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UTILIZATION OF BROILER LITTER PELLETS TO SUBSTITUTE MIXED FEED PELLETS IN FATTENING STEERS

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ABSTRACT

Thirty crossbred steers of Thai indigenous and Brahman cattle were used in an experiment for a 120 day period to determine effects of dietary broiler litter (BL) level on growth performance, carcass and meat quality, sensory grading, chemical composition of *Semitendinosus* (ST) and microbial contamination in carcass and beef. BL was provided as pellet. Six treatments substituted 0, 10.0, 20.0, 30.0, 40.0, and 50.0% BL pellet (total dietary level). At the end of the fattening period, all animals were slaughtered. After the experiment, productive performance in terms of weight gain, daily gain, dry matter (DM) rice straw intake, DM pellet diet intake, total DM feed intake and feed conversion ratio were found not to be influenced by diet ($P>0.05$). At slaughter, carcass and meat quality, sensory grading and chemical composition of ST did not differ significantly among treatments ($P>0.05$). All treatments of muscle, purge, and ground beef were culture-negative for *Escherichia coli*, *Salmonella* spp. and *Campylobacter* spp. These results indicated that 50.0% BL pellets may be used effectively as a feedstuff for cattle; beef cattle may consume properly handled pelleted BL without increasing the likelihood of carcass/meat contamination with pathogenic bacteria. However, a 15-day withdrawal time for exclusion of BL from diets of cattle before slaughter is suggested in order to avoid drug residue in meat.

Key words: feedstuff, manure, nutrient, pathogen, pelleting

INTRODUCTION

Rapid expansion within the broiler chicken (*Galllus gallus domesticus*) industry has resulted in critical environmental concerns in several areas of Thailand, due to excesses of substances entering groundwater (Suppadit, 2002). However, broiler litter (BL) has economic value associated with its nitrogenous and mineral components (Suppadit, 2005). Recycling BL as a ruminant feed could be beneficial for individual farmers and the broiler industry (Van Ryssen and Mavimbela, 1999; Suppadit *et al*., 2002b; Jackson *et al*., 2006). BL contains 12.0-35.0% crude protein (CP) (Davis *et al*., 2002). Most of the CP are true protein and non-protein nitrogen (Pongpiachan, 1996), which ruminants can metabolize into essential amino acids for growth and maintenance (Guseva, 1993; Owoigbe *et al*., 1998). BL also contains up to 22.5% digestible carbohydrates (Tancho, 1997). Given its potential as a source of nutrition, it is worthwhile to study how the litter can be processes and used as a feed source for cattle. This could reduce cattle feed costs, increase feed conversion efficiency and increase daily weight gain (Rossi *et al*., 1999). However, fresh BL added directly to cattle feed can lead to unacceptable problems associated with worms, insects, parasites, palatability and odor (Suppadit *et al*., 2002a). This has an adverse impact on the health of cattle and farm workers; in addition can be a source of odor pollution (Suppadit, 2009).

To overcome these problems, pelleting the BL is being proposed. Pelleting is a process used to eliminate the worm, insect, microorganism, noxious odor, antibiotic residue and hormone in BL (Suppadit, *et al*., 2008). Furthermore, pelleting can support the feeding, handling, storing and transporting management (John *et al*., 1996). Developing a process of converting a voluminous waste byproduct into a valuable, environmentally safe feed could be very beneficial (Suppadit, 2004). Therefore, the present experiment aims to access the effectiveness of BL pellet to substitute the mixed feed (MF) pellet for steer at ~18 months of age in order to indicate the differences in terms of productive performance, carcass and meat quality, sensory grading, chemical composition of *Semitendinosus* (ST) and microbial contamination in carcass and beef.

MATERIALS AND METHODS

Comparison of Productive Performance

Data on productive performance, carcass and meat quality, sensory grading, chemical composition of ST and microbial contamination were assessed in six treatments with five replications in a completely randomized design. The mixture of six ratios of BL pellets and MF pellets as follows: control (without BL pellets) (T_1), BL pellets mixed with MF pellets at substitution level of 10.0% : 90.0%, (w/w) (T_2), 20.0% : 80.0%, (w/w) (T_3), 30.0% : 70.0%, (w/w) (T_4), 40.0% : 60.0%, (w/w) (T_5) and 50.0% : 50.0%, (w/w) (T_6). Thirty steers were used in the experiment. The SAS program version 6.12 (SAS Institute, 1996) was used to calculate the analysis of variance and Duncan's New Multiple Range Test, to compare the experimental treatments.

