Comparison of Effects of Two Aging Methods on the Physicochemical Traits of Pork Loin

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Abbreviated running title: Effects of aging methods on pork quality

Abstract

The objective of this study was to compare effects of two different aging methods on physical, chemical, and microbial traits of pork loin: Dry and wet-aged meat was hung in the cooler at 8±1°C and 85±2.1% humidity for 14 days, while wet-aged meat was immersed in a 3.5% salt solution of brine in vacuum pouches. On day 7, pH and moisture content were higher in dry-aged loins than in wet-aged, while drip loss and total plate counts ($p<0.05$) were lower on day 14. As aging continued, the pH and drip loss of dry-aged loins decreased, while their total plate counts and water holding capacity (WHC) increased ($p<0.05$). After 7 and 14 days of aging, redness in dry-aged loins was higher than that in wet -aged muscles ($p<0.05$). On day 14 of aging, hardness, chewiness, and adhesiveness were lower in dry-aged pork loin as compared to those in wet -aged samples ($p<0.05$). Consequently, the results suggested that dry and wet aging methods differently affects meat quality traits of pork loin.

Key words: dry-aging, immersion in brine, meat quality, pork loin

Introduction

In Korea, pork is the most widely consumed meat (Korea Meat Trade Association, 2017). Notably, limited body parts of pork are used for consumption, for example the belly and the neck. Such a specific utilization of pork's body parts for consumption can be attributed to their tenderness. Tenderness is a crucial factor for determining meat quality, and has a significant influence on consumers' repurchase of meat (Shackelford et al., 2001).

Aging, also referred to as "ripening" or "conditioning", is widely practiced in the meat industry, as it improves meat tenderness and flavor during aging, thereby improving palatability (Sitz et al., 2006). Dry- and wet-aging are the two popular commercial beef aging techniques. Dry aging refers to a process in which unpackaged meat is stored in a refrigerated room with controlled temperature (0-4℃) and humidity (62%-87%). This process requires more time and physical space, making it expensive (DeGeer et al., 2009; Stenström et al., 2014). However, it minimizes yield loss due to trimming and meat contraction owing to the dried surface (Smith et al., 2008). Conversely, wet-aging, in other words, vacuum aging, is a relatively low-cost process in which the meat is packaged under vacuum in a water-impervious bag under refrigerated conditions (Ahnström et al., 2006; Smith et al., 2008). Besides, it prevents weight loss caused by water evaporation and bacterial growth (Campbell et al., 2001). The optimal duration for dry aging for dry-aged meat is 14-21 days while for wet-aged meat, 7-10 days for wet-aged meat at optimal temperature (0-1℃) (Leroy et al., 2003). Dry-aged beef has beefy and brown-roasted flavor while wet-aged beef has a sour and blood/serum-like flavor with more tenderness (Adegoke and Falade, 2005; Campbell et al., 2001). However, some studies on sensory analysis of dry and wet-aged beef have reported inconsistent results. Several literatures on dry-aged beef reported storage temperatures from 0-4℃, relative humidity of 62%-87%, aging time of 14-62 days (USMEF, 2018). The traditional meat salting technologies are usually divided into two modes: dry-salting and wet-salting. Wet salting is done by plunging the

product into brine or injecting the solution directly into meat (Varnam & Sutherland, 1995). Little study addressing the effects of vacuum aging with salting in brine on quality traits of pork was found in the literature. Although several researchers have compared the impact of wet and dry-aged beef on meat quality (Adegoke and Falade, 2005; Ahnström et al., 2006; Campbell et al., 2001; DeGeer et al., 2009; Leroy et al., 2003; Sitz et al., 2006; Stenström et al., 2014), no study investigating the effects of dry aging and wet aging with salting in brine on the physical, chemical, and microbial traits of pork loin muscle has been published. Our study compares the effect of dry aging and wet aging with salting in brine on the physical, chemical, and microbial traits of pork loin.

Materials and Methods

Sample preparation and aging conditions

The *M. longissimus dorsi* (LD) was taken from 6 carcasses of swine, offsprings of Landrace/Yorkshire (sow) and Duroc (boar) crossbreed. The average live weight of pigs was 108 kg during slaughtering. Pork loins were harvested from commercial processors and transferred to the laboratory by a commercial refrigerated transport (3±1°C). Subsequently, the *M. longissimus* was chopped into 6 parallel slices of about 15 cm each. Loins were divided horizontally into two equal parts, which were allotted to one of the two aging treatments (dry/hanger aging, or wet aging with salting in brine in a vacuum pouch at random. Dry and wet aging with salting in brine was carried out at 8±1°C with relative humidity of 85±2.1% for 14 days. Dry aging samples were hung unpacked in presence of air in a refrigerated cooler. Cooler temperatures and humidity were monitored and recorded using temperature probes (175-H2; Testo, Germany). Wet aging samples were vacuum-packaged in vacuum pouches containing brine solution with 3.5% sodium chloride and then stored in a refrigerated cooler at 8±1°C. The samples in both treatment were taken on day 0 (non-aged), 7 and 14 (aged) for

analyses.

