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Meat yield and quality of Tanzania Shorthorn Zebu cattle finished on molasses/maize grain with agro-processing by-products in 90 days feedlot period

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Abstract

This study was conducted to evaluate the effects of feeding molasses or maize grain with agro-processing by-products on yield and quality of meat from Tanzania shorthorn zebu (TSZ) cattle. Forty five steers aged 2.5 to 3.0 years with 200 ± 5.4 kg body weight were allocated into five dietary treatments namely hominy feed with molasses (HFMO), rice polishing with molasses (RPMO), hominy feed with maize meal (HFMM), rice polishing with maize meal (RPMM) and maize meal with molasses (MMMO). *Ad libitum* amount of each dietary treatment and hay were offered to nine steers for 90 days. Cooking loss (CL) and Warner Bratzler shear force (WBSF) values were determined on *M. longissimus thoracis et lumborum* aged for 3, 6, 9 and 12 days. Steers fed on HFMO diet had higher ($P < 0.05$) nutrient intake (86.39 MJ/d energy; 867 g/d CP), weight gain (919 g/d) and half carcass weight (75.8 kg) than those fed other diets. Meat of steers from all diets was tender with average WBSF values of 47.9 N cm^{-2}. The CL (22.0 ± 0.61 %) and WBSF (53.4 ± 0.70 N cm^{-2}) were highest in meat aged for 3 days followed by 6, 9 and 12 days. WBSF values for meat aged for 9 and 12 days from steers fed HFMO and RPMM diets were similar and lower than those on other dietary treatments × aging periods. Overall, molasses and hominy feed can be used to replace maize meal in feedlot finishing diets to spare its use in animal feeds.

Keywords: agro-processing by-products, feedlot, retail cuts, steers

1 Introduction

Meat quality is a complex parameter with varying properties and is influenced by several intrinsic and extrinsic factors. The intrinsic factors include breed, sex, and slaughter weight, whereas pre- and post-slaughter carcass handling, type and feeding level are some of the extrinsic factors (Mushi *et al.*, 2009; Safari, 2010). In Tanzania, meat is mainly produced from Tanzania shorthorn zebu (TSZ) cattle which are extensively managed on range lands. In most of these range lands, pastures are in short supply with low nutritive values especially during the dry seasons resulting in low animal growth rates, and late attainment of slaughter weights. Studies have reported loss in weight leading to poor body condition which affects meat yield (du Plessis & Hoffman, 2004) and quality (Muchenje *et al.*, 2008). The constraint of poor nutrition in beef production could

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be minimised by finishing animals in feedlot using diets based on agro-processing by-products. Rice polishing and hominy feed are agro-processing by-products that can substitute part of maize grain in concentrate feed for beef cattle (Matz, 1991). A study by Sani *et al.* (2014) on Bunaji bulls fed rice offal as energy source showed rice offal to yield high quality carcass with lean meat (less amount of fat) compared to maize offal. Rice polishing and hominy feed have been found to give consistent results when combined with molasses and urea (Lopez & Preston, 1977; Larson *et al.*, 1993). A study by Hunter (2012) on beef cattle found that inclusion of sugar cane molasses in feedlot diets has the potential of producing meat with good eating quality. Earlier study in Tanzania by Mwilawa (2012) on beef fattening using maize meal and molasses has shown that TSZ cattle responds well to fattening by increasing carcass quantity from 90 kg for sole grazing group to 154 kg for maize meal and molasses fed group. Similarly, the quality of meat was improved from 60 $N\,cm^{-2}$ in the sole grazing group to 45 $N\,cm^{-2}$ for maize meal and molasses fed group. However, the major limitation of using maize meal as cattle diet in Tanzania is the role it plays as the main food source for humans. Thus, it is of interest to find out alternatives to maize meal as feedlot diet which is less competitive to humans' food. The available by-product feeds that could be used for finishing cattle under feedlot at national level were estimated to be (tones DM) maize bran (5.6×10^5), rice-polishing (8.9×10^4), cotton seedcake (6.2×10^4), wheat-bran (1.4×10^4), sunflower seedcake (2.1×10^4), wheat-pollard (4.2×10^3) and molasses (4.5×10^4) (Nandonde, 2008). We hypothesize that molasses with other agro-processing by-products can substitute maize meal in feedlot diets without reducing meat yield and quality. Therefore, the objective of this study was to assess the yield and quality of meat produced from TSZ cattle finished on molasses or maize meal with agro-processing by-products under feedlot conditions.

