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Association of Residual Feed Intake with Performance Traits in Two Different Crossbred Chicken

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ABSTRACT

The experiment was conducted during February, 2024 to January, 2025 at the Poultry Research Farm of the Directorate of Livestock Farms, Guru Angad Dev Veterinary and Animal Sciences, University, Ludhiana to study the residual feed intakes (RFI) and their association with performance traits in two distinct chicken crosses viz Desi cross 1 (Rhode Island Red x Punjab Brown) and Desi cross 2 (Punjab Red×Punjab Brown). RFI was calculated at three phases: one at the grower phase, 16–20 weeks (RFI 1), and two at the layer phase, 28–33 weeks (RFI 2), and 36–40 weeks (RFI 3). Statistical analysis revealed significant differences in performance traits in between the crosses. The association between RFIs and performance traits in Desi cross 1 here also RFI 1 and RFI 2 are not affected by any performance traits. Remarkably, RFI 3 in Desi cross 1 showed a negative correlation with late-stage body weight and egg weight, while RFI in Desi cross 2 depicted positive correlations with egg production traits. Additionally, partial regression analysis identified egg mass as a significant factor influencing expected feed intake in Desi cross 2. The predicted partial regression coefficient for RFI may be useful for the selection of these two Different Crossbred Chicken to improve their feed efficiency. These findings highlight the importance of considering RFI as a selection tool in poultry breeding program for reduction in feed requirement without compromising the performance traits in chicken.

KEYWORDS: Residual feed intake, Desi cross, performance traits, association

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1. INTRODUCTION

The poultry farming is a keystone of global agriculture, supplying an affordable protein source to billions worldwide. Rising feed costs in the poultry industry have the greatest impact on the price of the final product (Ramankevich et al., 2025). India possesses a vast and expanding poultry industry, with a total poultry population of approximately 851 million. Of these, 317 million are in backyard poultry systems, and 534.74 million are in commercial farming. Egg production from indigenous fowl breeds in India reaches 17.24 billion annually, with an average yield of 178.71 eggs layer^{-1} (Anonymous, 2023). In Punjab, backyard poultry farming plays a relatively minor role. The state has around 2.45 lakh backyard poultry, producing 55.9 million eggs annually from desi fowls. Despite this modest contribution compared to the national level, poultry farming remains a crucial source of nutrition and income for many rural households in Punjab. The global demand for animal protein is projected to increase significantly in the coming decades due to population growth. To meet this demand sustainably, the livestock industry must adopt efficient practices that minimize environmental impact. A key challenge lies in improving feed conversion efficiency (FCE), which is the amount of feed required to produce a unit of animal product, such as eggs or meat. Given that feed constitutes the largest share of production costs, enhancing FCE offers direct financial benefits for poultry farmers and food producers. Genetic selection programs have significantly improved poultry productivity, increased meat and egg yields with lower feed intake. Traditional FCE measures, such as the feed conversion ratio (FCR), calculate the ratio of feed intake to weight gain. However, FCR can be influenced by factors like body weight, growth rate, and milk production, making it an imperfect measure of accurate feed efficiency.

To address these limitations, scientists have developed residual feed intake (RFI), a more precise metric. Unlike FCR, which does not account for maintenance energy needs, RFI provides a clearer picture of an animal's inherent feed efficiency. RFI was first proposed in 1963 as a measure of feed utilization efficiency in livestock (Koch, 1963). RFI is defined as the difference between an animal's actual feed intake and its predicted feed intake based on production performance and body weight (Prakash et al., 2020, Van Eerden et al., 2004). Formulas for calculating RFI must take into account body weight and changes in body weight, but depending on the utility, they will be adjusted for egg production for laying hens and for daily gain. (Varkoohi et al., 2011, Bi et al., 2022, Chen et al., 2021, Chang et al., 2024, Pezeshkian et al., 2023). Birds with a low predicted feed intake need less feed to achieve a similar body weight and production efficiency. Therefore, breeders must avoid birds with a higher feed intake through effective selection programs (Fathi et al., 2021). The formula for RFI is: RFI=Actual Feed Intake-Predicted Feed Intake. Animals with a low RFI (-RFI) are considered efficient, consuming less feed than expected for their production level, while animals with a high RFI (+RFI) are inefficient, consuming more feed than necessary. Studies have shown that RFI is moderately heritable, indicating that genetic selection can effectively improve this trait in poultry.

