

DRY-AGING OF BEEF




EXECUTIVE SUMMARY

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INTRODUCTION

Dry aging beef to enhance its flavor and tenderness is used by a very small number of meat purveyors for upscale hotels and restaurants and by an even smaller number of retailers for the gourmet market. Dry aging is a process whereby beef carcasses, primals, and/or subprimals are stored – without protective packaging – at refrigeration temperatures for one to five weeks to allow the natural enzymatic and biochemical processes that result in improved tenderness and the development of the unique flavor that can only be described as “dry-aged beef.”

Dry aging beef may be more art than science. Popular articles, sales brochures, and Web sites devoted to promoting or merchandising dry-aged beef use terms such as “buttery and rich,” “superb in taste and texture,” “superior in taste and tenderness,” “mellow and intense,” and “earthy and nutty” to describe the advantages for dry-aged compared to wet-aged beef. In fact, differentiating between dry-aged and wet-aged beef has been a relatively recent event. Up until the development of vacuum packaging and boxed beef in the 1960s, if beef were to be aged, the only option would have been to dry age it. As vacuum packaging became an alternate way to ship beef, first in the U.S. and then internationally, its dominance as the primary way beef was transported, stored, and aged took off in the 1970s. By the 1980s, well over 90% of beef marketed was in this form. Compared to the historic way beef was handled, the advantages of vacuum packaging were such that avoiding

shrinkage and trim loss made economic sense to both the packer/processor and retail/foodservice sectors.

Two very important scientific articles published in the 1970s – Minks and Stringer (1972) and Hodges et al. (1974) – demonstrated the advantages of vacuum packaging from a shrinkage and shelf-life standpoint without sacrificing palatability traits found in unpackaged beef. The growth of boxed beef, for the most part, transformed how steaks and roasts were prepared for the foodservice and retail channels, making the dry aging process a minor contributor to the processes used in purveying and retailing beef.

Compared to the volume of research studies on a wide variety of topics related to beef, dry aging has not been the subject for much scientific literature. Studies devoted to the direct comparison of dry aging to wet aging may be limited in number but are not limited in the quality of the work reported. This review will focus on the advantages and disadvantages of the dry aging process with special emphasis on quality, palatability, and economic parameters important to those who market and purchase this product. And not all dry aging is focused on improving the flavor and tenderness of beef. The University of Wisconsin Center for Meat Process Validation concluded that dry aging is an intervention treatment to reduce pathogens on beef carcasses (Algino et al., 2007), giving this age-old process new life in the food safety arena.

DRY-AGING PARAMETERS

PROCEDURES

In developing dry aging beef guidelines, the primary factors to consider are: (1)

days of aging, (2) storage temperature, (3) relative humidity, and (4) air flow. These are important as they relate to development of

flavor notes, shelf-life, product shrinkage, microbial spoilage, and other issues of quality and economics.

Air flow has not been addressed from a research standpoint; however, there are some parameters that help ensure this process is conducted in the best manner. Special wire racks, perforated shelves, trees or hooks are used to hold products for dry aging so that all surfaces are exposed to the cold temperatures to allow for uniform drying and to minimize spoilage and resulting off-odor development. It is not uncommon to find supplementary fans in dry aging coolers to help in the movement of air around products to assist in the drying process. Some commercial dry aging coolers use ultraviolet light as a way to retard microbial spoilage. Not all uses of ultraviolet light require direct exposure to the dry-aged product. Warren and Kastner (1992) obtained dry-aged beef from a cooler where the air was recirculated every 30 minutes through ultraviolet light before it reentered the room.

DAYS OF AGING

The number of days products are dry-aged varies tremendously in practice as well as in the literature. Smith (2007) found no differences in overall like, flavor like, tenderness like, and level of tenderness when aging (dry and wet aging combined) periods of 14, 21, 28, and 35 days were compared. However, when Warner-Bratzler shear force values were compared over these four aging periods, Smith (2007) found significant decreases with a 17% reduction in shear force from 14 to 35 days, showing that at least from an objective tenderness assessment standpoint, tenderness improvements were still occurring. Campbell et al. (2001) compared dry aging periods of 7, 14, and 21 days with minor benefits found in some palatability traits for increased aging, but, for the most part, no real advantages for extended aging past 14 days.

