Evaluation of alternative fabrication specifications to increase gross value of pork carcasses

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ABSTRACT: Modifying fabrication specifications of domestic pork carcasses to reflect product specifications in key export markets may increase gross value for U.S. pork. Changes in specifications may also yield value-added cuts that increase demand for U.S. pork in both export and domestic markets. The objective was to evaluate differences in value of carcasses fabricated using either typical U.S. cutting specifications, or alternative specifications. Paired left and right sides (30 sides total; $n = 15$) were weighed and cut into primal and subprimal pieces according North American Meat Institute (**NAMP**, **DOM**) or alternative-style specifications (**ALT**). Alternative-style carcasses were separated into shoulder (4th/5th rib separation), loin, belly, and ham (sirloin-on) primals. Alternative-style shoulders were fabricated into a cellar-trimmed (**CT**) butt, triceps brachii (cushion), boneless picnic, and a brisket. Carcass values for all three pricing scenarios were calculated using the USDA Agriculture Marketing Service Carlot Report values from the weeks of April 5, 2013, to April 7, 2017. Value for the pork brisket was estimated based on relative value of the beef brisket compared to the beef shoulder clod (NAMP #114) resulting in a value of \$2.485/kg for the pork brisket. Comparisons between fabrication styles and value of each side were made using a paired T-test. Whole bone-in loin yields of ALT carcasses were 6.23 units less ($P < 0.0001$) than DOM carcasses. Similarly, yields from trimmed and squared bellies of ALT carcasses were 0.83 units less than ($P \le 0.01$) DOM carcasses. In contrast, trimmed shoulders of ALT carcasses were 3.81 units greater ($P < 0.0001$) and hams were 3.39 units greater ($P < 0.0001$) than DOM carcasses. Despite reductions in yield of loins and bellies, ALT carcasses were numerically \$1.29 ($P = 0.17$) and \$0.66 ($P = 0.56$) more valuable than DOM carcasses in the 4 yr average and best pricing scenarios, respectively. Alternative-style carcasses were \$1.99 ($P = 0.03$) more valuable than DOM carcass when using the most depressed pricing scenario. Fabricating pork carcasses using alternative-style specifications reduced the yield, and therefore the value, of the loin and belly compared with DOM carcasses. However, added value from the pork brisket and CT butt recuperated this value. Therefore, alternative-style fabrication methods may increase gross carcass value in some pricing scenarios.

Key words: carcass, cutability, export, fabrication, gross value, pork

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INTRODUCTION

The United States is among few countries in the world that fabricate pork carcasses to

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maximize yield of the loin and belly. American pork processors generally follow specifications derived from North American Meat Institute (**NAMP**) standards, with the shoulder–loin separation made between the second and third rib, and the loin–ham separation made 3.81 cm from the anterior portion of the pelvis, leaving the sirloin attached to the loin (NAMP, 2014). These specifications allow for the greatest potential for belly and loin yield, reflecting the popularity of bacon and pork chops in American markets. Other countries, notably China, Japan, and South Korea, make the shoulder–loin separation between the fourth and fifth rib, and the loin–ham separation so that the sirloin remains attached to the ham (Swatland, 2000). Although this reduces belly yield, the center section, from where the majority of #1 slices [slices suitable for retail-style packaging, as described by Person et al. (2005)] originate, is left intact. The reduction in loin yield may be compensated by the increase in shoulder yield, and an increase in potential value may be captured from the addition of the pork brisket. Potential economic differences between domestic and Asian-inspired fabrication specifications are worth investigating as exports are a vital component to the American swine industry. In 2016 alone, 21% of domestically raised pigs were exported once slaughtered (USDA ERS, 2017), with nearly $3 billion in domestic pork sold to China, Japan, and South Korea (USMEF, 2017). The objective of this study was to evaluate potential yield differences and economic implications between pork sides fabricated according to domestic-style and alternative-style specifications.

