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AN OBJECTIVE METHOD TO MEASURE FIRMNESS IN FRESH PORK LOINS

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Introduction

The pork industry currently uses several different meat characteristics to separate fresh pork into quality groups. These characteristics commonly include pH, color, marbling, and firmness. While most of these quality measurements can be obtained through both subjective and objective methods, there is currently no objective method to quantify firmness of fresh meat either in the laboratory setting or in the plant. The pH of a fresh product is can be quickly measured with a portable pH meter such as the pH Star from SFK (SFK Technologies). There is no standard for subjective determination of pH. Color can be scored subjectively using standards such as the NPPC pork quality standards (NPPC 1991; NPPC 1999) or the Japanese Color Score tiles. Color can also be measured objectively with the use of colorimeters such as those produced by Minolta™, Hunter™, and ColorTec™. Subjective marbling scores may be obtained through visual evaluation, however, objective measurements, such as extraction with solvent or acid hydrolysis, are generally considered to be more precise. Of the previously mentioned quality characteristics, firmness is the only one that cannot currently be objectively quantified. Methods for measuring firmness include visual and hands on evaluation combined with knowledge from previous experiences. Consistency, repeatability, and uniformity throughout the industry are some potential problems with these methods. Standards currently utilized for firmness evaluation of fresh pork are the three-point scale described by the NPPC in 1999 and the five-point scale described by the Wisconsin pork quality standards in 1963 and the NPPC in 1991. These scales range from a score of one, being very soft and very watery, to the top score of either three or five, being very firm and dry.

Objectives

The primary goal of the following research was to identify a method, either destructive or nondestructive, to objectively quantify firmness of fresh pork loins. Focus was placed on the use of either a universal testing machine (i.e. Instron) or a texture analyzer.

Methodology

Part 1.

Forty-two fresh pork loins were selected from the boneless loin line of a commercial slaughter facility at 24 hours post mortem. Product was selected based on subjective firmness of the whole boneless loin. Using the NPPC 5-point scale, twenty-one loins of subjective firmness score less than 3 as well as twenty-one loins with subjective firmness score of greater that 3 were selected in hopes of finding forty-two total loins with a somewhat uniform subjective firmness distribution.

At two days post mortem, the blade end of each boneless loin was removed at the area of the tenth rib and the loin was placed randomly on a table for evaluation by a 5 member panel utilizing a 5-point scale (NPPC 1991). Four boneless loins with subjective firmness scores of 1, 2, 3, and 4 were made available to panelists as standards during evaluation. A loin with a subjective firmness score of 5 was not readily available. Panelist scores were evaluated for uniformity and all scores were averaged to determine the subjective firmness of each loin for use during analysis of data.

Following evaluation by the panelists, loins were prepared for evaluation with the TA.XT2 texture analyzer (Texture Technologies Corporation). It was decided from preliminary data that a compression of less than 40 % was most effective in identifying differences amongst various firmness scores of loins and that utilizing 2.54 cm chops worked better than utilizing the intact loin. With this in mind, four separate compression tests were performed on four separate chops from each loin. Duplicate compressions of a set distance (5 mm and 7.5 mm) and two compressions based on percent of chop height (20% and 30%) were performed on chops from each loin. The rationale for this is that if all of the chops were cut to the exact same width and did not deform or sag when placed flat then the 5 mm and 20 % compressions should yield very similar results (because 20 % of 25.4 mm is 5.1 mm and 30 % of 25.4 mm is 7.62 mm). However, because it was assumed that the less firm chops would sag when laid flat, it was not immediately clear which method would be more beneficial.

Chops were consistently cut to 2.54 cm by use of two knives mounted together. Two 10-inch Forschner cimiter knives (available from Koch Industries, Kansas City, MO, item no. 3367 00581) were bolted together at the handle to yield 2.54 cm between the blades. The double bladed knife was drawn through the loin to yield a chop of 2.54 cm and a chop of approximately 1.0 cm with each slice. The 1.0 cm chop was discarded and the 2.54 cm chop was utilized for analysis. This ensured that the texture test was performed on a fresh cut surface each time and dehydration did not affect the results. Chops were placed on the platform of the TA.XT2 and the test initiated within 30 seconds of cutting. After it was placed on the platform, it was allowed a 5 sec rest period prior to being compressed in the center of the chop. Random sampling of loin temperature determined that they were not different and averaged 3.0° C.

