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GROWTH STANDARDS OF BODY WEIGHT AND MEASUREMENTS OF HOLSTEIN-FRIESIAN HEIFERS KEPT UNDER INTENSIVE MANAGEMENT

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ABSTRACT

Growth standards were developed for body weight (BW) and measurements (BMs) of wither height (WH) and chest girth (CG) of Holstein-Friesian (HF) heifers kept during a period of 1994 - 2002 at an intensive dairy breeding station (BS) in Banyumas district, Central Java. Data of repeatable measurements of individual body traits were mostly recorded bimonthly from non-contemporary heifers within an age range of 2 - 570 d. Specified values at any given ages of BW, WH and CG were predicted from individually best fitted growth-curve equations derived from initial records of heifers' body traits. Growth standards of BW, WH and CG were developed by fitting up to the third terms of regression of means of the specified values of individual body traits on age. Similar regressions were fitted to the means ± 1 SD to establish a range around the population estimate. Quadratic regression resulted in the best fitted models in developing the growth standards of individual body traits and to produce their confidence ranges. This was due to the significances ($P<0.01$) and the highest R^2 values yielded from the quadratic expressions of means of BW (R^2 = 99.7 - 100), WH (R^2 = 99.7 - 99.9) and CG (R^2 = 99.9 - 100) on age. By developing the growth standards, recommendation of predicting values of BW, WH and CG at various ages, from 2 to 570d, of HF heifers can be determined. Growth rates of BW and BMs of HF heifers were lower to those of HF heifers kept in temperate regions and some tropical regions. Low growth potential, inferior feeding and management, disease incidence and tropical heat stress might be crucial factors in diminishing the growth rates of HF heifers in the current study.

Keywords: Holstein-Friesian heifers, growth standard, body weight and measurements

INTRODUCTION

Rearing heifers is one aspect of major concern in dairy replacement management as this is an unproductive but an expensive period in dairy production systems. The growth pattern can summarize information required to understand the biological phenomenon of the growth of animals which is important in dairy replacement management. Standards of body growth of heifers in a herd can be used to monitor the growth process in order to identify particular effects of nutrition, management and environment (Heinrich and Losinger, 1998) and to compare growth rates of heifers from different populations (Heinrich and Hargrove, 1987). Developing body growth standards, therefore, is necessary with regarding to maintain optimal growth rate of the heifers. This is useful for determining major factors that can affect efficiency in operating dairy production and for ensuring sustainability of producing heifer replacement stocks.

The specific aim of this research was to develop standards of growth curves of BW and BMs of HF heifers raised under the BS in Banyumas District, Central Java, Indonesia.

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MATERIALS AND METHODS

Data of BW (kg) and BMs of WH and CG (cm) of HF heifers were collected in a period of 1994 - 2002 at an intensive dairy breeding station (BS) in Banyumas district, Central Java. Collecting data of BW, WH and CG provided repeated measurements recorded bimonthly at the same dates and a few, at early life, recorded monthly for non-contemporary heifers within the age ranges of 2 - 570 d. To specify the values of BW, WH and CG at any given ages, individually best fitted growth-curve equations were derived by fitting up to the third terms of regression and by fitting exponential equations from initial growth records of the heifers. Completion was executed after the equation attaining the highest R^2.

Standards of the growth curves of individual body traits were tested by fitting up to the third terms of regression of means of the specified values of individual body traits on age, from 30 d to 540 d. Similar regressions were fitted to two sets data determined as the means plus 1 SD and the means minus 1 SD to establish a range around the population estimate. By omitting identified outliers in box plot transformation resulted in the final number of animals and observations for BW (160, 1539), CG (97, 926) and WH (74, 691) respectively.

RESULTS AND DISCUSSION

Specified values of body traits at any given ages

Table 1 shows means and standard deviations (SDs) of BW and BMs of HF heifers specified at any given ages, from 30 to 540 d. The SDs of BW, WH and CG increased with progressive ages indicating an increased variation of body traits when heifers grew up. The variation could be due to many factors involving individual growth potential and vigour, feeding and management as well as environment. Brody (1945) described every animal has an inherent mature body size towards which it grows at a genetically controlled rate which is accelerated or delayed by environmental factors resulting in a little influence on mature body size.

