Honors Research Thesis

Comparison of Low, Medium, and High Marbling Pork Loin Chops: lipid content and resulting tenderness

Submitted by Curtis Pittman

Research Advisors: Henry Zerby and Steve Moeller

1. Introduction

As the pork industry tries to expand its market share, it is important to produce products that provide both a healthful and enjoyable eating experience. Marbling is a fresh pork characteristic that can be easily evaluated by consumers and can influence their point-of-purchase decisions; therefore, a greater understanding of marbling's impact on eating satisfaction is important. Palatability of meat products is often defined as the combination of juiciness, flavor and tenderness. A variety of studies have indicated the tenderness is the most important attribute for consumers as they determine overall desirability or overall preference (Savell et al., 1987; Huffman et al., 1996; Miller et al., 2001; Platter *et al.*, 2003). Intramuscular fat (IMF) content or marbling has also been shown to influence tenderness; however, the extent to which marbling positively contributes to tenderness varies within the literature. DeVol et al. (1988) reported that among different quality traits, IMF content was the characteristic that had the greatest relationship with shear force values in pork (r = -0.29), Verbeke et al. (1999) reported that an IMF within the range of 2 to 4% was optimal for pork palatability, and Rinker et al. (2008) reported that IMF across a broad range of 1 to 6% had little influence on palatability attributes.

Several factors such as genetics (breed, halothane gene, Rendement Napole gene) nutrition, physiological maturity and muscle location or function can impact pork tenderness. In most research studies evaluating tenderness, cooking methodology is standardized using methodologies that have been shown to be repeatable with reduced variation, thus allow differences due to the aforementioned attributes to be evaluated. However, consumers use a variety of cooking methods. Furthermore, due to personal preferences, consumers cook fresh meat products to a broad range of degree of doneness.

One of the most popular fresh pork products is center-cut pork loin chops, and grilling is a recommended cooking method for this particular cut. However, even within a cooking method such as grilling, variations in equipment can alter the cooking process and the resulting eating experience. Two popular methods of grilling include using a gas grill or using a George Foreman grill. A gas grill cooks with an open flame and uses convection (hot, dry air) as its method of cooking. A George Forman grill cooks with direct contact on both the top and bottom surfaces simultaneously, which sears the surface of the product and facilitates more rapid heat transfer and reduces moisture loss and cooking time.

As previously noted, there are varied results surrounding the influence of marbling on palatability, namely tenderness, of pork. Some of the variation in results may be due to differences in cooking method as well as degree of doneness. This study was designed to evaluate the influence of various levels of marbling in center-cut pork loin chops on resulting tenderness (shear force) when cooked to different end-point temperatures using two markedly different grilling methods.

2. Objectives

The objective of this study is to compare Low, Medium and High IMF on the tenderness of pork chops prepared at various end-point temperatures and grilling methodologies.

Specific aim 1: To determine if level of IMF impacts shear force values.

Hypothesis: Level of IMF will impact resulting shear force values.

Specific aim 2: To determine if degree of doneness impacts shear force values.

Hypothesis: Chops cooked to a greater end-point temperature will have greater shear force values.

Specific aim 3: To determine if cooking methodology impacts shear force values.

Hypothesis: Pork chops cooked with dry heat (convection) will have greater shear force values than those cooked via direct heat (surface contact).

Specific aim 4: To determine if there is an interaction among IMF, end-point temperature and cooking methodology on resulting tenderness (shear force values).

Hypothesis: There will be an interaction among IMF, degree of doneness and cooking methodology on shear force values.

3. Procedure and Methods

3.1 Loin selection

This study was completed utilizing a subset of the pork loins that were selected for the National Pork Board, Pork Quality Benchmark Study (Moeller et. al., 2008). Briefly, loins were selected within three commercial U.S. pork packing facilities and were selected to represent and test combinations of pork color, 24 h loin pH, and intramuscular fat (IMF) that encompass the normal range of industry observed values for each quality attribute. For selection purposes, a 3 x 3 x 3 classification arrangement of pH, marbling score and Minolta L* color was used to initially create a near uniform representation of quality combinations.

Whole, boneless loins were collected along the fabrication line at approximately 24 h postmortem. Using the size of the spinalis dorsi muscle as an anatomical indicator, the loin was cut at approximately the 7^{th} rib and the cut surface allowed to bloom for 10 min. Loin pH was measured using a portable pH meter (HI98240, Hanna Instruments, Italy) equipped with a glass-tipped pH probe (FC201D, Hanna Instruments, Italy) inserted approximately 1 cm under the cut surface and placed in the center on the exposed 7^{th} rib loin surface. After bloom, loin color was measured on the exposed 7^{th} rib loin surface using a Minolta Colorimeter (CR-310, 50 mm diameter orifice, 10° standard observer, D^{65} light source; Minolta Company, Ramsey, New Jersey), recording L*, a* and b* values. Subjective visual color and marbling scores were collected by trained personnel using a 1 to 6 scale as outlined by the National Pork Producer Council (NPPC, 2000). A 1.25 cm-thick section of loin was cut immediately posterior to the 7th rib exposed location, subcutaneous fat and connective tissue removed, an the remaining muscle sample used for assessment of IMF according to the ether extract using AOAC (1995) procedures. Moisture and fat amounts were attained by the air-dry oven and Soxhlet ether extraction methods, respectively. Approximately 2 g of powdered sample from each chop was added to dried, pre-weighed thimbles (filter paper #1, Whatman®, Maidstone, England) and weights were recorded. Analysis of the samples was performed in triplicate. The samples were dried in a convection oven at 100°C for 18-24 h then removed and placed in a dessicator for cooling. Weights were taken and recorded to determine percent moisture. Samples were placed in a Soxhlet apparatus and refluxed with petroleum ether for approximately 18 h. Samples were removed and placed under a hood to allow ether to evaporate, and placed in a convection oven for approximately 12 h. Samples were removed and placed in a dessicator until cooled to room temperature. Weights were taken and recorded to determine percent fat in each sample.

