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A comparison of the USDA ossification-based maturity system to a system based on dentition

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ABSTRACT: Two studies using commercially fed cattle were conducted to determine the relationship of the USDA bone ossification-based maturity system to one based on the number of permanent incisors present at slaughter. These studies showed that 91.5 to 100% of cattle with zero permanent incisors (< 23.8 mo of age), 89.1 to 97.5% of cattle with two permanent incisors (23.8 to 30.4 mo of age), 75 to 82.2% of cattle with four permanent incisors (30.4 to 38.0 mo of age), 64 to 72.5% of cattle with six permanent incisors (38.0 to 45.3 mo of age), and 40% of cattle with eight permanent incisors (> 45.3 mo of age) were graded as A maturity by the USDA maturity classification system. Kappa tests revealed no statistical relationship between the dentition- and skeletal ossification-based maturity systems. Dentition-based maturity agreed with ossification/lean maturity for only 162 of 1,264 carcasses in Exp. 1 and only 54 of 200 carcasses in Exp. 2. Cattle with two, four, six, or eight permanent incisors were classified in more youthful categories of USDA bone ossification/lean maturity than they should have been. Male cattle were more likely to be misclassified into a younger age category by the USDA system than were female cattle. It seems that determining physiological maturity by number of permanent incisors rather than by the current USDA method of subjectively evaluating skeletal and lean maturity may prove to be a more accurate technique of sorting beef carcasses into less-variable age groups.

Key Words: Beef, Dentition, Maturity, Ossification

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Introduction

In 1924, the USDA published the initial beef grading standards. These standards were created to provide guidelines for the evaluation of beef carcasses for accurate price determination. Written into the standards were three chief requisites for a beef grading and classifying system: 1) "the system should be logical and workable", 2) "it should be specific, individual fancy or personal prejudice can have no place in a standard system of grading," and 3) "it should have permanence" (USDA, 1924). These standards stated that age of a carcass was determined by the color and hardness of the bones.

Current USDA beef grading standards (USDA, 1997b) state that carcass maturity is determined by evaluating the size, shape, and ossification of the bones and cartilages, especially the split chine bones, and the color and texture of the lean. USDA standards (USDA, 1996) suggest that A maturity cattle should be less than 30 mo of age and that B maturity cattle should be between 30 and 42 mo of age.

South Africa and Australia use the number of permanent incisors present at slaughter to estimate maturity in their beef carcass classification systems (Government Gazette, 1990; AUS-MEAT, 1995). The South African system uses dentition scores of A, B, and C, where A = no permanent incisors, B = one to six permanent incisors, and C = seven or eight permanent incisors. The Australian system consists of dentition age grades (zero, two, four, seven, or eight permanent incisors).

The objective of this study was to compare the USDA bone ossification/lean-based maturity system to a dentition-based maturity system.

Materials and Methods

Experiment 1

At slaughter, the number of permanent incisors present (zero, two, four, six, or eight; Figure 1) was individually recorded on 1,264 commercially fed steers of Mexican origin. A pair of teeth was considered present when

