



Consumer Acceptability and Demand for Cooked Beef Sausage Formulated With Pre- and Post-Rigor Deboned Beef¹

Anuraj T. Sukumaran², Kalyn Coatney³, Jack Ellington³, Alexander J. Holtcamp⁴, M. Wes Schilling⁵, and Thu T. N. Dinh^{4*}

²Department of Poultry Science, Mississippi State University, Mississippi State, MS 39762, USA

³Department of Agricultural Economics, Mississippi State University, Mississippi State, MS 39762, USA

⁴Department of Animal and Dairy Sciences, Mississippi State University, Mississippi State, MS 39762, USA

⁵Food Science, Nutrition, and Health Promotion, Mississippi State University, Mississippi State, MS 39762, USA

*Corresponding author. Email: thu.dinh@msstate.edu (T. T. N. Dinh)

Abstract: The objective of this study was to compare consumer acceptability and demand between pre- and post-rigor cooked beef sausage. Consumers ($N = 100$) evaluated the appearance, aroma, flavor, texture, and overall acceptability on a 9-point hedonic scale and formulated an independent bid for each product. Consumers preferred the aroma and flavor of pre-rigor sausage to those of post-rigor sausage ($P = 0.008$ and 0.029 , respectively). This resulted in a greater overall acceptability of pre-rigor sausage than that of post-rigor sausage ($P = 0.011$). Cluster analysis revealed that 45 consumers in clusters 3 and 4 led to such greater acceptability. Average predicted unit-demand for the experiment was 1.59 kg (3.50 lbs)/(USD)\$ greater for pre-rigor than for post-rigor sausage ($P \leq 0.001$). Overall, the results indicated that pre-rigor processing yielded sausage with greater consumer acceptability and demand.

Keywords: beef sausage, consumer demand, sensory, willingness to pay

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Introduction

Pre-rigor meat is deboned from the carcasses early postmortem when the muscles are still physiologically active with high pH and ATP content and has not entered rigor mortis onset (Barbut, 2014; Claus et al., 1998; Claus et al., 1997). Pre-rigor meat has technological advantages such as greater pH, water-holding capacity, and protein functionality (Claus and Sørheim, 2006; Sukumaran et al., 2018b). These advantages lead to superior sensory attributes of pre-rigor processed meat products such as sausages. Sørheim et al. (2006) reported greater hardness, springiness, cohesiveness, and chewiness of pre-rigor ground beef patties than those of post-rigor ones.

Moreover, it is estimated that pre-rigor processing could reduce chill space requirements by up to 50%, resulting in cumulative savings in refrigeration energy and capital investment and quicker plant turnover (Pisula and Tyburcy, 1996; Kim et al., 2014). While employed in some countries, predominantly in Australia and New Zealand, pre-rigor processing is not commonly used in others, including the United States. This is due to the long established industry with significant financial investment in post-rigor processing with great concerns regarding capital and training costs. Moreover, increased toughness due to the shortening of muscles (Pisula and Tyburcy, 1996; Keenan et al., 2016) and decreased juiciness and overall liking in whole muscle products due to pre-rigor deboning, even in beef longissimus lumborum and psoas major muscles, are also of concern (Crownover et al., 2017). Although these authors also reported an increase in tenderness, juiciness, and overall liking

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for the pre-rigor semimembranosus muscle, pre-rigor processing of whole muscles may not be possible in the United States. However, pre-rigor deboning of selected subprimals for further processing into ground products may be explored as an alternative to increase carcass value within the existing post-rigor beef processing infrastructure.

