IMAGE ANALYSIS TECHNIQUES FOR EVALUATION OF MEAT YIELD INDICATORS OF BOVINE CARCASS.

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Background

Individual grading of bovine carcass is defined by a set of yield and quality attributes corresponding to animal category. Visually judgement of quality and profitable carcass indicators allow to order a ranking of consumer meat quality preferences. However, the strong subjectivity is not free of biased personal understanding. Present development of Video Image Analysis (VIA) skip subjective evaluation problems (*Procisur Forum, 1998*). *Butterfield et al.* (1977), used 5 to 10 photographic successive sections of sheep carcass, they found an accuracy of $R^2 = 89\%$ to 99% in percent of lean content prediction, respectively. *Wassenberg et al.* (1986) found an accuracy of 95,6% for VIA method higher than USDA expert committee ($R^2 = 94\%$), with the advantage that VIA minimizes the variation of prediction. *Newman,* (1987) with adapted VIA technique found a relationship of $r = 0.96$ between intramuscular fat and chemical analysis determination. Otherwise, *Gerrard et al.* (1996), by means of VIA appraised beef colors and marbling, they found with trained panel a accuracy of 86% for color and 84% for marbling in beef cut. *Scholz et al.* (1996), in pork carcasses, confirmed advantages of VIA ($r = 0.85$) *versus* visual method ($r = 0.56$) for marbling determination and chemical intramuscular fat. *Shackelford et al.* (1998), verified VIA accuracy of $R^2 = 89\%$ against $R^2 = 77\%$ for USDA beef grading in percent wholesale cut, while in Kg lean content was, $R^2 = 95\%$ against $R^2 = 90\%$ for USDA grading procedure.

Objective

To find out algorithms groups for image analysis yield indicators visually perceivable in the transversal section of *Longissimus dorsi* muscle of bovine carcass.

Materials and Methods

Experimental module for captures and image analysis was designed. It consisted of an e-Photo 1690 digital camera for image capture, a translucent plastic poli-C cone, a high frequency fluorescent tube and a Pentium II personal computer. Module "hole area" of Image Pro-Plus 4.1 program was adapted for image data processing.

Spectral characteristics of *Longissimus dorsi* muscle image components were processed and the "eye-beef area" (EBA), fat thickness and marbling were estimated. All evaluations of EBA area and fat thickness by VIA method was compared with digital planimeter (Placon KP-92N) and digital Caliper (Digimatic) measured on tracing acetate film.

Two groups of 10 Hereford steers of 380 Kg live weight, on average, finished on grass with and without winter supplement (control) were considered. After 48 hours *post-mortem* in the chilled left side was removed the so call "pistol" wholesale cut and 10 retail cuts were fabricated in compliant with the Argentine Meat Board standard (ex-JNC). The "pistol" cut was selected because it has a high correlation with lean, fat and bone composition of bovine whole carcass. All cuts were dissected in muscle, fat, bone, fiber and tendon tissue component. Previously, the normality and data consistency was tested. All statistical analysis was realized by GLM procedure of SAS *(1988)*.

Results and Discussion

Table 1 shows yield carcass composition of grass + supplement and control bovine finished groups were not significant ($P<0.05$). Therefore, the sample variation was consistent and a "pool" of data was analyzed for VIA validity measurements and regression models design.

Table 2 shows the carcass data at slaughter level of the 20 steers used. Total fat, dorsal fat thickness and marbling variation were high, what is in agreement with the irregular adipose tissue depot in bovine carcass and finished effects. Marbling value 1.95 is agreed with "moderate" USDA class. Yield of "pistol" wholesale cut was 39.5%, characteristic in medium live weight steers.

Total area or "work area", ATO, is defined as the visible *cranial* surface of *Longissimus dorsi* muscle in the 10 - 11 rib cross section. This area is located between two parallel lines traced towards dorsal direction in the larger axis ends of EBA. The area so established was least variable than total area of beef cut. Inside of delimited ATO area were measured the indicators of yield and quality meat.

Table 3 shows that ATO area measured by VIA technique was larger that manual planimetric method ($P<0.05$). VIA method might contain a redundant information, because a lack of precision for distinguish the frontiers between fat and meat tissues in the zone adjacent to ventral edge of *Longissimus dorsi* muscle (nearest to *Intercostalis, Levator costarum and Multifidus* muscles). The largest spectral constituent of meat in ATO area was the EBA component and his measurement by VIA method was 1.65 cm^2 in average, larger than planimetric method ($P<0.05$). This difference is due to variation in beef sample presentation (oblique direction of cut, light scattered effects, etc). Total meat area (TCO) is the summation process of meat spectral signature inside ATO area (aggregate of transversal sections of *Longissimus dorsi, Spinalis et Semispinalis dorsi et cervicis* muscles areas). The VIA measurements shown grater accuracy than planimeter results so much as meat (TCO) and fatty areas (TGO). VIA method over-estimate the larger axis measurement makes by caliper, probably because the axis ends fixation in EBA area changes the slope of the axis and therefore, its length. VIA and caliper measurement methods were coincident in the *Longissimus dorsi* muscle thickness (EBA width). Direct lineal measurement of VIA was more accurate than manual caliper method, because previous tracing EBA contour on acetate film implicate a extra variation font.