MATERIALS AND METHODS

Pigs were slaughtered at the University of Illinois Meat Science Laboratory (Urbana, IL) under the inspection of the USDA Food Safety and Inspection Service and under the teaching and use protocol approved by the University of Illinois IACUC. Fifteen pork carcasses were used. Carcasses were divided into left and right sides. One side of each carcass was randomly assigned to be fabricated using either North NAMP specifications (**DOM**) or alternative (**ALT**) specifications such that 15 left sides and 15 right sides were fabricated using NAMP specifications. The opposite side of each carcass was fabricated using the alternative method such that 15 left sides and 15 sides were fabricated using the alternative cutting specifications. One side of each carcass was fabricated using NAMP specifications and the opposite side was fabricated using alternative specifications. Sides were alternated within fabrication methods such that both left and right sides were fabricated in each style to remove any bias associated with workmanship or bilateral asymmetry.

Chilled sides were standardized before weighing by removing heart, pelvic, and residual body wall fat. Jowls remained on the carcass for initial chilled side weight determination. Chilled sides were weighed to serve as the denominator for all cutability calculations. Primal and subprimal pieces used in both methods were weighed before further fabrication for calculation of cutting yield.

Domestic-Style Fabrication

Domestic-style sides were weighed and then fabricated similarly to Lowell et al. (2018). Initially, sides were cut into a whole shoulder (NAMP #403), skin-on whole loin (NAMP #410), whole belly (NAMP #408), pork leg (NAMP #401), and jowl (NAMP #419). Whole shoulders were separated from the loin between the second and third rib. The front foot was removed at the upper knee (radiocarpal joint) and the jowl removed with a cut parallel to the loin side just posterior to the ear dip. Front feet, jowls, and whole shoulders were weighed independently. Whole shoulders were skinned and trimmed to meet the specifications of a NAMP #404 skinned pork shoulder. Boston butts and picnics were separated into a NAMP #406 bone-in Boston butt and a NAMP #405 bone-in picnic. Boston butts and picnics were deboned to produce a NAMP #406A boneless Boston butt and then separated into a NAMP #405B triceps brachii (shoulder cushion) and boneless picnic. Whole loins and bellies were separated by a cut starting no more than 7.62 cm ventral to the longissimus muscle on the shoulder end and ending no more than 1.27 cm ventral to the tenderloin on the ham end. The loin was trimmed to yield a #NAMP 410 trimmed loin, then further fabricated to meet the specifications of a NAMP #414 Canadian back loin, NAMP #413D sirloin, and NAMP #414A tenderloin. Spareribs (NAMP #416) were removed from the belly and weighed. The sternum and the ventral end of costal cartilages were removed to yield “St. Louis style” spareribs (NAMP #416A). Bellies were skinned, and teat lines and fat backs removed to meet the specifications of a NAMP #409B center-cut, skinless belly. Pork legs were generated by separating the ham from the loin 3.81 cm anterior to the symphysis pubis bone, and the hind foot was removed at the hock (tibiotarsal joint). Pork legs were skinned and trimmed to meet the specifications of a NAMP #402 trimmed ham. Further fabrication of hams produced an inside ham (NAMP #402F), outside ham (NAMP #402E), knuckle (NAMP #402H), and lite butt (a portion of the gluteus medius). Insides, outsides and knuckles were weighed independently. All trim was collected and segregated into fat trim (approximately 42% lean) and lean trim (approximately 72% lean). Each category of trim was placed in a bin and weighed at the end of fabrication of the corresponding side.

Alternative-Style Fabrication

Alternative-style sides were weighed and then separated into primals. The shoulder–loin separation was made between the fourth and fifth rib, and the loin–ham break was made at the first sacral vertebrae at approximately a 135° angle to the spine, leaving the sirloin attached to the ham. The loin–belly separation was made at the same anatomical location as the DOM sides. Whole shoulders were skinned and trimmed, then separated into a NAMP #407 cellar-trimmed butt, bone-in shoulder clod, a NAMP #405B cushion, neck bones, petite tender (teres major), and pork brisket. The shoulder clod was then deboned (scapula removed) to produce a boneless shoulder clod. Pork briskets were cut to contain pectoralis profundis muscle and associated fat, so as to be analogous to the beef brisket (NAMP #120). The tenderloin was loosened on the posterior end so as to remain with the loin primal and not sever the most posterior portion of the tenderloin (butt tender) during the loin–ham separation. Loins and bellies were further fabricated to be as consistent with DOM sides as possible. Hams were fabricated similarly to DOM hams, but did not include the lite butt. Sirloins were separated from the ham by deboning from the hip bone. Trim was separated and weighed as described for DOM sides.

