

THE ESTIMATION OF GROWTH CURVE OF BALI CATTLE AT BONE AND BARRU DISTRICTS, SOUTH SULAWESI, INDONESIA USING TEN BODY MEASUREMENTS

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Received October 25, 2011; Accepted November 22, 2011

ABSTRAK

Dugaan kurva pertumbuhan dan ukuran dewasa tubuh pada calon pejantan dan calon induk sapi Bali umur 12, 15, 18, 21 dan 24 bulan diukur berdasarkan sepuluh dimensi tubuh yaitu tinggi pundak, tinggi punggung, panjang badan, lingkar dada, dalam dada, lebar dada, panjang kelangkang, lebar punggung, lebar kelangkang, dan lebar tulang tapis. Penelitian ini menggunakan 108 ekor calon pejantan dan 146 ekor calon induk sapi Bali di Kabupaten Bone serta 152 ekor calon pejantan dan 110 ekor calon induk sapi Bali di Kabupaten Barru, Propinsi Sulawesi Selatan, Indonesia untuk menduga kurva pertumbuhan dan ukuran dewasa tubuh dari 10 dimensi tubuh sapi Bali berdasarkan model kurva pertumbuhan Brody. Hasil analisis memperlihatkan bahwa dimensi tubuh sapi Bali masih sedang bertumbuh pada usia 24 bulan dan belum mencapai titik puncak ukuran dewasa tubuh. Lokasi pemeliharaan, jenis kelamin dan umur sangat mempengaruhi pertumbuhan dimensi tubuh Sapi Bali.

Kata kunci: sapi Bali, calon pejantan, calon Induk, dimensi tubuh, kurva pertumbuhan

ABSTRACT

The estimation of growth curves and mature size of ten body measurements, namely withers height, hip height, body length, chest girth, chest depth, chest width, rump length, hip width, thurl width, and pin bone width, were studied in Bali bulls and heifers at the age of 12, 15, 18, 21 and 24 months. 108 bulls and 146 heifers at Bone district and 152 bulls and 110 heifers at Barru district, South Sulawesi, Indonesia were measured. The Brody growth function was fitted to each animal's records and least-squares analysis were used to investigate the effects of place, sex, and age to growth curve and mature size of body measurements of Bali bulls and heifers. The result showed that the growth of body measurements of Bali cattle until 24 months of age were still increasing and not reaching the mature size yet. The place, sex and age factors were significantly affected to the growth of body measurements of Bali cattle.

Keywords: Bali cattle, bull, heifer, body measurements, growth curve

INTRODUCTION

Bali cattle (*Bos sondaicus*, *Bos javanicus*, *bos/Bibos banteng*) is one of the genetic resources of indigenous Indonesian livestock and also one of important beef cattle breed that contribute to the development of livestock industry in Indonesia. Bali cattle dominates the beef cattle population primarily in eastern of Indonesia such as East and West Nusa Tenggara islands and South Sulawesi. Chamdi (2005) indicated that

Bali cattle has superiorities in some aspects such as high fertility rate, high production performance, high adaptation capability, good beef performance traits, high innate resistance to ticks and tick-borne diseases, good ability to rapidly recover condition after poor usage, and good work capability. Majority of the Bali cattle farmers in Indonesia raise their Bali cattle under three management systems such as grazing on open lands, grazing within plantations, and intensive cut and carry management with animals

held in separate individual animal housing (Siregar *et al.*, 2003) beside that the farmers do not give special attention for the quality and quantity of feeding.

The measurements of cattle's body measurements are widely used for genetic improvements of meat production in live beef cattle because it could help the breeder to recognize the early and late maturing animals of different sizes and to evaluate growth performance of farm animals. Cattle's body measurement affects efficiency, maintenance requirements, cattle's profitability, reproduction, and cull cattle value. The characterization of some body measurements of beef cattle related to the growth will lead to a more efficient utilization of these important genetic resources. Therefore mature size, which is estimated by growth curve of body measurement, impacts the profitability of beef enterprises and thus should be considered in selection programs (Marco *et al.*, 2010). Information regarding the growth curve of body measurements of Bali cattle is needed to understand the biological phenomenon of growth and it is useful in developing a genetic improvement program of Bali cattle production system. Previous studies identified growth pattern of Angus cattle (Beltrans *et al.*, 1992), mature size of Angus cow (Archer *et al.*, 1998), mature weight or puberty weight of Bali cattle (Talib *et al.*, 2003), and mature weight of Holstein cow (Berry *et al.*, 2005). However, there is no information of growth curve and mature size of body measurements of Bali cattle.

