DETERMINATION OF AN OPTIMAL TUMBLING TREATMENT REQUIRED TO MAXIMIZE SELECTED QUALITY AND YIELD FACTORS IN A BONELESS PRERIGOR CURED, SECTIONED AND FORMED HAM ROAST

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SUMMARY: The three hour prerigor intermittent tumbling treatment is an adequate tumbling requirement for producing desirable quality characteristics in a boneless, prerigor cured, sectioned and formed ham roast. From using prerigor cured muscle tissue in the manufacture of boneless tumbled hams, the meat processor could reap the financial benefits of hot processing. Any additional tumbling up to 6 hours with prerigor tissue would not be of any additional economic significance to the meat processor.

INTRODUCTION: The purpose of tumbling is to cause cellular disruption in muscle tissue, by utilizing the kinetic energy of the meat pieces falling inside a rotating, baffled drum. The result of cellular disruption to the muscle tissue is improved yield, tenderness, cohesiveness, and cure distribution (Addis and Shanus 1979). Tumbling fractures the myofibrillar membrane structure and allows greater solubilization of myofibrillar proteins by cure ingredients (e.g. salt; Soloman et al. 1980; Theno et al. 1978). Tumbling is responsible (Troutman 1964) for greater extraction of salt soluble proteins (SSP). Tumbling also enhances product quality and uniformity (Ockerman 1984; Lawlis 1985).

Researchers disagree as to the optimum time table for tumbling meat products (Ockerman et al. 1978; Gillet et al. 1981; Theno et al. 1978). Gillet et al. (1981) reported a positive correlation between tumbling time and quality parameters such as yield, color, cure distribution, and cohesiveness associated with the tumbled pork products.

The two basic methods of tumbling treatment are intermittent and continuous tumbling. Intermittent tumbling allows for a "rest period" within each hour of the tumbling cycle (Krausse et al. 1978). The rest period of intermittent tumbling allows for the curing solution to migrate and diffuse more uniformly throughout the tissue and enhances solubilization of the salt soluble proteins. The salt soluble proteins that are extracted form a creamy white exudate on the meat surface and upon cooking is responsible for the muscle-to-muscle bonds which are formed between meat pieces in the cooked product (Siegal 1978; Marsh 1977). Krausse et al. (1978) found an 18 hour intermittent tumbling schedule resulted in significantly better tumbled yields than continuous tumbled yields.

Data regarding the efficacy of using pre-rigor meat in conjunction with tumbling is limited. Knipe et al. (1981) suggests that the higher temperature of pre-rigor meat enhances cure distribution, and uniformity, and the rate of color development. Tumbling pre-rigor muscle tissue can substantially reduce processing times without affecting the quality of the finished product. The meat processors can use this processing technique to increase production and turnover rates along with the economic savings this system has to offer via reducing processing times. Therefore the objective of this study was to determine an optimal tumbling time using an intermittent tumbling time schedule and pre-rigor muscle tissue and comparing the data of the tumbled prerigor muscle tissue to postrigor tumbled muscle tissue which is typically used in a tumbled, boneless, cured, sectioned and formed ham roast.

MATERIALS AND METHODS: Twenty-five heavy gilts (Range=134.5-157.3 kg) were obtained from The Ohio State University swine herd to provide fifty sides used in this investigation. The experimental design can be found in Table 1.

Table 1: Experimental Design

(25 hogs = 50 sides total)

Rigor condition during tumbling	PRERIGOR	POSTRIGOR
Number of Hams	40	10
Number of Roasts	120	30
Intermittent Tumbling[a] Treatment (Hours)	0, 3, 6	0, 3, 6

Note: Three roasts were made from each whole ham, resulting in 3 observations per ham.

[a]Ten minute tumble, fifty minute resting period per hour of tumbling

Each side was randomly assigned a rigor treatment group (pre- and postrigor) and at approximately 40-45 minutes post-exsanguination, the sides were removed from the slaughter rail to facilitate ham removal . Each ham was boned and separated into the three major muscle regions, (1) **semimembranosus**, (2) **biceps femoris/semitendinosus**, and (3) **quadriceps**. All visible external and intermuscular fat was removed. The procedure for the conventional postrigor control group was the same as the prerigor tumbling treatment group except the procedures were conducted at 24 hours postmortem.

