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COMPARISON OF ULTRASOUND BASED GRADING TECHNOLOGIES

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Objectives

The overall goal of this project was to examine all of the various different types of ultrasound technology and ultrasound analysis techniques available in order to determine which could be used most effectively to develop an objective grading system. Results would allow comparisons: A) between different ultrasound technologies and B) between ultrasound technologies and the current grading system. Technology comparisons were made in light of the eventual requirements of an ultrasound based grading system. A total automated grading system would evaluate both meat quality as directly indicated by taste panel assessment and yield of trimmed retail product and be applicable to either hide-on or hide-off carcasses.

1. Design and build an ultrasound instrument that allowed evaluation of multiple ultrasound technologies and analytical techniques without human operator input at the same time (no commercial devices are available for several of the technologies evaluated). Further, it had to collect specific data appropriate for both quality grading and yield grading.
2. Development of needed computer software for radio frequency (RF) or image data analysis.
3. Collect detailed carcass information, cutting data and sensory evaluation on scanned cattle.
4. Select ultrasound measures related to quality or yield, then develop prediction equations for yield and quality based on ultrasound and existing USDA measures to allow assessment of the various ultrasound technologies.

Materials and Methods

Equipment and Data Acquisition

The machine we built basically consists of 4 components; a high power ultrasound signal generator and transducers, a control and data acquisition computer, a motor driven, 4 axis positioning system (The 3 x, y, z dimensions as well as transducer tip angle, Θ) and a structure to attach the transducer and positioning system to the carcass. A full description of this instrument and its capabilities has already been published (Hein et al, 1992). Data were analyzed "off-line" so obtaining a wide range and large amount of high quality data was much more important than speed. Two standardization checks of instrument performance were conducted before each scanning session (hot hide-on and hide-off scans were completed in the same session) to verify machine operation and for latter use in calibrating data and images. 1) A custom "cattle phantom" similar to medical "phantoms" was designed and scanned. This phantom is made of proprietary plastic with known acoustical properties and contains a variety of point and diffuse targets. 2) A steel plate reflector in silicone oil was also scanned. This check allowed absolute calibration of transducer and amplifier performance. On each carcass, RF signal data was obtained immediately following slaughter (hot, hide-on), after hide removal (hot, hide-off) and after an over night chill (cold, hide-off; carcass temp ranged from 6°C to 13°C). Carcasses were not split until after the cold scan so that only a single positioning structure had to be made. Scans were made on both sides of the carcass and at 3 locations on hide-off and cold carcasses. The RF signal data from phantom and carcass scans was digitized at 50 mHz and stored on 940 MB write-once read-mostly (WORM) optical disks (Panasonic). The RF data comprised about 100 MB per animal.

Ultrasound Measures and Carcass Data

A number of ultrasound technologies and analytical techniques yielding an array of acoustic property measures were evaluated. Within each category of ultrasound technology, from 5 to 60 individual parameters were determined. USDA quality and yield grade traits were evaluated at 48 hr postmortem. Samples for sensory evaluation and Warner-Bratzler shear were vacuum packaged and held at 4°C for either 0, 7 or 14 days, then frozen (-30°C) and held for subsequent evaluation. Carcass cutting yields and cut composition was evaluated on the left of each carcass at 48 hr postmortem.

Table 1. Ultrasound techniques

Technique	Technology basis
Automated thickness measurements	Image
Elastography measures	RF/Image
Markovian and Run-length texture properties	Image
Properties related to acoustic attenuation	RF
Reflected signal spectral properties	RF
Scattering site size characteristics and distribution	RF/Image
Velocity measurements	Image

Results

Cattle used in the study covered the range of existing grades and represented a variety of crossbred types. Cattle were selected so that the distribution roughly corresponded to commercial slaughter percentages. As expected, carcass characteristics correlated much better with actual yield than with eating quality. Eating quality, as measured by taste panel tenderness score (14=best, 0=worst) or Warner-Bratzler shear force had only moderate correlations with any carcass measures. Fat thickness measures had the highest correlations (r=-0.37 to -0.34 with day 0 WB shears; r=0.22 to 0.17 with day 14 taste panel tenderness). Marbling and longissimus fat content (LDEE) had significant, but fairly low correlations with quality indicators. Marbling and LDEE had r= 0.22 to r=-0.29 for taste panel tenderness and shears, respectively. Taste panel scores at day 3 had no correlation with marbling or LDEE, with even the low correlation only becoming apparent after aging. Measures of marbling, but not fat thickness, correlated with day 14 taste panel scores for juiciness (r=.20 to r=0.24).

