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Article

Estimation of the basic quality grade of beef carcasses according to bone maturity, marbling, and *Bos indicus* phenotypic predominance

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Abstract:

In order to estimate the Basic Quality Grade of beef carcasses according to bone maturity, marbling and *Bos indicus* racial predominance, data from 1,417 carcasses processed in four Federal Inspection Type establishments were analyzed. The following variables were recorded: cavitary fat, rib eye area, dorsal fat thickness, hump length and height, marbling, and bone maturity. Using the variables marbling and bone maturity, the Basic Grade of Quality was estimated in accordance with the norm NOM-004-SAGARPA-2018. The hump height was used as a criterion to determine racial predominance, and four groups were generated from this information. Based on the recorded values, descriptive statistics, analysis of variance, comparison of means, and Tukey's test were determined. The hump height in each group was 7.19, 10.54, 14.38, and 20.11 cm (P<0.01), respectively. 82 % of the carcasses were predominantly *Bos indicus*. The hot carcass weight was 310.05 kg for group

1 *vs* 326.99 kg for group 4 (P<0.01). The rib eye area was 85.59 cm^2 for group 1 *vs* 89.14 cm^2 for group 2 (P<0.05). Of the total number of carcasses evaluated, 60 were classified as Supreme quality (4.23 %), 655 as Select quality (46.22 %), 621 as Standard quality (43.82 %), and 81 as Commercial quality (5.72 %). The beef carcasses in this study have mainly a *Bos indicus* breed component, and their Basic Quality Grade corresponded primarily to a greater number of carcasses with grade A bone maturity, but with less marbling.

Keywords: Bovine carcass, *Bos indicus*, Marbling, Bone maturity.

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Introduction

Mexican beef production in 2021 was 2'128,590 t, which represents 2.3 % more than in 2020, when beef production was 2'078,158 t(1); this is indicative of a very dynamic agricultural and livestock sector. The interest in adding value to beef production in Mexico has its origin in the establishment of the Livestock and Beef Classification Service in Mexico, implemented for the first time in 1969 by the Government of the State of Sonora(2). Years later, in order to identify differences in carcass quality and yield, on September 18, 1991, the norm NMX-FF-078-1991(3) was published in the Official Gazette of the Federation (Diario Oficial de la Federación). This norm is based on the classification system of the United States of America and adapts the concept of carcass evaluation to emphasize the existing differences between production systems. This norm recognized and awarded the following classification grades: Prime, Choice, Select, Standard, and Commercial; it also awarded performance grades identified as 1, 2, 3, 3, 4, and 5. It was subsequently repealed and gave rise to the norm NMX-FF-078-2002(4), also of a voluntary nature, whose purpose was to support cattle breeders and other agents involved in the beef production, processing, marketing and consumption chain, by defining the quality characteristics that carcasses must meet for marketing purposes; with the following quality grades: Prime, Choice, Standard, Commercial, and Unclassified, considering the levels of marbling and texture or firmness; however, unlike its predecessor NMX norm, it does not specify or take into account the performance grades.

Through all these years, the issue of the evaluation of Mexican bovine carcasses has always been controversial; for some, it is an incentive for livestock production activities; however, for others it is an uncomfortable method to punish the product(5). With the recent approval of the Mexican Official Norm NOM-004-SAGARPA-2018, "Bovine Meat-Classification of carcasses according to their physiological maturity and marbling characteristics"[6], it is established that one of the accepted ways to provide certainty and, therefore, order to the beef carcass supply sector is to establish a quality classification that will provide information on product attributes, preventing confusion in the domestic and export markets, as well as the arbitrary establishment of qualities that are not officially recognized. In this regard, beef carcass classification or grading seeks to evaluate the final merit of an animal by assessing parameters of economic importance for the carcass[7], since the variables that help classify bovine carcasses seek to define parameters that can be accurately identified, either in absolute terms (weight) or in relative terms (scores), which will converge in a fair commercialization of the carcasses[8].

Mexican beef production comes from different production systems; therefore, its quality must be assessed through the evaluation and classification of carcasses, considering the racial factor, age, and type of cattle, in addition to the specifications of the norm NOM-004-SAGARPA-2018. Based on the above, the objective of this study was to estimate the Basic Quality Grade of bovine carcasses according to bone maturity, marbling, and *Bos indicus* breed predominance.