Physicochemical analysis

Four grams of raw meat was sampled and homogenized with 16 mL distilled water for 1 min at 8000 rpm. (Ultra-Turrax T25, Janke & Kunkel, Germany). Subsequently, the pH value of the sample was determined with an electronic pH meter (Model 340, Mettler-Toledo GmbH, Swizerland). Also, 3 g of raw meat was sampled, dried in a drying oven at 105°C for 12 hours, and moisture content was evaluated by calculating weight difference between pre-dried and post-dried samples. Water-holding capacity (WHC) of the samples was measured by the modified method of Joo (2018). Briefly, 3.0 g of intact meat was weighed and placed on a previous desiccated and weighed filter-paper (Whatman No. 1 of 11 cm of diameter) with two thin plastic films. After weighing them, the filter-paper and plastic film with meat sample were placed between plexiglass plates, then a load of 2.5 kg was applied for 5 min. After accurately removing the compressed meat sample, the damp filter-paper and two plastic films were rapidly weighed. WHC (%) was calculated as follows: WHC (%) = (Damp filter- paper and plastic films weight) − (filter- paper and plastic films weight) / meat sample weight × 100. Drip loss was estimated by calculating the difference between final weight and the initial weight of meat samples in a bag. Briefly, a 2 cm thick slice (weight 100 ± 5 g) cut from the muscle was vacuum packaged in a polypropylene bag and stored at 4°C. The percent change in weight over the subsequent 48 h was taken as the drip loss.

Meat color was measured with a colorimeter (Minolta CR-400, Minolta Co., Japan) that was standardized with a white plate (Y=93.5, X=0.3132, y=0.3198) before color measurement. The color parameters were shown as L* (lightness), a* (redness), and b* (yellowness). To determine the texture profiles, the meat blocks (40×40×25 mm) were cooked in a preheated water bath at 85℃ for 38 min until the core temperature reached to 75℃, and then cooled under running water

(ca. 15℃) for 25 min to achieve a core temperature below 30℃. Sliced samples with a 25-mm diameter were analyzed using a texture analyzer (TA-XT2i, Stable Micro System, UK) and their hardness, chewiness, and adhesiveness were measured. Lipid oxidation of the samples was measured using thiobarbituric acid distillation (Yang et al., 2009). 2-Thiobarbituric acid reactive substances (TBARS) was reported as milligrams of malonaldehyde (MDA) per kg of meat sample. For total microbial count analysis, samples (20 g) were aseptically obtained and moved into stomacher bags with 180 mL of 0.85% sodium chloride solution and homogenized for 180 sec in a stomacher (400 Lab Blender, Seward, UK). Total microbial counts were plated using 1 mL sample, inoculated on plate count agar (Difco, Sparks, MD, USA) and incubated for 48 h at 37℃ (APHA, 1992). Microbiological results were expressed as the log of colony forming unit (CFU)/g.

Statistical analysis

All experimental data were analyzed by analysis of variance (ANOVA) procedure of SPSS (2011) program with three replications. Means of the two groups were compared using the *t*-test. The significance of differences among the means at the same storage time was determined using Duncan's multiple range tests. ($p<0.05$).

Results and Discussion

Effects of two aging methods on physicochemical traits of pork loin are presented in Table 1. In both samples, pH decreased with aging. We observed significant variation between the dry-aged (pH 5.88) and wet-aged (pH 5.68) pork loin at day 7 of aging ($p<0.05$). This is in line with another recent literature (Lee et al., 2010), indicating that the pH in wet-aged pork was lower than that of dry-aged pork. This may be attributed to more nitrogen-containing compounds formed due to proteolysis of proteins in dry-aged pork samples, resulting in their

