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Accelerated dry curing of pork legs.

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Introduction

Dry curing of hams has been practiced in the United States since the early settlers established this technique to preserve pork. Virginia has maintained this tradition because of the unique cured and aged flavor that is acquired from the dry curing process, even though other preservation methods are now available. This process involves the application of cure adjuncts in granular form. Following cure application, salt penetration is normally permitted for 28-42 days. The residual cure is then removed and approximately 14 days of cure equalization is permitted. This process is followed by smoke application (optional) and aging at ambient temperature for 14-112 days for additional flavor development.

Recent research in our laboratories has suggested that the dry curing process for hams can be accelerated (Marriott et al., 1983, 1984, 1985, 1986; Tracy, 1979). Research at other institutions has indicated the potential of tumbling to accelerate the process for brine curing (Theno et al. 1977; Siegel et al.; Anonymous, 1981). Our research has revealed that vacuum tumbling of pork legs with the dry cure adjuncts (Marriott et al., 1984) or with NO gas (Marriott et al., 1983; Tracy, 1979) will accelerate cure penetration. Further study in our laboratories of the accelerated dry curing concept has involved blade penetration with a Ross Tenderizer to accelerate the dry cure penetration process (Marriott et al., 1985).

These previously devised techniques have not consistently yielded flavor equal to dry cured hams with aging to or beyond 70 days after initial cure application. The aged flavor of dry cured pork legs is attributable to chemical changes contributed by cure adjuncts, aging time and elevated temperature during aging. McCain et al. (1968) have suggested that free amino acids in cured pork leg muscle that has resulted from extended aging contribute to the mellow, aged flavor of country cured ham. During aging, the lipid fraction is altered by hydrolysis and oxidation. Oxygen attacks the methylene group of unsaturated fats causing formation of unsaturated hydroperoxides. Subsequent degradation of hydroperoxides contributes to flavor through the creation of free radicals which form carbonyl compounds (Sulzbacher et al., 1963). Kingsley et al. (1978) reported that after aging, both unfrozen and frozen hams were higher ($P<0.05$) in stearic acid and lower in palmitic acid. Graham and Blumer (1971) identified microbial flora of dry cured ham and its relationship to flavor. These researchers have revealed that microorganisms are potential flavor enhancers for dry cured meats.

The optimal tumbling time or curing period has not yet been determined. This investigation was conducted to study the effect of tumbling and cure time on the chemical, visual and taste attributes of dry cured pork legs. Furthermore, this research was designed to investigate the influence of inoculating tumbled and dry cured pork legs with microbial flora typical of dry cured and aged hams on their appearance and sensory attributes.

Experimental Methods

Study A

Twenty pork legs that weighed from 7.8 to 10.9 Kg were removed from 10 carcasses within 24 hours postmortem, skinned, trimmed 2/3 of the distance from the butt surface to the shank (to reduce fat variability) and weighed. All legs from the right side of each carcass were tumbled in a prototype tumbler manufactured by the Virginia Polytechnic Institute and State University Lab Support Services at 18 rpm for 30 minutes at 94.5 KPa vacuum, rested without vacuum for 30 minutes and tumbled for 30 minutes more at 94.5 KPa vacuum (TRT). Those legs from the left side were tumbled for only 30 minutes at 94.5 KPa vacuum (T). Cure adjuncts (8% of the product weight of NaCl and 2180 ppm of $NaNO_3$) were placed on top of the pork legs in the tumbler for all samples and were permitted contact with the pork legs for 40 days. After 7 days of storage, all samples were again treated with approximately 50% of the original amount of NaCl. Following 40 days of cure application, the residual adjuncts were removed by washing and the cured pork legs (hams) not utilized for product evaluation were transferred to a 12°C storage environment with 75% RH for 16 days of cure equalization. Those samples not evaluated after 56 days of curing were aged in a 30°C environment with 65% RH for 14 days. After 70 days from the initial cure application, the remaining samples were evaluated.

Objective measurements at each evaluation interval included sampling of the Biceps femoris (B) and the medial and lateral side of the Semimembranosus muscles for percentage moisture and salt (AOAC, 1980), and ppm NO_3 and NO_2 (USDA, 1979). Subjective evaluations were determined by a seven-member rating panel according to a scaling method described by Larmond (1979). Evaluations included color and overall appearance before curing (8=very desirable; 1=very undesirable); cured color, before and after cooking (5=bright cured color development; 1=no cured color development); percentage of cure penetration (5=100; 1=0); and tenderness, juiciness and flavor (8=very desirable; 1=very undesirable). Data were subjected to analysis of variance (SAS, 1979; Snedecor & Cochran, 1967) and mean separation analyses according to Duncan (1955).