The genetic background of chickens, particularly the specific breed or cross, can significantly influence the relationship between RFI and performance traits. Moreover, the age at which RFI is measured can also affect its relationship with performance traits. Keeping in view the present study was aimed to determine the RFIs in different age group as RFI1 RFI2 and RFI3 and their association with performance traits in two different crosses of chicken.

2. MATERIALS AND METHODS

The experiment was conducted during February, 2024 to January, 2025 on two different crosses of chicken, namely Desi cross 1 and Desi cross 2 where, Desi cross 1 and Desi cross 2 were produced by cross between Rhode Island Red×Punjab Brown and Punjab Red and Punjab Brown respectively. A total of 200-day-old chicks of two genetic groups, namely Desi cross 1 and Desi cross 2, were taken from the hatchery unit and reared at the Poultry Research Farm of the Directorate of Livestock Farms, Guru Angad Dev Veterinary and Animal Sciences, University, Ludhiana. A deep litter system was used for raising birds from day-old to 13th weeks of age, in which 3.5 to 4 sq. ft. floor space per bird was provided. Weekly turning of litter was done. Four waterers of 3-liter capacity were placed at four different locations and were filled twice a day. Sexing of birds was done at the age of 12th week by the vent method. Then, only the female birds were shifted to particular cages with a size of approximately 14×16×17 cubic inches and then were maintained in an organized manner. For tracking the daily feed intake of individual birds, boxes were fitted in the feeder. Feed is measured and given once a day. The leftover feed was measured the next morning before the new feed was offered. Feeding with the help of the following mentioned ration table 1.

Tri-weekly Body weight from 0 to 20th week and 40th week of age, and egg weight from 28th to 40th week was recorded with an electronic weighing balance for reducing the chance of error. Egg production was obtained by recording the number of eggs laid during the period from the 28th to the 40th week. Daily feed offered after measuring. Leftover feed is measured on the following day before offering new feed. Observed feed intake: leftover subtracted from daily feed offered for each bird. Initial body weight (IBW) and

Table 1: Feed composition of layer chicks (As per BIS)

Index	Layer chick	Layer grower	Layer phase-I	Layer phase-II
Salt % (max.)	0.5	0.5	0.5	0.5
Moisture content (max.)	11	11	11	11
Linoleic acid (g 100 g^{-1} feed) min.	1.0	1.0	1.0	1.0
CP% (min.)	20	16	18	16
CF% (max.)	7.0	9.0	9.0	10
AIA% (max.)	4.0	4.0	4.0	4.5
EE% (min.)	2.0	2.0	2.0	2.0
Ca% (min.)	1.0	1.0	3.0	3.5
Phosphorus % (min.)	0.7	0.65	0.65	0.65
ME (Kcal g^{-1}) min.	2800	2500	2600	2400
Aflatoxin B1 (ppb), max.	20	20	20	20

(Source: Reddy, 2020)

final body weight (FBW) of all the birds were recorded to calculate body weight gain for three periods. The egg weight of each bird of the three genetic groups was recorded daily. Egg mass calculated for the experiment period (28th to 33rd week and 36th to 40th week) for individual birds. Although RFI has been promoted by researchers as a more biologically representative measure of feed efficiency than the FCR (Aggrey and Rekaya, 2013).

