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Original Article

Effects of different finishing feeding strategies for culled cows on lipid and organoleptic characteristics of the meat

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Abstract

Culled dairy cows (n=32) were either slaughtered immediately after culling-off (control) or subjected to a finishing period of 12 weeks. For finishing, three different diets were tested. A forage-only group was fed with *ad libitum* with corn silage. Two other groups either received a high-fiber concentrate feed (crude rice bran) or a concentrate feed with lower fiber content (cassava pulp). Cows were slaughtered on four days with two cows per treatment each. Samples of the *Longissimus dorsi* were individually excised 24 hrs post-mortem. Feeds were analyzed for proximate contents and fatty acid profile. In the LD, apart from fatty acid analysis, thiobarbituric acid reactive substances (TBARS), color and sensory grading was determined in LD aged for 0, 1, 3, 5, and 7 days in vaccuumized form. Treatment effects were determined by analysis of variance. Finishing on corn silage only increased the proportions of conjugated linoleic acids, docosahexaenoic acid and total polyunsaturated fatty acids (PUFA) and led to rather dark meat. The other traits remained widely unaffected. Adding crude rice bran to the finishing diet did not cause a lot of differences to control. The lipids in the LD of the rice-bran fed cows had higher PUFA proportions and a lower shelf life. Finishing with a diet lower in fiber increased intramuscular fat to 6.7% vs. 3.4-4.2% in the other groups. Concomitantly, sensory scoring in terms of tenderness, juiciness, flavor intensity and overall acceptability was mostly highest. Concerning fatty acid profile (except palmitic acid), TBARS and color the meat of the group receiving cassava pulp resembled that of the control. In conclusion, it seems advantageous in terms of lipid- and sensory-related sense to finish culled cows either with high-quality forage alone or this forage supplemented with cassava pulp.

Keywords: culled dairy cow, diet, fatty acid, lipid oxidation, organoleptic properties

1. Introduction

Traditionally, the term "meat quality" covers a number of inherent properties of meat decisive for the suitability of the meat for eating, further processing and storage including retail display. The main attributes of interest are safety, nutritional value, flavor, color, fat content, oxidative stability, and uniformity. Four sensory quality characteristics, namely appearance, color, texture and flavor, determine the acceptance of the product and thus strongly influence the consumer's purchase decision. Apart from the organoleptic properties as such, fat content and fatty acid composition of the meat are of major importance for consumer due to their importance for meat quality and nutritional value (Wood *et al.*, 2004). Meat products as foods are considered critically due to its often high fat content. The lipids in the muscle still

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are very important for eating quality as they determine color, oxidative stability and flavor of meat. In addition, fat also provides palatability and flavor to foods and play a key role in manufacture and cooking processes (Williamson *et al.*, 2005).

A large quantity of the meat available on the market originates from culled dairy cows. It is important to valorize meat of this source to overcome the reservations of the consumers and to be able to sell valuable cuts as such and not to have to use these for meat products. One such strategy consists in finishing the cows after they get dry until they are ready for harvesting valuable carcasses. The main purpose of fattening off culled cows before slaughter is to increase meatiness and meat palatability (especially tenderness), but it may have side effects on lipid composition and shelf life and as a consequence, sensory perception.

Actually, the feeding system has a major impact on the fatty acid profile of beef. In the study by Alfaia *et al.* (2009) 27 of the 36 fatty acid analyzed were affected by the production system. In detail, certain saturated fatty acids (C14:0 and 18:0) were affected by the dietary treatment, being lowest in animals fed with forage only. Concomitantly, the amounts and proportions of PUFA and n-6 PUFA were higher in forage-fed animals (French *et al.*, 2000). In addition, Aharoni *et al.* (1995) reported that an increase in energy content of the diet was associated with decrease saturated fatty acid (SFA) content in intramuscular and subcutaneous fat, whereas linoleic acid content was increased in both tissues. Lipid oxidation is major deterioration reaction which often results in a significant loss of meat product quality, due to causing a rancid off-flavor and off-odor in meat. Numerous factors affect lipid oxidation including light, oxygen concentration, temperature, presence of anti- and pro-oxidant, degree of unsaturation of the fatty acids, and the presence of enzymes (Skibsted *et al.*, 1998). Moreover, content and fatty acid composition of intramuscular fat of ruminant meat are major factors affecting its technological and sensory quality, mainly shelf life (lipid and pigment oxidation) and flavor (Wood *et al.*, 2004). The importance of the extent of fatty acid oxidation for desirable and undesirable flavor in beef has been shown by Campo *et al.* (2006). Increasing amounts of unsaturated fatty acids can also lead to a reduced retail display shelf-life due to accelerated lipid and color oxidation. Polyunsaturated fatty acids are preferentially deposited in the phospholipids, which have a key role in flavor development (Mottram and Edwards, 1983), but at certain concentrations also contributing to undesirable off-flavors.