To invest in pre-rigor processing, significant financial investment may be needed to either alter or add logistic requirements to packing plants, distribution system, and further processing facilities. Such investment requires cost analysis, which includes but is not limited to acceptability of new pre-rigor products, willingness-to-pay (WTP), and consumer demand. Assessment of product acceptability based on sensory evaluation is important for food marketing because it helps food companies understand their consumers, identify market opportunities, optimize product concepts, and evaluate their product prototypes before launching these products into the market (Grunert et al., 2011). As such, it is also important to understand consumer WTP for the cost incurred by improved or new features of a product. Willingness-to-pay is a monetization of consumers' preferences and is linked to purchase intent (Ajzen and Driver, 1992). The WTP provides insights into how consumers value the product and its characteristics; therefore, it is also used to analyze product marketability (Van Loo et al., 2011). Although based on liking, the willingness-to-pay provides more concrete likelihood of purchase at a given price than ratings of liking (Lawless et al., 2015). For food companies, consumer market (aggregate) demand is more readily estimated from observed quantities sold due to price changes than identifying individual consumer WTP. To construct a comparable market-based analysis from experimental data using the observed individual WTPs for a single unit, an aggregate unit-demand curve is constructed (Lusk and Hudson, 2004). Unit-demand is a function that identifies the number of subjects that would be willing to purchase the product at a given price. This approach allows for a direct comparison of product demands and can be used to provide further insights into the viability of product success relative to expected production costs. Research has been conducted to determine consumer acceptability of sausages produced from pre-rigor chicken and pork (Bradley et al., 2011; Peng et al., 2009; Ogunbanwo and Okanlawon, 2006; Puolanne and Terrell, 1983); however, most consumer acceptability research on meat products lacks an association with WTP and consumer demand. By combining data collection from sensory evaluation and an experimental auction, the objective of the current study

was to compare (1) the consumer acceptability of, and (2) the demand for sausages produced from pre-and post-rigor beef.

Materials and Methods

Experimental design

Product development. Sausage production was detailed by Sukumaran et al. (2018a, b). Briefly, beef trimmings were collected from five 24-mo-old Holstein steers that were slaughtered at the federally inspected Mississippi Meat Science and Muscle Biology Laboratory, Mississippi State, MS. The left beef sides were designated for the pre-rigor deboning; whereas the right sides were used for the post-rigor deboning. The chuck primal was selected for deboning. For the pre-rigor treatment, the chuck was deboned and coarse-ground (1.27-cm plate) and the coarsely ground meat was salted (1.5% sodium chloride, w/w) using a paddle mixer and chilled to 2°C by powdered dry ice (15% w/w; Sørheim et al., 2006) within 2 h postmortem. The salted pre-rigor beef was stored at 2°C and was processed into sausage on d 6 postmortem. For the post-rigor treatment, beef sides were hung in a cooler (2°C) and the post-rigor chucks were deboned on d 4 postmortem. Post-rigor beef was also coarse-ground, salted, and processed to sausage on d 6 postmortem. A proprietary formula including beef sausage spice mix, a water/ice slurry, corn syrup, erythorbate, nitrite, salt, and 0.25% w/w sodium tripolyphosphate was used. The raw sausage mixture was stuffed into 32-mm synthetic collagen casings, portioned into 15.2-cm links, and chilled at 2°C before being cooked with a smoked sausage cycle including pre-drying, smoking, and steaming to a core temperature of 74°C prior to a cold shower. Cooked sausage was chilled for 24 h, vacuum-packaged, and stored at 2°C for 30 d to simulate commercial processing, transportation, and retail distribution. After that, the sausage links were removed and stored at -20°C until consumer sensory evaluation and auction experiment.

Consumer sensory evaluation. This experiment was approved by the Institutional Review Board for the Protection of Human Subjects in Research (IRB #15-376) at Mississippi State University.

Frozen sausage links were thawed for 24 h at 4°C prior to sensory evaluation by consumers. Sausage links were heated in a shallow pan with a 0.64-cm water layer (Viking Professional, Greenwood, MS) with occasional turning for even cooking to reach an

internal temperature of 74°C. They were then cut perpendicular to the axis into 2.54-cm thick samples. The samples were served warm in 3-digit coded serving cups. A total of 100 consumer subjects were recruited from Mississippi State University students, staff, and faculty to evaluate the appearance, aroma, flavor, texture, and overall acceptability of the sausages on a 9-point hedonic scale (1-dislike extremely, 2-dislike very much, 3-dislike moderately, 4-dislike slightly, 5-neither like nor dislike, 6-like slightly, 7-like moderately, 8-like very much, and 9-like extremely; Civille and Carr, 2015). Each subject was served with both pre- and post-rigor sausage from the same steer during each session. Subjects evaluated 6 samples (from 3 steers) in the first panel and 4 samples (from 2 steers) in the second panel. The third panel was also conducted with a commercial all-beef cooked sausage to validate the WTP model. Subjects evaluated all attributes for a sample before being served with the next. Sample order was randomized to avoid sampling bias. Sensory panels were conducted in a designated, air-conditioned (20°C), dark room with red lights in 7 separated booths for individual subjects. Subjects were provided with written instructions and guided through the panels by a CompuSense system (CompuSense Inc., Ontario, Canada). Each subject was provided with a tray containing coded steak samples, water, apple juice, unsalted crackers, and an expectoration cup. Subjects were instructed to cleanse their palate with apple juice, water, and unsalted crackers between samples.