This study is aimed to analysis of the growth curve of body measurements namely withers height (WH), hip height (HH), body length (BL), chest girth (CG), chest depth (CD), chest width (CW), rump length (RL), hip width (HW), thurl width (TW), and pin bone width (PBW) during growing period of bulls and heifers of Bali cattle, and to estimate of mature size along the growing period of Bali cattle. Additional objectives were to clarify the effects of place, sex and age on the growth of body measurements of Bali cattle.

MATERIALS AND METHODS

Data Source, Animal Management and Parameters

The Bali cattle were reared at local farmer by traditional rearing system at Bone and Barru District, South Sulawesi, Indonesia. The location of Bone district was at the hill and the Barru

district was near the beach. The cattle at both of places were continuously grazed on paddy field or backyard and they were fed by *ad libitum* field grass without any additional supplement or concentrate. Sometimes the napier grass and the salt block were given to the cattle.

The bulls and heifers at Bone district were born from 22 sires and those at Barru district were born form 12 sires. The cross-sectional data for ten body measurements (WH, HH, BL, CG, CD, CW, RL, HW, TW, and PBW, respectively) were recorded on 108 bulls and 146 heifers at Bone district and those of 152 bulls and 110 heifers at Barru district at the age of 12, 15, 18, 21, and 24 months. All body measurements were recorded in centimeters unit using the calibrated calipers and the steel rods.

Growth Functions

Least square means were calculated as appropriate. An analysis of variance was carried out to determine the differences of the growth of body measurements of Bali cattle among the place, sex, and age effects and it were also conducted for the main effect of place, sex, and age group as the independent variables whereas the degrees of maturity for body measurements as dependent variables. Data were analyzed by the least squares and maximum likelihood procedure (Harvey, 1977) in which the model was:

$$Y_{ijkl} = \mu + P_i + S_j + A_k + e_{ijkl}$$

where Y_{ijkl} = observed linear measurement of body measurement; μ = overall mean; P_i = effect of i^{th} place ($i = 1,2$); S_j = effect of j^{th} sex ($j = 1,2$); A_k = effect of k^{th} age ($k = 1, 2, 3, 4, 5$); e_{ijkl} = residual error of the dependent variable

In this study, growth pattern were obtained from Brody growth curve models (Koenen and Groen, 1996) to estimate the growth curve parameters under individual records for the body measurements of Bali cattle datasets. The formula used to estimate the parameters of the growth curve model was as follows:

$$Y = A [1 - \exp (-\lambda + \beta t)]$$

where Y = observed body measurements of bulls or heifers of Bali cattle at age t ; A = estimate of mature size; λ = constant; β = rate of maturity; t = value at t months of age.

RESULTS AND DISCUSSION

The development and growth pattern after weaning was generally influenced by genetic growth potential of each cattle, sex, hormone, environment, rearing place, and rearing management system but nutrition level of feeding is a major factor. The growth of body measurements are post-natal growth and it is mostly expressed as a continuous distribution and thought of an associated strategy for the genetic improvement. The analysis of variance of growth rate of body measurements of Bali bulls and heifers are presented at Table 1.

Significant place, sex, and age effects were present for the growth of all body measurements of Bali bulls and heifers. Generally the mean of growth body measurements of heifers of Bali cattle were higher than those of bulls except the growth of WH, HH and BL at adult age (over 18 months of age). It could be related to the preparation condition for the growth of reproduction organs. In cattle, muscle distribution is influenced more by sex than by breed. In the fact, the growth of proximal hindlimb and abdominal muscles were heavier in heifers than in bulls.

Table 1. Analysis of Variance of Growth Rate of Body Measurements of Bali Cattle

Source of Variation†	Place	Sex	Age
df	1	1	1
WH	2373.3**	0.004	5897.2**
HH	2038.1**	79.089	5911.6**
BL	1381.3**	639.7**	7980.0**
CG	1813.8**	868.4*	21793.0**
CD	461.2**	19.4	2952.6**
CW	39.2*	264.8**	1041.8**
RL	278.9**	30.1*	800.7**
HW	171.5**	180.4**	1617.3**
TW	265.7**	17.5	1071.6**
PBW	6.2*	162.1**	490.2**

**P<0.01; *P<0.05

† WH: withers height, HH: hip height, BL: body length, CG: chest girth, CD : chest depth, CW: chest width, RL: rump length, HW: hip width, TW: thurl width, PBW: pin bone width

Bali cattle is *Bos sondaicus* that have relatively small body size and have slow growth rate and mature size compare with the other Asia beef breed of *Bos indicus* (Jelantik *et al.*, 2008) and British breeds of Angus, Simmental, and Shorthorn (Cundiff *et al.*, 1993). The cattle breeds of small mature size have low of the average daily gain and narrow of pelvis development which indicates of low muscling in addition and slow skeletal development (Alberti *et al.*, 2008).