Table 4 shows the relationship between digital and manual methods. Dorsal fat thickness was the most accurate and precise measurement. Larger axis accuracy of EBA area measurement was adequate with both techniques. TCO area, in spite his highest accuracy (R^2= 97.3%) it lacks some precision (RSD = 1.10). VIA direct marbling evaluation *versus* USDA visual scale shown a suitable relation (R^2= 77.5%). However, his precision was low (RSD = 2.66), this suggests no agreement with visual method. BEA direct scanning surface for fat particle counting was a very consistent method. The results let us concluding what digital techniques of VIA was useful for objective direct bovine carcass evaluation by means surface scanning *Longissimus dorsi* muscle transversal cut.

Correlation between every indicator and composition of bovine carcass "pistol" cut. Table 5 shows good correlation of side weight and ATO area but only adequate for TCO, TGO and EBA areas and low for fat thickness. Weight of "pistol" cut shown good correlation with the same areas also. However, TGO area and fat thickness correlations were low with "pistol" cut fat content.

Moreover, it was designed multiple regression models, which include as independent variables to VIA measurement and muscle and fat dissected tissues of "pistol" cut as dependent variables. Table 6 shows some models analyzed, bone model prediction is not included. In spite the high accuracy of models (between 90.6 to 80%), the big residual standard deviation (RSD) suggests some data inconsistence that affected the model fitting. Weight variable inclusion into regression models generates a multicolinearity effect, therefore, it is required carcass weight independents indicator so much *Longissimus dorsi* surface cut section as in whole bovine carcass. The percentage transformation of the bovine carcass data and the VIA measurements could stabilize the variations to assure a better adjustment of prediction models.

Conclusions.

Meanwhile it is not validate the soundness of "pistol" cut models against opposite side of bovine carcass. The multiple regression basic models designed here, it should take into account provisionally to find and check news independents variables measured with VIA techniques on transversal cut of *Longissimus dorsi* muscle and entire carcass of a larger number of animals. The usage of Video Image Analysis techniques showed to be promising to evaluate the carcass composition indicators and was more accurate and precise than any visual evaluation assayed.

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TABLE 1. Percent composition of bovine carcass "pistol" cuts. Treatment groups B and V, with n = 10 steers every one. Means % and (±DS)

ASSAY	%MUSCLE	% EXT FAT	% INT. FAT	% BONE	%Fib+Tend
B (grass)	57.56 (2.57) a	7.33 (2.36) a	5.89 (1.21) a	7.52 (0.71) a	2.57 (0.61) a
V(supl+grass)	56.94 (2.15) a	7.85 (1.95) a	6.19 (0.92) a	7.13 (0.66) a	2.53 (0.58) a

Means with same letter within columns, not differ (P<0.05).

TABLE 2. Characteristics of bovine carcass (n = 20 steers).

VARIABLE	MEANS	±SD	CV%
Hot carcass weight, Kg	248.25	22.46	9.05
Left side weight,. Kg	123.80	11.97	9.07
Pistol cut weight, Kg	48.54	3.98	8.20
Fémur bone weight, Kg	3.20	0.21	9.56
Shank, Kg	2.37	2.36	10.68
Total bone, Kg	8.47	0.84	9.92
Total muscle, Kg	28.08	2.36	8.40
Total fat, Kg (*)	6.63	1.38	20.81
Total fibre and tendón, Kg	1.26	0.27	21.43
Eye-Beef Area, EBA, cm²	62.21	5.27	8.47
Dorsal fat thickness, mm	12.87	3.90	33.71
Marbling (USDA score)	1.95	0.43	21.85
Fat Area/Total Area x 100 ᵃ	21.49	3.95	18.38
Muscle Area/Total Area x 100 ᵃ	76.22	6.53	8.57
Pelvic fat Kg	1.45	0.51	35.2

(*) Without kidney fat neither cod fat. (ᵃ) Delimited area in the transversal section of 11th beef cut.