2 Materials and methods

2.1 Animals and diets

A total of 45 TSZ steers aged 2.5–3.0 years with initial body weight 200 ± 5.4 kg (mean ± SEM) were allocated in a completely randomised design to feedlot experiment performed at Kongwa ranch, located in Dodoma region, central Tanzania. These animals were grazing on pastures available at the ranch area for back grounding before starting the experiment. Animals were also assessed for health and nutritional status prior to the experiment to minimise variation errors. Five concentrate diets were formulated from different proportions of the raw materials of the agro-processing by products to contain hominy feed with molasses (HFMO), rice polishing with molasses (RPMO), hominy feed with maize meal (HFMM), rice polishing with maize meal (RPMM) and a control maize meal with molasses (MMMO). The proportions of the ingredients composition shown in Table 1 were determined by trial and error method using nutritive values of ingredients from feedstuff tables for ruminants developed by Doto *et al.* (2004). Each formulated diet was fed together with hay *ad libitum* to 9 steers for a period of 90 days. All animals were provided with free access of fresh drinking water throughout the experiment and were housed in individual pens. During the experimental period, all animals were weighed after every two weeks and the amount of feed eaten was weighed daily. The amount of consumed compounded diet was 6.20 kg DM/day for MMMO, 6.91 kg DM/day for HFMO, 7.05 kg DM/day for RPMO, 5.29 kg DM/day for HFMM and 6.18 kg DM/day for RPMM diet while the consumed hay was 1.20 kg DM/day for MMMO, 1.15 kg DM/day for HFMO, 1.24 kg DM/day for RPMO, 1.31 kg DM/day for HFMM and 1.32 kg DM/day for RPMM diet. The metabolisable energy (ME) content of hay was 4.8 MJ/kg DM while the crude protein (CP) content was 33 g/kg DM. The ME contents of compounded feeds were estimated using the equation by MAFF (1975), that was ME (MJ/kg DM) = 0.012 CP + 0.031 EE + 0.005 CF + 0.014 NFE, whereas that of hay was determined by the McDonald *et al.* (2002) equation: ME (MJ/kg DM) = 0.016 DOMD, where DOMD = g digestible organic matter per kg dry matter.

2.2 Slaughter procedures

After 90 days of feeding, all animals were weighed for three days consecutively to obtain the final body weight and transported by truck to Dodoma Abattoir (82 km from Kongwa ranch). At the abattoir, the animals were deprived of feed for 24 hours, but had access to fresh drinking water. Slaughtering and dressing of the animals followed the abattoir procedures as described by Bourguet *et al.* (2011). The animals were stunned using electrical stunner, slaughtered and suspended on an overhead rail system for bleeding, de-hiding and evisceration. The head was removed at the atlanto-occipital joint, the forefeet and hind feet were removed at the carpal–metacarpal and tarsal–metatarsal joints, respectively. The dressed carcasses were halved into two us-

Table 1: *Ingredient composition (kg/100 kg), Crude protein (g/kg DM) and Metabolisable energy (MJ/kg DM) levels of the dietary treatments*

Ingredients	*Compounded diets*				
	MMMO	*HFMO*	*RPMO*	*HFMM*	*RPMM*
Ingredient composition (kg/100 kg as fed)					
Maize meal	38	–	–	38	38
Hominy feed	–	40	–	50	–
Rice polishing	–	–	41	–	51
Molasses	47	47	47	–	–
Cotton seed cake	13	11	10	10	09
Mineral mix	1	1	1	1	1
Urea	0.5	0.5	0.5	0.5	0.5
Salt	0.5	0.5	0.5	0.5	0.5
Nutritive values					
Crude protein (g/kg DM)	122	120	97	145	111
Metabolisable energy (MJ/kg DM)	11.0	11.7	10.1	12.6	10.2