Carcass Cutability

Carcass cutability of primals and subprimals was calculated as a percentage of chilled side weight. Cutting yields were determined by dividing the weight of the primal or subprimal by the standardized chilled side weight. The following equation was used to determine cutting yields for DOM sides:

$$\text{Domestic boneless cutting yield, \%} = [(\text{boneless Boston butt (NAMP \#406A), kg} + \text{boneless picnic (NAMP\#405A), kg} + \text{Canadian back (NAMP \#414), kg} + \text{tenderloin (NAMP \#415A), kg} + \text{sirloin (NAMP \#413D), kg}) + \text{skinned natural fall belly (NAMP \#408), kg} + \text{inside ham (NAMP \#402F), kg} + \text{outside ham (NAMP\#402E), kg} + \text{knuckle (NAMP \#402H), kg,} + \text{lean trim (72\% lean), kg} + \text{fat trim (42\% lean), kg})) / \text{chilled side weight}] \times 100$$

The equation was modified to determine cutting yields for ALT sides:

$$\text{Alternative boneless cutting yield, \%} = [(\text{cellar-trimmed butt, kg} + \text{boneless shoulder clod, kg} + \text{teres major (petite tender), kg} + \textit{triceps brachii} \text{ (cushion), kg} + \textit{pectoralis profundis} \text{ (brisket), kg} + \text{skinned, trimmed, strap-off boneless loin, kg} + \text{tenderloin, kg} + \text{sirloin, kg} + \text{skinned natural fall belly, kg} + \text{inside ham, kg} + \text{outside ham, kg} + \text{knuckle, kg} + \text{lean trim (72\% lean), kg} + \text{fat trim (42\% lean), kg}) / \text{chilled side weight}] \times 100$$

Carcass Value

Carcass values were determined using the USDA-AMS National Weekly Negotiated Pork Report, using prices reported from the week of April 5, 2013, through the week of April 7, 2017 (USDA). All prices within this report were on a century weight basis ($/100 lbs) with primal and retail cut values reported as value per lb. Primal and retail cut weights were multiplied by the associated price, then converted to value per kg. Best-, worst-, and 4-year (2013–2017) average pricing scenarios were calculated similar to the manner described by Harsh et al. (2017). The best (2014) scenario was determined when average pork carcass prices were the most elevated. The worst (2016) scenario was based on when average pork carcass prices were the most depressed. Pork brisket price was calculated based on the relative price of beef brisket to beef shoulder clod, resulting in a price of approximately $2.485/kg. The following equations were used to determine value:

$$\text{Best price, \$} = (\text{Cut wt, kg} \times \text{average price in 2014, \$})$$

$$\text{Worst price, \$} = (\text{Cut wt, kg} \times \text{average price in 2016, \$})$$

$$\text{Average price, \$} = (\text{Cut wt, kg} \times \text{average price 2013} - \text{2017, \$})$$

Statistical Analysis

Cutting yields and monetary value differences between fabrication methods were compared using the paired option of the PROC T TEST in SAS 9.4 (SAS Inst. Inc., Cary, NC). Statistical significance was accepted at $P \leq 0.05$.