The goal of this work was to test a number of different finishing diets differing in fiber (starch) content. It detail, the effects of using a low fiber forage either unsupplemented or together with a high-fiber-low cost concentrate ingredient, which is also available to poor small-holders, or a concentrate ingredient lower in fiber were investigated. This should provide information concerning fatty acid profile in the muscle, susceptibility to lipid and color oxidation and organoleptic characteristics of differently long stored culled cow dairy meat.

2. Materials and Methods

2.1 Animal, housing and treatments

Thirty-two non-pregnant Holstein × Thai Native crossbred (>75% Holstein blood proportion) dairy cows, selected to be culled after lactation ceased, were investigated in an experiment based on a complete randomized design. Cows were penned individually before and during the experiment. They had been feed fresh Guinea grass (*Panicum maxima*) (zero grazing system) and provided concentrate depending on milk yield before the experiment started. They were allocated to one of four treatments by balancing for body weight. The control group (C) was slaughtered immediately after culling-off. These cows had been selected when the 80-day period for the other cows had been passed. From then on, all cows subjected to finishing received corn silage at *ad libitum* access. One of the groups was only fed this forage, the others additionally received 6 kg of either a high fiber concentrate feed (crude rice bran, i.e. bran additionally containing residues of germ and endosperm) or a concentrate feed with lower fiber content (cassava pulp, the residue obtained after the extraction of starch from cassava roots); Suksombat *et al.* (2007). The analyzed chemical composition of the experimental feeds is shown in Table 1. All feeds were low in crude protein (CP) but differed in ether extract content (highest in crude rice bran, lowest in corn silage). Rice bran had highest fiber content followed by corn silage and cassava pulp. Concerning non-fiber carbohydrates (most of it likely being starch), the order from high to low was cassava pulp, rice bran, and corn silage. The dominant fatty acids were palmitic acid, oleic acid and linoleic acid. The feeds largely differed in proportions of the unsaturated fatty acids. Palmitic acid was highest in cassava pulp, oleic acid in crude rice bran, and linoleic acid in corn silage.

After 80 days of experimental feeding, or directly without finishing, cows were slaughtered in a commercial slaughterhouse. For this, on four days each two cows per treatment were slaughtered. The animals were stunned using a captive bolt stunner and dressed according to commercial practices. After chilling at 4°C for 24 hrs post mortem, muscle samples were cut from the M. *longissimusdorsi* (LD) from the 9^{th} to the 13^{th} rib. All samples were placed in plastic bags and placed on ice for transfer to laboratory. In the laboratory, each LD was cut into steaks of 2.54 cm thickness. These LD slices were vacuum-packaged and then stored at -20°C until further analysis. Samples subjected to thiobarbituric acid reactive substance (TBARS), color and sensory analysis were aged after thawing for either 0, or 1, 3, 5 and 7 days in a refrigerator at +4°C in either vacuumized (TBARS, color; one bag for all ageing days) or sealed plastic bags (sensory analysis; one bag per ageing day).

Table 1. Chemical composition of the dietary ingredients used for finishing of the cows in the experiment.