Twenty broiler farms were randomly chosen from 200 farms, all located in Saraburi province, Thailand in November, 2008 that had broilers of the same age (45 days), duration, bedding materials (rice husks), area ratio (9 broilers per square meter) and open-housing system. From each broiler farm, 500 kilograms of BL was collected for the study. Collected BL were mixed together. Next, they were mixed with sugarcane molasses at the ratio (% BL: % sugarcane molasses; w/w) as 92.0: 8.00. After mixing, the BL were pelleted by Siriwan Model machine using the Suppadit and Panomsri (2009) method. The pelleting process produced heat up to 90.0 C and pellet size was 6.00 mm in diameter and 1.50-2.00 cm in length. After pelleting, BL pellets were sampled, crumbled and sent to the laboratory at Thailand Institute of Scientific and Technological Research for analysis of nutrient contents (AOAC, 2000).

The MF components were calculated for steer feedlot-type requirements according to National Research Council (1996) by the feed formulation software (FeedLive 1.00) (Live Informatics Co., Ltd., 2009). Next, MF were pelleted by Siriwan Model machine according to the Suppadit and Panomsri (2009) method. These were randomized, crumbled and analyzed for nutrient content at the laboratory at Thailand Institute of Scientific and Technological Research (AOAC, 2000).

From each 300-gram sample of the rice straw, BL pellet and MF pellet, the CP content was determined using the Kjeldahl method (6.25 x N) (model TLE 230, behr Labor-Technik, Dusseldorf, Germany). Dry matter (DM) (drying method; model Sharp IEC, Tokyo, Japan), crude fat (CF) (ether extraction method; Tecator Ltd., Haganas, Sweden), crude fiber (CFI) (ceramic fiber filter method; model Labconco, Missouri, USA), ash (dry ash method; ICP-AES, St. Pual, MN), calcium (Ca) (dry ash method; ICP-AES, St. Pual, MN) and phosphorus (P) (photometric method; model Hirama, Kanagawa, Japan) contents were analyzed according to the procedure described in the Association of Analytical Chemists manual. Gross energy (GE) content was determined in a Parr adiabatic oxygen bomb calorimeter (model RSBI, Dew Delhi, India) (AOAC, 2000).

Thirty crossbred steers of Thai indigenous and Brahman cattle obtained from local farmers

located in Nakhon Ratchasima province, Thailand with an average initial weight of 250 ± 10.0 kg at ~18 months of age were used. The steers were divided into six equal groups, containing five steers per group by random selection. Each steer was then allocated to an individual pen and remained in the pen for 120 days of the study. The steers were vaccinated (hemorrhagic septicemia and foot and mouth disease) and dewormed (ivermectin drug) by the veterinarian, adapted to the environment and conditions and fed the experimental feed for 20 days prior to the trial. The steers were fed the BL pellets and MF pellets in each treatment at 1.00% of initial body weight each morning. They were weighed every 15 days and the ration was adjusted to 1.00% of the new body weight. The rice straw was provided *ad libitum* daily in the afternoon. Prior to providing rice straw, all leftover feed pellets were weighed and recorded. The leftover rice straw was weighed and recorded the next morning. The production efficiency of the growing cattle including weight gain, daily gain, DM rice straw intake, DM pellet diet intake, total DM feed intake and feed conversion ratio was calculated and analyzed.