MMMO: maize meal with molasses; HFMO: hominy feed with molasses; RPMO: rice polishing with molasses; HFMM homing feed with maize meal; RPMM rice polishing with maize meal.

ing an electrical saw, weighed within 45 minutes post-mortem to obtain the hot carcass weight. Temperature and pH measurements were recorded after 45 minutes and 6 hours post-mortem at room temperature then carcasses were transferred to a cold room set at 0°C where further measurements after 24 hours and 48 hours were recorded.

2.3 Fabrication of retail cuts

Twenty five (25) right half carcasses (five carcasses from each treatment (5*5)) were randomly selected from the total of 45 TSZ steers for retail cuts fabrication. After 48 hours in a chilling room set at 0°C, the carcasses were weighed to obtain cold carcass weight and then quartered between 10th and 11th ribs into fore and hind quarters. After recording the weights, the hind quarters were fabricated into nine bone-in retail cuts as described by FAO (1991), the cuts were hind shin, topside, silverside, fillet, rump, loin strip, thin flank, wing ribs and thick flank. All visible fat were trimmed and similar procedure was carried out with the fore quarters, which were fabricated into eight bone-in retail cuts as brisket, prime ribs, hump, flat ribs, chuck, shoulder blade, neck and fore shin. The weight of each individual cut was recorded. The retail cuts from the fore and hind quarters were grouped as prime and nonprime cuts based on guidelines issued by VETA (2006). The prime cuts comprised the following cuts: shoulder blade, loin strip, prime ribs, rump, wing ribs, topside, silverside, thick flank and fillet. The nonprime cuts included fore and hind shin, hump, neck, flat ribs, chuck, brisket, and thin flank.

2.4 Meat quality measurements

2.4.1 Temperature and pH measurements

Temperature and pH of the carcasses were taken at 45 min, 6, 24 and 48 hours post-mortem at the same point on the 10th rib of left side carcass in the *M. longissimus thoracis et lumborum* (LL). The temperature was measured by inserting a digital meat thermometer (FUNKOTION Digital stegetermometer, HA 250K, Japan), while the pH was measured by inserting an electrode (Mettler Toledo) of a portable pH-meter (Knickportamess 911, Germany) in the same muscle. The temperature and pH readings at 45 min and 6 hours post-mortem were taken at room temperature while temperature and pH readings at 24 and 48 hours post-mortem were taken when the carcasses were in the chilling room.

2.4.2 Determination of cooking loss (CL) and Warner-Bratzler shear force (WBSF)

At the abattoir the LL muscle from 7th to 13th rib of the left side carcass was removed 48 hours post-mortem and prepared for cooking loss (CL) and Warner-Bratzler shear force (WBSF) determination. The LL muscle was cut into 4 pieces measuring approximately 9 cm long which were labelled and placed in the chilling room set at 0°C for ageing for 3, 6, 9 and 12 days. After each ageing time the samples were taken from the chilling room, vacuum packed in polythene bags and frozen at –20°C in a deep freezer. Thereafter the samples were transported to the laboratory at the Department of Animal Science and Production of Sokoine University of Agriculture, where CL and WBSF values were determined. The LL muscle samples were thawed at 4°C overnight, removed from the polythene bags, wiped up with paper towel trimmed down to reduce the size to approx mean weight ($W1$) of 298 ± 36 g and then re-sealed using a vacuum pack machine. The samples were heated at 75°C for 1 hour in a thermostatically controlled water bath. The heated samples were left to cool under running tap water for 2 hours, and then transferred to a refrigerator set at 4°C and stored overnight. The samples were removed from the polythene bags, dried with paper towel and re-weighed ($W2$). CL was calculated as $((W1 - W2)/W1) * 100$. Muscle sample for WBSF assessment were prepared from the cooked samples by cutting seven cubes measuring 1×1×1 cm, 5 cm long in fibre direction. Warner Bratzler shear blade attached to Zwick/Roell (Z2.5, Germany) instrument was used to determine the force (N cm^{-2}) required for shearing through a muscle cube at a right angle to the muscle fibre direction. The Zwick was set with 1 kN load cell with a crosshead speed of 100 mm min^{-1}.

