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Live Weight and Body Conformation Responses of Culled Local Yellow Cows Fed Maize Silage and Urea-Treated Rice Straw in an Intensive Feedlot System in Northwest Vietnam

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Abstract | The aim of this study was to evaluate the effects of the substitution of maize silage (MS) for urea-treated rice straw (URS) in feedlot diets on finishing performance and body conformation traits of culled local Yellow cows; and to develop prediction equations for live weight (LW) of local Yellow cows using these body measurements. Twelve non-pregnant local Yellow cows (74.8 ± 23.6 months of age) were blocked by weight into 4 groups and then randomly allocated to one of three roughage treatments: 30% fresh maize + 70% URS (DM basis) (Control); 30% fresh maize + 40% URS + 30% MS (LMS); 30% fresh maize + 20% URS + 50% MS (HMS). Cows were individually supplemented with concentrate (1.1 kg DM/100 kg LW) and had free access to mixed roughage and water throughout the 12-week feeding trial, after a 2-week adaptation. Maize silage inclusion significantly increased daily feed intake and average daily gain (ADG) ($P < 0.05$). Moreover, the roughage containing 30% MS recorded the lowest feed conversion rate (7.8) and the highest final body condition score (3.43). However, LW and body measurements were not affected by the substitution ($P > 0.05$). Positive and significant correlations between LW and body measurements were observed. Regression analysis between chest girth (CG) and LW resulted in an equation with adjusted an R^2 value of 82.0%. The multiple regression, which included CG, body length (BL) and withers height (WH) yielded the most reliable equation (adjusted R^2 = 87.4%). The results indicate that MS can be a good alternative roughage source for feedlot culled local Yellow cows during winter in Northwest Vietnam. It is highly recommended that smallholder farmers raising non-pregnant Yellow cows use the regression equation: LW = 3.39 CG - 249 for prediction of LW in the absence of weighing scales.

Keywords | Feed intake, Average daily gain, Feed conversion rate, Chest girth, Body condition score.

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INTRODUCTION

Yellow cattle is the most common indigenous breed of cattle in Vietnam and usually grown for meat production and draught power (Le et al., 2018b). They well adapt to local feeding and climate conditions and have good fertility (Burns et al., 2001). However, the Yellow cattle have small body size and low meat yield. The Yellow cows are

used in national breeding programs as dams for crossing with exotic breeds to improve their progeny genetic performances (Trung, 2014). Annually, thousands of Yellow cows are culled from the national herd because of age, reproductive failure, poor health condition, unsatisfactory performance and management decisions. Generally, culled beef cows usually have low carcass yield and low quality meat, and are sold in a poor condition with a low price (Sugimoto et al., 2011). Studies have reported that intensively feeding a high-energy diet to thin culled cows increased general appearance, carcass composition, intramuscular fat deposition and sensory properties (Moreno et al., 2012; Santos et al., 2019; Soulat et al., 2019). DeClerck et al. (2020) and Sugimoto et al. (2011) explained that these cows have the potential to express compensatory gain because of improved efficiency of energy supply and nitrogen retention. However, limited information is available in Vietnam on the beneficial effects of finishing diets on live weight (LW) and body conformation in culled native Yellow cows. These animals are usually sold and slaughtered before undergoing a finishing period, and farmers fail to maximise their income from culled livestock sales.

Although roughage plays an important role in ruminant nutrition, locally available forage sources vary widely depending on a range of factors including season, natural pasture capacity, cultivated grasses and local crop by-products (Wanapat, 2009). During winter, many cattle producers in Vietnam regularly feed their animals with dry rice straw or urea-treated rice straw (URS) based diets due to the shortage of green forage (Nguyen et al., 2020). Numerous studies have been conducted on the effects of URS on both dairy and beef cattle performance in Vietnam (Man and Wiktorsson, 2001; Sanh et al., 2002; Nguyen and Dang, 2020). Regarding agriculture products, maize is the second most important staple crop in Vietnam, after rice (Nguyen et al., 2018). Maize is mostly cultivated for grain which is the major component of feed for Vietnam's livestock industry (Nguyen et al., 2020). During winter or dry season, maize stover silage is also used to replace fresh fodder (Huyen et al., 2011). However, the research on biomass maize silage and its usage in small household farms have received little attention in Vietnam. Moreover, there is limited research investigating how live weight and body conformation may be influenced by substitution of biomass maize silage (MS) for URS in finishing diets.