Material and methods

Study area

Data from 1,417 beef carcasses processed in four Federal Inspection Type (TIF) establishments located in the state of Sinaloa, Mexico, were analyzed. The information was obtained from the primary cuts' production line. All cattle came from an intensive beef production system in finishing pens located within a radius of 50 km from the TIF establishments.

Post mortem procedure

After stunning and bleeding of the bovines, their chronological age was estimated based on the appearance and wear of the teeth, according to the guidelines established in the

Operational Manual, which serves as a tool for the identification, separation, and elimination of Specific Risk Material[9]. The animals were thus classified into two groups: cattle under 30 mo of age and cattle aged 30 mo or more. During the process, the bovines were decapitated; their forelimbs and hind limbs were removed, and they were skinned and eviscerated so that they could be cut along the midline and divided into two half-carcasses. Once the carcasses were washed and sanitized, they entered the refrigeration chamber, after weighing the hot carcass (HCW). Carcasses of male and female animals less than 30 mo old, as well as from male and female animals 30 mo old or older, were included in this study.

Recording variables of interest

After 48 h after slaughter and kept refrigerated at a temperature of 2 to 4 °C, the following variables were evaluated in the bovine carcasses[10].

Estimation of renal, pelvic, and cardiac fat. The amount of cavitary fat was determined subjectively and expressed as a percentage of the weight of the cold carcass; normally the weight of these fat accumulations represents between 1 and 5 % of the weight of the cold carcass. The weight of the kidneys was excluded from this measurement.

Determination of the rib eye area. This was measured with a template marked with small squares, where each square was added up to measure the complete area of the *Longissimus dorsi* muscle, the muscle area was perfectly delineated with a permanent marker; in this measurement, the adjacent fat and other surrounding tissues were not included.

Dorsal fat thickness. This variable was determined at the height of the 12th rib, three-quarters of the distance from the long axis of the *Longissimus dorsi* muscle, starting from the midline. The thickness was measured and recorded in millimeters with the help of a caliper.

Hump length and hump height**.** The dimensions of the hump indicate the approximate degree of *Bos indicus* ancestry of the animals; the height of the hump was measured at the middle of its base, taking as a reference the ligament of the nape of the neck; while the length of the hump was measured in a straight line, from the beginning of the base to the end of the hump.

Marbling**.** The amount and distribution of intramuscular fat (marbling) in the *M. longissimus dorsi* was evaluated after the half carcass was presented with a deep cross-section, with one of the following categories being awarded: devoid, trace, slight, small, modest, moderate and slightly abundant, stated in the norm NOM-004-SAGARPA-2018.

Determination of bone maturity. This variable was estimated visually on the carcass based on the degree of ossification of the cartilages of the first three spinous processes below the cut line with reference to the 12th and 13th ribs. The maturity values were determined according to the bone maturity criteria established in NOM-004-SAGARPA-2018, which refers to the Average Percentage of Ossification. It establishes maturity criteria A for cattle from 9 to 30 mo of age; maturity B, for cattle from 30 to 42 mo of age, and maturity C, for cattle over 42 mo of age.

Based on the variables of marbling and bone maturity, the Basic Grade of Bovine Carcass Quality was estimated according to the following categories: Prime, Choice, Select, Standard and Commercial, in accordance with the provisions of the norm NOM-004-SAGARPA-2018. This standard establishes that once the physiological maturity and the degree of marbling have been determined; these two factors must be considered in order to classify the beef carcass, under the following integral classification system shown in Figure 1.

Figure 1: Integral classification of bovine carcasses based on the norm NOM-004-SAGARPA-2018

<table>
<tr><th rowspan="2">Degree of marbling</th><th colspan="3">Maturity</th></tr>
<tr><th>Group A
(9 to 30 months)</th><th>Group B
(30 to 42 months)</th><th>Group C
(over 42 months)</th></tr>
<tr><td>Slightly abundant</td><td>Prime</td><td rowspan="4"></td><td rowspan="4">Commercial</td></tr>
<tr><td>Moderate
Modest
Low</td><td>Choice</td></tr>
<tr><td>Slight</td><td>Select</td></tr>
<tr><td>Traces
Practically devoid</td><td>Standar</td></tr>
</table>

The hump height was used as a criterion to determine breed predominance, based on the information shown in Table 1.

