Indian Journal of Animal Sciences **89**(6): 652–657, June 2019/Article
https://doi.org/10.56093/ijans.v89i6.91137

Evaluation of two way cross developed for free range poultry farming under farm and free range conditions

U RAJKUMAR[1], S HAUNSHI[2], C PASWAN[3], B PRAKASH[4], M K PADHI[5] and S V RAMA RAO[6]

ICAR-Directorate of Poultry Research, Rajendranagar, Hyderabad, Telangana 500 030 India

Received: 7 June 2018; Accepted: 2 November 2018

ABSTRACT

A comprehensive study was conducted to evaluate the performance of a two way cross developed for free range poultry farming under farm and field conditions. Chicks (412) produced by mating PD-1 males with PD-4 females in single hatch were utilized for the study. The data collected on 200 chicks from field and 193 chicks from farm were analysed to study the effect of system of rearing on growth and production performance. The body weights were significantly higher in males from 6–12 weeks of age revealing sexual dimorphism in birds both under farm and field conditions. The shanks were significantly longer in males. The mean dressing percentage was 68.51±2.82. Legs contributed 21.90±0.23% of live weight, followed by back, breast and wings. Abdominal fat proportion was 0.5% of body weight. The adult body weights were significantly higher in farm reared hens. The age at sexual maturity (ASM) was significantly higher in free range hens (205.12±18.23 days) compared to farm reared hens (152.35±1.03 days). The egg weights were significantly higher in farm reared birds at 40 and 52 weeks of age. The part period egg production up to 40 and 52 weeks of age was significantly higher in farm reared birds (69.22±3.89 and 122.54±4.64) than free range birds (43.42±4.62 and 83.74±8.12). The annual egg production (72 weeks) was 189.61±6.72 eggs in farm conditions. The peak production (17.12 eggs) reached at 25–28 weeks and maintained till 49–52 weeks of age in farm conditions. Under free range conditions, the peak production was attained at 37–40 weeks of age and maintained up to 45–48 weeks. It can be concluded that, the performance of the cross is quite encouraging under free range conditions with good growth rate and high production potential compared to indigenous/ native chickens, offering a bright scope as a promising dual purpose chicken variety for free range poultry.

Key words: Backyard poultry, Cross, Egg production, Free range poultry, Growth

Poultry production has a major role in the economy of developing countries and plays an important role in poverty alleviation by income generation and household food security (Abdelqader *et al.* 2007, Sambo *et al.* 2015). Free range poultry farming also known as rural poultry/backyard poultry/family poultry is highly suitable as an integral component of agriculture as supporting activity to generate additional income and highly nutritious food with minimal cost (Pica-ciamarra *et al.* 2010). Backyard chickens are excellent transformers of low value natural food base (flora and fauna) in to highly nutritious human food, i.e. egg and meat (Muchadeyi *et al.* 2004, Rajkumar *et al.* 2010). Backyard poultry is mostly managed by women in the family leading to women empowerment (Aklilu *et al.* 2007, Sambo *et al.* 2015, Rajkumar *et al.* 2010). The requirements for backyard poultry varieties are; birds having desirable plumage colour, high performance compared to local indigenous birds and ability to withstand harsh environmental conditions with minor change in husbandry practices (Dessie *et al.* 2011, Padhi *et al.* 2016).

Crossbreeding is widely used in commercial chicken production as a means of exploiting heterosis when the desired phenotype is a combination of existing lines/breeds or to impose the efficiency of the operation through the use of specialized sire and dam lines (Padhi *et al.* 2016). Various pure lines which, were developed through genetic selection are being used to develop crossbreds for backyard poultry farming involving native and exotic strains for free range poultry farming (Ayyagari *et al.* 2008, Khan *et al.* 2008, Padhi *et al.* 2012, 2016). Many rural chicken varieties namely *Vanaraja, Gramapriya, Srinidhi, Giriraja, Rajasri, Swarnadhara, Gramalakshmi* etc. available for rural poultry farming in India were developed by crossing exotic germplasm. The increased productivity with exotic crosses was not sustainable because the birds were not adopted widely by the rural farmers due to several socio-economic and environmental challenges (Teklewold *et al.* 2006). There is a definite need for bird with some proportion of local inheritance to withstand the harsh conditions under free range farming. Presence of native inheritance also

