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Effect of three different diets on sensory attributes and meat quality of feedlot finished Tswana yearling steers

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The study was conducted to assess the effect of roughage source on meat quality and sensory attributes of yearling Tswana cattle. The sensory traits and meat quality of yearling Tswana steers fed maize stover diet (treatment A), sorghum stover diet (treatment B) or commercial beef finisher diet (treatment Control) were evaluated and allotted feeding trial by adopting Completely Randomized Design (CRD). The commercial diet had Lucerne (*Medicago sativa*) as a roughage source at inclusion level of 15% in total diet dry matter. Animals were slaughtered after 24 hour fast at Botswana Meat Commission (BMC) at Lobatse and samples were collected by cutting approximately 5 kg rump steak of the left side of halved carcasses. Trained individuals were used in sensory consumer evaluation to assess flavor, tenderness, moistness, appearance and overall impression of meat using eight point hedonic scales. No significant difference between the treatment groups for meat colour attribute was found. However, the colour values are slightly lower for the treatments indicating paler colour of the meat. There was also no significant difference among treatments in tenderness (P > 0.05) although treatments A and B almost significantly differed (P = 0.067). The proximate parameters crude protein, moisture and total fat were similar in all treatments (P > 0.05). There was statistically significant difference for muscle pH between sorghum stover diet (5.5) and commercial beef finisher diet (5.0) at P < 0.05. The pH values of meat from maize stover diet and sorghum stover diet were within the normal pH range of 5.4-5.8 which is an indication of good quality product. The sensory evaluation of rump steaks from yearling Tswana steers showed that 86% of the panelists rated meat steaks highest on overall impression from maize stover diet finished animals followed by 79% rankings from sorghum stover diet finished animals while steak cuts from commercial diet were the least ranked from like moderately to like extremely. It was concluded that meat products from cereal stover diets had good meat qualities and overall acceptability as compared to commercial beef finisher diet.

Key words: Commercial beef finisher, maize stover diet, meat quality, sensory attributes, sorghum stover diet, yearling Tswana bulls.

INTRODUCTION

Meat production is normally based on the growth and development of the animals, while site of fat and amount in the carcass determines the quality of meat (Mahgoub and Lu, 1998). The attributes of meat quality includes flavor, juiciness, tenderness, colour and muscle pH. These attributes are useful particularly on the evaluation of chemical and sensory assessment of meat (Dhanda et al., 1999). Generally meat supplies human beings with

quality proteins in the form of essential amino acids, essential vitamins and minerals (Sebibe, 2014). The overall meat consuming quality is influenced by tenderness and juiciness attributes (Chulayo and Muchenje, 2013). In most cases meat quality is influenced by muscle pH, however consumers usually evaluate meat qualities basing on the tenderness, juiciness and flavor attributes of cooked meat (Chulayo and Muchenje, 2013).

Myoglobin content and nature, the composition and physical state of muscle are the key determinants of meat colour (Renerre, 1990). Consumers use meat colour to assess meat quality and acceptability (Conforth, 1994). The freshness of meat and quality is highly influenced by desirable colour (Machete et al., 2012). There are so many other aspects during beef production such as cattle genetics, use of implants, feeding practices, quality of feedstuffs as well as meat processing procedures which influence the variation of beef quality or characteristics in various countries around the world (Killinger et al., 2004). Fresh products can be potentially affected in variable manner by these above mentioned factors. Normally the palatability of the product is influenced by aging of the fresh meat. Research has shown that meat aging is associated with development of flavors and incremental tenderness with time (Sitz et al., 2006). The current study was carried out in order to address the lack of documentation or characterization information of this indigenous Tswana breed of cattle in the aspect of meat evaluation. Therefore, the study was conducted to assess the effect of roughage source on meat quality and sensory attributes of yearling Tswana cattle.

MATERIALS AND METHODS

The study was conducted at the Department of Agricultural Research (DAR) feedlot facility at Sebele (24° 33''N, 025° 54''E,**)** 10 kilometers from Gaborone, Botswana. Twenty-seven Tswana yearling steers (227±11 kg) obtained from ranches of DAR were used in a 93-day feeding trial by adopting Completely Randomized Design (CRD). Tswana cattle are the famous indigenous cattle breed of Botswana, which are closely related to the humped Sanga cattle. The adult size is approximately 400 kg and an 18 month old weighs roughly 250 kg when raised extensively under communal natural pastures (Animal Production Research Unit Report, 1992).