RESULTS

Cutability

Yields of ALT whole shoulders were 3.96 percentage units greater ($P < 0.0001$) than DOM whole shoulders (Table 1). Yields of ALT whole bone-in loins, trimmed bone-in loins, and strap-on boneless loins were 6.23, 5.2, and 1.62 percentage units less ($P < 0.0001$) than DOM loins, respectively. Yields of ALT strap-off loins ($P < 0.01$) and back ribs ($P < 0.01$) were 0.5 and 0.35 percentage units less than DOM cuts, while ALT tenderloins were 0.14 percentage units more ($P < 0.01$; Table 2). Yields of ALT whole bone-in bellies and natural fall bellies were both 1.43 percentage units less ($P \leq 0.01$) than DOM bellies. Yields of trimmed and squared bellies from ALT sides were 0.83 percentage units less ($P < 0.01$) than bellies from NAMP sides. Spare rib yield did not differ ($P = 0.16$) between cutting styles (Table 2). Yields of ALT pork legs were 3.74 percentage units greater ($P \leq 0.0001$) than DOM pork legs. Outside, knuckle, inner shank, and bone-in outer shank yields were not different ($P \geq 0.08$; Table 3). Alternative-style carcasses yielded 3.66 units less lean trim ($P < 0.0001$) but 1.83 units more fat trim ($P = 0.02$, Table 4). Boneless cutting yield was not different ($P = 0.08$) between DOM and ALT carcasses (Figure 1).

Economic Value

ALT shoulders were worth more ($P \leq 0.0001$) overall by \$6.62, \$6.07, and \$6.26 in the worst-, best-, and 4-year average scenarios (Figure 2). DOM loins were valued higher ($P \leq 0.01$) than ALT loins in the worst-, best-, and 4-year average scenarios by \$2.03, \$2.45, and \$2.20, respectively (Figure 3). DOM trimmed and squared bellies were also valued higher ($P \leq 0.001$) in all three scenarios by \$1.97, \$2.29, and \$2.18, respectively (Figure 4). ALT hams were valued higher ($P \leq 0.01$) in the worst year scenario by \$0.84, but were worth \$1.45 and \$1.15 less ($P \leq 0.01$) in the best- and 4-year average scenarios, respectively (Figure 5).

ALT carcasses were numerically, but not statistically, more valuable in the 4-yr average and best pricing scenarios by \$1.29 ($P = 0.17$) and \$0.66 ($P = 0.56$), respectively. ALT carcasses were more valuable ($P = 0.03$) by \$1.99 in the worst pricing scenario (Figure 6).

Table 1. Effect of fabrication method on cutting yields of pork shoulders[a]

Item	Domestic style	SEM	Alternative style	SEM	*P* value
Carcasses, *n*	15		15		
Chilled side wt, kg	47.21		46.99		
Whole shoulder[b]	24.42	0.26	28.38	0.33	<0.0001
Trimmed shoulder	20.18	0.25	23.99	0.60	<0.0001
Neck bones	1.92	0.10	2.78	0.13	<0.01
Triceps brachii (cushion)	2.18	0.13	2.21	0.04	0.82
Bone-in Boston butt	9.43	0.16			
Boneless Boston butt	8.68	0.16			
Bone-in picnic	10.71	0.22			
Boneless picnic	7.05	0.48			
Cellar-trimmed butt			4.82	0.18	
Bone-in clod			13.20	0.15	
Boneless clod			7.77	0.24	
Teres major (petite tender)			0.29	0.02	
Brisket			3.97	0.14	

[a]Cuts not compared were not generated in opposite fabrication method.

[b]Cutting yields provided as a % of chilled side weight.

Table 2. Effect of fabrication method on cutting yields of loin and bellies

Item	Domestic style	SEM	Alternative style	SEM	*P* value
Carcasses, *n*	15		15		
Whole bone-in loin[a]	24.67	0.61	18.44	0.37	<0.0001
Trimmed bone-in loin	20.77	0.43	15.57	0.26	<0.0001
Strap-on loin	11.65	0.34	10.03	0.19	<0.0001
Strap-off loin	7.76	0.21	7.26	0.16	<0.01
Back ribs	1.49	0.08	1.14	0.05	<0.01
Tenderloin	0.99	0.04	1.13	0.05	<0.01
Sirloin	1.73	0.07	2.55	0.10	<0.0001
Whole bone-in belly[a]	19.43	0.38	18.00	0.35	<0.01
Natural fall belly	15.76	0.39	14.33	0.42	<0.01
Skinned natural fall belly	13.59	0.34	12.49	0.33	<0.0001
Trimmed and squared belly	10.05	0.31	9.22	0.34	<0.01
Spare ribs	3.82	0.12	3.61	0.06	0.16
St. Louis style spare ribs	3.23	0.11	3.17	0.05	0.70

[a]Cutting yields provided as % of chilled side weight.