Study B

Eighteen pork legs that weighed from 7.4 to 8.9 Kg were removed from 9 carcasses within 24 hours postmortem, skinned, trimmed according to Study A, deboned leaving the muscles intact and weighed. All deboned legs from the right and left side of each carcass were tumbled as described for Study A. Each leg was separated into the bottom section (Biceps femoris and Semitendinosus), Quadriceps group (Rectus femoris, Vastus lateralis, Vastus medialis and Vastus intermedius) and top section (Adductor and Semimembranosus) with subsequent stuffing into 170 mm diameter casings. Cure adjuncts were introduced as in Study A except that no cure was applied 7 days after tumbling. Following 40 days of cure application, three pairs, both left and right, were evaluated and those hams not utilized for product evaluation were transferred to a 12°C storage environment with 75% RH for 19 days of cure equalization. Those samples not evaluated at 56 days were aged in a 30°C environment with 65% RH for 14 days. After 70 days from initial cure application, the remaining samples were evaluated. Measurements were the same as for Study A.

Study C

Twenty paired pork legs with the same characteristics as for Studies A and B were tumbled for 30 minutes as indicated for Studies A and B. After 40 days, the residual cure was removed by washing and all cured legs (hams) from the right side of each carcass were inoculated with a mixed culture obtained from commercially cured and aged ham (I) and those from the left side were not inoculated and served as control samples (C). The designated hams were inoculated by submerging them in the inoculum for 10 seconds. All hams were transferred to a 12°C storage environment with 75% RH for 16 days of cure equalization. Those samples not evaluated after 56 days of curing were aged at 30°C with 65% RH for 17 days and then evaluated. Measurements and data analyses were the same as for Studies A and B except that microbial analyses were conducted.

Results and Discussion

Study A

Tumble and cure time had no effect ($P>0.05$) on cured color development of uncooked bone-in samples. Cooked TRT samples which were cured for 40 days achieved more color development ($P<0.05$) than the T hams, although this difference did not exist ($P>0.05$) between those that were cured and aged for 70 days. Tumble time was not critical for uncooked color development, but appeared to affect the cured color fading during cookery. The accelerated color development achieved for the uncooked samples that were cured for 40 days agrees with our previous research (Marriott et al., 1984) which revealed that tumbling enhances cured color development of uncooked samples but color fading of shorter cured hams can occur during cookery. This past research supports the higher ($P<0.05$) color values for the cooked samples that were cured and aged for 70 days.

Tumble time did not affect ($P>0.05$) any of the sensory traits of the bone-in samples. Although the TRT samples at 40 days were more juicy and more tender ($P<0.05$) than the counterparts cured and aged for 70 days, this difference was not found among the T hams. These results suggest that this accelerated process, regardless of tumble time stabilized the sensory attributes enough at 40 days that minimal benefits were attained by an increase of curing and aging time. Although the differences between the TRT samples cured for 40 and 70 days were significant ($P<0.05$) these differences may not be important since the variation was only 0.5.

The effects of tumble time and cure time for bone-in cured pork legs on the analytical data are presented in Table 1. Although tumble time had no effect ($P>0.05$) on percentage moisture after 40 days of cure, the TRT samples cured and aged for 70 days sustained more moisture loss ($P<0.05$) than the T hams. Both tumbling treatments at 70 days sustained more moisture loss ($P<0.05$) than those cured for 40 days which agrees with our earlier research (Marriott et al., 1984). The trend for salt percentage is similar to that observed for moisture content. The higher percentage of salt ($P<0.05$) for the TRT samples at 70 days support the lower moisture content ($P<0.05$) for the same treatment, since a higher salt content should contribute to less moisture. Nitrate content did not differ ($P>0.05$) among the treatments, suggesting that regardless of tumbling time the conversion of NO_3 to NO_2 was expedited. The TRT samples that were cured for 40 days sustained more NO_2 depletion ($P<0.05$) than the T counterparts although this difference did not exist at 70 days. The longer tumble time accelerated NO_2 depletion for the shorter cure time.

