

Physicochemical Characteristics that influence the meat pork quality in Supermarkets in the Central Highlands of Mexico

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Abstract: Introduction: Twenty-two supermarkets in the Central Highlands of Mexico were sampled in order to classify them and to compare their pork meat quality based on its physicochemical characteristics. The supermarkets were classified in three types in accordance with socioeconomic status of buyers as low, medium, and high. **Methods:** Samples were obtained from the *Longissimus dorsi* muscle from 10th to 12th ribs. **Results:** Objective color was L* 46.97, a* 6.22 and b* 5.1. Subjective color indicated that it was red with a value of 3.06, subjective marbling was 2.8 %, and objective value was 2.9 %. Moisture varied from 690 to 739.3 g/kg, protein varied from 205.5 g/kg to 229.6 g/kg and shear force (SF) was 2.87 kg/cm². There were no significant differences (P≥0.05) between the variables besides subjective marbling. Tukey's test indicated that the lowest average included low and medium socioeconomic status supermarkets, which means that the fat content found in the chop eye is less than in meat in high socioeconomic level supermarkets. **Conclusions and recommendations:** According to the results, pork sold in the supermarkets in the Central Highlands of Mexico was a tender meat with reddish pink color, firm texture and little exudation and with an appropriate protein and intramuscular fat contents.

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Key words: pig, shear force, meat quality, marbling.

1. Introduction

Supermarkets in the Central Highlands of Mexico are demanding a product with certain desirable characteristics for the consumer. It has to be edible, nutritious and healthy, among others. Then, meat has to combine a number of characteristics that allows producing the most satisfactory quality with the best yield too. Meat quality includes many factors, some linked to human senses, health, safety and technological (Verbeke *et al.*, 2010, Hui, 2007, Grunert *et al.*, 2004; Rosenvold and Andersen, 2003; AMSA 2000). In Mexico, one of the most pork meats producing is the Estado de México. Mexicans annually consume more than 1.7 million tons of pork meat, which 34.0 % are acquired abroad, mainly from United States markets.

One of the principal factors that affects domestic pig production performance is the rising cost of the grains used in livestock feed. In contrast to technically advanced and integrated producers who has an appropriation of marketing, value added and livestock processing. The complicated situation of world economy and the rising cost of the grains used in livestock feed, are two of the main factors that impact on domestic pig production performance (SAGARPA, 2009).

Mexican supermarkets are great pork meat buyers, which are characterized to sell fine cuts meat with suitable hygienic conditions. Even when at the beginning its market linkage corresponded to offer a wide range of products to the consumers. Now days, one of the most dynamic sections within the supermarkets is meat. They have had a positive impact in the Mexican society because they generate a wide supply of products (variety, quality, brands and prices), but mainly a constant supply throughout the year. Then, it is also recognized that the market systems modernization has allowed the proliferation of small supermarkets, letting to extend the points of sale in order to make the constant supply. Nevertheless, meat quality changes among the supermarkets, originating different prices (meat/kilo) for the same cut because of the supermarket kind.

In summary, this study proposes supermarkets classification based mainly on the socioeconomic status of the consumers. Although a previous classification does not determine the meat quality sold in each one of these supermarkets. Furthermore, the present research proposes to apply a methodology in order to determine the meat quality (Physicochemical parameters) from an objective and subjective perspective.

2. Materials and Methods

Sixty six samples 2.5 cm pork meat chop (*Longissimus dorsi*) from the 10th to 12th ribs were collected from 22 supermarkets of Mexico's Central Highlands (three chops for super), during 3 fall-winter periods. Samples were stored at 2-4 °C (Eusse, 2007). Meat quality parameters were done at Toluca city, Mexico.