TABLE 5. VIA relationships with weight characteristics of bovine carcass. r (DSR) (n= 20 steers)

INDEPENDENT VARIABLE (VIA)	DEPENDENT VARIABLE: LEFT SIDE WEIGHT Kg.	¼ PISTOL, Kg	MUSCLE PISTOL CUT, Kg	TOTAL FAT PISTOL CUT, Kg
ATO	0.813 * *(6.01)*	0.719 * *(3.54)*	-	0.703 * *(5.43)*
TCO	0.706 * *(5.31)*	0.780 * *(3.04)*	0.602 * *(4.75)*	0.760 * *(4.36)*
TGO	0.643 * *(4.00)*	-	-	0.445 * *(5.00)*
EBA	0.689 * *(4.15)*	0.775 * *(3.72)*	0.647 * *(3.51)*	0.639 * *(5.22)*
FAT thickness I	0.512 * *(5.33)*	-	-	0.482 * *(4.09)*
FAT thickness II	0.598 * *(5.10)*	-	-	0.472 * *(5.11)*

(*) r significant values (P<0.05) ATO = Total work area delimited in beef cut surface. TCO = Total meat area into ATO area. TGO = Total fat area into ATO area. EBA = Eye-beef area. Fat thickness I = Thickness fat measurement 1/4 upper of EBA area. Fat thickness II = Thickness fat measurement 1/4 lower.

TABLE 3. Instrumental measurement of useful indicators on transversal cut surface of *Longissimus dorsi* muscle. Means *(±DS)*

VARIABLE	PLANIMETER	VIA	CALIPER
EBA (cm^2)	62.21 *(5.27)* a	63.86 *(4.20)* b	
FAT THICKNESS I (mm)		12.20 *(4.25)* a	12.16 *(4.28)* a
FAT THICKNESS II (mm)		11.63 *(4.43)* a	12.05 *(3.52)* b
ATO (cm^2)	88.34 *(9.96)* a	91.86 *(10.81)* b	
TGO (cm^2)	19.74 *(5.14)* a	20.91 *(5.60)* b	
TCO (cm^2)	69.77 *(6.46)* a	69.54 *(5.72)* a	
EBA LENGHT (cm)		13.03 *(0.41)* a	11.97 *(0.52)* b
EBA WIDTH (cm)		7.00 *(0.40)* a	6.87 *(0.54)* a

VIA = Video Image Analysis. EBA = Eye-Beef area. Thickness I = ¼ upper axis of EBA. Thickness II = ¼ Lower of EBA area. ATO = Total work area (predetermined beef area). TCO = Total meat area of ATO. TGO = Total fat area of ATO. Means with same letter into row, not differ (P<0.05)

TABLE 4. Coeficient of Determinations (R^2) and Residual Standard Deviation (RSD) of VIA relationships with manual caliper and planimeter measurement techniques (n=20).

TECHNIQUE	MEASUREMENT	R^2 % (*)	RSD
VIA x PLANIMETER	EBA	97.0	0.96
VIA x CALIPER	Thickness I	99.2	0.38
VIA x CALIPER	Thickness II	96.5	0.76
VIA x CALIPER	Width T	90.1	0.45
VIA x CALIPER	EBA length axis	85.6	0.71
VIA x PLANIMETER	TCO	97.3	1.10
VIA x PLANIMETER	TGO	97.1	0.89
VIA x PLANIMETER	ATO	99.3	0.86
VIA x USDA (1)	Marbling	77,5	2,66

VIA = Video Image Analysis. EBA = Eye-Beef area. ATO = Total work area. PLAN = Digital Planimeter. Thickness I = ¼ upper axis of EBA. Thickness II = ¼ lower axis of EBA. T = Width of EBA area. TCO = Total meat area of ATO area. TGO = Total fat area of ATO area. (*) = R^2 Significant (P<0.05). (1)= USDA Photographic score.

TABLE 6. Regression models for predict meat and fat weight composition (Kg) In "pistol" wholesale cut. (n = 20 steers)

Eq.Nro.	R^2	C_p	DSR	Equation
				Kg muscle (*)
1	81.30	4.30	2.80	$Y = 2.547 - 0.095X_1 + 0.791X_2 + 0.124X_3 - 0.131X_4$
2	80.00	2.35	2.50	$Y = 3.759 - 0.097X_1 + 0.825X_2 - 0.055X_4$
				Kg Fat (*)
3	90.60	4.24	0.54	$Y = 0.004X_1 + 1.188X_5 - 0.074X_6$
4	90.60	4.82	0.48	$Y = 1.107X_5 + 0.064X_7 - 0.076X_8$

X_1 = Left side weight, Kg X_2 = Pistol cut weight, Kg. X_3 = EBA VIA cm^2 X_4 = TCO VIA cm^2
X_5 = Internal fat weight, Kg X_6 = Fat thickness, VIA II mm. X_7 = ATO VIA cm^2 X_8 = TGO VIA cm^2.
(*) All parameters were significant (P<0.05).