Measurement of Carcass and Meat Quality

After the experiment, the steers in each treatment were slaughtered randomly within three days at the Duangkamol slaughterhouse, Nakhon Ratchasima province, Thailand, following procedures outlined in Allingham *et al*. (1998). All experimental procedures were carried out following the animal welfare standards of Department of Livestock Development, Ministry of Agriculture and Cooperatives, Royal Thai Government. The carcass weight and fat depth at the P8 site for each side was measured before chilling. The left side of each carcass was electrically stimulated with a low voltage application (2.00 mA; model LF 196, WTW, Weilheim, Germany) for 40.0 s immediately after exsanguinations, and chilled according to conventional abattoir procedures. The ST was removed from the left side of each carcass at 48 hr *post mortem*, weighed, blast frozen and stored at -20.0°C until required for analysis.

The tenderness of cooked ST samples was determined objectively by way of measurements of a modified Warner-Bratz shear (model 5565, Instron Co., Ltd., UK), compression (CO) and adhesion strength (ADH), following the established methods of Bouton *et al*. (1977). The parameters measured from shear force deformation curves were (i) peak force (PF), (ii) initial yield (IY) and (iii) the peak force minus initial yield (PFIY) (Bouton *et al*., 1975; Harris and Shorthose, 1988). All measurements were made on samples taken from cooked (70.0 C for 1 hr) 250 g blocks cut from the proximal section of the ST. Shear force was also measured on pressure-heat treated samples (60.0 C and 1,500 psi for 1 hr prior to the normal shear protocol). Samples taken from the distal section of the ST were used for measurement of sarcomere length (Bouton *et al*., 1973), ultimate pH (pH_u: pH meter model no. 250A, Orion Research Inc., USA) and meat surface color (L, 'a' and 'b' values; Minolta CR-300, Osaka, Japan). Samples were allowed to bloom for 1 hr at 4.00 C prior to the color measurements. Cooking loss was also measured.

For sensory evaluation, a test panel was selected from a number of Siriwan Co., Ltd. Staff, Saraburi province, who had undergone sensory evaluation training following the methods of Viriyajare (1992). Grilled 2.50-cm slices of ST were cut into pieces of 1.30 x 1.30 x 1.90 cm and served warm. Panelists were asked to grade samples for tenderness, juiciness, flavor and overall acceptability by a scale ranging from 1 (low) to 9 (high). Samples were served subsequently in a randomized order with respect to group and animal. The 30 samples (from 30 animals) were tested by 6 persons each.

Samples of the ST were minced and analyzed in duplicate for moisture, fat and protein contents (Kjeldahl; 6.25 x N) according to AOAC (2000). Cholesterol concentrations were determined in samples after extraction of the fat (Folch *et al*., 1957) and its saponification (Abell *et al*., 1951). In the residual extract cholesterol was measured colorimetrically according to Jung *et al*. (1975).

Isolation of Microbial Contamination

The comparison of microbial contamination followed the procedures outlined by Davis *et al*. (2002). After steers were slaughtered carcass quality was compared. The right sides of carcass were thoroughly washed with cool (8.00 C) water. The right side of each carcass received a 2.00% lactic acid rinse to simulate a post-harvest sanitation step possibly employed by small-scale meat processors. Muscle and fat samples from the neck and bung areas (incision samples) of the carcass were taken from right side, placed in individually identified bags (Whirl-Pak), and immediately cultured for *Escherichia coli* (*E. coli*), *Salmonella* spp. and *Campylobacter* spp. Approximately 5.00 kg of pre-rigor beef trimmings from the external surfaces of the round, loin, rib, chuck, flank, plate and brisket were removed from this side, packaged in individual sterile plastic bags and refrigerated at 2.00 C. After six days of refrigerated storage, samples of purge (moisture that collects in the bottom of packages of meat) were collected for microbial analyses, and trimmings were then ground twice through a grinder (model 310, Hobart, Troy, OH) with a 3.20-mm plate. All parts and equipment were washed with hot (79.0 C) water and commercially available detergent (Ecolabs, St. Paul, MN), and sanitized with a 4.00% chlorine solution between sample grindings. Random samples of ground beef, as well as purge samples, were subsequently cultured for the presence of *E. coli*, *Salmonella* spp. and *Campylobacter* spp.