The TA.XT2 was set up in a cold room at the meat science laboratory with an air temperature of 3.1° C overnight and allowed to equilibrate. The texture analyzer was equipped with a 5 kg load cell and 25 mm diameter flat acrylic cylindrical plunger for the tests. It was calibrated using a 2 kg check weight prior to each day's activities. The analyzer was set with a pre test speed of 4.0 mm / sec, a test speed of 2.0 mm / sec, a post test speed of 2.0 mm / sec, and a trigger force of 1.0 g (when the load cell detected 1.0 g of force being applied to it, it would capture this point as the initial height of the product and start the appropriate compression test from the four described earlier.) Data was collected using Texture Expert, version 1.11. Dependent variables captured and/or calculated by the Texture Expert software included initial height of product (when the probe contacted the meat), peak force of the second curve, area under the first curve, area under the second curve, area over the curve measuring adhesiveness, hardness (peak force of the first curve), adhesiveness, springiness, cohesiveness, gumminess, chewiness, and resilience. Because the data generated a force * time curve, all area calculations will have the units of grams * seconds or g*s. Although it has been documented that gumminess and chewiness should not be calculated on the same product because gumminess is a measure of semisolid foods and chewiness is a measure of solid foods, both were calculated initially (Szczesniak 1995).

Statistical analysis was performed using the REG procedure of SAS on all measurements independently in addition to using the MAXR option to create the best fit equation using all variables available and setting them equal to subjective firmness in the model (SAS Institute, Inc. version 8.2 1999). This was done for all four compression tests previously described in this chapter.

Part 2.

A total of 233 fresh boneless pork loins were transported to the University of Illinois Meat Science Laboratory for further evaluation. Loins were evaluated over a 2-day period with 100 loins evaluated on day 1 and 133 loins evaluated on day 2. Vacuum bags were opened and blade ends were removed at the area of the 10th rib for panelist subjective firmness evaluation. Loins with subjective firmness scores of 1, 2, 3, 4, and 5 were made available for the 7-member panel during evaluation. Panelist subjective firmness scores were averaged to determine the subjective firmness score for each individual loin.

Following panel evaluation, loins were analyzed using the TA.XT2 texture analyzer (Texture Technologies Corporation). Compression values of 7.5 mm from contact with the chop and 30 % of initial chop height were utilized for this population of loins. Chop preparation and machine setup were identical to that in Part 1.

Dependent variables utilized for the analysis included initial chop height, area 1 (area under the first curve), and area 4 (area under the curve from the first compression but stopping at the peak of that curve). Two separate regressions were run to determine the effect of using the equation calculated from area 1 versus using the equation calculated from area 4 to predict subjective firmness. The reg procedure of SAS was utilized to asses the effectiveness of predicting subjective firmness scores (SAS Institute, Inc. version 8.2 1999).

Results & Discussion

Part 1.

Subjective firmness scores as determined by the panel ranged from 1.0 to 4.0 for the population of 42 loins. Ideally, the range would have been from 1.0 to 5.0, however, no loins of firmness score 5 could be identified during loin selection. Figure 1 displays a histogram for the population of loins as they relate to subjective firmness scores. Even though loins were selected to be above and below a firmness score of 3, it is difficult to not select loins of average firmness.

Results from the analysis of the data from all four compression types indicated that certain calculations correlated consistently better with subjective firmness scores than others. Based on these results, the five following dependent variables were selected to build the prediction equation: initial height, hardness (peak force of the first compression), force 1 (peak force of the second compression), area 1 (area under the curve from the first compression, and area 4 (area under the curve from the first compression but stopping at the peak of that curve). Not much was gained concerning the R^2 when the MAXR option of SAS was utilized. The final prediction equations for each compression method included four models. Subjective firmness was regressed against 1) height and force 1, 2) height and area 1, 3) height and area 4, and 4) height and hardness. The R^2 values for each of these equations can be seen in Table 1. Multiple prediction equations were created to use in conjunction with future data sets. However, based upon the results, the 7.5 mm compression coupled with the area under the first compression curve was the most likely candidate to create the prediction equation for this population of fresh pork loins. Figure 2 displays the plot of subjective firmness by height and the area under the curve from the first compression (area 1) that yielded a regression line with an R^2 of 0.54. Figure 3 displays a similar plot, but from area 4 rather than area 1. The R^2 from the equation with area 4 is 0.55. The range of values for the area under the curve from the first compression (area 1) was from 246.55 to 1295.73 while area 4 was 218.06 to 1122.09.