Place and age effects gave highly significant effect (P<0.01) to all of the growth of body measurements of Bali cattle except those of CW and PBW (P<0.05). These results indicated that rearing place was one of important factor to let the cattle growth optimally. Beside that the results of age effect could be used as a basic achievement of adequate growth and reproductive performance. On the other hand the growth of WH, HH, CD and TW of Bali cattle were not significantly affected by sex effect.

The body measurement allows us to draw conclusions concerning maturity and may also serve as important selective considerations (Szabolcs *et al.*, 2007). The importance of body size to efficiency become to be traits associated with size, mass and body measurement being included in selection programs and breeding objectives. In Japan, fattening cattle in the field were usually measured of withers height, chest girth and body length. The height of a beef animal at a given age could be used to predict of its growth curve and fattening pattern as well as its mature size.

The least square means and standard errors for body measurements by age group for Bali cattle using the parameters derived from the Brody models are shown at Table 2.

All of the body measurements were increasing rapidly from 12 months to 24 months of ages and it still tended to grow based on the growth curve. Generally the growths of all body measurements were fast between the ages of 12 and 15 months. Even though the body measurements namely RL, HW, TW, and PBW showed slowly of growing rate. This result showed that the fattening program of Bali cattle could be continued after 24 months of age. Thus further investigation of the real mature age and mature size of Bali cattle are needed.

The real mature age of Bali cattle was unknown exactly. Generally, the mature age of Bali bulls were started if the red hair and reddish brown color on the body begins to darken, to be

Table 2. Least Square Means and Standard Errors for Body Measurements by Age Group for Bali Cattle using the Parameters Derived from the Brody Model

Body Measurements*	Age (Months)				
	12	15	18	21	24
WH	95.87± 0.49	99.79±0.62	101.43±0.59	103.29±0.61	105.46±0.75
HH	96.40± 0.50	100.31±0.62	101.39±0.59	103.51±0.61	106.48±0.76
BL	92.19± 0.62	97.11±0.77	98.43±0.73	100.81±0.76	103.82±0.94
CG	118.30±50.84	125.30±1.05	128.20±0.99	132.55±1.02	137.49±1.27
CD	46.48± 0.33	49.44±0.41	50.49±0.39	51.67±0.40	53.44±0.49
CW	23.35± 0.25	24.96±0.31	25.16±0.29	26.68±0.31	27.47±0.38
RL	28.74± 0.21	29.63±0.26	30.05±0.25	30.98±0.26	32.59±0.32
HW	24.59± 0.22	26.87±0.27	27.29±0.26	28.44±0.27	29.92±0.33
TW	27.59± 0.19	29.35±0.25	29.74±0.23	30.87±0.24	31.70±0.29
PBW	13.13± 0.99	14.51±0.25	14.83±0.24	15.59±0.24	15.78±0.30

*The abbreviations are similar to Table 1

black gray/dark bluish black, and completely black at finally. That condition could be seen around of 12-18 months of ages (Martoyo, 2012). There are some difficulties to explain the changes of body size which be observed throughout the life cattle because the shapes of cattle are determined by differences in relative growth. An appropriate way to describe them using few parameters is to use mathematical models. Growth models mathematically express the lifetime growth course. The simplest equation to explain the growth function is the Brody model that was used to estimate the growth curve parameters (e.g. mature body measurements, maturing rate, degree of maturity, etc.). Hirooka (2010) showed that mathematical models for growth have been used for many years in animal science to describe the change in body weight with age. Previous studies were examined the fitting non-linear growth model for describing growth pattern of body measurements and estimate curve parameters in Japanese calves (Kumazaki *et al.*, 1955) and in Japanese Black females (Obata and Mukai, 1982; Wada *et al.*, 1983). However there is no report about non-linear model fitted to the growth curve of body measurements of Bali cattle.

