GENETIC FACTORS INFLUENCING FEED EFFICIENCY IN PURE AND CROSSBRED BROILER RABBITS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "**Genetic factors influencing feed efficiency in pure and crossbred broiler rabbits**" is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled "**Genetic factors influencing feed efficiency in pure and crossbred broiler rabbits**" is a record of research work done independently by **Dr. D.Kasiviswanathan** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

INTRODUCTION

India with a burgeoning population of 980 million is facing acute animal protein shortage. The supply of this basic food item is expected to be far below the demand. Presently the per capita consumption of meat is less than 5 kg/year, which is almost three times less than the world average of 14 kg/year (Shanmugasundaram, 1997).

In this context, rabbits, being a high quality quick source of protein, may be a suitable option. It was pointed out by an FAO Expert Consultation on rural Poultry and Rabbits held in Rome in 1981 that, if the high rate of growth in meat consumption in future years is to be met, much of the increase in production will have to come from short-cycle animals such as rabbits and especially from animals kept by small scale farmers (Lebas, 1983).

Rabbits have a relatively short gestation period, high growth rate and early sexual maturity. The feed energy required to produce one kg of rabbit meat is only one quarter of that needed to produce the same amount of lamb or beef (Lebas, 1981). When compared with poultry, 30 per cent more feed energy is required to produce one kg of rabbit meat, but it has the economic advantage of thriving on feed stuffs rich in roughages. (Cook, 1977). These factors make rabbit farming more advantageous to small holder subsistence type integrated farming systems in developing countries.

Seventy to eighty per cent the cost of rearing rabbits to market weight is for feed. It is likely that nearly all the variation in production costs within a group is due to difference in efficiency of feed utilisation. So feed efficiency is one of the most important economic factors to be improved, for economic broiler rabbit production. Information on genetic and non-genetic factors influencing efficiency of feed utilisation in broiler rabbits is scanty and hence an attempt is made to conduct a study with the following objectives.

1. To compare the growth and efficiency of feed utilization in purebred and cross bred broiler rabbits and
2. To study the effect of various genetic and non-genetic factors affecting body weight and feed efficiency.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

2.1 Growth traits

2.1.1 Body weight at different ages

A brief review on body weight of broiler breeds of rabbits at different ages is presented in Table 2.1.

2.1.2 Effect of different factors on body weight

2.1.2.1 Effect of breed

Gogelia *et al.* (1982) could not find any significant breed difference between Soviet Chinchilla (SC) and Grey Giant (GG) rabbits.

Ahmed *et al.* (1986) reported that breed difference for growth was significant only at five to six month of age in Baladi and Flemish rabbits and there was significant breed-sex interaction for body weight at two to three months.

Ferraz *et al.* (1991) found that effect of breed was significant only for body weights at fifth, seventh and eighth weeks in New Zealand White (NZW) and Californian (CAL) rabbits.

Ozimba and Lukefahr (1991) working with NZW and CAL purebreds, CAL X NZW and Flemish Giant crossbreds found that breed type was an important source of variation for post weaning growth performance.

Gupta *et al.*(1993) reported that there was no significant difference among SC, White Giant (WG), GG and NZW rabbits for body weight at three, four, six, eight, 12, 18 and 24 weeks of age. He also concluded that WG and SC were more suitable for meat production than the other two breeds in tropical regions.

Radhakrishnan (1992) while comparing the growth performance of SC, GG and NZW rabbits observed significant effect of breed for body weights at four, six, eight, 10 and 12 weeks of age.

Rathore *et al.* (1994) reported a highly significant effect of genetic groups on body weight at all ages from weaning (six weeks) to slaughter (24 weeks) of four broiler breeds viz. WG, GG, NZW and SC.

Ledur *et al.* (1994) observed that breed of dam significantly affected body weights at 21 and 70 days of age among NZW and CAL pure breeds and their crosses while breed of sire had no influence.

Paci *et al.*(1995) found that breed of sire did not significantly affect body weight.

2.1.2.2 Effect of sex

Ahmed *et al.* (1986) compared the growth performance of Baladi and Flemish rabbits and found that sex difference significantly affected body weight at eight to nine months.

Roedcha and Chanpingsang (1986) found that sex had no significant effect on body weight from birth to weaning for crossbred rabbits.

Khalil *et al.* (1987) while analysing body weight traits in young Bouscat and Giza White rabbits could not find any significant effect of sex on body weights.

Erjavec *et al.* (1990) reported that sex had a significant effect on body weight at 65 days of age in NZW rabbit.

Polastre *et al.* (1992) could not find any significant effect of sex on body weight at slaughter in Selecta breed of rabbit.

Radhakrishnan (1992) reported non-significant effect of sex for body weight from four to 12 weeks of age among NZW, SC and GG rabbits.

McNitt and Lukefahr (1993) reported non-significant effect of sex for fourth week weight in NZW rabbits.

2.1.2.3 Effect of litter size at birth

Rouvier *et al.* (1973) found non-significant effect of litter size on growth rate among NZW and Burgundy Fawn rabbits.

Narayan *et al.* (1981) reported that litter size affected significantly body weights at two, four and 14 weeks in NZW rabbits.

Mgheni *et al.* (1982) observed decreasing trend in body weight with increasing litter size in NZW rabbits at 28, 42, 56, 84 and 112 days of age, but the difference was only significant in litters of more than four kits.

Swai *et al.* (1986) reported significant difference in body weight at all ages between 21 and 98 days among rabbits born in litter size greater than six.

Erajavec *et al.* (1990) found significant effect of litter size on body weight at 65 days for NZW rabbits.

Ferraz *et al.* (1992) in the course of his study of genetic trend and genetic parameter for growth rate of NZW and CAL rabbits from weaning to 11 weeks of age observed that 30 to 50 per cent of variation in the growth rate was due to litter effect. He also found that litter effect was more important at earlier ages than at later ages.

El-Sheikh and El-Bayoni (1994) attributed 40 per cent of the variation in pre-weaning body weight to litter-size and found a significant effect of litter size after weaning.

Ledur *et al.* (1994) found that litter size significantly affected body weights at 21 and 70 days of age among NZW, CAL pure breeds and their crosses.

2.1.2.4 Effect of season of birth

Narayan *et al.* (1981) while comparing two strains of NZW rabbits up to 14 weeks of age found that month of birth had significant effect on body weight at all ages in one line while in the other line it had significant effect from two to six and at 14 weeks of age.

Blasco *et al.* (1983) found a significantly higher growth rate in NZW and CAL rabbits born in summer and spring than those born in winter and autumn.

Erjavec *et al.* (1990) reported that growth rates at 65 days and 95 days were affected significantly by season of birth.

Somade and Adesina (1990) found that the average weight of litter at weaning and 16 week of age were influenced by season and litters born in wet season had higher weight than those born in dry season. The study was conducted in NZW, Chinchilla, CAL and their crosses.

Ozimba and Lukefahr (1991) reported a highly significant influence of the season of birth on total weaning weight and post weaning weight gain in four breed types NZW, CAL pure breed and CAL x NZW and FG crossbred.

Polastre *et al.* (1992) found that month of birth had significant effect on weaning weight and slaughter weight in Selecta rabbits.

Rathore *et al.* (1994) reported that season of kindling significantly influenced body weight only in the early stages (up to 12 week) in WG, GG, NZW and SC rabbits.

According to Ledur *et al.* (1994) month of birth had significant effect on body weights at 21 and 70 days of age among NZW, CAL pure breeds and their crosses.

2.1.2.5 Effect of year of birth

McNitt and Lukefahr (1993) found that year was a significant source of variation for weaning weight (four week) among NZW, CAL, Palomino and White Satin breeds.

Khalil *et al.* (1987) reported significant effect of year of production in Giza White and Bouscat rabbits from six to 12 weeks of age.

Table 2.1
Body weights of different breeds of rabbits at different ages.

Sl. No	Breed	Body weight (g) at different ages (weeks)					References
		4-th	6-th	8-th	10-th	12-th	
1	SC					1080	Gogelia *et al.* (1982)
2	NZW	384±87	551±121	785±149	1180±202	1528±279	Mgheni et al. (1982)
3	NZW	545				2390	Niedzwiadek (1983)
4	NZW		637.9	914.2	1294.2	1747.2	Rathore *et al.* (1994)
	SC		714.9	986.5	1274.9	1621.3	
	SC x NZW		574.7	959.1	1349.2	1727.5	
5	SC					1084.8	Kosba *et al.* (1985)
6	NZW	640	920	1420	1880		Damodar and Jatkar (1985)
7	NZW	680				2633	Mach (1986)
8	NZW x SC Males					1373.4	Swai *et al.* (1986)
	NZW X SC Females					1163.4	
9	NZW	475.3			1715.9		Ledur and Carregal (1988)
10	NZW				1860	2670	Erjavec *et al.* (1990)
11	NZW X SC			800.61		1008.8	Mishra (1990)
12	NZW	383.3	573.4	788.6	1000.5	1000.6	Radhakrishnan (1992)
	SC	452.3	679.1	903.9	1129.5	1354.1	
13	NZW	625.32				1601.9	Mukundan (1993)
	SC	607.62				1544.3	
	SC X NZW	568.57				1507.1	
	NZW X SC	478.93				1417.9	
14	SC					1975	Gour *et al.* (1995)

2.2 Daily gain

2.2.1 Daily gain at different periods

Table 2.2 summarizes the daily gain at different periods in different breeds of broiler rabbits.

2.2.2 Effects of different factors on daily gain

2.2.2.1 Effect of breed

Grobner *et al.* (1985) in the course of comparing NZW and Palomino rabbits found no significant difference in the daily gain from weaning to 56 days of age.

Masoero *et al.* (1985) while studying growth performance of crossbreds involving NZW, CAL, Flemish Giant, Argente de Champagne, Vienna Blue and Burgundy Fawn rabbits observed that the breed of sire significantly influenced growth rate.

Mach *et al.* (1986) reported significant breed difference in daily gain between NZW x CW litters (30 g) and NZW, CW and CW x NZW (32, 31 and 34 g respectively) during a fattening period from five to 13 weeks of age.

Reodecha and Kijparkorn (1988) while studying the effects of crossbreeding of NZW and Thai native rabbits on growth characteristics found a breed - sex interaction for average daily gain.

Chievicate and Filotto (1989) in the course of studying fattening performance in NZW, Hyla and Provisal Virgin rabbits reported non-significant effect of breed on daily gain.

2.2.2.2 Effect of sex

Vogt (1979) reported non-significant effect of sex for daily gain in crossbred rabbits from eight to 12 weeks of age.

Reodecha and Kijparkorn (1988) reported a significant breed x sex interaction for average daily gain in NZW and Thai native rabbits and their reciprocal crosses.

Erjavec *et al.* (1990) found significant effect of sex in Slovenia rabbits for daily gain from four to eight weeks of age.

El-Maghawry (1988) observed a non-significant effect of sex on daily gain in a group of NZW and CAL breeds of rabbits.

2.2.2.3 Effect of litter size at birth

Rouvier *et al.* (1973) found no significant effect of litter size on growth rate (daily gain) from 21 to 56 days of age in NZW and Burgundy Fawn rabbits.