Study B

Tumble and cure time had no effect ($P>0.05$) on cured color development of uncooked samples except for the TRT samples at 70 days (Table 2). The color scores for reduced cure times suggest that tumbling, regardless of tumble time, accelerated cure color development. The higher value for the TRT samples suggests a trend similar to the bone-in cured legs in Study A. The lower color scores ($P<0.05$) of the cooked samples that were cured for less time agree with Study A and our past research (Marriott et al, 1984). Although tumble time had no effect ($P>0.05$) on the color of cooked samples, the boneless hams that were cured and aged for 56 days exhibited superior color ($P<0.05$) to those at 40 days. As with the uncooked samples, the TRT hams that were cured and aged for 70 days had superior color ($P<0.05$) to their counterparts that were cured for 56 days. Tumble time and cure time had a minimal effect on cured color development of uncooked samples but increased cure time was responsible for superior color retention during cookery.

No consistent effects of tumble time and cure time on sensory attributes were found. A shorter cure time generally yielded increased juiciness and tenderness, perhaps because of the higher ($P<0.05$) moisture content. The T samples that were cured and aged for 56 and 70 days received lower ($P<0.05$) juiciness scores than those cured for 40 days, suggesting that the reduced tumbling did not accelerate moisture loss as much as a longer tumble time. The reduced flavor ($P<0.05$) of the T samples cured for 56 days was attributable to less juiciness and tenderness than those cured for 40 days suggesting that decreased juiciness and tenderness were equated with a less desirable flavor. Tumble time had no apparent effect ($P>0.05$) on the sensory attributes but this accelerated process enhanced weight loss and flavor development without extended curing and aging.

The only effect of tumble time within each cure period on moisture content was after 70 days of curing and aging when the T samples had lower values ($P<0.05$) than the TRT counterparts. Although tumble time did not affect ($P>0.05$) salt percentage, this value generally increased with a longer cure time. This observation agrees with our past research (Marriott et al., 1984) related to accelerated curing of bone-in and boneless hams. With the exception of the T samples at 40 days, tumble and cure time did not affect ($P>0.05$) NO_3 content. This observation agrees with Study A and previous research by Marriott et al. (1984) and suggests that tumble time has a minimal effect on the analytical values and that increased cure time reduces moisture content.

Study C

No differences in the microbial load existed between the I and C samples that were evaluated after 56 days of cure and the C hams that were cured for 73 days. However, the I hams that were cured for 73 days yielded more growth of the mixed culture. The higher microbial load for the I hams that were cured for 73 days would be expected to affect the traits of these samples.

Subjective evaluations for appearance traits of all uncured legs revealed no differences ($P>0.05$) in these traits prior to cure application and that all samples were desirable in appearance. Inoculation of the cured

Table 1

Analytical data of bone-in cured pork legs with different tumble times.

	Cure time allocation (days)							
	40				70			
	T		TRT		T		TRT	
Measurement	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Percentage moisture	66.4[a]	0.45	67.3[a]	0.45	63.4[b]	0.45	62.0[c]	0.45
Percentage salt	3.4[c]	0.16	3.6[c]	0.16	4.0[b]	0.16	5.4[a]	0.16
Nitrate content (ppm)	27.7[a]	5.95	17.5[a]	5.95	11.9[a]	4.77	14.7[a]	5.15
Nitrite content (ppm)	168.9[a]	8.70	75.8[b]	8.70	18.8[c]	6.97	35.6[c]	7.53

[abc]Means in the same row with a common superscript are not different (P>0.05).

Table 2

Color scores[a] of boneless cured pork legs before and after cookery.

	Cure time allocation (days)											
	40				56				70			
	T		TRT		T		TRT		T		TRT	
Sample Time	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Before cookery	4.5[c]	0.10	4.5[c]	0.10	4.5[c]	0.10	4.4[c]	0.10	4.4[c]	0.10	4.9[b]	0.10
After cookery	3.8[d]	0.11	3.9[d]	0.11	4.4[bc]	0.11	4.3[c]	0.11	4.5[bc]	0.11	4.7[b]	0.11

[a]Means are based on a 5-point scale (5=bright color throughout; 1=no cured color development).
[bcd]Means in the same row with a common superscript are not different (P>0.05).

legs with a mixed culture (Table 3) yielded a superior cured color (P<0.05) after 56 days of curing. No color differences (P>0.05) among these samples were noted at 73 days. This lack of difference was attributable to the additional cure time to permit equal color development between the I and the C samples. The I samples achieved the same (P>0.05) color development before cookery at 56 and 73 days suggesting that the inoculum may have accelerated the cured color development; whereas, the C hams were rated lower (P<0.05) at 56 days than after 73 days of curing. The lower color scores (P<0.05) after cookery at 73 days do not agree with our previous research (Marriott et al., 1985; 1986) and cannot be fully explained.