Slaughtering and Sampling

Twenty-seven intact yearling Tswana steers from a feeding trial were transported to a slaughter abattoir, Botswana Meat Commission (BMC) a day before they were subjected to slaughter procedures. There were three dietary treatments of maize stover diet (30% roughage level, treatment A), sorghum stover diet (30% roughage level, treatment B) and commercial diet (15% roughage level, treatment control,C). Formula feed (ground maize, 57.8%; maize stover, 30%; molasses cane, 65%; wheatbran, 2.1%; urea, 1.5%; limestone,1.1%; vitamin premix, 0.5%; dicalcium phosphate, 0.3% and salt, 0.2%) was used for maize stover diet, formula feed (ground maize, 55.1%; molasses cane, 6.5%, wheatbran, 4.7%; urea, 1.5%; limestone, 1.2%; vitamin premix, 0.5%; dicalcium phosphate, 0.3%; salt, 0.2% and sorghum stover, 30%) was used for sorghum stover diet. The cereal-based diets were formulated to have Crude protein content of 12.5%. Ingredients composition of the commercial diet was unknown and it was formulated to have minimum crude protein content of 12%. Each dietary treatment had nine yearling steers which were individually fed. Animals were slaughtered after a 24 h fast in this commercial slaughter house BMC at Lobatse and samples were collected from the running conveyor belt automatic system by cutting approximately 5 kg rump steak of one left side of the halved carcasses. All rump steak samples were kept in cooler boxes on ice blocks and transported to Botswana College of Agriculture (BCA) Meat Science Laboratories for further analysis. One quarter of each rump steak were cut after 24 hours ageing and sent to National Food Technology Research Centre (NFTRC) laboratories at Kanye for chemical analyses. All samples at BCA Meat science laboratory were kept at -20 ^{0}C until analyses of meat pH (pH done obtained from post-thawing sample), sensory evaluation and meat firmness procedures were carried out except for small portions which were for meat colour assessment, done the following morning on fresh, non-frozen samples (Sawyer et al., 2007).

Instrumental objective colour

The meat colour of external surface of the muscles was measured using Precision Meat colorimeter, mini-scan, model NR20XE of Shenzhen 3NH Technology Co., LTD, Shenzhen, China. The device had a 2.54 cm port and was standardized using a black tile and a white tile. Readings were taken from two random locations on each muscle and the average of the readings for lightness (L*), redness (a*), and yellowness (b*) were recorded (Sawyer et al., 2007).

Measurement of pH

The 200 g post-thawing portion of rump steak samples was used for pH determination using Portable waterproof meat pH meter, model HI99163 of Hanna Instruments, USA. The pH meter was equipped with a temperature-compensating combination pH electrode and probe calibrated to both pH 4.0 and 7.0. The meter is fitted with a sharp probe which pierces through the muscles, and readings were obtained from three locations on each sample and the average of the readings was recorded (Lee et al., 2008).

Instrumental firmness measurement / Tenderness

The objective evaluation of tenderness was performed using Digital Firmness Tester model Agrosta R 15, electronic durometer designed and manufactured by AGRO-TECHNOLOGIE of APOLLINAIRE lm AEROSPACE and INSTRUMENTS, France. Meat samples were thawed at 4°C for 24 h and then meat samples from rump steak were boiled and fry-finished to an internal temperature of 72°C or well done. The cooked samples were allowed to equilibrate to room

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Table 1. Least square means and standard errors of mean of meat colour, tenderness and pH for rump steaks of yearling Tswana steers fed maize stover diet, sorghum stover diet and commercial diet finisher.