2.5 Statistical analysis

In data analysis, individual animal was considered as experimental unit in all the variables analysed and initial weight was used as covariate. Contrast statements were used to compare molasses vs maize meal and hominy feed vs rice polishing. The GLM procedure of SAS (version 9.3, 2002) was used to analyse the data on yield, with dietary treatment as the main effect. The differences were considered significant at $P < 0.05$ and least squares means were separated by LSD. For meat quality parameters (CL, WBSF, pH and temperature) dietary treatments, time and their interactions were regarded as fixed effects. The MIXED procedure of SAS (Version 9.3, 2002) was used with repeated statement where compound symmetry was used as covariance structure. Differences were considered significant at $P < 0.05$ and least squares means were separated by Turkey-Kramer protection.

Table 2: *Performance of Tanzania Shorthorn Zebu steers fed molasses or maize meal with rice or maize by-products*

Parameters	*Diets*					*SEM*	*P-values*	*P-contrasts*	
	MMMO	*HFMO*	*RPMO*	*HFMM*	*RPMM*			*MO-MM*	*HF-RP*
Initial live weight (kg)	198	203	199	198	203	5.37	0.9253	0.8937	0.9263
Final live weight(kg)	259 ^{c}	283 ^{a}	264 ^{bc}	271 ^{b}	258 ^{c}	4.12	0.0005	0.0368	0.0003
Average daily gain (g)	658 ^{c}	919 ^{a}	709 ^{bc}	791 ^{ab}	639 ^{c}	0.05	0.0005	0.0368	0.0003
ME intake (MJ /day)	73.89 ^{b}	86.39 ^{a}	77.18 ^{b}	72.83 ^{b}	69.38 ^{b}	2.76	0.0013	0.0004	0.0264
CP intake (g/day)	795 ^{b}	867 ^{a}	725 ^{b}	809 ^{ab}	737 ^{b}	29.6	0.0095	0.421	0.0007
Hot half carcass weight (kg)	69.2 ^{b}	75.8 ^{a}	68.0 ^{b}	69.9 ^{b}	65.8 ^{b}	1.70	0.0052	0.0339	0.0021
Cold half carcass weight (kg)	67.4 ^{b}	74.4 ^{a}	66.2 ^{b}	68.1 ^{b}	64.1 ^{b}	1.70	0.0062	0.0314	0.0019
Chilling shrinkage (%)	2.63	1.93	2.61	2.49	2.55	0.45	0.7872	0.6030	0.4136

$^{a\,b\,c}$ Least squares means with a common superscript in the same raw are not significantly different ($P > 0.05$); SEM, Standard error of the mean; MMMO, maize meal with molasses; HFMO, hominy feed with molasses; RPMO, rice polishing with molasses; HFMM, hominy feed with maize meal, and RPMM, rice polishing with maize meal; MO-MM, molasses versus maize meal; HF-RP, hominy feed versus rice polishing.

3 Results

3.1 Carcass yield

Steers from different dietary treatments differed ($P <$ 0.05) in CP and ME intake, growth rate, final live weight and carcass yield. Steers fed on HFMO diet had higher ($P < 0.05$) values than their counterparts from other diets (Table 2). There was a positive correlation between growth rate and final live weight ($r = 0.99$) and between growth rate and hot/cold carcass weight ($r = 0.89$). The tendency of dietary treatments to give high values observed on carcass weight was similar to that observed in trimmed fat weight as proportion of half carcass. It was observed that the amount of trimmed fat increased with increase in growth rates. At the highest growth rate (919 g/day) for HFMO steers the amount of trimmed fat exceeded that of the lowest growth rate (639 g/day) for RPMM steers by 65 %. When expressed as proportion of half carcass weight, hind and fore quarter weight, saleable cuts, prime and non-prime cuts did not differ ($P > 0.05$) between dietary treatments despite the differences in half carcass weight (Table 3). Dietary treatments had no effects ($P > 0.05$) on yield of retail cuts as proportion of side carcass weight (Table 4). When comparisons were made between the diets, it was observed that molasses and hominy feed based diets had higher performance than maize meal and rice polishing based diets in all the parameters measured.