Determining the number of days of dry aging seems to be based more on personal

preference than any scientific literature where findings support a definite minimum or maximum days of storage. Dry aging periods of 14 to 35 days have all appeared to be effective in producing the desired results of this process, but there does not seem to be a magical threshold where sufficient time is required beyond about 14 days to truly call this beef “dry aged” from a performance standpoint. Without question, there are various opinions on length of dry aging, and purveyors of such products are passionate about their programs. Unfortunately, the scientific information is so limited that it cannot be used to support a minimum recommended period of dry aging.

STORAGE TEMPERATURE

Temperature of storage is critical in that if it is below freezing temperatures for meat (-2 to -3°C), the enzymatic processes involved with aging will cease. If the temperature of storage is elevated, the enzymatic processes involved with aging will work quite well, but so will the microbial spoilage process resulting in the development of off-odors and off-flavors. In addition, elevated temperatures may promote pathogen growth, so finding the appropriate storage temperature for dry-aged beef is very important.



No scientific studies have evaluated the effect of different storage temperatures on the quality, palatability, and shrinkage of dry-aged beef. For the most part, dry aging literature has reported storage temperatures around 0 to 4°C. Campbell et al. (2001) conducted their dry aging study at 2°C,

Ahnström et al. (2006) aged beef loin sections at 2.5 and 2.6°C, Parrish et al. (1991) used an aging cooler set at 0-1°C, Warren and Kastner (1992) used a dry aging room that operated at 3.1 to 3.6°C, Oreskovich et al. (1988) aged meat at 2°C, Miller et al. (1985) stored beef loins from 1 to 3°C, Smith (2007) aged shortloins at 1°C, and Laster (2007) stored beef subprimals at -0.6°C. It may be that dry aging storage temperature parameters do not need to differ from those for any other meat products where controlling quality and shelf-life parameters through proper cold storage are important.

RELATIVE HUMIDITY

One of the greatest questions concerning dry aging parameters is what relative humidity should be used to store products. Relative humidity is important because, if it is too high, spoilage bacteria can grow and result in off-odors and possible off-flavors.

If relative humidity is too low, excess product shrinkage will occur.

There are a number of relative humidity parameters reported in scientific literature. Campbell et al. (2001) dry-aged beef in a cooler with 75% relative humidity. Parrish et al. (1991) used a range of 80 to 85% relative humidity in their study, and Warren and Kastner (1992) stored products in a cooler with a relative humidity of $78 \pm 3\%$. Smith (2007) stored dry aged product in a cooler with $83 \pm 11\%$ relative humidity, and Ahnström et al. (2006) used a cooler with a relative humidity of $87 \pm 2.6\%$. There are no published studies that have compared the effects of different relative humidity levels on dry-aged beef, and it appears the studies in this area have used a relative humidity of approximately 80% with a considerable range around that number.

PALATABILITY ATTRIBUTES

FLAVOR

The greatest reason for dry aging beef is to further enhance its flavor and to impart the flavor notes that are generally associated with this product. Flavor is a difficult attribute to study because it requires very specifically trained panelists to evaluate the complexity of the positive and negative notes that may occur in meat in general and dry-aged beef in particular.

Campbell et al. (2001) conducted one of the most extensive studies to date on the effect of dry aging on beef flavor. They evaluated Certified Angus Beef® brand striploins and shortloins that were first vacuum packaged to simulate initial packaging and shipping conditions (7 or 14 days), followed by various times of dry aging (0, 7, 14 or 21 days) before vacuum packaging, storage (0, 2, 9 or 16 days) and steak cutting. A number of sensory traits were evaluated including two very specific

flavor intensities important to the dry aging consumer:

- overall aged-beef flavor intensity – defined as a full, blended and sustained, cooked beef flavor that has few dominating individual flavor notes and creates a smooth, balanced impression
- brown/roasted flavor intensity – defined as a round, full, dark, caramelized aromatic generally associated with beef that has been cooked with dry heat.

The authors found that with at least 14 days of dry aging, aged flavor and brown-roasted flavor increased significantly compared to those cuts dry aged for fewer days or that were not dry aged at all. They also found that aged flavor peaked at 9 days of vacuum storage after the dry aging period and actually declined when stored at 16 days, indicating that some benefits of dry aging were reversed slightly with this additional vacuum storage period.