Vogt (1979) found non-significant pre-weaning carry over effects of litter sizes for average daily gain and for gross feed efficiency for a period from eight week to 12 week in crossbred rabbits.

Narayan *et al.* (1981) reported significant effect of litter size on growth rates in the course of his study on inheritance of growth rate in rabbits.

Erjavec *et al.* (1990) reported that the daily gain in NZW rabbits up to 94 days of age was affected by litter size.

2.2.2.4 Effect of season of birth

Narayan *et al.* (1981) reported a significant effect of month of birth on growth rates up to 14 week of age.

According to Blasco *et al.* (1983) season of birth had a highly significant effect on growth rate, for rabbits born in summer and spring.

El-Maghawry A.M. (1988) reported significant effect of month of birth on average daily gain from five to 12 weeks of age among New Zealand White and CAL rabbits.

2.2.2.5 Effect of year of birth

El-Maghawry A.M. (1988) found that average daily gain was affected significantly by the year of birth in NZW and CAL rabbits.

McNitt and Lukefahr (1993) observed that the year of birth had a significant effect on post-weaning daily gain in NZW, CAL, Palomino and White Satin breeds.

Table 2.2

Daily gain at different periods in rabbits.

Sl No.	Breed	Period*	Daily gain (g)	References
1	SC	45 – 90 d	28.7	Titarev (1971)
		90 – 120 d	15.9	
2	NZW	4 – 6 w	39.1	Rao *et al.* (1977)
		6 – 8 w	36.3	
3	NZW	28 – 77 d	21.83	Lebas and Ouhayoun (1988)
	NZW x CAL	28 – 77 d	31.7	
4	NZW		20.34	Roedecha and Kijparkorn (1988)
	NZW x Thai		21.01	
5	NZW	0 – 65 d	35.41	Erjavec *et al.* (1990)
		65 – 95 d	31.36	
6	NZW x SC	8 – 12 w	8.47	Mishra *et al.* (1990)
7	SC	0 – 4w	16.0	Sundaram and Bhattacharya (1991)
		4 – 16 w	18.0	
8	Selecta	0 – slaughter	22.68	Polastre *et al.* (1992)
9	NZW	28 – 76 d	39.9	Mc Nitt & Lukefahr (1993)
	CAL		35.0	
	Palomino		34.5	
	White Satin		36.0	
10	SC	28 – 84 d	22.45	Gangadevi (1995)
	NZW x SC	28 – 84 d	24.09	

* - d= days, w= weeks

2.3 Feed efficiency

2.3.1 Feed efficiency in different breeds

A brief review on feed efficiency in different breeds of rabbits at different periods is presented in Table 2.3.

2.3.2 Effect of different factors affecting feed efficiency

2.3.2.1 Effect of breed

Ozimba and Lukefahr (1991) found no breed type differences for litter feed efficiency (from 28-70 days) in NZW, CAL purebreds, CAL x NZW and Flemish Giant crossbred rabbits.

Paci *et al.* (1995) reported that in rabbits produced by mating Burgundy Fawn x NZW males with crossbred females the feed conversion ratio did not differ significantly between the two breeds.

2.3.2.2 Effect of sex

Vogt (1979) found in the course of his study on crossbred rabbits non-significant effect of sex on gross feed efficiency.

Battaglini *et al.* (1995) could not find a significant effect of sex on feed conversion efficiency in a group of crossbred rabbits (WG, Heavy Grimand Freres and Light Grimand Freres) with NZW as dam breed.

2.3.2.3 Effect of litter size at birth

Vogt (1979) found a non-significant effect of litter size at birth for gross feed efficiency in crossbred rabbits for a period from eight to 12 weeks.

Ozimba and Lukefahr (1991) reported that the overall linear covariate of litter size at weaning was related negatively to litter feed efficiency in rabbits in four breed types.

2.3.2.4 Effect of season of birth

Crimella *et al.* (1978) while analysing the causes of variation in feed conversion efficiency of rabbits observed a highly significant effect of season of birth.

Barbosa *et al.* (1992) found that season had no significant effect on feed conversion in NZW rabbits.

Ozimba and Lukefahr (1991) reported significant effect of season of birth on feed efficiency in rabbits representing four breed types (NZW, CAL, CAL x NZW and FG crossbred rabbits).

2.4 Heritability

2.4.1 Heritability of body weight

Table 2.4 presents some estimates of heritabilities of body weight at different ages for rabbits.

Table 2.3

Estimates of feed efficiency in broiler rabbits.

Sl No.	Breed	Feed efficiency	Period *	References
1	NZW	3.9	28 d to 56 d	Grobner *et al.* (1985)
2	NZW	3.5	28 d to 90 d	Niedzwiadek (1983)
3	CAL NZW CAL x NZW NZW x CAL	3.7 3.5 3.5 3.2	5 to 13 w	Mach *et al.* (1986)
4	NZW	3.41	28 d to 77 d	Grandi and Stefanetti (1987)
5	NZW	5.108	45 d to 75 d	Pizzzi and Crimella (1987)
6	NZW Thai native NZW x Thai	3.71 4.14 3.80	1 to 10 w	Roedech and Kijparkorn (1988)
7	SC GG WG	3.22 3.93 3.78	7 to 12 w	Das and Nayak (1991)
8	NZW CAL CAL x NZW FG	3.3 3.9 3.7 3.2	28 d to 70 d	Ozimba and Lukefahr (1991)

* d – days, w - weeks

Table 2.4

Estimates of heritabilities of body weight at different ages.

Sl. No	Breed	Heritability estimates			Reference
		Sire	Dam	Sire + Dam	
					4th week weight (weaning)
1	NZW	Negative	1.45 ± 0.16		Blasco *et al.* (1983)
2	NZW	0.85 ± 0.89	0.87 ± 0.75	0.86 ± 0.45	Radhakrishnan (1992)
3	SC	0.35 ± 0.73	0.72 ± 0.88	0.54±0.37	Radhakrishnan (1992)
					1 month weight (weaning)
4	NZW	0.10 ± 0.05	0.55 ± 0.15	0.33 ± 0.11	El-Amin (1974)
					6th week weight
5	Bouscat			0.63 ± 0.08	Khalil (1986)
6	Giza White			0.80 ± 0.10	Khalil (1986)
7	NZW	0.69 ± 0.81	0.96 ± 0.74	0.83 ± 0.41	Radhakrishnan (1992)
8	SC	0.46 ± 0 .73	0.56 ± 0.82	0.52 ± 0.38	Radhakrishnan (1992)
					8th week weight
9	NZW	0.57 ± 0.16	1.55 ± 0.2	1.060	Randi and Scossciroli (1980)
10	Bouscat			0.59 ± 0.08	Khalil (1986)
11	Giza White			0.61 ± 0.10	Khalil (1986)
12	NZW	0.69 ± 0.82	0.55 ± 0.80	0.62 ± 0.43	Radhakrishnan (1992)
13	SC	0.41 ± 0.71	0.58 ± 0.82	0.49 ± 0.37	Radhakrishnan (1992)
					2 month weight
14	NZW	0.72 ± 0.31	1.61 ± 0.09	1.17 ± 0.86	El-Amin (1974)
					10th week weight
15	Bouscat			0.59 ± 0.09	Khalil (1986)
16	Giza White			0.68 ± 0.11	Khalil (1986)
17	NZW	0.57 ± 0.75	0.23 ± 0.80	0.40 ± 0.41	Radhakrishnan (1992)
18	SC	0.4 ± 0.71	0.58 ± 0.23	0.49 ± 0.37	Radhakrishnan (1992)
					12th week weight
19	Bouscat			0.39 ± 0.08	Khalil (1986)
20	Giza White			0.64 ± 0.12	Khalil (1986)
21	NZW	0.47 ± 0.73	0.28 ± 0.85	0.37 ± 0.41	Radhakrishnan (1992)
22	SC	0.23 ± 0.73	0.89 ± 0.94	0.56 ± 0.37	Radhakrishnan (1992)

2.4.2 Heritability of daily gain

The brief review of estimates of heritability of daily gain is given in Table 2.5.

2.4.3 Heritability of feed efficiency

Table 2.6 gives the review of estimates of heritability of feed efficiency.

2.5 Correlation

2.5.1 Phenotypic correlation

2.5.1.1 Among body weights at different ages

The review of phenotypic correlation between body weights at different ages is summarised in Table 2.7.

2.5.2 Genetic correlation

2.5.2.1 Among body weights at different ages

The estimates of genetic correlation are reviewed in Table 2.8.

2.5.2.2 Genetic correlation of FE and body weight and daily gain

Vogt (1979) reported that the genetic correlation between daily gain and feed efficiency ranged from -0.85 to -1.00 for four generations of crossbred rabbits by regression of offspring on mid-parent method.

Moura *et al.* (1996) estimated the genetic correlation between average daily gain and feed efficiency as – 0.71 in Selecta rabbits.

Table 2.5

Estimates of heritabilities of daily gain.

Sl No.	Breed	Period *	Heritability estimate	References
1	NZW	21-56 d	0.22	McReynolds (1974)
2	Cross breds		0.13±0.11to0.54±0.13	Vogt (1979)
3	NZW	0-65 d	0.290	Erjavec *et al.* (1990)
4	NZW		0.20	Mc Nitt & Lukefahr (1995)

* d - days

Table 2.6

Estimates of heritability of feed efficiency.

Sl. No.	Breed	Period *	Heritability	References
1	CB	8 – 12 w	0.08± 0.05 to 0.60 ± 0.13	Vogt (1979)
2	NZW	28 – 90 d	0.312 ± 0.128	Niedzwiadek (1978)
3	White Termonde		Low	Varewyek *et al.* (1987)
4	NZW	6 – 9 w 6 – 12 w 9 – 12 w	0.26 0.35 0.29	Kustos & Huller (1992)
5	CB		0.47	Moura *et al.* (1996)

* - d – days, w - weeks

Table 2.7

Estimates of phenotypic correlations between rabbit body weights at different ages.

Sl. No.	Correlation between body weights at	Breed and estimate		References
1		NZW		
	4 and 12 weeks	0.577		Niedzwiadek (1978)
2		Bouscat, Chinchilla, Giza Whtie and their crosses		Afifi *et al.* (1980)
	6 – and 8 weeks	0.879		
	6 - and 10 weeks	0.774		
	6 - and 12 weeks	0.718		
	8 - and 10 weeks	0.906		
	8 - and 12 weeks	0.824		
	10 - and 12 weeks	0.910		
3		NZW		Randi and Scossiroli (1980)
	8 - and 11 weeks	0.71		
	8 - and 14 weeks	0.64		
	11 - and 14 weeks	0.75		
4		NZW		
	4 - and 11 weeks	0.61		Blasco *et al.* (1983)
5		Bouscat	Giza White	Khalil (1986)
	5 - and 6 weeks	0.77	0.77	
	5- and 8 weeks	0.59	0.55	
	5 - and 10 weeks	0.51	0.49	
	5 - and 12 weeks	0.47	0.45	
	6 - and 8 weeks	0.76	0.69	
	6 - and 10 weeks	0.63	0.59	
	6 - and 12 weeks	0.54	0.55	
	8 - and 10 weeks	0.81	0.74	
	8 - and 12 weeks	0.71	0.64	
	10 - and 12 weeks	0.84	0.63	
6		NZW	SC	Radhakrishnan (1992)
	4 and 6 weeks	0.985	0.995	
	4 and 8 weeks	0.948	0.995	
	4 –and 10 weeks	0.886	0.993	
	4 - and 12 weeks	0.888	0.962	
	6 - and 8 weeks	0.956	0.999	
	6 - and 10 weeks	0.887	0.998	
	6 - and 12 weeks	0.888	0.966	
	8 - and 10 weeks	0.950	0.999	
	8 - and 12 weeks	0.951	0.966	
	10 - and 12 weeks	0.996	0.968	

Table 2.8
Estimates of genetic correlations between rabbit body weights at different ages.

