection

| Generation | SL-6, mm | | BW-6, g | |
|---|---|---|---|---|
| | Mass selection | Selection index | Mass selection | Selection index |
| G-1 | 1.11 | 1.23 | 1.08 | 1.52 |
| G-II | 0.82 | 1.15 | 0.79 | 1.46 |
| G-III | 0.67 | 0.88 | 0.59 | 1.63 |

Table 6. Spearman rank correlation coefficients between selection index and mass selection

| Generation | BW-6 (SI&MS) | | SL-6(SI&MS) | |
|---|---|---|---|---|
| | Male | Female | Male | Female |
| G-1 | 0.96** | 0.98** | 0.52** | 0.60** |
| G-II | 0.95** | 0.97** | 0.69** | 0.58** |
| G-III | 0.99** | 0.99** | 0.60** | 0.73** |

** Correlation significant at the 0.01 level (P≤0.01).

higher in SI method for males, females and also on pooled basis compared to mass selection in all three generations for the primary trait, SL-6. The response to selection was also higher in SI method compared to MS (Table 3). A similar trend was observed for BW-6 with respect to selection differential and response to selection, wherein the SI method recorded higher values (Table 4). The selection intensity was also higher in the SI method compared to MS (Table 5) for both traits.

The findings of higher selection parameters (S, R and I) observed in the SI method was due to the low or moderate heritability estimates (0.21 to 0.28 for BW-6) and 0.22-0.27 for SL-6) observed in the PD-1 population studied. The observed superiority of the SI over MS may be attributed to the low $h^2$ of the traits considered. The established fact that the mass selection is always better for highly heritable traits (Falconer and Mackay 1997) may not be true in cases where $h^2$ has gone down due to long term selection for the trait which is the fact in the present study as well. The prolonged single trait directed selection may result in reduced performance in unselected economically important traits of commercial importance (Ogbu and Nwosu 2017).

The spearman rank correlation coefficients between SI and MS were highly significant, nearing 100% for body weight, while it was significant and ranged from 52-73% for shank length (Table 6). The results of rank correlation clearly showed that the SI method of selection was superior compared to the MS for shank length. The superiority of SI was observed in selection differential and response, intensity over the three generations data. However, if body weight was the primary trait, both methods are equally good as per the rank correlation. If the trait under selection is body weight, the SI method may not be a better choice; however, other than body weight in spite of the highly inheritable nature of the trait the SI method was the superior method of selection as per the findings of the study.

Jeyruban *et al.* (1995) demonstrated the reduction of the relative efficiency of BLUP over the selection indices as the heritability increases in chicken. Selection indices utilize information from different sources, including individual, family, sibs, etc., compared to mass selection, wherein only individual information was used. The added genetic information was valuable to increase the precision of the breeding value when the heritability of the trait is low (Jeyruban *et al.* 1995). The SI method was employed for improving body weight along with antibody response, age at first egg, egg number and egg weight in the Tanzanian local chicken with positive results for body weight and other traits in the desirable direction (Lwelamira and Kifaro 2010). Chomchuen *et al*. (2022) used a selection index with growth and egg production traits, viz. body weight, breast circumference, age at first egg and egg production with reasonable performance for different traits in Thai native synthetic chicken.

The study concluded that, the selection differential, response and selection intensity were higher in SI method compared to the MS for SL-6 the primary trait of selection. The SI constructed with two highly heritable and correlated traits (BW-6 and SL-6) resulted in better performance in a simulation study in Vanaraja male line chicken. However, the magnitude of $h^2$ was important before inferring the superiority of the SI in a breeding program. Further studies in a population with above 0.40 heritability may provide better inference to decide the superiority of the selection method.

## REFERENCES

Ayyagari V. 2008. Development of varieties for rural poultry. *Souvenir Seminar on Sustainable Poultry Production: Rural and Commercial Approach*. pp. 1-5.

Chomchuen K, Thuntiyasawasdikul V, Chankitisakul V and Boonkum W. 2022. Genetic evaluation of body weighs and egg production traits using a multi trait animal model and selection index in Thai native synthetic chickens (Kaimook e-san2). *Animals* **12**: 335.

Falconer D S Mackay T F C. 1997. *Introduction to Quantitative Genetics*. Longman Group, Essexx, England.

Harvey W R. 1990. User's gude for PC-2 version of LSM LMW mixed model least-squares and maximum likelihood computer program. W. R. Harvey, Columbus, OH.

Haunshi S, Rajkumar U, Prince L L L, Kannaki R, Kandeepan G, Devatkal S and Chatterjee R N. 2022. Genetic parameters of growth traits, trend of production and reproduction traits, and meat quality status of Ghagus, an indigenous chicken of India. *Tropical Animal Health and Production* **54**: 170.

Haunshi S, Rajkumar U, Paswan C, Prince L L L and Chatterjee R N. 2021. Inheritance of growth traits and impact of selection on carcass and egg quality traits in Vanashree, an improved indigenous chicken. *Tropical Animal Health and Production* **53**: 128.