Finishing feed	Crude rice		
	Corn silage	bran	Cassava pulp
Gross nutrients (% in dry matter)			
Dry matter (in original substance)	24.8	87.6	88.9
Organic matter (OM)	93.4	93.8	96.1
Crude protein (CP)	6.79	5.70	2.58
Ether extract (EE)	1.35	4.81	2.50
Neutral detergent fiber (NDF)	62.7	42.1	37.6
Acid detergent fiber	36.2	14.1	9.80
Acid detergent lignin	8.67	4.48	3.90
Non-NDF carbohydrates[1/]	22.5	41.2	53.4
Gross energy (kcal/kg dry matter)	3,065	3,315	3,856
Fatty acids (FA; % of total FA)			
Saturated FA (SFA)			
Palmitic acid (C16:0)	23.52	12.2	31.0
Stearic acid (C18:0)	10.35	5.69	2.70
Monounsaturated FA (MUFA)			
Oleic acid (C18:1 n-9)	12.61	41.7	37.5
Polyunsaturated FA (PUFA)			
Linoleic acid (C18:2 n-6)	41.93	25.7	14.5
Linolenic acid (C18:3 n-3)	6.30	3.55	7.9
Arachidonic acid (C20:4 n-6)	0.38	0.97	1.01
Eisosapentaenoic acid(C20:5 n-3)	0.22	0.91	0.94
Docosahexaenoix acid(C22:6 n-3)	0.30	0.41	0.21
Total SFA	34.84	18.7	33.9
Total MUFA	14.28	49.8	41.1
Total PUFA	50.88	31.5	24.9

[1/]Non-fiber carbohydrate (NFC) calculated by difference: NFC=100-CP-EE-Ash-NDF.

2.2 Feed analysis

Dry matter, ash, crude protein, ether extract, neutral detergent fiber, acid detergent fiber and acid detergent lignin. Gross energy was analyzed by using a bomb calorimeter (model 6100, Parr, Illinois, U.S.A.). All analyses followed AOAC (1995), and fiber analysis was performed according to Van Soest *et al.* (1991).

2.3 Intramuscular fat content and fatty acid analysis in feeds and intramuscular fat

At the end of the experimental period, feed samples were taken and dried at 60°C for 48 hrs for further chemical analysis. Samples were ground through a 1-mm mesh and lipids were extracted for fatty acid analysis. Fatty acids were determined by Raes *et al.* (2001). In addition, intramuscular fat was extracted from the ground, non-aged LD using a modied of the method recommended by AOAC (1995). As described by Ways and Hanrahan (1964), before the extraction, the steaks were prepared from the interior of each muscle and trimmed of intermuscular and subcutaneous fat and ground using a blender (Moulinex; model DPA1). Fifteen gram of each sample was homogenized for 2 min with 90 ml of chloroform-methanol (2:1) (Nissel AM-8 Homogenizer, Nihonseikikaisha, Ltd., Japan).

Intramuscular fatty acids were quantified as their fatty acid methyl esters (FAME), prepared by the procedure described by Ostrowska *et al.* (2000). The solution was centrifuged at 2,000 g, at 10°C for 20 min and then the hexane layer was dried and transferred into vial for analyzing by gas chromatography (GC) (14B, Shimadzu, Tokyo, Japan) fitted with a flame ionization detector (FID). The FAME were separated on a 100 m × 0.25 mm × 0.2 μm film fused silica capillary column (SP2560, Supelco Inc., Bellefonte, PA, U.S.A) coated with cyanopropylpolysiloxane stationary phase, using a split/splitless injection system (split ratio of 1:5) and helium as carrier gas at a flow rate of 1.5 mL/min. After injection (10 μL), the column temperature was held at 140°C for 5 min and then increased to 230°C at 2°C/min. The temperature was kept at 230°C for 15 min and finally, held at 225°C for 40 min. The detector and injection temperatures

were set at 250°C. Identification was accomplished by comparing the retention time of peaks from samples with those of FAME standard mixtures. Quantification of FAME was based on the internal standard technique, using margaric acid (17:0) as internal standard and on the conversion of relative peak areas into weight percentages, using the corrected response factor of each fatty acid (ES ISO 5508, 1990). Fatty acids were expressed in gravimetric contents (g/100 g total FA).

2.4 TBARS analysis

Susceptibility of lipids to oxidize was assessed by the TBARS method (Rossell, 1994) using 2-thiobarbituric acid. The sample solution was obtained from raw meat distilled with 4 M HCl. The 5 ml of distillate allowed to reacts with 5 ml of TBA reagent. The sample was measured against a blank at 538 nm. The TBARS were calculated by multiplying the absorbance by 7.8. The results were given as concentrations of mg malonaldehyde in the kg of fresh meat.

2.5 Color measurements

Instrumental color measurements were recorded at 48 hrs post mortem for L* (lightness), a* (redness) and b* (yellowness) on the exposed cut surface of the LD between 11^{th} and 12^{th} ribs after 1 hr of bloom time by using a Minolta Chroma Meter (CR 400 Osaka, Japan). Additional color measurements were made on the aged samples. Measurements were replicated three times on each steak.