Table 1: Breed predominance based on hump height recorded in cattle processed in processing plants in Mexico

Predominance of zebu cattle	Hump height, cm (mean ± SE)
≤ ¼ *Bos indicus*	7.92 ± 0.95
½ *Bos indicus*	9.44 ± 0.17
¾ *Bos indicus*	13.13 ± 0.18
4/4 *Bos indicus*	14.07 ± 0.34

Source: Rubio *et al*(10); SE= standard error.

Statistical analysis

Carcass data were entered into a Microsoft Excel® spreadsheet, based on the hump height described in Table 1, and each carcass was assigned to a group according to *Bos indicus* predominance: group 1= ≥ zebu; 2= ½ zebu; 3= ¾ zebu; 4= zebu. Descriptive statistics were obtained for the following variables: hot carcass weight (HCW), rib eye area (REA), back fat thickness (BFT), renal pelvic fat (RPF), hump height (HH), hump length (HL), marbling, and bone maturity. Next, the normality analysis of the values was performed with the Kolmogorov-Smirnov test corrected by Lilliefors(11), with the R software(12). Analysis of variance between groups was performed for the variables HH, HCW, and REA, and the means were compared using Tukey's test. The variables marbling and bone maturity did not have a normal distribution, so they are presented with descriptive statistics of the median and interquartile range. In order to determine the distribution of basic quality grades and marbling, the results are shown as absolute frequency (n) and percentage. The association between groups with the degrees of marbling was carried out with the Chi-square test for a 5 x 4 contingency table (5 degrees x 4 groups). Because there was a statistical association, Chi-square tests were then performed for permutations of 4 groups, taking 2 at a time (4P2) in each degree of marbling. In the case of groups 3 and 4 in the commercial grade, Fisher's exact test was used. In all statistical analyses, the maximum alpha level for statistical significance was 0.05.

Results and discussion

Table 2 shows the results of the characteristics of beef carcasses from intensive finishing pens and processed in Federal Inspection Type establishments.

Table 2: Characteristics of beef carcasses from intensive finishing and processed in Federal Inspection Type establishments (n= 1,417)

Variable	Mean	SD	Minimum	Maximum	CV (%)
HCW, kg	318.16	36.43	201.80	451.80	11.45
REA, cm^2	87.87	11.36	49.03	141.93	12.93
BFT, mm	6.70	3.73	1.0	33.0	55.67
CF, %	2.10	0.65	1.0	4.0	30.95
HL, cm	27.86	5.25	8.0	49.0	18.84
HH, cm	12.58	4.40	4.0	30.0	34.98
Marbling	300.00*	100**	100.0	500.0	25***
Maturity	100.00*	0**	100.0	400.0	0***

HCW= hot carcass weight; REA= rib eye area; BFT= back fat thickness; CF= cavitary fat; HL= hump length; HH= hump height; SD= standard deviation; CV= coefficient of variation. *Medians; ** Interquartile range (IQR). ***(IQR/Range)x100.

According to the information presented above, the characteristics that show the highest coefficient of variation are dorsal fat thickness (55.67 %), hump height (34.97 %), and cavitary fat (31.39 %). Back fat or subcutaneous fat thickness is related to body condition, as well as to the energy reserves of the bovines[(13)]. In the present study, the wide variation in this value may be mainly due to the number of days that the bovines remain in the finishing pens which, given the heterogeneity in terms of breed type, starting weight, body condition and gender, determines the duration of their stay in intensive production units before being processed in the slaughterhouses. In Mexico, Vázquez-Mendoza *et al*[(14)], observed significant differences in the characteristics of the carcasses of bovines of different genotypes finished in feedlots; precisely this variable is included in the USDA carcass classification system, as is the percentage of renal, pelvic, and cardiac fat[(15)]. The accumulation of cavitary fat is influenced by a variety of factors, including the level of feed intake during fattening, the energy concentration of the diet, the finishing time of the bovines in the feedlot, and the use of muscle growth promoters[(16)].