Part 2.

Subjective firmness scores as determined by panel evaluation ranged from 1.7 to 5.0 with a mean of 3.0 for the population of 233 loins. Predicted firmness values were calculated using two separate equations, one with height plus area 1 and one with height plus area 4, and yielded ranges from 2.4 to 5.8. The prediction equations utilized were previously generated from the population of 42 loins using height, area 1, and area 4 (Part 1).

Figure 4, a histogram displaying the subjective firmness scores of the population of 233 loins, demonstrates that this would be considered a normal distribution of loins centered around an average score of 2.98. The bulk of the values are between a subjective firmness score of 2.5 and 3.5. One must keep in mind that when looking at a population that is a small segment of the overall scale, regression can be very difficult because one can not predict how the population would have looked beyond the present data. Histograms of predicted values from equations utilizing area 1 and area 4 can be found in Figures 5 and 6, respectively.

Keeping this in mind, regressions were performed to compare the predicted firmness values to the subjective panel firmness values. Figure 7 displays the regression of subjective firmness with predicted from height plus area. The heavy concentration of loins with average firmness (scores of 2.5 to 3.5) can be easily detected in this figure. The R^2 value from this regression was 0.30. Had this population contained more loins with low and high firmness scores, the plot may have been extended and a higher R^2 might have been achieved. Figure 8 displays similar results, but utilizes the dependent variables height and area 7 from the texture analyzer. The same trends visible in Figure 4 are also visible in Figure 8. The R^2 value from the regression involving area 4 was 0.29.

Conclusions

The prediction equation generated with this data did a moderately successful job of correlating objective values obtained by the TA.XT2 texture analyzer to subjective values as assessed by a panel. The authors feel that the approach used herein was successful to a point. It is believed that a better prediction equation could be built with a larger and more uniformly distributed population of loins concerning firmness scores. Upon building a more precise equation, it would then be possible to create a standard protocol to be used in future studies. Future experiments should not only evaluate the accuracy and repeatability of the method, but also search for quick and possibly hand held devices to be utilized in conjunction with or separately from the texture analyzer.

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Tables and Figures

Table 1. R^2 Values for Selected Variables Regressed with Initial Height vs. Compression Setting

Compression Method	Force1(g)	Area4(g*s)	Area1(g*s)	Hardness(g)
5.0mm	0.40	0.32	0.32	0.38
7.5mm	0.49	0.55	0.54	0.49
20%	0.46	0.36	0.38	0.43
30%	0.35	0.39	0.36	0.35

Figure 1. Histogram displaying the subjective firmness distribution of 42 loins.