2.6 Sensory evaluation

The steaks aged for different times were first wrapped in aluminum foil and cooked to reach an internal temperature of 70°C in a convection oven pre-heated at 200°C before being served to the panelists after cooling to ambient temperature. During cooking the samples' internal temperature was monitored with a date logger and a thermocouple probe (Consort T851, Cohasset, MA, U.S.A.) inserted horizontally at the steaks' center points. Eight trained panelists rated each of the 5×32 samples during 20 sessions (8 samples per session) according to the procedures outlined by AMSA (1995). Steaks were evaluated for tenderness, juiciness, flavor intensity, off-flavor intensity and overall acceptability amount using a nine-point scale.

2.7 Statistical analysis

Data were analyzed by ANOVA with the GLM procedure of SAS (1996) with treatment as a fixed factor. Variables where samples were aged for different periods were analyzed by two ways: across treatments within day and across days within treatment where the focus of the comparison was put on evaluating significant changes from day 0 of ageing. The least squares means (LSM) of treatments and ageing days were compared for significance of the difference using Duncan's New Multiple Range Test.

3. Results

3.1 Content and fatty acid composition of the intramuscular fat

The clearly and significantly highest intramuscular fat content was found in the cassava-pulp diet whereas there was no significant difference among the other treatment groups (Table 2). The proportions of only few fatty acids of total fatty acids differed between treatment groups. The proportion of palmitic acid (C16:0) was significantly higher in the cassava-pulp diet when compared with the other groups. Corn silage only as a finishing feed enhanced the proportions of conjugated linoleic acids and docosahexaenoic acid (C22:6n-3) different from the other diets. Concerning groups of fatty acids, only total, PUFA were affected with elevated values with corn silage only and when adding crude rice bran compared to the other diets.

3.2 Oxidative stability of the intramuscular lipids

The TBA-reactive substance (TBARS), expressed as mg of malonaldehyde per kg of meat, differed between diets from Day 1 of storage onwards (except on Day 5) (Table 2). The levels of TBARs were (often significantly) the highest when supplementing cows with corn silage and crude rice bran. By contrast, when feeding only corn silage, TBARS remained low. As expected, TBARS levels increased with time, this being significant only on Day 7 compared to Day 0.

3.3 Meat color and its stability during storage

The L* (lightness) value was influenced by diets whereas a* (redness) value and b* (yellowness) remained unaffected (Table 3). The cassava group was the lightest meat entire of storage day. On Day 7, the meat color got lighter in all experimental groups. In detail, the meat of the cows finished on corn silage only was lighter than the meat of some of the other groups during most of the periods the meat was stored.

3.4 Sensory evaluation

Results for the sensory (eating) quality in culled cow meat either not finished or finished with different diets are shown in Table 3. Tenderness was scored significantly highest with the cassava-pulp diet compared to all other diets on Days 0 and 7 and all except corn silage only on Day 1. Initially (especially on Day 2) the cassava-pulp diet scored significantly highest in juiciness. Different from that, flavor intensity differences only developed with time, with the best scores again with the cassava pulp diet. The crude rice bran diet scored was most unfavorable since Day 1 and increased

Table 2. Effect of type of finishing on the fatty acid composition of the M. *longissimusdorsi* lipids and oxidative shelf life as measured by the thiobarbituricacid reactive substances (TBARS) depending on ageing period.