Loins were weighed and individually vacuum-sealed for storage and transportation. All loins were transported under refrigeration to The Ohio State University Meat Science Laboratory, Columbus, OH where the loins were stored and aged at 2 C for 7 to 10 days, with processing occurring on the Friday following the previous sampling week.

3.2 Processing

This subset contains 15 Low (< 1.5%), 14 Medium (4.0 to 4.5%), and 15 High (> 8%) intramuscular fat pork loins; and marbling level served as a complete block. Whole pork loins were removed from packaging and weighed to measure purge loss. Then they were tempered in a -28.8º C freezer to facilitate accurate slicing. Eight pork loin chops, 2.54 cm thick, were cut from each loin (four chops were used for Slice-shear force which is not presented in this report). Two loin chops from each loin were randomly assigned to each of the cooking methods (direct contact simulated using a George Foreman grill; dry convection simulated using a Weber® gas grill). Then each of the chops designated to cooking method was randomly assigned to an end-point temperature (68.3 C or 73.8 C). The chops were then vacuum packaged with identification and sorted into their respective groups. Chops designated for shear force were randomly assigned to one of five different cooking days, with all chops from the same loin being cooked on the same day.

3.3 Shear force procedures

Warner-Bratzler Shear force (WBS) was assessed at two end-point temperatures (68.3 C and 73.8 C). Chops were cooked using a George Foreman grill (direct contact) according to AMSA (1995) and using a Weber® gas grill (dry convection). Initial weights were recorded as well as final cooked weights in order to calculate cooking yield for each chop. Internal temperature (Digi-sense, Model # 277653 or equivalent) was monitored by copper constant thermo couplers inserted in the geometric center of each chop (Digi-sense, K-type probe, 30.48cm x 1.016 cm diameter, Code 93631-11, or equivalent). Chops were then cooled to room temperature (22.2 C) for approximately four hours after cooking. Six cores (1.27cm in diameter) were removed from each chop parallel to the longitudinal orientation of the muscle fibers. Each core was sheared with a WBS shearing device (Model TA TX^{plus}), maximum force was recorded in kg, and analyzed as an average of the six cores.

3.4 Statistical analysis

Data were analyzed using the PROC MIXED procedure of SAS for a randomized complete block split-split plot design. The model included IMF level as the block, loin was the whole plot and cooking methodology was the split-plot with end-point temperature as a split-split plot. Cooking method and end-point temperature were treated as repeated measures within loin. Loin ph was included as a covariate in the models for cook loss and WBS. All possible interactions were tested and subsequently removed from the model if not significant at $P < 0.05$. Least squares means were separated using the probability difference procedure (PDIFF option). Simple correlations were produced using the PROC CORR procedures of SAS.

4. Results

Pork loin quality and response variable arithmetic means, standard deviations, and ranges are presented in Table 1. Ploys characterizing the distribution of response variables around main effects are presented in the appendix. Least squares means for main effects are presented in Table 2.

4.1 Percent Intramuscular Fat

Level of intramuscular fat did not ($P > 0.05$) impact cook time or cook loss, however, pork chops from Low IMF loins (1.3% ±0.2) had greater ($P < 0.05$) WBS values than chops from

Medium (4.3% ±0.2) and High (9.1% ±1.1) chops. Some researchers have proposed that there is a threshold of marbling that is necessary to promote tenderness.

Table 1. Loin characteristics and response variable means for Low, Medium and High marbling loins

	n	Mean	Std. Dev.	Min	Max
Marbling Level					
Low					
IMF, %	15	1.3	0.2	0.9	1.6
pH	15	5.73	0.28	5.26	6.28
Cook time, s	58	832	445	287	1760
Cook loss, %	60	25.5	11.8	8.8	47.4
WBS, kg	60	3.46	1.00	1.86	6.02
Medium					
IMF, %	14	4.3	0.2	4.0	4.5
pH	14	5.69	0.35	5.39	6.54
Cook time, s	56	800	435	297	1830
Cook loss, %	56	24.5	11.6	5.4	46.7
WBS, kg	56	2.77	0.80	1.37	4.87
High					
IMF, %	15	9.1	1.1	8.2	12.2
pH	15	5.61	0.10	5.47	5.81
Cook time, s	58	753	395	267	1946
Cook loss, %	60	25.1	11.4	7.9	48.6
WBS, kg	60	3.05	0.87	1.71	5.79

Savell and Cross (1988) reported that a 3% level of IMF would help ensure an acceptable eating experience and Verbeke et al. (1999) reported that an IMF with in the range of 2 to 4% was optimal for pork palatability. Although this study was not designed to test this hypothesis, the results do support that there may be a threshold between the Low and Medium chops within this study (1 to 4% IMF; it should be noted that the level of IMF in this study designated as Medium would be considered to be a high level of IMF in the retail market place). In contrast, Hodgson et al. (1991) reported a linear relationship between percent fat and shear force values. In their study they reported the mean percent fat within three resulting shear force categories (4.1

to 6.8 kg, 2.7 to 4.0 kg, and 0.5 to 2.6 kg). Chops that had a shear force between 4.1 and 6.8 kg had a mean fat percent of 3.1, Chops that had a shear force between 2.7 and 4.0 kg had a mean fat percent of 5.3, and chops that had a shear force between 0.5 and 2.6 kg had a mean fat percent of 9.0. Interestingly, Rincker et al. (2008) reported that intramuscular fat content had limited effects on perceived tenderness in a group of loins selected to provide a continuous and uniform distribution of extractable lipid ranging from 1 to 8%. However, in agreement with results of this study where IMF was negatively correlated (r = -.18; P < 0.018) with shear force, Rincker et al. (2008) reported that Warner-Bratzler shear force was negatively related (R^2 = 0.10; P < 0.0001) to extractable lipid.