Consumer willingness-to-pay and demand. This experiment was conducted under the same IRB approval listed under section 2.1.2. After subjects had rated the samples for acceptability, the WTP experiment was conducted. Since consumers tend to overstate their WTP in a hypothetical setting (List and Gallet, 2001), a non-hypothetical method, i.e., the auction method in the current study, was used to obtain a realistic estimation of consumers' true preference (Chang et al., 2009). To collect individual WTP data, a Becker–DeGroot–Marshak (BDM) auction was conducted on the sausage after each panelist completed the consumer session. A BDM auction mechanism was chosen because it is relatively incentive-compatible with induced valuations and homegrown valuations and yields similar results to other auction mechanisms for one-shot solicitation (Lusk and Hudson, 2004; Lusk et al., 2007). Moreover, it is a convenient method that can be used with the random arrival of busy subjects (particularly students, staff, and faculty) to the experiment, sometimes as few as a single individual. The instructions are designed to be simple for novice bidders to understand.

All subjects retained a copy of their sensory record sheets to refresh their memories when placing their bids. Subjects were provided with a copy of instructions explaining the auction procedure, which was also read aloud by the experimenter, and a bidding record sheet. Subjects were instructed to refer to their answers in the previous sensory evaluation prior to placing bids. To establish a reasonable range of possible values, allowable bids were first centered on the current local market price for cooked beef sausage from March to May of 2017. The local market price of fully cooked beef sausage at the time was an average of \$5.99 per 0.454 kg (1 lb). This market price was determined over a 3-mo period when all-beef, fully-cooked sausages were purchased for various training purposes from a local market, including the commercial sausage used in the auction as a reference price point. Subjects were provided with a \$6.00 gift card to fund their maximum attempt to purchase a 0.227 kg (0.5 lb) pre-packaged serving of sausage. The gift card was redeemable at a University-run food store. The \$6/0.227 kg stipend was equivalent to a maximum \$12 bid for 0.454 kg (1 lb) of sausage. Bids were translated to \$/0.454 kg (\$/lb) to maintain consistency with the common transactional unit of sale in the market place. Price and cost, therefore, were presented on the basis of 0.454 kg in the current study.

Subjects were instructed to enter 1 bid in terms of \$/0.454 kg, ranging from \$0 to \$12 in penny increments, centered on a \$6 (approximate market value). The range of bids was chosen to minimize censoring of bids. Censoring of bids is of concern when estimating factors that impact subject bids (WTP; Lusk and Shogren, 2007). By extension, censoring may impact estimation of the aggregate unit-demand estimation. At the end of the session, a market price from a uniform distribution, ranging from \$0 to \$12/0.454 kg in penny increments, was randomly drawn for each sausage serving. If the subject submitted a bid greater than or equal to the market price, they were eligible to win that particular sausage serving at market price. If a subject was eligible to win more than 1 serving, then, to maintain independent valuations and avoiding the complications of demand reduction (Ausubel and Cramton, 2002), the experimenter randomly determined which serving the subject won. For the serving won, the market price was deducted from the \$6.00 stipend. Due to the experiment's product supply constraint, the participant received a comparable commercial brand sausage and the remaining balance on the gift card. If no serving was won by a subject, the subject retained the full \$6.00 value on the gift card.

Using the subjects' multiple independent bids (WTPs), independent product aggregate unit-demands were constructed by means of the following thought experiment. The quantity demanded was equivalent to the number of subjects in the experiment that were willing to purchase a unit of each product at any given price, ranging from \$0 to \$12/0.454 kg in 10-cent increments. Therefore, aggregate unit-demand was a probabilistic distribution of quantity that was sold per product over possible prices. More formally, aggregate unit-demand can be represented by the following equation: $Q(p) = N[I - F(p)]$, where N was the number of active consumers in the market (subjects) and $[1 - F(p)]$ was the survival function over increasing prices (p). Though generally declining in price, this procedure results in a stair-step type function. The coarseness of the steps is dependent on the number of observed bids per product and price step. The demand becomes smoother as the number of bids increase and/or the larger the price steps.