Present address: [1,2,6]Principal Scientist (ullengala @yahoo.com, santosh575g@gmail.com, svramarao1 @gmail.com), [3]Scientist (drcdvet17@gmail.com), [4]Senior Scientist (drbhukyaprakash@gmail.com). [5]Principal Scientist, ICAR-Central Avian Research Institute Regional Station, Bhubaneswar, Odisha.

improves the acceptability of the birds in rural and tribal areas. Keeping in view, a new promising variety with PD-1 and PD-4 (improved Aseel) was developed and tested under farm conditions for two cycles before testing under field conditions. In the present study, the performance of the 2 way cross was evaluated under farm and field conditions simultaneously.

MATERIALS AND METHODS

Experimental population: Two way cross chicks (412) produced in a single hatch by mating PD-1 males with PD-4 females were utilized for evaluating the growth, carcass and production performance. At 6 weeks of age, 200 chicks were distributed to 20 farmers in Korravani Thanda, a tribal village in Ranga Reddy district, Telangana, India. Remaining chicks (193) were reared under intensive farm conditions at experimental farm of the institute. PD-1 line was evolved from a mediocre red Cornish population and is being selected for higher shank length at 6 weeks of age for the last 10 generations (Ayyagari 2008). PD-1 is being utilized as a male line for production rural chicken varieties for village poultry. PD-4 line evolved from Aseel peela is being improved for body weight and egg production. The experiment was approved by the Institutional Animal Ethics Committee.

Rearing and management practices: The chicks were wing banded on day one and brooded in a deep litter system, with a decreasing temperature schedule from 33°C during first week to 23°C at the end of fifth week in an open-sided house under standard management practices. The chicks were fed *ad lib.* with broiler starter (2900 kcal/kg ME and 22% CP) diet based on maize-soybean meal up to 6 weeks of age. At the end of the 6 weeks period, chicks were sexed based on the physical appearance and data were collected and analyzed. After completion of six weeks, 200 (88 cocks and 112 hens) chicks were distributed to the farmers in Korravani Thanda village for field evaluation under free range conditions. The birds were reared like native birds with grazing/scavenging during day time and kept in a night shelter during night. Supplementary feeding with grains, broken rice, rice bran, kitchen waste etc., was practiced by the farmers based on the availability. The birds were vaccinated against New Castle disease at 6 months interval under free range conditions.

The remaining 193 (101 cocks and 92 hens) birds were reared under deep litter system till 16 weeks of age on restriction feeding schedule from 7th week onwards to maintain the target body weight during the laying cycle for better egg production. The birds were maintained on a broiler grower ration (2600 kcal/kg ME and 18% CP) upto 16 weeks of age. The remaining 101 hens were reared upto 72 weeks of age in individual cages on broiler breeder ration (2700 kcal/kg ME, 17% CP and 3.5% calcium) till the end of the production cycle. The birds were vaccinated against Marek's disease (1st day), Newcastle disease (ND), Lasota (7th and 30th day), infectious bursal disease (14th and 26th day), fowl pox (6th week), ND R_2B (9th week), infectious Bronchitis (IB) and ND inactivated (18th week).

Traits measured: Juvenile growth traits such as body weight (day old, 2, 4, 6, 8 and 12 weeks); shank length (4, 6, 8 and 12 weeks) and adult body weight (20, 40, 52, 64 and 72 weeks) were measured. The production parameters like age at sexual maturity (ASM), egg weight (28, 40, 52, 64 and 72 weeks) and egg production (40, 52, 64 and 72 weeks) were recorded in hens up to end of the production cycle, i.e. 72 weeks of age in farm. The data on free range birds were measured up to 52 weeks of age. The egg production was divided in to four weekly intervals starting from 20 weeks of age and analyzed for pattern of egg production and its distribution during the production cycle.

Total 20 cocks were selected randomly and sacrificed by cervical dislocation for evaluating the carcass traits at 14 weeks of age. The relative weights of dressed carcass, dressing percentage (DP), cutup parts (breast, legs, wings and back), giblets (gizzard, liver and heart) and offals (feather, head and blood), abdominal fat and immune organs (bursa and spleen) were recorded and expressed as percentage of live weight.