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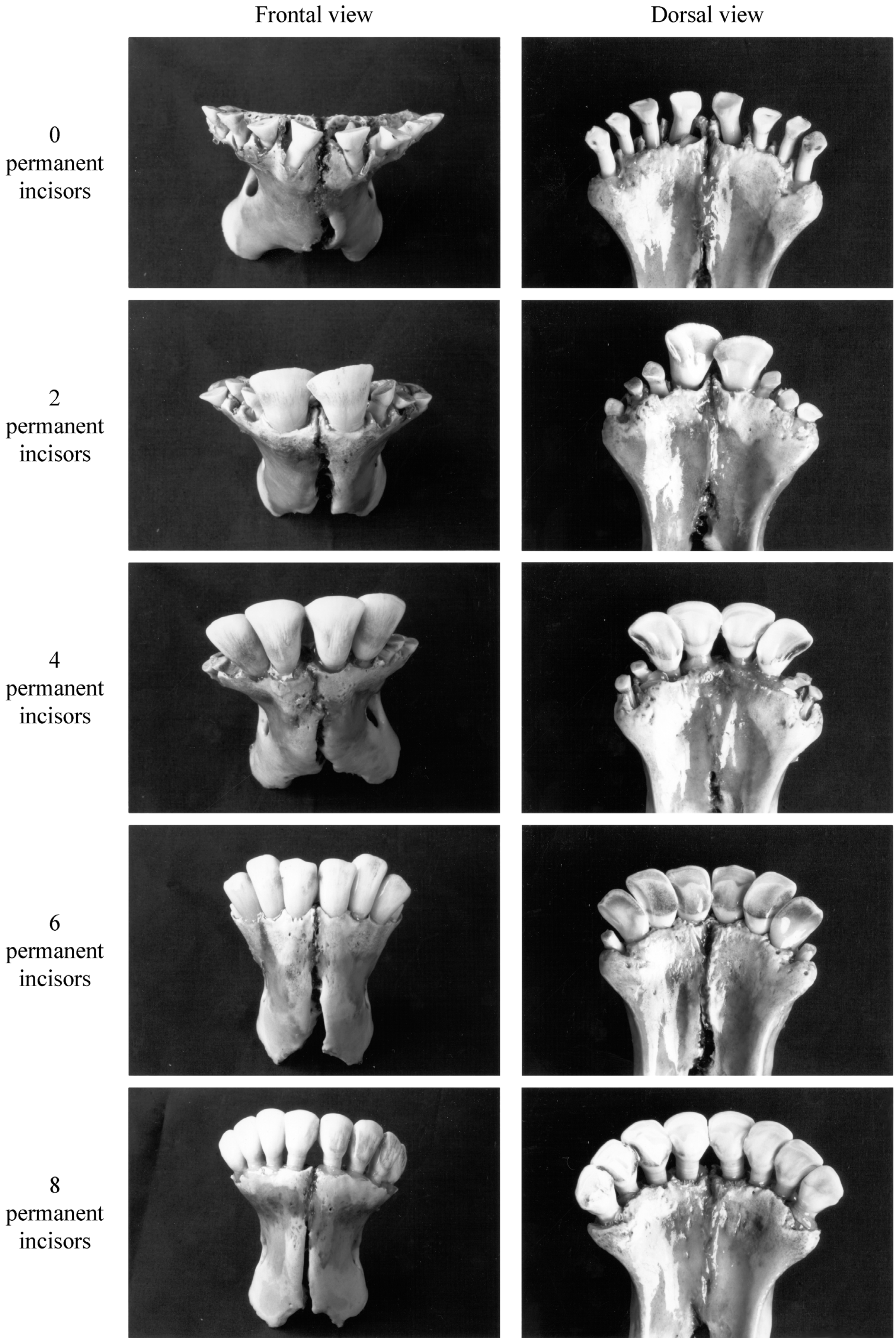

Figure 1. Frontal and dorsal views of the lower jaw, with each set of incisors up and in wear.

either tooth of a pair had penetrated through the gum. After a chill time of approximately 40 h, two USDA grading supervisors determined USDA maturity (skeletal and lean) scores. One supervisor determined skeletal maturity of all carcasses, and the other determined lean maturity of all carcasses. At a chain speed of approximately 400 carcasses per hour, this technique provided the most accurate assessment of skeletal and lean maturity.

Experiment 2

At slaughter, the number of permanent incisors present (zero, two, four, six, or eight; Figure 1) was individually recorded on 11,136 commercially fed cattle slaughtered on four different days. A pair of teeth was considered present when either tooth of a pair had penetrated through the gum. Ten carcasses were randomly selected per dentition group per day, for a total of 200 carcasses. After a chill time of approximately 40 h, four USDA meat graders (one per day) determined USDA carcass maturity (skeletal and lean) scores on a stationary rail. By chance, there were four different graders working during the 4 d when these carcasses were evaluated.

Statistical Analysis

Data were arranged in tables comparing the number of carcasses classified in USDA and dental maturity categories. A statistical computer program (PEPI, Abramson and Gahlinger, 1997) was used to determine kappa statistics and McNemar's test for bias between dentition-based age and USDA skeletal/lean maturity-based age. If McNemar's test was significant, tables were visually inspected to determine the nature of the disagreement between the classification systems.

