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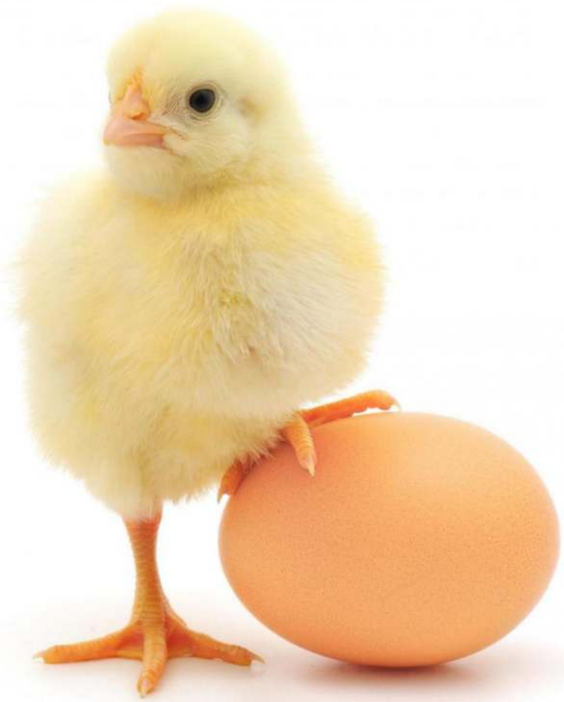

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ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

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The Japanese Quail: A Review

Nasrollah Vali
Department of Animal Sciences, Faculty of Agriculture, Islamic Azad University, Shahrekord Branch, Iran

Abstract: The Japanese quail belongs to the order *Galformes*, family *Phasidae*, genus *Coturnix* and species *japonica*. Several aspects account for the utility of this bird. First, it has attained economic importance as an agricultural species producing eggs and meat that are enjoyed for their unique flavor. Egg production is important in Japan and Southeast Asia, while meat is the main product in Europe. Second, the low maintenance cost associated with its small body size (80-300 g) coupled with its short generation interval, (3-4 generation per year), resistance to diseases and high egg production, rendered it an excellent laboratory animal. Third, Japanese quail also is the smallest avian species farmed for meat and egg production. It has thus been used extensively in many studies. The Japanese quail is bred for egg and meat production. Few studies have been published on egg production but, reports on quail growth and body composition are numerous. Some of the estimated genetic parameters for various traits of Japanese quail were reported by several workers.

Key words: Japanese quail, coturnix, heritability coefficients, genetic parameters

Introduction

The Japanese quail belongs to the order *Galformes*, family *Phasidae*, genus *Coturnix* and sp. *japonica*. The scientific designation for Japanese quail is *Coturnix japonica*, different from the common quail "*Coturnix coturnix*" (Thear, 1998; Mizutani, 2003). The first record of wild Japanese quail appeared in the eight century in Japan. The plumage color of the wild type is predominately dark cinnamon brown. However, adult female have pale breast feathers that are speckled with dark colored spots. Adult males have uniform dark rust-red feathers on the breast and cheek (Mizutani, 2003). The Japanese quail originally domesticated around the 11th century as a pet song bird (Howes, 1964; Crawford, 1990; Kayang *et al*., 2004), has gained in value as a food animal since (Wakasugi, 1984; Kayang *et al*., 2004). Several aspects account for the utility of this bird. First, it has attained economic importance as an agricultural species producing eggs and meat that are enjoyed for their unique flavor (Kayang *et al*., 2004). Egg production is important in Japan and Southeast Asia, while meat is the main product in Europe (Baumgartner, 1994; Minvielle, 1998). Second, the low maintenance cost associated with its small body size (80-300 g) coupled with its short generation interval, (3-4 generation per year), resistance to diseases and high egg production, rendered it an excellent laboratory animal (Woodard *et al*., 1973; Baumgartner, 1994; Yalcin *et al*., 1995; Oguz and Minvielle, 2001). Third, Japanese quail also is the smallest avian species farmed for meat and egg production (Baumgartner, 1994). It has thus been used extensively in many studies (Kayang *et al*., 2004).
Experimental research established that body weight of Japanese quail responded quickly to selection (Nestor *et al*., 1982b; Caron and Minvielle, 1990; Marks, 1993a). At the same time, Japanese quail farming for meat production expanded in several countries (Baumgartner, 1994; Yalcin *et al*., 1995; Minvielle, 1998).
In order to establish a breeding program, it is essential to estimate genetic parameters for improving the traits. The scale of the genetic parameters could show the amount of improvement by selection. Some of the estimated genetic parameters for various traits of domestics Japanese quail were reported by several workers (Kawahara and Saito, 1976; Toelle *et al*., 1991; Minvielle *et al*., 1999a, 2000a; Vali *et al*., 2005). Kawahara and Saito (1976) reported the genetic parameters of different organs and body weights in the Japanese quail. Toelle *et al*. (1991) estimated genetic and phenotypic relationships between body weight, carcass and some of the organ parameters. Minvielle *et al*. (2000a) reported the carcass characteristics of a heavy Japanese quail line under introgression with the roux gene.