Table 2. Least squares means for main effects of IMF level, cooking method, and end-point temperature on cook time, cook loss and Warner-Bratzler shear force.

	Cook time (s)	Cook loss (%)	WBS (kg)
IMF level			
Low	821	25.9	3.53[a]
Medium	800	24.7	2.79[b]
High	752	24.5	2.96[b]
Std err	30	0.5	0.19
P-value	0.2565	0.1543	0.0109
Cooking method			
Direct Contact	443[b]	15.1[b]	2.92[a]
Dry Convection	1139[a]	35.0[a]	3.27[b]
Std err	23	0.4	0.12
P-value	<0.0001	<0.0001	<0.0001
End-point temperature			
68.3, ºC	685[b]	21.4[b]	2.88 [b]
78.3, ºC	997[a]	28.7[a]	3.30 [a]
Std err	23	0.6	0.12
P-value	<0.0001	<0.0001	<0.0001
Temperature × Cooking Method			
P-value	0.0003	0.0002	

[a,b]Means with different superscripts within a column within each treatment effect are different (P < 0.05).

4.2 Cooking Method and End-point Temperature

Direct contact resulted in a more desirable ($P < 0.05$) shear force than dry convection. Cooking to lower end-point temperature (68.3 C vs 78.3 C) also resulted in a more desirable ($P < 0.05$) shear force. Although significant, the absolute difference between treatment least squares means for cooking method temperature (0.35 kg ±0.12) and end-point temperature (0.42 kg ±0.12) are approaching a level that may not be detectable by consumers.

Christensen et al. (2000) reported that toughness of meat increases with temperature in multiple phases. In the first phase, there is a sharp initial increase in toughness between 40 and 50 C, which is followed by a dip or a plateau in toughness between 50 and 60 C depending on the measurement technique, and then a second phase of increasing toughness above 65 C. Bouton et al. (1981) provided evidence that intramuscular connective tissue contributes highly to shear force at low cooking temperature (40 to 60 C); however, its contribution is much less above 60 C. Lewis and Purslow (1989) also showed that perimysial connective tissue strength increases in meat cooked up to 50 C and decreases above this temperature. However, Kopp and Bonnet (1987) showed that isolated intramuscular connective tissue shrinks above 65 C and Lepetit et al. (2000) have stated that this shrinkage causes volume reduction in the myofibers resulting in increased toughness and presumably increased cook loss. However, Purslow (1999) reported that the ratio of transverse to longitudinal shrinkage in meat during cooking, and especially how these vary with sarcomere length, indicates that there are other major factors in addition to collagen contributing to increases in toughness and cook loss. Mutungi et al. (1996) showed that the strength of porcine muscle fibers continually increases up to 90 C. Christensen et al. (2000) concluded that the increase in toughness of whole meat cooked from 60 to 80 C is likely related to strength of myofibrilar proteins, as the myofibrilar component explained 47% of the variation in tenderness resulting from different end-point temperatures and adding perimysial connective tissue to the analysis accounted for an additional 6% (53% in total). Purslow (2005) also hypothesized that changes in other components such as cytoskeletal proteins may also contribute to changes in toughness and cook loss.

There was a significant interaction between cooking method and end-point temperature for cook time (Figure 1). As expected, it required a greater ($P < 0.05$) period of time for chops to reach 78.3 C than 68.3 C and direct contact also allowed the chops to reach their designated end-point temperature more rapidly. Chops prepared with direct heat required an additional 110 seconds to reach the greater end-point temperature (78.3 C), whilst chops cooked with dry convection required an additional 310 seconds to reach the higher temperature.

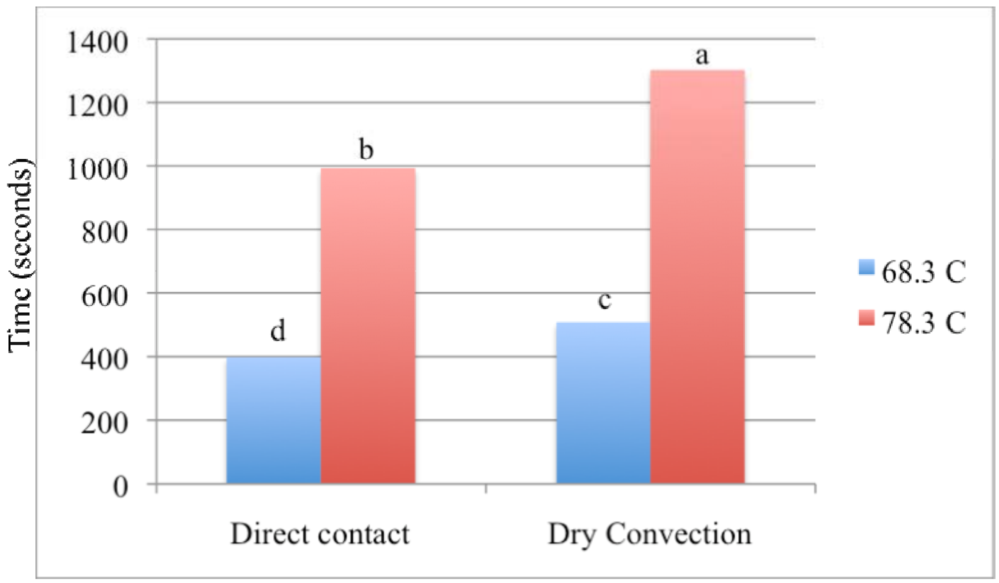

Figure 1. Least squares means for cook time by cooking methodology and end-point temperature. Least squares means bearing different superscripts differ ($P < 0.05$).

Cook time was highly correlated with cook loss ($r = 0.85$; $P < .0001$), and as such, there was also a significant interaction between cooking method and end-point temperature for cook loss (Figure 2). Taking chops to 78.3 C verses 68.3 C using direct heat resulted in 5.0%

additional cook loss, however when using dry convection it resulted in 9.5% additional cook loss. The greater amount of cook loss associated with dry convection is partially related to the chops being exposed to a heating treatment for a greater duration. Additionally, cook loss was likely reduced due to the direct contact of the cooking surface and the chop which may have seared the surface and also provided a physical barrier to prevent excessive moisture loss.