The isolation of *E. coli* from purge and meat samples followed the procedure outlined by Hitchins *et al*. (1998). Approximately 25.0 g of meat (either neck and bung incision samples or ground beef) were placed in Stomacher bags (Seward, London, UK) with 225 ml of buffered peptone water, stomached for 1 min in a Model 400 Lab Stomacher (Seward, London, UK), and subsequently incubated for 6 h at 37.0 C. One milliliter of stomached solution or purge was placed into an 8.00-ml tube containing lauryl sulfate tryptose broth with 4-methylumbelliferyl-ß-D-glucuronide (MUG, REMEL, Lenexa, KS), and incubated at 37.0 C for 24 h. After incubation, samples were streaked for isolation on MacConkey agar (MAC, REMEL, Lenexa, KS) and MacConkey agar with sorbitol (SMAC, REMEL, Lenexa, KS), and incubated for 24 h at 37.0 C. Colony morphology was examined, and typical round, light-colored, smooth colonies were picked from SMAC plates and tested for indole production with Kovacs reagent (REMEL, Lenexa, KS). Indole positive colonies were selected from SMAC plates and transferred to tubes with lauryl sulfate tryptose broth containing 4-methylumbelliferyl-ß-D-glucuronide (MUG, REMEL, Lenexa, KS) and a Durham tube. Tubes were observed for gas production and phosphorescence after 24 h of incubation at 37.0 C. Gas positive-phosphorescence negative isolates were agglutinated with O157 antisera (REMEL, Lenexa, KS), and O157-positive isolates were streaked on blood agar (REMEL, Lenexa, KS) and incubated at 37.0 C for 24 h. One colony was picked from the blood plate and tested for agglutination with H7 antisera (REMEL, Lenexa, KS). The relative specificity of the serotyping procedures was greater than 99.0%.

Procedures for the isolation of *Salmonella* spp. followed those outlined by Andrews and Hammack (1998). Briefly, 25.0 g of meat were stomached with 225 ml of buffered peptone water as described previously (*E. coli* isolation). One millimeter of solution (from stomached/incubated meat samples) or purge was placed into a 10.0-ml tube of tetrathionate broth (REMEL, Lenexa, KS) for *Salmonella* enrichment and incubated at 42.0 C for 24 h. After incubation, samples were streaked for isolation on brilliant green agar with novobiocin and XLT-4 agar (REMEL, Lenexa, KS). Colony morphology was compared, and three typical round, black ("bull's-eye") colonies were selected from XLT-4 plates and stab-streaked into Kingler's iron agar slants (Edge Biologicals, Memphis, TN). Then, H_2S-positive isolates from Kingler's iron agar slants were selected and re-streaked on MacConkey agar and agglutinated with *Salmonella* O polyvalent (A-E, Vi) antisera (REMEL, Lenexa, KS). Isolates, which were agglutinated with the *Salmonella* O polyvalent antisera, were further agglutinated with *Salmonella* group B and D antisera (REMEL, Lenexa, KS). Again, the relative specificity of *Salmonella* isolation was greater than 99.0%.

The isolation of *Campylobacter* spp. from purge and meat samples followed the procedure

by Zweifel *et al*. (2004). Approximately 25.0 g of meat were inoculated into 250 ml of selective enrichment broth (*Brucella* bouillon [(Difco 0495-17-3) with *Campylobacter* growth supplement (Oxoid SR84) and Skirrow *Campylobacter*-selective supplement (Oxoid SR69), Oxoid]) and incubated at 42.0°C for 24 h under microaerobic conditions (5% O_2, 10% CO_2, 10% N_2) provided by commercial gas packs (BBL 271045). The enrichment samples were streaked onto selective agar media (*Brucella* agar [(Difco 0964-17-5) with 6.00% horse blood (Oxoid SR48) and Butzler *Campylobacter*-selective supplement (Oxoid SR8) and incubated at 42.0 C for 36 h under microaerobic conditions. Suspect colonies were identified by typical morphology, gram-negative stain, catalase and oxidase reactions, characteristics motion, hippurate hydrolysis and intrinsic resistance to cephalotin. The relative specificity of *Campylobacter* isolation was greater than 99.0%.

RESULTS AND DISCUSSION

The chemical composition of rice straw, MF pellet and BL pellet, including the dietary ingredients of MF are shown in Table 1.