The kappa statistic objectively quantifies the amount of agreement in the categorization of the same individual using two classification systems, beyond what would be expected due to chance agreement (Martin, 1977). Kappa is calculated as [(observed agreement − chance agreement)/(1 − chance agreement)] (Martin et al., 1987a). Landis and Koch (1977) use kappa < 0.00 to indicate poor agreement; 0.00 to 0.20, slight; 0.21 to 0.40, fair; 0.41 to 0.60, moderate; 0.61 to 0.80, substantial; and 0.81 to 1.00, almost perfect. Martin and Bonnett (1987), conversely, use kappa of 0.3 to 0.5 as acceptable; 0.5 to 0.7, good; and > 0.7, excellent.

McNemar's test for bias is a chi-squared test for paired observations that evaluates the pattern of disagreement between two classification systems (Martin et al., 1987b; Zar, 1999). A significant result ($P < 0.05$) indicates that the pattern of disagreement observed is not what would be expected from random errors and there is a systematic disagreement between classification systems. In the case of the data reported here, a significant McNemar's test suggests that one classification system indicates carcasses are younger or older than does the other classification system.

Results

The majority (93.3%) of Mexican steers observed in Exp. 1 had two or four permanent incisors (Table 1) and were 86% A maturity, 9.02% B maturity, and 4.98% C maturity. In contrast, the population of 11,136 carcasses in Exp. 2 was represented by 75.4% of carcasses with 0 permanent incisors, 16.22% with two permanent incisors, 5.94% with four permanent incisors, 1.61% with six permanent incisors, and 0.84% with eight permanent incisors. The 200 carcasses randomly chosen by dentition group from the 11,136 observed were 77% A maturity, 9% B maturity, and 14% C maturity; no D or E maturity cattle were represented. Female carcasses in Exp. 2 (n = 96) were 68.8% A maturity, 7.3% B maturity, and 23.9% C maturity, whereas male carcasses (n = 104) were 84.6% A maturity, 10.6% B maturity, and 4.8% C maturity.

The percentages of USDA carcass maturity scores within each dentition score for Exp. 1 and 2 are shown in Figures 2 and 3, respectively. Our data suggest that a number of older carcasses with four, six, or eight permanent incisors (> 30.4 mo) are graded as A maturity. Unexpectedly, over 9% of the steers of Mexican origin (Exp. 1) with 0 permanent incisors were classified as B maturity. Age estimates based on USDA maturity score were in agreement with the dentition-based age estimates for 162 of 1,264 (Table 2) and 54 of 200 (Table 3) carcasses for Exp. 1 and 2, respectively. Overall kappa of USDA and dentition-based age estimates in Exp. 1 and 2 (0.00 and 0.07, respectively) suggested that there was only slight agreement. McNemar's test for bias of USDA and dentition-based age estimates in Exp. 1 and 2 (P = 0.000 and P = 0.000, respectively) indicated that misclassifications were biased toward the USDA-based age estimates estimating carcasses to be more youthful than they were expected to be.

For cattle in Exp. 2, the kappa and McNemar tests were calculated on females and males separately (Tables 4 and 5, respectively). Visual examination of the data suggests that male cattle were more likely to be misclassified into a younger age category by the USDA system than were female cattle. USDA maturity scores were in agreement with dentition-based age estimates for only 28 of 96 (overall kappa = .12) females (Table 4) and 26 of 104 (overall kappa = 0.01) males (Table 5).

Discussion

Dentition has long been used to evaluate cattle age. Scientists have studied the relationship between the number of permanent incisors and chronological age of cattle from the major cattle-producing regions of the world. Most scientists considered a pair of teeth to have erupted when the first tooth of a pair penetrated the gum. Table 6 summarizes the literature available relating chronological age to dentition.

Limited data are available on the relationship between chronological age and USDA maturity score.

Table 1. Number (percentage) of carcasses with zero, two, four, six, or eight permanent incisors within each experiment

	Number of permanent incisors									
	0		2		4		6		8	
Item	n	%	n	%	n	%	n	%	n	%
Experiment 1	59	(4.7)	679	(53.7)	501	(39.6)	25	(2.0)	—	—
Experiment 2										
Slaughter group										
1	2,154	(75.4)	491	(17.2)	161	(5.6)	40	(1.4)	12	(0.4)
2	1,897	(69.1)	511	(18.6)	223	(8.1)	62	(2.3)	51	(1.9)
3	2,169	(80.7)	340	(12.6)	127	(4.7)	41	(1.5)	11	(0.4)
4	2,177	(76.5)	464	(16.3)	150	(5.3)	36	(1.3)	19	(0.7)