The marbling and bone maturity variables used in the norm NOM-004-SAGARPA-2018 to assign a quality grade to Mexican beef carcasses that were evaluated in the present study showed disparate values; marbling exhibited a coefficient of variation of 35.18 %, while bone maturity exhibited a coefficient of variation of 18.0 %. This indicates that the bone maturity of the carcasses favorably impacts the assignment of a higher Basic Quality Grade according to the integral classification of the beef carcass, but, to a certain extent, prevents them from being classified with a higher quality grade, given the low level of marbling in the rib eye area.

Table 3 shows the hump height values by group according to racial predominance. The mean values between the four groups showed a statistical difference (*P*<0.01). It is worth noting that the coefficient of variation for this variable in groups 1, 2, and 3 was less than 10 %, indicating little dispersion of these values.

Table 3: Hump height by group as an indicator of *Bos indicus* breed predominance in bovines from intensive finishing units and processed in Federal Inspection Type establishments (n= 1,417)

Group	**n**	**Mean (cm)**	**SD (cm)**	**CV (%)**
≤ ¼ zebu	252	7.19 [a]	0.89	12.37
½ zebu	536	10.54 [b]	1.10	10.44
¾ zebu	399	14.38 [c]	1.13	7.89
zebu	230	20.11 [d]	3.07	15.28

SD= standard deviation; CV= coefficient of variation.
[abcd] Means with different letters are significantly different (*P*<0.01).

According to Boleman *et al*[17], hump length indicates the approximate degree of *Bos indicus* ancestry; bovines with a hump height above 10.2 cm will have phenotypic characteristics of cattle with this racial predominance. To reaffirm the above, a study[18] determined that the hump height in *Bos indicus* (Brahman) cattle ranged between 15 and 18 cm. In another research[19], it was observed that, based on hump height, approximately 90 % of the beef cattle population in Mexico have a strong *Bos indicus* genetic background. Thus, based on the fact that groups 2, 3, and 4 have a mean hump height of over 10 cm, it can be deduced that the genetic background of the zebu carcasses included in this study is 82 %.

Table 4 shows the values for hot carcass weight and rib eye area according to breed predominance in cattle from intensive finishing units and processed in Federal Inspection Type establishments. The results show that the mean HCW of group 1 is lower than that recorded in groups 3 and 4 (*P*<0.01), but similar to the mean of group 2 (*P*<0.01).

Table 4: Hot carcass weight and rib eye area by group according to the racial predominance of cattle from intensive finishing and processed in Federal Inspection Type establishments (n= 1,417)

		HCW			REA		
Group	**n**	**Mean (kg)**	**SD (kg)**	**CV (%)**	**Mean (cm^2)**	**SD (cm^2)**	**CV (%)**
1	252	310.05 [a]	37.79	12.19	85.59 [c]	11.32	13.23
2	536	316.89 [ab]	34.33	10.83	89.14 [a]	11.73	13.17
3	399	319.91 [bc]	35.73	11.17	88.31 [ab]	11.11	12.59
4	230	326.99 [c]	38.83	11.88	86.68 [bc]	10.49	12.11

HCW= hot carcass weight; REA= rib eye area; SD= standard deviation; CV= coefficient of variation. Group 1= ≤zebu; 2= ½ zebu; 3= ¾ zebu; 4= zebu.

[abcd] Means with different letters are significantly different ($P<0.01$).

The HCW values of group 2 are similar to those of group 3, but the mean values of group 3 are equal to those of group 4 ($P<0.01$). In one experiment, hot carcass weights between 354 and 412 kg were recorded in Hereford x Angus bovines that received different levels of zilpaterol during finishing(20). Cancian *et al*(21) recorded 292 and 321 kg of HCW in young Nelore oxen and bulls, respectively. On the other hand, Huerta *et al*(8), recorded 272 kg of HCW in predominantly zebu bovines. In another study(22), the carcass performance of Brahman bulls and F1 crossbreeds fattened in tropical pastures was evaluated. Also, the HCW in the Brahman breed was observed to be 242 kg, while it was 255 kg in F1 Angus 249 kg in F1 Chianina, 272 kg in F1 Romosinuano, and 252 kg in F1 Simmental bovines. These values indicate that European-type racial dominance favorably influences the HCW; however, the predominance of the zebu breed in the present study resulted in a better HCW.