Table 1. Chemical composition of rice straw, MF pellet and BL pellet.

Feed composition (DM basis)	Rice straw	MF pellet[1]	BL pellet
DM (%)	89.1	89.4	84.6
Moisture (%)	10.9	10.6	15.4
CP (%)	4.20	18.5	26.0
CF (%)	1.45	6.50	1.10
CFI (%)	34.7	15.8	15.4
Ash (%)	16.6	9.10	19.9
Ca (%)	0.220	1.33	3.72
P (%)	0.0840	0.690	1.68
GE (kcal/g)	3.96	4.26	3.99

1

Composition of MF pellet: cassava meal, 42.4%; rice bran, 12.4%; palm kernel meal, 3.00%; coconut meal, 24.2%; bone meal, 2.00%; salt, 1.00%; cattle premix, 0.500% [2]; ipil-ipil meal, 12.5%; urea, 2.00%.

[2] Cattle premix composition per kg: vitamin: A 2,400,000 IU, D_3 500,000 IU, E 500 IU, B_{12} 2.00 mg; mineral: Mn, 8.00 g; Zn, 8.00 g; Fe, 10.0 g; Cu, 2.00 g; Co, 400 mg; I, 400 mg; Mg, 26.4 g; Se, 40.0 mg; food preservative, 40.0 mg; carriers, add wholely , 1.00 kg.

In general, moisture content of BL is not an important measure of nutrient value (Suppadit, 2000). The CP in BL is usually a very inexpensive source of protein for cattle. Most of the CP is true protein and non-protein nitrogen (Pongpiachan, 1996). The non-protein nitrogen is mostly uric acid that is excreted by poultry (Biely *et al*., 1980). Young or steer cattle do not utilize non-protein nitrogen as readily as more mature beef cattle (Davis *et al*., 2002). The CF and GE of BL is fairly low in comparison to grain (Ruffin and McCaskey, 1991). The fiber in BL cannot effectively meet the cattle's need for fiber, because cattle also need long roughage to properly maintain their digestive systems (Boyles and Golden, 2000). Ash content is one of the important measures of a quality of BL because ash contents of over 28.0% are too high and should not be fed to beef cattle (Davis *et al*., 2002). The BL pellet analyzed contained an average of 19.9% ash. BL is an excellent source of Ca and P. But the excess minerals are not a problem except under specific conditions (Boyles and Golden, 2000).

The addition of BL pellet in the steer diet did not significantly affect the weight gain, daily

gain, DM rice straw intake, DM pellet diet intake, total DM feed intake and feed conversion ratio (*P*>0.05) (Table 2) due to the cattle having a unique digestive system that enables them to use a number of non-conventional feedstuffs having high CF (cellulose and hemicelluloses) such as BL (Tancho, 1997). Cattle have many microorganisms in the digestive system that can digest the true protein and non-protein nitrogen compounds (Pongpiachan, 1996). Microorganisms will use protein in nitrogen form to expand and enrich their cells. When microorganisms move into the digestive system, they will be digested by gastric juices in the real stomach. Cattle can get essential and non-essential amino acids from the cells of microorganisms in this way (Ruffin and McCaskey, 1991). Suppadit *et al*. (2002b) found similar results when they compare a control feed which diets containing 15.0 and 30.0% BL. Mekasha *et al*. (2004) and Jackson *et al*. (2006) found that organic matter, CP, acid detergent fiber and neutral detergent fiber digestibilities were not affected by the addition of 40.0 -60.0% BL in the goat diet. It is possible that low residues of growth promoters, unidentified growth factors and drugs support a positive impact on growth rate and feed efficiency (Webb and Fontenot, 1975). Lactic acid and ethanol-producing bacteria, that occur naturally in BL, produces lactic acid and acetic acid. The two acids produce a sour smell and taste which cattle favor (Suppadit *et al*., 2002a) although, during the pelleting process, heat was produced from pressure at the BL (~90.0 C) (Suppadit and Panomsri, 2009). The nutrient content was affected slightly by the heat and pressure (McCaskey *et al*. 1989). The nitrogen becomes insoluble (bound), the amount of bound nitrogen increases, and the DM digestibility decreases which cattle can digest less easily (McCaskey and Martin, 1988). Besides, heat from the pelleting process destroyed some useful microorganisms and lactic acid (Wenger, 1997). However the high temperature from the pelleting process over a short period of time gave no adverse influence on nutrient content of BL pellet clearly (Suppadit *et al*., 2008).