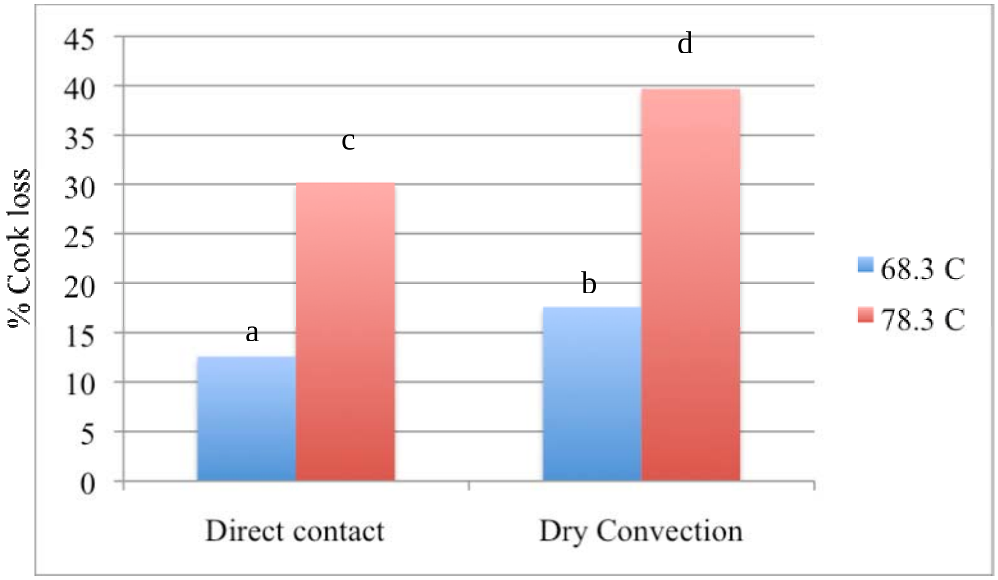

Figure 2. Least squares means for cook loss by cooking methodology and end-point temperature. Least squares means bearing different superscripts differ ($P < 0.05$).

5. Conclusions

Level of IMF did impact time to reach a specific end-point temperature or cook loss regardless of the cooking methodology. However, level of IMF did impact Warner-Bratzler shear force values. Pork chops that had Medium or High levels of IMF (> 4%) were more tender than those with Low IMF (< 1.6%), which may support the hypothesis that there is a threshold between 1.5% and 4.0% IMF that helps ensure an acceptable eating experience for consumers. Additionally, these results suggest that the improvements in tenderness can be obtained without targeting higher levels of intramuscular fat (> 4.5%) which could be less desirable for health conscious consumers.

Cook time was highly correlated with cook loss and there was a significant interaction between cooking methodology and end-point temperature with pork chops cooked to 78.3 C with dry heat convection resulting in the greatest time to reach their targeted end-point temperature and the greatest cook loss. Cook loss relates to juiciness, which is important as decreased juiciness ratings can negatively impact consumer perceptions of tenderness (via the halo effect) and over eating satisfaction. The results of this study indicate that marbling level, cooking methodology, and degree of doneness are all important factors that should be considered in the production and preparation of pork products to improve customer satisfaction and market share.