Shackelford et al. (1995) reported that carcass maturity was moderately related to chronological age ($r^2 = 0.60$) but that carcass maturity scores increased at a faster rate than indicated by USDA standards. They stated that the following age groups more accurately reflected USDA maturity scores: A (9 to 24 mo), B (24 to 36 mo), C (36 to 48 mo), D (48 to 60 mo), and E (> 60 mo). In combining Table 6 with the data from Shackelford et al. (1995) we concluded that cattle with zero permanent incisors should be classified as A maturity, cattle with two or four permanent incisors should be classified in the B maturity category, cattle with six permanent incisors into the C maturity class, and cattle with eight permanent incisors into the D and E maturity classes. The results of Shackelford et al. (1995) contrast with USDA standards (USDA, 1996), which suggest that A maturity cattle should be less than 30 mo of age and that B maturity cattle should be between 30 and 42 mo of age. Although not stated in USDA grading standards, it is commonly believed throughout the beef industry that C, D, and E maturity cattle are approximately 42 to 72, 72 to 96, and > 96 mo of age, respectively.

A major factor influencing skeletal maturity is estrogen concentration in the animal. This fundamental principle of endocrinology was demonstrated by Silberberg and Silberberg (1939), who concluded that estrogen administration to immature guinea pigs caused premature ossification of cartilage in the epiphysial disks, ribs, and vertebrae. In cattle, this concept was illustrated by Field et al. (1996), who reported that single-calf cows (C^{02}) exhibited more advanced skeletal maturity than virgin heifers (B^{37}), which themselves exhibited more advanced skeletal maturity than spayed heifers (A^{86}) even though all were born within 45 d and raised together. This physiological process may also create bias in maturity scores among steers and heifers of similar age reared under similar conditions. The 1995 National Beef Quality Audit (Boleman et al., 1998) found heifers to have more advanced skeletal maturity

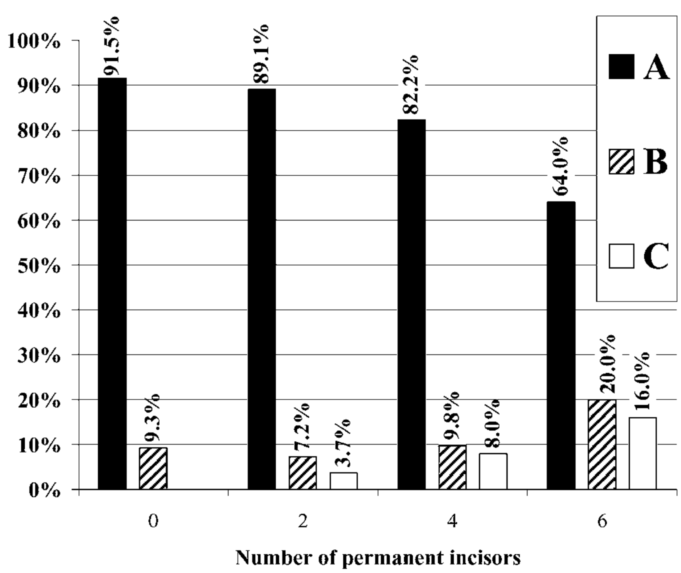

Figure 2. Percentage of USDA A, B, and C maturity carcasses found within dental classification groups among 1,264 steers of Mexican origin (Exp. 1).

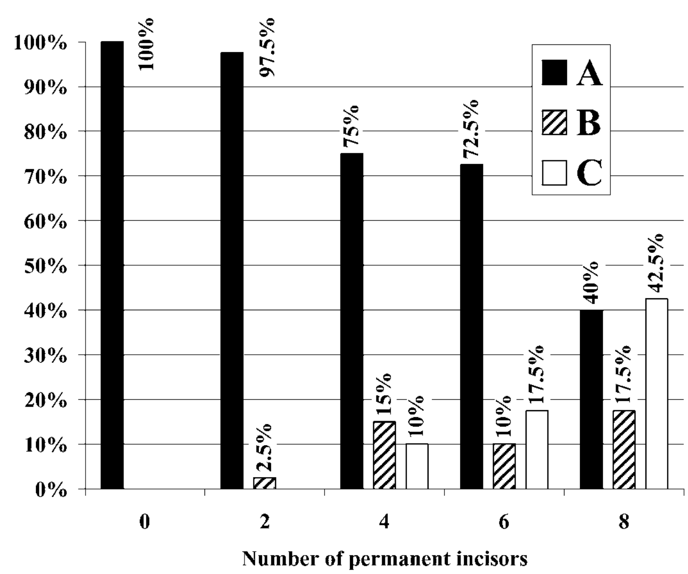

Figure 3. Percentage of USDA A, B, and C maturity carcasses found within dental classification groups among 200 carcasses randomly chosen by dentition group from 11,136 carcasses (Exp. 2).