2.1 Characteristics of Central Mexican Highlands Supermarkets

The commercial centers in Mexican Republic were sort considering the researcher's proposal and it was sustained mainly on the consumer's socioeconomic status. In general, they had been divided in three kinds: low, medium and high. According to their location area they were numbered from 01 to 22; within low (06, 08, 09, 18, 19, 21, 22), medium (01, 02, 03, 04, 05, 07, 10, 11, 13, 14 and 15) and high (12, 16, 17, 20). *Low*: Small establishments that are wide but little deep assortment stores of products because of the establishment small dimensions. They had a high perishable food sections (butcher, fish market, poultry shop, fruits, cheeses and products with denomination of origin, among others) and essentially, they play with (low) prices and services. They have been proximity stores adapted to the proximity customer's area. They haven't been made with additional services to attract customers and are limited to the basic purchase products. Consequently, they cannot compete with some other most evolved. They usually have heavily discounted, which are short assorted, many own brands, aggressive prices and very little services. *Medium*: Their fundamental differences are size and the presence of perishable food sections attended. Those sections have a skilled staff, who realize the own functions of direct dispatch without payment and its always on departure. They have a very aggressive pricing policy with a very similar food assortment that the low one. They have been catalogued as great feeding surfaces and every time they dedicate more areas to non-food sections. They work with very tight margins related to food products, performing their pricing policy to hang up consumers, who buy some other products with higher margins in the sections of non-food. They have an attractive atmosphere that is complemented with other services, such as travel agencies, ATM (Asynchronous Transfer Mode) and free parking. These kinds of supermarket usually have soft discounts, in other words, wide assortment, great presence for many brands and discount only on their brands. *High*: They are specialized stores; who offer a reduced but deep assortment in their small internal establishments, like fruit shop, fish market, butchers and bakery. Their competitive weapon is selectivity, variety and quality for a suitable assortment to the buyer. Its location is not only in an average attraction area, but also they are

close to the customers. Client used to pay for comfort, fast service, freedom of choice, freedom in their purchase decisions and comparing of prices and brands, although their prices does not determine their purchase decision. These supermarkets usually don't have discounts (Alonso, 2001; Fiengenbaum and Thomas 1995; Alonso, 1992; Fiengenbaum and Thomas, 1990 and Hamilton, 1989)

2.2 Instrumental analysis

Chops were used for marbling, subjective color (Gómez and Gómez, 1984 and Wright *et al.*, 2005) using the NPPC scale (1999) (National Pork Producers Council Scale) and for objective color (Colorimeter Minolta Chroma meter CR-400, measuring head CR-400, calibration plate CR-A43, view angle of 20°, made in Tokyo, Japan), L* (brightness), a* (reddish) and b* (yellow). Samples were homogenized using a food processor Moulinex, Ecuallly (France) for official method AOAC #991 adapted to total fat determination (Huff-Lonergan *et al.*, 2002; Mariezcurrena *et al.*, 2010). Kjeldahl protein analysis and AMSA method for Shear force (kg_f) (Honikel, 1998).

2.3 Statistical analysis

An ANOVA was applied which general lineal model was a completely randomized experimental design. The study factors (treatments) were the 22 supermarkets and the three samples were considered as repetitions, including the three fall-winter periods. Tukey's test ($P \leq 0.05$) was performed. Answer variables were fat (g/kg), protein (g/kg), humidity (g/kg), shear force (kg/cm²), objective color (L*, a*, b*), subjective color and marbling. These analyses were completed by the lineal correlation between variables pairs and by the corresponding analysis of principal components (APC) (Sánchez, 1995; Martínez, 1988; SAS, 1988; Gómez and Gómez, 1984)

3. Results

Results (Table 1), show X1=subjective color, X2=subjective marbling, X3=L*, X4=a*, X5=b*, X6=protein (g/kg), X7=fat (g/kg), X8=moisture (g/kg), X9=shear force (kg/cm²).

Those results indicated not significant differences ($P \geq 0.05$) for any of the variables except for X2 ($P \leq 0.05$) (subjective marbling), which a mean comparison Tukey's test was applied. This indicated that the first one group was low and medium level supermarkets with the lowest mean due to chop eye fat content was lower than in high level supermarkets meat.

3.1 Correlation analysis

In Table 2 can be observed positive and significant correlations between the following variables; subjective color/subjective marbling (X1/X2), subjective marbling/protein and fat content (X2/X6 and X7, respectively), L*/a* (X3/X4), L*/b*

values and protein (X4/X5 and X6), protein/fat (X6/X7) and between fat/shear force (X7/X9); and negative and significant correlations for subjective color/L* values (X1/X3), moisture (X8)/a* and b* and protein/fat (X4/X7).