Table 3. Effect of fabrication method on cutting yields of hams[a]

Item	Domestic style	SEM	Alternative style	SEM	*P* value
Carcasses, n	15		15		
Pork leg[b]	24.93	0.27	28.67	0.24	<0.0001
Trimmed ham	22.63	0.34	26.02	0.28	<0.0001
Inside	3.95	0.09	3.81	0.07	0.04
Outside	5.13	0.24	5.14	0.12	0.93
Knuckle	3.00	0.10	2.97	0.05	0.62
Lite butt	0.53	0.06			
Inner shank	1.46	0.05	1.51	0.03	0.17
Bone-in Outer shank	1.54	0.03	1.48	0.03	0.08

[a]Cuts not compared were not generated in opposite fabrication method.
[b]Cutting yields provided as a % of chilled side weight

Table 4. Effect of fabrication method on yields of miscellaneous cuts

Item	Domestic style	SEM	Alternative style	SEM	*P* value
Carcasses, *n*	15		15		
Back foot[a]	1.56	0.07	1.59	0.05	0.33
Front foot[a]	1.20	0.06	1.27	0.06	0.05
Jowl[a]	1.96	0.09	2.01	0.08	0.71
Lean Trim (72%)[a]	6.75	0.33	3.09	0.39	<0.0001
Fat trim (42%)[a]	11.59	0.96	13.42	0.76	0.02

[a]Cutting yields provided as % of chilled side weight.

DISCUSSION

Foreign markets have a substantial impact on American pork producers, with U.S. exports accounting for $5.941 billion dollars in 2016 (USMEF) and making up 27.9% of total domestic production during the beginning months of 2017 (Igoe, 2017). Oh and See (2012) acknowledged this growing sector by describing the need to understand consumer preferences in key export countries. As these markets become more important to packers and therefore producers, questions may arise as to how to maximize profitability while balancing consumer expectations both domestically and abroad. Although many acknowledge the growing need for understanding and incorporating export market needs into American pork production, the literature analyzing value or cutability differences between domestic specifications and Asian-inspired specifications is nonexistent. Its possible alternative fabrication methods may increase gross carcass value in some pricing scenarios.

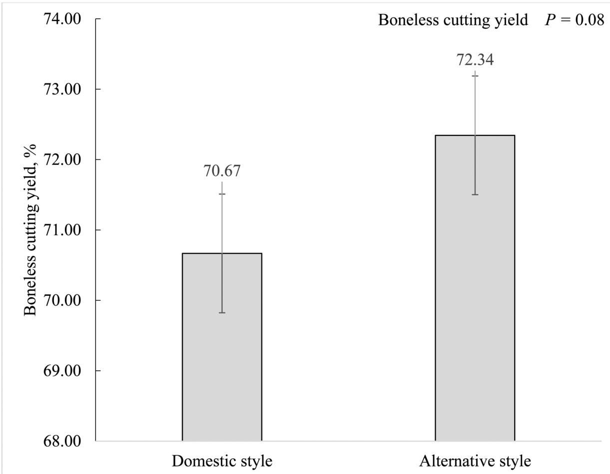

Figure 1. Effect of fabrication style on boneless carcass cutting yields. Data are depicted as least squared means ± the standard error of the mean (greatest reported). Domestic boneless cutting yield, % = [(boneless Boston butt (NAMP #406A), kg + boneless picnic (NAMP #405A), kg + Canadian back (NAMP #414), kg + tenderloin (NAMP #415A), kg + sirloin (NAMP #413D), kg) + natural fall belly (NAMP #408), kg + inside ham (NAMP #402F), kg + outside ham (NAMP #402E), kg + knuckle (NAMP #402H), kg + 72% lean trim, kg + fat trim (42% lean), kg)/chilled side weight] × 100. Alternative boneless cutting yield, %= [(cellar-trimmed butt, kg + boneless shoulder clod, kg + teres major (petite tender), kg + triceps brachii (cushion), kg + pectoralis profundis (brisket), kg + skinned, trimmed, boneless loin, kg + tenderloin, kg + sirloin, kg + natural fall belly, kg + inside ham, kg + outside ham, kg + knuckle, kg + 72% lean trim, kg + fat trim (42% lean), kg)/chilled side weight] × 100.