Calculation of residual feed intake

RFI=OFI−EFI

OFI: Observed feed intake EFI: Expected feed intake

For growing birds during the 16th to 20th week as RFI 1

$RFI=ADFI-(b_o+b_1\times MMBW+b_2\times ADG)+e$ (Yi et al., 2018)

Where ADFI is the average of the daily feed intake of individuals during the period of the experiment, b_0 Is the intercept, b_1 and b_2 are partial regression coefficients for MMBW (mid-metabolic body weight) and ADG, respectively, and e is the residual.

For laying birds during 28th to 33rd week as RFI 2 and 36th to 40th week as RFI 3

$EFI=aBW^{0.75}+bEM_i+c\Delta BW_i+d$ (Badawe et al., 2005)

where EFI=expected feed intake of hen i (g); $BW_i^{0.75}$=mean metabolic body weight of hen i ($g^{0.75}$); EM_i=egg mass production of hen i (g); ΔBW_i=body weight gain (g); a, b, and c=partial regression coefficients; d=intercept.

The statistical analysis related to descriptive statistics, comparative analysis of RFI, and association of RFI with production performance traits was done using SPSS (V 25.0) software. RFI was calculated using MS-Excel.

3. RESULTS AND DISCUSSION

The means of Performance traits are shown in Table 2. Body weight at the 15th week of age has drastically increased compared to the body weights at the 3rd, 6th, 9th and 12th week. The body weight at 15th week is 761.33±13.66, and 755.30±20.35, respectively, for the two genetic groups. A similar trend was noticed with the body weight at the 18th week and 20th week. Dana et al. (2011) found the body weights at 0, 4, 6, 8, 12 and 16 weeks to be 24.9±0.13 g, 59.6±0.46 g, 113.9±1.10 g, 181.6±1.58 g, 277.8±2.60 g, 285.5±5.97 g and 701±12.13 g, respectively, of which 0th, 3rd and 16th week were lower than the current study but all others are higher. Similarly, Jha et al. (2013) conducted a study to evaluate the growth traits of the crosses of Dahlem red and local desi birds and their body weight for 0, 4, 6, 8, 12, 16, 20 and 40 weeks and found to be 32.67±0.25 g, 138.34±2.25 g, 346.38±1.53 g, 478.23±2.32 g, 785.36±4.25 g, 1136.27±3.97 g, 1468.52±2.78 g and 1724.58±4.63 g, respectively of which only 0th and 40th week were less as compared to the values in the present study but 3rd, 6th, 9th, 12th, 15th, 18th and 20th of this study were low when

Table 2: Means of performance traits for Desi cross 1 and Desi cross 2

Traits	Desi cross 1 (N=60)	Desi cross 2 (N=60)
BW0 g	38.16^a±0.14	43.92^b±0.26
BW3 g	58.76^a±2.16	74.22^b±1.30
BW6 g	103.87^a±3.40	88.13^b±1.35
BW9 g	116.54^a±3.22	99.28^b±1.71
BW12 g	254.25^a±10.39	146.83^b±7.97
BW15 g	761.33±13.66	755.30±20.35
BW18 g	1215.96^a±6.52	1155.45^b±11.14
BW20 g	1385.93±6.57	1392.80±7.47
BW40 g	2065.21^a±25.99	2581.28^b±33.85
BWEFP g	1071.15±10.89	1055.43±11.38
EN40	83.55^a±0.85	69.75^b±1.44
EW40 g	47.35±0.45	48.40±0.39
EN52	123.10^a±2.70	104.35^b±2.59
EW52	52.73a±0.56	55.77^b±0.40
EM 36 to 52 g	3060.58±87.81	3289.40±115.32
RFI1	0.001±5.30	0.007±1.86
RFI2	36.43^a±3.48	152.91^b±6.20
RFI3	113.18^a±3.62	335.55^b±6.19

compared. Kumar et al. (2016) calculated the least square means of body weight at 20- and 40-week age were recorded as 1596.6±11.7 and 1701.4±9.6, respectively, which were lower than the means of body weight at 20 and 40 weeks in the present study. The least square mean of the body weights at 0, 4, 8, 12, 20 and 40 weeks were calculated to be 38.47±0.5 g, 210.76±2.24 g, 504.39±5.37 g, 809.37±14.93 g, 1637.48±15.48 g and 1910.26±20.26 g respectively by Chu et al. (2020) which were higher as compared to the present study performed except for the body weight at 40th week is lower.