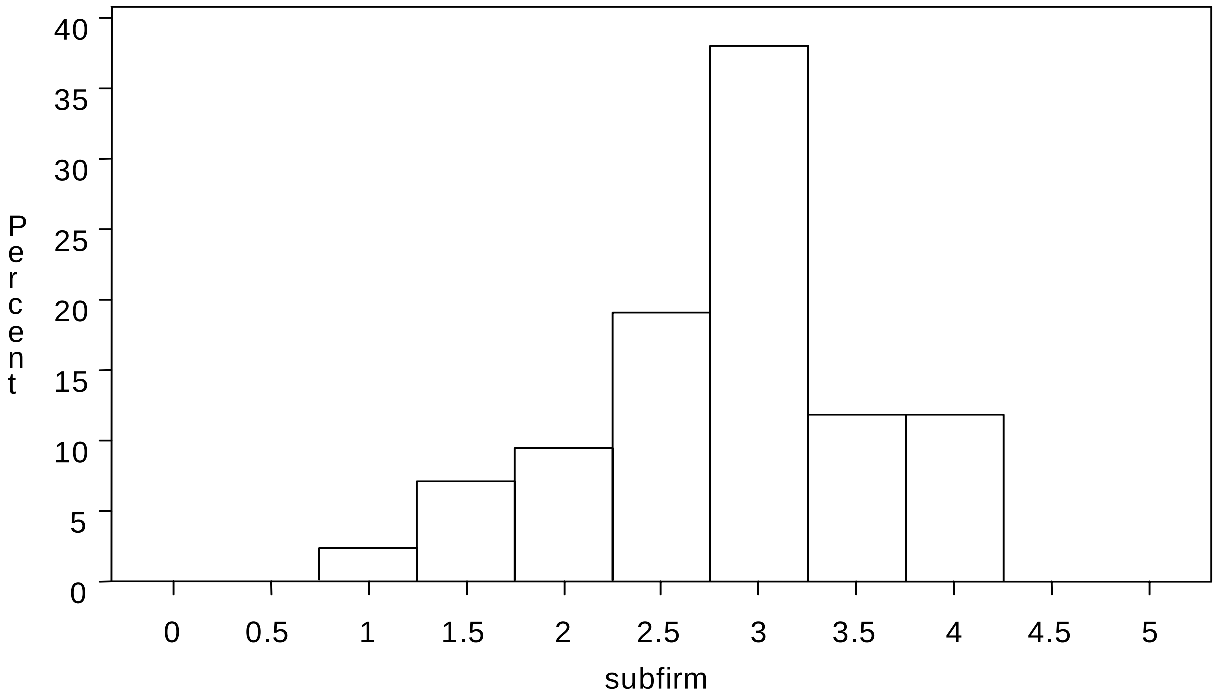
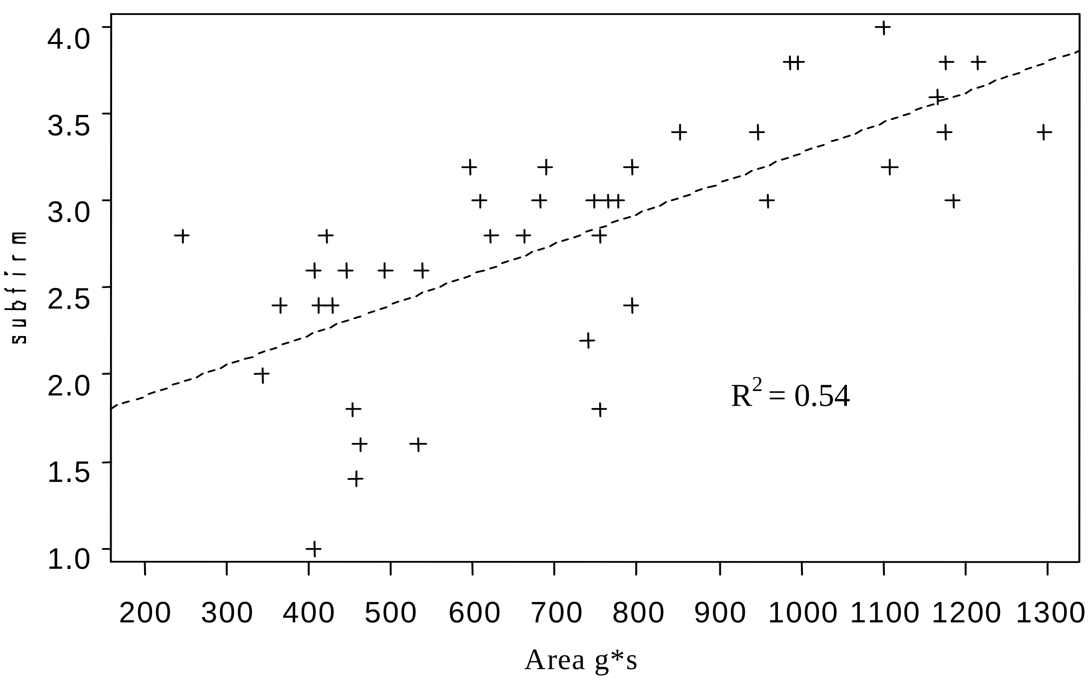