Traits	Treatments				
	Maize stover	Sorghum stover	Commercial diet	S.E.M	P-value
Lightness (L*)	35.37	34.44	35.73	1.071	NS
Redness (a*)	17.06	16.78	17.82	0.529	NS
Yellowness (b*)	5.45	5.5	5.8	0.266	NS
Tenderness (N)	21.25	16.44	16.56	1.777	NS
pH	5.29[a]	5.51[a]	5.02[b]	0.137	S

[a,b,c]Means with a different superscript across the row differ significantly (P< 0.05), Each value is an average of nine observations (n = 9), NS=Non significant (P > 0.05), S = Significant, S.E.M= standard error of mean.

temperature. Two cores of 2.0 cm diameter were removed from each cooked meat sample using a sharp knife. The coring was done parallel to the orientation of muscle fiber and each core was sheared at two locations with single bladed digital firmness tester device.

Chemical composition

The chemical analysis of rump steaks for steers finished on feedlot was done at NFTRC laboratories in which the Association of Official Analytical Chemists (AOAC) 1990.03, 1990 Dumas method was used for crude protein determination, AOAC 934.01, 1934 oven drying was used to obtain moisture content while total fat was determined by the FOSS Tecator application sub note for hydrolysis unit 1047 (ASN 3121); ISO 1443-1973, in focus vol.11No.1 (1998).

Sensory evaluation analysis

A total of thirty-eight orientated or semi-trained individuals were used in a sensory consumer evaluation exercise. The consumer panelists were of mixed sex (males and females) of unequal numbers that volunteered to participate in response to a verbal announcement sent to all employees of the Department of Agricultural Research and Botswana College of Agriculture as well as students of the College. The panelists rated each of the meat samples in duplicates using an 8-point hedonic scale; 1=dislike extremely; 2=dislike very much; 3=dislike moderately; 4=dislike slightly; 5=neither like nor dislike; 6=like moderately; 7=like very much; 8=like extremely for meat quality attributes; flavor, moistness, appearance and overall impression. For tenderness, a 5-point scale was used; 1=much too tough; 2=too tough; 3=just about right; 4=too tender; 5=much too tender. Equal bite size from each treatment were coded and served in an odourless formy plates or containers. Each sample was evaluated independent of the other on a well-structured consumer ballot sheet.

Statistical analysis

The analysis of variance (ANOVA) for the objective meat colour, meat pH, instrumental firmness and chemical composition data were generated with PROC MIXED of SAS 9.2 2008 (SAS Institute, year of publication), and the fixed effects included in the statistical model included treatments and measured parameters. Least square means were calculated for all the main and interactive effects, and when significant (P < 0.05) F values were observed, least squares means were statistically separated with t-tests PDIFF. The consumer evaluation data were subjected to the frequency and cross tabulation procedures of Descriptive statistics (IBM SPSS Statistics version 22, 2013) to compute frequencies of occurrence of each qualitative trait.

RESULTS AND DISCUSSION

Meat quality attributes of the sampled rump steak portions are presented in Table 1. The values for the meat colour traits scored between 34.44 and 35.73 for lightness, 16.78 and 17.82 for redness while yellowness values were found between 15.45 and 15.80 respectively (Table 1). The values are slightly lower for all the treatments indicating a paler colour of the meat. The paleness of the rump steaks from maize stover diet (A), sorghum stover diet(B) and commercial beef finisher(C) fed animals may be due to the influence of nutritional as well as genetic factors (Raes et al., 2003). The significant difference (P < 0.05) between treatments A, B and C were not determined within the meat colour traits. This may be due to the fact that the amount and redox state of myoglobin is responsible for the colour of the muscle surface (Byrne et al., 2000). Some studies have indicated that dark coloured muscles and oxidative fibres are experienced from free range feeding system and pale muscles also associated with feedlot system (Vestergaard et al., 2000). Variations in the levels of feeding and physical involvement among feedlot feeding system and pasture-fed animals influence changes in muscle colours and their metabolic behaviours (Vestergaard et al., 2000). In addition, pasture feeding will always have an upper effect on the condition of animal and its products because pasture production in the country (Botswana) is not really established or available since every farmer let his or her animals graze freely in communal areas without bearing any cost of pasture maintenance. Meat tenderness is the most important quality trait that consumers prefer and will pay more especially in European countries (Koohmaraie, 1988). A threshold shear force of 38.22 N has been used to distinguish intermediate and tender steaks (Delgado et al., 2005). A Warner-Bratzler shear force values of less than 31.36 N is considered very tender, 31.36 to 38.22 N

Table 2. Least square means for chemical composition (g/100g edible meat) of yearling Tswana steers` rump steaks fed maize stover diet, sorghum stover diet and commercial beef diet finisher.