Juiciness scores were not affected (P>0.05) by inoculation or cure time even though one might expect the samples at 73 days to be less juicy because of their lower moisture content. Nevertheless, the extended aging time increased tenderness, suggesting the contribution of aging instead of microbial inoculation to tenderness. This observation is based on the lack of differences (P>0.05) in tenderness between the I and C samples within the same cure time. Cure time and microbial inoculation had no effect (P>0.05) on flavor scores.

Table 3

Color scores[a] of cured pork legs before and after cookery.

	Cure time allocation (days)							
	56				73			
	Before cookery		After cookery		Before cookery		After cookery	
Treatment	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Inoculated	4.6[b]	0.11	4.3[b]	0.16	4.6[b]	0.11	3.7[c]	0.16
Not inoculated	4.2[c]	0.11	3.6[c]	0.16	4.6[b]	0.11	3.7[c]	0.16

[a]Means are based on a 5-point scale (5=bright cured color development; 1=no cured color development).
[bc]Means in the same row and column for each cure time with a common superscript are not different (P>0.05).

Table 4 suggests that increased cure time was associated with reduced moisture (P<0.05). Although the C hams were lower (P<0.05) in moisture content after 73 days of cure, this difference was attributable to experimental variation instead of treatment differences. Microbial inoculation did not enhance (P>0.05) moisture loss nor accelerate (P>0.05) salt penetration for either cure time, but the samples at 73 days contained more (P<0.05) salt than those for the same treatment cured only 56 days. These data suggest that cure time and not microbial inoculation increased salt penetration. No consistent effect of inoculation on nitrate content was observed. The I samples at 56 days contained less NO_3 than the controls while at 73 days the C legs had less (P<0.05) NO_3 than the I samples. The samples at 73 days yielded less (P<0.05) nitrite than those evaluated at 56 days, but

Table 4

Objective measurements of pork legs with different cure treatments.

	Cure time allocation (days)							
	56				73			
	Not inoculated		Inoculated		Not inoculated		Inoculated	
Objective measurement	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Percentage moisture	67.5^{a}	0.30	67.8^{a}	0.30	64.7^{c}	0.30	66.4^{b}	0.30
Percentage salt	3.2^{bc}	0.15	2.9^{c}	0.15	3.9^{a}	0.15	3.6^{ab}	0.15
Nitrate content (ppm)	25.3^{a}	3.48	10.7^{b}	3.48	10.3^{b}	3.48	23.1^{a}	3.48
Nitrite content (ppm)	86.5^{b}	6.26	120.9^{a}	6.26	28.9^{c}	6.26	26.4^{c}	6.26

^{abc}Means in the same row with a common superscript are not different ($P>0.05$).

microbial inoculation had no effect ($P>0.05$) on NO_2 content at 73 days. The higher NO_2 content ($P<0.05$) after 56 days of cure is attributable to lower NO_3 since the amount of NO_3 and NO_2 present can be a function of each other. These objective measurements suggest that cure time reduced the moisture percentage and increased salt penetration but that microbial inoculation had no consistent effect on any of these traits.

Conclusions

1. Increased tumble time for short cured (40 days) bone-in pork legs reduced color fading during cookery.
2. Increased cure time of boneless pork legs enhanced color retention during cookery.
3. Accelerated curing, regardless of tumble time, stabilized the sensory attributes enough at 40 days that minimal benefits were attained by an increase of curing and aging time for bone-in and boneless samples.
4. Increased cure time of the bone-in samples was responsible for additional ($P<0.05$) moisture loss and salt content and additional tumble time increased moisture loss and salt content of those samples with a longer cure time.
5. Tumble time had a minimal effect on the analytical data for the boneless samples.
6. Inoculation with a mixed culture improved ($P<0.05$) the uncooked color after 56 days of cure.
7. Cure time and microbial inoculation had no effect ($P>0.05$) on juiciness or flavor.
8. Microbial inoculation did not accelerate ($P>0.05$) the cure penetration rate and had no consistent effect on the amount of NO_3 and NO_2.
9. Although the effects of an increased tumble time were not always obvious, this treatment reflected a trend toward acceleration of the dry cure process.

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