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Technical note: The effect of freezing on Warner-Bratzler shear force values of beef longissimus steaks across several postmortem aging periods¹

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ABSTRACT: The objective of this study was to compare fresh and frozen protocol procedures for Warner-Bratzler shear force (WBSF) determination on steaks aged for different periods of time. The fresh protocol consisted of measuring WBSF on steaks cooked on the exact day the aging period ended. The frozen protocol consisted of measuring WBSF on steaks that were aged, frozen (-16°C) for approximately 2 mo, thawed for 24 h, and then cooked. Twenty-two strip loin steaks from each of 20 crossbred heifers and steers were individually vacuum-packaged and assigned to either the fresh or frozen protocol and one of 11 aging periods (1, 2, 3, 4, 5, 6, 7, 10, 14, 21, or 35 d). The frozen protocol resulted in lower ($P < 0.05$) WBSF values than the fresh protocol for beef longissimus steaks that were aged for 1, 2, 3, 4, 6, 7, 10, 14, or 35 d postmortem. An interaction ($P < 0.05$) between protocol and postmortem aging resulted

from larger differences between protocols at shorter aging periods than at longer aging periods. Correlations and mean differences revealed that frozen protocol WBSF values were not highly indicative of fresh protocol WBSF values at the same period of postmortem aging, but rather suggested that frozen protocol WBSF values at shorter aging times were useful in estimating WBSF values from fresh protocols at longer aging times. Cooking loss was higher ($P < 0.05$) for frozen vs fresh protocol steaks at all aging periods except for 14, 21, or 35 d. These findings suggest that if research constraints warrant the freezing of samples, shorter aging periods before freezing (6 and 7 d) should be used to estimate WBSF of fresh aged beef (14 to 21 d). In trials in which several postmortem aging periods or very short aging periods are of interest, we recommend that WBSF be assessed using the fresh protocol.

Key Words: Aging, Beef, Freezing, Tenderness

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Introduction

Warner-Bratzler shear force (WBSF) has been established as a standard for prediction of beef tenderness (Smith et al., 1969). Thus, researchers have evaluated WBSF protocols and their effects on subsequent tenderness values. Recently, the importance of standardizing core orientation and cooking conditions for WBSF values has been demonstrated (Wheeler et al., 1994) and numerous variables that affect WBSF, including thawing of frozen steaks, sampling, aging, cooking, and coring, have been characterized (Wheeler et al., 1996).

Because meat is a perishable product and many experimental conditions, time constraints, and schedul-

ing difficulties exist, samples must often be frozen for a period of time before tenderness can be assessed. Several researchers (Law et al., 1967; Smith et al., 1969; Wheeler et al., 1990) have designed studies exploring the effects of freezing on beef tenderness by aging the samples, storing the samples frozen, thawing, and then cooking the samples, thus emulating many research situations. However, findings from the studies are inconsistent, so the effect of freezing on WBSF values remains unresolved. Furthermore, to our knowledge, the effect of freezing on WBSF measurements across numerous aging periods has not been addressed. Therefore, the objective of this study was to determine the effect of freezing on WBSF values of cooked beef longissimus steaks across several postmortem aging periods to aid in standardizing WBSF measurement procedures.

Materials and Methods

Animal Management and Harvest

Twenty progeny (6 steers and 14 heifers) from random matings of three Charolais sires to Angus-cross-

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bred cows were managed uniformly from birth through the finishing phase (finishing period ranged from 102 to 136 d). Cattle (15 to 16 mo of age) were harvested in three groups (each group represented the entire feedlot pen) at the South Dakota State University Meat Laboratory when visual evaluation and ultrasound scans indicated that they had attained approximately 1.0 cm of external fat thickness at the 12–13th rib.

Postmortem Sampling and Storage

Following a 24-h chill period in a 1°C cooler, right sides of carcasses were ribbed between the 12th and 13th ribs, and two longissimus steaks were removed from the 13th rib section. One steak (1-d steak) from each carcass was individually vacuum-packaged and assigned to frozen storage (–16°C) and one steak (1-d steak) was cooked at 1130 on the same day (48 h postmortem). At 48 h postmortem, left sides of carcasses were ribbed between the 12th and 13th ribs and USDA yield and quality grade data (USDA, 1997) were collected by experienced evaluators. Strip loins (IMPS 180; NAMP, 1997) from left and right sides were also removed at 48 h postmortem.