In the values of rib eye area per group according to their racial dominance, a significant difference ($P<0.01$) of 3.55 cm^2 was observed when comparing groups 1 and 2, which indicates that the presence of *Bos indicus* half-blood bovines improved the REA compared to animals containing only ≤¼ Zebu blood. When comparing the animals with less zebu racial predominance (group 1) against those with more racial predominance (group 4), no significant differences were observed; this suggests that for the regions where this study was carried out, crosses between *Bos indicus* and *Bos taurus* cattle are better for the REA variable than purebred animals. The REA in cattle is an indicator of muscularity and an important factor in determining yield grade; therefore, as the REA increases, retail product yield increases. In this regard, Torrescano-Urrutia *et al*(23), carried out a study to characterize cattle carcasses in the center of the state of Sonora, and found that the REA registered a range of 80.66 to 82.15 cm^2; subsequently, in another study(24), values ranging from 69.2 to 89 cm^2 were observed. The results of both experiments are for cattle finished in feedlots, so they are similar to those recorded in the present study. However, the expression of the value of the bovine HCW is influenced by the production system, as shown in the results of another study previously referred to(22), which was carried out in a grazing system and shows the following:

the Brahman's REA was 54.84 cm^2; that of F1 Angus, 63.80 cm^2; that of F1 Chianina, 61.06 cm^2; that of F1 Romosinuano, 76.39 cm^2, and that of F1 Simmental, 60.05 cm^2. The values shown therein are lower than those recorded in the present research, probably due to the type of production system used, although the study indicates that crossbred animals improve the REA, in agreement with the results of the present work.

Table 5 shows the distribution of beef carcasses by bone maturity and marbling. It was observed that 1,191 carcasses (84.05 %) registered maturity A, i.e. it is estimated that they belong to animals under 30 mo of age, while 226 carcasses (15.95 %) correspond to cattle over 30 mo of age. With regard to the marbling grades, 1,339 bovine carcasses (94.48 %) were described as Virtually Devoid, Traces and Slight. According to the integral classification of the bovine carcass indicated in the norm NOM-004-SAGARPA-2018, this may have contributed to the assignation of the Select and Standard basic quality grades to the carcasses. However, their Basic Quality Grade may be lower when the Marbling indicator is associated to the Bone Maturity factor.

Table 5: Distribution of bovine carcasses according to bone maturity and degree of marbling

Bone maturity			**Marbling**		
	Carcasses	**%**		**Carcasses**	**%**
A	1,191	84.05	Virtually devoid	254	17.92
B	140	9.88	Traces	388	27.38
C	75	5.29	Slight	697	49.18
D	11	0.77	Small	74	5.22
Total	1,417	100	Modest	4	0.28

According to Lee *et al*[25], age is a fundamental factor in beef carcass grading systems when combined with other factors, such as nutrition and genetics. One of the main factors affecting carcass quality is marbling, which translates as stored body energy; therefore, this fat deposit will augment as the age of the cattle and the energy density of the diet increase.

The presence of marbling in the *Longissimus dorsi* muscle depends on the genetic potential of the bovine and the amount of energy consumed. Thus, young cattle that are processed at 15 mo of age have been shown to have equal or higher marbling scores than genetically similar bulls processed between 18 and 24 mo of age when fed diets with a sufficient energy density to allow marbling[26]. The presence of marbling in the REA is of particular importance in the grading system of the United States of America and northern Mexico[27] and is given a unique value as it is related to the tenderness and palatability of the meat.

Table 6 shows the distribution of the degree of marbling in bovine carcasses by group according to the predominance of marbling *Bos indicus*. The marbling of the REA in meat producing animals is related to intramuscular fat content and plays an important role in several aspects of meat quality.

The results of this study indicate that in 17.9 % of the bovine carcasses there was no marbling, in 27.4 % there were traces of marbling, and in 49.2 % there was slight marbling. These values show that the marbling of 94.49 % of beef carcasses has a low intramuscular fat content, which has a direct impact on the classification of these carcasses. According to the degree of marbling, it is observed that the nil marbling classification corresponds to ½ and ¾ carcasses of *Bos indicus*, occurring less frequently (P<0.05) than in ¼ carcasses or in over ¾ carcasses; as to the trace degree, the frequency increases for ½ and ¾ carcasses of *Bos indicus* and decreases significantly in carcasses under ¼ and above ¾. Slight marbling occurred more frequently in under ¼ carcasses of *Bos indicus*, being similarly frequent in ½ carcasses of *Bos indicus* (P>0.05). There were no significant differences in the degree of "little" marbling, which was found in similar proportions in all the groups of carcasses.