Traits	Treatments				
	Maize stover	Sorghum stover	Commercial diet	S.E.M	P-Value
Crude Protein	19.21	19.59	20.59	1.059	NS
Moisture	69.76	69.67	67.02	1.802	NS
Total fat	7.71	4.64	8.42	1.348	NS

Each value is an average of nine observations; NS=Non significant (P > 0.05); S.E.M= standard error of mean.

being tender, 38.22 to 45.08 N being intermediate and more 45.08 being tough (Shackelford et al., 1991). In the current study shear force value was not affected by roughage source (P > 0.05) and the meat from all treatment groups was considered very tender with an average value of 18.10 N. The sorghum stover diet (B) fed animals numerically had relatively tenderer rump steaks than rump steaks from maize stover diet (A) fed animals since less force was used to penetrate or cut through the steaks. Overall tenderness can be improved by increasing of high-energy diets which influence the myofrillar fragmentation to be easier and increasing detectable connective tissue (Boleman et al., 1996).

After slaughter, glycogen is converted to lactic acid and there is reduction of muscle pH from neutral value of 6.56 at two hours postmortem to 5.48 at twenty-four hours postmortem (Byrne et al., 2000). The pH can also affect meat tenderness and pH of 5.48 – 5.89 is regarded as normal. The values for meat pH (rump steaks) from the three diet treatments are presented in Table 1, and range from 5.02 to 5.50. Some significant difference for muscle pH was noticed between treatments B and treatment C (P < 0.05). Nevertheless treatment A was not statistically different from treatment B (P > 0.05). The pH value of the commercial diet was lower than the normal pH range of 5.48-5.89. This is attributable to high energy density of the diet which resulted in more glycogen being available for conversion into lactic acid (Bello and Tsando, 2014; Li et al., 2014). Table 2 contains chemical composition for rump steaks (gluteus muscle) of steers which were fed different diets. The results include crude protein, moisture and total fat. The average crude protein levels found in this research work for treatments A, B and C were 19.21 g/100 g; 19.59 g/100 g and 20.59 g/100 g respectively (Table 2). There was no significant difference for crude protein across the three treatments (A, B and C) (P > 0.05). Treatment A (steaks from maize stover diet fed steers) was similar to treatment B (steaks from sorghum stover diet fed steers) in terms of crude protein P = 0.8014 while content of crude protein from treatment A showed some similarities with treatment C with p-value of 0.3654. The results also indicated that protein amount in treatment B did not differ significantly from treatment C (P = 0.5104). The values found for crude proteins are similar or slightly lower than those observed by Prado et al. (2009) and Williams 2007. This is in agreement with the previous study by Prado et al 2008a suggesting that genetic constitution does not change the crude protein percentage in beef animals. It was mentioned that there is very little variation of crude protein in beef chemical composition, approximately 21% regardless of physiological condition, breed, genotype and diet (Marques et al., 2006a; Padre et al., 2009a; Macedo et al., 2007,). Similar results were observed in another study by Patten et al., 2008 in which they found no difference in protein content. Therefore, treatment A, B and C were similar (P > 0.05) for mean percentage protein in rump steaks (Gluteus muscles) of feedlot-developed steers.

There were no significant differences observed in the moisture content between treatments A, B and C (P > 0.05). The moisture amount in this study has no variation with values such as 69.76, 69.67 and 67.02 g/100 g respectively Table 2. The values seemed to be slightly lower than those reported in previous studies (Prado et al., 2008a; Rotta et al., 2009; Delgado et al., 2005; Williams, 2007), who reported values ranging from 70.16 to 74.25%. However, the moisture content of this study is in accordance with that reported by Brown et al. (2007). The rump steaks from commercial diet(C) fed steers had the lowest numerical value for mean percentage moisture, however there was no significant difference in moisture content from rump steaks of treatment A and B (Table 2). Some research work had indicated that the variation in moisture levels can also occur due to the total lipid content in the muscle (Moreira et al., 2003; Rotta et al., 2009). The higher percentage of total lipids in the muscle is usually related to lower moisture content in the muscle (Prado et al., 2009). High total fat contents are reported in this study with values ranging between 4.64 and 8.42 g/100 g (Table 2). The increased content of total fat is normally associated with the lower moisture percentage by these treatment groups. There was no significant difference between treatments A, B and C (P > 0.05), however treatment B had the lowest numerical value which nearly differed from treatment C in total fat from rump steaks of yearling steers (P = 0.0589) (Table 2). It is worth mentioning that the average total fat content of the muscles observed here was moderately higher (>4%). These results are in line with those observed in gluteus medius in cow and beef muscles (Patten et al.,