Sl. No.	Breed	Estimates based on			References
		Sire	Dam	Sire + Dam	
					4 – and 6 – week weight
1	NZW	1.002	0.989	0.996	Radhakrisnan (1992)
	SC	1.020	0.996	0.997	Radhakrisnan (1992)
					4 – and 8 –week weight
2	NZW	0.930	0.973	0.947	Radhakrisnan (1992)
	SC	1.017	0.993	0.998	Radhakrisnan (1992)
					4 - and 10 -week weight
3	NZW	0.934	1.109	0.987	Radhakrisnan (1992)
	SC	1.016	0.991	0.997	Radhakrisnan (1992)
					4 - and 12 -week weight
4	NZW	0.992	1.007	0.997	Radhakrisnan (1992)
	SC	0.927	1.030	0.994	Radhakrisnan (1992)
					6 - and 8 -week weight
5	Bouscat	1.16±0.07	0.72±0.07	0.81±0.05	Khalil *et al.* (1986)
	Giza White	1.17±0.08	0.62±0.12	0.79±0.07	Khalil *et al.* (1986)
6	NZW	0.952	0.941	0.944	Radhakrisnan (1992)
	SC	1.002	1.001	1.001	Radhakrisnan (1992)
					6 - and 10 –week weight
7	Bouscat	0.96±0.08	0.57±0.11	0.66±0.09	Khalil *et al.* (1986)
	Giza White	1.23±0.11	031±0.19	0.66±0.11	Khalil *et al.* (1986)
8	NZW	0.973	0.967	0.971	Radhakrisnan (1992)
	SC	1.002	1.001	1.001	Radhakrisnan (1992)
					6 - and 12 –week weight
9	Bouscat	1.04±0.24	0.49±0.14	0.58±0.12	Khalil *et al.* (1986)
	Giza White	0.91±0.10	0.34±0.19	0.54±0.14	Khalil *et al.* (1986)
10	NZW	1.038	0.851	0.976	Radhakrisnan (1992)
	SC	1.048	1.017	0.992	Radhakrisnan (1992)
					8 - and 10 –week weight
11	Bouscat	1.15±0.17	0.81±0.06	0.83±0.05	Khalil *et al.* (1986)
	Giza White	0.99±0.04	0.69±0.11	0.78±0.08	Khalil *et al.* (1986)
12	NZW	1.016	1.959	0.998	Radhakrisnan (1992)
	SC	0.999	1.001	0.999	Radhakrisnan (1992)
					8 - and 12 –week weight
13	Baladi Red			0.058	Nossier (1970)
14	Bouscat	1.34±0.64	0.70±0.1	0.73±0.09	Khalil *et al.* (1986)
	Giza White	1.25±0.13	0.46±0.16	0.66±0.11	Khalil *et al.* (1986)
15	NZW	1.072	0.846	0.996	Radhakrisnan (1992)
	SC	1.022	1.014	1.092	Radhakrisnan (1992)
					10 - and 12 –week weight
16	Baladi Red			0.056	Nossier (1970)
17	Bouscat	1.24±0.20	0.76±0.08	0.82±0.06	Khalil *et al.* (1986)
18	NZW	1.009	1.004	0.997	Radhakrisnan (1992)
	SC	1.027	1.009	0.991	Radhakrisnan (1992)

2.6 Carcass characteristics

A brief review of dressing per cent is presented in Table 2.9.

2.7 Selection Index

Mostageer *et al.* (1970) working with Giza White rabbits, concluded that body weight at weaning (at four weeks) could be used for selection and improvement of body weight at 90 days of age.

McReynolds (1974) working with NZW rabbits constructed an index for selecting rabbits based on 21-day weight (P_{21}) and gain from 21 to 56 days of age (P_G). The index was

$I = 0.875\ P_{21} + 0.169\ P_G$. The index was found to be approximately 1.13 times more accurate than direct selection.

Khalil (1986) constructed four selection indices for Bouscat and Giza White rabbits in Egypt. He found that the index based on body weight at sixth and eighth week was the best criterion for selection for the genetic improvement of rabbits at six and 12 weeks.

Table 2. 9
Dressing percentage in broiler rabbits.

Sl. No	Breed	Dressing per cent	Reference
1	SC	58.40	Parillo and Vaseninam (1984)
2	NZW	48.80	Grobner *et al.* (1985)
3	SC NZW	53.51 54.72	Kuttinarayanan and Nandakumar (1989)
4	WG GG x *Chinchilla*	49.21 49.21	Gupta *et al.* (1993)
5	SC NZW SC x NZW NZW x SC	41.69 43.70 48.08 41.78	Mukundan (1993)
6	SC Cross bred	47.43 48.41	Gangadevi (1995)

MATERIALS AND METHODS

MATERIALS AND METHODS

The experimental work was carried out at the rabbitry attached to the Animal Science Division of the Regional Agricultural Research Station, Pilicode during the period from October 1997 to May 1999.

3.1 Rabbits

The experimental animals belonged to three genetic groups *viz*. New Zealand White, Soviet Chinchilla and their crosses. Each group consisted of three paternal half-sib groups. The data were generated by producing young ones by purebreeding New Zealand White and Soviet Chinchilla and by crossing Soviet Chinchilla males with New Zealand White females.

3.2 Management and husbandry

3.2.1 Breeding

The breeding was done by transferring each doe to the buck's hutch to be mated. Hand mating was exercised by restraining the doe to assure copulation. Does were palpated ten days after the date of mating to determine pregnancy. The does that failed to conceive were returned to the same buck for service once again. After 28 days of pregnancy a specially prepared nest box was provided to each female. The litter of young rabbits was recorded within 24 hours after birth.

The weaning was done at four weeks after birth. At weaning each bunny was ear tagged and caged individually.

3.2.2 Feeding

Rabbits were fed concentrate feed (Appendix-1) and green fodder (Hybrid Napier) *ad libitum*. Drinking water was provided throughout day and night in each cage. Concentrate feed was provided in the form of wet mash. Concentrate feed and green grass were given twice daily i.e., in the morning and in the evening.

3.3 Observations

3.3.1 Body weight

Body weight of each animal was recorded at biweekly intervals from fourth week to twelfth weeks of age.

3.3.2 Feed intake

The weight of concentrate feed and green fodder being fed were recorded before each feeding and the balance was weighed.

3.3.3 Carcass characteristics

A rabbit from each sire group was slaughtered at the end of the experiment and carcass yield was recorded for working out dressing percent.

3.3.4 Feed efficiency

Feed efficiency was calculated as a ratio of weight in gram of feed consumed to the weight gain in gram for each animal,

$$FE = \frac{\text{weight of feed consumed (g)}}{\text{weight gain (g)}}$$

3.3.5 Daily weight gain

Average daily gain (ADG) between four and 12 weeks was worked out for each animal as a ratio of the difference in body weight and number of days.

$$ADG = \frac{W_1 - W_0}{D}$$

Where W_1 = Final weight

W_0 = Initial weight

D = No. of days

3.4 Statistical Analysis

The influence of genetic and non-genetic factors on feed efficiency, body weight at various ages and ADG during different periods were worked out by least squares analysis of variance as described by Harvey (1987) for non-orthogonal data. The non-genetic factors considered were sex, litter size (from two to six), season and year of birth. The season was divided into summer

(February to May), monsoon (June to September), post-monsoon (October to November) and winter (December to January). The model used was,

$$Y_{ijklmn} = \mu + B_i + S_j + Z_k + E_l + R_m + e_{ijklmn}$$

where

Y_{ijklmn} - observation on the n^{th} rabbit of the i^{th} breed of j^{th} sex, k^{th} litter size, born on l^{th} season of m^{th} year

μ - common mean

B_i - effect of i^{th} genetic group (i = 1-3)

S_j - effect of the j^{th} sex (j =1-2)

Z_k - effect of the k^{th} litter size at birth (k=1-5)

E_l - effect of the l^{th} season of birth (l=1-4)

R_m - effect of the m^{th} year (m=1-3)

e_{ijklmn} - random error

The significance of the genetic and non-genetic factors was tested by the 'F' test.

3.4.1 Estimation of Heritability

The heritability and its standard error were estimated by the method described by Becker (1975) for unbalanced design. The statistical model was,

$$Y_{ijk} = \mu + S_i + D_{ij} + e_{ijk}$$

Where,

Y_{ijk} - observation of the k^{th} progeny of the j^{th} dam mated to the i^{th} sire.

μ - common mean.

S_i - effect of the i^{th} sire.

D_{ij} - effect of j^{th} dam mated to the i^{th} sire.

e_{ijk} - uncontrolled environmental and genetic deviations attributable to the individual.

All effects are assumed to be random, normal and independent with expectations equal to zero.

3.4.2 Estimation of correlation

The genetic and phenotypic correlation and their standard error values were calculated for all combinations of body weights, for FE with body weight at 12 weeks and for FE with ADG from four to 12 weeks by the analysis of covariance for nested design as described by Becker (1975).

3.5 Selection Index

A selection index for estimating the breeding values of the animals based on the phenotypic value of the body weight at 12^{th} week and feed efficiency from four to twelve weeks and the economic weights of the traits, was constructed for each pure breed as given below

$I = b_1 (y_1 - \mu) + b_2 (y_2 - \mu)$, the index equations are

$$b_1 p_{11} + b_2 p_{12} = w_1 g_{11} + w_2 g_{12}$$

$$b_1 p_{12} + b_2 p_{22} = w_1 g_{21} + w_2 g_{22}$$

where,

I	-	Index
b_1	-	the coefficient by which 12th week body weight was weighed
b_2	-	the coefficient by which feed efficiency is weighed
μ	-	mean value for respective traits
y	-	phenotypic value for the respective traits.
p_{11}, p_{22}	-	phenotypic variance for 12th week weight and FE respectively
g_{11}, g_{22}	-	genotypic variance for 12th week weight and FE respectively
p_{12}, g_{12}	-	phenotypic and genetic covariance
w_1, w_2	-	economic weights for 12th week weight and FE respectively

Economic weights

a) Twelfth week body weight

The average dressing per cent of each breed and the market rate (Rs.100 per kg dressed meat) were considered in calculating the economic weight for 12th week body weight.

b) Feed efficiency

The quantity of feed taken by each animal and its cost (Rs 9/kg concentrate feed and Rs. 0.5/kg of fodder) were considered in calculating economic weight for feed efficiency.

RESULTS

RESULTS

4.1 Growth traits

4.1.1 Body weight at different ages

The mean body weights of New Zealand White (NZW), Soviet Chinchilla (SC) and Crossbred (CB) rabbits at different ages are presented in Table 4.1.