Measurement of production characteristics: The Japanese quail is bred for egg and meat production. Few studies have been published on egg production (Minvielle *et al*., 1995; Minvielle *et al*., 1999b; Minvielle *et al*., 2000b; Minvielle *et al*., 2000c; Vali *et al*., 2006) but, reports on quail growth and body composition are numerous (e.g., Collin *et al*., 1970; Chahil and Johnson, 1974; Strong *et al*., 1978; Bacon *et al*., 1982; Nestor and Bacon, 1982b; Nestor *et al*., 1983; Bacon *et al*., 1986; Marks, 1993b; 1993c; 1993d; Yalcin *et al*., 1995).

Characteristics related to the laying: Nestor and Bacon (1982b) studied egg production, mature body weight, egg weight, yolk weight, fertility, hatchability and mortality during the early growing period were compared in strains of Japanese quail. The strains were either a random bred control (R1) that served as the base population or strains divergently selected for high (HW) or (LW) 4 week body weight or high (HP) or (LP) plasma phosphorus (yolk precursor) early in the laying period. They reported change in 4 week body weight in HW and LW was associated with corresponding changes in mature body weight, yolk weight and total egg weight. Egg production decreased in HW, but there was no significant change in LW. Mortality, increased in LW and decreased in HW. Egg production of HP declined at a rate similar to that observed in HW. No other consistent significant changes occurred in the phosphorous strains. Fertility and hatchability did not exhibit significant strain differences in the fifth generation of selection. Foo and Chandran (1996) reported that, five week old layer breeder quails were individually weighed and were grouped into 6 body weight ranges. Groups U weighted 90-98 g, group V, 100-108 g, group W, 110-118 g, group X, 120-128 g, group Y, 130-138 g and group Z, 140-148 g. Bigger quail (130 g and above) come to sexual maturity and peak production earlier and had an overall higher egg production. Feed consumption was lower (40.6 v. 41.9 g feed/egg). They reported that this strain of quails requires a minimum body weight of 130 g at the fifth week. Vali *et al.* (2006) worked that, comparison of egg weight between two quail strains, Japanese quail (*Coturnix japanese*) and Range quail (*Coturnix ypisilophorus*). Egg weight of Japanese quails and Range quails were 11.23±0.03 and 11.17±0.05, respectively which were not significantly different (p>0.05). Nestor *et al.* (1983) reported from a random bred control population of *Coturnix coturnix Japonica* strains were divergently selected for high (HE) and low (LE) 120-day egg production based on individual egg records. Based on five generations of selection, realized heritability for HE and LE were 0.063±0.55 and 0.353±0.020, respectively. In the first generation, the 120- days period started when approximately 50% of the hens laid their first egg. The 120-days period began with the date of first egg for each female in later generations. Effect of divergent selection for HE and LE on egg production and egg weight showed in Table 1 (Nestor *et al.*, 1983).