The three muscle regions of the ham were weighed together, then subjected to multiple stitch needle injection with a Fomaco pickle injector (Model FMG 20S) calibrated to deliver a 120% pump of green weight. The curing brine was composed of 84.7% water, 10% salt, 2.5% sucrose, 2.5% tripolyphosphate, 0.25% sodium erythorbate, and 0.075% sodium nitrite. Following pumping, a second weight on the muscles were taken to ensure the proper percent pump was delivered.

Immediately after injection, each muscle was sliced into uniform slices (2.5 cm) on a Hobart (Model 1612) slicing machine. Additional brine was added to account for any loss of brine during the slicing process. All muscle slices were put into a container and thoroughly mixed manually. The muscle sections were divided into three equal lots and each lot was placed into a plastic bag. Three boneless roasts (approximately 0.9-1.8 kg/roast) were made from each whole ham. The purpose of putting the muscle portions into plastic bags was to maximize tumbling space and prevent or reduce the amount of exudate loss due to smearing on the tumbler walls. A final weight (pre-tumble wt.) was taken on each bagged roast and each boneless ham roast was randomly assigned to one of the three tumbling treatments. The boneless ham roasts in bags were placed into the tumbler after being assigned to a tumbling treatment group.

The tumbler used, was a 38 cm. diameter X 84 cm. long stainless steel drum

positioned at a slight vertical incline (approximately 12-15°) and attached to a motor and a timer. The tumbler drum had 3 internal baffles and rotated at twelve and one-half r.p.m.

An intermittent tumbling schedule was used for each tumbling cycle, either 3 or 6 hours. The intermittent schedule consisted of tumbling for ten minutes each hour of the cycle, followed by a fifty minute rest period. Weights were also recorded for the roasts out of the tumbler.

After tumbling the muscle sections were manually stuffed into a 9.5 cm. Visekase pre-smoked, 6M casing (Visekase Corp., Chicago, IL). Pre-cook weights were recorded. The stuffed products were placed into an Alkar smokehouse with automatic time, temperature, relative humidity sequence controls and cooked to an internal temperature of 68.3°C using the cooking schedule in Table 2. Cooked roast weights were recorded 24 hours post cooking. From this point, tests were conducted for objective and subjective measurements.

Table 2: Cooking Schedule using the Alkar Smokehouse

Cooking Cycle	Dampers	Temperature (°C) Dry Bulb	Wet Bulb	Time	Smoke
1	Auto	39	54	45 min.	Auto
2	Closed	43	66	2 Hours	On
3	Closed	68	85	2 Hours	On
4	Auto	74	88	*	Off
5	---	---	---	Shower 15 minutes	---

* Cooked at this cycle until an internal temperature of 68.3°C was reached.

Sampling Procedures

Random samples for salt soluble proteins (SSP), and water binding potential (WBP) determinations were taken from the ham roasts immediately prior to stuffing, from meat pieces of each roast utilizing a 2.5 cm. coring tool. From these core samples, duplicate measurements were taken for pH, total moisture, SSP, and WBP.

After cooking, 0.3 cm thick slices were taken from the end of each roast and evaluated objectively and subjectively. A total of sixteen slices were removed from each roast. Ten slices were used for sensory panel evaluation and the remaining were used for testing bind force/strength via the Instron Universal Testing Machine (Instron Corp., Canton, MA).

Objective Tests:

Salt Soluble Protein (SSP) Determination

The salt soluble protein (SSP) concentration was determined by the Biuret method in a procedure devised by Johnson and Henrickson (1970) and they defined SSP as including water soluble and salt soluble proteins in a three percent salt solution.

Water Binding Potential (WBP) Determination

The centrifuge method developed by Miller et al. (1968) was used to determine water binding potential in this experimental study. The water binding potential is reported as a percentage of bound water.

Total moisture, required to calculate water binding potential, was determined by using the oven dry method (Ockerman, 1985).

Cohesiveness/Bind Force Determination

The degree of cohesion between muscle pieces was determined on 0.3 cm thick x 2.5 cm wide slices from the cooked ham roasts using the Instron Universal Testing Machine (Model 1132). The slices were placed into gripping jaws (Ockerman et al., 1988) across the width of the slice and force was applied perpendicular to the junction site. The bind force/strength measurement was recorded as the peak force (grams) to separate the muscle-muscle bond.