Statistical analysis: The data collected on various traits were analyzed using standard statistical methods (Snedecor and Cochran 1994). Single factor ANOVA model (SPSS 16.0) was used to assess the effect of sex and type of rearing on different traits.

RESULTS AND DISCUSSION

All the rural chicken varieties available till date in India were developed from exotic chicken breed/lines. The cross developed and evaluated in the present study has native inheritance up to 50% as the female line is improved Aseel (Aseel pela) which make the variety a unique one. The presence of native Aseel inheritance adds to phenotypic characters of the bird such as attractive plumage, longer shanks, appearance, gait, active and vigour. The acceptance of this bird was high by rural farmers due to its phenotypic appearance and production potential by rural farmers.

Growth traits: Sex had significant effect ($P \leq 0.05$) on the body weights in two way cross chicken. The body weights were significantly higher ($P \leq 0.05$) in males from six weeks onwards till 12 weeks of age revealing sexual dimorphism in birds (Table 1). Similar growth pattern of higher body weights in males (1120.12±31.21 g) as compared to females (820.54±26.15 g) was observed in birds reared under free range conditions in farmer's fields also (Table 1). The growth rate was faster in cocks compared to hens with a distinct sexual dimorphism in the two way cross birds. The body weights were significantly higher in males in the present study which was similar to the observations of Ajayi *et al*. (2009), Padhi *et al*. (2012, 2016). The juvenile body weights up to 6 weeks of age in the present study were higher compared to the reports of Haunshi *et al.* (2009) in Vanaraja and Gramapriya, Padhi *et al*. (2016) in three way cross and Rajkumar *et al.* (2018) in three way cross developed for free range poultry. However, the body weights were comparable to Vanaraja

(779.84±12.01 g) at 8 weeks of age and higher (1548.17±24.59 g) at 12 weeks of age (Haunshi *et al*. 2009) which might be due to the breed variations and feeding regime followed during the rearing period. Similarly, significant sexual dimorphism was also visible in the free range conditions as cocks were significantly heavier (P≤0.05) than hens; these findings were similar to the observations made in a crossbred developed for rural poultry (Padhi *et al*. 2014). The shanks were significantly (P≤0.05) longer in males till 12 weeks of age. Stronger and longer shanks play a major role in success of village/rural/backyard poultry as it enables the birds to run fast and escape from the predators under free range conditions. Sex had significant (P≤0.05) effect on shank length with longer shanks in males (Table 1). The present results were in agreement with the reports which reported significant effect of sex on growth and shank length (Padhi *et al*. 2016, Rajkumar *et al*. 2017). The mortality during the chick phase was 4.61% up to 6 weeks of age while 1.03% mortality was observed during 6–12 weeks of age in farm. The mortality was 9% (6–12 weeks) under free range conditions.

Table 1. Growth performance of 2-way cross under farm condition

Trait	Female	n	Male	n
	Body weight (g)			
Day old	32.54±0.24	412		
2	117.89±1.34	399		
4	320.36±3.53	396		
6	421.89±6.21[b]	204	638.01±8.01[a]	189
8	865.48±12.89[b]	92	985.41±22.27[a]	101
12 Farm	1474.20±16.13[b]	90	1962.60±25.72[a]	101
12 Field	990.54±26.15[b]	97	1388.12±31.21[a]	85
	Shank length (mm)			
4	58.04±0.29	396		
6	70.24±0.32[b]	204	81.12±0.31[a]	189
8	91.69±0.46[b]	92	97.49±0.71[a]	101
12	106.76±0.0.35[b]	90	126.46±0.80[a]	101

[a,b]Means with different superscripts differ significantly (P≤0.05) within a row.

