TECHNICAL NOTE: A method for detection of differences in cook loss and tenderness of aged pork chops cooked to differing degrees of doneness using sous-vide

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ABSTRACT: The objective was to determine the ability to detect differences in cook loss and Warner–Bratzler shear force (**WBSF**) values between chops aged for differing time periods and cooked to varying degrees of doneness with in a sous-vide style cooker. Loins from pigs (HCW = 96 kg) humanely slaughtered at the University of Illinois Meat Science Laboratory were separated between the 10th and 11th rib into anterior and posterior sections. The posterior section was cut into 6 separate 2.54-cm-thick chops. The middle 4 chops were randomly designated for aging of 3 d and cooked to 63 °C, aged 7 d and cooked to 63 °C, aged 14 d and cooked to 63 °C, or aged 14 d and cooked to 71 °C. Chops were cooked by placing them in a water bath with an immersion circulator set to the desired end-point temperature for 90 min. Cook loss was calculated for each chop by measuring initial and final weight, and accounting for packaging weight. Four cores measuring 1.25 cm in diameter were cut parallel to the muscle fibers from each chop and analyzed for WBSF. Data were analyzed using a 1-way ANOVA. Least squares means were separated using the probability of difference option in the MIXED procedure of SAS. Among chops cooked to 63 °C, chops aged 3 d has less ($P < 0.01$) cook loss than those aged 7 d, and chops aged 7 d had less ($P < 0.01$) cook loss than those aged 14 d. Among chops aged for 14 d, chops cooked to 71 °C had greater ($P < 0.001$) cook loss than chops cooked to 63 °C. Differences in tenderness were also detected between aging periods. Among chops cooked to 63 °C, chops aged 3 d required more ($P = 0.02$) force to shear than those aged 7 d, but chops aged 7 d did not differ ($P = 0.15$) from those aged 14 d. Chops aged 14 d and cooked to 71 °C required ($P < 0.0001$) more force than those aged 14 d and cooked to 63 °C. Overall, these data indicate that sous-vide is an acceptable cooking method for use in experiments as expected differences in cook loss and WBSF were detected in chops aged to differing time points or cooked to differed degrees of doneness.

Key words: aging, pork, sous-vide, tenderness

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INTRODUCTION

Sous-vide cooking is a method of the cooking of food products by immersion in a heated water bath. The water bath temperature is maintained by a submerged heating element and water is circulated to maintain a constant temperature. Sous-vide became a research topic of interest in the 1990s, primarily as a method of extending shelf life of minimally processed foods (Baldwin, 2012). The commercial application of this consisted of vacuum packaging and precooking products in water at lower temperatures for a longer period of time than used with traditional cooking methods (Schellekens, 1996). Currently, sous-vide is becoming more popular with chefs and private households due to the precision temperature control and reproducibility (Baldwin, 2012). Because the water bath temperature is equal to that of the desired end-point cooking temperature of the food

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itself, foods can be cooked and held at that temperature. Therefore, even with extended cooking times, the desired end-point temperature cannot be exceeded. These advantages may be of importance to meat science researchers, particularly in the context of sensory and tenderness assays. Greater control of the degree of doneness has the potential to reduce variability among samples. Reproducibility reduces the variation between studies due to cooking. However, very little work is available to validate the use of sous-vide cooking in meat quality research.

Postmortem aging increases tenderness of pork products (Ellis et al., 1998; van Laack et al., 2001; Channon et al., 2003; Dilger et al., 2010; Clark et al., 2014; Jones-Hamlow et al., 2015). Sarcoplasmic and myofibrillar proteins are denatured, leading to a weakening of the muscle structure and subsequently an increase in tenderness (Wagner, 2007). The differences in tenderness can be detected using Warner–Bratzler shear force (**WBSF**) in pork chops cooked to 70 °C, with a decline in peak force values from chops aged 1 to 20 d (Ha et al., 2017). This tenderization occurs via a rapid decline in peak force values during early aging (days 1 to 7) followed by a less steep decline in peak force values (days 7 to 14) until finally a plateau is reached (Dransfield et al., 1981; van Laack et al., 2001; Rees et al., 2002; Dilger et al., 2010). Other studies indicate that tenderization can extend to day 14, potentially up until day 21 (Clark et al., 2014). It was expected that these established differences in tenderness with postmortem aging would be detectable when chops were cooked using a sous-vide cooking method.