higher pH (Aksu et al., 2005). On day 7, the slightly higher moisture content was found in dry-aged loin (71.5%) than in wet-aged sample with salting in brine (69.82%) ($p<0.05$) and tended to be similar at day 14. This may be because there were no significant differences in the water activity of pork until day 14 for both aged pork meats (data not shown in Table). Ahnström et al. (2006) also found dry-aging method had no effect on moisture contents during the aging periods. Changes during aging in the present study were small and suggested that the samples are relatively static. The WHC of dry-aged loin muscles increased as the aging period increased ($p<0.05$) as in another study (Cho et al., 2018). Aging condition did not adversely affect WHC. On days 7 and 14, more drip loss was observed in wet-aged sample with salting in brine than in dry-aged loin ($p<0.05$). As aged, drip losses in the samples of both aging conditions decreased ($p<0.05$). Straadt et al. (2007) found a decrease in drip loss with aging of pork, confirming what we observed in the present study. The supposition that increased viscosity of drip is a factor in the reduction of drip loss with aging is supported by the work of Rossi et al. (1953). Dry aging of loin samples resulted in increased lipid oxidation during aging ($p<0.05$). However, TBARS values for wet-aged loins with salting in brine maintained constantly for 14 days ($p>0.05$). Wet-aged loins with salting in brine had lower TBARS values than dry-aged muscles on day 14 ($p<0.05$). Lipid oxidation is closely correlated with oxygen exposure (Cho et al., 2018). Elimination of oxygen contact by vacuum packaging could be caused by inhibiting the development of lipid oxidation during storage (Ahn et al., 1992). A level of TBARS value of 0.5 mg MDA/kg is the point at which meat is considered to be off-odor and rancid flavor as perceived by consumers (Wood et al., 2008). This value was not attained in our study. Thus, no excessive lipid oxidation was observed during aging up to day 14. Counts of total aerobic bacteria increased during the aging period. There was no significant difference in total plate counts between the dry-aged and wet-aged cuts with salting in brine on day 14 ($p>0.05$). Berger et al. (2018) described

similar results, This phenomenon could be attributed to the fact that conventional dry-aging naturally produces a protective crust layer or dehydrated lean surface (Berger et al., 2018).

Table 2 describes the color measurements of pork loin samples as a result of aging methods. Regardless of the aging method deployed, L* value increased after aging ($p<0.05$), which is in line with the results of previous study (Obuz et al., 2014). On day 7, wet-aged pork loins with salting in brine had higher L* values as compared to that of dry-aged cuts ($p<0.05$). This finding is in line with a previous study, which showed that the wet-aged pork cuts with salting in brine had higher L* values than the dry-aged cuts (Hwang et al., 2018). Previous study reported that dry-aged beef showed lower L* values due to moisture evaporation, which causes lower reflection of light (Dikeman et al., 2013). The wet aging with salting in brine of loin muscle resulted in decreased a* values with increased aging period ($p<0.05$). This might be explained by higher pigment oxidation as the aging period increased. Dry-aged muscles showed higher a* values than the wet-aged muscles with salting in brine on days 7 and 14 ($p<0.05$). A similar pattern was observed in another study where a* value for wet-aged samples decreased till 14 d of aging (Hwang et al., 2018). In case of b* value, the highest value in the wet -aged muscles with salting in brine was observed on day 7. The higher L* values and lower a* values for wet-aged samples could be due to increased WHC during aging (Hwang et al., 2018). Our findings indicate that dry aging did not adversely affect the color and the dry-aged pork samples were lower lightness value and higher redness value than the wet-aged samples with salting in brine.

Table 3 describes the texture profiles of pork loin as influenced by aging methods. There was no significant difference between the dry-aged and wet-aged cuts with salting in brine on day 7 of aging ($p>0.05$). However, there were significantly differences between the dry-aged and wet-aged pork loin with salting in brine on day 14. Wet-aged pork loins with salting in brine

exhibited a higher hardness, chewiness, and adhesiveness than the dry-aged samples at day 14 of aging ($p<0.05$).

Conclusions

The results suggested that the quality parameters of pork loin were dependent on aging conditions to some extent. Although dry aging led to higher pH, moisture content and redness values, as well as it exhibited lower drip loss and texture profiles, both dry and wet aging with salting in brine and dry aging methods has no negative impact on physicochemical quality of pork loin during aging. Further study using different pork cuts and novel aging methods should be carried out for establishing optimal aging parameters ensuring high quality, feasibility, and consumer benefit.

Conflicts of Interest

The authors declare no potential conflict of interest.