Table 2. Slaughter parameters expressed as percentage of live weight in cocks of 2-way cross at 14 weeks of age (n=20)

Parameter	Mean	SE
Live weight (g)	1987.80	47.300
Dressing percentage (%)	68.51	2.820
Cut up parts (%)		
Breast	16.20	0.180
Legs	21.90	0.230
Wings	10.01	0.150
Back	20.40	0.230
Giblets (%)		
Heart	0.45	0.012
liver	1.92	0.044
Gizzard	1.78	0.063
Others/Offals (%)		
Abdominal fat	0.50	0.084
Bursa	0.10	0.010
Spleen	0.18	0.008
Blood	3.78	0.230
Head	3.81	0.080
Feather	4.23	0.390

Table 3. Adult body weight (g) in 2-way cross hen under farm and field condition

Age	Farm			Field		
	Mean	SE	n	Mean	SE	n
20 wks	1972.02[a]	21.26	88	1507.92[b]	68.12	91
40 wks	2489.74[a]	38.22	84	2018.81[b]	112.24	77
52 wks	2499.46[a]	43.37	84	2134.12[b]	128.12	68
64 wks	2472.80	42.36	83			
72 wks	2625.89	47.02	81			

[a,b]Means with different superscripts differ significantly (P≤0.05) within a row.

The mature body weight significantly (P≤0.05) varied between farm and free range rearing system. The adult body weights were significantly (P≤0.05) higher in farm compared to field reared hens (Table 3). The body weight of hens at 64 and 72 weeks was 2472.80±42.36 and 2625.89±47.02 g, respectively under farm conditions. The adult body weights were significantly (P≤0.05) higher in farm reared birds in spite of feed restriction, which is justified by the fact that the birds were fed with a balanced diet (2700 kcal/kg ME, 17% CP and 3.5% calcium) whereas the free range hens were on scavenging system with or without supplementary feeding. The body weights (20 and 40 weeks) in hens were higher than that of *Vanaraja* (1698.75±21.62 and 2277.00±37.02 g) and *Gramapriya* (1407.50±66.48 and 1810.42±60.38 g) hens, respectively in farm conditions which was in contrast to earlier work where lower body weights at 20 and 40 weeks of age were recorded in the crossbred hens under field conditions (Niranjan *et al*. 2008, Padhi *et al*. 2014). Lower body weights at 72 weeks were also reported in crosses developed for backyard poultry (Padhi *et al*. 2014, Niranjan *et al*. 2008). Higher body weights in this type of birds at the end of production cycle (72 weeks) may be beneficial to the farmers as it may fetch better price at the time of liquidating the flock. The mortality was 2.2 and 6.6% in farm and free range conditions during grower phase (12–20 weeks). The mortality rate was 7.95% (20–72 weeks) in farm and 25.20% (20–52 weeks) in free range conditions during laying phase.

Carcass parameters: Generally, in village poultry system, cocks are utilized for meat purpose at the age of 12–15 weeks based on the body weight. Meat quality and carcass traits are important indices to measure performance of meat birds and livestock (Rajkumar *et al*. 2016). Studies on carcass quality of cocks are important to convince the consumers about the meat quality and taste. The mean dressing percentage was 68.51±2.82, which was within the normal range (65–75%) as observed by many authors in chicken (Rajkumar *et al*. 2011, Haunshi *et al*. 2013,

Sarsenbek *et al*. 2013, Rajkumar *et al*. 2016) (Table 2). Legs contributed 21.90±0.23% of live weight, followed by back (20.40±0.23%), breast (16.20±0.18%) and wings (10.01±0.15%). Giblets (heart, liver and gizzard) contributed 4.12% of the live weight. The breast meat proportion was significantly lower in the present birds compared to broilers, which conventionally undergo selection for broader breast (Rajkumar *et al*. 2016). Lower proportion of breast and higher proportion of legs similar to present findings was reported by many authors (Haunshi *et al*. 2013, Padhi *et al*. 2016, Rajkumar *et al*. 2016) in native and crossbred chicken. Higher proportion of thigh muscle indicates the stronger legs suitable for the rural chicken variety which might be due to the presence of Aseel inheritance in the cross, as Aseel has stronger and longer legs (Rajkumar *et al*. 2017). Abdominal fat proportion was 0.5%, which was lower in the present two way cross, a desirable character for a dual purpose bird. Similarly, low proportion of abdominal fat was reported (Rajkumar *et al*. 2016, Haunshi *et al*. 2013) in native and rural chicken varieties. The losses due to blood and feathers were 3.78±0.23 and 4.23±0.39%, respectively of the live weight of the bird. The proportion of immune organs (spleen and bursa) was less (Table 2). The feather proportion and other offal were comparable to the earlier reports (Padhi *et al*. 2013, 2016) in crossbred chickens.