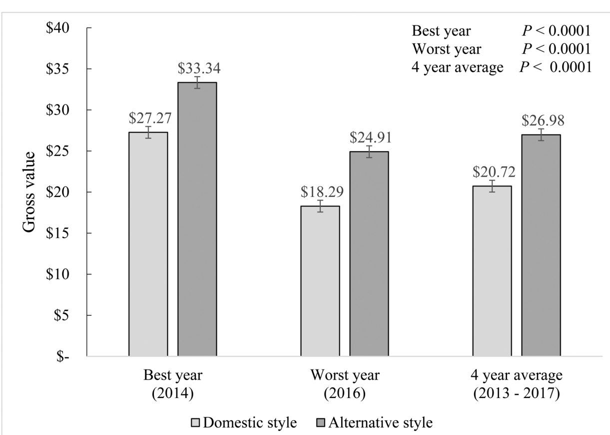

Figure 2. Effect of fabrication style on gross value of shoulders from DOM or ALT pork carcasses. Data are depicted as least squared means ± the standard error of the mean (greatest reported).

One such conflict between markets observed in this study is the reduction in belly and loin yield in order to increase shoulder yield in carcasses fabricated more similarly to export market specifications. In ALT-fabricated carcasses, loin and belly weights were reduced compared to DOM carcasses. Consequently, the reduction in belly and loin yield is accompanied by an increase in shoulder and ham yield. These data are consistent with the results discussed by Cravens (2001), in a benchmark study comparing U.S. specifications

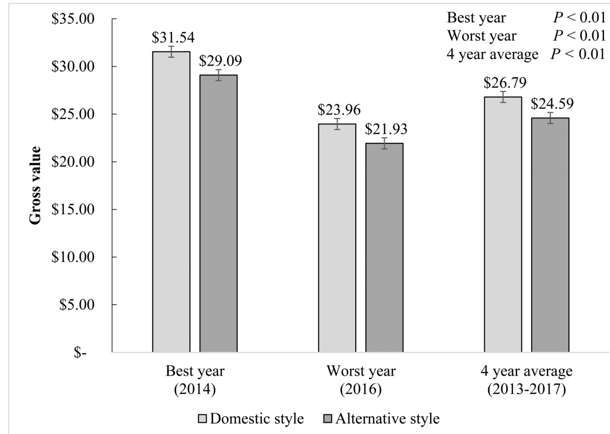

Figure 3. Effect of fabrication style on gross value of loins from DOM or ALT pork carcasses. Data are depicted as least squared means ± the standard error of the mean (greatest reported).

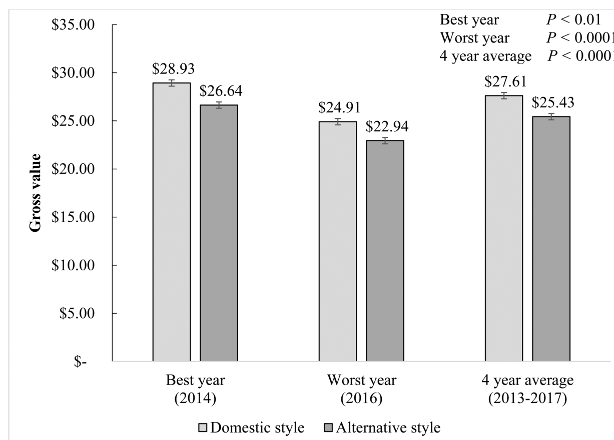

Figure 4. Effect of fabrication style on gross value of bellies from DOM or ALT pork carcasses. Data are depicted as least squared means ± the standard error of the mean (greatest reported).