The estimates of growth curves of body measurements of Bali cattle at Bone and Barru District based on the Brody models are plotted at

Figure 1 and Figure 2. The results showed that the bulls at Barru district were start to reach the mature size at 24 months of ages of WH (106.2 cm), HH (106.5 cm), BL (102.1 cm), CG (136.3 cm), CD (53.3 cm), CW (27.0 cm), TW (31.5 cm), and PBW (15.8 cm), respectively. At similar ages, the bulls at Bone district were start to reach the mature size only for CD (54.4 cm) and RL (33.9 cm). In the case of heifer, only the PBW (16.7 cm) of heifers at Barru district were start to reach the mature size while those at Bone district were start to reach the mature size of HH (108.1 cm) and CD (53.9 cm) at the age of 24 months. Those indicated that the growth curves of all body measurements of bulls and heifer at both places were still increased and it was not reached the real mature size yet. Panjaitan *et al.* (2003) reported the mature height (114.7 cm) of female Bali cattle were reached at the age of 2.5 – 3.0 years and those of 117.6 cm by Pastika (1976). The different situation was come when the mature size is based on the growth of carcass traits. Sri Rachma and Harada (2010) reported the estimate carcass traits of Bali cattle using ultrasound that the Bali bulls were also start to reach the mature period at the 24 months of ages but it still tend to grow. Those results showed that the mature size and growing rate of Bali cattle still very variables.

Based on data of normal growth curve of Japanese Black cattle (The Japanese National