Item	Control	Finishing			SEM[1/]	P-value
		Corn silage only	Corn silage + Crude rice bran	Corn silage + Cassava pulp		
Intramuscular fat (%)	3.38[b]	3.98[b]	4.22[ab]	6.69[a]	0.885	0.009
Fatty acids (FA, g/100 g total FA)						
Saturated FA (SFA)						
Myristic acid	4.60	4.35	4.35	4.52	0.067	0.905
Palmitic acid	26.0[b]	25.8[b]	25.9[b]	27.2[a]	0.43	0.015
Stearic acid	20.9	18.4	20.8	20.7	1.45	0.185
Monounsaturated FA (MUFA)						
Palmitoleic acid	6.57	6.99	6.54	6.23	0.091	0.248
Oleic acid	26.0	26.1	25.6	25.3	0.29	0.456
Polyunsaturated FA (PUFA)						
Linoleic acid	4.18	3.65	4.15	4.13	0.158	0.073
Conjugated linoleic acids	5.14[b]	6.86[a]	5.53[b]	5.77[ab]	0.868	0.001
Linolenic acid	1.19	1.53	1.41	1.22	0.011	0.167
Arachidonic acid	1.13	1.71	1.45	0.98	0.076	0.067
Eicosapentaenoic acid	0.72	0.75	0.74	0.54	0.332	0.316
Docosahexaenoic acid	0.28[b]	0.42[a]	0.13[b]	0.21[ab]	0.018	0.042
Total SFA	53.3	50.2	51.5	53.9	1.24	0.181
Total MUFA	34.5	35.2	34.5	35.3	0.36	0.563
Total PUFA	12.6[b]	14.9[a]	14.4[a]	12.9[b]	0.44	0.023
TBARS (mg of malondialdehyde/kg of meat)						
Day 0	0.71	0.68	0.79	0.49	0.111	0.063
Day 1	0.62[b]	0.61[b]	0.91[a]	0.79[ab]	0.046	0.039
Day 3	0.85[ab]	0.63[b]	0.96[a]	0.82[ab]	0.065	0.058
Day 5	0.91	0.77	0.99	0.97	0.145	0.143
Day 7	1.57[ab]*	1.17[b]*	1.79[a]*	1.38[ab]*	0.046	0.029

[a,b] Means within the same row with different superscripts differ significantly ($P<0.05$). * Means differ from day 0 at $P<0.05$. [1/] Standard error of the mean.

with the time of storage. The overall acceptability was best on Day 1 and Day 5 against some of the other diets. Acceptability increased with storage time in all diets (significant for Day 7). A number of other sensory traits were found to be improved on Day 7 in the non-finished cows.

4. Discussion

In the present study, the effects of finishing in general and of different finishing strategies on lipid dependent and sensory traits of the meat of culled cows were tested. The finishing strategies included one where forage of higher energy content (corn silage) as that fed to the cows before (Guinea grass) was used either alone or with a cheap, fibrous supplement (crude rice bran) or a supplement richer in starch (cassava pulp). This means that dietary energy content was likely lowest with extra crude rice bran, followed by corn silage only and extra cassava pulp.

4.1 Relationship between diet, intramuscular fat content, fatty acid composition and lipid oxidation

Generally, the diet type caused clear changes in intramuscular fat and fatty acid composition. The large amount of intramuscular fat deposition by grain-finished cattle was attributed to the diet with less fiber (Leheska *et al.*, 2008). The cassava pulp used in the present study was more comparable to grain in this respect than the other feeds, but still likely less rich in starch as a large part of that had been removed in advance. Palmitic acid was affected by dietary treatment, showing the lowest value in animals fed with forage only, whereas starch from cassava probably was converted into long-chain fatty acids in the metabolism of the cows. The lipid oxidation process probably starts immediately after slaughtering and during the post slaughtering events. Differences in total lipid content and fatty acid composition in meat are dependent on animal species and dietary

Table 3. Effect of type of finishing on visual and organoleptic qualities of the M. *longissimusdorsi* depending on ageing period.