Table 1. Specified body weight and measurements at any given ages of Holstein-Friesian heifers

Given Age (d)	Body Trait (cm)								
	BW			WH			CG		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
30	464	49.5	10.6	100	77.7	2.8	150	84.0	3.8
60	460	62.8	9.1	100	81.0	2.4	154	89.1	3.5
120	466	90.0	11.3	102	87.6	2.5	154	99.4	3.3
180	469	118.2	16.3	97	93.6	2.7	145	108.9	3.5
240	453	146.4	20.8	91	99.3	2.9	139	118.4	3.8
300	443	176.0	25.0	89	105.2	3.5	137	127.7	4.0
360	419	206.9	29.0	81	110.5	3.5	126	136.5	3.9
420	396	240.4	31.7	71	115.4	3.0	110	145.5	4.7
480	369	274.0	34.6	69	121.0	3.2	101	154.7	4.9
540	326	311.5	35.4	66	126.3	3.2	95	164.0	5.2

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Growth standards of body traits

R^2 values and regression coefficients of the linear, quadratic and cubic terms of regression to determine the best fitted models in developing standards of individual body growth curves on age of HF heifers are presented in Table 2. The results revealed that the quadratic regression was to be the best model to express relationships between age and means of specified values of individual body traits. This was due to significances ($P<0.01$) and the highest R^2 yielded from the quadratic regressions of means of BW (R^2 = 100), WH (R^2 = 99.9) and CG (R^2 = 100) on age.

Therefore, the growth standards were entirely derived by the quadratic equation of the means of BW, WH and CG, at any given ages from 30 to 540 d, on age. As the quadratic regression also had a consistency to produce confidence ranges around the fitted lines, these equations were fitted separately for the means plus and minus their respective SDs. Table 3 presents the means and plus and minus 1 SD at monthly-interval ages of BW, WH and CG derived from the growth standards of.HF heifers. By comparing the growth standards among BW and BMs, it can be inferred that the trend of inclining growth rate of BW was faster than those of the two BMs, then the trend of increasing growth rate of CG was higher than WH. Body composition of animals reach maturity in the orders of skeletal, muscle and fat tissues leading to slower growth rate for earlier maturing body depots during postnatal period (Lawrence and Fowler, 2002). This indicates that earlier maturity of skeletal (WH and CG) to muscle (BW) resulting in faster growth rates in the orders of BW, CG and WH during postnatal period of HF heifers in the BS.

Comparison of growth standard of Holstein-Friesian heifers

The development of growth standards can be valuable to compare the body growth curves of HF heifers in the present study to those of HF heifers maintained in different locations. Table 4 is presented to compare the growth standards of BW and WH of HF heifers in the BS to some previous data sets of the Holstein populations in several regions in USA, within 1934 to 1997 (Heinrich and Losinger, 1998). It is obviously all predicted BWs of HFs up to the age of 18 mo in the BS were lower to those of Holsteins from USA, even to Holstein heifers maintained since several decades in USA (Ragsdale, 1934). Similar condition occurred for WH with the exception at the two ages of 1 mo and 18 mo from which WHs of HF heifers in the BS were higher than the respective WHs of Holstein heifers of the initial study (Ragsdale, 1934).

HF heifers maintained in the BS were mostly daughters of HF cows from New Zealand and Australia that were imported to replace a number of culling old cows. These cows were inseminated by semen of Holstein and HF bulls imported from USA, Australia, New Zealand and Japan. Genetic make up was certainly an essential factor of causing different growth rates of the HF heifers in the BS to those in USA. Beside of that, many environmental factors and their interaction to genetic component could greatly contribute to the growth performance of the HF heifers in the BS. These might probably from the factors of feeding, management, diseases incidence and tropical heat stress.