Live weight and body conformation are important economic traits in beef production. They are also good indicators of animal status for veterinary management (Ozkaya et al., 2016). The most widely accepted method measuring LW is using a calibrated weighing scale (Lukuyu et al., 2016). However, weighing cattle could be beyond the means of many livestock producers because weighing scales are expensive and not readily affordable by many small rural households (Rashid et al., 2016). Currently, producers and traders have mostly depended on empirically visual assessment to estimate LW of cattle. In absence of weighing scales, body measurements have been shown to be useful predictors of LW (Abdelhadi and Babiker, 2009; Sawanon et al., 2011; Lukuyu et al., 2016). Various studies have been conducted to develop methods of estimating LW of cattle using formula derived from a range of body measurements (Sawanon et al., 2011; Lukuyu et al., 2016; Rashid et al., 2016; Tebug et al., 2018). However, Lukuyu et al. (2016) stated that different prediction models might be needed to estimate LW in different sex, breed, age and environmental conditions. In Vietnam, the development of LW prediction equations for native Yellow cattle has received little attention (Noi et al. 1991) and even there have been no research estimating LW of culled Yellow cows using equations obtained from body measurements.

The aim of this study was to determine the effects of the substitution levels of maize silage in roughage on growth performance and body conformation traits of culled native Yellow cows; and to derive prediction equations for LW of native Yellow cows using body linear measurements in an intensive finishing management system in Northwest Vietnam.

MATERIALS AND METHODS

This study was conducted at the Extension Centre for Livestock Breeds and Crop Varieties, Dien Bien province, Vietnam from December 2019 to March 2020. All experimental animals were cared for following 2013 Australian Code of Practice for the Care and Use of Animals for Scientific Purposes. All procedures were approved by the University of Tasmania Animal Ethics Committee (Permit Number A0017801).

Urea-treated rice straw and maize silage preparation

Urea-treated rice straw and maize silage were prepared in November, 2019. Biomass maize was harvested at 90 days old, chopped into 10-15 cm and incubated with 2% corn flour (fresh matter basis). Rice straw was treated with urea following a popular formula: 100 kg dry rice straw + 4 kg urea + 80 litre clean water. These roughages were anaerobically preserved in separate concrete containers and started feeding to animals after four weeks.

Animals, diets and experimental design

Twelve mature native Yellow cows, with an initial weight of 205 ± 32 kg (mean ± s.d.) were used a randomized complete block experimental design. The average initial age of the cows was 74.8 ± 23.6 months, and the number of par-

turitions was 3.2 ± 1.7. They were blocked into four groups by their LW then were randomly allocated to one of three dietary treatments. The daily diets were formulated to meet the maintenance requirements and deliver an expected daily LW gain of 700-900 grams (NRC, 2016). The cows were raised in individual pens and daily offered 1.1 kg DM concentrate per 100 kg LW at 07.00 am and 5.00 pm. They had *ad libitum* access to roughage treatments: 30% fresh maize + 70% URS (DM basis) (Control); 30% fresh maize + 40% URS + 30% MS (LMS); 30% fresh maize + 20% URS+ 50% MS (HMS). Roughage of each treatment was *ad libitum* offered as a mixture. The animals were dewormed using Ivermectin prior to the commencement of the feedlot trial and had unlimited access to clean water throughout the trial. The study lasted for 12 weeks following a 2-week adaptation period. Feed offered and refusals were recorded daily to determine daily feed intake. On days 1, 28, 56 and 84 of the experimental period, offered and refusal feed samples were collected for subsequent analyses.

Live weight and body conformation measurement

Live weight and body conformation traits were measured every two weeks on two consecutive days before morning feeding to determine average daily gain (ADG) and to adjust the amount of feed offered. After the trial finished, live weight and each traits of body conformation had a set of 168 individual data, which were used to compute correlation coefficients and estimate equations for LW obtained from body conformation traits.