Table 3. Sensory evaluation for rump steaks of yearling Tswana bulls fed maize and sorghum stover diets and commercial beef finisher diet.

Traits	Treatments					
	Maize stover diet		Sorghum stover diet		Commercial diet	
Flavour	**Frequency**	**Percent**	**Frequency**	**Percent**	**Frequency**	**Percent**
Dislike	2	6	7	19	12	31
Like	36	94	31	81	26	69
Tenderness						
Tough	3	8	8	21	10	27
Tender	35	92	30	79	28	73
Moistness						
Dislike	8	21	7	18	13	34
Like	30	79	31	82	25	66
Appearance						
Dislike	5	13	11	29	14	37
Like	33	87	27	71	24	63
Over Impression						
Dislike	5	14	8	21	11	29
Like	33	86	30	79	27	71

2008; Brown et al., 2007). All these researchers suggested that percentage moisture decreases as fat percentage increases with higher marbling scores. The relationship between moisture and fat content was also observed by Patten et al. (2008) in which they revealed that the amount of intramuscular fat is a major contributor to the difference in percentage of moisture and fat content (Table 2, 69.17, 4.64 vs 67.02, 8.42), as an increase in marbling increases fat content and eventually decrease water content.

The panelists rated sensory evaluation attributes for the rump steaks of Tswana feedlotted yearling steers from different treatments of diets in terms of flavor, tenderness (texture), moistness (juiciness), appearance and overall impression (Table 3). The sensory results of this study revealed that 84% of the panelists ranked the flavor of rump steaks (like moderately to like extremely) from maize stover diet treatment, 81% of the consumers rated steaks from sorghum stover diet treatment while 69% of the panelists score steaks from commercial beef finisher diet treatment ranging from like moderately to like extremely showing lower preference for the control treatment. Low rating of commercial diet (C) is attributable to high fat content as reflected in Table 2. The results of this study are in agreement with earlier studies by Warris (2000), who indicated that meat flavor could be improved to a greater height through potential dietary manipulations. Resconi et al. (2010) revealed that beef flavour intensities are influenced by the content of the diets. In another study (Resconi et al., 2009) it was reported that species-specific flavours were associated with the concentrates proportion in the diet of farm animals. Nevertheless, there are other factors such as pre-slaughter stress and ageing that influence the meat flavor in various ways (D`Souza et al., 1998; Kontsidis et al., 2003). Flavour especially of roasted meat is more associated with the typical maillard reaction products such as furanes, thiazoles, pyrroles and pyrazines (Raes et al., 2003). Both dry and wet aging are responsible for the development of meat flavor in farm animals (Miller et al., 1997; Campbell et al., 2001).

Ninety-two percent of the panelists rated rump steaks from yearling Tswana steers finished from maize stover diet to be just about right to much too tender (Table 3). The rankings by the respondents were followed by 79% from sorghum stover diet finished animals meanwhile commercial diet finished animals were rated the least (73%). The study indicated that most of the respondents preferred most or favored the rump steaks from maize stover (A) finished animals and the least preferred rump steaks were from commercial beef finisher (C) diet animals. Studies by Raes et al. (2003) stated that assessment of taste panel tenderness seemed to be associated with collagen content. The resistance of collagen and myofibrillar to shearing is determined by the heat treatment as they vary for taste panel than firmness testing evaluations (Raes et al., 2003).