6. References

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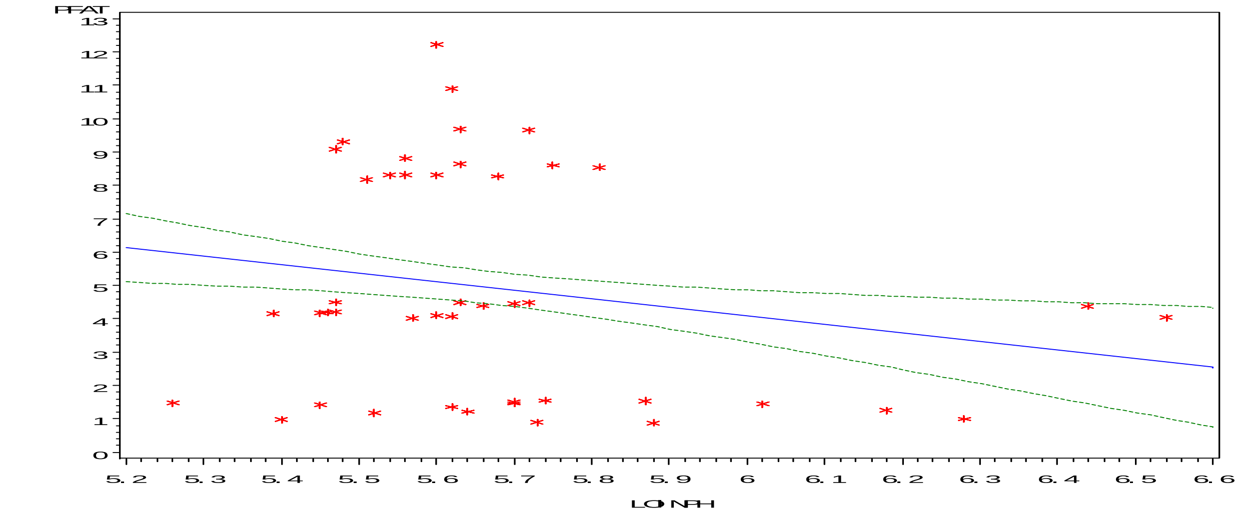
Appendix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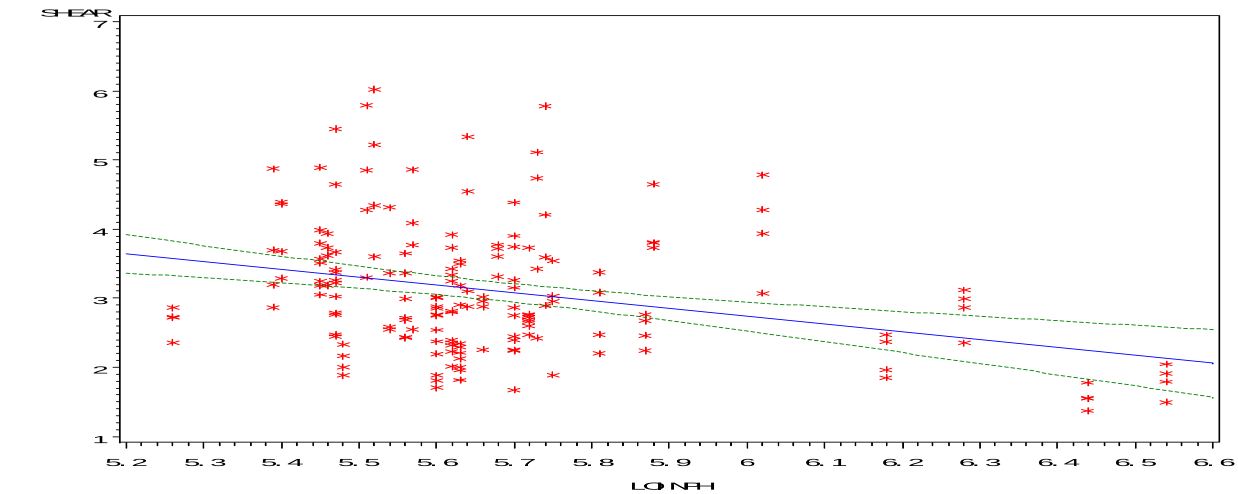
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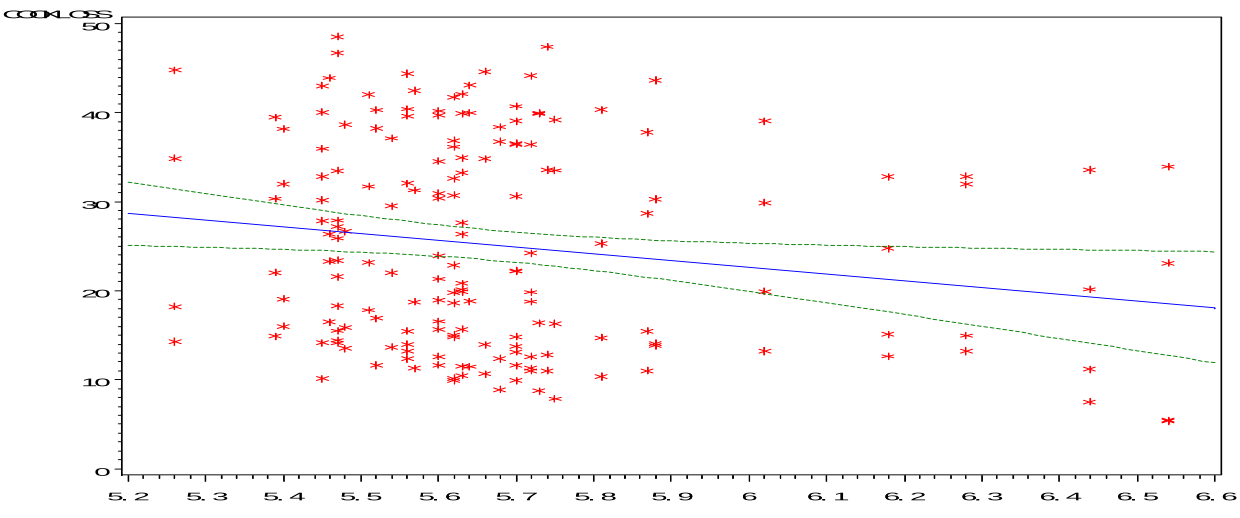