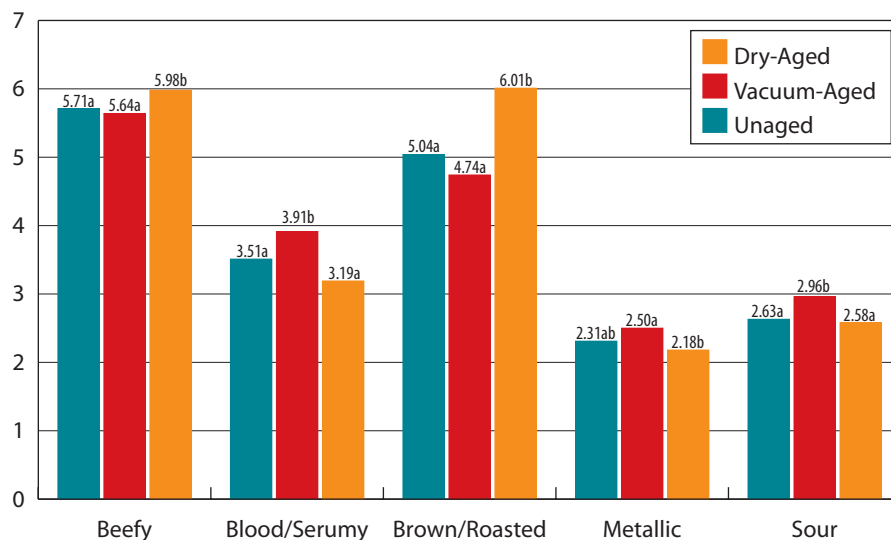
Warren and Kastner (1992) obtained U.S. Choice striploins at three days postmortem and, after obtaining an unaged sample from each striploin to serve as an unaged treatment, either vacuum-aged or dry-aged them for 11 days. A trained taste panel evaluated cooked steaks for a variety of flavor (both lean and fat) intensities. The findings of this study are dramatic. The five lean flavor intensities the panel evaluated included beefy, bloody/serumy, brown/roasted, metallic, and sour. All five traits were impacted by the aging treatments (Figure 1). Dry-aged steaks had significantly higher beefy and brown/roasted flavor intensities than the unaged or vacuum-aged steaks. Vacuum-aged steaks had significantly higher bloody/serumy and sour flavor intensities than the unaged or dry-aged steaks and significantly higher metallic flavor intensity than the dry-aged steaks. There was no difference in metallic flavor intensity between the unaged and vacuum-aged steaks. It is clear that dry aging helped develop more positive flavor intensities (beefy and brown/roasted) whereas vacuum aging resulted in the development of potentially more negative flavor intensities (bloody/serumy, metallic, and sour). It appears from this study that method of aging leads

to the development of vastly different flavor intensities, which must be considered when determining where steaks from these processes are to be marketed.

Not all dry aging studies have found improved flavor for dry-aged beef. Parrish et al. (1991) used both trained and consumer sensory panels to evaluate steaks from dry-aged and wet-aged (21 days) U.S. Prime, Choice, and Select ribs and loins. Neither panel found flavor intensity or flavor desirability differences between the aging treatments. Oreskovich et al. (1988) found no differences in beef flavor intensity between dry-aged beef and beef aged in polyvinyl chloride film or in vacuum packages for 7 days. Smith (2007) did not find flavor like differences between steaks from dry- and wet-aged shortloins. However, he did find an interaction for level of beef flavor where steaks from U.S. Select, dry-aged shortloins were similar to steaks from U.S. Choice, dry-aged shortloins, but steaks from U.S. Select, wet-aged shortloins were significantly lower in level of beef flavor from steaks from U.S. Choice, wet-aged shortloins.

In an analytical study determining volatile compounds from wet-aged versus dry-aged beef, cooked using oven-roasting or with a microwave, King et al. (1995) found, of the hydrocarbons present, heptane was in the greatest proportion regardless of aging treatment or cooking method. However, dry-aged beef had significantly more heptane than wet-aged beef when either oven-roasted or microwave cooked. The authors stated that heptane can arise from the autoxidation of oleate, which is a major fatty

Figure 1: Lean Flavor Intensities (10 = very strong; 1 = threshold) for dry-aged, wet-aged and unaged beef strip loin steaks



Means with different letters (a, b) differ ($P < 0.05$). Adapted from Warren and Kastner (1992).



acid in beef muscle, and that the greater exposure to air may have contributed to this finding.