Cooked Yield

The cooked yield was calculated by dividing the 24 hour cooked chilled weight by the pre-cook stuffed weight times 100.

Subjective Test:

Sensory Evaluation

Sensory evaluation of each roast was conducted using an eight member sensory panel. The panelists were asked to evaluate cohesiveness of meat pieces, uniformity of cured color distribution and tenderness of the product using a nine point scale.

Statistical Analysis

The data collected in this study was analyzed using the Statistical Analysis System (SAS; SAS Institute Inc., Cary, NC, 1988). Analysis of variance (ANOVA) was performed by using the General Linear Model (GLM) procedure found in SAS. Least square means (LSM) and standard errors (SE) were calculated for all the dependent variables in the general linear model. Duncan's multiple comparison test was utilized to determine any differences among the treatment means.

RESULTS AND DISCUSSION:

Salt Soluble Protein (SSP)

All three postrigor treatments had higher salt soluble protein values than the prerigor treatments (Table 3). The zero prerigor treatment had a salt soluble content that was significantly lower ($P<0.05$) than 3 hour prerigor intermittent tumbling treatment and all three (0, 3, and 6 hour) postrigor tumbling treatments. This outcome is contradictory to what other researchers have found, typically, prerigor tumbled tissue has been shown to have greater salt soluble protein solubilization than postrigor tumbled muscle tissue. A possible explanation for this is the postrigor control being held in the cooler 24 hours may have had enhanced proteolytic enzyme activity causing more myofibrillae degradation to occur, resulting in a greater SSP concentration than the zero time prerigor tumbling treatment. Nevertheless, the 3 and 6 hour prerigor tumbling treatments have sufficient extracted salt soluble protein concentrations for adequate bind and cohesion of a cured, tumbled pork product.

Water Binding Potential (WBP)

The 3 hour prerigor tumble treatment was significantly higher ($P<0.05$) in water binding potential than 3 hour postrigor tumble treatment (Table 3), this being the only significant difference among the tumbling treatment means. The 3 and 6 hour prerigor tumble treatment means have water binding potential values

greater than all the postrigor tumble treatments. It should also be noted the water binding potential increased with increasing tumbling time in the prerigor tumbling groups.

Tumbling Yield

The zero no tumble group for both the pre- and postrigor tumbling treatments (Table 3) have been shown to exhibit a tumbling yield of 100% and this is somewhat misleading since the hams in neither of these treatments were not tumbled. The 100% tumbling yield value was obtained by these two treatments since no moisture or protein exudate could be lost in the tumbling process, therefore these two values should be interpreted with discretion. Otherwise the 3 and 6 hour postrigor tumbling treatments are significantly higher ($P<0.05$) than the 3 and 6 hour prerigor tumbling treatments but the magnitude of difference among these four means is rather small (1.36 percentage points).

Instron Bind Force

The no tumble prerigor and postrigor tumbling treatments were significantly lower ($P<0.05$) than the 3 hour prerigor and the 3 and 6 hour postrigor tumbling treatment means (Table 3). The Instron bind force scores peaked at 3 hours tumble time within each respective rigor tumbling treatment group. There was no significant difference between the 3 and 6 hour prerigor and the 3 and 6 hour postrigor tumbling treatment groups. This data would suggest a three hour tumbling treatment would be an adequate tumbling treatment for producing a desirable bind in a cured, tumbled pork product. Tumbling beyond 3 hours would not have any additional beneficial affect on the hams bind characteristic factors.

Sensory Panel Cohesion Scores

The no tumble prerigor treatment had significantly lower ($P<0.05$) sensory panel cohesion score than both the 3 and 6 hour tumbling treatments of the pre- and postrigor treatment groups (Table 3). It's apparent from the sensory panel cohesion scores that cohesion is enhanced up to 3 hours of tumbling but any additional tumbling beyond 3 hours is of no advantage for creating a better bind among the muscle particles.

