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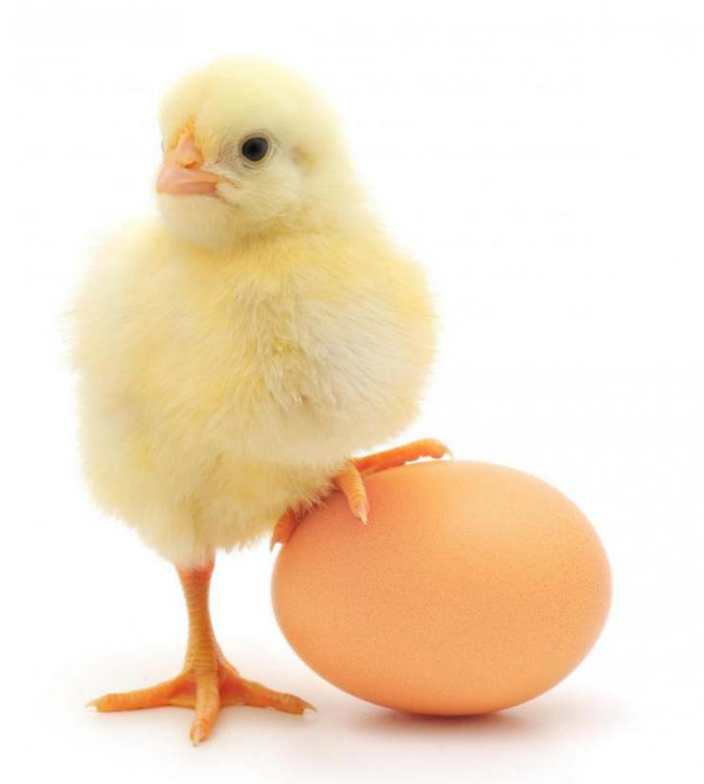

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Comparison of Growth in Three Varieties of the Japanese Extremely Long-Tailed Chicken Breed (Tosa-no-Onagadori)

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Abstract: The aim of this study is to reveal whether there are differences in live body weights and growth curves based on Gompertz function among three plumage color varieties (black-breasted white, black-breasted red and white) of the Japanese extremely long-tailed chicken breed (Tosa-no-Onagadori, briefly Onagadori), Special National Natural Treasure of Japan. Body weights were recorded every week from hatching to 30 weeks of age. In males, black-breasted red showed higher values than black-breasted white from 13 to 30 weeks of age. In females, black-breasted red was also higher than black-breasted white in body weights at 17, 19 and 26 to 30 weeks of age. Comparing the earliness of inflection points in growth curves among three varieties, the order was black-breasted white>black-breasted red>white in the female and black-breasted red>black-breasted white>white in the male. The differences in the body weights and inflection points are thought to be due to the genetic background differences between varieties. The information from this study will be useful in developing future strategies for conservation and improvement of the Onagadori as valuable genetic resource.

Key words: Body weight, growth curve, native Japanese chickens, Onagadori, plumage color varieties

INTRODUCTION

In Japan, there are approximately 50 breeds of indigenous chickens (Tsudzuki, 2003). Almost all of them were developed for ornamental purposes, e.g. special body shape and plumage, long crowing and cock fighting, as opposed to European and American breeds that were mostly established for meat and egg production (Osman *et al*., 2006; Goto *et al*., 2010). Among them, 15 breeds and two groups have been designated as National Natural Treasure of Japan. Especially, the Tosa-no-Onagadori breed (briefly, Onagadori) has been designated as a Special National Natural Treasure of Japan (Tsudzuki, 2003). Males of this breed show no molting in some of tail feathers and saddle hackles and the non-molting tail feathers grow approximately 100 cm in average per year. This breed has three plumage color varieties (black-breasted white, black-breasted red and white) and the black-breasted white is believed to be the original plumage color of the Onagadori. Black-breasted red and white varieties were established by crossing with other breeds (Tsudzuki, 2006). In the recent study based on microsatellite DNA polymorphisms, it was revealed that these varieties have genetically different background (Tadano *et al*., 2009). Growth is one of the priority traits for improvement and conservation of not only ornamental breeds but also industrial chickens (The Japanese Fowls Association, 1997; Beiki *et al*., 2013). However, no comparison of growth has been done so far for three varieties of the Onagadori. Therefore, the aim of this study is to reveal the differences in growth of three varieties of the Onagadori based on live weights measured serially and growth curves estimated with a non-linear model, Gompertz function.