3.2 Principal components analysis (PCA)

PCA1 (29.0%) and PCA2 (21.0%) explained the 50.0% of original data variation (Figure 1). The chart of PCA1 (Group 1) is mainly explained by values of L* and b*, while PCA2 (Group 2) was associated in a greater degree with subjective color (SC), marbling (M), protein (P) and shear force (SF). In Figure 1 biplot were partially tested and the detected correlations between the variables presented in Table 2, M, SC and fat (F) were identified in subgroup 1, while moisture (Ms), P and SF were detected in subgroup 2 and L*, a* and b* values were classified in subgroup 3. It was also detected that biplot allowed to classify faithfully the interrelationships between shopping centers and this variables group: In subgroup 1, 17 were most prominent in SC and M to have the highest values, while 12 was for F. In Group 2, 13 and 19 highlighted in Ms, while it was 21 for P and SF, in group 3 the highest averages for L* corresponded to 8 and 11, and for the a* b* values stood out 7, 9 and 16.

4. Discussion

Subjective color values were 2.0-3.66. In 08, 15, 17, 19 and 20 supermarkets the highest means were recorded, where acceptable quality are 3 or higher and below 2 values indicate soft and exudative meat (PSE) (Livingston *et al.*; 2004 and Wright *et al.*, 2005). This conditions known as PSE and DFD (Dark, firm and dry meat) are specific problems in swine industry due to genetics and pre-and post-mortem management. According NPPC scale (1999) optimum pork quality is 3-4. Huff-Lonergan *et al.* (2002) reported 3.25 values and observed that meat products with higher color score (darker) tended to be associated with a higher *post mortem* pH.

Subjective marbling values were 2.0-4.33 (Table 1). Wright *et al.* (2005), said that quality pork chops are those that scope marbling scores of 3 or higher in NPPC scale. High veined marble slabs not only indicates a great intramuscular fat presence (which influences directly meat sensory attributes such as juiciness, tenderness and flavor), but also it determines consumers acceptability. Ngapo *et al.* (2012) investigated that the highest marbling degree (≥ 3.0) had the greatest IMF (Intramuscular fat) content, drip loss, a* and b* but the lowest protein and moisture contents. Therefore, fat generally is accepted as that one that provides flavor and volatile aroma impacting on flavor. Foint-I- Furnols *et al.* (2012) investigated the relationship between eating and visual acceptability of meat pork with different IMF content in two groups

of Spanish consumers, loin lovers and marbled loin lovers, based on their visual preferences. Nevertheless, consumers preferred loins with higher IMF content according to eating acceptability (Moeller *et al.*, 2010). Wood *et al.* (2008) mentioned that the IMF or marbling fat had a role in tenderness and juiciness in cooked meat; in contrast, Brewer *et al.* (2001b) and Chen *et al.* (2010) mentioned that marbling appeared to have less effect in purchase intent than in tenderness, juiciness and flavor.

L* values were from 42.36 (12)-52.22 (08) (Table 1) and coincided with Brewer (1999) and Alarcon (2006), they reported values above 57 that are related to PSE meat with a lower meat water-holding capacity due to their partial protein denaturation, and a higher acidity too. Then, this meat releases more water, thus its surface refracts more light, looks brighter and it increases L* values. These authors propose that values closer to 51 indicates good quality meats, as its have a reddish pink color, firm texture and exhibit little or no exudate. On the other hand, they proposed that values below 38 are indications of DFD meat, which is characterized by a strong reddish color and a dry constitution, this normally is related to a lower meat water-holding capacity. Huff-Lonergan *et al.* (2002) obtained similar values from 44.07 to 46.87, and they reported a relatively high correlation with subjective color. Those values indicated that Hunter L-value are predictive of subjective color scores and tended to be associated with a higher *post mortem* pH. It was mentioned that pork meat with high ultimate pH, frequently is darker, compared with a low ultimate pH, which are lighter in color. Those aspects could be related with chilling process after slaughter, where a high ultimate pH allows a putative enzyme activity and as a result the oxidation of the oxymyoglobin molecule. Then the meat color is affected by a darker color appearance as Van Wijk *et al.* (2005) reported an average L-value of 48.3 with a high correlation between water holding capacity traits (drip loss and purge), ultimate pH and color traits (L* and b* and subjective color from the cut surface). This matched with Brewer *et al.* (2001a), who identified a relationship between L* and ultimate pH, whereas pH reaches the isoelectric point from different water binding muscle proteins, free water increases and then more light is reflected so the tissue appears to be "lighter". The NPPC scale (1999), reported that PSE meat had values from 55 to 61, as an optimum quality meat. On the other side, DFD meat is presented when recorded values from 31 to 37.

a* values shown in (Table 1) were from 4.21 and 8.37. These results are in accordance with Van Wijk *et al.* (2005) who reported a mean value of 6.9, as a good quality factor. Brewer *et al.* (2001a) indicated that as

pH increases meat appearance to be more intensely pink and reported a 7.52 mean value.