4.1.2 Effect of different factors on body weight at different ages

Least squares means for body weights at different ages according to breed, sex, litter size at birth, season and year of birth are presented in Table 4.1 and least square analysis of variance in Table 4.2.

4.1.2.1 Effect of breed

Effect of breed was highly significant ($P \leq 0.01$) for fourth week body weight. Least squares means were highest for CB rabbits (319.0 ± 21.6 g) followed by SC (268.6 ± 18.2 g) and NZW (236.7 ± 20.6 g).

Three genetic groups differed significantly ($P \leq 0.01$) for sixth week body weight. Soviet Chinchilla had the highest body weight of 568.1 ± 24.2 g followed by CB rabbits (506.6 ± 28.8 g). Lowest body weight at sixth week was observed in NZW (461.7 ± 27.4 g).

The effect of breed on body weight at eighth week was found to be highly significant ($P \leq 0.01$). Least squares means were highest for SC with 809.6 ± 27.4 g followed by cross bred and NZW.

Table 4.1

Least-squares means for body weight at different ages in rabbits according to breed, sex, litter size, season and year of birth

Source	No	4-th week weight g.	6-th week weight g.	8-th week weight g.	10-th week weight g.	12-th week weight g.
Breed						
NZW	28	236.7 ± 20.6^{a}	461.7 ± 27.4^{a}	678.2 ± 31.0^{a}	934.2 ± 44.1^{a}	1117.7 ± 51.5^{a}
SC	21	268.6 ± 18.2^{b}	568.1 ± 24.2^{b}	809.6 ± 27.4^{b}	1007.1 ± 38.9^{b}	1272.3 ± 45.4^{b}
Cross bred	22	319.0 ± 21.6^{c}	506.6 ± 28.8^{c}	708.1 ± 32.5^{a}	1019.5 ± 46.3^{b}	1214.2 ± 54.0^{b}
Sex						
Male	37	285.9 ± 14.4^{a}	515.5 ± 19.2	736.3 ± 21.7	1001.2 ± 30.9	1220.9 ± 46.0
Female	34	263.7 ± 14.9^{b}	508.7 ± 19.8	727.6 ± 22.4	972.7 ± 31.8	1181.9 ± 37.1
Litter size						
Two	6	$298.9 \pm 22.9^{a,b}$	533.6 ± 30.5^{a}	$763.2 \pm 34.5^{a,b}$	1002.8 ± 49.0^{a}	1207.8 ± 57.2^{a}
Three	18	334.9 ± 13.3^{a}	625.3 ± 17.7^{b}	869.9 ± 20.0^{c}	1074.9 ± 28.4^{a}	1323.4 ± 33.2^{b}
Four	36	290.0 ± 12.5^{b}	578.1 ± 16.6^{a}	811.9 ± 18.7^{b}	1041.1 ± 26.6^{a}	1256.4 ± 31.1^{a}
Five	5	215.8 ± 29.2^{c}	476.0 ± 38.7^{a}	707.8 ± 43.8^{a}	1001.0 ± 62.3^{a}	1189.1 ± 72.7^{a}
Six	6	234.3 ± 32.9^{c}	374.6 ± 43.7^{c}	506.9 ± 49.5^{d}	814.9 ± 70.4^{b}	1030.3 ± 21.1^{c}
Season of birth						
Summer	27	324.4 ± 19.2^{a}	608.0 ± 25.5^{a}	830.4 ± 41.0^{a}	1053.6 ± 41.0	1350.8 ± 47.9
Monsoon	30	291.0 ± 19.1^{b}	461.2 ± 25.3^{b}	662.3 ± 28.7^{b}	948.0 ± 40.7	1140.6 ± 47.5
Post-monsoon	11	288.1 ± 20.7^{b}	453.0 ± 27.4^{b}	$676.2 \pm 31.1b^{c}$	955.7 ± 44.1	1134.8 ± 51.5
Winter	3	195.6 ± 38.4^{c}	526.4 ± 51.0^{b}	$758.9 \pm 57.7^{a,c}$	990.5 ± 82.0	1179.5 ± 95.6
Year of birth						
1997	28	330.4 ± 12.2^{a}	592.8 ± 16.2^{a}	796.2 ± 18.3^{a}	1028.4 ± 26.0	1294.3 ± 30.3^{a}
1998	24	235.2 ± 19.7^{b}	458.7 ± 26.2^{b}	670.5 ± 29.7^{b}	940.5 ± 42.2	1127.9 ± 49.2^{b}
1999	19	258.8 ± 25.7^{b}	484.9 ± 34.2^{b}	729.1 ± 38.7^{c}	992.0 ± 55.0	1181.9 ± 64.2^{b}
Overall mean (μ)	71	274.8 ± 13.6	512.1 ± 18.1	732.0 ± 20.5	986.9 ± 29.1	1201.4 ± 33.9

Values bearing different superscripts within source differ significantly ($P \leq 0.05$)

Table 4.2

Least-squares analysis of variance for the effect of breed, sex, litter size at birth, season and year of birth among broiler rabbits

Source	df	4-th week	6-th week	8-th week	10-th week	12-th week
		Mean squares	Mean squares	Mean squares	Mean squares	Mean squares
Overall	71	19240.2	31357.1	32293.4	15991.5	40785.5
Breed	2	19199.8**	23135.5**	29169.5**	27540.6*	62383.0**
Sex	1	7769.0*	721.5	1177.9	12716.7	23836.6
Size	4	9456.4**	35317.3**	57956.7**	28176.2*	35528*
Season	3	6107.0*	15642.0**	20037.6**	7240.3	29215.0
Year	2	16191.4**	31047.9**	34874.7**	19618.7	52820.6*

* $P \leq 0.05$
** $P \leq 0.01$

Effect of breed was significant ($P \leq 0.05$) for tenth week body weight. Cross breds had highest least square means of 1019.5 ± 46.3 g followed by NZW and SC.

Three genetic groups differed significantly ($P \leq 0.05$) for twelfth week body weight. Soviet Chinchilla had highest least square means of 1272.3 ± 45.4 g.

4.1.2.2 Effect of sex

Effect of sex was significant ($P \leq 0.05$) at fourth week only with an average of 285.9 ± 14.4 g and 263.7 ± 14.9 g for males and females respectively.

4.1.2.3 Effect of litter size at birth

Effect of litter size was highly significant ($P \leq 0.01$) at fourth week. Highest least-squares mean was observed in litter size three with 334.9 ± 13.3 g followed by litter size two with 298.9 ± 22.9 g. Litter size five group had the lowest mean of 215.8 ± 29.2 g.

At sixth week, litter size exerted highly significant effect ($P \leq 0.01$) on body weight. Least squares means ranged from 374.6 ± 43.7 g for six sized litter to 625.3 ± 17.7 g for three sized litter.

Effect of litter size was highly significant ($P \leq 0.01$) at eight weeks of age. Three-litter sized group had highest least square mean

(869.9 ± 20.0 g) followed by four-litter sized group (811.9 ± 18.7 g). Six-litter sized group had least mean value of 506.9 ± 49.5 g.

Significant ($P \leq 0.05$) effect of litter size at tenth week body weight was observed. Highest least square mean was observed in three litter sized group (1074.9 ± 28.4 g) and least value in six litter sized group (814.9 ± 70.4 g).

Groups with different litter sizes differed significantly ($P \leq 0.05$) at 12th week. Least square means ranged from 1323.4 ± 33.2 g in three sized group to 1030.3 ± 21.1 g in six-litter size group.

4.1.2.4 Effect of season of birth

Effect of season of birth was significant ($P \leq 0.01$) at fourth week. Summer born rabbits had highest least square mean of 324.4 ± 19.2 g followed by monsoon born kits (291.0 ± 19.1 g), post-monsoon born (288.1 ± 20.7 g) and winter born (195.6 ± 38.4 g) rabbits.

At 6th week of age significant ($P \leq 0.01$) effect of season of birth was found. Least square means ranged from 453.0 ± 27.4 g for post-monsoon born rabbits to 608.0 ± 25.5 g for summer born rabbits.

Highly significant ($P \leq 0.01$) effect of season was found at eighth week of age. Summer born rabbits had highest least square mean of 830.4 ± 41.0 g followed by winter born rabbits (758.9 ± 57.7 g). Least value was observed in monsoon born rabbits(662.3 ± 28.7 g).

Season of birth had no significant effect on body weight at tenth week of age. Least square means were 1053.6 ± 41.0, 948.0 ± 40.7, 955.7 ± 44.1 and 990.5 ± 82.0 g for summer born, monsoon born, post-monsoon born and winter born rabbits respectively.

At twelfth week season of birth had significant ($P \leq 0.05$) effect on body weight. Least square means were highest for summer born rabbits (1350.8 ± 47.9 g), followed by winter born rabbits (1179.5 ± 95.6 g), monsoon born rabbits (1140.6 ± 47.5 g) and post-monsoon born rabbits (1134.8 ± 51.5 g).

4.1.2.5 Effect of year of birth

Year of birth significantly ($P \leq 0.01$) affected body weight at fourth week. Least square mean was highest for year 1997 (330.4 ±12.2 g), followed by year 1999 (258.8 ± 25.7 g) and year 1998 (235.2 ± 19.7 g).

Highly significant ($P \leq 0.01$) year effect was found at sixth week. Rabbits born in 1997 had highest mean of 592.8 ± 16.2 g, followed by those born in 1999 (484.9 ± 34.2 g) and those born in 1998 (458.7 ± 26.2 g).

At eighth week of age year of birth had highly significant ($P \leq 0.01$) effect on body weight. Least square means were highest for rabbits born in 1997 (796.2 ± 18.3 g), followed by those born in 1999 (729.1 ± 38.7 g) and those born in 1998 (670.5 ± 29.7 g).

Year of birth exerted no significant effect on tenth week body weight. Least square means were higher for year 1997 (1028.4 ± 26.0 g), followed by year 1999 (992.0 ± 55.0 g) and year 1998 (940.5 ± 42.2 g).

Effect of year of birth on body weight was not significant at twelfth week. Least square means were highest for year 1997 (1294.3 ± 30.3 g) followed by year 1999 (1181.9 ± 64.2 g) and year 1998 (1127.9 ± 49.2 g).

4.2 Daily Gain

4.2.1 Daily gain at different periods

Overall average daily gain were 16.95 ± 0.74, 15.70 ± 0.97, 18.21 ± 0.91, 15.32 ± 1.17 and 16.54 ± 0.52 g for 4 to 6, 6 to 8, 8 to 10, 10 to 12 and 4 to 12 week periods respectively. (Table 4.3.)

4.2.2 Effect of different factors on daily gain

Least square means for daily gain at different periods according to breed, sex, litter size at birth, season and year of birth are presented in Table 4.3 and least square analysis of variance in Table 4.4.

4.2.2.1 Effect of breed

Soviet Chinchilla had highest overall daily gain of 17.90 ± 0.69 g followed by CB (15.98 ± 0.83 g) and NZW (15.72 ± 0.79 g).

Table 4.3

Least-Squares means for daily gain at different intervals in rabbits according to breed, sex, litter size, season and year of birth. in g.