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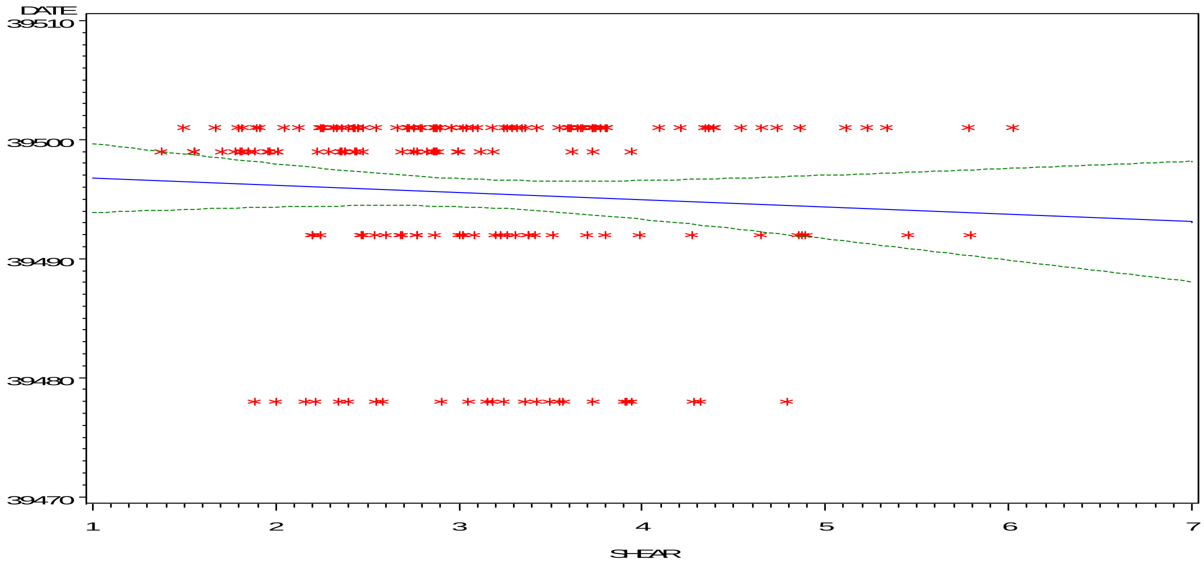
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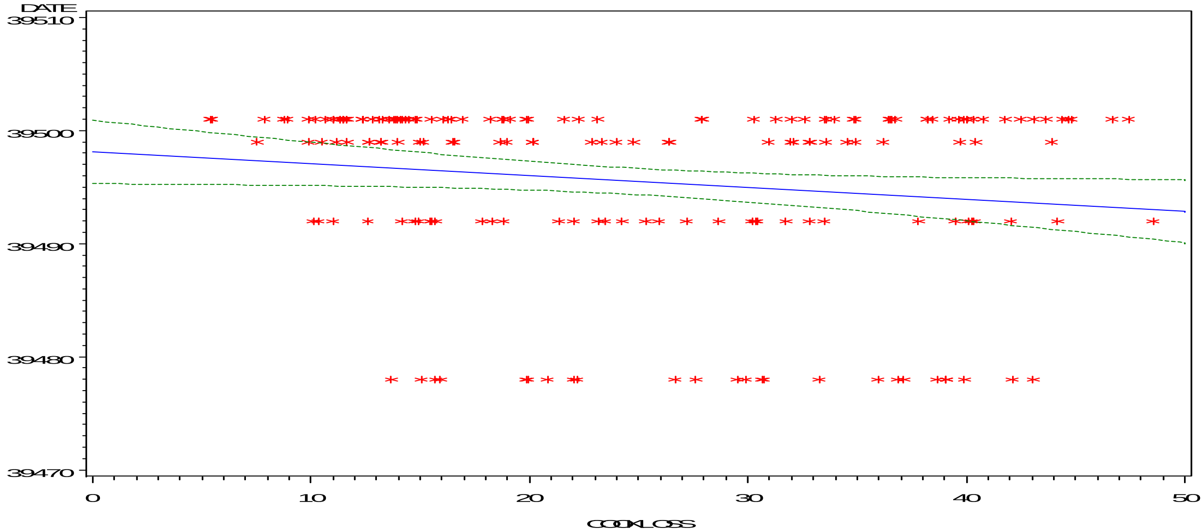
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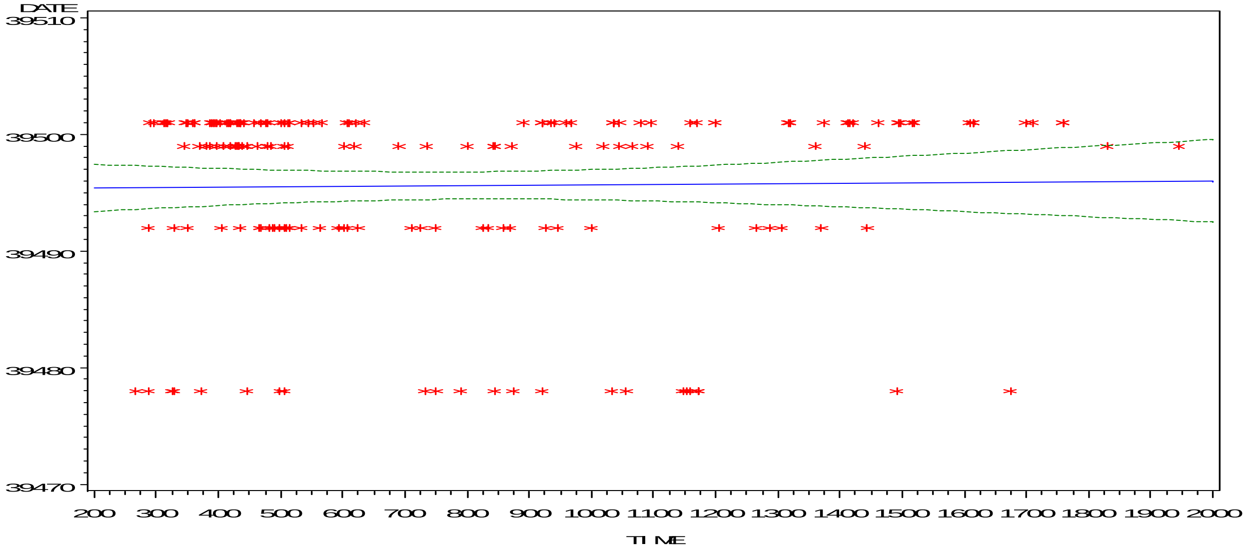