In terms of moistness (juiciness), the consumers rated

the rump steaks from sorghum stover diet (B) finished animals to be more juicy (82%) falling between like moderately and like extremely. Juiciness is usually influenced by intramuscular fat (marbling). The rankings were followed by maize stover diet (A) finished animals at 79%. Nevertheless the rump steaks from commercial beef finisher diet were ranked less juicy with only 66% (Table 3) suggesting that the commercial diet was associated with the driest rump steaks cuts. It was reported in some research work that the whole variation found in juiciness depends on both biophysical-biochemical state of water in the meat and cook loss; particularly water distribution and motility which play a vital role in meat juiciness (Toscas et al., 1999). Moreover, meat juiciness is also influenced by low quality protein diets resulting in slightly drier meat (Ngapo et al., 2003).

The sensory panelists indicated that in terms of appearance attribute, they preferred rump steak cuts colour from maize stover diet (A) finished animals ranging from like moderately to like extremely (89%). However, the rump steak cuts from sorghum stover diet (B) finished animals were moderately preferred (71%) while the least rated rump cuts were from commercially beef finished diet (C) scoring only 63% (Table 3). It was noted that most of the cooked beef colour ranged from purplish-brown, light and dark brown colour as result of Maillard reaction. Lanari et al. (1995) stated that consumer assessment of meat quality depends on the perception of meat colour. Moreover the colour perception is determined by the observer of the meat product and therefore the background value of relative colour measurements should be known to the subjective judgment of acceptable colour (Van Oekel et al., 1999). Research showed that colour is an important indicator of quality of cooked meat; as such the appearance of meat influences its acceptance by the consumers (Northcutt, 1997).

In terms of overall acceptability, steers fed maize stover diet (A) were well received by the panelists from like moderately to like extremely (86%) followed by 79% rankings from sorghum stover diet (B) finished animals while steak cuts from commercial beef finisher diet (C) were the least ranked from like moderately to like extremely. It is very important for the meat industry to produce beef of acceptable quality in order to satisfy consumers` preference and needs at the least costs (National cattlemen`s Beef association, 2005). The respondents had indicated that Tswana beef finished from maize stover diet (A) were more palatable than the ones finished from sorghum stover diet (B) and commercial beef finisher diet (C) respectively. Therefore the overall acceptability ratings were directed towards maize stover diet (A) finished steak cuts except for moistness (juiciness) attribute where the highest rankings were obtained from sorghum stover diet (B) finished animals` steak cuts.

Conclusion

The current study indicated that differences in colour traits and tenderness of meat from yearling Tswana steers were less evident. However, the muscle pH of sorghum stover diet finished animals was significantly different from commercial diet finished animals. Consumers ranked higher meat from animals finished on maize stover diet in attributes of flavor, tenderness, and appearance except in moistness (juiciness) which was rated the best from animals finished with sorghum stover diet. Therefore, the sensory result suggested that feeding steers with maize stover had no detrimental effects and has also increased sensory attributes on meat quality. However, the chemical composition of the meat from the current study was not influenced by the roughage type.

Conflict of Interests

The authors have not declared any conflict of interests.

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REFERENCES

Animal Production Range Research Division (1992). Livestock and range research in Botswana, Gaborone, Botswana.

AOAC (1990). An Association of Official Analytical Chemists methods of analysis. 15th edition, AOAC Benjamin Frankin Station, D.C. U.S.A.

Bello AA, Tsado DN (2014). Quality and Sensory evaluation of meat from Yankasa rams fed sorghum stover supplemented with varying levels of dried poultry droppings based diet. Int. J. Agric. Food Sci. Tech. 5(2):1-8.

Boleman SJ, Miller RK, Buyck MJ, Cross HR, Savell JW (1996). Influence of realimentation of mature cows on maturity, colour, collagen solubility and sensory characteristics. J. Anim. Sci. 74:2187-2194.

Brown Jr. AH, Camfield PK, Rowe CW, Rakes LY, Pohlman FW, Johnson ZB, Tabler Jr GT, Sandelin BA (2007). Effect of Beef growth type on cooking loss, tenderness and chemical composition of pasture or feedlot developed steers. Asian-Aust. J. Anim. Sci. 20(11):1746-1753.

Byrne CE, Troy DJ, Buckley DJ (2000). Postmortem changes in muscle electrical properties of bovine M.longissimus dorsi and their relationship to meat quality attributes and pH fall. Meat Sci. 54:23-34.