Table 2. Performances of cattle fattened with MF pellets substituted by various ratios of BL pellets. [1] Standard error of the mean.

Performance	Percent of Substitution						SEM[1]	*P*-value
	0 (T_1)	10 (T_2)	20 (T_3)	30 (T_4)	40 (T_5)	50 (T_6)		
No. of steers (head)	5	5	5	5	5	5	-	-
Initial weight/head (kg)	252	251	253	250	251	252	6.10	0.400
Final weight/head (kg)	313	310	313	313	314	313	10.8	0.320
Weight gain/head (kg)	61.0	59.0	60.0	63.0	63.0	61.0	2.10	0.180
Daily gain (kg/head/day)	0.508	0.492	0.500	0.525	0.525	0.508	0.01	0.660
DM rice straw intake/head/day (kg)	4.12	4.12	4.13	4.16	4.18	4.15	0.11	0.280
DM pellet diet intake/head/day (kg)	2.32	2.32	2.33	2.35	2.36	2.30	0.045	0.910
Total DM feed intake/head/day (kg)	6.44	6.44	6.46	6.51	6.54	6.45	0.074	0.340
Feed conversion ratio (kg DM of feed/kg weight gain)	12.7	13.1	12.9	12.4	12.4	12.7	0.080	0.850

Carcass qualities are summarized in Table 3. Mean final live weight, hot carcass weight, dressing, ST weight, ST as a percent of side and P8 fat depth of six treatments were not significantly different (*P*>0.05). Meat color (*L**, *a** and *b**) of ST, cooking loss, pH_u and sarcomere length of samples were not significantly different (*P*>0.05). Including shear PF and PFIY values gave no

significant difference (P>0.05). After pressure-heat treatment, shear PF and PFIY values of ST were not significantly different (P>0.05) as pre-treatment results. ADH values showed a similar trend with CO values and were not significantly different (P>0.05). The ST muscles from the steers of six treatments were all acceptably tender as determined by PF shear. PF values which ranged from 4.50-4.65 kg, a shear force below the value that Thai consumer studies have shown that consumers consider tough (Jaturasitha *et al*., 2009). In the USA, Huffman *et al*. (1996) have shown that a shear force below 4.60 kg was required to ensure high levels of consumer acceptance (98.0%).

All grilled 2.50-cm slices of ST in each treatment were similarly accepted by consumers in all palatability attributes (tenderness, juiciness, flavor, overall acceptability) and differences in consumer acceptance, based upon palatability attributes were not observed (P>0.05) (Table 4). Chemical compositions of ST did not differ due to treatment in moisture, protein, fat and cholesterol (P>0.05).

Table 3. Carcass and meat quality of cattle fattened with MF pellets substituted by various ratios of BL pellets.