MATERIALS AND METHODS

Data were collected from three different plumage color varieties (black-breasted white, black-breasted red and white) of the Onagadori reared at the Laboratory of Animal Breeding and Genetics, Graduate School of Biosphere Science, Hiroshima University. Body weights were recorded weekly from hatching to 30 weeks of age. Moreover, rate of weekly body weight gain was calculated as follows:

$$R_g = (W_g/W_b)\times 100$$

Where:

R_g = Rate of weekly weight gain
W_g = Weight gain per week
W_b = Body weight before gain

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Newly hatched chicks were numbered with wing-band for individual identification and reared in a temperature controlled brooder with 24 h lighting until 10 weeks of age. Then, chicks were transferred into a colony room with fluorescent lighting from the ceiling during 0500 and 1900 h. They were grouped in wire meshed cages until 17 weeks of age and thereafter housed individually in wire cages to the end of experiment. Feed and water were provided *ad libitum* during the experiment. Standard commercial starter diet (0-6 weeks: crude protein (CP), 20%), grower diet (7-10 weeks: CP, 17%), developer diet (11-16 weeks: CP, 15%) and layer diet (17-30 weeks: CP, 17%) were supplied.

In addition to live body weight measuring, growth curves were estimated with a non-linear growth model, Gompertz function (Gompertz, 1825), because this model well fits the growth of chickens (Mignon-Grasteau *et al*., 1999; Goto *et al*., 2011). The formula is as below (Norris *et al*., 2007):

$$W_t = A \times \exp[-\exp(b-ct)]$$

Where:

W_t = Body weight at time t (age in weeks)
A = Asymptotic body weight of the bird that is the weight at an infinite age
b = ln (A/W_0)
W_0 = Estimated hatching weight of birds
C = Maturation rate

The age at inflection is defined as $1/c \times \ln(b)$ and the body weight at hatching W_0 as A x $\exp^{(-b)}$ (Laird, 1966). Curve parameters were calculated with statistical software R (version 3. 0. 1; available as a free download form http://www.r-project.org).

RESULTS

Table 1 shows means and standard errors for body weights in three varieties of the Onagadori breed of chickens from hatching (0 week) to 30 weeks of age. From 0 to 12 weeks of age, no significant differences were observed between three varieties in males. Whereas, from 13 to 30 weeks of age, black-breasted red males showed higher values than black-breasted white males. White variety males showed lower values than black-breasted red males at 21 and 23 weeks of age, though there were no differences between white and black-breasted white males.

On the other hand, body weights of females showed different tendency as compared with those of males. No significant differences were observed between three varieties at 0 to 1, 6 to 12, 20 and 22 to 25 weeks of age. Black-breasted red showed higher values than black-breasted white and white at 2 and 3 weeks of age. Black-breasted red also showed higher values than white at 4 and 5 weeks of age, though there was no difference between white and the other varieties. At the age of 13 to 19, 21, 28 and 29 weeks, body weights of black-breasted red were higher than those of white. Also, Black-breasted red showed higher values than black-breasted white at 17, 19 and 26 to 30 weeks of age.

Table 2 shows the rate of body weight gain in both sexes of three varieties of the Onagadori. At 1-2 week period, black-breasted red showed a significantly higher value than black-breasted white in females. Whereas, at 23-24 week period, black-breasted red showed a significantly lower value than black-breasted white in males. There were no significant differences in the other periods.