Campbell RE, Hunt MC, Levis P, Chambers E (2001). Dry-aging effects on palatability of beef longissimus. J. Food Sci. 66:196-199.

Chulayo AY, Muchenje V (2013). Effect of pre-slaughter conditions on physico-chemical characteristics of mutton from three sheep breeds slaughtered at a smallholder rural abattoir. South Afr. J. Anim. Sci., 43:64-68.
Conforth D (1994). Colour: Its basis and importance. In Pearson AM, Dutson TR, Quality attributes and their measurement in meat, poultry and fish products. Glasgow: Blackie Academic & Professional, Adv. Meat Res.9:35-77.
D'Souza D, Dunshea FR, Warne RD, Leury BJ (1998). The effect of handling pre-slaughter and carcass processing rate post-slaughter on pork quality. Meat Sci. 50:429-437.
Delgado EJ, Rubio MS, Iturbe FA, Mendez RD, Cassis L, Rosiles R (2005). Composition and quality of Mexican and imported retail beef in Mexico. Meat Sci. 69:465-471.
Dhanda JS, Taylor DG, Murray PJ, McCosker JE (1999) The influence of goat genotype on the production Capretto and Chevron carcasses on meat quality. Meat Sci. 52:363-367.
Killinger KM, Calkins CR, Umberger WJ, Feuz DM, Eskridge KM (2004). A comparison of consumer sensory acceptance and value of domestic beef steaks and steaks from a branded, Argentine beef program. J. Anim. Sci. 82:3302-3307.
Kontsidis D, Mottram DS, Elmore JS, Oruna-Coucha MJ (2003). Sugars and related compounds as flavor precursors in meat. Proc. the 10th Weurman flavour Res. Symp. pp. 654-657.
Koohmaraie M (1988). The role of endogenous proteases in meat tenderness. Recipr.l Meat Conf. Proc. 41:89-100.
Lanari MC, Schaefer DM, Scheller KK (1995). Dietary vitamin E supplementation and discolouration of pork bone and muscle following modified atmosphere packaging. Meat Sci. 41:237-250.
Lee MS, Yancey JWS, Apple JK, Sawyer JT, Baublits RT (2008). Within-muscle variation in colour and pH of beef semimembranosus. J. Musc. Foods. 19:62-73.
Li L, Zhu Y, Wang X, He Y, Cao B (2014). Effects of different dietary energy and protein levels and sex on growth performance, carcass characteristics and meat quality of F1 Angus x Chinese Xiangxi yellow cattle. J. Anim. Sci. Biotechnol. 5:21.
Macedo LM, Prado IM, Ducatti T, Prado JM, Matsushita M, Prado IN (2007). Performance, carcass characteristics and chemical composition of non-pregnant or pregnant heifers finished in feedlot. Acta Sci. 29:425-432.
Mahgoub O, Lu CD (1998). Growth, body composition and carcass tissue distribution in goats of large and small sizes. Small Rum. Res. 27:267-278.
Marques JA, Prado IN, Moletta IM, Macedo LM, Prado IM, Prado JM, Souza NE Matsuhita M (2006). Carcass and meat traits of feedlot finished heifers submitted to surgical or mechanical anoestrous. Braz. J. Anim. Sci. 35:1514-1522.
Miller MF, Kerth CR, Wise JW, Lansdell JL, Stowell JE, Ramsey CB (1997). Slaughter plant location, USDA quality grade, external fat thickness, and aging time effects on sensory characteristics of beef loin strip steak. J. Anim. Sci. 75:662-667.
Moreira FB, Souza NE, Matsushita M, Prado IN, Nascimento WG (2003). Evaluation of carcass characteristics and meat chemical composition of Bos indicus x Bostaurus crossbred steers finished in pasture systems. Braz. Arch. Biol. Tech. 46:609-616.
National cattlemen`s Beef Association (2005). Beef bytes. Retrieved from www.beef.org/uDocs/BeefBytesComplete03-28-05.pdf. Accessed 20/04/2015.
Ngapo TM, Dransfield E, Martin JF, Magnusson M, Bredahl L, Nute GR (2003). Consumer perceptions: pork and pig production. Insights from France, England, Sweden and Denmark. Meat Sci. 66:125-134.