Data analysis

Consumer sensory evaluation data analysis. Sensory data were analyzed in a general linear model with deboning time serving as a fixed effect and panelist serving as a random effect. Analysis of variances was performed in the MIXED procedure of SAS v9.4 (SAS Inst. Inc., Cary, NC). Means, when different, were separated by a protected t test in the LSMEANS option of the MIXED procedure. A cluster analysis was conducted using Ward's method within the Agglomerative Hierarchical Clustering procedure in XLSTAT 2018.2.50198. Sensory data within each cluster were analyzed similarly. Actual probability values were reported.

Willingness-to-pay and empirical aggregate unit-demand model. A similar statistical model was used to compare the average bidding values between pre-rigor and post-rigor sausages within deboning time serving as a fixed effect and subject serving as a random effect. For statistical comparisons between product demands, each demand function was estimated with an assumption of a smooth and continuous function. Without presumption of the underlying 'aggregate' utility or its corresponding survival function, an independent fourth degree polynomial was estimated. The degree of polynomial was chosen based on model fit and parameter significance given the sample data and is not to be construed as a general approximation. The regression model is as follows:

$$Q_i(P) = a_0 + a_1P + a_2P^2 + a_3P^3 + a_4P^4 + a_5D_{\text{pre-rigor}} + e_i \quad [1]$$

The term $Q_i(P)$ in Eq. [1] is the unit-quantity demand as a function of price (P), with P ranging from \$0 to \$12/0.454 kg. The coefficients a_1 to a_5 are price related regression coefficients. The variable $D_{\text{pre-rigor}}$ is the fixed effect dummy variable for pre-rigor product as compared to the post-rigor product. The variable e_i is the error term. Censoring of bids is a possibility, by the design of the experiment, and may bias the regression coefficients (Greene, 2003). However, Arabmazar and Schmidt (1982) reported that if samples are less than 25% censored, there is virtually no bias. If sufficient censoring is present, then a Tobit regression will be estimated by means of the QLIM procedure of SAS 9.4. If not, then the regression will be estimated by means of ordinary least squares in the REG procedure of SAS 9.4.

It may be found that demand is greater for one of the deboning technologies. However, this does not necessarily mean that 1 technology would be more profitable than the other given costs of production relative to market price. Reconsidering the literature that indicates that pre- and post-rigor deboning costs may not be equal (Pisula and Tyburcy, 1996; Kim et al., 2014), as such, the following thought experiment can be undertaken to provide additional insights of which product may be more profitable to produce. First, to solve for the required cost reduction for the least demanded product given a set of market prices to remain profit-neutral, the following profit balance equation,

$$\pi_{\text{pre-rigor}} = \pi_{\text{post-rigor}} \quad [2]$$

is solved for the respective technology cost. In more detail, Eq. [2] is

$$Q_{\text{pre-rigor}} \times (P_{\text{pre-rigor}} - C_{\text{pre-rigor}}) = Q_{\text{post-rigor}} \times (P_{\text{post-rigor}} - C_{\text{post-rigor}}) \quad [3]$$

In Eq. [3], the variables $Q_{\text{pre-rigor}}$ and $Q_{\text{post-rigor}}$ are the predicted quantities sold from the regression model Eq. [1] as a function of their respective market prices, $P_{\text{pre-rigor}}$ and $P_{\text{post-rigor}}$, based on the simulated quantities sold for 100 experimental subjects. The respective per unit production costs are $C_{\text{pre-rigor}}$ and $C_{\text{post-rigor}}$, and are assumed constant per unit output.