Production performance: The type of rearing system significantly (P≤0.05) influenced ASM, egg weight and egg production till 52 weeks of production (Table 4). The ASM was significantly (P≤0.05) lower in farm reared hens. Free range reared birds attained sexual maturity at a later age, 53 days later than farm birds. The delay in ASM in free range conditions was common as the birds might not have got required nutrients for maturity leading to lower growth rate resulting in delayed onset of egg production. The uncontrolled photoperiod in free range conditions might be another possible reason for late maturity in hens as proper lighting schedules are practiced in farms (Bell 2002). Higher ASM than the present results were reported in various backyard varieties like Vanaraja (163.14 days), Gramapriya (160.89 days) and 3 way cross (163.14 days) in farm conditions (Niranjan *et al*. 2008, Haunshi *et al*. 2009, Padhi *et al*. 2016).

Table 4. Production performance of 2-way cross under farm and field conditions

	Farm			Field		
Trait	Mean	SE	n	Mean	SE	n
ASM (days)	152.35	1.03	88	205.12	12.23	86
Egg weight (g)						
28 wks	47.17	0.58	87			
40 wks	56.20[a]	0.52	84	50.12[b]	1.35	77
52 wks	56.29[a]	0.49	84	50.96[b]	2.01	68
64 wks	59.78	0.57	83			
72 wks	60.45	0.54	81			
Egg production (n)						
40 wks	69.22[a]	3.89	84	43.42[b]	4.62	77
52 wks	122.54[a]	4.64	84	83.74[b]	8.12	68
64 wks	165.61	5.93	83			
72 wks	189.61	6.72	81			

[a,b]Means with different superscripts differ significantly (P≤0.05) within a row.

The egg weights were significantly higher in farm reared birds at 40 and 52 weeks of age (Table 4). The farm produced eggs were heavier than the free range eggs, which may be attributable to the body weight of the birds reared under farm conditions. The egg weight at 28 weeks was lower than in earlier rural crosses (Niranjan *et al*. 2008, Padhi *et al*. 2016). The egg weights were lower than a 3 way cross at 40, 52 and 64 weeks (Padhi *et al*. 2016), while almost similar egg weight (59.56 g) at 72 weeks was recorded at all ages in four crosses developed for rural poultry including *Vanaraja* and *Gramapriya* (Niranjan *et al*. 2008).

The part period egg production was significantly (P≤0.05) higher in farm reared birds than free range birds at 40 and 52 weeks of age due to the availability of better management conditions in terms of feed, housing and health care. The annual egg production (72 weeks) was 189.61±6.72 eggs in two way cross in farm conditions. The egg production at 52 weeks was 84 eggs in the cross, which is quite good for a dual purpose rural chicken variety in spite of the harsh environmental conditions in the field. The free range birds were on scavenging feeding in the farmer's fields/backyards with varying levels of natural food base which determines the bird's performance. The free range birds were exposed to challenging conditions to obtain the required nutrients for optimum production as the birds need higher level of nutrients for both maintenance and production. The reduced production in free range conditions might be due to the improper lighting period as 16 h light is essential for proper maturity in hens (Muchadeyi *et al*. 2004). Therefore, supplementary feeding becomes essential for optimum production from free range birds. The annual production of parents PD-1 and PD-4 was about 150 and 157 eggs, respectively, while the annual egg production was 189.61±6.72 egg in the cross under farm conditions (Table 4). The production potential of the cross was higher than both the parents indicating the presence of heterosis due to over dominance effect of the genes. The phenotypic characters of the cross were almost similar to the native chickens and are preferred by farmers in villages. The presence of native inheritance in the bird makes it more attractive and suitable for the rural poultry farming.