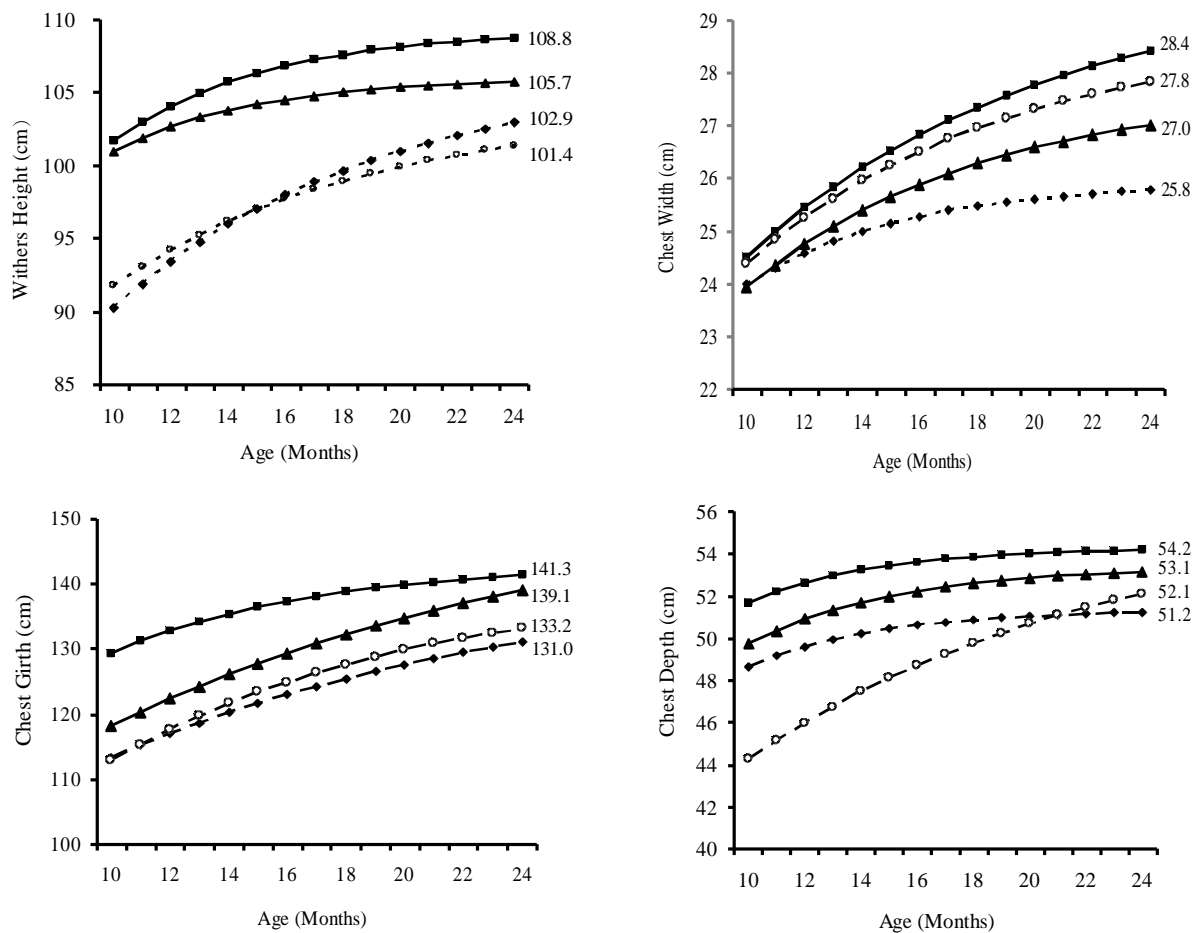


Figure 1. Mature size of Four Body Measurements of Front Part body of Bali Cattle (Fitted by Brody Model). —■—: Bull-Bone; —◆—: Bull-Barru; —▲—: Heifer-Bone; —○—: Heifer-Barru

Beef Cattle Registration Association, 2004) that the estimated age of reaching mature size of Bali cattle were late compare to the candidate sire and dam of Japanese Black cattle at the age of 24 months (WH: 139.8 cm vs 126.9 cm; HH : 137.3 cm vs 127.1 cm; BL: 164.4 cm vs 146.8 cm; CG: 199.9 cm vs 177.5 cm; CD: 72.6 cm vs 65.4 cm; CW: 50.3 cm vs 43.8 cm; RL: 56.8 cm vs 50.4 cm; HW: 50.0 cm vs 47.1 cm; TW: 49.8 cm vs 44.8 cm and PBW: 31.6 cm vs 29.3 cm, respectively). Alberti *et al.* (2008) reported that the young bull of Jersey and Limousin breeds had low withers height (112.9 cm and 118.7 cm), Aberdeen Angus, Charolais and Simmental breeds had intermediate values (120.2 cm, 120.6 cm and 126.1 cm, respectively) and Holstein had the greatest (133.1 cm). On the other hand Holstein and Simmental breeds had shorter body length (129.8 cm and 125.9 cm) while Aberdeen Angus and Charolais breeds had greatest body

lengths (142.7 cm and 145.0 cm). Minezawa (2003) found that the Japanese Black, Poll, and Shorthorn cattle were shown the means of mature withers height of 124 cm, 122 cm, and 128 cm, respectively. Average mature weights of Bali bull for NTB, NTT, and South Sulawesi range 335–363 kg (Talib *et al.*, 2003) and mature weight of Bali female for NTB, NTT, and South Sulawesi are 241.9 kg, 221.5 kg, and 211.0 kg, respectively (Martoyo, 2012). However, there is no report were presented to compare the mature size and age based on body measurements of Bali cattle. Those results could be use as basic information for fattening program, optimum time to slaughter the cattle, and optimum time to select the candidate sire of Bali cattle at both places.

The estimates of mature size, rate of maturity, and coefficient of determinations (R^2) of body measurements of bulls and heifers of Bali cattle at Bone and Barru district fitted by Brody