Protein arithmetic means were 20.55% (05) to 22.96% (21). These results matched with those reported by Aguilar (2002); Eusse (2007) and Hennet and Cannon (2007) who coincided that the optimal protein content desired in pork meat is considered 20.0-23.0% dry basis. Lower values could indicate a PSE meat, because of the myofibrillar proteins degradation by proteolytic enzymes.

Fat (Table 1) were from 1.97 to 3.82%. Laack *et al.* (2001); Daszkiewicz *et al.* (2004) and Galián *et al.* (2007), indicated that IMF values between 2.0 and 3.0%, were ideal in relation to the sensory meat quality. Furthermore, Fernandez *et al.* (1999) showed that an increase in the values of IMF increased sensory meat quality in some measure. However, values above 3.5% caused a consumer rejection. Ngapo *et al.* (2003) reported that consumers from some countries such as France, England, Sweden and Denmark were evaluated considering four factors as indicators of good quality. Those were: fat cover, price, country of origin and place of purchase. They also mentioned that it is important to have some fat cover for cooking, moisture retention and taste, but not too much because of health issues.

Moisture (Table 1) showed no significant differences for this characteristic since the percentages varied from 69.0% to 73.82%. Water holding capacity (WHC) and drip loss measure the ability of meat to hold moisture, which is subjected to post mortem metabolism (Malek *et al.*, 2001). Kapper *et al.* (2014) reported that significant moisture has been lost from muscle tissue on early postmortem, where WHC is a biochemical and physical result from the occurred changes into muscle tissue. It is also influenced by several factors such as: stress, genetic, pre-slaughter handling conditions and carcass cooling. They recommended a 75.0% of water account from the meat weight as a good value. This report values are close to that water account percentage that is related with the ability of muscle to retain moisture as a key for meat quality. Therefore, it has been suggested that present moisture results could be associated with a good amount of tightly associated water in fresh pork meat.

Finally, *shear force Kg/cm²* results shown in Table 1, the range of variability of tested samples was 1.86 to 3.54 kg/cm². Wright *et al.* (2005) and Galián (2007) mentioned that shear strength values lower or equal than 2.27 kg/cm² pressures means a tender meat. Values from 2.27 to 3.63 kg/cm² represent fairly tender meat and a value over 5.44 kg/cm² denotes tough meat. Overall, it suggested that shear force showed tenderness (or softness) of meat and subsequently, it becomes a decisive factor in assessing the acceptance, in other words the consumer's decision to continue

buying this product. Fortomaris *et al.* (2005) and Wright *et al.* (2005), stated that tenderness is a complex attribute, which involves several factors such as content and fiber density in the muscle, amount, type and connective tissue arrangement, intramuscular fat content, farm work conditions, animal stress, until product preparation before consumption and breed genetics. Recent studies have been showed a meat quality shear force with values 3-5 kg/cm² (Laack *et al.*, 2001 and Fortomaris *et al.*, 2005). But it has been also important to remain that SF increased values have been related with consumer's perceptions, because there is a decline in consumer ratings as Warner Bratzler values increases (Wright *et al.*, 2005).

5. Conclusions and Recommendations

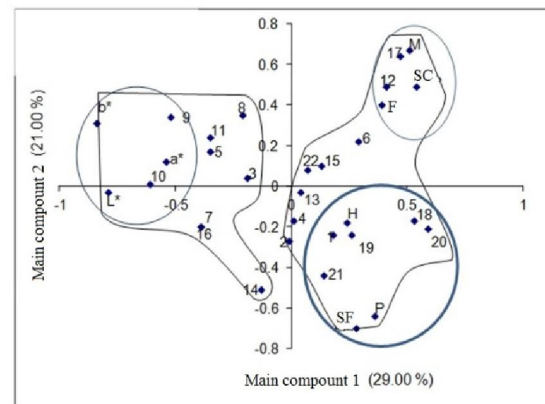


Figure 1. Graphic representation of biplot analysis between establishments by variable.

CS=Subjective color; M=Subjective Marbling; X3=L*; X4=a*; X5=b*; P=Protein; F=Fat; H=Moisture; FC=Shear force.

1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22=supermarkets, G1=Group 1 and G2=Group 2.