Singh et al. (2023) the BWs of male birds of different Indian indigenous chicken breeds at 12th, 16th, 20th, 40th and 72nd week ranged from 528.80±16.70 g to 842.78±19.30 g, 957.57±5.66 to 1181.83±18.18 g, 1465.93±21.35 g to 1841±20.7 g, 1478.68±8.63 g to 2737±50.8 g and 1620±16 g to 3794±20.8 g, respectively from which are high when compared with the body weights of current study.

Egg number of Desi cross 1 was higher compared to another group both at 40th and 52nd week, with 83.55±0.85 and 123.10±2.70, respectively. At 50th week, the Desi cross 2 egg weight was higher than the other group, 55.77±0.40. Overall egg mass was higher in the Desi cross 2 3289.40±115.32. Jha et al. (2013) studied the first egg weight and egg weight at 40 weeks of production as 38.75±0.22 g and 55.87±2.24 g, respectively, in the Dahlem red breed, which was higher as compared to current study. Das et al. (2018) studied the first egg weight in Hilly×Fayuomi crossbred and reported it as 33.7±0.5g, which was less than that of current study. RFI 1 0.002±9.42, 0.001±5.30, 0.007±1.86, respectively, didn't show any significance. RFI 2 3.52±7.58, 36.43±3.48 and 152.91±6.20 of the two genetic groups are significantly different (p<0.05). Similarly, RFI 3 is significantly different in Desi cross 1(113.18±3.62) and Desi cross 2 (335.55±6.19).

4. ASSOCIATION OF RFI WITH PERFORMANCE TRAITS

The association between RFIs and performance traits in Desi cross 1 here also RFI 1 and RFI 2 are not affected by any performance traits but RFI 3 is negatively correlated to body weight at 40th week and egg weight at 52nd week at p<0.05 and positively correlated to RFI 2 at p<0.01 (Table 3). Association of RFIs and performance traits for Desi cross 2 is presented in table 4. RFI 1 is positively correlated with egg numbers at the 40th week (p<0.01) and egg numbers at the 52nd week, and egg mass from the 36th to 52nd week (p<0.05). RFI 2 is positively correlated with egg numbers at the 40th and 50th week, and also RFI 1 at p<0.01. RFI 3 is negatively correlated with body weight at 20th week at p<0.05 and positively correlated with egg numbers at 40th and 52nd week, and similarly correlated with egg mass from 36th to 52nd week, and RFI 2 at p<0.01.

Table 3: Association of RFIs with performance traits in Desi cross 1 (N=60)

Traits	BW20	BW40	BWEFP	EN40	EW40	EN52	EW52	EM36-52	RFI1	RFI2
BW20	1									
BW40	.198	1								
BWEFP	.308*	.072	1							
EN40	.055	.079	-.059	1						
EW40	.054	.002	-.051	.215	1					
EN52	.192	.060	.128	-.045	-.231	1				
EW52	.050	.279*	-.103	-.007	.455**	.116	1			
EM36-52	.107	-.046	.062	-.043	.084	.850**	.197	1		
RFI1	.000	-.080	.107	-.219	.118	-.123	.068	-.110	1	
RFI2	-.015	.016	.109	-.046	-.076	-.053	-.253	.008	.018	1
RFI3	-.090	-.264*	.114	-.043	-.066	-.166	-.276*	-.100	.047	.878**

The means of the performance traits wise metabolic body weight, initial and final body weight, egg mass and observed feed intake which are used for calculating RFI are depicted in table 5 RFI 1 for the period of 16-to-20-week, table 6 RFI 2 for the period of 28 to 33 week and RFI 3 in table 7 for the period of 36 to 40 week. Yang et al. (2020) The RFI was significantly positively correlated with feed conversion ratio and average daily feed intake, while it was not significantly correlated with initial body weight (BW), final BW, average daily body weight gain, and metabolic BW0.75. The abdominal fat weight and yield of the high RFI group were significantly greater than those of the medium and low RFI groups, and the abdominal fat yield was significantly positively correlated with RFI. The findings in the present study are also in the same manner.