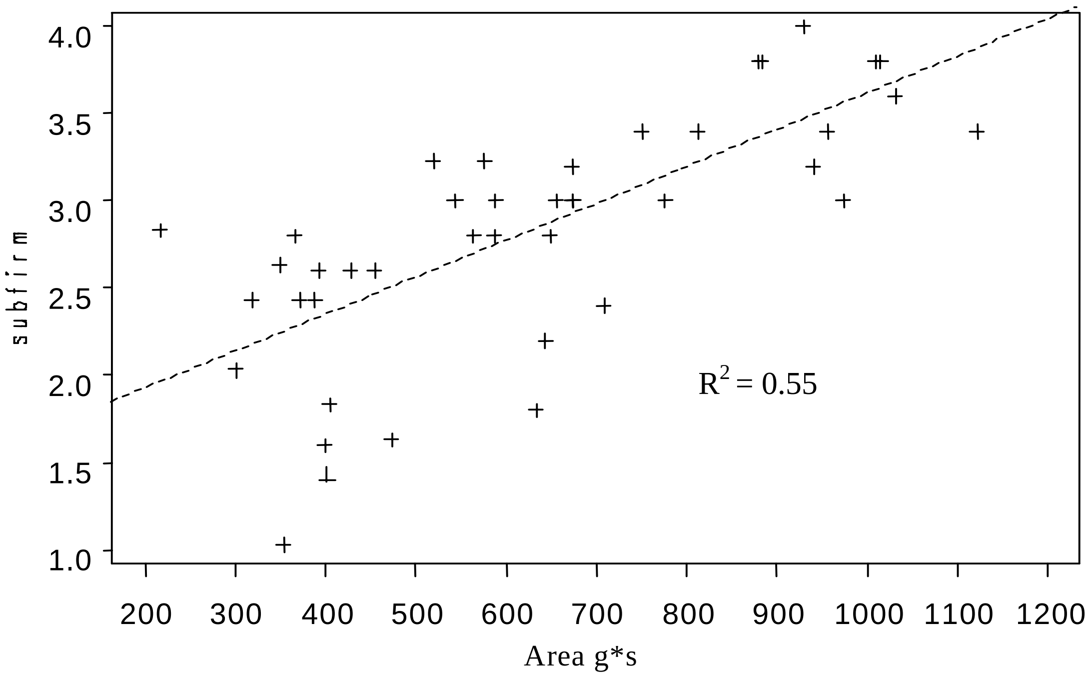