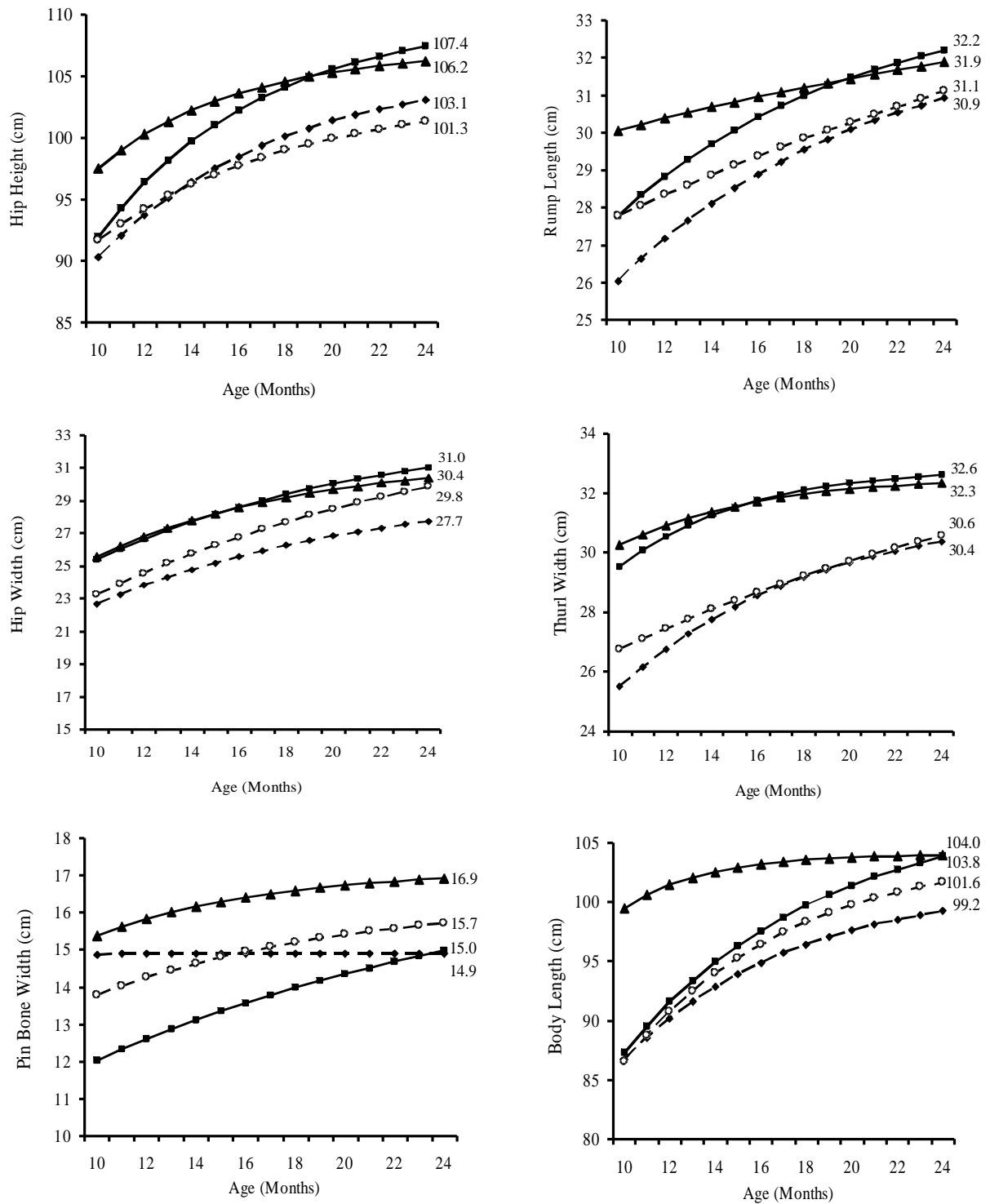


Figure 2. Mature Size of Six Body Measurements of Back Part Body of Bali Cattle (Fitted by Brody Model). —■—: Bull-Bone; —◆—: Bull-Barru; —▲—: Heifer-Bone; —○—: Heifer-Barru

model are presented at Table 3. All of the values of estimate mature size were higher than the real value of body measurements at 24 months of age that presented in Figures 1 and 2. All of the rate

maturity estimates of body measurements showed negative value with the high coefficient of determination (98.5-99.0%). It indicated that the real maturity or mature size of body

Table 3. The Estimate of Mature Size, Rate of Maturity and Coefficient of Determinations (R^2) of Body Measurements of Bulls and Heifers of Bali Cattle at Bone and Barru District Fitted by Brody Model

Traits*	Sex	Estimate		Constant		Rate of		R^2	
		Mature Size (A)		(λ)		Maturity(β)		(%)	
		Bone	Barru	Bone	Barru	Bone	Barru	Bone	Barru
WH	Bull	109.3	106.52	1.14	0.45	-0.19	-0.11	99.6%	99.6%
	Heifer	106.0	103.8	0.72	0.36	-0.20	-0.12	99.7%	99.7%
HH	Bull	109.8	105.7	0.68	0.52	-0.15	-0.13	99.6%	99.6%
	Heifer	107.1	103.5	0.47	0.37	-0.17	-0.12	99.7%	99.7%
BL	Bull	107.9	101.5	0.60	0.56	-0.12	-0.13	99.5%	99.4%
	Heifer	104.1	104.3	2.27	0.66	-0.27	-0.14	99.6%	99.4%
CG	Bull	143.3	141.9	1.06	0.40	-0.14	-0.07	99.4%	99.3%
	Heifer	154.4	140.1	0.43	0.52	-0.06	-0.09	99.4%	99.4%
CD	Bull	54.3	51.4	2.28	1.59	-0.23	-0.22	99.3%	99.2%
	Heifer	53.4	55.9	0.96	0.46	-0.19	-0.08	99.4%	99.5%
CW	Bull	29.8	25.9	0.86	1.22	-0.09	-0.18	98.6%	98.5%
	Heifer	27.6	28.7	0.46	0.69	-0.12	-0.11	99.9%	99.9%
RL	Bull	33.7	32.8	0.47	0.51	-0.09	-0.09	99.3%	99.3%
	Heifer	34.6	37.7	0.19	0.35	-0.04	-0.03	99.3%	99.2%
HW	Bull	33.6	29.9	0.75	0.56	-0.08	-0.09	99.0%	99.0%
	Heifer	31.6	34.7	0.71	0.61	-0.12	-0.06	99.1%	99.1%
TW	Bull	32.9	31.5	1.44	0.62	-0.18	-0.12	99.5%	99.3%
	Heifer	32.6	35.3	0.86	0.37	-0.17	-0.04	99.3%	99.3%
PBW	Bull	17.4	14.9	0.54	0.69	-0.06	-0.71	98.7%	96.7%
	Heifer	17.2	16.3	1.15	0.43	-0.14	-0.10	99.4%	99.1%