3.2 Meat quality attributes

3.2.1 Temperature and pH

The dietary treatments had no effects on the rate of carcass temperature decline post-mortem (Table 5). The decline in temperature was faster in the first 6–24 hours after which very little change was observed. No difference ($P > 0.05$) was observed between dietary treatments on post-mortem muscle pH decline, but there was a sharp decline in pH values in the first six hours followed by a gradual decrease till ultimate pH (pHu) was attained at 24 hours post-mortem (Table 5).

3.2.2 Cooking loss (CL) and Warner-Bratzler shear force (WBSF)

The CL and WBSF values of *M. longissimus thoracis et lumborum* (LL) were not ($P > 0.05$) influenced by dietary treatments, but were affected ($P < 0.05$) by ageing time (Table 6). Higher ($P < 0.05$) CL and WBSF values were observed on muscle aged for 3 days compared to muscles aged for 6, 9 and 12 days. The lowest values for both CL and WBSF were observed on meat aged for 9 and 12 days. An interaction ($P < 0.05$) between dietary treatments and muscle ageing time was observed for WBSF values. The meat from steers fed HFMO and RPMM diets and aged for 9 and 12 days had the lowest WBSF values compared to those from other dietary treatments × aging times (Table 7).

Table 3: *Carcass yield from Tanzania Shorthorn Zebu steers fed molasses or maize meal with rice or maize by-products*

Parameters	*Diets*					*SEM*	*P-values*	*P-contrasts*	
	MMMO	*HFMO*	*RPMO*	*HFMM*	*RPMM*			*MO-MM*	*HF-RP*
Carcass yield (% side carcass weight):									
Fore quarter	47.5	48.3	47.8	47.8	46.9	0.87	0.8499	0.4523	0.4015
Hind quarter	49.9	50.0	49.6	49.7	50.6	0.75	0.9418	0.5689	0.6220
Saleable cuts	87.1	85.7	88.5	88.0	87.7	1.20	0.5619	0.5718	0.2897
Prime cuts	46.7	46.4	45.2	46.5	47.6	1.13	0.8286	0.3008	0.9482
Non-prime cuts	40.4	39.3	43.3	41.4	40.1	1.34	0.4659	0.6978	0.3215
Aitch bone	3.08	3.29	3.47	3.12	3.47	0.28	0.7790	0.7927	0.3532
Fat trimmings	4.33^{b}	6.36^{a}	4.18^{b}	4.09^{b}	3.84^{b}	0.59	0.0394	0.0487	0.0488
Waste trimmings	2.50	2.42	1.36	1.99	2.56	0.43	0.4882	0.4112	0.5755
Uncountable loss	0.39	0.29	0.26	0.39	0.12	0.30	0.9689	0.9507	0.6208

^{ab} Least squares means with a common superscript in the same raw are not significantly different ($P > 0.05$); SEM, Standard error of the mean; MMMO, maize meal with molasses; HFMO, hominy feed with molasses; RPMO, rice polishing with molasses; HFMM, hominy feed with maize meal, and RPMM, rice polishing with maize meal; MO-MM, molasses versus maize meal; HF-RP, hominy feed versus rice polishing.