Live weight was measured using a calibrated Ruddweigh 2000XT walk-over weighing electronic scale. Average daily gain was calculated as total body weight gain divided by the number of days on the feeding trial. Feed conversion rate (FCR) was calculated as kg feed DM consumed per kg LW gain.

The body conformation measurements were taken measuring plastic tape marked in centimetre (cm) and a measuring metal vernier made with two adjustable arms sliding vertically up and down to record span. The measurements included chest girth (CG): a circumference measured around the chest just behind the front legs and withers; wither height (WH): measured at the top of the wither; body length (BL): distance from point of shoulder (lateral tuberosity of the humerus) to the pin bone (tuber ishii) (Rashid et al., 2016). Body condition score (BCS) was measured by three trained observers on a scale of one to five described by Silveira et al. (2015). All measurements were assessed by the same researchers throughout the trial while cows were restrained and in a relaxed state, with heads comfortably erect and standing stably upon all four legs on flat ground to ensure consistency, accuracy and repeatability.

Chemical composition analyses

Each type of collected feed samples was pooled and ground through a 1-mm screen. The total nitrogen content of URS was determined from stored frozen samples following the Kjeldahl protocol of AOAC (1990). The samples were dried in a fan-forced oven to a constant weight at 65^{0}C to determine DM content. Total nitrogen contents of fresh maize, MS, and concentrate were determined from dried samples by the Kjeldahl protocol as described by AOAC (1990). Crude protein (CP) content was calculated by multiplying total nitrogen by 6.25. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined using the methods of Van Soest et al. (1991). The samples were combusted in a furnace at 550^{0}C for 5 hours to quantify ash content. Organic matter (OM) was computed as OM = 100 – ash. Non-fibrous carbohydrate (NFC) was calculated as NFC = 100 - (CP +NDF + EE + Ash) (Mertens, 2002). Total digestible nutrient (TDN) were estimated using equations TDN = 0.479 NDF + 0.704 NFC + 1.594 EE + 0.714 CP and TDN = 0.323 NDF + 0.883 NFC + 1.829 EE + 0.885 CP for forage and concentrate respectively (Jayanegara et al., 2019). Metabolisable energy (ME) was calculated by converting TDN to digestible energy (DE (MJ/kg DM)) = TDN x 0.01 x 4.4 x 4.185) which was converted as ME = DE x 0.82) as per Le et al. (2018a). The concentrate ingredients and chemical composition of the dietary feed are presented in Table 1.

Statistical analyses

All collected data were analysed using the Minitab statistical software version 16.2 (Minitab, 2010). Summary descriptive statistics including means and standard errors of mean were calculated and scrutinised for any erroneous data input. The data were subjected to ANOVA using a general linear model with different roughage and block fitted as fixed effects; and feed intake, LW, ADG and body conformation traits as dependent variables. The final statistical model used for the analysis was:

$Y = \mu + T_i + B_j + E_{ijk}$

Where Y = dependent variable, μ = overall mean, T_i = effect of roughage treatment, B_j = effect of block, E_{ijk} = residual error.

Significant differences and mean separations at the $P < 0.05$ threshold were performed using Tukey's probability pairwise comparison tests.

Pearson's correlation coefficients between LW and body conformation traits were also estimated and significance established using Bonferroni probability pairwise test. The linear prediction equations for LW obtained from body conformation traits (CG, BL and WH) as independent variables were determined using regression.

Table 1: Chemical compositions of fresh rice straw and feeds used in the experiment

Item	Concentrate	Urea-treated rice straw	Maize silage	Fresh maize
Ingredient (g/kg)				
Rice bran	260			
Corn flour	275			
Cassava	290			
Soybean	170			
Premix	5			
Chemical composition (%DM)				
Dry matter (%)	88.1	51.5	25.2	19.5
Organic matter	95.6	87.6	92.2	95.4
Crude protein	12.3	10.7	9.1	10.0
Ether extract	7.2	1.9	1.9	1.5
NDF	14.8	70.8	49.2	52.7
ADF	8.2	38.2	25.5	27.3
Total ash	4.4	12.4	7.8	4.6
NFC	61.3	4.2	32.0	31.2
TDN	83.0	47.5	55.6	56.7
DE (MJ/kg DM)	15.3	8.8	10.2	10.4
ME (MJ/kg DM)	12.5	7.2	8.4	8.6