King et al. (1995) further stated that when aging method was pooled across cooking method, dry-aged beef had significantly greater percentages of esters and miscellaneous compounds than wet-aged beef, but wet-aged beef had significantly greater percentages of acids than dry-aged beef. It is clear, from a chemical standpoint, dry-aged beef produces different volatile compounds compared to wet-aged beef. What is less clear is how these compounds interact to result in positive or negative flavor notes to the consumer.

There are incidences where panelists have preferred wet-aged compared to dry-aged beef. Sitz et al. (2006) found that wet-aged U.S. Prime steaks had significantly higher flavor desirability and overall acceptability scores than dry-aged Prime steaks. The authors conducted proximate analysis of the wet-aged and dry-aged steaks and found, although the dry-aged Prime steaks had significantly less moisture and more protein than the wet-aged Prime steaks, the wet-aged Prime steaks had significantly more fat (11.56% for dry-aged versus 16.16% for wet-aged). The premise

was that this increased level of fat in the wet-aged steaks contributed to the higher flavor desirability scores compared to the dry-aged steaks. It is unclear why dry aging would have resulted in lower, not higher fat percentages when moisture loss should have concentrated both the protein and fat components of the meat.

TENDERNESS

For the most part, dry aging is not used to promote a tenderness advantage when compared to wet aging. Although studies have shown improvements in tenderness with additional days of dry aging, especially when compared to unaged controls, these really do not differ from wet-aged counterparts obtained from the same sources and handled in a similar manner. The question then arises about how much dry aging is required for adequate tenderness or at what point optimum flavor and tenderness occur.

Campbell et al. (2001) stated that panelists found steaks from the 14-day dry aging treatment to be significantly more tender compared to those dry-aged for 7 days or the controls. Dry aging for 21 days did not result in steaks that were rated more tender by the panelists. However, Warner-Bratzler shear force was significantly lower (more tender) for those dry-aged 21 days compared

to steaks dry-aged for shorter periods. In this study, tenderness continued to improve in the vacuum-storage period that followed the initial dry aging treatment, indicating those biochemical and structural changes that occur in postmortem aging continue at some level.

Warren and Kastner (1992) found that both vacuum aging and dry aging for 11 days resulted in tenderness scores that were significantly higher than the unaged controls. However, the method of aging – vacuum or dry – did not differ in tenderness. Parrish et al. (1991) found that rib and loin steaks from their wet aging treatment were significantly more tender than the rib and loin steaks from their dry aging treatment. The authors gave no explanation for this but did comment that panel scores for steaks from both the dry and wet aging treatments were quite high.

Sitz et al. (2006), in a study designed more to investigate the willingness to purchase dry- and wet-aged products, found that there were no tenderness differences between dry-aged (30 days of dry aging followed by 7 days in vacuum packaging for shipping and storing before cutting) and wet-aged (vacuum packaged for 37 days) steaks from U.S. Choice striploins. However, following the same aging protocols for Prime striploins, wet-aged were significantly more tender than dry-aged steaks. For both the Prime and Choice comparisons, Warner-Bratzler shear force values did not differ between the dry- and wet-aged steaks.

Oreskovich et al. (1988) obtained striploins from U.S. Good (today's U.S. Select grade) carcasses and aged products for 7 days either without packaging (dry-aged) or with polyvinyl chloride film (steaks only) or vacuum packaging (as steaks or as subprimals). They found steaks from dry-aged striploins did not differ in consumer tenderness ratings or Warner-Bratzler shear force compared to steaks stored in polyvinyl

chloride or vacuum bags or when steaks were cut from striploins stored in vacuum bags.



Smith (2007) compared steaks from dry-aged and wet-aged shortloins and Laster (2007) compared steaks from dry-aged and wet-aged bone-in ribeyes, bone-in striploins, and top sirloin butts. The only tenderness difference between dry-aged and wet-aged steaks occurred in the bone-in ribeye group (Laster, 2007) where panelists gave wet-aged steaks significantly higher tenderness like scores. In both of these studies, consumers generally found significant grade effects for most palatability traits, but did not find differences between steaks from dry- versus wet-aged treatments.