*The abbreviations are similar to Table 1

measurements of Bali bulls and heifers do not reached at the age of 24 months yet. Late mature at cows tended to have higher weight at maturity (Kratochvilova *et al.*, 2004). That results refer that there is a possibility to have higher weight at maturity because Bali cattle tended to have late matured.

Generally, the mature size of the bulls at Bone district was higher than those at Barru district. This was because of the different rearing system of Bali cattle in those two regions. The Bali cattle at Bone district were reared by semi intensive system which was kept at the simple paddock with the feeding of cut and carry system. On the other hand, the rearing system of Bali cattle at Barru district were extensive system which the cattle were grazed to the hills, paddy field, corn field or peanut field that far away from

residential areas and relatively without any owner supervision. The feeding types that were consumed of Bali cattle at both districts were rather similar. They were fed the grass field, waste of corn plantations, waste of peanut plantations and sometimes the salt block was given. It was shown that the Bali cattle performance is varied and dependent upon environment effect such as feed and temperature beside the genetic effect of the sire or dam.

CONCLUSION

Bali cattle tended to have late mature size. The growth of body measurements (withers height, hip height, body length, chest girth, chest depth, chest width, rump length, hip width, thurl width, and pin bone width) of Bali cattle were still

increasing at 24 months of age and not reaching the mature size yet. The place, sex and age factors were significantly affected to the growth of body measurements of Bali cattle.

ACKNOWLEDGMENT

This study was supported by the Directorate of Higher Education of Indonesia for providing the fund of *Hibah Bersaing XIII-2005* and the Directorate of Human Resources-Directorate General of Higher Education-Ministry of National Education Indonesia for providing the fund under the Program of Academic Recharging (PAR-C) 2010. The authors wish to thank to Animal Husbandry Service of Barru and Bone District South Sulawesi-Indonesia with all the staffs and the farmers for technical assistance in the collecting field data.