Minvielle *et al.* (2000c) evaluated four Japanese quail line were developed using 13 generations of reciprocal recurrent (lines AA and BB) or within-line selection (lines DD and EE) for high egg number until 98 of age. Minvielle *et al.* (1999b) reported Roux plumage was significantly associated with 3% lower body weight and less abdominal fat pad. Egg production was not influenced by the roux mutation, but egg weight was 2% lower. Minvielle and Oguz (2002) obtained egg quality is affected by selection on body weight, but these effects differ somewhat between experiments, maybe in relation to the origins of breeding lines. Selection on egg production could increase yolk content. Direct selection work on egg quality traits has shown that there was genetic variation for yolk related characters. The ω6/ω3 polyunsaturated fatty acids (PUFA) ratio can be improved by selection.

It was concluded that selecting for total plasma phosphorus in laying female Japanese quail is effective in quantitatively but not qualitatively altering the days < 1.006 lipoprotein levels in the laying hen plasma, without affecting the days>1.006 lipoprotein levels (Bacon *et al.*, 1982). Strong *et al.*, (1978) reported the average plasma lipophosphoprotein (LPP) concentration was 11.5±0.6 mg/mL. Total plasma calcium concentration (119.4±0.2 mg %) was similar to that reported for chickens and turkeys, while total plasma phosphorus concentration (799±8 μg/mL) was higher then reporters for other avian species. Heritability coefficients (h^2) and standard error (± SE) related to the laying Japanese quail (*Coturnix japonica)* several papers shown in Table 3.

Relevant characteristic with growth and production meat: Numerous selection experiments on live body weight have been carried out (Oguz and Minvielle, 2001) and were quite successful at increasing or decreasing body weight. In some of them, carcass and quality traits were also monitored (Marks, 1993a). Marks, (1993a) investigated body weight, feed intake, feed efficiency and carcass composition changes following 51 generation of selection for high 4 week body weight in Japanese

Table 1: Effect of divergent selection for HE and LE on egg production and egg weight

Generation of selection	120-day egg production (no./hen)			Egg weight (g)		
	R[1]	HE[2]	LE[3]	R[1]	HE[2]	LE[3]
1	109	111	106	10.18	10.19	10.20
2	113	115	108	10.29	10.22	10.25
3	113	114	103	10.43	10.38	10.55
4	113	116	99	10.54	10.51	10.64
5	112	115	93	10.20	10.44	10.37

Source: Nestor *et al.*, (1983), [1]Control group, [2](HE) high 120-day egg productions, [3](LE) low 120-day egg productions quail. Mean body weight of selected (p line) and unselected (C line) quail from 0-56 days of age (Table 2), that body weight of p line quail were significantly (p<0.05) large then body weight of C line quail at all ages with the greatest deviation occurring at the age of selection. Feed intake was significantly greater in the p line and paralleled body weight increases.

Syed Hussien *et al.* (1995) reported the results of continuous selection that were showed marked improvement of the various traits. At 0 generation, the population average body weight at 5 weeks old of the male line was 182 g. After 10 generations of selection the average population body weight has reached to 261 g, an increase of 79 g or 44% gain. In the female line, after 9 generations of selection, improvement in body weight gain was 41.2%. However, improvement in body weight has caused sexual maturity to delay by 3 days. Both egg production and egg weight improved

Table 2: Mean body weight of selected (P line) and unselected (C line) Japanese quail from 0 to 56 days of age

Age (days)	P line (g)	C line (g)	Ratio[1]
0	9.3±0.1[a]	6.3±0.1[b]	1.48
1	11.0±0.1[a]	7.1±0.1[b]	1.55
4	23.4±0.3[a]	12.1±0.2[b]	1.93
7	41.9±0.6[a]	19.3±0.3[b]	2.17
10	68.7±0.8[a]	28.5±0.5[b]	2.41
14	95.2±1.7[a]	39.0±0.6[b]	2.44
21	164.5±2.4[a]	65.8±0.8[b]	2.50
28	218.8±4.2[a]	86.5±1.0[b]	2.53
42	251.1±6.0[a]	112.2±2.0[b]	2.24
56	268.7±8.3[a]	121.9±3.1[b]	2.20