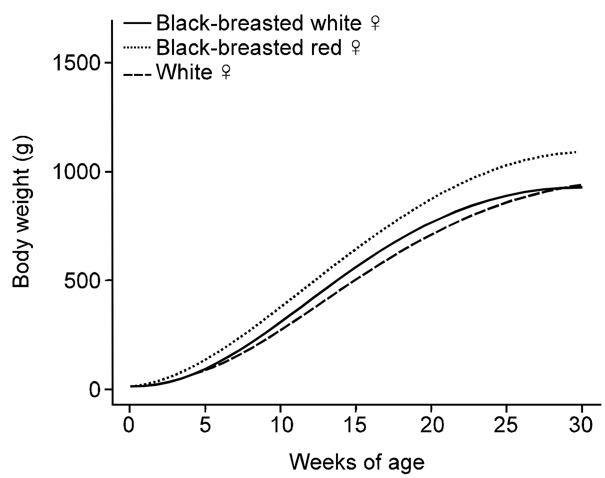

Fig. 1: Average growth curves estimated with the Gompertz function for three plumage color varieties of Onagadori females during the first 30 weeks of age.

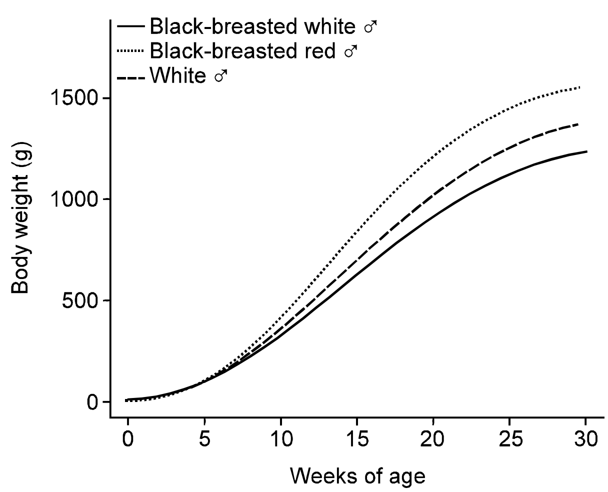

Fig. 2: Average growth curves estimated with the Gompertz function for three plumage color varieties of Onagadori males during the first 30 weeks of age.

Table 1: Means and standard errors for body weight in three varieties of the Onagadori breed of chickens at 0-30 weeks of age