Northcutt JK (1997). Factors affecting poultry meat quality. College and Environmental Sciences, University of Georgia. Retrieved on 08/12/2014 from http://athenaeum.libs.uga.edu/bitstream/handle10724/12453/B1157.htm.
Padre RG, Aricetti JA, Moreira FB, Mizubuti IY, Prado IN, Visentainer JV, Souza NE, Matsushita M (2006). Fatty acid profile, and chemical composition of Longissimus muscle of bovine steers and bulls finished in pasture system. Meat Sci. 74:242-248.
Patten LE, Hodgen JM, Stelzleni AM, Calkins CR, Johnson DD, Gwartney BL (2008). Chemical properties of cow and beef muscles: Benchmarking the differences and similarities. J. Anim. Sci. 86:1904-1916.
Prado IN, Oliveira AN, Rotta PP, Perotto D, Prado RM, Silva RR, Souza NE, Moletta JL (2009). Chemical and fatty acid composition of Longissimus muscle of crossbred bulls finished in feedlot. Asian-Aust. J. Anim. Sci. 22(7):1054-1059.
Prado RM, Prado IN, Marques JA, Rotta PP, Visentainer JV, Silva RR, Souza NE (2009a). Meat quality of the Longissimus muscle of bulls and steers (½ Nellore vs ½ Simmental) finished in feedlot. J. Anim. Feed Sci. 18:221-230.
Raes K, Balcaen A, Dirinck P, De Winne A, Claeys E, Demeyer D, De Smet S (2003). Meat quality, fatty acid composition and flavor analysis in Belgian retail beef. Meat Sci. 65:1237-1246.
Renerre M (1990). Review: factors involved in the discolouration of beef meat. Int. J. Food Sci. Tech. 25:613-630.
Resconi VC, Campo MM, Furnols MFI, Montossi F, Sanudo C (2010). Sensory quality of beef from different finishing diets. Meat Sci. 86:865-869.
Resconi VC, Campo MM, Furnols MFI, Montossi F, Sanudo C (2010). Sensory evaluation of castrated lambs finished on different proportions of pasture and concentrate feeding systems. Meat Sci. 83(1):31-37.
Rotta PP, Prado RM, Moletta JL, Silva RR, Pertto D, Prado IN (2009). Carcass characteristics and chemical composition of the Longissimus muscle of Nellore, Caracu and Holstein-friesian bulls finished in feedlot. Asian-Aust. J. Anim. Sci. 22:598-604.
Sawyer JT, Baublits RT, Apple JK, Meullenet JF, Johnson ZB, Alpers TK (2007). Lateral and longitudinal charateristics of colour stability, instrumental tenderness and sensory characteristics in beef semimembranosus. Meat Sci. 75(4):575-584.
Sebibe A (2014). Sheep and goat characteristics and quality, Chapter 12. Ethiopian sheep and Goat productivity improvement programme. Assessed from www.esgpip.org on 25/06/2015.
Shackelford SD, Morgan JB, Cross HR, Savell JW (1991). Identification of threshold levels for warner-bratzler shear force in beef top loin steaks. J. Muscle Foods, 2(4):289-296.
Sitz BM, Calkins CR, Feuz DM, Umberge WJ, Eskridge KM (2006). Consumer sensory acceptance and value of wet-aged and dry-aged beef steaks. J. Anim. Sci. 84:1221-1226.
Toscas PJ, Shaw FD, Beilken SL (1999). Partial least squares (PLS) regression for the analysis of instrument measurements and sensory meat quality data. Meat Sci. 52:173-178.
Van Oeckel M, Warnants J, Boucque CHV (1999). Measurement and prediction of pork colour. Meat Sci. 52:347-354.
Vestergaard M, Oksbjerg N, Henckel P (2000). Influence of feeding intensity, grazing and finishing feeding on muscle fibre characteristics and meat colour of semitendinosus, longissimus dorsi and supraspinatus muscles of young bulls. Meat Sci. 54:177-185.
Warris PD (2000). Meat Science – An introductory text. CAB International Publisher. United Kingdom. pp. 147-261.
Williams PG (2007). Nutritional composition of red meat. Nutr. Diet. 64(s4):S113-S119.