Second, finding the required cost reduction if demands are different to remain profit neutral is as follows. If it is found that demand is less for post-rigor sausage, the required production cost reduction for

post-rigor sausage to remain profit-neutral is found by solving Eq. [3] for $C_{post-rigor}$ resulting in:

$$C_{post-rigor} = P_{post-rigor} - \frac{Q_{pre-rigor} \times (P_{pre-rigor} - C_{pre-rigor})}{Q_{post-rigor}} \quad [4]$$

For post-rigor to be more profitable than pre-rigor sausage, the “true” cost of post-rigor production must be less than $C_{post-rigor}$ found in Eq. [4]. Otherwise, if demand is found to be less for pre-rigor sausage, the required production cost reduction for the pre-rigor sausage to remain profit-neutral can be solved in the same manner.

Results and Discussion

Consumer sensory evaluation

On average, consumers preferred the aroma and flavor of pre-rigor sausage to post-rigor sausage ($P = 0.008$ and 0.029 , respectively; Table 1). These attribute preferences likely resulted in greater overall acceptability for pre-rigor sausage in comparison to post-rigor sausage ($P = 0.011$; Table 1). Consumers were sorted into 5 clusters based on overall acceptability (Table 2). Clustering allows for a more in-depth analysis of consumer preference types by focusing on a specific attribute within smaller groups of consumers with more homogeneous variances. Consumers in cluster 1 ($N = 34$) and cluster 5 ($N = 6$) did not differ in acceptability of aroma, flavor, and texture of pre- and post-rigor sausages ($P \geq 0.091$), therefore, had similar overall acceptability as well ($P = 0.130$ and 0.340 , respectively). Overall acceptability ratings (Table 2) indicated that cluster 1 included consumers who “liked very much” sausages; whereas cluster 5 included consumers who “disliked moderately” or “disliked slightly” sausages, regardless

Table 1. Acceptability ratings of cooked beef sausages produced from pre- and post-rigor beef and stored for 30 d in vacuum package under refrigeration (4°C), as determined by a consumer panel ($N = 100$)

Attribute ¹	Pre-rigor	Post-rigor	SE	P^2
Appearance	6.7	6.6	0.11	0.356
Aroma	7.3	7.0	0.14	0.008
Flavor	7.4	7.1	0.15	0.029
Texture	6.5	6.2	0.20	0.252
Overall	7.0	6.7	0.15	0.011

¹Consumer acceptability was evaluated on a hedonic scale, in which 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely).

²Means are different if $P \leq 0.05$.

of how it is produced. Moreover, cluster analysis revealed that among 60 consumers in cluster 2, 3, and 4, who differed in their overall acceptability, 45 of them (cluster 2 and 3), preferred the sensory attributes of pre-rigor to those of post-rigor sausage. Consumers in cluster 3 ($N = 37$) preferred the texture of pre-rigor to that of post-rigor sausage ($P = 0.001$), in addition to greater acceptability for pre-rigor aroma and flavor ($P = 0.011$ and $P < 0.001$, respectively). Similarly, 8 consumers in cluster 4 preferred the flavor and texture of pre-rigor to those of post-rigor sausage ($P = 0.001$ and 0.020 , respectively). Cluster 3 rated flavor of pre-rigor sausage as “like very much” and that of post-rigor sausage as “like moderately”. Cluster 4 rated flavor of pre-rigor sausage as “like moderately” and that of post-rigor sausage between “dislike slightly” and “neither like nor dislike”. Moreover, cluster 3 rated the texture of pre-rigor sausage as “like moderately” and that of post-rigor sausage as “like slightly”. Cluster 4 rated the texture of pre-rigor sausage between “neither like nor dislike” and “like slightly” but that of post-rigor sausage between “dislike slightly” and “dislike moderately”. Only

Table 2. Clustering of 100 consumers based on their overall acceptability¹ of pre- and post-rigor cooked beef sausage

Clusters ²	N	Overall			Aroma			Flavor			Texture		
		Pre-rigor	Post-rigor	P^3	Pre-rigor	Post-rigor	P^3	Pre-rigor	Post-rigor	P^3	Pre-rigor	Post-rigor	P^3
1	34	7.9	8.1	0.130	7.9	8.1	0.336	7.9	8.3	0.091	7.4	7.5	0.767
2	15	5.1	6.5	<0.001	6.5	6.1	0.387	6.5	7.1	0.223	4.1	5.9	0.004
3	37	7.7	6.4	<0.001	7.4	6.8	0.011	7.9	6.9	<0.001	7.2	6.2	0.001
4	8	6.6	4.4	<0.001	7.6	6.5	0.158	7.1	4.6	0.001	5.7	3.7	0.020
5	6	3.9	3.4	0.340	5.3	4.5	0.501	4.0	4.7	0.563	3.7	3.1	0.294

¹Consumer acceptability was evaluated on a hedonic scale, in which 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely).