There were no significant differences for any of the studied variables (X1-X9) except for X2 (subjective marbling). Chop eye fat presence had been lower in high level supermarkets meat. In addition to the above, there was a mean comparison between all the supermarkets in order to determine whether different subgroups were formed with similar characteristics, however, this was not so. On average, meat objective color from Central Highlands of Mexico Supermarkets showed good luminosity (*L), reddish color (a*) and a yellow color (b*); this means excellent meat quality. The red subjective color was pleasant to the consumer. Subjective marbling measure and intramuscular fat values indicated a lean meat that could lead to the consumer's rejection by product visual appearance. At first, it is suggested that the pork meat from Central Highlands of Mexico Supermarkets was soft and

tender, which must be preserved by the local pork industry. The present methodology has had determinate that Central Highlands of Mexico Supermarkets could offered an average on pork meat quality with good values for subjective color, L*, a* and b* values, and specially, in tenderness. Even though, that the three economical kinds of Supermarkets only differed by the

subjective marbling values, then this value records could be a putative reason for a dilution into the connective tissue that gives tender meats. Finally, according to subjective color, moisture, fat and marbling high levels, most of the supermarkets showed to be medium and high classes.

Table 1. Means comparison results from pork chop (*Longissimus dorsi*) of 22 supermarkets.

Treatments (comercial centers)	Socio Economic Status	Variables								
		X1	X2	X3	X4	X5	X6	X7	X8	X9
06	Low	3.67 ^a	3.67 ^{ab}	46.32 ^{abcd}	5.91 ^{abcd}	4.31 ^{bcd}	22.41 ^a	2.86 ^{abcd}	70.85 ^{ab}	2.29 ^{cde}
08	Low	2.67 ^{abc}	3.67 ^{ab}	52.22 ^a	5.51 ^{bcd}	5.81 ^{abc}	21.73 ^a	2.69 ^{bcd}	72.60 ^{ab}	1.86 ^e
09	Low	3.33 ^{ab}	2.67 ^{bcd}	50.49 ^{abc}	7.57 ^{abc}	6.84 ^a	22.22 ^a	2.66 ^{bcd}	71.63 ^{ab}	2.21 ^{de}
18	Low	3.33 ^{abc}	3.00 ^{bcd}	44.92 ^{bcd}	4.22 ^d	3.72 ^{de}	22.49 ^a	3.07 ^{abc}	70.97 ^{ab}	3.21 ^{abcd}
19	Low	3.67 ^a	3.00 ^{bcd}	45.19 ^{bcd}	5.97 ^{abcd}	4.93 ^{abcd}	22.27 ^a	2.17 ^{cd}	73.94 ^a	3.41 ^{abc}
21	Low	3.00 ^{abc}	3.00 ^{bcd}	49.19 ^{abc}	5.84 ^{abcd}	4.31 ^{abcde}	22.96 ^a	2.12 ^{cd}	71.66 ^{ab}	3.54 ^a
22	Low	2.66 ^{abc}	2.66 ^{bcd}	48.02 ^{abcd}	6.18 ^{abcd}	5.20 ^{abcde}	21.56 ^a	3.60 ^{ab}	70.93 ^{ab}	3.42 ^{abc}
Mean		3.19	3.09^x	48.05	5.88	5.03	22.23	2.73	71.79	2.85
01	Medium	3.00 ^{abc}	2.67 ^{bcd}	44.26 ^{cd}	6.75 ^{abcd}	4.88 ^{abcde}	22.38 ^a	2.69 ^{abcd}	68.33 ^{ab}	3.49 ^{ab}
02	Medium	2.66 ^{abc}	2.00 ^d	46.38 ^{abcd}	6.42 ^{abcd}	5.45 ^{abcd}	22.20 ^a	3.15 ^{abc}	72.86 ^{ab}	3.23 ^{abcd}
03	Medium	2.67 ^{abc}	3.00 ^{bcd}	48.14 ^{abcd}	6.90 ^{abcd}	5.84 ^{abc}	21.84 ^a	2.58 ^{bcd}	72.05 ^{ab}	2.75 ^{abcde}
04	Medium	2.33 ^{bc}	2.33 ^{cd}	46.15 ^{abcd}	5.23 ^{bcd}	4.22 ^{cde}	21.63 ^a	2.21 ^{cd}	71.71 ^{ab}	2.57 ^{abcde}
05	Medium	3.33 ^{ab}	2.67 ^{bcd}	46.96 ^{abcd}	7.23 ^{abc}	6.41 ^a	20.56 ^a	2.07 ^{cd}	72.73 ^{ab}	2.93 ^{abcde}
07	Medium	2.67 ^{ab}	2.33 ^{cd}	48.46 ^{abcd}	8.37 ^a	6.60 ^a	22.63 ^a	2.63 ^{bcd}	71.04 ^{ab}	3.22 ^{abcd}
10	Medium	2.00 ^c	2.33 ^{cd}	50.90 ^{ab}	6.03 ^{abcd}	6.20 ^{abc}	21.51 ^a	1.98 ^d	69.01 ^b	2.30 ^{cde}
11	Medium	2.67 ^{abc}	2.33 ^{cd}	51.24 ^{ab}	6.70 ^{abcd}	6.27 ^{ab}	21.29 ^a	2.74 ^{bcd}	70.79 ^{ab}	2.84 ^{abcde}
13	Medium	3.00 ^{abc}	3.33 ^{abc}	49.95 ^{abc}	5.49 ^{bcd}	5.31 ^{abcde}	21.86 ^a	2.58 ^{bcd}	73.83 ^a	3.06 ^{abcd}
14	Medium	2.33 ^{bc}	2.00 ^d	50.55 ^{abc}	4.84 ^{cd}	5.43 ^{abcd}	22.37 ^a	2.34 ^{cd}	72.83 ^{ab}	3.43 ^{abc}
15	Medium	3.67 ^a	2.67 ^{bcd}	44.36 ^{cd}	6.13 ^{abcd}	4.38 ^{bcd}	21.28 ^a	2.20 ^{cd}	73.59 ^a	2.24 ^{de}
Mean		2.75	2.51^y	47.94	6.37	5.54	21.77	2.49	72.01	2.91
12	High	3.00 ^{abc}	3.67 ^{ab}	42.36 ^d	5.06 ^{bcd}	4.89 ^{abcde}	21.06 ^a	3.82 ^a	72.35 ^{ab}	2.37 ^{bcd}
16	High	2.67 ^{abc}	2.33 ^{cd}	50.27 ^{abc}	7.74 ^{ab}	5.96 ^{abc}	22.09 ^a	2.20 ^{cd}	73.43 ^{ab}	2.89 ^{abcde}
17	High	3.67 ^a	4.33 ^a	45.13 ^{bcd}	6.71 ^{abcd}	5.59 ^{abcd}	21.98 ^a	2.97 ^{abcd}	71.72 ^{ab}	2.73 ^{abcde}
20	High	3.67 ^a	3.33 ^{abc}	41.99 ^d	6.13 ^{abcd}	3.35 ^{de}	22.29 ^a	2.39 ^{cd}	73.13 ^{ab}	3.39 ^{abc}
Mean		3.25	3.41^y	44.94	6.41	4.95	21.85	2.84	72.65	2.84