Age (week)	Varieties											
	Black-breasted white				Black-breasted red				White			
	Female	n	Male	n	Female	n	Male	n	Female	n	Male	n
0	24.80±0.43^{a}	32	24.58±0.58^{a}	23	24.72±0.44^{a}	14	26.15±0.70^{a}	6	23.77±0.51^{a}	8	24.30±0.64^{a}	8
1	29.78±0.79^{a}	25	30.72±1.14^{a}	18	32.33±1.99^{a}	8	33.03±2.31^{a}	4	28.68±1.75^{a}	5	29.34±2.12^{a}	5
2	38.45±1.27^{b}	32	41.65±1.94^{ab}	23	49.45±2.56^{a}	14	47.22±4.95^{ab}	6	34.42±2.92^{b}	8	43.55±3.75^{ab}	8
3	52.16±1.93^{b}	32	58.56±3.23^{ab}	23	69.21±5.02^{a}	14	63.63±4.87^{ab}	6	42.88±5.40^{b}	7	64.59±5.12^{ab}	7
4	71.14±3.73^{ab}	29	79.45±4.78^{a}	22	89.79±5.58^{a}	12	87.07±5.21^{a}	6	51.75±5.10^{b}	7	85.23±4.62^{a}	8
5	92.71±5.29^{ab}	32	105.34±8.25^{a}	22	112.21±8.32^{a}	14	113.20±14.34^{ab}	6	67.28±3.66^{b}	8	119.54±8.20^{a}	8
6	111.74±5.92^{a}	28	120.00±10.95^{a}	20	143.01±9.47^{a}	13	141.30±14.61^{a}	6	92.66±4.27^{a}	7	139.05±10.73^{a}	8
7	147.12±8.75^{a}	32	152.77±12.72^{a}	23	185.87±12.84^{a}	14	192.97±25.61^{a}	6	120.52±6.80^{a}	7	166.40±14.34^{a}	8
8	195.33±10.73^{a}	32	207.44±16.43^{a}	23	236.19±16.06^{a}	14	268.85±30.95^{a}	6	169.66±11.61^{a}	7	226.14±18.82^{a}	7
9	247.06±12.31^{a}	32	262.96±20.37^{a}	23	297.09±18.67^{a}	14	343.87±33.04^{a}	6	216.23±15.03^{a}	6	286.40±25.63^{a}	5
10	292.98±13.00^{b}	32	315.55±26.65^{ab}	22	364.53±19.72^{ab}	13	414.83±30.78^{a}	6	254.72±15.90^{b}	7	318.28±24.20^{ab}	8
11	344.67±13.39^{b}	32	379.42±27.95^{ab}	23	420.92±23.17^{ab}	14	501.03±28.63^{a}	6	291.16±25.65^{b}	7	403.36±22.16^{ab}	8
12	412.58±19.28^{b}	32	449.26±28.18^{ab}	23	486.48±24.58^{ab}	14	586.43±31.34^{a}	6	364.28±26.75^{b}	8	463.15±21.44^{ab}	8
13	451.13±16.21^{bc}	31	506.53±32.32^{bc}	23	547.39±24.08^{ab}	14	676.12±25.43^{a}	6	395.88±25.20^{c}	8	550.83±19.99^{ab}	8
14	507.78±15.83^{cd}	32	583.40±32.61^{bc}	23	600.05±27.30^{bc}	14	783.92±25.79^{a}	6	461.82±27.37^{d}	8	637.29±16.36^{ab}	8