²Cluster analysis was conducted using Ward’s method within the Agglomerative Hierarchical Clustering procedure in XLSTAT 2018.2.50198 based on overall acceptability ratings by panelists.

³Means are different if $P \leq 0.05$.

Table 3. Mean bidding value (\$/0.454 kg) for pre-rigor and post-rigor sausages within each consumer cluster

Clusters ¹	Consumers	Pre-rigor, \$				Post-rigor, \$				P-value
		Mean	SD	Min	Max	Mean	SD	Min	Max	
1	34	4.82	2.27	0.75	10.00	5.37	2.30	0.50	9.00	0.093
2	15	3.06	2.64	0.00	9.70	4.71	3.22	0.50	10.99	0.014
3	37	5.44	2.86	0.50	11.20	4.18	2.03	0.50	9.00	< 0.001
4	8	6.91	3.09	2.50	11.50	1.89	0.77	0.50	3.00	< 0.001
5	6	3.77	2.93	0.00	6.50	4.62	2.71	0.00	8.22	0.009
Overall	100	4.92	2.80	0.00	11.50	4.50	2.45	0.00	10.99	0.136

¹Cluster analysis was conducted using Ward's method within the Agglomerative Hierarchical Clustering procedure in XLSTAT 2018.2.50198 based on overall acceptability ratings by panelists.

consumers in cluster 2 ($N = 15$) preferred the texture of post-rigor sausage to that of pre-rigor sausage ($P = 0.004$). However, they did not differ in pre- and post-rigor aroma ($P = 0.387$) and flavor ($P = 0.223$).

Beef flavor is influenced by various factors such as pH, lipid composition, oxidation, amino acid composition, and concentrations of metal ions, nucleotides, reducing sugars and salt (Calkins and Hodgen, 2007; Dinh et al., 2018). Many flavor compounds in beef are water-soluble. When the pH of meat is greater, the proteins in meat have greater water-holding capacity. Therefore, fewer water-soluble components are lost during cooking since cooking loss is less (Miller, 2001; Calkins and Hodgen, 2007). Meat with greater pH was reported to have more aromatic flavors and very high beef flavor intensity (Miller, 2001). In the current study, the greater preference by the consumers for pre-rigor sausage flavor might be a result of the greater pH of pre-rigor beef, which allowed for a greater water-holding capacity and ultimately greater retention of water-soluble flavor compounds. As reported by Sukumaran et al. (2018a,b), the pH of pre-rigor meat was 6 to 6.8, which was greater than the pH of 5.6 to 5.8 of post-rigor meat. Although pH of cooked sausages was 6.0 to 6.2 and did not differ (Sukumaran et al., 2018a,b) due to the addition of 0.25% phosphate, post-mortem metabolism may change the flavor precursors in post-rigor meat. Tikk et al. (2006) reported that the degradation of nucleotides such as inosine-5'-monophosphate to hypoxanthine and ribose increases when the meat pH is declining postmortem. Although ribose reacts with amino acids, yielding desirable roasted flavor, early degradation of nucleotides leads to more hypoxanthine formed during cooking, potentially increasing undesirable flavors in cooked meat (Koutsidis et al., 2008). Peptides and various amino acids are also increased as postmortem metabolism increases due to proteolysis; many of them contribute to bitterness after cooking (Koutsidis et al., 2008; Dinh et al., 2018). With post-mortem metabolism being minimized in pre-rigor beef,

so was the accumulation of these undesirable water-soluble compounds. Moreover, limited post-rigor metabolism in pre-rigor beef might leave an abundance of most nucleotides such as 5'-ribonucleotides, which are important for umami taste (Tikk et al., 2006). It should be noted that no difference in flavor descriptors between pre- and post-rigor sausages was found by the trained panelists (Sukumaran et al., 2018b). Although pre-rigor texture was preferred by the consumers, Sukumaran et al. (2018b) also reported no differences in descriptive texture attributes between the 2 types of sausages, even though pre-rigor beef had greater protein extractability than post-rigor beef.