Source	No.	4-6th week	6-8th week	8-10th week	10-12th week	4-12th week
Breed						
NZW	28	16.07 ± 1.12^{a}	15.46 ± 1.47	18.29 ± 1.39^{a}	13.10 ± 1.78^{a}	15.72 ± 0.79
SC	21	21.39 ± 0.99^{b}	17.24 ± 1.29	14.11 ± 1.22^{b}	18.94 ± 1.57^{b}	17.90 ± 0.69
Cross bred	22	13.40 ± 1.18^{c}	14.39 ± 1.54	22.24 ± 1.46^{c}	13.91 ± 1.87^{a}	15.98 ± 0.83
Sex						
Male	37	16.40 ± 0.78	15.77 ± 1.02	18.92 ± 0.97	15.69 ± 1.24	16.69 ± 0.55
Female	34	17.51 ± 0.81	15.63 ± 1.06	17.51 ± 1.00	14.94 ± 1.28	16.39 ± 0.57
Litter size						
Two	6	16.76 ± 1.24^{a}	16.40 ± 1.63	17.11 ± 1.54^{a}	14.64 ± 1.98	16.22 ± 0.87
Three	18	20.76 ± 0.72^{b}	17.45 ± 0.94	14.64 ± 0.89^{b}	17.75 ± 1.15	17.65 ± 0.51
Four	36	20.58 ± 0.68^{b}	16.70 ± 0.89	16.38 ± 0.84^{a}	15.38 ± 1.07	17.26 ± 0.48
Five	5	18.58 ± 1.58^{a}	16.56 ± 2.07	20.95 ± 1.96^{c}	13.43 ± 2.51	17.36 ± 1.11
Six	6	8.09 ± 1.79^{c}	11.38 ± 2.34	21.99 ± 2.21^{c}	15.39 ± 2.84	14.19 ± 1.26
Season of birth						
Summer	27	20.26 ± 1.04^{a}	15.88 ± 1.36	15.95 ± 1.29	21.22 ± 1.65^{a}	18.33 ± 0.73^{a}
Monsoon	30	12.16 ± 1.03^{b}	14.36 ± 1.35	20.40 ± 1.28	13.76 ± 1.64^{b}	15.16 ± 0.73^{b}
Post-monsoon	11	11.78 ± 1.12^{b}	15.94 ± 1.47	19.96 ± 1.39	12.79 ± 1.78^{b}	15.11 ± 0.79^{b}
Winter	3	23.62 ± 2.08c	16.61 ± 2.72	16.54 ± 2.58	13.50 ± 3.31^{b}	17.56 ± 1.46^{a}
Year of birth						
1997	28	18.75 ± 0.66	14.53 ± 0.86	16.59 ± 0.82	19.00 ± 1.05^{a}	17.21 ± 0.46
1998	24	15.96 ± 1.07	15.13 ± 1.40	19.28 ± 1.33	13.39 ± 1.70^{b}	15.93 ± 0.75
1999	19	16.15 ± 1.40	17.44 ± 1.83	18.77 ± 1.73	13.57 ± 2.22^{b}	16.47 ± 0.98
Overall Mean (μ)	71	16.95 ± 0.74	15.70 ± 0.97	18.21 ± 0.91	15.32 ± 1.17	16.54 ± 0.52

Values bearing different superscripts within source differ significantly ($P \leq 0.05$)

Table 4.4

Least-squares analysis of variance for the effect of breed, sex, litter size, season and year of birth on daily gain in broiler rabbits

Source	df	4-6th week	6-8th week	8-10th week	10-12th week	4-12th week
		Mean squares	Mean squares	Mean squares	Mean squares	Mean squares
Overall	71	7.52	0.037	14.472	29.1224	0.01346
Breed	2	59.429**	7.4876	64.172**	54.4171*	0.07601
Sex	1	19.1158	0.2888	31.3736	8.8474	0.013662
Size	4	73.6088**	16.4076	33.2922**	13.4378	0.4948
Season	3	99.8634**	6.2353	17.588	42.2818*	0.08559*
Year	2	12.6417	14.1332	12.5111	50.7914*	0.03436

* $P \leq 0.05$

** $P \leq 0.01$

Breed had significant effect on daily gain at four to six weeks interval ($P \leq 0.01$), eight to ten week period ($P \leq 0.01$) and 10 to 12 week period ($P \leq 0.05$).

Soviet Chinchilla rabbits maintained higher gains at all periods except between eighth and tenth week at which CB gained more. CB *rabbits had highest gain at eight to ten week period* (22.24 ± 1.46 g) followed by NZW (18.29 ± 1.39 g) and SC (14.11 ± 1.22 g).

4.2.2.2 Effect of sex

Sex did not have significant influence at any period on daily gain.

4.2.2.3 Effect of litter size at birth

Litter size had significant effect on daily gain at four to six week ($P \leq 0.01$) and eight to ten week ($P \leq 0.01$) periods only.

Least squares mean for overall daily gain (from four to 12 weeks) for litter sizes two, three, four, five and six were 16.22 ± 0.87, 17.65 ± 0.51, 17.26 ± 0.48, 17.36 ± 1.11 and 14.19 ± 1.26 g respectively.

4.2.2.4 Effect of season of birth

Season of birth had significant ($P \leq 0.05$) effect on daily gain from *four to 12 weeks ($P \leq 0.05$), ten to 12 week ($P \leq 0.05$) and four to six week* ($P \leq 0.01$) periods.

Summer had highest mean of 18.33 ± 0.73 g, followed by winter (17.56 ± 1.46 g), monsoon (15.16 ± 0.73 g) and post monsoon (15.11 ± 0.79 g) for daily gain from four to 12 weeks.

4.2.2.5 Effect of year of birth

Year effect was significant at ten to 12 week ($P \leq 0.05$) period only. Year 1997 had highest mean of 17.21 ± 0.46 g, followed by 1999 (16.47 ± 0.98 g) and year 1998 (15.93 ± 0.75 g) for four to 12 week period.

4.3 Feed efficiency

4.3.1 Feed efficiency at different stages

Overall mean and standard error of feed efficiency for different periods are presented in *Table* 4.5.

4.3.2.1 Effect of different factors on feed efficiency

Table 4.5 depicts least square means of feed efficiency for different periods according to breed, sex, litter size at birth, season and year of birth and data on least square analysis are presented in Table 4.6.

4.3.2.2 Effect of breed

Breed effect was found to be highly significant for feed efficiency from 4 to 12 week period. Crossbred rabbits had highest feed efficiency of 3.766 ± 0.061, followed by SC (4.125 ± 0.051) and NZW (4.179 ± 0.058) between 4 to 12 weeks of age.

Crossbred rabbits had the highest efficiency at all periods from 4 to 12 weeks which ranged from 2.803 ± 0.079 for 4 to 6 week period to 4.695 ± 0.081 for 10 to 12 week period. The efficiency of feed conversion was the lowest for SC rabbits during 4 to 6 week (3.148 ± 0.066) and 10 to 12 week (5.119 ± 0.068) periods while NZW had the lowest mean at 6 to 8 week *period (4.252 ± 0.130) and 8 to 10 week period (4.599 ± 0.105).*

4.3.2.2 Effect of sex

In Table 4.6 data on least square analysis of variance of sex effect on FE are presented. Sex had no significant effect on FE at any period.

4.3.2.3 Effect of litter size

Data on least square analysis of variance for the effect of litter size at birth on FE is detailed in Table 4.6. Litter size had no significant effect on FE.

4.3.2.4 Effect of season of birth

Least square analysis of variance of effect of season of birth on FE *is shown in Table 4.6. Season had no significant effect on FE* at all periods.

4.3.2.5 Effect of year of birth

Least squares analysis of variance for effect of year of birth on FE is given in Table 4.6. Year of birth had no significant effect on FE.

Table 4.5

Least-Squares means for feed efficiency at different intervals in rabbits according to breed, sex, litter size, season and year of birth.

Source	No.	4-6th week	6-8th week	8-10th week	10-12th week	4-12th week
Breed						
NZW	28	2.853 ± 0.075	4.252 ± 0.130	4.599 ± 0.105^{a}	5.011 ± 0.077	4.179 ± 0.058^{a}
SC	21	3.148 ± 0.066	3.943 ± 0.114	4.291 ± 0.092^{b}	5.119 ± 0.068	4.125 ± 0.051^{a}
Cross bred	22	2.803 ± 0.079	3.667 ± 0.136	3.900 ± 0.110^{c}	4.695 ± 0.081	3.766 ± 0.061^{b}
Sex						
Male	37	2.943 ± 0.053	3.920 ± 0.091	4.289 ± 0.073	4.953 ± 0.054	4.026 ± 0.041
Female	34	2.927 ± 0.054	3.988 ± 0.093	4.237 ± 0.075	4.930 ± 0.056	4.021 ± 0.042
Litter size						
Two	6	2.942 ± 0.083	3.963 ± 0.144	4.352 ± 0.116	4.877 ± 0.086	4.033 ± 0.064
Three	18	2.901 ± 0.048	3.938 ± 0.083	4.280 ± 0.067	4.964 ± 0.050	4.021 ± 0.037
Four	36	2.993 ± 0.045	3.863 ± 0.078	4.318 ± 0.063	5.024 ± 0.047	4.050 ± 0.035
Five	5	3.130 ± 0.106	3.884 ± 0.183	4.217 ± 0.148	4.986 ± 0.109	4.054 ± 0.082
Six	6	2.708 ± 0.120	4.121 ± 0.207	4.149 ± 0.167	4.857 ± 0.123	3.959 ± 0.093
Season of birth						
Summer	27	2.896 ± 0.070	3.814 ± 0.120	4.217 ± 0.097	4.874 ± 0.072	3.950 ± 0.054
Monsoon	30	2.992 ± 0.069	3.795 ± 0.120	4.347 ± 0.097	4.884 ± 0.071	4.005 ± 0.054
Post-monsoon	11	2.808 ± 0.075	3.707 ± 0.130	4.332 ± 0.105	4.936 ± 0.077	3.946 ± 0.058
Winter	3	3.043 ± 0.139	4.500 ± 0.241	4.157 ± 0.194	5.073 ± 0.143	4.193 ± 0.108
Year of birth						
1997	28	2.992 ± 0.044	3.742 ± 0.076	4.301 ± 0.062	4.988 ± 0.045	4.006 ± 0.034
1998	24	2.900 ± 0.072	4.074 ± 0.124	4.227 ± 0.010	4.938 ± 0.074	4.035 ± 0.055
1999	19	2.911 ± 0.094	4.045 ± 0.161	4.261 ± 0.130	4.899 ± 0.096	4.029 ± 0.072
Overall Mean	71	2.935 ± 0.049	3.954 ± 0.085	4.263 ± 0.069	4.942 ± 0.051	4.023 ± 0.038

Values bearing different superscripts within source differ significantly ($P \leq 0.05$)

Table 4.6

Least-squares analysis of variance for the effect of breed, sex, litter size, season and year of birth on feed efficiency in broiler rabbits

Source	df	4-6th week	6-8th week	8-10th week	10-12th week	4-12th week
		Mean squares	Mean squares	Mean squares	Mean squares	Mean squares
Overall	71	0.0003	0.2944	0.0689	0.0000	0.0041
Breed	2	0.1367	1.0454	1.423**	0.2682	0.44151**
Sex	1	0.0042	0.0716	0.0411	0.0084	0.0053
Size	4	0.0684	0.0381	0.0314	0.0255	0.0053
Season	3	0.0469	0.2683	0.0258	0.0241	0.0246
Year	2	0.0140	0.1803	0.0119	0.0079	0.0015

** $P \leq 0.01$

4.4 Heritability

4.4.1 Heritability of body weight at different ages

The heritability estimates of body weights at different ages for the three genetic groups are given in Table 4.7.