Eleven 2.5-cm-thick steaks were immediately sliced from each left side strip loin. Steaks were vacuum-packaged individually and assigned randomly to a 2-d aging period for the frozen protocol or randomly assigned to 2, 3, 4, 5, 6, 7, 10, 14, 21, or 35 d of postmortem aging for the fresh protocol. Fresh protocol steaks were aged at 2°C for the appropriate time period and then cooked at 1130 on the day the aging period ended. Nine 2.5-cm-thick steaks were sliced from each right side strip loin. Steaks were vacuum-packaged individually and randomly assigned to 3, 4, 5, 6, 7, 10, 14, 21, or 35 d of aging for the frozen protocol. All frozen protocol steaks were aged at 2°C for the appropriate time period and then frozen and stored at –16°C.

WBSF and Cooking Loss Determination

Frozen protocol steaks were stored for approximately 2 mo, then steaks were selected at random and thawed for 24 h in a 1°C cooler before cooking. All steaks (frozen and fresh protocol) were broiled on Farberware Open Hearth electrical broilers (Farberware, Bronx, NY). Steaks were turned every 4 min during broiling until an internal temperature of 71°C was reached. Internal temperature was monitored by a digital thermometer (Model 31308-KF, Atkins Tech. Inc., Gainesville, FL) placed in the approximate geometric center of each steak. Cooked steaks were cooled to room temperature (≈20°C) before five to six 1.27-cm cores were sheared once perpendicular to the muscle fiber orientation on a Warner-Bratzler shear machine (G-R Elec. Mfg. Co, Manhattan, KS). An average shear force was calculated and recorded for each steak. All steaks were weighed before and after cooking to determine cooking loss.

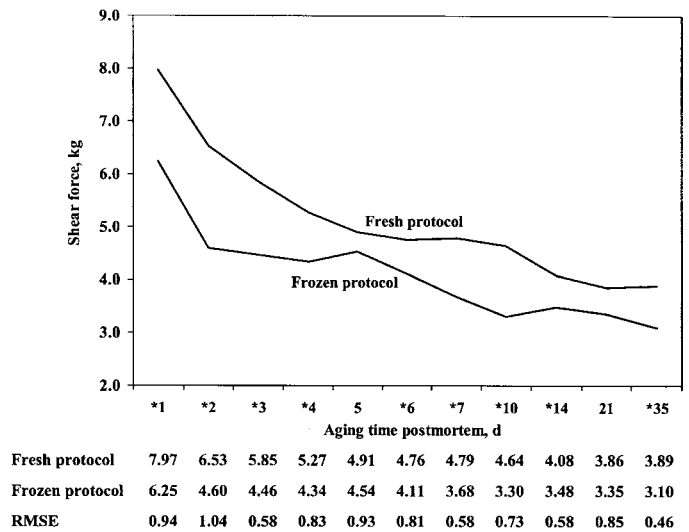


Figure 1. Means for Warner-Bratzler shear force values of cooked beef longissimus steaks from frozen and fresh protocols at several different postmortem aging periods ($n = 20$). *Treatment means differ ($P < 0.05$).

Statistical Analysis

Simple descriptive statistics were computed for live weight and carcass traits to characterize the animals in the experiment. Data were analyzed (SAS Inst. Inc., Cary, NC) using a multivariate repeated measures analysis. The model included the random effect of animal and the fixed effect of protocol (fresh vs frozen). Least squares means were calculated and separated ($P < 0.05$) using pairwise t -tests (PDIF option of SAS). Tests for interactions between protocol (fresh vs frozen) and postmortem aging period were included in the design. Simple correlations were computed between selected variables.

Results and Discussion

Yield grades (mean = 3.0 ± 0.5), maturity scores (mean = $A^{54} \pm 16$), and marbling scores (mean = $\text{Small}^{09} \pm 67$) were generally representative of industry averages reported in the 1995 National Beef Quality Audit (Boleman et al., 1998). However, cattle (mean slaughter weight = $456 \text{ kg} \pm 40$) and carcasses (mean hot carcass weight = $299 \text{ kg} \pm 27$) used in our study were lighter than the reported industry average (Boleman et al., 1998).