Table 2. Comparison between USDA overall maturity classification and dental classification for 1,264 steer carcasses of Mexican origin (Exp. 1)[a]

Overall kappa = 0.00[b], McNemar test for bias P = 0.000[c]

Dental classification	USDA overall maturity classification[d]		
	A maturity (9 to 24 mo)	B maturity (24 to 36 mo)	C maturity (36 to 48 mo)
O Permanent incisors (< 23.8 mo)	54[e]	5	0
2 or 4 Permanent incisors (23.8 to 38.0 mo)	1,018	104[e]	59
6 Permanent incisors (38.0 to 45.3 mo)	15	5	4[e]

[a]Values are number of carcasses in each category of the respective row and column classification system.
[b]Indicates the strength of agreement between the two classification systems with < 0.00, poor; 0.00 to 0.20, slight; 0.21 to 0.40, fair; 0.41 to 0.60, moderate; 0.61 to 0.80, substantial; and 0.81 to 1.00, almost perfect.
[c]A significant result (P < 0.05) indicates that the pattern of disagreement observed is not what would be expected from random errors and there is a systematic disagreement between classification systems.
[d]Shackelford et al. (1995).
[e]Indicates agreement between both maturity classification systems.

Table 3. Comparison between USDA overall maturity classification and dental classification for 200 beef carcasses randomly chosen within five dentition groups (Exp. 2)[a]

Overall kappa = 0.07[b], McNemar test for bias P = 0.000[c]

Dental classification	USDA overall maturity classification[d]			
	A maturity (9 to 24 mo)	B maturity (24 to 36 mo)	C maturity (36 to 48 mo)	D maturity (> 48 mo)
0 Permanent incisors (< 23.8 mo)	40[e]	0	0	0
2 or 4 Permanent incisors (23.8 to 38.0 mo)	69	7[e]	4	0
6 Permanent incisors (38.0 to 45.3 mo)	29	4	7[e]	0
8 Permanent incisors (> 45.3 mo)	16	7	17	0[e]

[a]Values are number of carcasses in each category.
[b]Indicates the strength of agreement between the two classification systems with < 0.00, poor; 0.00 to 0.20, slight; 0.21 to 0.40, fair; 0.41 to 0.60, moderate; 0.61 to 0.80, substantial; and 0.81 to 1.00, almost perfect.
[c]A significant result (P < 0.05) indicates that the pattern of disagreement observed is not what would be expected from random errors and there is a systematic disagreement between classification systems.
[d]Shackelford et al. (1995).
[e]Indicates agreement between both maturity classification systems.

Table 4. Comparison between USDA overall maturity classification and dental classification for female (n = 96) beef carcasses randomly chosen within five dentition groups (Exp. 2)[a]

Overall kappa = 0.12[b], McNemar test for bias P = 0.000[c]

Dental classification	USDA overall maturity classification[d]			
	A maturity (9 to 24 mo)	B maturity (24 to 36 mo)	C maturity (36 to 48 mo)	D maturity (> 48 mo)
0 Permanent incisors (< 23.8 mo)	17[e]	0	0	0
2 or 4 Permanent incisors (23.8 to 38.0 mo)	31	4[e]	4	0
6 Permanent incisors (38.0 to 45.3 mo)	11	0	7[e]	0
8 Permanent incisors (> 45.3 mo)	7	3	12	0[e]

[a]Values are number of carcasses in each category.
[b]Indicates the strength of agreement between the two classification systems with < 0.00, poor; 0.00 to 0.20, slight; 0.21 to 0.40, fair; 0.41 to 0.60, moderate; 0.61 to 0.80, substantial; and 0.81 to 1.00, almost perfect.
[c]A significant result (P < 0.05) indicates that the pattern of disagreement observed is not what would be expected from random errors and there is a systematic disagreement between classification systems.
[d]Shackelford et al. (1995).
[e]Indicates agreement between both maturity classification systems.