In 2011, the United States Department of Agriculture (USDA) lowered the recommended minimum cooking temperature for whole muscle pork cuts from 71 °C (medium) to 63 °C (medium-rare; Pork Checkoff, 2011; USDA, 2013) because the safety of the product is maintained (Gamble et al., 2000) and eating quality might be improved (Moeller et al., 2010a,b). Pork chops cooked to 63 °C are more tender than those cooked to 71 °C (Rincker et al., 2008; Klehm et al., 2018), though the majority of this work occurred using direct-heat cooking methods. Often, these differences in tenderness at varying degrees of doneness are attributed to the increased cook loss at higher temperatures (Klehm et al., 2018). It was expected that differences in tenderness and cook loss between chops cooked to 63 °C compared with 71 °C would be detected in chops cooked using a sous-vide cooking method. Therefore, the objective was to determine cooking loss and WBSF of chops aged to 3, 7, and 14 d postmortem and cooked to 63 °C or those aged 14 d postmortem and cooked to 71 °C. These values were compared with previous results to establish whether expected difference in tenderness is detectable using sous-vide cooking methods.

MATERIALS AND METHODS

Chop Selection

Loins (*n* = 67) were sourced from pigs (HCW = 96 kg) slaughtered at the University of Illinois Meat Science Laboratory. Pigs were raised for a nutritional study with procedures reviewed and approved by the Institutional Animal Care and Use Committee at the University of Illinois and fed a corn-soy diet. Left carcass sides were cut between the 10th and 11th rib, separating the loin into an anterior and posterior section. The posterior section was cut into a total of six 2.54-cm-thick chops. Chops were standard in weight (CV = 5.42). The middle 4 chops were collected and randomly assigned to either 3 d aging and 63 °C end-point cooking temperature, 7 d aging and 63 °C end-point cooking temperature, 14 d aging and 63 °C end-point cooking temperature, or 14 d aging and 71 °C end-point cooking temperature. Samples were identified, individually vacuum packaged, and sorted into boxes by aging day. Once the designated aging period was achieved, chops were frozen at −20 °C until further analysis. Once the 14-d aging was complete, chops were resorted into boxes by animal identification number such that all chops from the same loin were cooked and analyzed on the same day. Samples were stored frozen until further analysis.

Cook Loss

Chops were allowed to thaw at 4 °C for at least 24 h prior to analysis. Three 37-L plastic open containers were filled with approximately 25 L of hot water. An ANOVA precision immersion cooker (ANOVA Applied Electronics, Inc., San Francisco, CA) was placed in the water and tightened to the rim of the tub. Two precision cookers were set to 63 °C and the third was set to 71 °C. Thawed chops were weighed in vacuum packaging for an initial weight. Once the water reached the set temperature, the chops were placed in the tub with the designated cooking temperature and allowed to cook for 90 min. Approximately 13 chops were cooked in each tub resulting in 6 groups of chops to complete cooking. A validation study was completed prior to analysis of experimental chops to ensure 90 min was sufficient to reach the desired internal temperature of the pork chops. After 90 min, chops were removed from their packaging and a temperature was verified using a digital thermometer to ensure complete cooking. If a chop was not at the appropriate temperature, it was repackaged and placed back into the water bath. This was only required once. Chops were allowed to cool in ambient air (22 °C) to approximately 22 °C before the chops were weighed to determine the final weight. For every group of chops in a tub, the packaging was removed, dried, and weighed to determine the average packaging weight. This average was then subtracted from the initial weight of each chop within that tub to estimate initial chop weight. Cook loss was then determined using the following equation:

$$\text{Cook loss }(\%) = \{[\text{Initial wt (g)} - \text{Cooked wt (g)}]/\text{Initial wt (g)}\} \times 100$$

Warner–Bratzler Shear Force

After chops were cooled, 4 cores measuring 1.25 cm in diameter were removed. Cores were cut parallel to the orientation of the muscle fibers. Samples were sheared using a Texture Analyzer TA.HD Plus (Texture Technologies Corp., Scarsdale, NY/Stable Microsystems, Godalming, UK) with a blade speed of 3.33 mm/s and a load cell capacity of 100 kg. The WBSF values for each core were averaged to yield a single shear force value for each chop.