The frozen protocol resulted in lower ($P < 0.05$) WBSF values than the fresh protocol for beef longissimus steaks aged for 1, 2, 3, 4, 6, 7, 10, 14, or 35 d postmortem (Figure 1). As discussed in the introduction, there are conflicting statements in the literature regarding the effect of freezing on tenderness. In meat aged prior to freezing, researchers have found freezing causes tenderization in beef (Law et al., 1967) and lamb (Smith et al., 1968); others have shown detrimental effects of

freezing in beef (Pearson and Miller, 1950) and lamb (Smith et al., 1968). Smith et al. (1969) reported no effect of freezing in beef that had been stored frozen for 3 to 6 wk but concluded that freezing resulted in a decrease in WBSF values of beef stored frozen for 4 mo. Wheeler et al. (1990) found similar WBSF values between chilled and frozen top loin and top sirloin steaks when compared at similar postmortem aging periods (chilled 13 d postmortem vs chilled 14 d and then frozen). When meat was aged after freezing, some studies have indicated lower WBSF values (Crouse and Koohmaraie, 1990; Whipple and Koohmaraie, 1992) or no effect at all (Hildrum et al., 1999). Winger and Fennema (1976) showed that in beef sternomandibularis muscle, freezing and thawing before aging resulted in lower shear force values than in samples that were aged and then frozen. Yet, Stuby et al. (1993) and Stuby-Souva et al. (1994) demonstrated that in several different beef muscles aging either prior to freezing or aging after freezing resulted in similar WBSF values. Discrepancies in past studies may be attributed to variations in rate of freezing, storage temperature, frozen storage duration, and sample location within the carcass. Perhaps differences between the current investigation and those reported in the literature are a result of similar complications. Our findings of improved tenderness in steaks that were frozen/thawed prior to cooking may be a direct consequence of physical disruption of muscle cells caused by intracellular ice formation. It has been shown (Hiner et al., 1945) that freezing itself causes muscle fibers to rupture and induces stretching and rupture of connective tissue. It is possible that freezing rate, storage temperature, and/or frozen storage duration may affect the amount of intracellular ice formation and physical disruption occurring in muscle, and thus the extent to which freezing causes tenderization.

As expected, postmortem aging affected ($P < 0.05$) WBSF values. An interaction ($P < 0.05$) existed between postmortem aging and protocol (fresh vs frozen), indicating that the effect of protocol on WBSF values was dependent on the length of postmortem aging. In general, as illustrated in Figure 1, freezing elicited a greater effect on WBSF values of samples aged for shorter than for longer postmortem periods.

Correlation analysis (data not presented in tabular form) revealed that frozen protocol WBSF values were not highly indicative of fresh protocol WBSF values at the same period of postmortem aging (average correlation = 0.53 for fresh vs frozen at identical aging times). Rather, correlations suggested that frozen protocol WBSF values at shorter aging times, especially 3, 6, and 7 d, were useful in estimating WBSF values from fresh protocols at longer aging times. For example, 7 d frozen WBSF was more closely related to 14 d fresh WBSF ($r = 0.85$) than 14 d frozen WBSF was related to 14 d fresh WBSF ($r = 0.58$), and 7 d frozen WBSF was more closely related to 21 d fresh WBSF ($r = 0.59$) than 21 d frozen WBSF was related to 21 d fresh WBSF

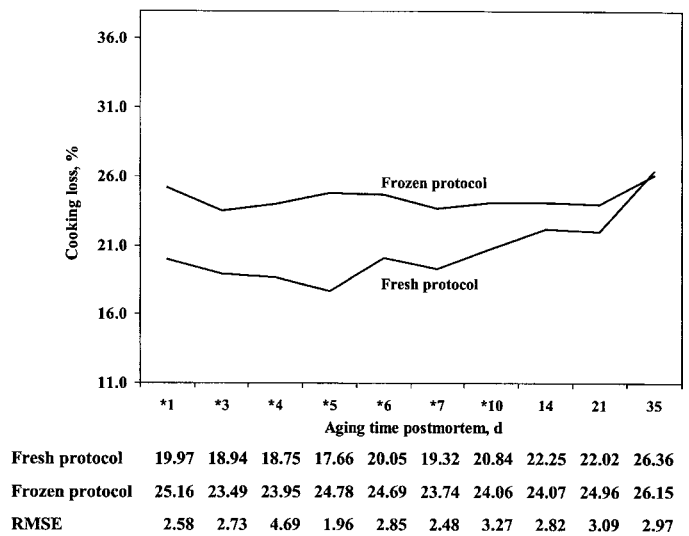


Figure 2. Means for percent cooking loss of beef longissimus steaks from frozen and fresh protocols at several different postmortem aging periods ($n = 20$). *Treatment means differ ($P < 0.05$).