Soviet Chinchilla recorded a heritability value of 0.204 ± 0.469, 0.363 ± 0.534, 0.528 ± 0.546, 0.720 ± 0.685 and 0.816 ± 0.713 for four, six, eight, ten and 12 weeks of age for the estimates based on sire + dam component. No trend could be discerned with the estimates for other genetic groups. In many cases the estimate obtained were either negative or greater than one.

4.4.2.1 Heritability of daily gain

Heritability estimates of daily gain for three genetic groups are presented in Table 4.7.

Estimates based on sire component of variance was 0.664 for NZW while SC had a value greater than one and CB rabbits had negative estimates. Heritability estimated by dam component of variance were 0.882 in SC and greater than one for NZW and CB rabbits and those based on sire + dam components were greater than one in three groups.

4.4.3 Heritability of feed efficiency

The heritability estimates of feed efficiency for three genetic groups are given in Table 4.7. Values of 0.619 ± 0.591 and 0.237 ± 0.356 were obtained for NZW and SC rabbits based on sire + dam components.

4.5 Correlation

4.5.1 Phenotypic correlation

4.5.1.1 Correlation among body weights

The phenotypic correlation estimates for NZW, SC and CB rabbits are presented in Table 4.8. and the estimates were positive and highly significant.

In NZW rabbits the estimates were highly significant ($P \leq 0.01$) for different body weight combinations at different ages except for the correlation of fourth week weight with eighth, tenth and twelfth week weights which were non-significant.

Highly significant ($P \leq 0.01$) to significant ($P \leq 0.05$) correlation estimates were obtained in SC rabbits for body weights.

Except for the non-significant correlation of fourth week weight with tenth and twelfth week weight all other correlation values in CB rabbits were highly significant ($P \leq 0.01$).

4.5.1.2 Correlation of feed efficiency with body weight and daily gain

The phenotypic correlation between feed efficiency and body weight at 12 weeks and feed efficiency and daily gain are given in Table 4.8.

The phenotypic correlation between twelfth week weight and feed efficiency was low: -0.032 ± 0.054 in NZW and 0.012 ± 0.537 in CB rabbits. Daily gain had a low correlation of -0.094 with feed efficiency in NZW rabbits.

4.5.2 Genetic correlation

4.5.2.1 Among body weights

The genetic correlation estimates are presented in Table 4.9 for NZW, SC and CB rabbits. The estimates based on sire + dam components of variance were high between body weights at different ages and was above one in many cases.

4.5.2.2 Correlation of FE with body weight and daily gain

Tables 4.9 presents the genetic correlation estimates between feed efficiency and body weight at 12 weeks of age and daily gain. The estimates based on sire component of variance were -0.031 for SC and -0.028 in CB rabbits. Correlation based on sire + dam components of variance was low and negative in NZW (-0.289) and low and positive (0.120) in CB rabbits.

Table 4.7

Heritability estimates of body weight in New Zealand White, Soviet Chinchilla and Cross bred rabbits

Body weight	Breed	Estimates based on		
		Sire	Dam	Sire + Dam
Fourth week	1 NZW	*	*	*
	2 SC	0.911±0.830	*	0.204 ± 0.469
	3 CB	0.051 ±0.899	**	0.545 ± 0.473
Sixth week	1 NZW	*	*	0.552 ± 0.226
	2 SC	**	*	0.363 ± 0.534
	3 CB	0.095 ± 0.639	**	**
Eighth week	1 NZW	0.301 ± 0.768	0.669 ± 0.908	0.485 ± 0.440
	2 SC	0.607 ± 0.989	0.449 ± 0.958	0.528 ± 0.546
	3 CB	0.441 ± 0.670	**	**
Tenth week	1 NZW	*	**	0.871 ± 0.555
	2 SC	**	*	0.720 ± 0.685
	3 CB	0.770 ± 1.583	**	**
Twelfth week	1 NZW	*	**	**
	2 SC	**	0.099 ± 0.617	0.816 ± 0.713
	3 CB	0.417 ± 0.683	**	**
Daily gain	1 NZW	0.664 ± 1.354	**	**
	2 SC	**	0.882 ± 0.999	**
	3 CB	*	**	**
Feed efficiency	1 NZW	**	*	0.619 ± 0.591
	2 SC	*	*	0.237 ± 0.356
	3 CB	*	*	*

* - heritability less than 0

** - heritability more than 1

Table 4.8

Phenotypic correlation among growth traits and feed efficiency in New Zealand White, Soviet Chinchilla and Cross bred rabbits

Correlation	NZW	SC	CB
Fourth and Sixth week	0.815 ± 1.762**	0.970 ± 0.559**	0.548 ± 1.572**
Fourth and Eighth week	0.332 ± 1.485	0.817 ± 0.219**	0.585 ± 1.379**
Fourth and Tenth week	0.181 ± 1.036	0.612**	0.405 ± 1.499
Fourth and Twelfth week	0.183 ± 1.476	0.819**	0.350 ± 1.777
Sixth and Eighth week	0.681 ± 1.850**	0.849 ± 0.237**	0.946 ± 0.334**
Sixth and Tenth week	0.516 ± 1.425**	0.624**	0.858 ± 0.420**
Sixth and Twelfth week	0.394 ± 0.707**	0.866**	0.816 ± 0.444**
Eighth and Tenth week	0.862 ± 1.384**	0.503*	0.943 ± 0.296**
Eighth and Twelfth week	0.532 ± 1.723**	0.859 ± 0.783**	0.846 ± 0.403**
Tenth and Twelfth week	0.687 ± 0.887**	0.596**	0.878 ± 0.731**
Twelfth week weight and Feed efficiency (4 to 12 weeks)	-0.032 ± 0.054	0.094	0.012 ± 0.537
Daily gain and Feed efficiency (4 to 12 weeks)	-0.094	-0.029	0.174

* $P \leq 0.05$
** $P \leq 0.01$

Table 4.9

Genetic correlation among growth traits and feed efficiency in New Zealand White, Soviet Chinchilla and Cross bred rabbits

Correlation	Breed	Estimates based on		
		Sire	Dam	Sire + Dam
Fourth and Sixth week	1 NZW	*	*	*
	2 SC	**	*	**
	3 CB	*	**	0.216 ± 1.971
Fourth and Eighth week	1 NZW	*	*	*
	2 SC	**	*	0.823 ± 1.314
	3 CB	*	**	0.268 ± 2.447
Fourth and Tenth week	1 NZW	***	*	*
	2 SC	0.261 ± 0.875	***	-0.186 ± 0.722
	3 CB	*	0.983 ± 12.221	0.059 ± 0.538
Fourth and Twelfth week	1 NZW	**	*	*
	2 SC	**	*	**
	3 CB	*	**	0.073 ± 0.670
Sixth and Eighth week	1 NZW	**	*	*
	2 SC	**	*	0.895 ± 1.654
	3 CB	-0.976 ± 0.342	0.966 ± 0.649	0.960 ± 0.924
Sixth and Tenth week	1 NZW	*	*	*
	2 SC	0.167 ± 0.871	**	-0.114 ± 0.661
	3 CB	-0.969 ± 0.435	0.900 ± 0.735	0.853 ± 0.875
Sixth and Twelfth week	1 NZW	*	*	*
	2 SC	1.000 ± 0.624	*	**
	3 CB	*	0.898 ± 0.627	0.812 ± 0.835
Eighth and Tenth week	1 NZW	*	0.997 ± 16.65	0.990 ± 12.54
	2 SC	-0.535 ± 1.387	*	-0.215 ± 0.497
	3 CB	***	0.985 ± 0.541	0.951 ± 0.868
Eighth and Twelfth week	1 NZW	*	0.970 ± 2.568	0.401 ± 0.684
	2 SC	**	0.570 ± 0.266	0.964 ± 0.512
	3 CB	***	0.915 ± 0.644	0.864 ± 0.836
Tenth and Twelfth week	1 NZW	***	0.975 ± 0.517	0.687 ± 1.012
	2 SC	0.082 ± 0.9	*	0.017 ± 0.210
	3 CB	-0.781 ± 0.704	0.841 ± 1.338	0.879 ± 1.300
Twelfth week weight and Feed efficiency (4 to 12 weeks)	1 NZW	*	*	-0.289 ± 0.324
	2 SC	-0.031 ± 0.054	*	*
	3 CB	-0.028 ± 0.031	0.470 ± 1.733	0.120 ± 1.434
Daily gain and Feed efficiency (4 to 12 weeks)	1 NZW	*	-0.006	-0.007
	2 SC	*	-0.032	-0.021
	3 CB	-0.108 ± 1.072	0.015 ± 0.093	0.014± 0.093

* - variance negative

** - values greater than 1

***- values lesser than -1

Correlation of feed efficiency with daily gain was - 0.006, - 0.032 and 0.015 for NZW, SC and CB respectively based on dam component of variance and –0.007, -0.021 and 0.014 for NZW, SC and CB respectively based on sire + dam components of variance.

4.6 Carcass characteristics

The mean dressing per cent for the three genetic groups are 45.78, 47.48 and 48.91 respectively for NZW, SC and CB rabbits.

4.7 Selection Index

The economic weights for FE and twelfth week body weight are shown in Table 4.10. Selection index for NZW (I_{NZW}) and SC (I_{SC}) based on twelfth week body weight (Wt_{12}), feed efficiency from four to 12 weeks of age (FE) and their relative economic weights are

$$I_{NZW} = 0.202\,(Wt_{12} - \mu_{Wt12}) - 0.186\,(FE - \mu_{FE}) \text{ and}$$

$$I_{SC} = 0.331\,(Wt_{12} - \mu_{Wt12}) - 0.094\,(FE - \mu_{FE})$$

where, μ_{Wt12} is the average for twelfth week weight and

μ_{FE} is the average for feed efficiency.

Table 4.10

Economic weights for FE and 12th week body weight

Sl.No	Breed	FE	12th week weight
1	NZW	-0.83	0.46
2	SC	-0.83	0.47

DISCUSSION

DISCUSSION

The results obtained during the course of the present study are discussed below.

5.1 Growth traits

5.1.1 Body weight at different ages

The mean body weights at weaning (fourth week), sixth week, eighth week, tenth week and 12th week for NZW rabbits were 236.7 ± 20.6, 461.7 ± 27.4, 678.2 ± 31.0, 934.2 ± 44.1 and 1117 ± 51.5 g respectively. These values are comparable to those reported by Radhakrishnan (1992). However higher values were recorded by Rathor *et al.* (1994), Damodar and Jatkar (1985), Erjavec *et al* (1990) and Mukundan (1993) in NZW rabbits.