NDF: Neutral detergent fibre; ADF: Acid detergent fibre; EE: Ether extract; NFC: Non-fibrous carbohydrate; TND: Total digestible nutrient; DE: Digestible energy; ME: Metabolisable energy; Premix includes vitamin A (4100.000 IU/kg), vitamin D3 (350.000 IU/kg), vitamin E (8 g/kg), vitamin B1 (850 mg/kg), vitamin B2 (1,6 g/kg), vitamin B6 (1,7 g/kg), vitamin B12 (6 mg/kg), Vitamin K3 (350 mg/kg), niacin (12 g/kg), folic acid (250 mg/kg), Biotin (16 mg/kg), Iron (30 g/kg), Copper (30 g/kg), Manganese (13 g/kg), other minerals (Zn, Se, I, Co) (380 mg/kg).

Table 2: The growth performance and daily feed intake of experimental animals

Item	Control	LMS	HMS	SEM	P value
Growth performance					
Initial live weight (kg)	201.3	216.3	207.3	11.10	0.880
Final live weight (kg)	240.0	283.6	265.0	13.22	0.441
Total weight gain (kg)	38.8^{b}	67.4^{a}	57.8^{a}	4.16	0.002
Average daily gain (kg/day)	0.46^{b}	0.80^{a}	0.69^{a}	0.05	0.002
Daily feed intake (kg DM/day)					
Concentrate	2.73	2.74	2.76	0.02	0.142
Roughage	3.07^{c}	3.57^{b}	3.73^{a}	0.01	<0.001
Dry matter	5.81^{c}	6.31^{b}	6.49^{a}	0.02	<0.001
Organic matter	5.39^{c}	5.89^{b}	6.08^{a}	0.02	<0.001
Crude protein	0.66^{b}	0.69^{a}	0.70^{a}	0.01	<0.001
NDF	2.48^{a}	2.42^{b}	2.41^{b}	0.01	<0.001
NFC	2.07^{c}	2.45^{b}	2.69^{a}	0.01	<0.001
TDN	3.82^{c}	4.17^{b}	4.32^{a}	0.02	<0.001
ME (MJ/day)	57.7^{c}	62.9^{b}	65.2^{a}	0.13	<0.001
DMI per 100 kg LW	2.62	2.55	2.75	0.05	0.142
Feed conversion rate (kg DMI/kg ADG)	12.6^{a}	7.8^{c}	9.4^{b}	0.43	<0.001
F:C	1.13^{b}	1.30^{a}	1.34^{a}	0.02	<0.001

Control: Roughage included 30% fresh maize + 70% urea-treated rice straw (DM basis); LMS: Roughage included 30% fresh maize + 40% urea-treated rice straw+ 30% maize silage; LMS: Roughage included 30% fresh maize + 20% urea-treated rice straw +

50% maize silage; SEM: Standard error of the mean; NDF: Neutral detergent fibre; NFC: Non-fibrous carbohydrate; TND: Total digestible nutrient; ME: Metabolisable energy; DMI: Dry matter intake; ADG: Average daily gain; F:C: Forage to concentrate ratio; Row means between groups bearing different superscript letters significantly differ (P < 0.05).

Table 3: Variation in experimental cow body conformation

Item	Control	LMS	HMS	SEM	P value
Initial chest girth (cm)	136.5	139.0	138.5	3.4	0. 959
Final chest girth (cm)	145.5	151.8	147.5	3.5	0.787
Initial wither height (cm)	106.3	102.8	105.6	2.2	0.824
Final wither height (cm)	107.6	104.9	108.1	2.3	0.846
Initial body length (cm)	111.9	117.5	115.0	2.7	0.728
Final body length (cm)	116.9	120.3	121.0	2.6	0.817
Initial BCS	2.13	2.28	2.17	0.13	0.524
Final BCS	2.84^{b}	3.43^{a}	3.09^{ab}	0.12	0.036

Control: Roughage included 30% fresh maize + 70% urea-treated rice straw (DM basis); LMS: Roughage included 30% fresh maize + 40% urea-treated rice straw + 30% maize silage; LMS: Roughage included 30% fresh maize + 20% urea-treated rice straw + 50% maize silage; SEM: Standard error of the mean; BCS: Body condition score; Row means between groups bearing different superscript letters significantly differ (P < 0.05).