Source: Marks, (1993a), [a,b]Means ± SEM within rows with no common, Superscripts differ significantly (p<0.05).
[1]Ratio = P line: C line

Table 3: Heritability coefficients (h^2) and standard error (± SE) related to the laying Japanese quail (*Coturnix japonica)*

Trait	Estimation method	Heritability coefficient (%)	Source
70 day egg production	SC	0.26±0.37	Strong *et al.* (1978)
70 day egg production	DC	0.58±0.26	Strong *et al.* (1978)
70 day egg production	S+D	0.42±0.20	Strong *et al.* (1978)
(HE) For high 120-day egg production	RH	0.063±0.055	Nestor *et al.* (1983)
(LE) For low 120-day egg production	RH	0.352±0.020	Nestor *et al.* (1983)
Sexual dimorphism	AM; REML	0.26	Minvielle *et al.* (1997)
Egg number at 13week of age	AM; REML	0.39	Minvielle *et al.* (1997)
Egg number at 18week of age	LS; HS	0.32	Minvielle (1998)
Egg weight		0.62	Minvielle (1998)
Egg weight	LS; DD	0.35	Baumgartner (1994)
Egg weight	LS; HS	0.49	Minvielle (1998)
Egg weight	AM; REML	0.50	Minvielle *et al.* (1997)
Egg weight at 12 weeks	FS	0.65	Sittmann *et al.* (1966)
Yolk weight		0.68	Minvielle (1998)
Yolk weight	LS; DD	0.35	Baumgartner (1994)
Yolk weight	AM; REML		Minvielle *et al.* (1997)
Albumen weight	LS; DD	0.35	Baumgartner (1994)
Yolk cholesterol content	LS; DD	0.14	Baumgartner (1994)
Egg shape index	LS; DD	0.24	Baumgartner (1994)
Shell weight	LS; DD	0.25	Baumgartner (1994)
Shell weight	AM; REML	0.60	Minvielle *et al.* (1997)
Shell weight		0.78	Minvielle (1998)
Egg Wt[1]. 1	SC	0.50±0.42	Strong *et al.* (1978)
Egg Wt. 1	DC	1.07±0.25	Strong *et al.* (1978)
Egg Wt. 1	S+D	0.78±0.22	Strong *et al.* (1978)
Egg Wt[2]. 2	SC	0.28±0.39	Strong *et al.* (1978)
Egg Wt. 2	DC	0.71±0.26	Strong *et al.* (1978)
Egg Wt. 2	S+D	0.50±0.20	Strong *et al.* (1978)
Plasma[3](LPP)	SC	0.19±0.30	Strong *et al.* (1978)
Plasma(LPP)	S+D	0.10±0.17	Strong *et al.* (1978)
Total plasma calcium	DC	0.25±0.28	Strong *et al.* (1978)
Total plasma calcium	S+D	0.12±0.19	Strong *et al.* (1978)
Total plasma phosphorus	SC	0.48±0.33	Strong *et al.* (1978)
Total plasma phosphorus	DC	0.19±0.25	Strong *et al.* (1978)
Total plasma phosphorus	S+D	0.34±0.18	Strong *et al.* (1978)

[1]The first two normal eggs laid by each quail were weighed and average was recorded (Egg Wt. 1). [2]After approximately two to three weeks of production, a sample of three consecutive eggs per quail was weight and this average was recorded (Egg Wt. 2), [3]Plasma (LPP) lipophosphopretein HS = half sib, FS = full sib, PP = parent-progeny, DD = daughter-dam, AM = animal model, LS = least squares estimation, REML = restricted maximum likelihood estimation, SC = sire component, DC = dam component, S+D = sire dam, RH = realized heritability