15	551.04±16.36^{cd}	32	642.96±34.09^{b}	22	653.40±28.46^{bc}	14	851.77±20.86^{a}	6	505.50±28.13^{d}	8	699.41±17.99^{ab}	8
16	600.86±18.23^{cd}	32	700.83±34.64^{b}	22	706.38±27.06^{bc}	14	944.03±23.57^{a}	6	558.34±26.43^{d}	8	773.98±14.92^{ab}	8
17	657.44±14.91^{c}	31	756.87±33.96^{b}	23	764.05±29.76^{b}	14	1002.70±20.96^{a}	6	594.48±23.72^{c}	8	835.68±19.02^{ab}	8
18	701.38±14.89^{cd}	31	830.97±38.42^{b}	22	802.84±30.65^{bc}	14	1079.25±34.71^{a}	6	636.72±24.61^{d}	8	913.31±17.59^{ab}	8
19	739.69±15.36^{c}	31	887.35±38.38^{b}	22	853.77±31.28^{b}	14	1132.20±39.46^{a}	5	671.44±18.31^{c}	8	981.96±30.66^{ab}	8
20	755.91±18.97^{c}	31	909.71±38.57^{b}	23	871.99±34.14^{bc}	13	1195.80±40.54^{a}	6	698.72±25.56^{c}	8	1007.69±31.11^{ab}	7
21	790.71±17.27^{de}	32	956.65±39.57^{bc}	23	899.82±28.77^{cd}	14	1295.03±48.15^{a}	6	730.32±25.27^{e}	8	1088.24±32.82^{b}	8
22	810.89±17.45^{d}	32	989.46±44.63^{bc}	22	929.24±29.53^{cd}	13	1341.27±48.74^{a}	6	767.28±31.89^{d}	8	1134.58±25.89^{ab}	8
23	837.48±18.29^{d}	31	1053.74±38.06^{bc}	22	944.91±28.56^{cd}	14	1382.70±51.57^{a}	6	782.92±30.77^{d}	8	1181.65±28.12^{b}	8
24	861.56±18.81^{d}	32	1094.69±42.67^{bc}	23	969.81±25.51^{cd}	14	1404.07±51.17^{a}	6	800.52±31.20^{d}	8	1208.46±26.03^{ab}	8
25	876.48±19.64^{d}	31	1119.17±46.18^{bc}	23	984.63±26.90^{cd}	13	1433.70±30.55^{a}	6	814.40±32.37^{d}	8	1242.18±32.25^{ab}	8
26	876.61±18.44^{d}	32	1159.99±47.84^{b}	22	1012.44±26.36^{c}	14	1464.23±25.47^{a}	6	842.68±33.13^{cd}	8	1272.09±24.35^{ab}	8
27	884.36±17.53^{e}	32	1182.06±45.80^{bc}	22	1047.39±29.94^{cd}	14	1464.45±37.06^{a}	6	864.08±35.14^{de}	8	1279.48±35.31^{ab}	8
28	893.59±18.31^{d}	31	1191.24±47.33^{bc}	22	1082.84±38.39^{c}	14	1508.85±40.53^{a}	6	889.66±34.57^{d}	8	1311.78±38.67^{ab}	8
29	921.26±17.58^{d}	32	1217.02±51.51^{bc}	22	1125.93±42.76^{c}	14	1555.13±39.98^{a}	6	918.60±36.83^{d}	8	1338.84±42.48^{ab}	8
30	933.24±20.35^{e}	32	1254.71±49.44^{bc}	21	1128.59±45.82^{cd}	14	1573.72±35.89^{a}	6	954.96±39.04^{de}	8	1397.28±36.65^{ab}	8