RESULTS

Live weight response and daily feed intake

The effect of roughage on the live weight and daily feed intake of the cows is given in Table 2. The total weight gain of cows fed roughage containing MS was significantly higher (P < 0.05) that of cow fed roughage without MS. Similarly, there was a significant difference in ADG (P < 0.05) between MS containing treatments (0.80 and 0.69 kg/day for LMS and HMS respectively) and the control treatment (0.46 kg/day). However, no difference in LW was observed among treatments (P > 0.05).

The HMS treatment recorded the highest total daily dry mater intake (DMI) (6.49 kg DM/day), whereas the lowest DMI was observed in the control treatment (5.81kg DM/day). The similar trend was observed for daily OM, NFC, TDN and ME intakes. The CP intake in LMS and HMS (0.69 and 0.70 kg DM/day respectively) was considerably higher (P < 0.05) than that in the control treatment (0.66 kg DM/day). In contrast, cows fed diets without MS had significantly higher NDF intake (P < 0.05) than those fed diets containing MS.

The DMI per 100 kg LW was not significantly affected (P > 0.05) by treatment, ranging from 2.55 – 2.57 kg DM. Cows in the control treatment recorded the highest FCR (12.6), while the lowest FCR was observed in LMS treatment (7.8). Moreover, forage to concentrate ratio in HMS and LMS (1.34 and 1.30 respectively) was significantly higher (P < 0.05) than that in the control treatment (1.13).

Body conformation traits

Cows in LMS (3.43) had significantly higher (P < 0.05) final BCS than those in the control treatment (2.84), although there are no significant differences in initial BCS among treatments. Dietary treatment had no significant effect (P > 0.05) on CG, WH and BL measurements (Table 3).

Pairwise correlations between body measurements

Table 4 illustrates that there were statistically significant correlations between LW and body measurements (P < 0.05). Furthermore, all of the relationships were positive. The relationships between LW and CG (0.91) and between LW and BL (0.83) were very high. Moderate correlations between WH and the other body conformation traits were observed with the exception of BL. The other correlations among body measurements were high ranging from 0.61 to 0.76.

Table 4: Pearson's residual correlation coefficients between body conformation traits.

Item	LW	CG	WH	BL
CG	0.91^{***}			
WH	0.55^{***}	0.59^{***}		
BL	0.83^{***}	0.76^{***}	0.65^{***}	
BCS	0.67^{***}	0.66^{***}	0.36^{*}	0.61^{***}

LW: Live weight; CG: Chest girth; WH: Withers height; BL: Body length; BCS: body condition score (each parameter: n=168); * P < 0.05; *** P < 0.001.

Linear regression equations for the estimation of live weight from body conformation measurements

Linear regression equations for the estimation of LW from body conformation measurements of adult native Yellow cows are presented in Table 5. Regressing LW on single CG measurements gave a highly reliable prediction equation: LW = - 249 + 3.39 CG with adjusted R^2 = 82.0% and root-mean-square error (RMSE) = 18.8. The model involving CG and BL slightly improved the efficiency of the prediction equation (adjusted R^2 = 87.0%), where a slight reduction in the adjusted coefficient of determination was observed from the model involving CG and WH (adjusted R^2 = 81.5%). The combination of HG, BL and WH involved the model gave the most reliable prediction equation: LW = - 297 + 2.48 CG + 2.06 BL - 0.61 WH with the highest adjusted R^2 and the lowest RMSE (87.4% and 15.8 respectively). The prediction equations using only BL or WH; or both of them in the model were not highly reliable enough because they had low adjusted coefficient of determination (< 80%).