Table 4: *Yield of retail cuts from Tanzania Shorthorn Zebu steers fed molasses or maize meal with rice or maize by-products*

Parameters	*Diets*					*SEM*	*P-values*	*P-contrasts*	
	MMMO	*HFMO*	*RPMO*	*HFMM*	*RPMM*			*MO-MM*	*HF-RP*
Prime cuts (% side carcass weight):									
Shoulder blade	9.60	9.50	8.60	9.60	9.20	0.90	0.9261	0.6869	0.5016
Prime ribs	5.33	5.56	5.93	5.86	5.97	0.40	0.6814	0.6720	0.5082
Wing ribs	2.02	2.44	1.95	1.95	2.05	0.36	0.8007	0.5638	0.5406
Loin strip	7.99	7.99	7.40	8.11	8.90	0.49	0.5435	0.1328	0.8366
Rump	4.02	3.99	3.70	3.58	4.85	0.34	0.2593	0.2934	0.1465
Topside	6.13	6.53	6.24	6.38	6.30	0.23	0.6763	0.8206	0.3606
Silverside	6.36	5.62	6.56	5.99	5.51	0.31	0.1322	0.2536	0.4025
Thick flank	4.25	3.90	3.72	4.28	3.88	0.33	0.5729	0.3919	0.3209
Fillet	0.90	0.94	1.07	0.83	0.89	0.13	0.7032	0.2561	0.3995
Non-prime cuts (% of side carcass weight)									
Fore shine	5.85	5.15	6.78	6.15	5.76	0.93	0.7981	0.9930	0.4458
Hump	2.17	1.79	1.72	2.31	2.30	0.21	0.2103	0.0252	0.8562
Neck	6.58	6.41	6.72	6.80	6.27	0.42	0.9454	0.9434	0.7904
Chuck	4.92	5.17	5.06	5.12	5.59	0.49	0.8979	0.6166	0.6873
Flat ribs	4.25	4.05	4.15	4.21	4.01	0.34	0.9881	0.9710	0.8958
Brisket	7.87	8.20	7.69	7.35	7.09	0.43	0.2896	0.0840	0.3100
Thin flank	3.95	4.50	6.38	4.84	4.51	0.71	0.1901	0.2566	0.2204
Hind shine	4.80	4.01	4.83	4.65	4.54	0.24	0.0920	0.4534	0.1032

SEM, Standard error of the mean; MMMO, maize meal with molasses; HFMO, hominy feed with molasses; RPMO, rice polishing with molasses; HFMM, hominy feed with maize meal, and RPMM, rice polishing with maize meal; MO-MM, molasses versus maize meal; HF-RP, hominy feed versus rice polishing.

Table 5: *Effect of time change on temperature decline and pH change post-mortem for five dietary treatments*

Dietary treatments	*Variables*							
	45 min		*6 (hrs)*		*24 (hrs)*		*48 (hrs)*	
	Temp	*pH*	*Temp*	*pH*	*Temp*	*pH*	*Temp*	*pH*
MMMO	35.7	6.46	26.2	5.88	1.4	5.62	1.1	5.52
HFMO	37.0	6.36	27.0	5.87	1.5	5.67	1.1	5.56
RPMO	36.0	6.41	26.1	5.84	1.2	5.71	1.0	5.52
HFMM	36.6	6.43	26.6	5.95	1.4	5.69	1.2	5.51
RPMM	35.8	6.30	26.3	5.86	1.0	5.63	0.8	5.50
SE	0.37	0.04	0.37	0.04	0.37	0.04	0.37	0.04
P-value	0.7973	0.4313	0.7973	0.4313	0.7973	0.4313	0.7973	0.4313

SE, Standard error of the mean; MMMO, maize meal with molasses; HFMO, hominy feed with molasses; RPMO, rice polishing with molasses; HFMM, hominy feed with maize meal and RPMM, rice polishing with maize meal; MO-MM, molasses versus maize meal; HF-RP, hominy feed versus rice polishing.