$^{a-e}$Means with the same superscript letter are not significantly different among varieties at $P<0.05$ in each week (one way ANOVA followed by Tukey's HSD test)

Table 2: Rate of body weight gain in three varieties of the Onagadori breed of chickens

	Varieties											
	Black-breasted white				Black-breasted red				White			
Age (week)	Female	n	Male	n	Female	n	Male	n	Female	n	Male	n
0-1	18.16±2.60^{a}	25	24.68±2.67^{a}	18	26.07±6.16^{a}	8	26.84±5.35^{a}	4	22.79±6.93^{a}	5	16.82±8.04^{a}	5
1-2	27.92±3.68^{b}	25	33.51±4.71^{ab}	18	53.42±9.39^{a}	8	28.01±6.23^{ab}	4	27.22±4.09^{ab}	5	28.51±5.61^{ab}	5
2-3	36.34±3.16^{a}	32	40.90±4.48^{a}	23	38.69±5.51^{a}	14	37.74±9.65^{a}	6	33.19±4.15^{a}	7	57.43±7.86^{a}	7
3-4	31.60±3.63^{a}	29	33.38±3.94^{a}	22	24.12±4.23^{a}	12	39.04±9.21^{a}	6	22.02±7.29^{a}	6	33.87±7.70^{a}	7
4-5	34.01±4.19^{a}	29	33.73±2.98^{a}	21	32.36±4.57^{a}	12	28.22±11.46^{a}	6	29.91±6.03^{a}	7	39.82±5.56^{a}	8
5-6	26.48±2.95^{a}	28	20.44±1.95^{a}	19	26.04±3.26^{a}	13	29.81±11.77^{a}	6	37.43±4.84^{a}	7	16.18±3.95^{a}	8
6-7	28.39±3.46^{a}	28	24.20±3.26^{a}	20	34.36±3.08^{a}	13	34.96±5.99^{a}	6	31.82±3.41^{a}	7	20.40±5.19^{a}	8
7-8	34.68±2.83^{a}	32	36.35±2.90^{a}	23	27.42±2.16^{a}	14	40.89±3.43^{a}	6	36.98±4.35^{a}	7	33.46±5.20^{a}	7
8-9	27.83±1.60^{a}	32	27.30±2.07^{a}	23	26.35±1.61^{a}	14	29.26±2.85^{a}	6	27.68±3.32^{a}	6	22.13±0.74^{a}	4
9-10	19.85±1.40^{a}	32	19.49±2.60^{a}	22	19.71±1.99^{a}	13	22.25±4.48^{a}	6	19.35±2.27^{a}	6	23.48±3.65^{a}	5
10-11	18.78±1.31^{a}	32	23.12±7.62^{a}	22	18.61±2.16^{a}	13	21.64±3.67^{a}	6	16.08±4.30^{a}	7	29.28±6.96^{a}	8
11-12	19.54±2.21^{a}	32	26.65±7.34^{a}	23	16.06±1.83^{a}	14	17.24±2.57^{a}	6	24.28±4.11^{a}	7	15.58±3.88^{a}	8
12-13	10.40±1.83^{a}	31	13.63±2.09^{a}	23	13.17±1.80^{a}	14	16.05±3.86^{a}	6	12.34±3.38^{a}	8	19.60±3.53^{a}	8
13-14	13.47±1.14^{a}	31	16.81±2.00^{a}	23	9.51±1.39^{a}	14	16.15±2.41^{a}	6	15.38±2.78^{a}	8	16.21±2.99^{a}	8
14-15	8.71±0.71^{a}	32	11.34±2.39^{a}	22	9.04±0.88^{a}	14	8.86±1.89^{a}	6	10.28±2.02^{a}	8	9.81±1.40^{a}	8
15-16	8.92±0.68^{a}	32	10.19±1.07^{a}	21	8.65±1.29^{a}	14	10.84±0.92^{a}	6	12.00±1.79^{a}	8	10.81±1.02^{a}	8
16-17	7.40±0.61^{a}	31	9.67±1.78^{a}	22	8.10±1.04^{a}	14	6.29±1.01^{a}	6	7.27±1.77^{a}	8	7.96±1.17^{a}	8
17-18	6.85±0.65^{a}	31	8.69±1.00^{a}	22	5.24±0.81^{a}	14	7.54±1.79^{a}	6	8.03±1.08^{a}	8	9.37±0.92^{a}	8
18-19	5.51±0.46^{a}	31	7.45±1.22^{a}	22	6.43±0.66^{a}	14	6.14±0.46^{a}	5	5.52±1.65^{a}	8	7.39±1.72^{a}	8
19-20	3.66±0.59^{a}	30	3.58±1.21^{a}	22	3.72±1.33^{a}	13	6.72±1.73^{a}	5	4.61±1.30^{a}	8	3.86±1.15^{a}	7
20-21	4.50±0.78^{a}	31	5.39±1.21^{a}	23	2.66±1.50^{a}	13	8.29±1.62^{a}	6	3.72±1.09^{a}	8	6.14±1.49^{a}	7
21-22	2.69±0.80^{a}	32	3.89±0.91^{a}	22	4.28±0.64^{a}	13	3.62±1.21^{a}	6	3.67±2.00^{a}	8	4.55±2.05^{a}	8
22-23	3.38±0.65^{a}	31	3.36±0.72^{a}	21	1.38±0.79^{a}	13	3.09±0.75^{a}	6	3.30±1.05^{a}	8	4.18±1.20^{a}	8
23-24	2.95±0.70^{b}	31	6.07±0.80^{a}	22	2.81±0.75^{ab}	14	1.57±0.63^{b}	6	2.60±0.74^{ab}	8	2.35±1.18^{ab}	8
24-25	1.84±0.99^{a}	31	2.09±1.02^{a}	23	1.82±0.65^{a}	13	2.46±2.29^{a}	6	1.56±0.79^{a}	8	2.82±1.69^{a}	8
25-26	0.22±0.73^{b}	31	4.61±0.59^{a}	22	2.44±0.75^{ab}	13	2.20±1.00^{ab}	6	2.73±0.66^{ab}	8	2.56±1.20^{ab}	8
26-27	1.06±0.79^{a}	32	2.22±0.70^{a}	22	3.42±0.88^{a}	14	0.21±3.25^{a}	6	3.52±0.67^{a}	8	0.49±1.32^{a}	8
27-28	0.79±0.71^{a}	31	0.79±0.94^{a}	22	3.16±0.92^{a}	14	3.06±1.26^{a}	6	2.09±1.23^{a}	8	2.53±1.41^{a}	8
28-29	3.53±0.73^{a}	31	1.98±1.04^{a}	22	3.95±1.37^{a}	14	3.11±1.19^{a}	6	3.47±1.32^{a}	8	2.17±2.15^{a}	8
29-30	1.21±0.82^{a}	32	1.78±1.35^{a}	21	0.15±1.05^{a}	14	1.36±2.35^{a}	6	3.51±0.85^{a}	8	4.70±2.42^{a}	8