Table 6: Distribution of the degree of marbling in bovine carcasses by group according to the predominance of *Bos indicus*

	Degree of marbling, n (%)				
Group	**Nil**	**Traces**	**Slight**	**Small**	**Modest***
1	58 (23.02) [a]	38 (15.08) [b]	140 (55.56) [a]	16 (6.35) [a]	0 (0)
2	69 (12.87) [b]	165) [a]	271 (50.56) [ab]	29 (5.41) [a]	2 (0.36)
3	63 (15.79) [b]	135 (33.83) [a]	184 (46.12) [b]	16 (4.01) [a]	1 (0.25)
4	64 (27.83) [a]	50 (21.74) [b]	102 (44.35) [b]	13 (5.65) [a]	1 (0.43)
Total	254 (17.9)	388 (27.4)	697 (49.2)	74 (5.2)	4 (0.3)

Group 1= ≤¼ zebu; 2= ½ zebu; 3= ¾ zebu; 4= zebu

[ab] Different letters in the frequencies within the degree of marbling indicate significant difference (Chi-square test 2 x 2; P<0.05)

* No analysis was performed due to expected frequencies under 5 in each cell.

Intramuscular fat content has been reported to vary between species, between breeds and between muscle types within the same breed. Although there are other factors involved in the variation of marbling in animals, including sex, age and diet, it has been indicated that the variability in intramuscular fat content is linked mainly to the number and size of intramuscular adipocytes, so the rate of intramuscular fat accumulation depends on the rate of muscle growth. In animals that have a higher muscle content with high glycolytic activity, they show a reduced intramuscular fat content[(28)]. In this regard, the intramuscular fat content analyzed by solvent extraction is stated to show a variation from 1.0 to 8.9 %; therefore, meat is considered to be lean when it has less than 3.6 % of intramuscular fat[(29)]. This agrees with the findings recorded in carcasses with little marbling and lean carcasses produced in tropical region(19,30). Given the importance of the marbling score in the global beef market, studies have been conducted to better understand the low marbling score in *Bos indicus*-influenced cattle compared to *Bos taurus* cattle. In a review of these studies(31), it was observed that there is no strong relationship between the ability to synthesize fatty acids de novo and the marbling score or the adipocyte volume, concluding that the low marbling scores typically observed in cattle with *Bos indicus* influence are mainly attributed to lower intramuscular adipocyte volume compared to *Bos taurus* breeds.

Table 7 shows the distribution of Basic Grades of carcass quality, grouped according to cattle breed predominance.

Table 7: Distribution of carcasses by basic quality grade by *Bos indicus* predominance

	Basic quality grades							
Group	**Prime**		**Select**		**Standard**		**Commercial**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
1	9	(3.57) [a]	117	(46.43) [a]	85	(33.73) [c]	41	(16.27) [a]
2	21	(3.92) [a]	256	(47.76) [a]	221	(41.23) [b]	38	(7.09) [b]
3	16	(4.01) [a]	181	(45.36) [a]	200	(50.13) [a]	2	(0.50) [c*]
4	14	(6.09) [a]	101	(43.91) [a]	115	(50.0) [a]	0	(0.0) [c*]
Total	60	(4.23)	655	(46.22)	621	(43.82)	81	(5.72)
Probability		0.49		0.77		0.01		0.01

Group 1= ≤zebu; Group 2= ½ zebu; Group 3= ¾ zebu; Group 4= zebu.
[abc] Different letters in the frequency percentages within the same basic quality grade indicate statistical difference (2 x 2 Chi-square test); *P*<0.05); * Fisher's exact test (*P* = 0.5354).