Items	Percent of Substitution						SEM[3]	*P*-value
	0 (T_1)	10 (T_2)	20 (T_3)	30 (T_4)	40 (T_5)	50 (T_6)		
Carcass quality								
Live weight (kg)	313	310	312	313	314	313	4.80	0.32
Hot carcass weight (kg)	171	170	172	172	174	170	1.70	0.88
Dressing (%)	55.2	54.1	54.4	55.5	55.6	54.0	0.200	0.24
ST weight (kg)	1.98	1.98	1.99	2.00	2.02	2.01	0.010	0.95
ST as a percent of side (%)	0.490	0.460	0.460	0.470	0.490	0.480	0.020	0.01
P8 fat depth (mm)	5.50	5.55	5.62	5.70	5.80	5.70	0.020	0.70
Meat quality								
Meat color of ST								
Lightness (L^*)	46.0	46.5	47.0	47.0	47.2	45.8	0.0500	0.23
Redness (a^*)	20.5	20.6	20.6	20.9	21.0	20.2	0.0700	0.87
Yellowness (b^*)	14.7	14.7	15.0	15.1	15.1	14.8	0.0400	0.64
Cooking loss (%)	22.4	22.4	22.5	22.8	22.8	22.5	0.0900	0.84
pH_u	5.50	5.50	5.50	5.60	5.60	5.60	0.0200	0.10
Sarcomere length (μm)	2.10	2.10	2.10	2.10	2.20	2.10	0.0500	0.28
PF[1] (kg)	4.50	4.50	4.60	4.65	4.65	4.60	0.100	0.53
PFIY[2] (kg)	1.30	1.40	1.40	1.50	1.50	1.45	0.120	0.45
PF (pressure heated samples) (kg)	4.70	4.75	4.80	4.90	4.95	4.80	0.200	0.89
PFIY (pressure heated samples) (kg)	2.50	2.55	2.55	2.60	2.60	2.60	0.200	0.90
CO (kg)	2.30	2.40	2.50	2.50	2.50	2.45	0.100	0.56
ADH (kg/cm)	0.600	0.610	0.650	0.670	0.670	0.640	0.0400	0.24

[1] Shear PF.
[2] Numerical difference between shear PF and IY.
[3] Standard error of the mean.

Carcass and meat quality, sensory grading and chemical composition of ST of cattle fattened with MF pellets substituted by various ratios of BL pellets were not distinguished from the control treatment in the present study, which is consistent with previous reports (Gomez *et al*., 1995; Jeremiah and Gibson, 2003). Although fat content tended to decrease with increasing BL pellet in diet there was no significant difference (*P*>0.05). Addition of BL pellet in feedlot diets for cattle does not decrease the carcass yield and meat quality of cattle and without compromising either palatability or consumer acceptance.

Table 4. Sensory grading and chemical composition of ST of cattle fattened with MF pellets substituted by various ratios of BL pellets.

Items	Percent of Substitution						SEM[2]	*P*-value
	0 (T_1)	10 (T_2)	20 (T_3)	30 (T_4)	40 (T_5)	50 (T_6)		
Sensory grading (1-9)								
Tenderness score[1]	5.88	5.90	5.90	5.92	5.94	5.92	0.013	0.078
Juiciness score[1]	5.55	5.60	5.68	5.90	5.90	5.70	0.051	0.20
Flavor score[1]	6.65	6.60	6.64	6.65	6.64	6.64	0.016	0.45
Overall acceptability score[1]	6.44	6.48	6.45	6.44	6.40	6.50	0.014	0.30
Chemical composition (g/100 g meat)								
Moisture	72.4	72.5	72.4	72.0	72.3	72.6	0.060	0.12
Protein	22.6	22.6	22.8	22.9	23.0	22.7	0.040	0.19
Fat	3.40	3.39	3.35	3.33	3.32	3.30	0.024	0.10
Cholesterol	42.4	42.5	42.9	43.1	42.6	42.0	0.300	0.24

[1] 1= low, 5 = moderate and 9 =high.

[2] Standard error of the mean.

In the experiment, no *E. coli*, *Salmonella* spp. and *Campylobacter* spp. were detected from neck and bung incision samples, purge samples and ground beef samples (Table 5). Results from this experiment support the contention that beef cattle, especially those destined for ground beef production, may be fed BL pellet without substantially increasing the likelihood of carcass and meat, contamination with *E. coli*, *Salmonella* spp. and *Campylobacter* spp. Result of this study concur with those from the studies of Martin *et al*. (1998) and Davis *et al*. (2002), although fresh BL showed harboring several pathogenic bacteria (Kelley *et al*., 1998; Davis *et al*., 2002; Suppadit *et al*., 2002a; Suppadit *et al*., 2008). However, within a short time period of pelleting the BL, the temperature of pelleting process reached 90.0 C, thus, producing an inhospitable environment for *E. coli*, *Salmonella* spp. and *Campylobacter* spp. survival. Suppadit (2005) found that, when BL inoculated with pathogenic bacteria was pelleted, heat generated within the chamber was sufficient to kill almost all bacteria.