Figure 2. Plot of subjective firmness = height + area 1



Equation: subjective firmness = -1.1449 + 0.1239 height + 0.0015 area1

Figure 3. Plot of subjective firmness = height + area 4



Equation: subjective firmness = -0.9284 + 0.1119 height + 0.0018 area4

Figure 4. Histogram Displaying Subjective Firmness Scores of Panel.

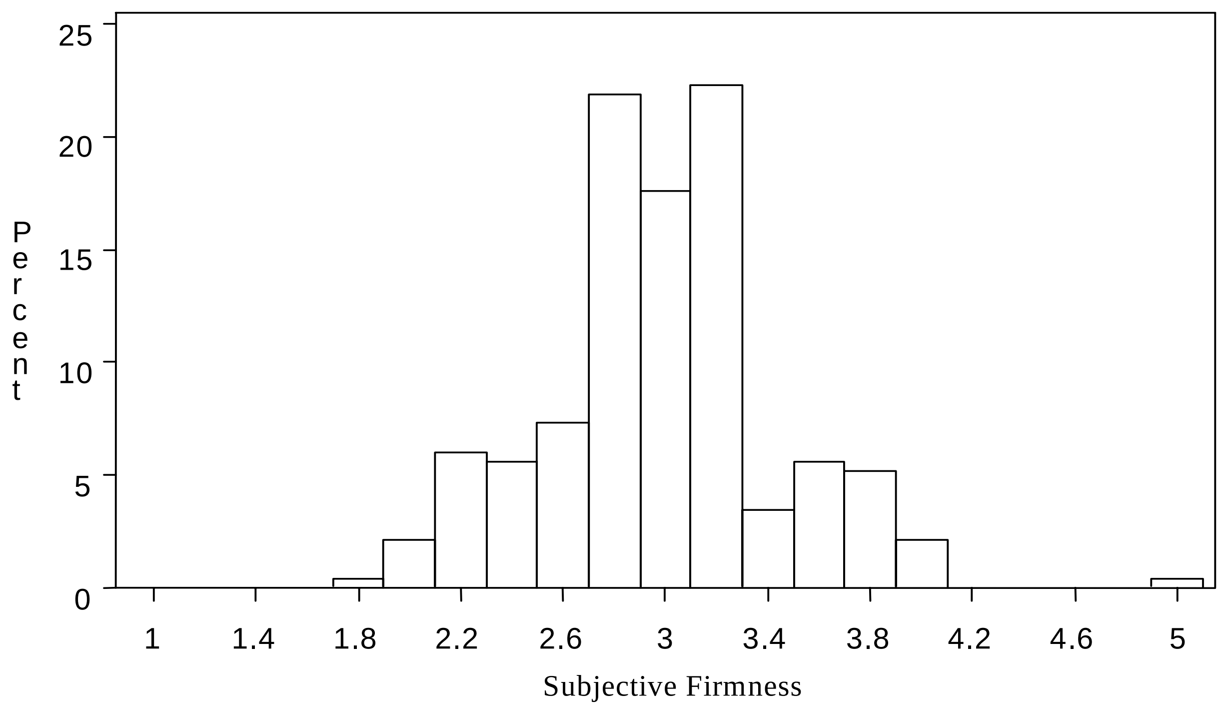


Figure 5. Histogram Displaying Predicted Firmness Scores from Area 1.

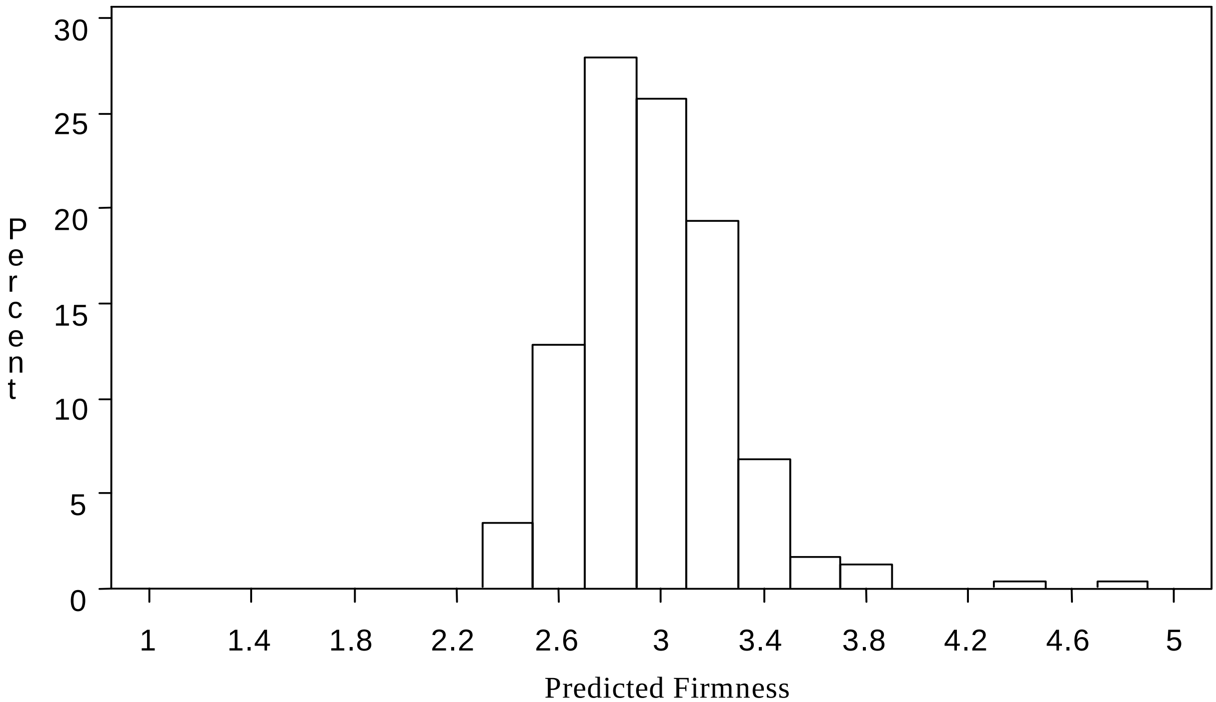


Figure 6. Histogram Displaying Predicted Firmness Scores from Area 4.