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Table 3. Means ± 1 SD of body weight and measurements derived from the growth standards of Holstein-Friesian heifers

Age (d)	Body Trait (cm)								
	BW			WH			CG		
	Mean	+ 1 SD	− 1 SD	Mean	+ 1 SD	− 1 SD	Mean	+ 1 SD	− 1 SD
30	50.1	57.1	43.0	78.1	80.5	75.7	84.1	87.7	80.4
60	62.8	72.5	53.1	81.3	83.8	78.8	89.1	92.6	85.4
90	75.9	88.1	63.6	84.4	87.1	81.8	94.0	97.5	90.3
120	89.2	103.9	74.5	87.5	90.3	84.8	98.9	102.4	95.2
150	102.9	120.0	85.9	90.6	93.4	87.8	103.8	107.3	100.0
180	116.9	136.2	97.7	93.6	96.5	90.7	108.6	112.2	104.8
210	131.3	152.6	110.0	96.5	99.5	93.5	113.4	117.0	109.6
240	145.9	169.2	122.7	99.4	102.4	96.4	118.1	121.8	114.2
270	160.9	186.0	135.8	102.3	105.3	99.2	122.8	126.6	118.9
300	176.2	203.0	149.4	105.1	108.2	101.9	127.5	131.4	123.5
330	191.8	220.2	163.4	107.9	111.0	104.6	132.2	136.2	128.0
360	207.8	237.6	177.8	110.6	113.7	107.3	136.8	141.0	132.5
390	224.0	255.2	192.7	113.3	116.4	109.9	141.4	145.7	136.9
420	240.6	273.0	208.0	115.9	119.0	112.5	145.9	150.5	141.3
450	257.5	291.0	223.8	118.5	121.6	115.1	150.4	155.2	145.6
480	274.7	309.2	240.0	121.0	124.1	117.6	154.9	159.9	149.8
510	292.3	327.6	256.7	123.5	126.6	120.1	159.3	164.6	154.1
540	310.1	346.2	273.7	125.9	129.0	122.5	163.7	169.3	158.2

Table 4. Standardised body weight and wither height of Holstein-Friesian heifers from the current study and several temperate regions in USA

Age	CS	Ragd.*	HH	NAH.*	CS	Ragd.*	HH	NAH*
Month	---------- Body weight (kg) ------------				----------- Wither height (cm) ----------			
1	50.1	50.8	60.4	64.6	78.1	77.7	80.4	81.4
3	75.9	87.6	102.1	108.1	84.4	87.1	89.5	90.6
6	116.9	161.2	167.2	178.4	93.6	100.8	101.0	102.4
9	160.9	231.1	233.5	251.7	102.3	110.5	110.3	111.8
12	207.8	286.9	299.1	324.3	110.6	116.8	117.6	119.2
15	257.5	338.7	362.1	392.7	118.5	121.7	123.2	124.9
18	310.1	383.6	420.6	453.4	125.9	125.2	127.4	129.1
21	-	432.2	472.6	502.6	-	128.5	130.5	132.3
24	-	485.3	516.2	537.6	-	131.3	132.7	134.6

*Note : Ragd.: Ragsdale (1934); HH: Heinrich and Hargrove (1979); NAH: National Animal Health Monitoring Services, USA (1997); * cited from Heinrich and Losinger (1998).*

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Table 2. Coefficient regressions of means ± 1 SD of specified body weight (kg) and individual body measurements (cm) on the linear, quadratic and cubic effects of age (days) of Holstein-Friesian heifers