JUICINESS

Campbell et al. (2001) found, by increasing dry aging time, panelists rated steaks juicier. Steaks from the 21-day dry aging treatment were significantly juicier than those from the 14-day treatment, which were significantly juicier than those from the controls (0 day) or 7-day treatment. The authors cited other research where increased aging resulted in significantly juicier steaks and attributed this finding to the possible loss in water-holding capacity – more juices were released as the meat was chewed – or that fat was concentrated by moisture loss during aging. These are two good theories about increased juiciness with dry aging. Unfortunately, no work has been conducted to substantiate how this may actually work.

ECONOMIC PARAMETERS

SHRINKAGE

One of the reasons that dry aging improves flavor is because of its ability to concentrate many of the compounds responsible for flavor when moisture is lost over time. Moisture loss is positive from a flavor standpoint. However, shrinkage results in reduced saleable yield of product, which means that the ultimate price of steaks must recuperate this loss.



Dry aging can result in substantial losses in both shrinkage (moisture loss) and trim loss (discolored and/or dehydrated lean and fat that must be trimmed before merchandising steaks and roasts from the primal or subprimal). Parrish et al. (1991) reported cooler shrinkage ranging from 3.31% to 4.74% for ribs and loins dry-aged for 14 days and 4.54% to 6.53% for ribs and loins dry-aged for 21 days. In addition, the trim loss from those cuts after 21 days of dry aging ranged from 5.06% to 6.55%. In comparison, the companion ribs and loins that were wet-aged for 21 days had no shrinkage and had trim losses ranging from 0.55% to 1.17%. These are very large differences in both shrinkage and trim loss. Oreskovich et al. (1988) reported that at the end of 7 days of aging, those striploins that were dry-aged had 4.62% shrinkage, which was significantly higher than steaks packaged with polyvinyl chloride film (2.93%), steaks packaged in vacuum bags (0.55%), and striploins packaged in vacuum bags (1.65%).

Ahnström et al. (2006) conducted a novel study to see if using a vacuum bag that is highly permeable to water vapor (8000 g/15 μ /m²/24 h at 38°C and 50% relative humidity) would allow products to age with moisture loss somewhat lessened compared to the loss from normal dry aging. In their study, Certified Angus Beef® brand striploins were obtained and divided into four treatments: dry-aged for 14 days (Dry 14), dry-aged for 21 days (Dry 21), aged in bag (refers to the highly moisture-permeable bag) for 14 days (Bag 14), and aged in bag for 21 days (Bag 21). There were no differences in weight loss in the striploins between the Dry 14 (6.5%) and Bag 14 (6.3%). However, striploins from the Dry 21 treatment had significantly greater weight loss than the striploins from the Bag 21 treatment (10.2% versus 8.8%, respectively). Trim loss was similar for striploins from the Dry 14, Bag 14, and Bag 21 treatments (15.0%, 15.3%, and 15.6%, respectively). However, it was significantly higher (17.9%) for the Dry 21 treatment. Sensory traits and shear force did not differ among the four treatments, which means that the use of this highly moisture-permeable bag may allow an alternative aging method to the normal, unprotected dry aging process.

RETAIL YIELDS

Two studies, Smith (2007) and Laster (2007), included extensive retail cutting tests to document the difference in saleable yields and processing times between dry-aged and wet-aged subprimals. Smith (2007) evaluated U.S. Choice and Select beef shortloins, dry- or wet-aged for 14, 21, 28 or 35 days, and Laster (2007) evaluated Top Choice and Select bone-in beef ribeyes (export style), bone-in striploins, and top sirloin butts, dry- or wet-aged for 14, 21, 28 or 35 days. Both studies used simulated cutting rooms and professional meat cutters to obtain the yield and time data. This is a procedure used by Voges et al. (2006) to

generate standardized information important to the retail segment of the beef industry.