REFERENCES

- Alberti, P., B. Panea, C. Sañudo, J.L. Oleta, G. Ripoll, P. Erthjerg, M. Christensen, S. Gigli, S. Faila, S. Connetti, J.F. Hocquette, R. Jailler, S. Rudel, G. Renand, G.R. Nute, R. I. Richardson and J.L. Williams. 2008. Live weight, body size and carcass characteristics of young bulls of fifteen European breeds. *Livest. Sci.* 114(1):19-30
- The Japanese National Beef Cattle Registration Association. 2004. Normal Growth Curve of Japanese Black Cattle. Japan.
- Archer, J.A., R.M. Herd, P.F. Arthur, and P.F. Parnel. 1998. Correlated responses in rate of maturation and mature size of cows and steers to divergent selection for yearling growth rate in Angus cattle. *Livest. Prod. Sci.* 54(3):183-192
- Beltran, J.J., W.T. Jr. Butts, T.A. Olson, and M.Koger. 1992. Growth patterns of two lines Angus cattle selected using predicted growth parameters. *J. Anim. Sci.* 70:734-741
- Berry, D. P., B. Horan, and P. Dillon. 2005. Comparison of growth curves of three strains of dairy cattle female. *Anim. Sci.* 80(2):151-160
- Chamdi, A.N. 2005. The characteristics of genetic resources of Bali cattle (*Bos-bibos banteng*) and the alternative of its conservation methods. *Biodiversitas.* 6:70-75
- Cundiff, L. V., F. Szabo, K. E. Gregory, R. M. Koch, M. E. Dikeman, and J. D. Crouse. 1993. Breed comparisons in the Germplasm Evaluation program at MARC. Proc. Beef Improv. Fed. 25th Anniv. Conf., Asheville, NC.
- Harvey, W. R. 1977. User's guide for LSML76, mixed model least-squares and maximum likelihood computer program (Mimeo). Ohio State University, Wooster.
- Hirooka, H. 2010. System approaches to beef cattle production systems using modeling and simulation. *J. Anim. Sci.*, 81:411-24
- Jelantik, I.G.N., R. Copland and M. L. Mullik. 2008. Mortality rate of Bali cattle (*Bos sondaicus*) calves in West Timor Indonesia. *Proc. Aust. Soc. Anim. Prod.* , 27:48
- Koenen, E. P. C. and A. F. Groen. 1996. Genetic analysis of body weight in black and white dairy cattle. In: 47th Annual Meeting of EAAP, Lillehammer. Pp.53
- Kratochvílová, M., L. Hyánková, H. Knížetová, J. Fiedler, and F. Urban. 2004. Growth curve analysis in cattle from early maturity and mature body size viewpoints. *Czech J. Anim. Sci.*, 47(4):125-132
- Kumazaki, K., H. Tanaka, and Y. Kihara. 1955. Studies on the growth of Japanese breed of cattle. I. Functional study of the normal growth of Japanese Black breed. Bulletin of the Chugoku National Agricultural Experiment Station, B4:73-108
- Marco, G. D., L. D. Van Vleck, and M. L. Spangler. 2010. Genetic analysis of mature size in American Angus cattle. *Nebraska Beef Cattle Reports.* Paper 560:29-30. <http://digitalcommons.unl.edu/animalscincbr/560>
- Martojo, H. 2012. Indigenous Bali cattle is most suitable for sustainable small farming in Indonesia. *Reprod. Dom. Anim.* 47 (Suppl. 1):10-14
- Minezawa, M. 2003. Cattle genetic resources in Japan: One successful crossbreeding story and genetic diversity erosion. <http://www.angrin.tlri.gov.tw/apec2003/Chapter2Cattle4.pdf> . Accessed: January 15, 2010].
- Obata, T. and F. Mukai. 1982. Relationship between dam growth patterns and her productivity in Japanese Black cattle. *Japanese Journal of Zootechnical Science*, 53:605-611 (In Japanese with English summary)
- Panjaitan, T., F. Geoffry, and P. Dennis. 2003. Bali cattle performance in the dry tropics of

- Sumbawa.. *JITV*. 8(3):183-188
- Pastika, L. M. 1976. Beberapa Segi Reproduksi Sapi Bali di Kecamatan Kediri. Tesis. Udayana University, Denpasar.
- Siregar, A.R., I. Inounu, and C. Talib. 2003. Options for genetic improvement of Bali cattle-assessing the strengths and weaknesses of alternative strategies: Option 2. Expensive technologies deleted, AI still included. Proceeding of an ACIAR Workshop on Strategies to Improve Bali Cattle in Eastern Indonesia. Denpasar, Bali, Indonesia. February 4-7, 2002. P.72-75.
- Sri Rachma, A.B. and H. Harada. 2010. The estimation of carcass traits of Bali bulls using ultrasound. *J. Indonesian Trop. Anim. Agric.*, 35:55-62
- Szabolcs, B., N. Barnabás, N. Lajos, K. Balázs, J.P. Polgár, and S. Ferenc. 2007. Comparison of body measurements of beef cows of different breeds. *Arch. Tierz., Dummerstorf*. 50 (4):363-373
- Talib, C., K. Entwistle, A. Siregar, S. Budiarti-Turner, and D. Lindsay. 2003. Survey of Population and Production Dynamics of Bali Cattle and Existing Breeding Programs in Indonesia. Proceeding of an ACIAR Workshop on "Strategies to Improve Bali Cattle in Eastern Indonesia. Denpasar, Bali, Indonesia. February 4-7, 2002. P. 3-9.
- Wada, Y, Y. Sasaki, F. Mukai, and Y. Matsumoto. 1983. Describing weight-age data in Japanese Black females with nonlinear growth models. *Japanese J. Zootechnical Sci.* 51:247-255 (In Japanese with English summary).