Table 5: Regression equations for the prediction of live weight from body conformation measurements of adult native Yellow cows

Prediction equation	R^2 adj (%)	RMSE
LW = - 249 + 3.39 CG	82.0	18.8
LW = - 277 + 4.36 BL	69.8	24.6
LW = - 122 + 3.38 WH	29.6	37.6
LW = - 320 + 2.39 CG + 1.82 BL	87.0	16.2
LW = - 257 + 3.34 CG + 0.14 WH	81.5	18.7
LW = - 279 + 4.33 BL + 0.06 WH	69.4	24.7
LW = - 297 + 2.48 CG + 2.06 BL - 0.61 WH	87.4	15.8

LW: Live weight; CG: Chest girth; WH: Withers height; BL: Body length (each parameter: n=168); RMSE: Root-mean-square error.

DISCUSSION

Clearly, MS is a superior quality roughage in comparison with URS because it has higher starch content with less indigestible fibre portion (Ranathunga et al., 2010; Nazli et al., 2018). In the present study, the substitution of MS for URS did show a significant increase in DMI, which is consistent with other previous studies reported by Keady et al. (2013) and Nazli et al. (2018) that observed an increase in DMI when replacing rice straw and grass silage by MS in beef cattle diets. The inclusion of MS in roughage might reduce NDF content and intake in the LMS and HMS treatments (Table 2). It is widely accepted in the literature that dietary NDF content and DMI are negatively correlated with each other (Ranathunga et al., 2010; Nguyen and Dang, 2020). In other words, Jeon et al. (2019) stated that low quality roughage, which contains a high NDF content, could decrease DMI because NDF induces satiety due to physical fill and a long ruminal retention time. In contrast to the results of the present study, several previous studies (Sugimoto et al., 2011; Jeon et al., 2019; Dung et al., 2020) showed that roughage sources did not affect DMI, ADG, and FCR among the treatments. This may be attributed to the similar NDF content among the diets (Salinas-Chavira et al., 2013). In addition, the high percentage of URS (70% DM of roughage) may be another reason for the reduction on DMI in the control treatment. Man and Wiktorsson (2001) and Sanh et al. (2002) reported that DMI and animal performance will be adversely influenced when URS accounts for more than 50% DM of roughage.

Our results herein demonstrated that the inclusion of MS in roughage also improved total weight gain and consequently better ADG. This might have been caused by the higher daily nutrient intakes including DMI, CP and ME in MS containing treatments compared to the control treatment (Table 2). The ADG of culled Yellow cows fed MS in this study are equivalent to the results observed by Ba et al. (2008) and Dung et al. (2019) when fattening young male Yellow cattle (15-18 months of age) with high-energy diets. Although the rate of LW gain declines when animals reach mature age, the high ADG of culled Yellow cows fed MS in our study could partly be attributed to the compensatory gains, which is more intense over the first 4 weeks of re- alimentation (DeClerck et al., 2020). Mullins et al. (2020) explained that these compensatory gains manifest in animals that have experienced a period of dietary restriction. They also stated that after being provided with adequate nutrition, the animal's growth rate accelerates, enabling it to achieve its genetically pre-determined growth potential. The compensatory gain phenomenon is a common practice in growing beef production systems as a means to reduce feed-related costs (Lopes et al., 2018). However, this phenomenon is also observed for culled beef cows feedlotted in intensive systems (Holmer et al., 2009; Missio et al., 2015), because prior to finishing, these animals are thin and in poor body condition as in this study.

The DMI per 100 kg LW in the present study were in the range of the feed intake suggested by Kearl (1982) and in agreement with the finding of Dung et al. (2019) fattening young male Yellow cattle with different forage sources. At the 30% MS inclusion level, the minimum FCR was observed (7.8); these results were similar to those observed for fattening young animals in both the native Yellow or Sindhi x Yellow crossed breeds (Vu et al., 2011; Dung et

al., 2013). Therefore, our results comply with the suggestion that inclusion of MS in silage-based diets increases ADG in finishing beef cattle (Keady et al., 2013; Zaralis et al., 2014).