Fathi et al. (2019) experimented with white and grey varieties

Table 4: Association of RFI with performance traits in Desi cross 2 (N=60)

Traits	BW20	BW40	BWEFP	EN40	EW40	EN52	EW52	EM36-52	RFI1	RFI2
BW20	1									
BW40	.009	1								
BWEFP	.130	-.004	1							
EN40	-.395**	-.119	-.091	1						
EW40	-.200	-.019	-.088	.399**	1					
EN52	-.352**	-.030	-.096	.915**	.323*	1				
EW52	-.072	-.028	-.011	.131	.210	.078	1			
EM36-52	-.251	-.083	-.030	.778**	.484**	.717**	.152	1		
RFI1	-.001	-.056	-.145	.337**	-.021	.279*	.087	.298*	1	
RFI2	-.126	-.113	.020	.332**	.113	.372**	.138	.232	.376**	1
RFI3	-.299*	.082	.067	.454**	.246	.489**	.110	.444**	.174	.584**

of Japanese Quails selected from the population. The correlation between RFI and egg quality, blood parameters, and carcass characteristics was also determined. Results indicated that white quails had significantly lower egg mass and high broken eggs compared to grey quails. The study was in different species but same parameters were considered in the present study. Zhang et al. (2019) conducted a study to investigate the relationship between residual feed intake (RFI) and production traits in a population of F2 ducks. The RFI had no significant correlation with live body weight and eviscerated carcass weight. RFI had negative effects on breast meat weight and gizzard weight. A positive correlation of RFI with abdominal fat weight, skin weight, and jejunum length was detected. The study was in different species from the current study but showed that RFI had no significant correlation with live body weight similar to the current study.

Performance of birds of two different genetic groups used to estimate the different parameters for the development of prediction equations for RFIs is presented in table 5. The partial regression coefficients, which are used for obtaining the prediction equations for the EFI of the genetic groups Desi cross 2 and Desi cross 1, respectively (Table 6). In case of Desi cross 2, the EFI is not affected by any traits except that the egg mass is affecting the RFI 3 at $p<0.05$. None of the factors affect the EFI in case of Desi cross 1 except the intercept, affecting all RFIs at $p<0.01$.

The following prediction equations for calculating RFIs in Desi cross 2 are developed:

Y_{RFI1}=2925.65–1.03 MBW+0.04 BWG

Y_{RFI2}=3942.39–1.05 MBW+0.10 BWG–0.02EM

Y_{RFI3}=4567.78–0.44 MBW–0.06 BWG+0.06EM

The following prediction equations for calculating RFIs in Desi cross 2 are developed:

Y_{RFI1}=2897.95–0.85 MBW+0.075 BWG

Y_{RFI2}=3942.39–1.05 MBW+0.1005 BWG–0.02EM

Y_{RFI3}=4692.79–0.213 MBW+0.048 BWG–0.02EM

Fathi et al. (2019) the partial regression coefficients for metabolic body weight and egg mass had significant effects in computing expected feed intake in both quail varieties. The intercept value also had a significant effect. On the

Table 5: Performance of birds for RFI 1, RFI 2 and RFI 3 used to estimate the different parameters for the development of prediction equations

Traits	RFI 1		RFI 2		RFI 3	
	Desi cross 2	Desi cross 1	Desi cross 2	Desi cross 1	Desi cross 2	Desi cross 1
Initial body weight (g)	1215.97	1155.45	1645.9	1462.67	2115.12	1863.07
Final body weight (g)	1385.93	1392.8	2194.02	2061.6	2581.28	2065.22
Body weight gain (g)	169.97	237.35	548.12	598.93	466.17	202.15
Egg number	-	-	20.28	24.15	14.35	14.7
Egg mass (g)	-	-	1006.67	1182.74	713.23	695.51
Observed feed intake (g)	2697.33	2745.85	3690.87	3700.54	4736.83	4749.39