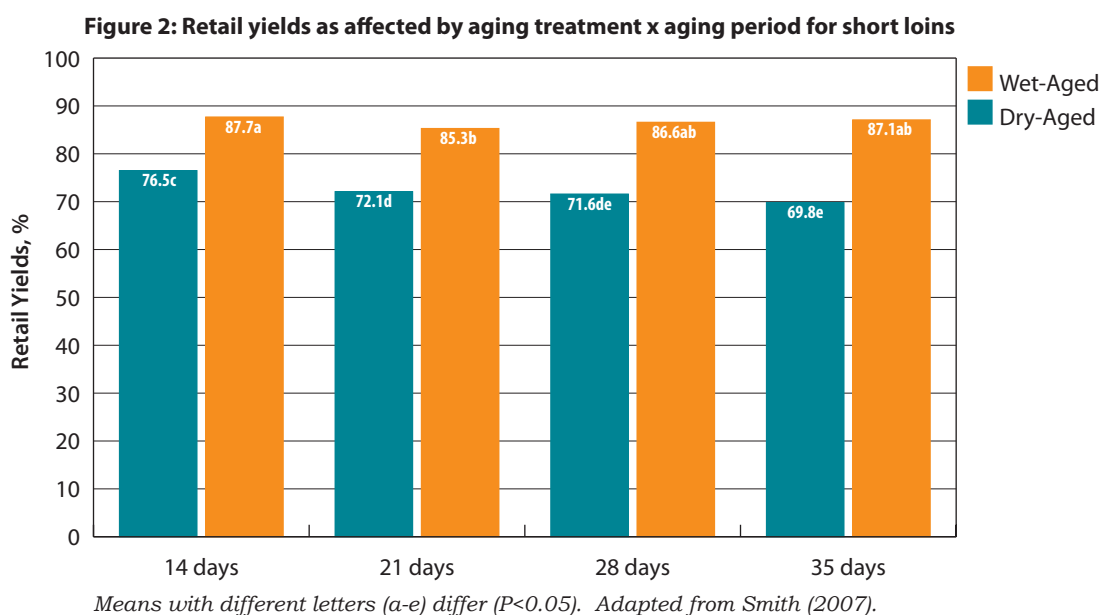
In Smith (2007), there was a significant increase in the time required to process dry-aged versus wet-aged shortloins into steaks and other saleable products (dry-aged: 331.6 seconds per shortloin; wet-aged: 243.1 seconds per shortloin). Much of this increased processing time was due to the removal of dried and discolored lean and fat (referred to as “crust” in the industry) from the dry-aged compared to the wet-aged shortloins. There was a trend towards increasing processing times with increased aging times but these differences were less evident compared to those found between the dry-aged and wet-aged subprimals. Laster (2007) also reported significant increases in time required to cut bone-in ribeyes, bone-in striploins, and top sirloin butts for dry-aged versus wet-aged products.

Smith (2007) reported retail yields for dry- and wet-aged shortloins when they were cut and merchandised for the retail market (Figure 2). Retail yields from the wet-aged shortloins did not differ among the four postmortem aging periods (14, 21, 28, and 35). However, dry-aged shortloins had significantly lower retail yields as the

days of aging increased. At all days of aging, dry-aged shortloins had significantly lower retail yields than wet-aged shortloins. The much greater shrinkage and discoloration/dehydration observed in dry aging makes a tremendous difference in retail yields of beef. Laster (2007) found similar retail yield differences between dry- versus wet-aged bone-in ribeyes (Figure 3) and top sirloin butts (Figure 4). However, there were no significant differences in retail yields between dry-aged and wet-aged bone-in striploins.

PRICING PARAMETERS

Sitz et al. (2006) conducted a variation of the Vickery (uniform-price) auction to determine what consumers would pay for dry-aged or wet-aged, U.S. Choice or Prime steaks. As mentioned earlier, no sensory differences were found between dry-aged and wet-aged Choice steaks. However, wet-aged Prime steaks were rated significantly higher than dry-aged Prime steaks for flavor, tenderness, and overall acceptability. When consumers were grouped according to their preference (based on overall acceptability score), 39.2% of the consumers preferred wet-aged Choice steaks, 29.3% preferred dry-aged Choice steaks, and 31.5% had no preference. Consumers who preferred the dry-aged Choice steaks were willing to bid



a \$2.02/0.45 kg (same relationship as per pound pricing) premium for their preference, whereas those who preferred the wet-aged Choice steaks were willing to bid \$1.76/0.45 kg more for those steaks. For the Prime steaks, 27.5% of the consumers preferred the dry-aged steaks, 45.8% preferred the wet-aged steaks (remember the significantly higher ratings given to the wet-aged Prime steaks), and 26.7% had no preference. Consumers who preferred the dry-aged Prime steaks bid \$1.94/0.45 kg more for these steaks, whereas those who preferred the wet-aged Prime steaks bid \$1.93/0.45 kg more for them.