Item		Control	Finishing			SEM[1/]	P-value
			Corn silage only	Corn silage + Crude rice bran	Corn silage + Cassava pulp		
Color trait							
L*	Day 0	34.7^{bc}	31.2^{c}	34.8^{b}	37.9^{a}	2.45	0.036
	Day 1	36.5^{ab}	34.0^{b}	36.5^{ab}	38.5^{a}	2.98	0.045
	Day 3	35.9^{b}	34.5^{b}	37.6^{ab}	40.8^{a}*	3.01	0.043
	Day 5	39.5^{a}	35.2^{b}	37.3^{ab}	40.0^{a}	3.87	0.034
	Day 7	40.6^{ab*}	36.1^{b}*	38.3^{ab}*	41.2^{a}*	2.67	0.034
a*	Day 0	13.3	16.0	14.9	16.0	4.89	0.568
	Day 1	16.6	16.7	16.8	16.8	3.98	0.987
	Day 3	15.9	13.8	16.0	16.6	2.76	0.567
	Day 5	13.6	12.9	14.7	15.7	4.67	0.945
	Day 7	13.6	13.2	14.7	17.4	4.87	0.654
b*	Day 0	9.7	10.6	10.8	11.0	4.97	0.768
	Day 1	13.3	13.9	13.9	16.7	4.67	0.346
	Day 3	13.1	11.6	13.4	12.5	3.23	0.765
	Day 5	13.1	11.3	13.0	13.1	2.89	0.567
	Day 7	12.6	11.5	13.9	13.9	3.56	0.678
Sensory traits[2/]							
Tenderness	Day 0	4.94^{b}	4.84^{b}	4.91^{b}	6.06^{a}	0.161	0.001
	Day 1	5.47^{b}	6.81^{a}	5.94^{b}	6.44^{a}	0.098	0.001
	Day 3	5.47	6.25	5.69	6.84	0.139	0.137
	Day 5	5.94*	6.06	6.09*	6.41	0.067	0.432
	Day 7	6.00^{b}*	6.00^{b}	5.63^{b}	6.97^{a*}	0.087	0.001
Juiciness	Day 0	4.89^{ab}	4.36^{b}	4.75^{ab}	5.32^{a}	0.123	0.021
	Day 1	4.91^{b}	5.03^{b}	5.19^{b}	5.78^{a}	0.146	0.001
	Day 3	5.22	5.31*	5.22*	5.44	0.245	0.123
	Day 5	4.97	5.06	5.09	5.69	0.137	0.149
	Day 7	5.66*	5.00	5.06	5.56	0.432	0.245
Flavor intensity	Day 0	5.72	5.31	5.41	5.84	0.086	0.137
	Day 1	5.97	5.47	5.38	6.00	0.123	0.096
	Day 3	5.88	5.31	5.13	5.84	0.149	0.345
	Day 5	5.81^{ab}	5.34^{ab}	5.13^{b}	6.06^{a}	0.245	0.023
	Day 7	5.91^{a}	5.28^{b}	5.22^{b}	6.03^{a}	0.137	0.013
Off-flavor intensity	Day 0	2.00	2.08	2.53	2.50	0.096	0.139
	Day 1	2.44^{b}	2.31^{b}	2.97^{a}	2.52^{b}	0.123	0.045
	Day 3	2.51^{ab}	2.38^{b}	2.97^{a}	2.91^{a}	0.145	0.038
	Day 5	2.54^{b}	2.53^{b}	3.69^{a}	2.56^{b}	0.265	0.034
	Day 7	2.66^{b}*	2.31^{b}	3.69^{a*}	2.68^{b}	0.137	0.012
Overall acceptability	Day 0	5.47	5.59	5.31	6.00	0.106	0.568
	Day 1	5.88^{ab}	6.09^{b}	5.38^{b}	6.75^{a}*	0.123	0.034
	Day 3	5.94	6.28	5.75	6.03	0.144	0.139
	Day 5	5.75^{b}	6.16^{a}	5.69^{b}	6.47^{a}	0.245	0.023
	Day 7	6.31*	6.38*	6.23*	6.92*	0.137	0.123

^{a,b} Means within the same row with different superscripts differ significantly ($P<0.05$). [1/] Standard error of the mean.
[2/] 1= extremely tough, dry, bland and not well accepted; 9=extremely tender, juicy, intense and well accepted.
* Means differ from day 0 at $P<0.05$.

fat (Min and Ann, 2005). Oxidation can occur in either the stored triglycerides or the tissue phospholipids. Several studies have demonstrated that phospholipids play a critical role in the development of lipid peroxidation in meat. The content, composition and quality of dietary fat and the tendency of animal species to store fatty acid into membrane phospholipids can affect the fatty acid composition of membrane and its susceptibility to lipid peroxidation (Ahn *et al.*, 2000; Song and Miyazawa, 2001). Unsaturated lipids are likely to be more predisposed to lipid oxidation than meat containing more saturated fatty acids (Scollan *et al.*, 2001). Despite the high PUFA proportion, still TBARS tended to be the lowest in the corn-silage only group of the present study; however, supplementing crude rice bran lead to a similar PUFA proportion and a clearly higher susceptibility to oxidation. Reasons of these differences may be due to the antioxidant property of CLA (Ip *et al.*, 1991), which was only elevated in the corn-silage only group. It has to be stated that the oxidation might have been much more pronounced when the ageing of the meat would not have taken place under vacuum, i.e., in a low oxygen environment.