X1=Subjective Color; X2=Subjective Marbling; X3=L*; X4=a*; X5=b*; X6=Protein (%); X7=Fat (%); X8=Moisture (%); X9=Shear force Kg;

a,b,c,d,e, Means with different superscript within each column denote significant differences (Tukey, $p \leq 0.05$).

^{x,y} Means with different superscript in a column for supermarkets groups (Low, medium, high) are statistically different (Tukey, $p \leq 0.05$)

Table 2. Simple lineal correlation analysis between variables evaluated X1-X9

Study Variable	X1	X2	X3	X4	X5	X6	X7	X8	X9
X1									
X2	0.39 **								
X3	-0.52 **	-0.23 NS							
X4	0.10 NS	-0.08 NS	0.29 **						
X5	-0.23 NS	-0.09 NS	0.64 **	0.63 **					
X6	0.13 NS	0.30 **	0.13 NS	0.27 **	0.10 NS				
X7	0.08 NS	0.37 **	-0.02 NS	0.18 NS	0.11 NS	0.33 **			
X8	0.05 NS	-0.15 NS	-0.22 NS	-0.35 **	-0.28 **	-0.45 **	-0.49 **		
X9	0.09 NS	-0.13 NS	-0.07 NS	0.08 NS	-0.06 NS	0.20 **	0.00 NS	-0.02 NS	

X1=Subjective color; X2=Subjective Marbling; X3=L*; X4=a*; X5=b*; X6=Protein; X7=Fat; X8=Moisture X9=Shear force

**Significant ($P \leq 0.05$); NS=No Significant ($P \geq 0.05$)

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