Pricing steaks that come from a more expensive production scheme such as dry aging is challenging at best. Sitz et al. (2006) concluded that even though their study showed no overall consumer preferences for dry-aged steaks, those consumers who did prefer it were willing to pay more, showing that marketing such product to a targeted group may be possible.

Dry-aged steaks have to command more in the marketplace to offset the significant losses in the dry aging process. Smith (2007) took the retail cutting test results from his study and applied financial

Figure 3: Retail yields as affected by aging treatment x aging period for ribeyes

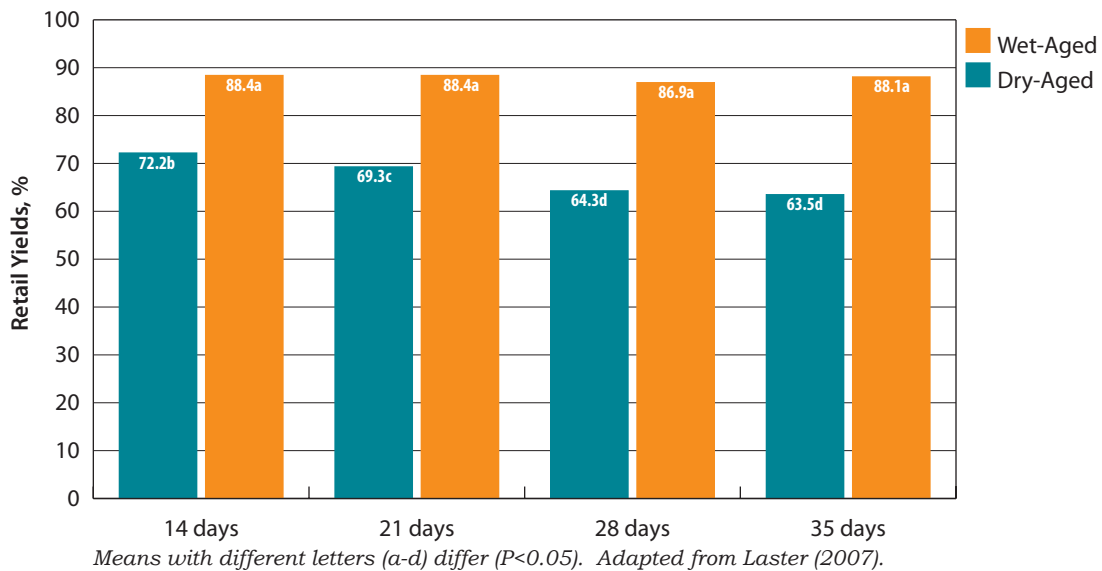
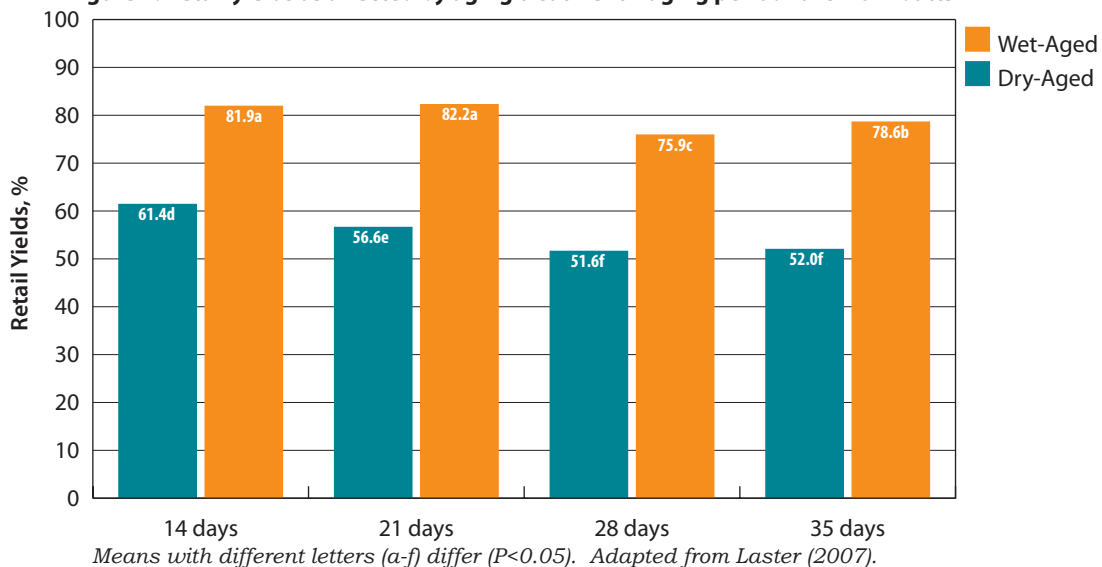