Body weight of SC averaged 268.6 ± 18.2, 568.1 ± 24.2, 809.6 ± 27.4, 1007.1 ± 38.9 and 1272.3 ± 45.4 g respectively at fourth, sixth, eighth, tenth and 12th weeks of age. Gogeliya *et al.* (1982), Kosba *et al.* (1985) and Radhakrishnan (1992) documented comparable values, while Rathore *et al* (1994), Mukundan (1993) and Gour *et al* (1995) reported higher values.

The average body weights at fourth, sixth, eighth, tenth and 12th weeks were 319.0 ± 21.6, 506.6 ± 28.8, 708.1 ± 32.5, 1019.5 ± 46.3 and 1214.2 ± 54.0 g respectively for SC X NZW crossbreds. However, Rathor *et al.* (1994) and Mukundan (1993) reported higher body weights for CB rabbits.

5.1.2 Effect of different factors on body weight at different ages

5.1.2.1 Effect of breed

Breed effect was highly significant on body weights at all ages. Least-square means indicated that though SC is advantageous with regard to body weight up to eighth week, the difference in body weight between SC and CB gets nullified by the time it reached market age of 12 weeks. But CB rabbits had higher average (1214 g) for 12th week body weight when compared to the mid-parent average (1195 g) and exhibited a heterosis of 2 per cent. This definitely showed that crossbred could be preferred over NZW and SC for meat production in rabbits, under hot and humid climatic conditions of Kerala.

Ferraz *et al* (1991), Ozimba and Lukefahr (1991), Radhakrishnan (1992) and Rathor *et al.* (1994) had endorsed the significance of breed effect on body weight. On the other hand Gogeliya (1982), Ahmed *et al.* (1986), Gupta *et al.* (1993) and Paci *et al* (1995) could not find any breed effect on body weights.

5.1.2.2 Effect of sex

Sex had a significant ($P \leq 0.05$) effect only at fourth week of age. The advantage of at early age could be due to the beneficial effects of sex hormones secreted by foetal gonads (Hafez, 1962) which is endorsed by Perry and Pomary (1956). Similar obserations were also made by Lebas (1983) in broiler rabbits.

The results concurs well with the non-significant sex effect reported by Roedcha and Chanpingsang (1986) for crossbred rabbits, Polastre *et al.* (1992) in Selecta rabbits and Radhakrishnan (1992) in NZW, SC and GG rabbits and McNitt and Lukefahr (1993) in NZW. But Erjawec *et al.* (1990) recorded significant sex effect for body weight at 65 days of age in NZW rabbits.

5.1.2.3 Effect of litter size at birth

Litter size at birth was a significant source of variation for body weight at all ages.

There is a general tendency of decrease in weaning weight as *litter* size increased which is continued till 12 weeks of age. The early differences could be due to the lower availability of nutrients for developing foetus at *later stages of gestation and less availability of uterine space. This* difference is maintained till 12 weeks of age. But the higher litter size is always advantageous because there is a clear trend of increase in total weight as age advanced, which is evident from the highest litter weight of 6180 g (1030 X 6) for litter size six at 12 weeks, though litter size four and five did not differ significantly at 12 weeks.

Significant effect of litter size at birth was well documented by Ledur *et al.* (1988), Mgheni *et al.* (1982), Erjawec *et al.* (1990) and Narayan *et al.* (1981) for NZW rabbits, and by Swai *et al.* (1986) for NZW x SC rabbits.

5.1.2.4 Effect of season of birth

Least squares analysis revealed that season of birth had a significant ($P \leq 0.05$) effect at weaning and highly significant effect at six and eight weeks and no influence at ten and 12 weeks of age. Rabbits born in *summer (Feb-May) maintained higher weights at all ages*. However, Blasco *et al.* (1983) reported that rabbits in temperate conditions born in summer and spring showed poor growth in NZW and Californian lines.

Rabbits born in winter (Dec-Jan) had the lowest body weight at fourth week (at weaning) but gained more in subsequent ages. Monsoon and post monsoon season did not differ much in their effect and body weights during these seasons were lesser than that of other seasons.

The significant effect of season/month of birth on body weight was amply demonstrated by the observations made by Narayan *et al.* (1981), Blasco *et al.* (1983) and Erjawec (1990).

The significant effect of season of birth was evident on early weights only, the influence of which is reduced at later ages. This indicates that body weight at market age is not affected by season of birth and breeding rabbits round the year will not affect body weight at market age.

5.1.2.5 Effect of year of birth

Year of birth had significant effect on body weights at four, six and eight ($P \leq 0.01$) and 12 weeks ($P \leq 0.05$) of age. This finding is in conformity with the findings of Khalil *et al.* (1987) for Giza White and Bouscat rabbits and McNitt and Lukefahr (1993) for NZW, Californian, Palomino and White Satin breeds.

Year effects could be attributed to the associated climatic variations as suggested by Khalil *et al.* (1987).

Among all the factors affecting body weight at different ages breed, litter size at birth and year of birth appeared to be most important. SC and CB are heavier over NZW at 12 weeks and as far as the litter weight at market age is concerned litter size six appeared to be the best.

5.2 Daily gain

5.2.1 Daily gain at different periods

The highest mean daily gain of 18.21 ± 0.91 g was observed for the period from six to eight weeks of age.

5.2.2 Effect of different factors on daily gain

5.2.2.1 Effect of breed

Least squares analysis of variance indicated that breed had no significant effect on daily gain from four to 12 weeks.

Grobner *et al.* (1985) and Chievicate and Filotto (1989) reported the non-significant effect of breed on daily gain in NZW rabbits. On the other hand, significant breed effects on growth rate were obtained by Masoera *et al.* (1985), Mach *et al.* (1986) and Roedecha and Kijparkorn (1988) for NZW and various other breeds of rabbits.

5.2.2.2 *Effect of sex*

Sex was found to have no effect on daily gain during four to 12 weeks. This observation is in confirmity with the findings of Vogt (1979) and El-Maghawry (1988). However, Erjavec *et al.* (1990) reported significant sex effect for Slovenia rabbits.

These findings underline the fact that, unlike in most domestic livestock species, the sex effect did not strongly influence post-weaning growth in rabbits similar was the findings of McNitt and Lukefahr (1993). The male and female hormone did not profoundly exert differential effect on growth rate of the two sexes.

5.2.2.3 Effect of litter size at birth

Litter size at birth had been a non-significant source of variation for *overall daily gain in the present study, though it was significant* at four to six and eight to ten week periods. Vogt (1979) and Rouvier (1973) conducting studies in crossbred rabbits in NZW and Burgundy Fawn rabbits respectively observed similar results, while Erjavec *et al.* (1990) and Narayan *et al.* (1981) reported significant effect of litter size on growth rates in NZW rabbits.

5.2.2.4 Effect of season of birth

Influence of season of birth on overall daily gain was found to be significant in this study. This finding is in agreement with that of Blasco *et al.* (1983), Narayan *et al.* (1981) and El-Maghawry (1988) in NZW rabbits.

Summer born rabbits had higher growth rate followed by winter-born rabbits. The growth period of rabbits born in summer period is mostly during monsoon period, which was not a stress period as far post weaning growth of rabbits was concerned.

5.2.2.5 Effect of year of birth

Least squares analysis of variance revealed no significant effect of year of birth on overall daily gain.

This finding is in contrast with the findings of El-Maghawry (1988) for NZW and CAL rabbits and McNitt and Lukefahr (1993) working with NZW, CAL, Palomino and white satin breeds of rabbits. McNitt and Lukefahr (1993) attributed the effect of year to the ambient temperature in different years.

Breed and sex did not affect daily gain in general. Only season of birth affected daily gain from four to 12 weeks of age with summer born kits gaining maximum. This indicates that gain is mainly dependent on the initial weights and no major factors except season of birth affect the overall daily gain.

5.3 Feed Efficiency

5.3.1 Feed efficiency

The overall mean and SE for FE is 4.023 ± 0.038 from four to 12 weeks of age in broiler rabbits.

5.3.2 Effect of different factors on feed efficiency

5.3.2.1 Effect of breed

Breed had highly significant effect ($P \leq 0.01$) on FE. This result is in contrast to the report of Ozimba and Lukefahr (1991) in litter feed efficiency between NZW, Califomian, their crosses and Flemish Giant Crossbred. Paci *et al.* (1995) also found no significant difference between cross breds involving Burgundy Fawn, NZW rabbits.

Crossbred rabbits had higher feed efficiency than either of the purebreds indicating that CB converts feed more efficiently than pure breds. This is evident from the observed heterosis value of 9.3 per cent for this trait. This suggests that cross breeding is advantageous for improving feed efficiency in broiler rabbits. New Zealand White and SC did not differ significantly in FE during four to 12 week period.

5.3.2.2 Effect of sex

Sex had no significant influence on FE. This corroborates well with the observation of Vogt (1979) for crossbred rabbits.

5.3.2.3 Effect of Litter size

Least-squares analysis of variance revealed insignificant effect of litter size on FE. Vogt (1979) reported similar observation in crossbred rabbits.

5.3.2.4 Effect of season of birth

Effect of season of birth was not significant in the present investigation.

Similar results were reported by Barbosa *et al.* (1992) in NZW rabbits. Conversely, Crimella *et al.* (1978) and Ozimba and Lukefahr (1991) documented significant effect of season of birth on FE.

5.3.2.5 Effect of year of birth

Effect of year of birth had no significant influence on FE in the present study.

The present study indicated that FE is not affected by non-genetic factors and breed is the only source of variation. Crossbred had more converting ability of feed than purebred NZW and SC rabbits as evidenced by a heterosis of 9.3 per cent. The increased body weight at 12 weeks (market age) for CB rabbits along with higher FE puts this breed (SC x NZW) as the best choice for economic rabbit production.

5.4 Heritability

5.4.1 Heritability of body weight

The heritability sire + dam estimates in SC revealed a trend of increasing value with age. In CB rabbits heritability estimate by sire component showed an increasing trend from fourth week to tenth week weight. This could be due to the fact that the common environment obtained during early stage of growth was reduced thereby reducing the total phenotypic variance and increasing heritability value. This is in accordance with the observations of El-Amin (1974) in NZW rabbits but contrasts with that of Radhakrishnan (1992) in NZW and SC rabbits. But no clear conclusion could be made because of low sample size.

5.4.2 Heritability of daily gain

Heritability estimates for daily gain for NZW, SC and CB rabbits were high, often more than one. Low heritability estimate was reported by McReynolds (1974), Erjavec *et al.* (1990) and McNitt and Lukefahr (1993) in NZW rabbits and by Vogt (1979) in crossbred rabbits. The high estimates might be due to sampling error.

5.4.3 Heritability of feed efficiency

The heritability estimates obtained were negative to low. The negative value obtained might be due to low sample size and sampling error. Low to moderate heritability was reported by Niedzwiadek (1978) in NZW rabbits, Vogt (1979) in CB, Varewyek *et al.* (1987) in White Termonde breed, Kustos and Huller (1992) and Moura *et al.* (1996) in NZW.

5.5 Correlation

5.5.1 Phenotypic correlation

5.5.1.1 Correlation among body weights

The estimates were positive and highly significant in NZW, SC and CB rabbits. The magnitude of the correlation increased as the difference between the two ages decreased. This is in agreement with the observation recorded by Khalil *et al.* (1986).