Table 4: Heritability coefficients (h^2) and standard error (± SE) of body weight of Japanese quail (*Coturnix japonica)*

Age	Estimation method	Sex	Heritability coefficient (%)	Source
4 week	LS; HS	M,F	0.54	Damme and Aumann (1992)
4 week	PP; REML	M,F	0.47	Minvielle (1998)
4 week	LS; HS	M,F	0.74	Minvielle (1998)
4 week	RH	M,F	0.37±0.05	Nestor *et al.* (1982_a)
4 week	SC	M,F	0.14	Marks (1978)
4 week	DC	M,F	0.78	Marks (1978)
4 week	RH	M,F	0.49±0.06	Marks (1978)
BW^1	SC	F	0.20±0.45	Strong *et al.* (1978)
BW^1	DC	F	1.16±0.28	Strong *et al.* (1978)
BW^1	S+D	F	0.59±0.23	Strong *et al.* (1978)
BW^2	SC	F	0.10±0.45	Strong *et al.* (1978)
BW^2	DC	F	1.16±0.28	Strong *et al.* (1978)
BW^2	S+D	F	0.63±0.23	Strong *et al.* (1978)
4 week	SC	M,F	0.49±0.13	Toelle *et al.* (1991)
4 week	DC	M,F	0.70±0.14	Toelle *et al.* 1991
4 week	S+D	M,F	0.59±0.08	Toelle *et al.* (1991)
5 week	DD	M,F	0.236±0.220	Chahil and Johnson (1974)
5 week	RH	M,F	0.470±0.150	Chahil and Johnson (1974)
45 days	RH (line 1)	M	0.13±0.02	Caron and Minvielle (1990)
45 days	RH (line 2)	M	0.19±0.01	Caron and Minvielle (1990)
45 days	RH (line 3)	M	0.17±0.02	Caron and Minvielle (1990)
45 days	RH (line c)	M	-0.03±0.07	Caron and Minvielle (1990)
45 days	RH (line 1)	F	0.22±0.04	Caron and Minvielle (1990)
45 days	RH (line 2)	F	0.24±0.02	Caron and Minvielle (1990)
45 days	RH (line 3)	F	0.18±0.04	Caron and Minvielle (1990)
45 days	RH (line c)	F	0.18±0.35	Caron and Minvielle (1990)
35 days	AM (multi-trait)	M,F	0.263±0.098	Vali *et al.* (2005)
42 days	AM (multi-trait)	M,F	0.224±0.093	Vali *et al.* (2005)
49 days	AM (multi-trait)	M,F	0.121±0.083	Vali *et al.* (2005)
63 days	AM (multi-trait)	M,F	0.374±0.196	Vali *et al.* (2005)
35 days	AM (single-trait)	M,F	0.325±0.107	Vali *et al.* (2005)
42 days	AM (single-trait)	M,F	0.289±0.110	Vali *et al.* (2005)
49 days	AM (single-trait)	M,F	0.195±0.094	Vali *et al.* (2005)
63 days	AM (single-trait)	M,F	0452±0.209	Vali *et al.* (2005)
12 week	SC	M	0.56	Baumgartner (1994)
12 week	SC	F	0.68	Baumgartner (1994)
12 week	DD	M	0.66	Baumgartner (1994)
12 week	DD	F	0.85	Baumgartner (1994)
25 week	FS	M	0.693	Kawahara and Satto (1976)
25 week	FS	F	0.300	Kawahara and Satto (1976)