Willingness-to-pay and aggregate unit-demand

There was no overall difference in average bids between pre-rigor (\$4.92/0.454 kg) and post-rigor (\$4.50/0.454 kg) sausages across all clusters ($P = 0.136$; Table 3). Further analysis of consumer clusters revealed that consumers in cluster 3 and cluster 4 ($N = 45$) placed a greater average bid for pre-rigor sausage than for post-rigor sausage ($P < 0.001$; Table 3). The average bidding values for pre-rigor sausage in cluster 3 and cluster 4 were \$5.44/0.454 kg and \$6.91/0.454 kg, respectively, compared with \$4.18/0.454 kg and \$1.89/0.454 kg, respectively, for post-rigor sausage. However, consumers in cluster 2 ($N = 15$) and cluster 5 ($N = 6$) placed greater average bids for post-rigor sausage than for pre-rigor sausage ($P \leq 0.014$). The average bidding values for pre-rigor sausage in cluster 2 and cluster 5 were \$3.06/0.454 kg and \$3.77/0.454 kg, respectively as compared to \$4.71/0.454 kg and \$4.62/0.454 kg, respectively, for post-rigor sausage. There was no difference in average bids for cluster 1 ($N = 34$; $P = 0.093$) for pre-rigor (\$4.82/0.454 kg) and post-rigor sausage (\$5.37/0.454 kg). Generally speaking, these WTP results were consistent with overall acceptability rankings, with an exception of cluster 5 that rated 3.9 for pre-rigor

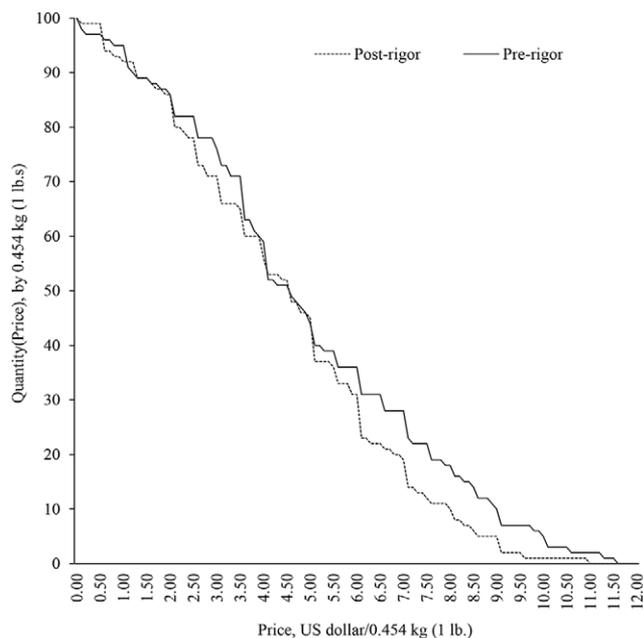


Figure 1. Simulated aggregate unit-demands of pre- and post-rigor sausages in 10-cent increments for $N = 100$ human subject bids per product resulting in $N = 121$ simulated quantity values per product.

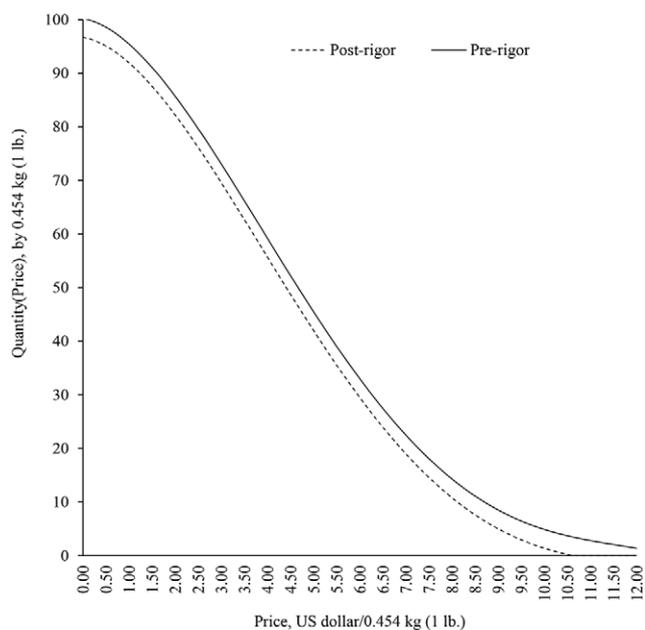


Figure 2. Predicted aggregate unit-demands from Eq. [1] for pre- and post-rigor sausages, for $N = 100$ human subject bids per product resulting in $N = 121$ predicted quantity values per product.

and 3.4 for post-rigor acceptability (not significant; $P = 0.340$), but was willing to pay less for pre-rigor.