In general, and regardless of breed predominance, there were 60 Prime quality carcasses (4.23 %), 655 Select quality carcasses (46.22 %), 621 Standard quality carcasses (43.82 %), and 81 Commercial carcasses (5.72 %). Of Group 1, with a lower predominance of the *Bos indicus* breed, 3.57 % of the carcasses were identified as Prime, 46.43 % as Select, 33.73 % as Standard, and 16.27 % as Commercial. A similar percentage distribution is observed among the rest of the groups from lesser to greater *Bos indicus* predominance; as the number of carcasses in each quality grade decreases or increases, the predominance of fattening is greater or lesser from group 2 onward. Thus, for example, in the Select Basic Grade, there are 256 carcasses in group 2,117 in group 1,181 in group 3, and 101 in group 4.

There are no previous studies with which these results can be compared, since they take as reference the Mexican Official Norm that recently came into force in Mexico. However, based on the now repealed Norm NMX-FF-078-2002, Zorrilla-Ríos *et al*[32] classified beef carcasses produced in a tropical region of Mexico according to five criteria: maturity, age, conformation, lean color, fat color, and distribution of subcutaneous fat cover. Carcasses were classified as 13.4 % Select, 45.8 % Standard, 27.4 % Commercial, and 10.6 % Unclassified. Based on this classification, no Prime category carcasses were recorded; in this regard, the authors describe that 79 % of the carcasses attained the Prime classification grade in the first instance, but when conformation was evaluated, only 0.5 % of the carcasses attained the definitive grade of Prime.

Table 8 shows the distribution of Basic Quality Grades of beef carcasses categorized by sex, age, and racial predominance. According to sex and age, in the group of females younger than 30 mo and males younger and older than 30 mo, there was a greater distribution of carcasses in the Select and Standard grades, and in the group of females aged more than 30 mo, there was a larger number of Commercial grade carcasses. In relation to the predominance of the zebu breed, it may be observed that, as this breed component increases, the number of carcasses in each category gradually decreases. This is attributed to the poor development of intramuscular fat in zebu cattle compared to European cattle[19,33].

Table 8: Distribution of Basic Quality Grades of carcasses categorized by sex, age, and group, according to racial predominance of cattle from intensive finishing units and processed in Federal Inspection Type establishments (n= 1,417)

			Basic Quality Grades								
Sex	Age	Group	Prime		Select		Standard		Commercial		Totals
			n	%	n	%	n	%	n	%	n
		1	2	4.55	33	75	9	20.45	0	0.00	44
	<30	2	0	0.00	18	85.71	3	14.29	0	0.00	21
		3	0	0.00	1	50.00	1	50.00	0	0.00	2
F		4	0	0.00	0	0.00	0	0.00	0	0.00	0
			2	2.98	52	77.61	13	19.40	0	0.00	67
		1	2	1.77	43	38.05	27	23.89	41	36.28	113
	>30	2	2	2.82	20	28.17	11	15.49	38	53.52	71
		3	0	0.00	5	41.67	5	41.67	2	16.67	12
		4	0	0.00	0	0.00	0	0.00	0	0.00	0
			4	2.04	68	34.69	43	21.94	81	41.32	196
		1	5	5.38	39	41.94	49	52.69	0	0.00	93
	<30	2	18	4.16	211	48.73	204	47.11	0	0.00	433
		3	15	4.12	167	45.88	182	50.00	0	0.00	364
M		4	14	6.28	97	43.50	112	50.22	0	0.00	223
			52	4.67	514	46.18	547	49.14	0	0.00	1113
		1	0	0.00	2	100.0	0	0.00	0	0.00	2
	>30	2	1	9.09	7	63.64	3	27.27	0	0.00	11
		3	1	4.76	8	38.10	12	57.14	0	0.00	21
		4	0	0.00	4	57.14	3	42.86	0	0.00	7
			2	4.87	21	51.21	18	43.90	0	0.00	41
Totals			60	4.23	655	46.22	621	43.82	81	5.72	1417

F= females; M= males; <30: aged less than 30 months; >30: aged more than 30 months; Group 1=≤ zebu; 2= ½ zebu; 3= ¾ zebu; 4= zebu.

Conclusions and implications

The cattle carcasses in this study had a mainly zebu breed component. Most of the carcasses corresponded were classified as belonging to the "Select and Standard" basic grades, a large number of them having a grade A bone maturity but low scores in the marbling grades; this fact limited their classification to a better basic quality grade in accordance with the provisions of the norm NOM-004-SAG/ZOO-2018, as an effect of the racial predominance of *Bos indicus*.

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