Body Traits	Regression Equation											
	Linear Regression			Quadratic Regression				Cubic Regression				
	Inter.	Linear	R^2	Inter.	Linear	Quadratic	R^2	Inter.	Linear	Quadratic	Cubic	R^2
Body weight												
Mean	28.86	0.508^{**}	99.7	67.67	0.408^{**}	0.00018^{**}	100	35.70	0.450^{**}	-0.00001^{**}	0.00000^{**}	100
Plus 1 SD	36.42	0.565^{**}	99.8	41.93	0.504^{**}	0.00011^{ns}	99.9	44.21	0.455^{**}	0.00033^{ns}	-0.00000^{ns}	99.9
Min. 1 SD	21.30	0.450^{**}	99.1	33.41	0.313^{**}	0.00024^{**}	99.7	27.19	0.446^{**}	-0.00034^{**}	0.00000^{ns}	99.8
Wither height												
Mean	76.20	0.094^{**}	99.7	74.89	0.109^{**}	-0.00003^{**}	99.9	74.37	0.120^{**}	-0.00008^{**}	0.00000^{ns}	99.9
Plus 1 SD	78.72	0.095^{**}	99.7	77.18	0.113^{**}	-0.00003^{**}	99.9	76.98	0.117^{**}	-0.00005^{**}	0.00000^{ns}	9.9
Min. 1 SD	73.68	0.092^{**}	99.8	72.60	0.104^{**}	-0.00002^{*}	99.9	71.76	0.122^{**}	-0.00010^{*}	0.00000^{ns}	99.9
Chest girth												
Mean	80.07	0.157^{**}	99.9	79.15	0.167^{**}	-0.00002^{**}	100	78.69	0.177^{**}	-0.00006^{**}	0.00000^{ns}	100
Plus 1 SD	83.21	0.160^{**}	100	82.80	0.165^{**}	-0.00001^{ns}	100	82.60	0.169^{**}	-0.00003^{ns}	0.00000^{ns}	100
Min. 1 SD	76.93	0.153^{**}	99.9	75.31	0.169^{**}	-0.00003^{**}	100	74.79	0.185^{**}	-0.00010^{**}	0.00000^{*}	100
Body length												
Mean	68.39	0.137^{**}	98.9	66.08	0.188^{**}	-0.00019^{ns}	99.7	67.88	0.123^{**}	0.00039^{ns}	-0.00000^{ns}	99.8
Plus 1 SD	71.43	0.139^{**}	97.4	67.60	0.225^{**}	-0.00032^{ns}	99.6	69.68	0.149^{**}	0.00035^{ns}	-0.00000^{ns}	99.7
Min. 1 SD	65.36	0.134^{**}	99.8	64.56	0.152^{**}	-0.00007^{ns}	99.8	66.07	0.096^{**}	0.00042^{ns}	-0.00000^{ns}	99.8

Note:
R^2 is coefficient determination (%)
**, * and ^{ns} are successively very significant (P< 0.01), significant (P<0.5) and non significant (P>0.05).

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The use of body growth standards for heifer management

With regarding to the need of dairy heifer management, the growth standards can be useful to control growth rate and BW at particular ages. This is, for example, to control whether a heifer is at a desired growth target to reach proper BWs at certain important phases such as at puberty, first serving and first calving. This can be illustrated by following an example.

The average age at first calving of HF in the BS was found 29 mo, meaning the average age of the heifers servicing for conception around the age of 20 mo. The predicted mean of BW of HF heifers in the BS at the age 20 mo, based on the equation in Table 2, would be 377.3 kg, within a range of 307.6 - 383.9 kg. Supposing the pubertal age was at an average of 15 mo, hence the predicted mean of pubertal BW would be 257.5 kg, within a range of 223.8 - 291.0 kg. The estimated BWs of HF heifers in the BS were lower than those respective BWs of HFs maintained under an intensive management in the tropical Venezuela (15 mo = 336.7 kg; 21 mo = 406.5 kg) (Vaccaro and Rivero, 1985). The estimated daily growth rate up to 18 mo for HF heifers in the BS (0.57 kg/d) was also lower than the average daily growth rate up to 24 mo for HF grade heifers raised in Central Mexico (0.6 – 0.7 kg) (Peters and Ball, 1986).

These results reveal that HF heifers in the BS had a lower pre and post pubertal growth rates than those reported by the previous workers. The lower growth rates and BWs resulted in delayed ages at puberty and at first calving leading to extended time of heifers in commencing reproductive activity and lactation. The consequence is to cause shortened productive life with the risk of reducing daily milk yield during productive life of HF heifers in the BS.

CONCLUSION

Standards of body growths of HF heifers were closely described by the changes of means of the specified values of individual body traits on age and these relationships can be expressed into the quadratic regression.

Various linear regression coefficients of the growth standards of each BW, WH and CG on age revealed that HF heifers in the current study grew at the slower rates than those of HF in temperate regions and in some tropical regions. The inferiority might be due to lower growth potential and vigour, feeding, management as well as higher disease incidence and more tropical heat stress.

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