Table 6: *Cooking losses and Warner-Bratzler shear force values for Tanzania Shorthorn Zebu steers fed molasses or maize meal with rice or maize by-products*

	Cooking loss (%)	*Shear force ($N\,cm^{-2}$)*
Dietary treatments (T)		
MMMO	21.5	49.0
HFMO	21.0	46.4
RPMO	20.3	50.8
HFMM	19.6	49.4
RPMM	19.7	44.0
SEM	0.82	3.72
P-value	0.42	0.72
Ageing (A, days)		
3	22.0^{b}	53.4^{c}
6	20.3^{a}	48.7^{b}
9	20.1^{a}	45.1^{a}
12	19.3^{a}	44.3^{a}
SEM	0.61	1.70
P-value	0.01	<0.0001
T × A	0.18	<0.0001
P-contrasts (MO-MM)	0.24	0.61
P-contrasts (HF-RP)	0.75	0.89

$^{a\,b\,c}$ Least squares means with a common superscript in the same raw are not significantly different ($P > 0.05$); SEM, Standard error of the mean; MMMO, maize meal with molasses; HFMO, hominy feed with molasses; RPMO, rice polishing with molasses; HFMM, hominy feed with maize meal and RPMM, rice polishing with maize meal; MO-MM, molasses versus maize meal; HF-RP, hominy feed versus rice polishing.

Table 7: *Effect of ageing time on tenderness for the five dietary treatments ($N\,cm^{-2}$)*

	Dietary treatments					
Ageing time	*MMMO*	*HFMO*	*RPMO*	*HFMM*	*RPMM*	*Mean*
3 days	53.4^{a}±3.5	56.3^{a}±1.2	54.1^{a}±1.2	53.9^{a}±1.2	50.1^{a}±1.2	53.5±0.6
6 days	50.9^{a}±3.5	47.4^{b}±1.2	50.3^{a}±1.2	50.3^{ab}±1.2	43.0^{bc}±1.2	48.4±0.6
9 days	50.0^{a}±3.5	40.6^{c}±1.2	50.0^{b}±1.2	44.5^{a}±1.2	40.8^{c}±1.2	45.2±0.6
12 days	44.3^{b}±3.5	40.5^{c}±1.2	48.8^{b}±1.2	44.5^{b}±1.2	40.6^{b}±1.2	44.3±0.6
Mean	49.0±3.4	46.4±0.7	50.8±0.7	49.4±0.7	44.0±0.7	

P-values for main effects: Dietary treatments, 0.72; Ageing time, 0.61; $^{a\,b\,c}$ Least squares means with a common superscript in the same column are not significantly different ($P > 0.05$); MMMO, maize meal with molasses; HFMO, hominy feed with molasses; RPMO, rice polishing with molasses; HFMM, hominy feed with maize meal and RPMM, rice polishing with maize meal.

4 Discussion

4.1 Carcass yield

The observed higher final body weight and carcass weight for steers fed HFMO diet compared to those fed other diets could be associated with high intake levels of both energy and protein nutrients. Likewise, steers fed HFMO diet had the highest level of fat deposition (highest amount of trimmed fat). Growth rate and fat deposition are directly related with the level of energy and protein intake as they increase muscle and fat mass (Safari, 2010; Khalid *et al.*, 2012). These findings coincide with observations by Pazdiora *et al.* (2013) who found the degree of fat cover to increase with the body weight of animals. Part of high final weights observed could be due to compensatory growth, which is commonly seen for old animals of this age given *ad libitum* access to feed following a period of restricted feeding, since these animals were grazing on poor range land pasture before they were taken in feedlot. The observed increased amount of trimmed fat was found to decrease the amount of saleable cuts. This implies economic losses to beef producers, since excess fat deposits are not part of usable carcass under certain market conditions (Kitts, 2011). It is however, important to note that preference for fat content varies with place and culture. For instance, Kamugisha (2014) reported that consumers in Arusha, Tanzania showed high preference to meat with high fat content which suggests the need for taking into account preferences of targeted consumers in feedlot finishing.

The observed chilling shrinkage of 2.4 % in the present study was comparable to the range of 2.4–2.7 % observed by Khalafalla *et al.* (2011) and Fadol & Babiker (2010) in Sudan Baggra bulls, and is slightly above the standard cold shrinkage of 2.0 % in 24 hours chilling (Pascoal *et al.*, 2010). The absence of dietary effects on yield of different retail cuts including primal and non-primal cuts suggests that differences in levels of dietary energy and protein in the present study were not large enough to elucidate differences in yield of retail cuts. Similar findings have been observed in several other studies involving beef cattle (Fadol & Babiker, 2010; de Souza Duarte *et al.*, 2011; Turki *et al.*, 2011). On the other hand, studies have shown that variation in terms of breed (Sharaf Eldin *et al.*, 2013), sex (Lazzaroni & Biagini, 2008) and age (Pazdiora *et al.*, 2013) of animals has significant effects on the distribution of cuts.