The simulated aggregate unit-demands are depicted in Fig. 1 and the predicted unit-demands are depicted in Fig. 2. Censoring of bids on the allowable bidding interval was observed on the left ($\$0/0.454$ kg) but not on the right ($\$12/0.454$ kg). The left censoring of bids occurred twice in cluster 5 (those tending to dislike sausage) and once in cluster 2 (Table 3). Given the small degree of censoring, the results of the ordinary least squares regression analysis are given in Table 4. The results revealed a coefficient of determination of 0.99. All the tested regression coefficients were significant ($P \leq 0.05$) including the dummy variable for pre- versus post-rigor deboning times. Moreover, the shift in demand for pre-rigor was greater than for post-rigor by 1.59 kg (3.50 lbs)/\$. It is important to note that this result is consistent across lesser degree polynomial regressions. Additionally, the smallest coefficient of determination (0.95) is associated with a first-degree linear regression.

Given demand for post-rigor is significantly less than that for pre-rigor sausage, the average production costs for post-rigor must be less than pre-rigor to be profit-neutral. Using the predicted aggregate unit-demands from (1) and assuming that a 0.454 kg (1 lb) package of pre- and post-rigor sell for the same local market price of $\$6.00/0.454$ kg, pre-rigor sausage quantity sold

would be 14.97 kg (33 lb) for the 100 experimental subjects; whereas post-rigor sausage quantity sold would be 13.38 kg (29.5 lb). Next, assuming pre-rigor production costs are $\$2.00/0.454$ kg, by substituting these respective values into (4), the required post-rigor sausage production cost would need to be $\$1.53/0.454$ kg, a $\$0.44$, or a 23.5% reduction per 0.454 kg. However, this result is based on the assumption of equal and constant output prices. For firms to make a final production technology decision, they should consider conducting a benefit cost analysis of switching to pre-rigor production by estimating expected long-term product prices for both pre- and post-rigor products, as well as expected transition and pre-rigor production costs. Expected

Table 4. Polynomial regression analysis of aggregate unit-demand for pre- and post-rigor sausages, $N = 242$ simulated quantities sold, or 121 per sausage product

Variables ¹	Coefficient	SE	P-value
Intercept	96.70	0.65	< .001
P	-1.51	0.74	0.044
P ²	-3.66	0.25	< .001
P ³	0.42	0.03	< .001
P ⁴	-0.01	0.00	< .001
D _{pre-rigor}	3.50	0.27	< .001
Coefficient of determination (R^2) = 0.99			

¹The regression model was based on the best-fit model according to the data, as follows:

$$Q_i(P) = a_0 + a_1P + a_2P^2 + a_3P^3 + a_4P^4 + a_5D_{\text{pre-rigor}} + e_i$$

price for the pre-rigor product will largely be determined by the availability of close substitute products (e.g., post-rigor and non-beef sausages), as well as price competition from rival firms within the larger sausage market. Due to a lack of firm level production cost data (i.e., labor time studies and equipment) and the required product pricing data (i.e., scanner data), a benefit to cost analysis is beyond the scope of this research.

Conclusions

The results from the current study indicate that pre-rigor beef sausage has greater consumer acceptability and demand than post-rigor beef sausage. The greater consumer acceptability of pre-rigor sausage was mainly driven by flavor and texture acceptability. Pay-off neutrality scenarios indicate that post-rigor would need to be more cost effective than pre-rigor for technology selection. However, previous research has found the pre-rigor production is more cost-effective. The combination of cost effectiveness with an increase in demand in the current study, pre-rigor beef sausage technology warrants further analysis as an economically viable alternative to post-rigor production technology in the United States.

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