Figure 4: Retail yields as affected by aging treatment x aging period for sirloin butts



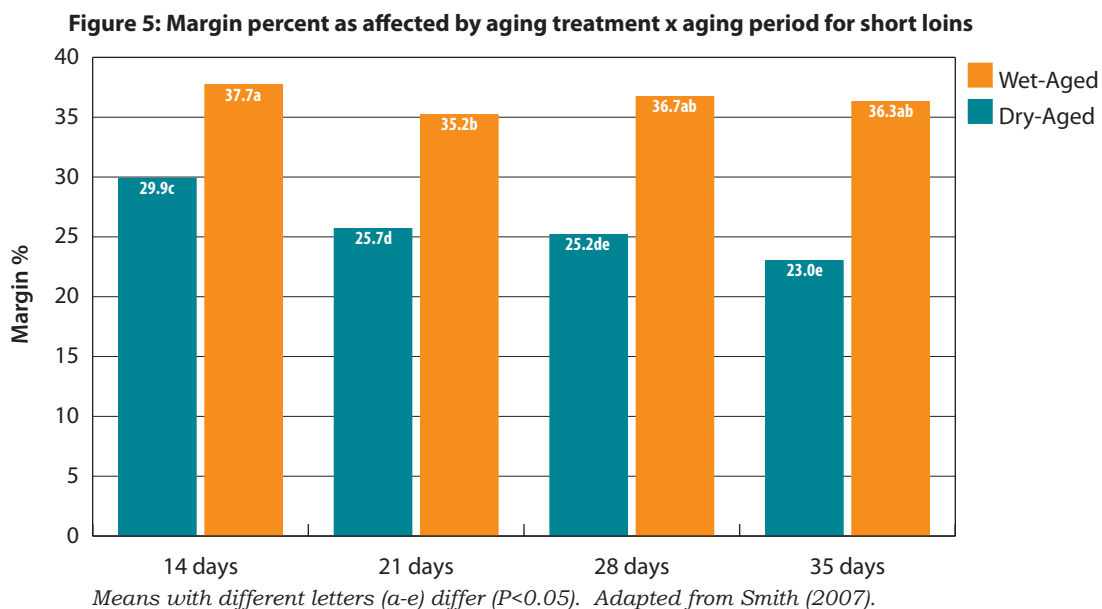
information in the form of wholesale and retail prices to see the impact of dry aging versus wet aging. The margin percent for the wet-aged shortloins ranged from 35.2% to 37.7% and was not really impacted by days of aging; the margin percent for the 14-day dry-aged shortloins was 29.9% and declined significantly until it reached 23.0% for the 35-day dry-aged shortloins (Figure 5). Not only are there large differences in percent margin between dry- and wet-aged shortloins when cut for the retail channel, but additional days of dry aging continued to reduce the margin percent forcing even higher retail prices.

CONCLUSIONS AND RECOMMENDATIONS

Dry aging is a costly enterprise. Recovering revenue losses in saleable yield that occur using this process requires higher pricing at retail or foodservice. In dry aging, because saleable yield is further impacted by additional weeks of storage, pricing mechanisms have to be in place to reflect the dynamic changes in yields with increasing time of aging.

It should remain no mystery why wet aging of beef eventually dominated the marketplace. The ability to increase tenderness by vacuum-packaged aging, while controlling shrinkage, has made this system widely used by the beef industry. It could be argued that dry aging fulfills a niche for those willing to pay for something that may be considered a luxury rather than a necessity.

Even with the stark economic realities of dry aging, for those who seek to deliver a uniquely flavored product with such preparation mystique, there is a great market. Dry aging requires refrigerated conditions where humidity and airflow are controlled as well as a sufficient number of days to achieve the desired outcome for the end user of the product. For those companies interested in producing dry-aged beef, these parameters may need to be tested to develop procedures that work best for them. For those companies currently dry aging beef, chances are, through many years of trial and error and experimentation, they have arrived at dry aging parameters that work well for them and deliver great tasting beef for the consumer.



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