Suppadit *et al*. (2008) reported that there were no parasites (roundworms, flatworms, tapeworms and flukes) and *Salmonella* spp. detected in the BL after pelleting process. Kelley *et al*. (1998) also showed that the heat reached 51.0 C in BL reduced *Salmonella* spp., *Listeria monocytogenes*, *Staphylococus aureus*, and *Clostridium perfringens* well below their respective detection limits, and *E. coli* was non-culturable in the BL. However, McCaskey *et al*. (1997) reported that BL is not normally used in diets for cattle destined for slaughter and feeding the BL within 15

days of slaughter should be stopped so as to avoid potential drug residues.

Table 5. Frequency of isolation of *E. coli*, *Salmonella* spp. and *Campylobacter* spp. from carcasses and ground beef of cattle fattened with MF pellets substituted by various ratios of BL pellets.

Pathogens	Sources	Percent of substitution					
		0 (T_1)	**10 (T_2)**	**20 (T_3)**	**30 (T_4)**	**40 (T_5)**	**50 (T_6)**
E. coli	*Cold water-rinsed (# positive/# cultured)*						
	Neck	0/5	0/5	0/5	0/5	0/5	0/5
	Bung	0/5	0/5	0/5	0/5	0/5	0/5
	Trim purge	0/5	0/5	0/5	0/5	0/5	0/5
	Ground beef	0/5	0/5	0/5	0/5	0/5	0/5
	Lactic acid-rinsed (# positive/# cultured)						
	Neck	0/5	0/5	0/5	0/5	0/5	0/5
	Bung	0/5	0/5	0/5	0/5	0/5	0/5
	Trim purge	0/5	0/5	0/5	0/5	0/5	0/5
	Ground beef	0/5	0/5	0/5	0/5	0/5	0/5
***Salmonella* spp.**	*Cold water-rinsed (# positive/# cultured)*						
	Neck	0/5	0/5	0/5	0/5	0/5	0/5
	Bung	0/5	0/5	0/5	0/5	0/5	0/5
	Trim purge	0/5	0/5	0/5	0/5	0/5	0/5
	Ground beef	0/5	0/5	0/5	0/5	0/5	0/5
	Lactic acid-rinsed (# positive/# cultured)						
	Neck	0/5	0/5	0/5	0/5	0/5	0/5
	Bung	0/5	0/5	0/5	0/5	0/5	0/5
	Trim purge	0/5	0/5	0/5	0/5	0/5	0/5
	Ground beef	0/5	0/5	0/5	0/5	0/5	0/5
***Campylobacter* spp.**	*Cold water-rinsed (# positive/# cultured)*						
	Neck	0/5	0/5	0/5	0/5	0/5	0/5
	Bung	0/5	0/5	0/5	0/5	0/5	0/5
	Trim purge	0/5	0/5	0/5	0/5	0/5	0/5
	Ground beef	0/5	0/5	0/5	0/5	0/5	0/5
	Lactic acid-rinsed (# positive/# cultured)						
	Neck	0/5	0/5	0/5	0/5	0/5	0/5
	Bung	0/5	0/5	0/5	0/5	0/5	0/5
	Trim purge	0/5	0/5	0/5	0/5	0/5	0/5
	Ground beef	0/5	0/5	0/5	0/5	0/5	0/5

CONCLUSIONS

Growth, feed efficiency, carcass and meat quality, sensory grading and chemical compositions in ST are similar for fattening steers fed diets containing 0, 10.0, 20.0, 30.0, 40.0 or 50.0% BL pellet. Beef cattle fed 50.0% in the diet through pelleting process did not show incidence of *E. coli*, *Salmonella* spp. and *Campylobacter* spp. on beef carcasses, beef trimmings, and in ground beef. The pelleting process contributes to the development of an environment not optimal for the survival and reproduction of pathogenic bacteria. Therefore, the BL diets tested in this study provided an adequate source of digestible nutrient and may be effective as a feedstuff for cattle feedlot diets. However, the recommended 15-day withdrawal period for exclusion of BL from diet of cattle destined for market provides an additional safety measure.

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