4.2 Meat quality attributes

4.2.1 Temperature and pH

The rate and extent of decline of muscle pH and temperature during the immediate post-mortem periods seriously influence meat quality development, mainly tenderness (Safari, 2010; Frylinck *et al.*, 2013), because temperature changes can initiate cold or heat shortening. A rapid decline in temperature during early post-mortem when muscle pH is still high can cause cold shortening (Frylinck *et al.*, 2013), which will lead to tough meat. In the present study, pH reading reached 6 while the temperature was still high (>26.5°C) which shows unfavourable conditions for cold shortening to occur. Lack of dietary effect on pH values for concentrate fed cattle observed in the present study is in agreement with findings from other studies (Mapiye *et al.*, 2010; Lage *et al.*, 2012). The findings indicate that there was sufficient glycogen content in the muscles of animals in these different dietary treatments. The average pH of 5.67 for carcasses in the present study is within the quality range of 5.5 to 5.8 which is considered normal and optimal according to shelf life and eating properties (Silva *et al.*, 1999; Mach *et al.*, 2008).

4.2.2 Cooking loss and Warner-Bratzler shear force

Cooking loss in muscles depend on ultimate pH, cooking conditions (Mushi *et al.*, 2009), and intramuscular fat content (Safari, 2010). Although intramuscular fat content was not measured in the present study, it can be argued that the magnitude of pH variation was not large enough to elicit differences in CL values. The values observed for CL are comparable to the range of 16.8 to 24.6 % reported by Mwilawa (2012) on TSZ steers fed 100 % concentrate, but are slightly lower than the 22.5 to 25.2 % reported by Mapiye *et al.* (2010) on Nguni steers. This deviation may be attributed to differences in feeding systems, breeds and ageing time used between studies. The observed WBSF values are within the range of 41.8 to 50.9 N cm^{-2} reported on carcases of TSZ steers fed concentrate diet with 125 g CP and 12 MJ ME per kg DM (Mwilawa, 2012). Lack of dietary effects on CL and WBSF concurs with previous studies (Lage *et al.*, 2012; Neto *et al.*, 2012).

Meat samples from carcasses from cattle in the five treatments in the current study are considered tender as WBSF values are less than 50 N cm^{-2} (Devitt *et al.*, 2002). The lowest values for CL and WBSF observed on meat aged for longer days (9 and 12 days) may be associated with enzymatic reactions that disintegrate the myofibrillar proteins with increasing ageing time. The influence of ageing time on CL and WBSF has also been observed in previous studies (Florek *et al.*, 2009; Filipčík *et al.*, 2009).

In general, post-mortem storage resulted in decreased CL and WBSF values. Observations from this study have shown that dietary treatment and ageing time are two factors that independently affect meat quality characteristics of steers but jointly influenced the WBSF values which decreased most for HFMO and RPMM diets on 9^{th} and 12^{th} days of ageing. Ageing increases tenderisation by degrading and weakening structural integrity of myofibrillar proteins brought by the calpain proteolytic enzyme system especially μ-calpain (Safari, 2010; Kemp & Parr, 2012). On the other hand, energy concentration consumed by the animal influences glycogen stores which decrease ultimate muscle pH, and thus influencing meat tenderness. The influence of consumed energy on glycogen reserve has also been reported by Koger *et al.* (2010). In addition, high energy diets influences tenderness by increasing intramuscular fat that gives rise to the dilution of muscle structure (Wood *et al.*, 1999; Cardeno *et al.*, 2006). It can be concluded that molasses with hominy feed can substitute maize meal in feedlot diets without reducing meat yield and quality of TSZ cattle finished in feedlots in 90-days feed lot period.

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