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278

279 **Table 1.** Physico-chemical traits of pork loin by two aging condition

		Aging period (d)				
	Condition	0	7	14	SEM	ANOVA[2]
pH	Dry	5.94^{a}	5.88^{Aa}	5.70^{b}	0.039	P^{***3}
	Wet	5.94^{a}	5.68^{Bb}	5.74^{b}	0.043	P*C**
	SEM[1]	0.032	0.046	0.010		
Moisture (%)	Dry	70.81^{b}	71.50^{Aa}	71.26^{ab}	0.121	P*
	Wet	70.81	69.82^{B}	70.70	0.260	P*C*
	SEM[1]	0.062	0.395	0.333		
Water holding capacity (%)	Dry	63.17^{b}	78.21^{a}	78.87^{a}	2.607	P***
	Wet	63.17^{b}	79.21^{a}	74.97^{b}	2.442	P*C*
	SEM[1]	0.604	0.439	1.126		
Drip loss (%)	Dry	16.06^{a}	3.84^{Bb}	0.48^{Bc}	2.376	P***
	Wet	16.06^{a}	6.50^{Ab}	6.16^{Ab}	1.648	C***
	SEM[1]	0.406	0.705	1.270		P*C***
TBARS (mg MDA/kg)[4]	Dry	0.19^{c}	0.24^{b}	0.48^{Aa}	0.041	P***
	Wet	0.24	0.24	0.21^{B}	0.009	C***
	SEM[1]	0.012	0.004	0.062		P*C***
Total plate counts (Log_{10} colony forming unit/g)	Dry	2.28^{b}	2.88^{b}	3.89^{a}	0.666	P**
	Wet	2.26^{c}	3.08^{b}	3.86^{a}	0.745	
	SEM[1]	0.009	0.066	0.048		

280 [1]Standard error of mean
281 [a-c]Means in the same row within the same aging condition with different letters are
282 significantly different ($p<0.05$).
283 [A-B]Means in the same column within the same aging period with different letters are
284 significantly different ($p<0.05$).
285 [2]ANOVA, two-way ANOVA analysis among the treatments; C, condition; P, aging period.
286 [3]*$P<0.05$; **$P<0.01$; ***$P<0.001$
287 [4]2-Thiobarbituric acid reactive substances (TBARS) (milligrams of malonaldehyde (MDA) per
288 kg)
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Table 2. Color characteristics of pork loin by two aging condition

		Aging period (d)				
	Condition	0	7	14	SEM	ANOVA[2]
L*[4]	Dry	46.77^{b}	51.32^{Ba}	50.67^{a}	0.838	P**[3]
	Wet	46.77^{b}	53.74^{Aa}	51.73^{ab}	1.356	
	SEM[1]	0.917	0.521	0.843		
a*	Dry	9.92^{b}	11.93^{Aa}	9.16^{Ab}	0.544	T**
	Wet	9.92^{a}	6.55^{Bb}	6.35^{Bb}	0.828	T*S**
	SEM[1]	0.236	1.224	0.651		
b*	Dry	2.63	1.22^{B}	3.05^{A}	0.409	T*S**
	Wet	2.63^{b}	5.56^{Aa}	1.17^{Bb}	0.724	
	SEM[1]	0.655	0.971	0.471		

[1]Standard error of mean

[a-b]Means in the same row within the same aging condition with different letters are significantly different ($p<0.05$).

[A-B]Means in the same column within the same aging period with different letters are significantly different ($p<0.05$).

[2]ANOVA, two-way ANOVA analysis among the treatments; C, condition; P, aging period.

[3]*$P<0.05$; **$P<0.01$; ***$P<0.001$

[4]L*: lightness, a*: redness, b*:yellowness

299 **Table 3.** Texture profile of pork loin by two aging condition

		Aging period (d)				
	Condition	0	7	14	SEM	ANOVA[2]
Hardness (kgf)	Dry	1.35^{b}	1.82^{a}	1.17^{Bc}	0.099	P^{***3}
	Wet	1.35^{b}	1.66^{a}	1.57^{Aa}	0.048	T*S*
	SEM[1]	0.004	0.056	0.090		
Chewiness (kgf,mm)	Dry	1.06	0.97	0.47^{B}	0.165	
	Wet	1.06	0.97	0.85^{A}	0.153	
	SEM[1]	0.298	0.081	0.105		
Adhesiveness (kgf)	Dry	0.23^{b}	0.47^{a}	0.15^{Bb}	0.052	
	Vacuum	0.23	0.34	0.31^{A}	0.024	
	SEM[1]	0.026	0.037	0.041		

300 [1]Standard error of mean
301 [a-c]Means in the same row within the same aging condition with different letters are
302 significantly different ($p<0.05$).
303 [A-B]Means in the same column within the same aging period with different letters are
304 significantly different ($p<0.05$).
305 [2]ANOVA, two-way ANOVA analysis among the treatments; C, condition; P, aging period.
306 [3]*$P<0.05$; **$P<0.01$; ***$P<0.001$
307