Egg production at different weeks of age (Fig. 1) indicated that the birds were laying reasonably good number of eggs with peak production (17.12 eggs) at 25–28 weeks, maintained till 49–52 weeks of age in farm conditions, while peak production was attained at a later age (37–40 week) in free range birds and maintained up to 45–48 weeks which was on expected lines as the performance of free range birds will be lower than the farm reared birds as the birds were on scavenging system wherein the available nutrients may not sufficient to meet both maintenance and production

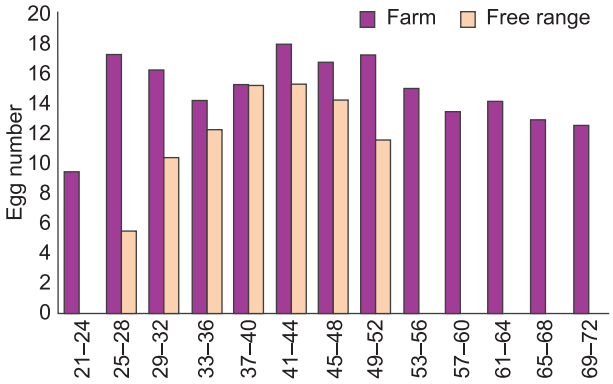

Fig. 1. Distribution of egg production at 4 week intervals under farm and free range conditions.

requirements of the birds. Also birds under free range conditions get exposed to higher pathogen challenge which may also have a negative impact on production potential. The production gradually reduced from 52 weeks of age in farm reared hens as age advanced. The gradual decrease in egg production towards later part of laying cycle was reported in PD-1 chicken (Padhi *et al*. 2016). Higher annual egg productions in rural crosses than the present results were reported except that of Vanaraja (149.47±4.48 eggs) which recorded lower egg production in farm (Niranjan *et al*. 2008). The egg production in present two way cross was lower than the layer crosses involving two local breeds of Egypt and Lohman brown (Ghanem *et al*. 2012) and a 3 way layer cross involving PD-1, White Leghorn and Dahlem Red layers (Padhi *et al*. 2016). The cross performance in free range conditions is quite encouraging and has potential to lay up to 140–150 eggs in a complete production cycle up to 72 weeks of age based on the farm production (189.61 eggs).

The study revealed that, the performance of the cross is quite encouraging under free range conditions with better growth and higher egg production than the indigenous/ native chicken. Therefore, the cross with comparable growth rate, acceptable meat quality and high production potential offers a bright scope for free range poultry as promising dual purpose chicken variety.

ACKNOWLEDGEMENTS

The authors are thankful to the Director, ICAR-Directorate of Poultry Research, Hyderabad for his constant encouragement and support in conducting the study. The technical help received from Dr S K Bhanja, Farm Manager and other technical staff is duly acknowledged.

REFERENCES

Abdelqader A, Wollny C B and Gaudy M. 2007. Characterization of local chicken production systems and their potential under different levels of management practices in Jordon. *Tropical Animal Health and Production* **39**: 155–64.

Ajayi F O and Ejiofor O. 2009. Effect of genotype × sex interaction on growth and some development characteristics of Ross and Anak broiler strains in the high rain forest zone of Nigeria. *Asian Journal of Poultry Science* **3**: 31–56.

Aklilu H A, Almekinders C J M and Van der Zijpp A J. 2007. Village poultry consumption and marketing in relation to gender, religious festivals and market access. *Tropical Animal Health and Production* **39**:165–68.

Ayyagari V. 2008. Development of varieties for rural poultry. Souvenir Seminar on Sustainable Poultry Production: Rural and Commercial Approach. 3rd March, Hyderabad, India. pp. 1–5.

Bell D D. 2002. Cage management for layers. *Commercial Chicken Meat and Egg Production*. (Eds) Bell D D and Weaver W D. 5th edn. Kluwer Academic Publishers, Massachusetts, USA. pp 1007–1040.

Dessie T, Taye T, Dana N, Ayalew W and Hanotte O. 2011. Current state of knowledge on phenotypic characteristics of indigenous chickens in the tropics. *World's Poultry Science Journal* **67**: 507–16.

Ghanem H H, Attia Y A, El-Tahawy W S and Nawar A N. 2012. Developing a three-way cross of chicken for improving egg production traits 1-heterosis effect and analysis of DNA polymorphism using RAPD-PCR. *Egypt Journal of Poultry Science* **32**: 833–49.

Haunshi S, Doley S and Shakutala I. 2009. Production performance of indigenous chicken of northeastern region and improved varieties developed for backyard farming. *Indian Journal of Animal Sciences* **79**: 901–05.