Statistical Analysis

Chop served as the experimental unit, with loin serving as a block and cooking day as a random effect. The effects of aging period and degree of doneness on cook loss and WBSF value were analyzed as a 1-way ANOVA using the MIXED procedure in SAS. Least squares means were separated using a probability of difference statement and were considered statistically significant at $P < 0.05$.

RESULTS AND DISCUSSION

Cook loss was expected to increase with increased aging time (Dilger et al., 2010; Jones-Hamlow et al., 2015). Those expected differences were detected in the present study. Among chops cooked to 63 °C, cook loss increased with increased postmortem aging (Fig. 1a). Cook loss was increased by 1.13 units ($P < 0.01$) in chops aged 14 d compared with those aged 7 d. Cook loss was increased 1.14 units ($P < 0.01$) in chops aged 7 d compared with those aged 3 d. Dilger et al. (2010) reported a 0.55-unit decrease in cook loss in chops aged 2 d compared with those aged 7 d, but only a 0.06-unit decrease in cook loss in chops aged 7 d compared with those aged 14 d. Similarly, Ellis et al. (1998) reported a 0.7-unit decrease in cook loss in chops aged 2 d compared with chops aged 9 d, and a 0.5-unit decrease from chops aged 9 d compared with chops aged 16 d. The lower magnitude of difference reported by Dilger et al. (2010) and Ellis et al. (1998) compared with the present study may be a result of increased degree of doneness (70 °C) in those previous works.

In addition, cook loss was expected to increase with increased cooking temperature. Among chops aged 14 d, cook loss was increased 10.04 units ($P < 0.001$; Fig. 1a) in chops cooked to 71 °C compared with those cooked to 63 °C. Protein denaturation decreases water holding capacity (Wagner, 2007), and cook loss increases as end-point temperature increases (Wood et al., 1995; Aaslyng et al., 2003; Klehm et al., 2018). Klehm et al. (2018) reported reduced cook loss for chops cooked to both 63 °C (11.29%) and 71 °C (12.93%) compared with the present study (15.35% and 25.39%, respectively). Because in the present study, chops were aged in the same packaging they were cooked in, cook loss represents both purge loss during aging and actual loss during cooking. In the previous study (Klehm et al., 2018), purge loss during aging was 4.81% and 4.76% for chops cooked to 63 °C and 71 °C, respectively. This makes total water loss of 16.1% and 17.69% for each group, respectively. Thus, cook loss of 25.39% in the present study appears increased compared with previous work. However, others (Lonergan et al., 2007; Arkfeld et al., 2015; Harsh et al., 2017) have reported cook loss of chops cooked to 71 °C ranging from 20.73% to 23.96%, similar to the current study. Thus, meaningful differences can be detected in cook loss using sous-vide cooking but care needs to be taken when comparing between studies when meat is aged postmortem in the same packages as used for cooking.

Warner–Bratzler shear force was expected to decrease with increased aging time (van Laack et al., 2001; Channon et al., 2003; Dilger et al., 2010; Clark et al., 2014; Jones-Hamlow et al., 2015). This expected difference was detected early in the aging curve. In chops cooked to 63 °C, shear force values decreased in early aging (Fig. 1b). Shear force was decreased by 0.27 kg ($P = 0.02$) in chops aged 3 d compared with chops aged 7 d. Shear force decreased numerically by 0.16 kg