Jeyruban M G, Gibson J P and Gowe R S. 1995. Comparison of Index selection and best linear unbiased prediction for simulated layer poultry data. *Poultry Science* **74**: 1566–76.

Johari D C, Deepak S and Sharma R D. 1991. Osborne index and semen quality inter relationships in a strain of White Leghorn. *Indian Journal of Poultry Science* **26**: 49–50.

King S C and Henderson C R. 1954. Variance component analysis in heritability studies. *Poultry Science* **33**: 147–54.

Lin C Y. 1978. Index selection for genetic improvement of quantitative characters. *Theoretical and Applied Genetics* **52**: 49–56.

Lwelamira J and Kifaro G C. 2010. Desired gain selection indices for improving performance of two Tanzania local chicken ecotypes under intensive management. *African Journal of Agriculture Research* **5**(2): 133–41.

Meyer K. 2007. WOMBAT: A tool for mixed model analyses in quantitative genetics by restricted maximum likelihood (REML). *Journal of Zhejiang University- Science* **8**: 815–21.

Ogbu C C and Nwosu C C. 2017. Genetic response to short term index selection in females and mass selection in males of the Nigerian heavy local chicken ecotypes. *Nigerian Journal of Animal Production* **44**(2): 1–17.

Osborne R. 1957. The use of sire and dam family averages in increasing the efficiency of selective breeding under a hierarchical mating system. *Heredity* **11**: 93–116.

Prince L L L, Rajaravindra K S, Rajkumar U, Reddy B L N, Paswan C, Haunshi S and Chatterjee R N. 2020. Genetic analysis of growth and egg production traits in synthetic colored broiler female line using animal model. *Tropical Animal Health and Production* **52**(6): 3153–63.

Rajkmuar U, Niranjan M, Prince L L L, Haunshi S, Paswan C and Reddy B L N. 2020. Genetic evaluation of growth and production performance and short-term selection response for egg mass in Gramapriya female line chicken. *Indian Journal of Animal Sciences* **90**(3). 401–06.

Rajkmuar U, Niranjan M, Prince L L L, Haunshi S, Paswan C and Reddy B L N. 2021a. Short term selection response for higher 52 week egg mass based on Osborn index in *Vanaraja* female parent line chicken. *Indian Journal of Animal Sciences* **91**(1): 41–45.

Rajkumar U, Padhi M K, Haunshi S and Chatterjee R N. 2016. Genetic and phenotypic response in Vanaraja male line chicken under short term selection experiment. *Indian Journal of Animal Sciences* **86**(11): 1287–90.

Rajkmuar U, Prince L L L, Paswan C, Haunshi S and Chatterjee R N. 2021b. Variance component analysis of growth and production traits in Vanaraja male line chicken using animal model. *Animal Biosciences* **34**(4): 471–81.

Rajkmuar U, Prince L L L, Haunshi S, Paswan C and Chatterjee R N. 2021d. Estimation of breeding value, genetic parameters and maternal effects of economic traits in rural male parent line chicken using pedigree relationships in an animal model. *The Journal of Animal Breeding and Genetics* **138**: 418–31.

Rajkmuar U, Prince L L L, Rajaravindra K S, Haunshi S, Niranjan M and Chatterjee R N. 2021e. Analysis of (co) variance components and estimation of breeding value of growth and production traits in *Dahlem Red* chicken using pedigree relationship in an animal model. *PLoS One* **16**(3): e0247779.

Rajkumar U, Rama Rao S V, Raju M V L N and Chatterjee R N. 2021c. Backyard poultry farming for sustained production and enhanced nutritional and livelihood security with special reference to India: A review. *Tropical Animal Health and Production* **53**: 176.

Rajkumar U, Sharma R P, Padhi M K, Rajaravindra K S, Reddy B L N, Niranjan M, Bhattacharya T K, Haunshi S and Chatterjee R N. 2011. Genetic analysis of juvenile growth and carcass traits in a full diallele mating in selected coloured broiler lines. *Tropical Animal Health and Production* **43**: 1129–36.

Siegel P and Dunnington E. 1997. Genetic selection strategies -population genetics. *Poultry Science* **76**(8): 1062–65.

Snedecor G W and Cochran W G. 1989. *Statistical Methods*. 8th Edn. Iowa State Press, Iowa, USA.

SPSS Inc. 1998. *SPSS for Windows*, Version 16.0, Chicago, SPSS Inc.

Tallentire C W, Leinonen I and Kyriazakis I. 2016. Breeding for efficiency in the broiler chicken: A review. *Agronomy for Sustainable Development* **36**: 66.

Villanueva B. 1990. 'Effect of truncated selection on genetic parameters of correlated traits.' PhD Thesis, Dept of Animal and Poultry Science, University of Guelph, Guelph, ON, Canada.