Table 5. Comparison between USDA overall maturity classification and dental classification for male (n = 104) beef carcasses randomly chosen within five dentition groups (Exp. 2)[a]

Overall kappa = 0.01[b], McNemar test for bias P = 0.000[c]

	USDA overall maturity classification[d]			
Dental classification	A maturity (9 to 24 mo)	B maturity (24 to 36 mo)	C maturity (36 to 48 mo)	D maturity (> 48 mo)
0 Permanent incisors (< 23.8 mo)	23[e]	0	0	0
2 or 4 Permanent incisors (23.8 to 38.0 mo)	38	3[e]	0	0
6 Permanent incisors (38.0 to 45.3 mo)	18	4	0[e]	0
8 Permanent incisors (> 45.3 mo)	9	4	5	0[e]

[a]Values are number of carcasses in each category.
[b]Indicates the strength of agreement between the two classification systems with < 0.00, poor; 0.00 to 0.20, slight; 0.21 to 0.40, fair; 0.41 to 0.60, moderate; 0.61 to 0.80, substantial; and 0.81 to 1.00, almost perfect.
[c]A significant result (P < 0.05) indicates that the pattern of disagreement observed is not what would be expected from random errors and there is a systematic disagreement between classification systems.
[d]Shackelford et al. (1995).
[e]Indicates agreement between both maturity classification systems.

than steers. Moreover, implanting steers, heifers, and bulls with estrogenic growth-promoting hormones advances skeletal maturity (Unruh et al., 1986; Foutz et al., 1997). The underlying concept is that the rate of bone maturity is increased by elevated endogenous estrogen due to onset of puberty, estrus, and estrogenic implants.

Spray-chilling carcasses has also been shown to influence skeletal maturity scores. Allen et al. (1987) reported spray-chilled carcass sides to have younger skeletal maturity scores than their counterparts that were not spray-chilled. They reported one extreme case in which the spray-chilled carcass side had a skeletal maturity score of A^{90} and the side not spray-chilled had a skeletal maturity score of C^{20}. They concluded that the difference in visual skeletal ossification was due to dehydration of the cartilaginous chine buttons for the sides not spray-chilled. The current widespread use of spray chilling may cause all skeletal maturity to be evaluated as younger than it actually is. It is important to remember that spray chilling was not in use when the maturity standards were created; therefore, the maturity classification system may not be as accurate as it once was.

A major factor influencing lean maturity is light source and intensity (Kropf et al., 1984). Kropf et al. (1984) found both lean color and lean maturity to be affected by light source and light intensity. More intense lighting resulted in a brighter lean color and more youthful lean. Neither type of lighting (e.g., incandescent vs fluorescent) nor light intensity is standardized across grading coolers. Other variable factors such as antemortem stress (caused by excessive transit distance, excessive lairage time at the abattoir, or unusual weather conditions), carcass fat cover, carcass weight, muscle conformation, sex, and nutritional regimen have been reported to affect lean color at the time of grading (Murray, 1989). Electrical stimulation and postmortem

Table 6. Eruption of permanent incisors into oral cavity (mo)

		First pair		Second pair		Third pair		Fourth pair	
Author(s)	Cattle type	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Andrews (1973)	Beef and dairy	23.0	2.7	26.4	0.3	37.9	2.0	44.6	3.8
Andrews (1974)	Dairy	22.7	1.8	27.6	2.2	34.6	2.8	42.8	4.4
Andrews (1975)	Beef and dairy	22.5	2.3	27.5	2.5	36.8	3.1	44.2	5.0
Brooks and Hodges (1979)	Beef and dairy	23.2	1.4	29.5	1.8	37.0	1.8	40.7	—
Brown et al. (1960)	Dairy	23.0	1.0	29.8	1.0	36.0	2.0	42.7	2.0
Brown et al. (1960)	Beef	23.0	—	30.6	—	35.3	2.0	41.0	2.0
Carles and Lampkin (1977)	Zebu (Boran)	24.3	2.0	30.4	2.7	36.3	3.2	43.3	3.7
Dodt and O'Rourke (1988)	Shorthorn	23.9	—	30.2	—	37.4	—	45.9	—
Dodt and O'Rourke (1988)	Brahman × British	25.5	—	32.7	—	40.8	—	50.0	—
England (1984)	Hereford and Brahman	23.0	—	30.0	—	36.0	—	43.0	—
Graham and Price (1982)	Beef	24.1	0.7	32.1	2.5	40.1	4.3	49.7	5.6
Lall (1948)	Indian	27.0	—	36.0	—	48.0	—	57.0	—
Steenkamp (1970)	Hereford and African	26.1	—	32.9	—	41.2	—	48.1	—
Tulloh (1962)	British	23.2	—	—	—	—	—	—	—
Weiner and Donald (1955)	Dairy	23.2	1.8	29.3	1.9	34.9	2.9	41.6	3.3
Weiner and Forster (1982)	Dairy	23.4	1.5	30.4	2.1	37.2	2.7	44.3	3.3
	Arithmetic mean	23.8		30.4		38.0		45.3	