($r = 0.37$). Although these correlations were calculated on only 20 pairs of observations and should therefore be interpreted cautiously, the trend suggests that shorter aging periods should be used with the frozen protocol when trying to predict never-frozen aged beef WBSF.

In the United States, the average aging period for fresh beef found at retail is approximately 18 to 22 d, based on average postmortem fabrication times reported by the 1991 and 1998 National Beef Tenderness Surveys (Morgan et al., 1991; Brooks et al., 2000, respectively). Therefore, most researchers utilize 14- or 21-d aging periods in tenderness research to simulate industry conditions and to make their results meaningful and applicable to industry. However, most researchers use the frozen protocol when determining tenderness, whereas in industry, meat is rarely frozen. Results from the current study suggest that tenderness research for industry application should be conducted using the fresh protocol; however, because of time constraints, the fresh protocol is usually not feasible. Therefore, based on our results, it appears that a 6- or 7-d aging period should be used when using the frozen protocol. We chose the recommendation of a 6- or 7-d aging period with the frozen protocol for two reasons: 1) WBSF (frozen protocol) at 3, 6, or 7 d aging best predicted (highest correlations) WBSF of beef found at retail (14 to 21 d WBSF, fresh protocol) and 2) the mean WBSF values of frozen protocol steaks aged 6 or 7 d were approximately equal to the mean WBSF values of fresh protocol steaks aged 14 to 21 d (Figure 1).

Percentage cooking loss was higher ($P < 0.05$) for frozen vs fresh protocol steaks aged 1, 3, 4, 5, 6, 7, and 10 d postmortem (Figure 2). No effect ($P > 0.05$) on cooking loss was detected for steaks aged for more extended periods of time (14-, 21-, and 35-d postmortem

aging periods). Because of missing data, 2-d cooking loss values were omitted. Marked increases in cooking losses from frozen protocol steaks at 1, 3, 4, 5, 6, 7, and 10 d postmortem aging may have been caused by damage to cellular membranes, allowing moisture to escape out of the muscle. Our findings lend support to the observations of other workers (Pearson and Miller, 1950; Crouse and Koohmaraie, 1990; Hildrum et al., 1999) that cooking losses in beef increase upon freezing. Wheeler et al. (1990) indicated that cooking losses were greater for frozen steaks regardless of aging time (chilled 13 or 20 d vs chilled 7 or 14 d and then frozen). Smith et al. (1969) noted that cooking losses increased significantly as a result of freezing at -34°C , but not at -23°C . However, Smith et al. (1968) failed to note any cooking loss differences in aged lamb as a result of extended frozen storage. The reason that cooking losses were the same for frozen and fresh protocol steaks at longer postmortem aging periods in the present study is not conclusively known. It may be that as meat ages and proteins degrade, muscle loses its inherent ability to hold moisture; however, in the frozen protocol, cellular damage due to freezing may have outweighed this effect. Therefore, there would be little change in cook loss following freezing for steaks that were aged for longer periods of time. It should be pointed out that cooking losses were computed based on weights of steaks immediately prior to cooking; thus, results do not directly reflect losses in weight associated with purge or thaw. For this reason, cooking loss data should be interpreted with caution.

Postmortem aging affected ($P < 0.05$) percentage cooking loss. An interaction ($P < 0.05$) existed between postmortem aging and protocol (fresh vs frozen), indicating that the effect of protocol on cooking loss was dependent on the length of postmortem aging. Data in Figure 2 reveal that freezing caused higher cooking losses in samples aged for shorter rather than longer postmortem periods.

Implications

Freezing can significantly decrease Warner-Bratzler shear force values of beef longissimus steaks across several postmortem aging periods. If research constraints warrant the freezing of samples, 6- or 7-d Warner-Bratzler shear force should be used because it best predicts fresh (never-frozen) aged beef (14 to 21 d) Warner-Bratzler shear force values. In trials in which several postmortem aging periods or very short aging periods are of interest, it is recommended that Warner Bratzler shear force be assessed using the fresh protocol.

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