$^{a-b}$Means with the same superscript letter are not significantly different among varieties at $P<0.05$ in each week (one way ANOVA followed by Tukey's HSD test)

Table 3: Gompertz model parameters and inflection points for each variety and sex

Varieties	Sex	A	b	c	Inflection Point
Black-breasted	Female	992.0	3.689	0.147	11.188
white	Male	1415.0	4.053	0.123	13.150
Black-breasted	Female	1195.0	3.878	0.133	11.321
red	Male	1707.0	4.179	0.139	12.372
White	Female	1017.0	3.756	0.130	12.410
	Male	1553.0	4.157	0.126	13.169

Gompertz model parameters and inflection points for each variety and sex are shown in Table 3 and the average growth curves estimated with the Gompertz function for three varieties of the Onagadori are shown in Fig. 1 and 2. A values in Table 3 shows the asymptotic body weight of the bird that is the weight at an infinite age. The ranking of asymptotic body weight was black-breasted red>white>black-breasted white in both sexes. Within the same varieties, sex differences were observed in all three varieties. The female had an inflecting point at age younger (11.188, 11.321 and 12.410 weeks of age in the black-breasted white, black-breasted red and white, respectively) than the male (13.150, 12.372 and 13.169 weeks in the black-breasted white, black-breasted red and white, respectively). Comparing the earliness of inflection points among three varieties, the ranking was black-breasted white (11.188 week of age)>black-breasted red (11.321 week of age)>white (12.410 week of age) in the female and black-breasted red (12.372 week of age)>black-breasted white (13.150 week of age)>white (13.169 week of age) in the male.

DISCUSSION

Body weight differences among three varieties were observed at many weeks of age, though there were only a few weeks of age at which differences in body weight gain rate were detected among three varieties. At 13 to 30 weeks of age, black-breasted red males showed higher body weight than black-breasted white males, and at 26 to 30 weeks of age, both sexes of the black-breasted red showed higher values than those of black-breasted white. Furthermore, asymptotic body weight of the black-breasted red is the highest in the three varieties in growth curve analysis. These differences are thought to be due to the differences in the genetic backgrounds among varieties. The black-breasted white is believed to be the original plumage color of the Onagadori, and the origin of the black-breasted red was in cross between black-breasted white Onagadori and Toutenkou (Tsudzuki, 2006). Toutenkou is also a Japanese indigenous chicken breed which is characterized by black-breasted red plumage and long crowing, and its body size is larger than Onagadori (Tsudzuki, 2003). Therefore, there is a possibility that genes from Toutenkou breed established the body size of black-breasted red Onagadori larger. Actually, Tadano *et al.* (2009) revealed on the basis of microsatellite DNA analysis that three plumage color varieties of the Onagadori have different genetic background and suggested that they should be considered as independent genetic units in a conservation strategy. To improve and approximate the genome of the black-breasted red to that of the original black-breasted white type, it is necessary that black-breasted red are successively backcrossed to black-breasted white. When enough generations (e.g. more than eight generations) have been passed, the body weight of black-breasted red will be similar to that of black-breasted white, and uniformity of breed will be accomplished between black-breasted white and black-breasted red.

In growth curve analysis, the female had the inflecting point at young age in comparison with that of the male in all varieties. In addition to this result, some researchers also reported that the female tends to have the inflecting point at age younger that of the male (Barbato, 1991; Mignon-Grasteau *et al.*, 2000; Goto *et al.*, 2011). Usually, ornamental chicken breeders in Japan treat with both sexes similarly in feeding their chickens. Judging from the difference in inflecting points between sexes, feeding program should be changed between sexes. To feed chickens under the best condition, diet for females should be changed from grower diet to developer diet one or two weeks earlier than for males.

In addition to the genetic improvement by backcrosses mentioned above, improvement of feeding program will lead to the better conservation of the Onagadori.

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