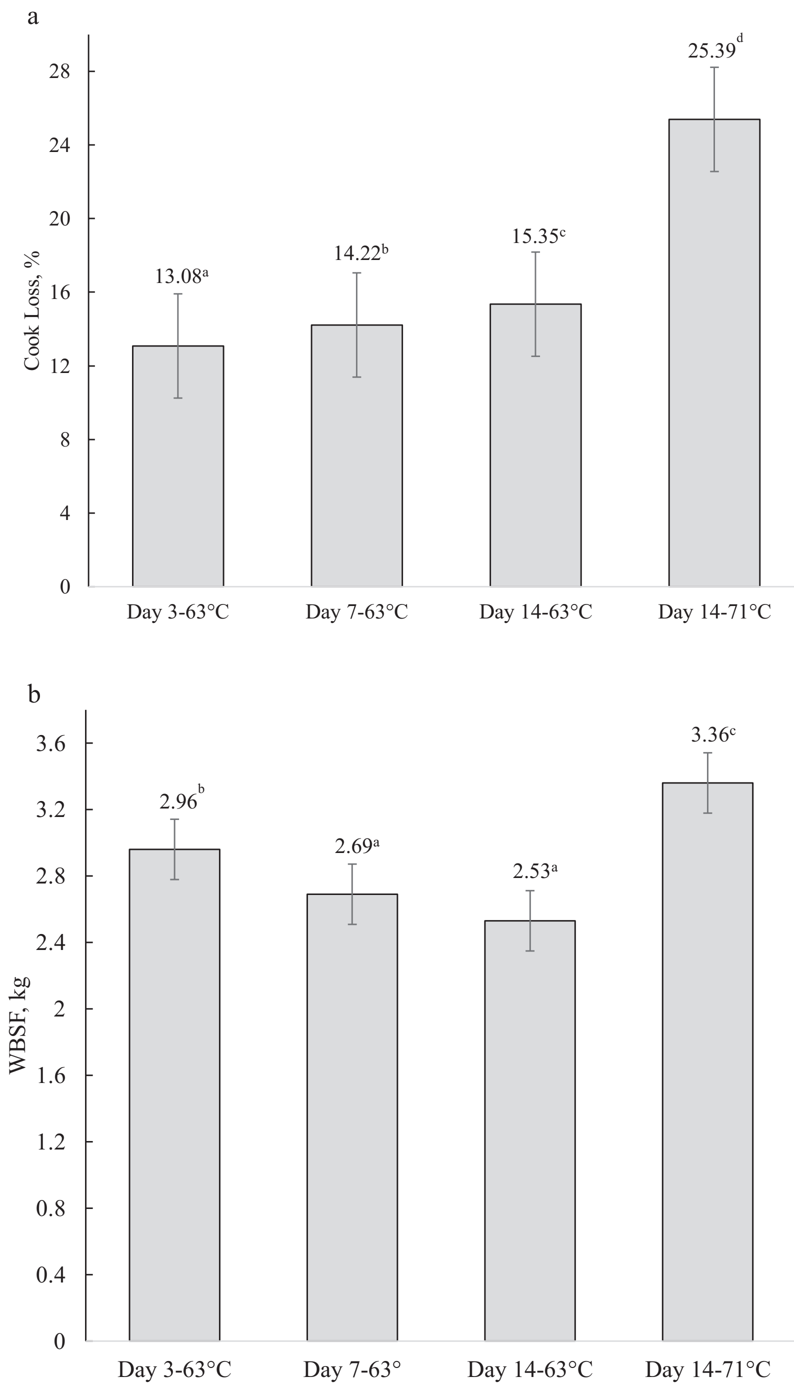

Figure 1. (a) Effect of aging period and degree of doneness on cook loss of boneless pork chops. (b) Effect of aging period and degree of doneness on Warner–Bratzler shear force (WBSF) value of boneless pork chops. Data are depicted as least squared means (reported) ± SEM. [a,b,c]Values depicted with differing superscripts are considered significantly different ($P < 0.05$).

but was not different ($P = 0.15$) in chops aged 7 d compared with chops aged 14 d. Chops aged 14 d and cooked to 71 °C had the greatest WBSF value, requiring 0.67 kg more force than chops aged 7 d and cooked to 63 °C ($P < 0.001$) and 0.83 kg more force than chops aged 14 d and cooked to 63 °C ($P < 0.001$; Fig. 1b).