4.2 Relationship between dietary treatment and color and lipid stability

Meat color is dependent on myoglobin content, oxidation state of the pigments and the chemical composition in meat. The meat of the cows receiving the diet with the cassava pulp was the lightest. This was possibly related to the higher intramuscular fat content in meat, which is white. As the proportion was almost 7%, fat was clearly visible as marbling. Supporting these results, Muir *et al.* (1998) found that lean color is associated with increased marbling score. The dietary treatment can modify the development of meat color also in other respect. There were detectable effects of increased yellow pigment level in body fat with increasing grass silage and the same might have been true for maize silage (Strachan *et al.*, 1993). In addition, Warren *et al.* (2008) showed that gradually a difference in color intensity developed between a concentrate- and a grass silage-fed group, with a less intensive red color found in the concentrate group. These results also agreed with Priolo *et al.* (2001) who found that muscle from grass-fed cattle tended to be darker (lower L* value) than those from grain-fed cattle. As the cows in the present study had been fed grass before the experiment started, no great changes between control and the forage-only group were expected whereas crude rice bran and cassava pulp might have reduced yellow and red pigments. Still, there were no significant differences in a* and b*. The L* and a* values for LD were increasing respectively decreasing with storage time. This instability in red color may be the result of less metmyoglobin reducing activity (MRA) of the muscles. Ledward, (1985) reported that a enzymatic reducing activity in the muscle as to be the most important factor determining the amount of metmyoglobin that accumulates in a cut of meat. Additionally, the light scattering (high L* value) properties of the contractile elements of the muscle fiber are increased with storage time because the myofibrillar protein reach the isoelectric point and protein is denaturated (Warriss, 2000).

4.3 Relationship of finishing diet and organoleptic qualities in relation to lipid content and susceptibility to lipid oxidation

The panelists scored tenderness best with the beef from the cows fed the cassava pulp diet. Part of this may be explained by the higher intramuscular fat content which decreases the muscle's resistance to shear. It is likely that these cows also accreted additional muscle tissue which may be inherently tenderer than that of very lean cows exploited for milk production for long. When eaten, fat is also a carrier of the taste and flavor, and dissolved in the saliva bind to the taste buds. This may improve both flavor intensity and juiciness impression. Accordingly, both were also scored best in the cows fed the cassava pulp diet which eventually also resulted in the clearly best overall acceptance of this meat. Concerning the higher incidence of undesirable off-flavor (higher scores) found in the crude rice bran diet can be associated with the occurrence of a higher level of oxidation products from the (poly-) unsaturated fatty acid. Lipid oxidation is the primary process by which quality loss of muscle foods occurs (Buckley *et al.*, 1995). In addition, the development of oxidative off-flavor (rancidity) has long been recognized as a serious problem during storage of meat products. The primary mechanism for the degradation of stored meat is lipid autoxidation mediate through free-radical reaction (Love, 1987). Vatansever *et al.* (2000) documented that PUFA were responsible for "off-flavor" occurrence in red meat due to lipid oxidation and generation of free radicals from these fatty acid which could lead to the production of alcohols and ketones. Barines and Mlotkiewicz (1984) described that lipid autoxidation in meat is initiated during the cooking process and continues throughout the storage period. Additionally, the content of the lipid autoxidation products and cyclic sulfur compounds increase during the storage period. The increase in the content of these two groups of compounds may be attributed to similar mechanisms (i.e. free-radical degradation reaction) and account for the formation of undesirable flavor in meat during storage. Thus, the decrease in desirable flavor during the refrigerated storage may be attributed to the masking of desirable flavor by the increased content of undesirable flavor compounds (Love, 1987).

5. Conclusions

This study tested finishing diets with different feeding value in culled dairy cows with respect to their efficiency in improve meat quality. The results show that the most promising method is finishing with a diet of low fiber content. This leads to a light, tender, juicy and well flavored beef

which has an appealing degree of marbling. Another approach is to use high quality forage like corn silage where the fatty acid profile is more favorable in terms of human health and susceptibility to oxidation of the intramuscular lipids is low. However, both strategies are more costly than diluting the high-quality forage with a low-quality ingredient like crude rice bran. Still, no real improvement compared to the non-finished control was achieved by finishing for quite a long period with corn silage and crude rice bran, making the last strategy not cost-efficient at all unless meat yield would be increased.

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