Haunshi S, Sunitha R, Shanmugam M, Padhi M K and Niranjan M. 2013. Carcass characteristics and chemical composition of breast and thigh muscles of native chicken breeds. *Indian Journal of Poultry Science* **48**: 219–22.

Khan A G. 2008. Indigenous breeds, crossbreds and synthetic hybrids with modified genetic and economic profiles for rural family and small scale poultry farming in India. *World's Poultry Science Journal* **64**: 405–15.

Muchadeyi F C, Sibanda S, Kusina N T, Kusina J F and Makuza S. 2004. The village chicken production system in Rushinga District of Zimbabwe. *Livestock Research for Rural Development* **16**(40). http://www.lrrd.org/lrrd16/6/much16040.htm.

Niranjan M, Sharma R P, Rajkumar U, Reddy B L N, Chatterjee R N and Bhattacharya T K. 2008. Comparative evaluation of production performance in improved chicken varieties for backyard farming. *International Journal of Poultry Sciences* **7**: 1126–31.

Padhi M K, Rajkumar U, Haunshi S, Niranjan M, Panda A K, Bhattacharya T K, Reddy M R, Bhanja S K and Reddy B L N. 2012. Comparative evaluation of male line of Vanaraja, Control broiler, Vanaraja commercial in respect to juvenile and carcass quality traits. *Indian Journal of Poultry Science* **47**: 136-–39.

Padhi M K and Chatterjee R N. 2013. Carcass quality traits in four different crossbreds developed for backyard poultry and the effect of age on carcass quality under intensive system of rearing. *Indian Journal of Animal Sciences* **83**: 1102–08.

Padhi M K, Chatterjee R N and Rajkumar U. 2014. A study on performance of a crossbred chicken developed using both exotic and indigenous breeds under backyard system of rearing. *Journal of Poultry Science and Technology* **2**: 26–29.

Padhi M K, Chatterjee R N, Rajkumar U, Niranjan M and Haunshi S. 2016. Evaluation of a three-way cross chicken developed for backyard poultry in respect to growth, production and carcass quality traits under intensive system of rearing. *Journal of Applied Animal Research* **44**: 390–94.

Pica-ciamarra U and Otte J. 2010. Poultry food security and

poverty in India: looking beyond the farm-gate. *World's Poultry Science Journal* **66**: 309–19.

Rajkumar U, Haunshi S, Paswan C, Raju M V L N, RamaRao S V and Chatterjee R N. 2017. Characterization of indigenous *Aseel* chicken breed for morphological, growth, production and meat composition traits from India. *Poultry Science* **96**: 2120–26.

Rajkumar U, Haunshi S, Paswan C and Reddy B L N. 2018. Evaluation of three way crossbred chicken developed for rural poultry under farm and backyard conditions for growth and production traits. *Indian Journal of Animal Sciences* **88**: 229–32.

Rajkumar U, Muthukumar M, Haunshi S, Niranjan M, Raju M V L N, RamaRao S V and Chatterjee R N. 2016. Comparative evaluation of carcass traits and meat quality in native *Aseel* chickens and commercial broilers. *British Poultry Science* **57**: 339–47.

Rajkumar U, RamaRao S V and Sharma R P. 2010. Backyard poultry farming: Changing the face of rural India. *Indian Farming* **59**: 20–23.

Rajkumar U, Sharma R P, Haunshi S, 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 diallel mating in selected coloured broiler lines. *Tropical Animal Health Production* **43**: 1129–36.

Sambo E, Betridge J, Dessie T, Amare A, Habte T, Wigley P and Chridtley R M. 2015. Participatory evaluation of chicken health and production constraints in Ethiopia. *Preventive Veterinary Medicine* **118**: 117–27.

Sarsenbek A, Wang T, Zhao J K and Jiang W. 2013. Comparison of carcass yields and meat quality between Baicheng-You chickens and Arbor Acres broilers. *Poultry Science* **92**: 2776–82.

Snedecor G W and Cochran W G. 1994. *Statistical Methods.* 8th edn. Iowa State University Press, Ames, Iowa, USA.

Teklewold H, Dadi L, Yami A and Dana N. 2006. Determinants of adoption of poultry technology a double hurdle approach. *Livestock Research Rural Development*. Vol **18**. http://www.lrrd.org/lrrd18/3/tekl18040.htm.