The objective of the present experiment was to demonstrate that sous-vide cooking is an acceptable method for meat science experiments given that expected differences in tenderness with aging or end-point cooking temperature differences could be detected. Therefore, results from the present study are displayed in Table 1 along with those from previous studies. Among these previous studies, WBSF decreased between 7.10% and 21.29% when comparing early aging (1 to 3 d) and mid-aging (7 or 9 d) and decreased between 3.53% and 15.38% when comparing mid-aging and late aging (14 to 21 d). In the present study, WBSF decreased 9.12%

Table 1. Reported values for Warner–Bratzler shear force (WBSF) and cook loss in pork loin chops aged postmortem and cooked to 63, 70, or 80 °C

Citation	Cooking method	Degree of doneness	Early aged[1]	Mid aged	Late aged	Early–mid	Mid–late	Early–mid
			Reported	Reported	Reported	% Difference[2]	% Difference[3]	% Difference[4]
WBSF, kg								
Ellis et al. (1998)	Open-hearth grill	70 °C	4.07	3.76	3.90	7.62	−3.72	4.18
van Laack et al. (2001)	Oven	70 °C	4.89	4.16	3.52	14.93	15.38	28.02
Channon et al. (2003)	Water bath	80 °C	4.65	3.66		21.29		
Dilger et al. (2010)	Open-hearth grill	70 °C	3.38	3.12	3.01	7.69	3.53	10.95
Clark et al. (2014)	Open-hearth grill	70 °C	3.38	3.14	2.82	7.10	10.19	16.57
Jones-Hamlow et al. (2015)	Open-hearth grill	70 °C	4.05	3.49	3.00	13.83	14.04	25.93
Present study	Water bath	70 °C			3.36			
Present study	Water bath	63 °C	2.96	2.69	2.53	9.12	5.95	14.53
Cook loss, %								
Channon et al. (2003)	Water bath	80 °C	35.19	34.51		1.93		
Dilger et al. (2010)	Open-hearth grill	70 °C	21.52	20.97	21.65	2.56	−3.24	−0.60
Jones−Hamlow et al. (2015)	Open-hearth grill	70 °C	24.29	23.62	23.70	2.76	-0.34	2.42
Present study	Water bath	70 °C			25.39			
Present study	Water bath	63 °C	13.08	14.22	15.35	−8.72	−7.95	−17.35

[1]Early-aged chops aged 1 to 3 d; mid-aged chops aged 7 or 9 d; aged chops aged 14 to 21 d.

[2]Percent difference calculated between early- and mid-aged chops.

[3]Percent difference calculated between mid- and late-aged chops.

[4]Percent difference calculated between early- and late-aged chops. –

from early aging to mid-aging and 5.95% from mid to late aging. This is consistent with the finding of van Laack et al. (2001), who reported a decrease in shear force value when chops were aged 7 d compared with 2 d and cooked to 70 °C in an oven. Channon et al. (2003) reported chops aged 2 d were less tender than those aged 7 d when cooked to 80 °C in a water bath. The agreement between these studies and the results from the current study indicate that differences in tenderness due to early aging are detectable in chops both cooked in a water bath and to a lower degree of doneness. The importance of this is not so much the differences reported between chops, but rather that those differences can be detected using the method and cooking temperature described here (Table 1).

However, the results from the present study regarding later aging is inconsistent with other studies (van Laack et al., 2001; Dilger et al., 2010) that reported increased tenderness in chops cooked to the same degree of doneness, but aged 14 d compared with 7 d. The discrepancy between previous studies and the results presented here may be due to the difference in end-point cooking temperature. These previous studies cooked chops to 70 to 71 °C, which may accentuate small changes in tenderization between aging periods. A lower internal end-point temperature allows the chop to retain more moisture resulting in an increase in juiciness and tenderness (Klehm et al., 2018).

Based on the results of this study, sous-vide style cooking of meat for experiments is a viable alternative to conventional direct-heat methods historically used in meat science. Given sufficient time in the water bath, all samples reach the desired end-point temperature, and based on the method, it is not possible for samples to exceed this temperature. In addition, constant monitoring of temperature during cooking is not needed. Based on the results of the present study, sous-vide can be used as an acceptable method to cook pork chops in meat science experiments as expected differences in tenderness and cook loss when chops were aged differently or cooked to different degrees of doneness were detected and were similar to those of previous works. Therefore, sous-vide cooking is a method that can be used in meat science experiments when tenderness measurement is an objective of the research.

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