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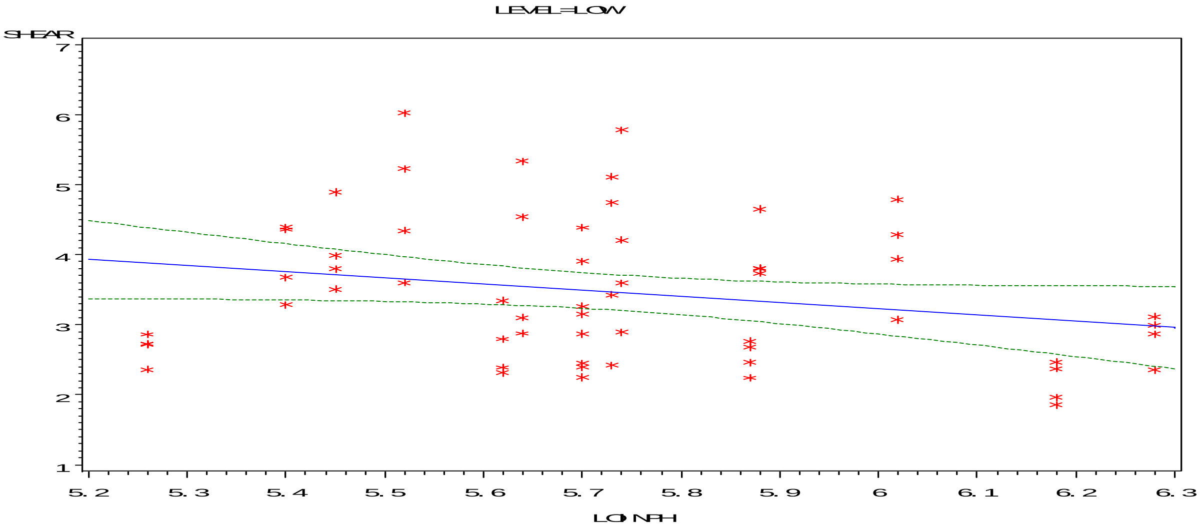
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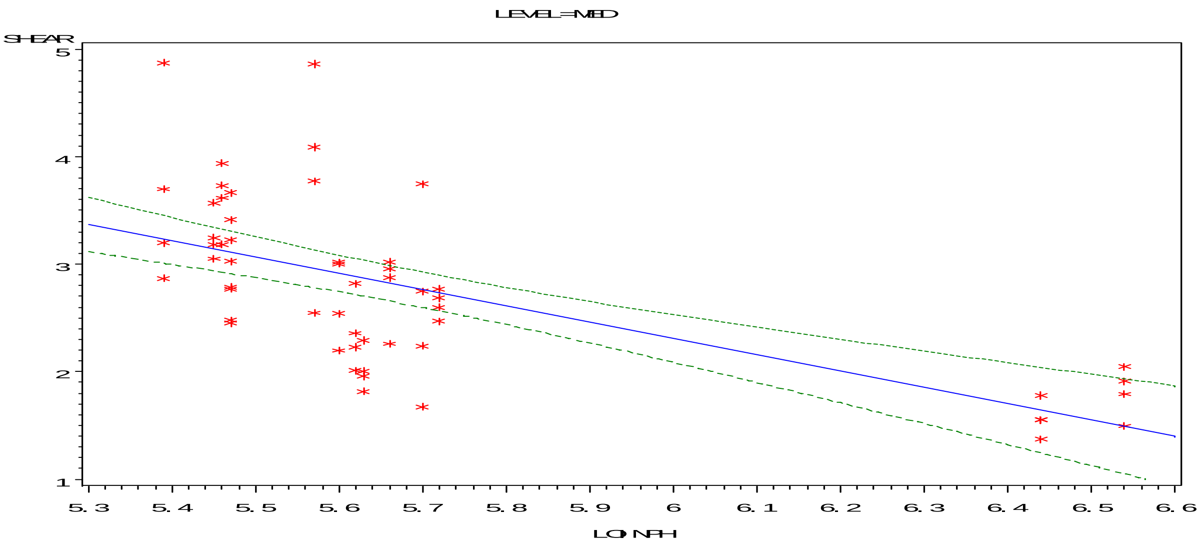
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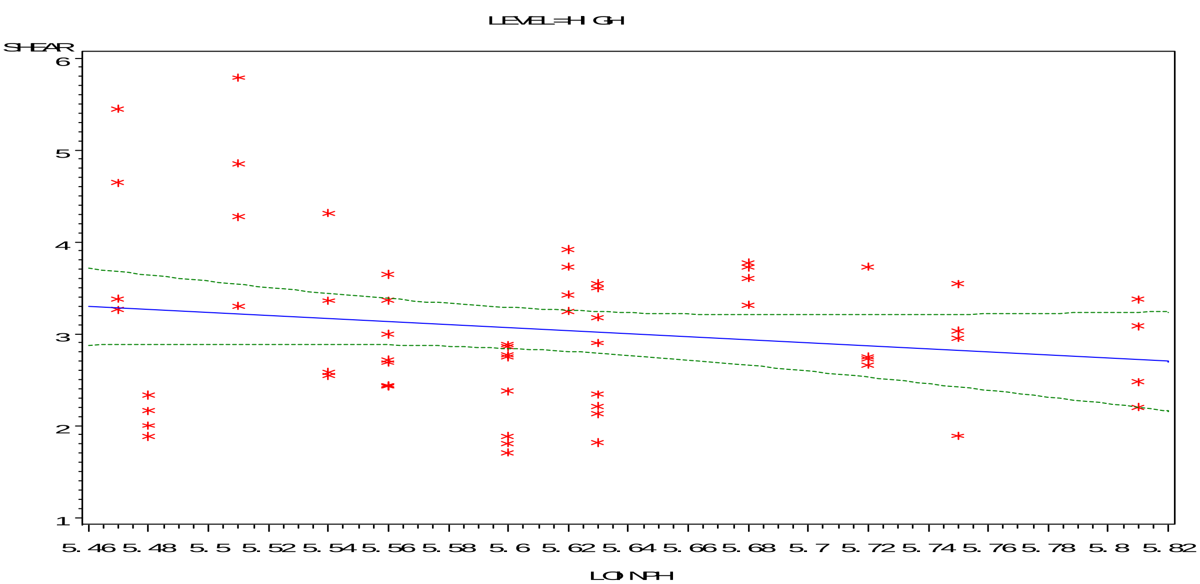