pH decline (Orcutt et al., 1984) also influence lean maturity. In essence, evaluating lean color at the time of grading is a subjective evaluation of muscle pH and(or) myoglobin concentration, the former being more highly related to meat quality issues.

Both skeletal and lean maturity descriptors (USDA, 1997a) lack objectivity. Phrases such as “nearly completely ossified,” “some evidence of ossification,” “slight tendency toward flatness,” and “moderately hard/ rather white” are used as descriptors to identify varying levels of vertebrae, rib, and chine bone skeletal maturity. Other vague descriptors such as “moderately light red to moderately dark red” and “tends to be fine to moderately fine” are used as lean color and texture criteria. These obscure terms provide limited guidance and objectivity to grading personnel when they evaluate carcass maturity.

There are numerous reports of various factors affecting rate of eruption of permanent incisors. The factor that seems to have the largest effect is malnutrition, which slows the eruption process, as reported by Brookes and Hodges (1979), England (1984), and Wass et al. (1986). Lall (1948) and Dodt and O’Rourke (1988) found breed to influence eruption of permanent incisors, whereas data published by Brown et al. (1960) and Graham and Price (1982) suggest no breed effect. Lall (1948), Brown et al. (1960), and Andrews (1973) found no difference among sexes in the eruption of permanent incisors. However, Andrews and Wedderburn (1977) observed that heifers erupted their permanent incisors about 1 mo earlier than male cattle. The range of estimates among studies and the standard deviations within studies summarized in Table 6 suggest that the variability of age at time of eruption is low enough to allow a reasonably accurate estimate of age.

Although we suggest that dentition is a more accurate and objective measure of carcass maturity, we have no evidence to suggest that dentition is more effective than USDA maturity scores in predicting lean palatability. In related work, we found no difference in shear force or sensory panel tenderness scores for longissimus steaks from cattle with zero, two, four, six, or eight permanent incisors, or among USDA maturity scores A, B, and C. Shorthose and Harris (1990) and Crosley et al. (1995) detected differences in lean palatability among dentition scores; however, Wythes and Shorthose (1991) suggested no difference among dentition scores. Data from Romans et al. (1965), Miller et al. (1983), and Field et al. (1997) suggested no difference in lean palatability among USDA maturity scores, whereas Smith et al. (1982, 1988) and Hilton et al. (1998) detected differences in shear force and sensory panel tenderness among maturity scores. Indeed, the literature concerning the relationship between maturity (as determined by dentition or ossification) and palatability of the lean is obscure.

Our data show little relationship between bone ossification/lean color-based maturity and dentition-based maturity determination systems. We suggest that objectively counting the number of incisors present at slaughter provides a more accurate method of age determination. Moreover, Graham and Price (1982) concluded that dental age classification provides a viable alternative to the ossification-based maturity classes used in the Canadian Beef Carcass Grading System. Dentition could prove to be useful in aiding USDA graders in the grouping of cattle into less-variable age categories.

Implications

These data show little evidence of agreement between age estimates derived from the USDA ossification-based maturity system and counting the number of permanent incisors present at slaughter. In addition, these data show that many cattle older than 30 mo of age are included in the A maturity category based on the current USDA maturity system. Replacing the USDA ossification-based maturity classification system with one based on the number of permanent incisors present at slaughter would allow beef producers to determine the age of their cattle prior to slaughter and would aid USDA meat graders in grouping cattle into less-variable age categories.

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