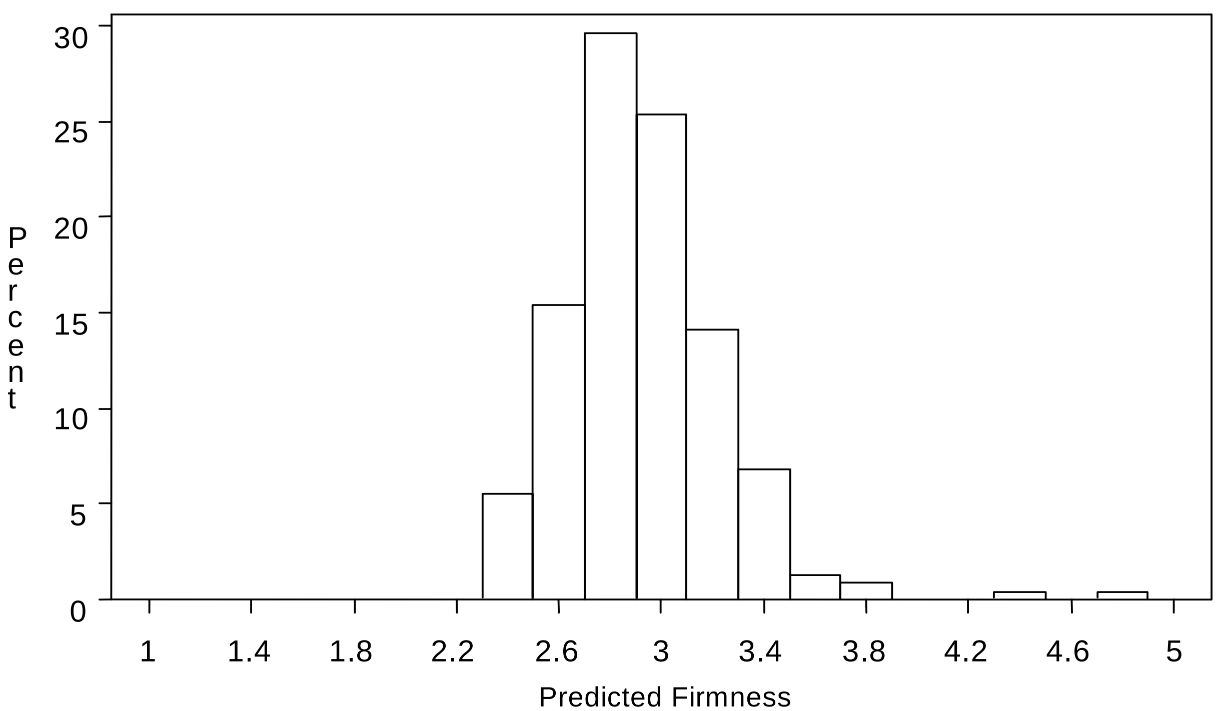
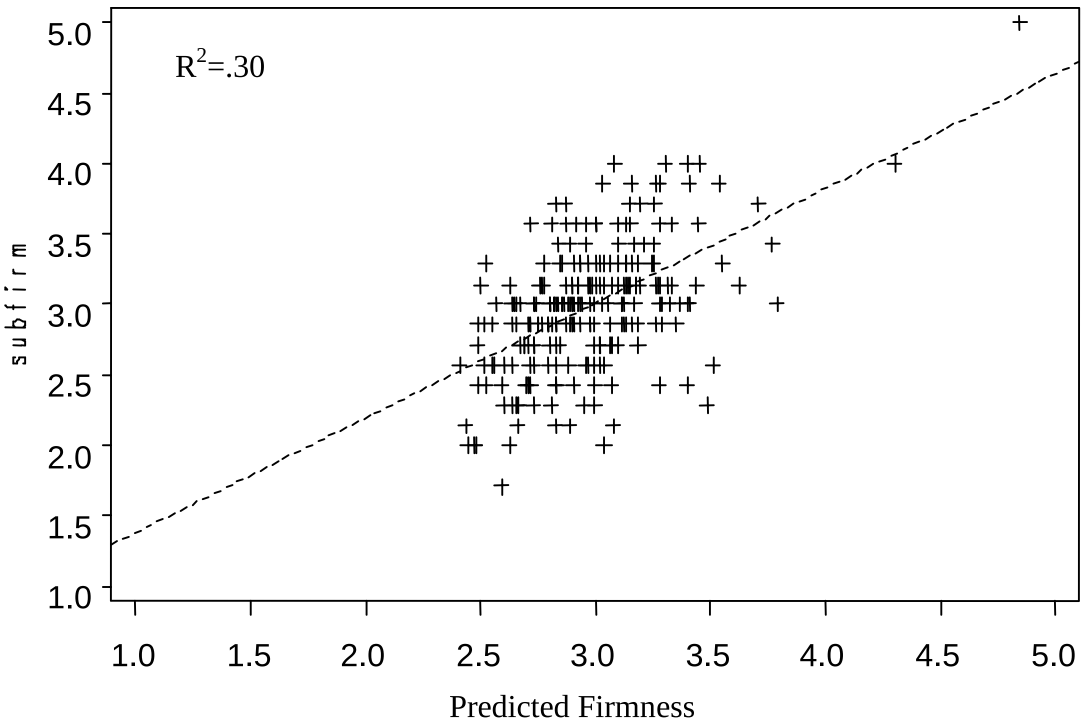
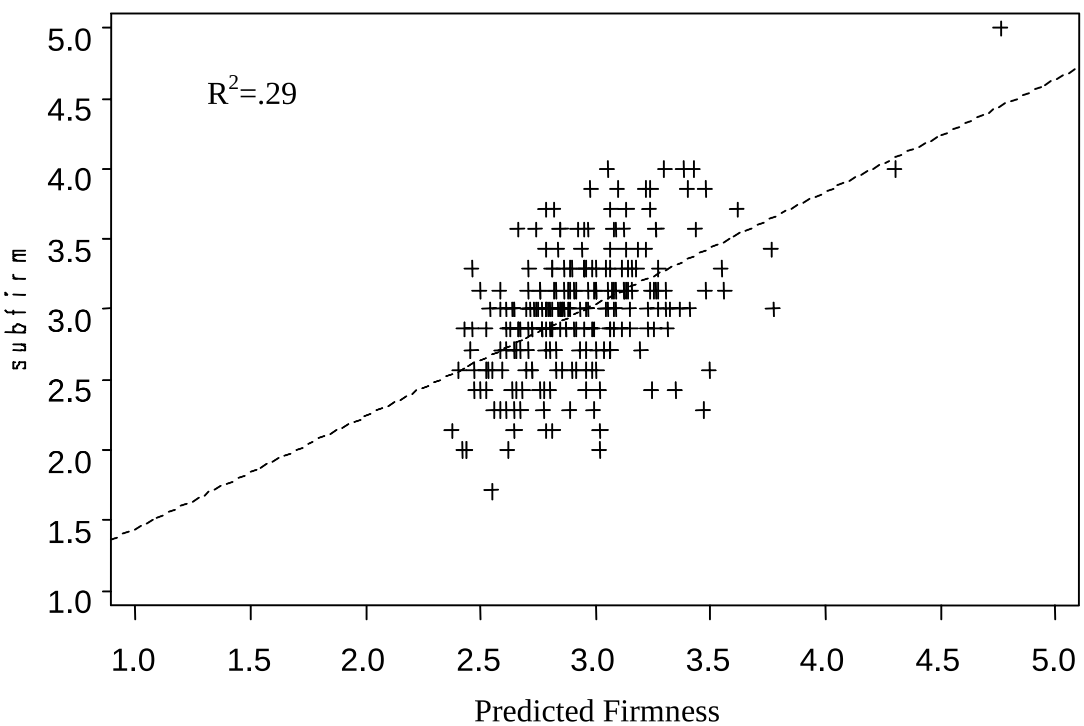


Figure 7. Regression Of Subjective Firmness By Predicted Firmness As Calculated From Initial Product Height Plus Area 1.



Equation: Subjective Firmness = 0.5653 + 0.8138 * Predicted Firmness

Figure 8. Regression Of Subjective Firmness By Predicted Firmness As Calculated From Initial Product Height Plus Area 4.



Equation: Subjective Firmness = 0.645 + 0.7973 * Predicted Firmness