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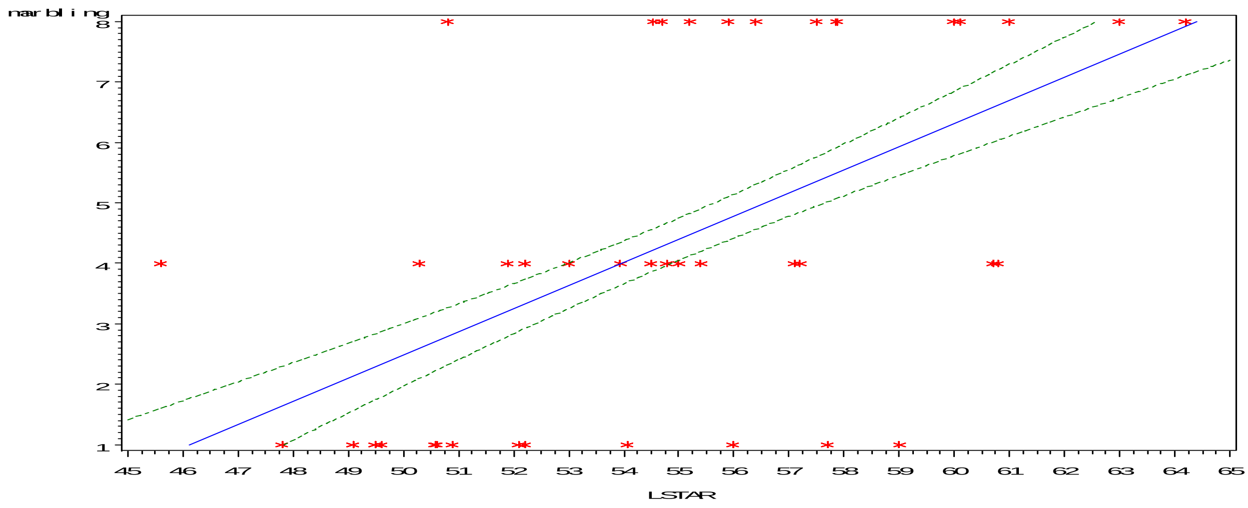
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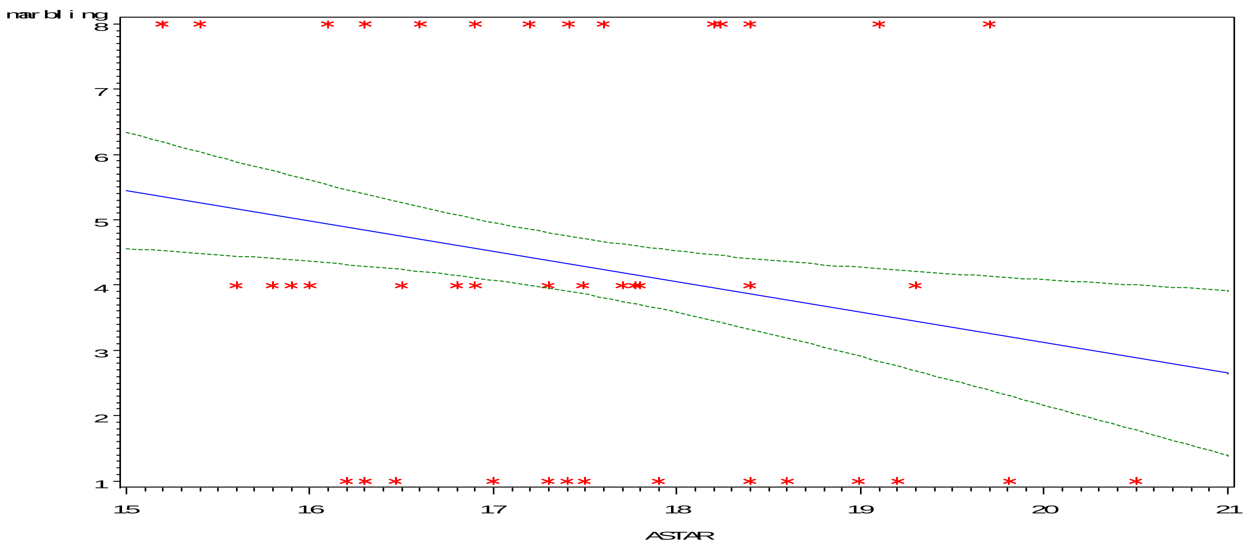
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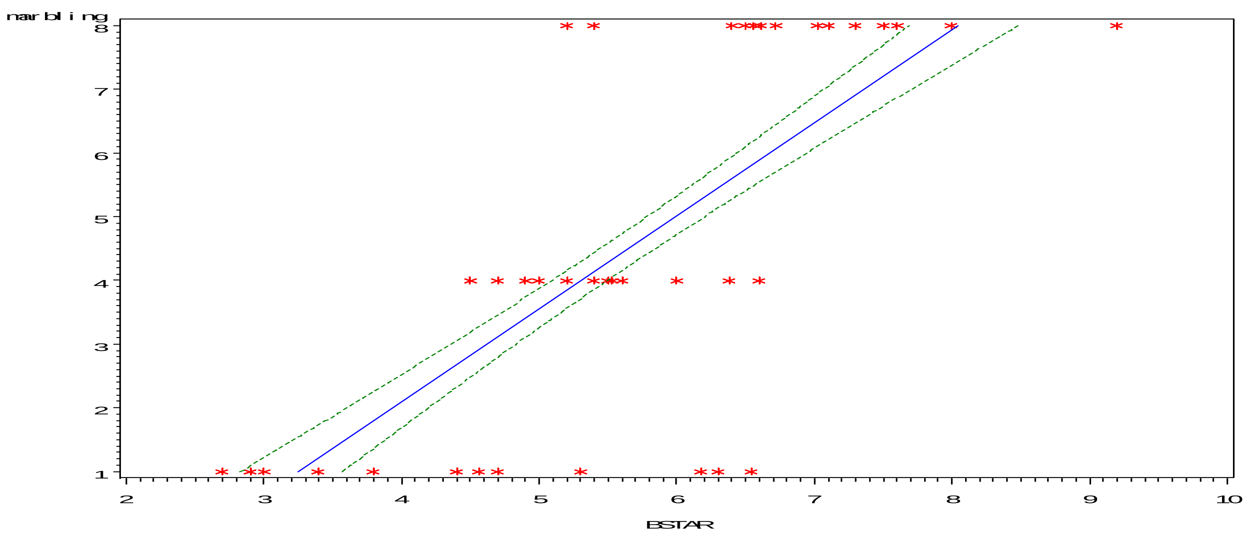
marbling
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