BW^1 body weight near the time of sexual maturity, BW^2 body weight three weeks after the time of sexual maturity, HS = half sib, PP = parent-progeny, DD = daughter-dam, AM = animal model, LS = least squares estimation, REML = restricted maximum likelihood estimation, SC = sire component, DC = dam component, S+D = sire dam, RH = realized heritability

until 19 and 14%, respectively. Vali *et al.* (2005) compared body weight of two quail strains (*Coturnix japonica* and *Coturnix ypisilophorus*) at 35, 42, 49 and 63 days of age, the respective mean body weight for two strains were: 135.49±1.40 and 125.95±1.91; 160.81±1.54 and 150.73±2.10; 181.54±1.62 and 172.36±2.16; 198.46±2.17 and 192.81±2.93, respectively for ages. They reported body weight of two strains at 35, 42 and 49 days of age were significantly different ($p<0.01$), but there were not any significant difference at 63 days of age ($p>0.05$). Caron and Minvielle (1990) reported mass selection for increased, live body weight at 45 days of age was carried out for 17 or 20 generations in three lines (1,2,3) of Japanese quail. One line (C) was an unselected control. They expounded that at the end study, the respective mean body weights for the four lines for males and females were, 237.6 and 261.4 g; 251.9 and 274.3 g; 195.1 and 218.1 g and 147.7 and 169.4 g. Mass selection was effective in lines 1, 2 and 3. Selected lines produced heavier carcasses, more meat and more abdominal fat. The females produced larger carcass than the males(161.7 versus 150.9 g, p = 0.05). But at 71.7%, the carcass yield was 5.8% larger for the males than the females. Vali *et al.* (2005) reported males quail showed higher percentage of carcass (70.58±0.46) than females (64.23±0.41). Marks (1993_a) investigated the carcass composition changes following 51 generations of selection for high 4 week body weight in Japanese quail. Carcass composition determinations revealed significant ($p<0.05$) age and line effects. He reported percentage carcass protein was significantly ($p<0.0001$)

influenced by age. Percentage protein values were low (15.5-16.5%) in both the P and C lines at 0 and 4 days and increased in a linear fashion to about 20% at 14 days of age. After 14 days of age in the P line and 28 days in the C line, percentage protein declined slightly in both lines through 56 days. Toelle *et al*. (1991) estimated the paternal half sib heritability for body, carcass and organ weights in Japanese quail were moderate to high for most traits studied, suggesting that selection to increase or decrease these traits should be successful. He reported that the genetic correlation of body weight with the other carcass measurements were positive and tended to be moderate to high. Minvielle *et al*. (1999a) reported roux plumage was significantly associated with 3% lower body weight and 30% less abdominal fat pad. Narayan *et al*. (2001) investigated purebred, heterosis, general and specific combining abilities (GCA and SCA, respectively), maternal ability (MA) and sex linked effect (SLE), which these traits were highly significant for body weights both at 4 and 5 weeks of age among the male progeny. General combining ability was more important than the specific combining ability for the complete array of traits, in their report, indicating that additive genetic effects were important than non-additive genetic effects. The magnitude of heterosis varied among the cross and traits. Syed Hussein *et al*. (1999) reported two trials were carried out to study the effects of crossing 3 strains of Japanese quails on growth and reproductive performances. In trial 1, strain FF (meat type) and strain JQ (egg type) were crossed to produce crossed strain FJ. Five week weights were significantly different among the strains (FF, 257 g; JQ, 122 g; FJ, 178 g) with negative heterosis (-6.1%). However positive hetrosis (8.3%) was observed for egg production. IN trial 2, strain FM was crossed with the crossed strain FJ to produce crossed strain M/FJ. There were significant differences in 5 week body weight and feed conversion ratio for strains. Five week body weight and feed conversion ratio for strains FM, FJ and M/FJ were 272 g and 2.63, 180 g and 3.07 and 237 g and 2.73, respectively. Positive heterosis (4.9%) was noted for body weight but negative heterosis (-4.2%) for feed conversion ratio. The results of these trials showed the advantages of using these crossing to combine growth rate and reproductive performance in producing breeding and commercial stocks for meat production. Heritability coefficients (h^2) and standard error (± SE) of body weight and carcass characteristics of Japanese quail (*Coturnix japonica)* several papers shown in Table 4 and *5*, respectively.