High and positive phenotypic correlations among body weights in broiler rabbits were documented by Afifi *et al.* (1980), Randi and Scossiroli (1980), Blasco *et al.* (1983) and Radhakrishnan (1992) in NZW and other breeds.

A high, positive phenotypic correlation between body weights at different ages gives considerable advantage in management and culling decisions.

5.5.1.2 Correlation of feed efficiency with body weight and daily gain

Low phenotypic correlation of feed efficiency with 12th week body weight indicated that increased body weight was not directly related to better feed efficiency. The correlation of near to zero FE and daily gain showed that higher FE did not result in higher gain, which is evident from the higher feed intake of 5.25 Kg for SC as against 4.67 and 4.57 Kg respectively for NZW and CB rabbits.

5.5.2 Genetic correlation

5.5.2.1 Among body weights

Genetic correlation estimates based on sire component of variance were either larger than one or low. High positive estimates based on sire + dam component of variance in this study concurs well with the estimates documented by Khalil (1986) in Bouscat and Giza White rabbits and by

Radhakrishnan (1992) in NZW rabbits. Estimates of more than one obtained in this study might be due to the sampling error.

5.5.2.2 Correlation of feed efficiency with body weight and daily gain

Genetic correlation between body weights and feed efficiency were low and negative in NZW rabbits and low positive CB rabbits. Negative correlation with low value was obtained for daily gain and feed efficiency in NZW, and SC rabbits and low positive estimate was observed for crossbred rabbits. These findings are in line with the observation of Vogt (1979) although low in magnitude. This indicates that FE value does not go up with an increase in body weight, which suggests a corresponding increase in feed intake also.

5.6 Carcass characteristics

Average dressing per cent of 45.76, 47.48 and 48.91 observed for NZW, SC and CB rabbits agree well with the observations made by various investigators.

For NZW rabbits higher dressing per cent of 48.80 and 54.72 were reported by Grobner *et al.* (1985) and Kuttinarayanan and Nandakumar (1989) respectively, while Mukundan (1993) reported a lower value of 43.70 per cent.

The dressing per cent obtained for SC concurs well with the observation of Gangadevi (1995), while Parillo and Vasenina (1984) and Kuttinarayanan and Nandakumar (1989) reported higher values of 58.40 per cent and 53.51 per cent respectively. However, Mukundan (1993) reported a lower value of 41.69 per cent.

Mukundan (1993) and Gangadevi (1995) reported greater dressing per cent of 48.41 and 47.43 for cross bred rabbits.

5.7 Selection index

Selection index was constructed using body weight at twelve weeks of age (W), and overall feed efficiency (F) and their economic weights. The indices were

$I_{NZW} = 0.202\ (W-\mu_W) - 0.186\ (F-\mu_F)$ for NZW rabbits

and $I_{SC} = 0.331\ (W-\mu_W) - 0.094\ (F-\mu_F)$ for SC rabbits.

The indices incorporating body weight at 12 weeks of age and FE from four to 12 weeks of age, the heritabilities and genetic correlation between these traits and their relative economic weights will be a better method for selection of rabbits as parents of next generation.

This study on factors affecting body weight and feed efficiency indicated that breed is a significant source of variation for body weight at all ages up to 12 weeks and also for feed efficiency. Though SC and CB did not show any difference in body weight at 12 weeks, CB were at an advantage in particular as far as feed efficiency was concerned. In dressing percentage also CB excelled over both the pure breeds. Taking into consideration all the three characteristics and their economic advantages it is found that

SC x NZW crossbreds have an advantage over NZW or SC to an extent of 1.80 times and 1.43 times respectively. Considering the superiority of crossbreds (SC x NZW), cross breeding is recommended for commercial rabbit production.

SUMMARY

SUMMARY

A study to compare the efficiency of feed utilisation and the effect of genetic and non-genetic factors affecting the feed efficiency was undertaken in the Regional Agricultural Research Station, Pilicode, Kerala Agricultural University. The factors considered were breed, sex, litter size at birth, season and year of birth of animals. Breed groups comprised New Zealand White (NZW), Soviet Chinchilla (SC) and crossbreds (CB). Crossbreds are produced by mating SC males with NZW females.

Rabbits were weaned at four weeks of age and are fed individually with concentrate feed and green grass (Hybrid Napier) *ad libitum* till 12 weeks of age. Daily feed intake and fortnightly body weights were recorded. Dressing per cent was recorded at the end of 12 weeks of age. The data was analysed by least squares method and adjusted for the effects of non-genetic factors before the genetic parameters were estimated.

1. Body weight

Fourth week (weaning) body weights were highest in crossbred rabbits which averaged 319.0 ± 21.6 g while NZW and SC averaged 236.7 ± 20.6 g and 268.6 ± 18.2 g respectively. Breed effect was significant at all ages. New Zealand White had the lowest body weight at all ages, while SC had highest body weight at sixth and eighth week and CB weighed more at tenth week. At twelfth week of age SC averaged 1272.3 ± 45.4 g, while CB

weighed 1214.2 ± 54.0 g and NZW had the lowest body weight of 1117.7 ± 51.5 g. Crossbred rabbits with higher 12^{th} week body weight over mid-parent average exhibited a heterosis of 1.6 per cent, which indicates that CB can be preferred over purebreds for meat production.

Sex was found to have non-significant effect on body weight except at weaning, which might be due to the beneficial effect of sex hormones *secreted by feotal gonads*.

Litter size at birth significantly influenced body weight throughout the period with a tendency to decreased weaning and subsequent body weights as litter size increased. These differences could be attributed to lower availability of nutrients for developing feotus at later stages of gestation and less availability of uterine space.

Season and year of birth had significant effect on body weight at early ages (4, 6 and 8 weeks) only. This indicates that breeding rabbits round the year did not affect body weight at market age (12 weeks).

2. Daily gain

The overall daily gain (from four to 12 weeks) averaged 15.72 ± 0.79, 17.90 ± 0.69 and 15.98 ± 0.83 g for NZW, SC and CB rabbits respectively. Soviet Chinchilla had highest daily gain between four and 6 week, 6 and 8 week and 10 and 12 week whereas CB gained more during 8 to 10 week period. Overall daily gain from four to 12 weeks of age was not found to be influenced by any genetic or non-genetic factors, except season of birth. Summer born rabbits had higher growth rate followed by winter born rabbits, while post-monsoon born rabbits had lowest daily gain. The growth period of rabbits born in summer predominantly falls on monsoon period, which does not adversely affect growth rate.

3. Feed efficiency (FE)

Feed efficiency from four to 12 weeks of age was highest in crossbred rabbits, which averaged 3.766 ± 0.061 while NZW and SC averaged 4.179 ± 0.058 and 4.125 ± 0.051 respectively. Breed had significant effect on FE from 8 to 10 week period and four to 12 week interval, whereas sex, litter size at birth, season and year of birth had non-significant effect on FE.

Effect of breed was the only significant source of variation for FE and CB rabbits are preferred over pure breds as it showed a heterosis value of 9.3 per cent for this trait.

4. Genetic parameters

Heritability estimates of body weight at different ages by sire component of variance were negative in NZW, positive in CB and greater than one in SC rabbits. Moderate to high values of heritability estimates were obtained by sire+dam component, and a clear trend of increasing heritability with age was noticed in Soviet Chinchilla rabbits. Phenotypic correlations among body weights at different ages were generally highly significant. The magnitude of correlation increased as the difference between the ages decreased. Genetic correlation estimates were low for earlier ages and higher in magnitude for later ages.

Heritability estimates for daily gain from four to 12 weeks were high and often greater than one for the three genetic groups. Heritability estimates for FE *were not different from zero for the three genetic groups. Phenotypic* and genetic correlation of FE with 12th week body weight and daily gain were near to zero.

5. Carcass characteristics

The carcass yields (dressing per cent) were 45.78, 47.48 and 48.91 for NZW, SC and CB respectively.

6. Selection Index

Selection indices to select pure breed rabbits at 12th week of age *using 12th week body weight ((W), feed efficiency upto 12th week (FE) and* their economic weights were constructed, they were

$I_{NZW} = 0.202\ (W-\mu_w) - 0.186\ (FE-\mu_{FE})$ and

$I_{SC} = 0.541\ (W-\mu_w) - 0.035\ (FE-\mu_{FE})$

These indices are more efficient for selection compared to single trait selection where FE, dressing percentage, body weight at 12 week and their economic values are considered.

The observations of this study suggest that breed is a significant source of variation for body weights at all ages up to 12 weeks and for FE. Crossbred rabbits are superior over pure breeds when FE, body weight and dressing percentage are taken into consideration. In economic point of view the advantage of SC X NZW crosses over NZW or SC are 1.80 and 1.43 times respectively. Hence, for economic commercial broiler rabbit production crossbreeding is strongly recommended over pure breeding.

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APPENDIX 1

Composition of concentrate feed

Wheat	:	35 parts
Bengal gram	:	20 parts
Black gram powder	:	20 parts
Gingilly oil cake	:	23 parts
Mineral mixture and salt	:	2 parts

GENETIC FACTORS INFLUENCING FEED EFFICIENCY IN PURE AND CROSSBRED BROILER RABBITS

By

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ABSTRACT OF A THESIS

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Master of Veterinary Science

Faculty of Veterinary and Animal Sciences

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ABSTRACT

An experiment was carried out to study the genetic and non-genetic factors influencing feed efficiency (feed g/gain g) in broiler rabbits viz. New Zealand White (NZW), Soviet Chinchilla (SC) and SC x NZW crossbreds (CB). The non-genetic factors included were sex, litter size at birth, season and year of birth. The data pertaining to fortnightly body weight from four to 12 weeks of age, feed efficiency (FE) and daily gain (DG) were subjected to least squares analysis.

Breed had significant effect on body weights at all ages. NZW had the least body weights through out the experiment and SC and CB did not differ significantly at market age of 12 weeks. Overall daily gain was not affected by breed while FE was significantly ($P \leq 0.01$) influenced by breed. CB had the highest FE followed by SC and NZW rabbits. Dressing percentage was highest (48.91) for CB compared to NZW and SC. Crossbred rabbits exhibited a heterosis of 1.6 and 9.3 per cent for 12th week body weight and FE respectively over the pure bred parents.

Sex was not a source of variation for any trait except for body weight at weaning (four weeks). Litter size at birth had significant effect on body weights at all ages but had no effect on overall DG and FE. Season and year of birth influenced body weights at early ages only and had no effect on overall DG and FE.

Estimates of heritability by sire + dam component of variance were moderate to high for body weights at different ages, high for DG and not different from zero for FE. Phenotypic correlations among body weights at different ages were high and significant and genetic correlation estimates were higher in magnitude for later ages. Phenotypic and genetic correlation of FE with twelfth week body weight and DG were near to zero.

The present study indicated that breed is a significant source of variation affecting body weight from four to 12 weeks of age and FE in during period. CB rabbits though did not differ from SC for 12th week body weight excelled the pure breeds when FE and dressing percentage are considered. In monetary terms CB rabbits are found to be superior by 1.6 and 1.43 times over NZW and SC rabbits. So, crossbreeding of SC and NZW rabbits is advocated for profitable commercial broiler rabbit production.