A significant difference in final BCS between LMS and control treatments in the present study could be due to the difference in total LW gain between these treatments. The prediction equation, when regressing LW on BCS, is LW = 55.6 BCS + 75.5 (adjusted R^2 = 42.1% and RMSE = 31.8). It means that a one-point variation in BCS resulted in 55.6 kg change in LW. This was in agreement with the findings of Lukuyu et al. (2016) and Otto et al. (1991), who concluded that a change of one unit of BCS was associated with a 53 kg and 56 kg change in LW respectively. Significant and positive correlations between LW and body conformation traits in this study were consistent with the findings of Sawanon et al. (2011) and Rashid et al. (2016). The relationship between LW and CG measurements was strongest compared to BL and HW. The strong correlation between LW and CG can be attributed to the fact that CG more closely reflects body condition of cows than the other body measurements (Lukuyu et al., 2016). This strong correlation was also previously reported by other workers (Sawanon et al., 2011; Tebug et al., 2018).

From such strong relationships, the LW estimation equations were developed based on CG, and the combinations of CG and other body measurements using linearly single and multiple regression models. The prediction equation for LW using only CG measurements in this study obtained from a small amount of samples (n = 168). However, its adjusted R^2 value (82.0%) was nearly equivalent to the findings of Lukuyu et al. (2016) (adjusted R^2 = 84.7%) and Rashid et al. (2016) (adjusted R^2 = 83.2%) who regressed LW on CG measurements obtained from the large numbers of animals (452 and 185 animals respectively). The improvements in adjusted R^2 value were detected in our study when the combinations of CG and BL or HG, BL and WH were involved in a multiple regression. This is in agreement with Sawanon et al. (2011) and Lukuyu et al. (2016) who stated that inclusion of additional body measurements to the regression model could increase the accuracy of LW estimation over models which used CG alone. Our results in combination with previous findings using other cattle breeds affirm that body conformation measurements can be used as predictors LW of indigenous Yellow cows.

The purpose of this study was to develop prediction equations for LW of Yellow cows which can be able to easily apply in smallholder farms. As mentioned above, a combination of body linear measurements in the multiple regression model increased the accuracy of prediction equation. However, the prediction equation required the use of BL and WH, which in turn required using a vernier to measure. This meant that a farmer would have to buy two tools (a measuring tape and vernier) and take additional time to measure individual animals. Meanwhile, the single regression equation for LW obtained from CG in this study is highly reliable and accurate (adjusted R^2 = 82.0%; RMSE = 18.8). Therefore, the regression equation developed in the present study using CG measurements is applicable. It provides a simple way of predicting LW by using only a measuring tape, which is easy for farmers to apply the technique on-farm.

CONCLUSION

The inclusion levels of MS significantly affected daily feed intake and ADG of finishing culled Yellow cows. Furthermore, the substitution of 30% URS for MS resulted in the lowest FCR and increased BCS. However, no effects of MS inclusion on LW and other body measurements were observed. Pairwise correlations between LW and body conformation traits were positive and highly significant. The combination of CG, BL and WH gave the most reliable prediction equation for LW. Chest girth as a single efficient predictor can be used to estimate LW of Yellow cows. It is hereby suggested that substituting 30% MS in URS-based diets of culled Yellow cows during the 12-week intensive finishing phase offers the best means of improving ADG and FCR. Based on this research and for on-farm management convenience, the regression equation: LW = 3.39 CG - 249 is recommended to predict LW of non-pregnant indigenous Yellow cows. Further research is required to determine the best-fitted prediction equations specific for Vietnamese Yellow cattle in different sex, age and growing periods.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHORS CONTRIBUTION

Don Viet Nguyen and Ngoc Bich Thi Tran contributed equally to this work as first authors: Conceptualiza-

tion, methodology, investigation, resources, data curation, writing-original draft, visualization, writing-review and editing. Me A Vang: Investigation, methodology editing data, visualization. Huyen Thanh Thi Le: Project administration, fund acquisition, resources, visualization, writing – review and editing. Giang Truong Thien Nguyen: methodology, visualization, writing-review and editing. Quang Hung Nguyen: visualization, writing-review and editing. Melanie Blanchard: data curation, visualization; Andrew Bailey: Conceptualization, methodology, investigation, visualization, writing-review and editing; Stephen Ives: Conceptualization, project administration, fund acquisition, visualization, writing – review and editing.

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