Sensory Panel Tenderness Scores

The no tumble prerigor treatment was significantly less tender ($P<0.05$) than the 6 hour postrigor tumble treatment (Table 3). All prerigor and postrigor tumbling treatments had tenderness scores above 6.26, which is within an acceptable range for tenderness.

Sensory Color Distribution Scores

There was no statistical difference among the prerigor and postrigor tumbling treatment means in regards to cured color distribution within the boneless hams (Table 3). Tumbling either pre- or postrigor cured muscle tissue did result in higher scores for color distribution when compared to the no tumble treatments of both the pre- and postrigor tumbling treatment groups, however, these differences were not large enough to be significant. The uniformity between the rigor tumbling treatments can be accounted for by the muscle tissue being pumped with an automatic multiple stitch injection machine as compared to single needle stitch injection curing used in past studies at the Ohio State University meat laboratory.

Cooked Yield

There was no difference in cooked yields among the prerigor and postrigor tumbling treatment groups (Table 3).

CONCLUSION: The 3 hour intermittent tumbling cycle utilizing prerigor cured muscle tissue is an adequate treatment for producing a boneless, sectioned and formed ham roast when comparing to conventional postrigor muscle tissue. The postrigor tissue is normally used in the manufacture of cured, tumbled pork products. Tumbling prerigor or postrigor muscle tissue beyond 3 hours would have little additional beneficial affect on the quality in the cured, boneless hams. From utilizing prerigor muscle tissue in the production of cured, boneless, tumbled hams, the meat processor could then capitalize on the economic gains of hot processing pork.

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TABLE 3: Least-Squares Means (LSM) and Standard Errors (SE) for the Effect of Tumbling Treatments on Pre-Cook Salt Soluble Proteins (SSP), Pre-Cook Water Binding Potential (WBP; % Bound Water), Tumbling Yield, Instron Bind Force, Sensory Panel Cohesion, Tenderness and Color Distribution Scores and Cooked Yield of Boneless, Pre- and Post-Rigor Cured, Fully Cooked, Sectioned and Formed Ham Roasts

Rigor Condition at Time of Cure	PRE			POST			
Tumbling Treatment,[a] Hours	0	3	6	0	3	6	
	LSM	LSM	LSM	LSM	LSM	LSM	SE[g]
Pre-Cook SSP[b,i]	38.76[j]	48.48[k]	44.76[j,k]	48.80[k]	50.60[k]	51.02[k]	2.83
Pre-Cook WBP,[h]	96.43[j,k]	97.37[k]	97.54[k]	95.97[j,k]	95.24[j]	96.82[j,k]	0.77
Tumbling Yield, %[c,i]	100.00[l]	95.03[j]	94.60[j]	100.00[l]	95.92[k]	95.96[k]	0.39
Instron Bind Force[d,i]	152.78[j]	191.11[k]	186.25[j,k]	153.75[j]	208.50[k]	198.43[k]	14.96
Cohesion Score[e1,i]	5.62[j]	6.34[k]	6.34[k]	6.05[j,k]	6.70[k]	6.64[k]	0.29
Tenderness Score[e2,h]	6.26[j]	6.65[j,k]	6.58[j,k]	6.74[j,k]	6.62[j,k]	6.86[k]	0.19
Color Distribution Score[e3]	5.10	5.63	5.72	5.21	5.79	5.69	0.34
Cooked Yield, %[f]	86.62	87.45	87.45	87.08	87.49	88.26	0.75

[a]Intermittent tumbling, 10 minute tumble/50 minute resting period
[b]Expressed in mg SSP/gm of sample
[c](Post-tumble weight/pre-tumble weight) x 100
[d]Instron bind force measurement, expressed in peak force (grams)
[e1]Sensory panel score, scored on a scale of 1-9, 1=extremely noncohesive and 9=extremely cohesive
[e2]Sensory panel score, scored on a scale of 1-9, 1=extremely tough and 9=extremely tender
[e3]Sensory panel score, scored on a scale of 1-9, 1=extremely uneven and 9=extremely even/uniform
[f](Chilled cooked weight/pre-cooked weight) x 100
[g]SE are the same across the row
[h,i]Tumbling treatment significant at (P<0.05) and (P<0.01) respectively
[j,k,l]LSM with different superscripts across the row are significantly different (P<0.05)