Table 5: Heritability coefficients (h^2) and standard error (± SE) of carcass characteristics of Japanese quail (*Coturnix japonica*)

Traits	Estimation method	Age	Sex	Heritability coefficient (%)	Source
Bone weight	FS	25 week	M	0.777	Kawahara and Satto (1976)
	FS	25 week	F	0.748	Kawahara and Satto (1976)
Heart weight	FS	25 week	M	0.553	Kawahara and Satto (1976)
	FS	25 week	F	0.232	Kawahara and Satto (1976)
Heart (unadjusted for BW)	S+D	34 day	M, F	0.23±0.06	Toelle *et al*. (1991)
	SC	34 day	M, F	0.21±0.10	Toelle *et al*. (1991)
	DC	34 day	M, F	0.26±0.13	Toelle *et al*. (1991)
Lung weight	FS	25 week	M	0.306	Kawahara and Satto (1976)
	FS	25 week	F	0.184	Kawahara and Satto (1976)
Liver weight	FS	25 week	M	0.346	Kawahara and Satto (1976)
	FS	25 week	F	0.469	Kawahara and Satto (1976)
Liver (unadjusted for BW)	S+D	34 day	M, F	0.17±0.06	Toelle *et al*. (1991)
	SC	34 day	M, F	0.28±0.11	Toelle *et al*. (1991)
	DC	34 day	M, F	0.07±0.13	Toelle *et al*. (1991)
Gizzard weight	FS	25 week	M	0.648	Kawahara and Satto (1976)
	FS	25 week	F	0.400	Kawahara and Satto (1976)
Gizzard	S+D	34 day	M, F	0.63±0.08	Toelle *et al*. (1991)
(unadjustedfor BW)	SC	34 day	M, F	0.84±0.15	Toelle *et al*. (1991)
	DC	34 day	M, F	0.43±0.14	Toelle *et al*. (1991)
Intestine weight	FS	25 week	M	0.174	Kawahara and Satto (1976)
	FS	25 week	F	0.175	Kawahara and Satto (1976)
Pancreas weight	FS	25 week	M	0.282	Kawahara and Satto (1976)
	FS	25 week	F	0.426	Kawahara and Satto (1976)
Spleen weight	FS	25 week	M	0.515	Kawahara and Satto (1976)
	FS	25 week	F	0.501	Kawahara and Satto (1976)
Kidney weight	FS	25 week	M	0.379	Kawahara and Satto (1976)
	FS	25 week	F	0.294	Kawahara and Satto (1976)
Ovary weight	FS	25 week	F	0.455	Kawahara and Satto (1976)

Table 5: Cotinued

Traits	Estimation method	Age	Sex	Heritability coefficient (%)	Source
Testis weight	FS	25 week	M	0.737	Kawahara and Saito (1976)
Oviduct weight	FS	25 week	F	0.542	Kawahara and Saito (1976)
Muscle weight (including	FS	25 week	M	0.693	Kawahara and Saito (1976)
skin and feather)	FS	25 week	F	0.348	Kawahara and Saito (1976)
Carcass weight	AM (multi-trait)	49 day	M, F	0.273±0.101	Vali *et al*. (2005)
Carcass percent	AM (multi-trait)	49 day	M, F	0.119±0.084	Vali *et al*. (2005)
Breast weight	AM (multi-trait)	49 day	M, F	0.262±0.100	Vali *et al*. (2005)
Breast percent	AM (multi-trait)	49 day	M, F	0.152±0.094	Vali *et al*. (2005)
Thigh weight	AM (multi-trait)	49 day	M, F	0.281±0.141	Vali *et al*. (2005)
Thigh percent	AM (multi-trait)	49 day	M, F	0.190±0.164	Vali *et al*. (2005)

HS = half sib, FS = full sib, PP = parent-progeny, DD = daughter-dam, AM = animal model, LS = least squares estimation, REML = restricted maximum likelihood estimation, SC = sire component, DC = dam component, S+D = sire dam, RH = realized heritability

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