N=60 birds/genetic group

Table 6: Partial regression coefficients for factors affecting expected feed intake of Desi cross 1

Parameters	Partial regression coefficient			*p*-value		
	RFI 1	RFI 2	RFI 3	RFI 1	RFI 2	RFI 3
Intercept	2925.65	3942.39	4567.78	1.31E-16	1.47E-25	3.52E-50
Metabolic body weight	-1.03	-1.05	0.44	0.38	0.24	0.08
Body weight gain	0.04	0.10	-0.06	0.73	0.29	0.07
Egg mass	-	-0.02	0.06	-	0.13	0.02

N=60; $^{*}p<0.05$; $^{**}p<0.01$

other hand, body weight gain (DBWT) did not significantly affect the computation of RFI in either the gray variety (p=0.08) or the white variety (p=0.63). Similarly, our present study also revealed that metabolic body, body weight gain, egg mass and intercept affect the RFIs and different breeds. In the present study, the performance traits like growth, production and reproduction of the birds of all three genetic groups. Further, the data was recorded to calculate residual feed intake considering the individual birds for observed and expected feed intake. Three RFI groups were taken considering different phases, viz, during growth from the age of 16th to 20th week as RFI1, during initial laying stage from the age of 28th to 33rd week as RFI2 and during middle laying stage from the age of 36th to 40th week as RFI3. Under the growth performance, body weight at the 15th week of age has drastically increased compared to the body weights at the 3rd, 6th, 9th and 12th week. The body weight at 15th week is 761.33±13.66 and 755.30±20.35, respectively, for the two genetic groups. A similar trend was noticed with the body weight at the 18th week and 20th week. Willems et al. (2023) and Wang et al. (2025) also studied effects of residual feed intake on the growth performance and found closed agreement with present findings. Egg number of Desi cross 1 was higher compared to the other group, both at 40th and 52nd week, with 83.55±0.85 and 123.10±2.70, respectively. At 50th week, the Desi cross 2 egg weight was higher than the other two groups, 55.77±0.40. Overall egg mass was higher in the Desi cross 2 3289.40±115.32. The partial regression coefficients are used for obtaining the prediction equations for the EFI of the genetic groups Desi cross 2 and Desi cross 1, respectively. In the case of Desi cross 2, the EFI is not affected by any traits except that the egg mass affects the RFI 3 at $p<0.05$. None of the factors affect the EFI in case of Desi cross 1 except the intercept, affecting all RFIs at $p<0.01$.

Table 7: Partial regression coefficients for factors affecting expected feed intake of Desi cross 2

Parameters	Partial regression coefficient			*p*-value		
	RFI 1	RFI 2	RFI 3	RFI 1	RFI 2	RFI 3
Intercept	2897.95	3942.39	4692.79	1.31E-16	1.47E-25	7.43E-39
Metabolic body weight	-0.85	-1.05	-0.21	0.38	0.24	0.67
Body weight gain	0.075	0.1005	0.048	0.73	0.29	0.42
Egg mass	-	-0.015	-0.0015	-	0.13	0.9

N=60; $^{*}p<0.05$; $^{**}p<0.01$

5. CONCLUSION

The association of different residual feed intakes (RFI 1, 2 and 3) with performance traits depicted that the residual feed intake can be considered as a nutritional breeding parameter for selecting the parent birds to reduce the feed requirement without compromising the production performance of the chickens. The determination of residual feed intake for three different phases (RFI 1, 2 and 3) have also been done for two genetic groups (Desi cross 1 and Desi cross 2) will further be helpful to estimate residual feed intake for these poultry genetic groups in future.

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