Product yield, expressed as the *percent* of closely trimmed retail product, was highly correlated with all the various measures of fat thickness (r=-0.79 for 12th rib 3/4 fat to -0.69 for lumbar fat at 5 cm). Correlations to muscle measures were lower. Only last rib loin muscle area (LMA) and muscle thickness (MT) at 5cm had r≥0.3. Both KHP fat (r=-0.50) and weights were significantly correlated to yield. In contrast, product yield expressed as the *pounds* of closely trimmed retail product, was highly correlated with all the various measures of muscling (r=0.68 for last rib LMA to -0.44 for last rib MT at 15 cm). Fat thickness measures did not correlate to yield in *pounds*. Measures of carcass weight and KHP fat were all correlated highly to yield in *pounds*.

Correlations between taste panel tenderness and Warner-Bratzler shears were significant at all time periods. Correlations were initially high but decreased with post mortem aging. On day three the correlation was r=-0.51, but by day 14 taste panel tenderness and shears were correlated at r=-0.35. Both juiciness and beef flavor correlated with tenderness. This correlation was initially low but increased with post mortem aging. At day 14, correlations of juiciness and beef flavor with tenderness were r=0.37 and r=0.60, respectively. One comparison of particular interest is day 3 Warner-Bratzler shear with taste panel scores at day 14 (r=-0.33 for tenderness). This is an important number because it represents the *best* correlation of a measure that could be made in a packing plant after slaughter to predict eating quality as seen by consumers 2 weeks later following retail distribution. The correlation reflects differences in aging which does not occur uniformly across different qualities of meat.

Correlations of ultrasound measures with quality and yield

A number of acoustical parameters correlated well with yield or quality. However, a small number of parameters correlated with *both* quality and yield. We believe such parameters are probably related to fatness, since in the carcass, only fat measures were related to both yield and quality. For the majority of ultrasound parameters, better correlations were obtained on warm carcasses than on cold carcasses although the reverse was true in some cases. Correlations for most parameters were not particularly improved by grouping cattle for analysis (ie Choice only) and we considered this to be a positive sign that ultrasound grading is potentially robust. A number of different types of parameters had significant correlations with Warner-Bratzler shear and taste panel tenderness. The numerical value of ultrasound correlations to quality attributes was similar to that of carcass measures for quality attributes in that they were generally low. We narrowed the number of parameters for subsequent analysis. We looked for those that correlated with both taste panel tenderness and Warner-Bratzler shears, believing these would be the most useful predictors. In general, correlations of ultrasound measures were higher with tenderness and shears on day 3 than on day 14.

Several attenuation measures made by FlexTech were highly correlated with day 3 shears on hot carcasses. Six parameters were significant at the P<.01 level (r=-0.3- to r=-0.52). However, only 3 of these (OSA, OSB, SLB) were also significantly correlated with tenderness at day 14. Run length parameters R0 and R6 and Markovian parameters M5, M6 and M19 had the highest significant correlations with taste panel tenderness at day 14 (r=-0.23, to r=0.18). The highest correlation of texture measures were with day 0 Warner-Bratzler shears on hot hide-off carcasses (M2, r=-0.25, P<.01).

The highest correlations of any individual acoustic parameters was with yield. These were measures of attenuation derived from backscatter images using an a-line correlation technique developed for this project (Roger Scheer, MS thesis, 1994). On hot carcasses, parameters A10, A11 and A12 had correlations of -0.56, -0.59 and -0.62 with retail yield. These parameters did not correlate for cold carcasses. A set of proprietary attenuation measures made by FlexTech also had good correlations with yield on hot carcasses. Parameters OSB, SLB, SLA and TV had correlations of r=-0.54, 0.47, 0.44 and 0.44, respectively. Another set of parameters created for this project with good correlations to yield are power spectrum measures and ratios. Parameters related to reflected power over the longissimus muscle (MP, MPmin, MPmax and MP/CP) had significant correlations with yield in hot carcasses (r≈0.32) and cold carcasses (r≈0.39).

Fully automated measures of fat and muscle correlated moderately well with yield but not as well as carcass measures. It should be noted that even manual measures of fat and muscle from the ultrasound images did not correlate as well as carcass measures, a result typically seen in the literature. Several Markovian texture properties had low but significant (P<.01) correlations with yield (r≈0.20 to 0.28). This correlation is true only at a specific transducer angle. We do not have a strong biological rational for the correlation other than that these parameters are also correlated to several fat thickness measures and to the fat content of the longissimus.

References

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