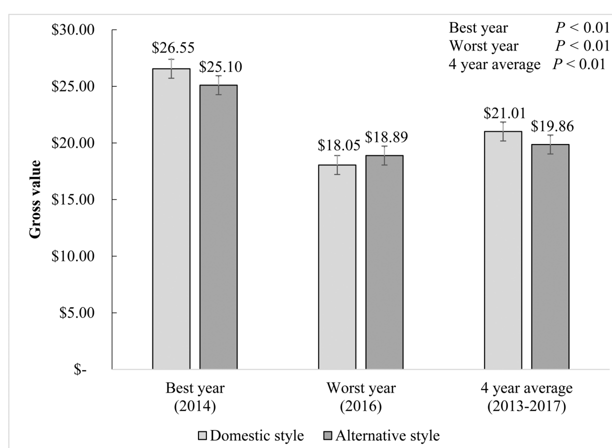

Figure 5. Effect of fabrication style on gross value of hams from DOM or ALT pork carcasses. Data are depicted as least squared means ± the standard error of the mean (greatest reported).

and Japanese specifications on primal yields. However, that preliminary study did not report an increase in ham yield, as all hams were cut to U.S. specifications.

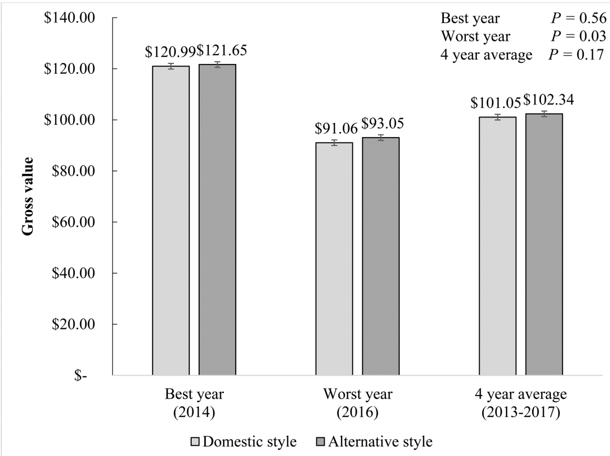

Figure 6. Effect of fabrication style on gross value of DOM and ALT pork carcasses. Data are depicted as least squared means ± the standard error of the mean (greatest reported).

Changes in yields of primals led to changes in the value of carcasses observed in this study. In the 4-year average pricing scenario, the value increase in the shoulder outsizes the decrease in the loin, belly, and ham by $0.73, meaning an increase in cut out value of $1.46 per carcass (multiplying by two to account for both sides of the carcass). Therefore, in total, ALT carcasses were worth $0.66, $1.99, and $1.29 more in the best-, worst-, and 4-year average pricing scenarios, respectively. Although only the increase in the worst year scenario was statistically significant, the monetary increases in the best- and 4-year average pricing situations may still be valuable to packers. Export values of retail cuts vary by company; therefore, domestic pricing was used to assign value to cuts. This provides a baseline value of these alternative-style cuts for individual packers and allows them to apply company specific pricing to determine impact on their value.

Because of the preferences of American consumers, packers are often reluctant to alter their style of fabrication. American consumers historically prefer bacon, thereby increasing the value of bellies. By changing both the loin–shoulder and the loin–ham break in the alternative-style fabrication method, belly weight was reduced. However, the belly weight lost when utilizing alternative specifications is not the portion of the belly that produces the majority of #1 (high quality) bacon slices, thus lessening the potential impact on domestic markets.

Similarly, the loin has consistently been an economically important primal due to American consumer demand for center-cut pork chops. Logically, shifting the loin–shoulder break more posterior and the loin–ham separation more anterior also reduced loin yield. However, this reduction is made by losing small portions of the blade and sirloin end of the loin. The center section, where center-cut pork chops are produced, is not affected. The loosening of the butt tender prior to making the loin–ham break allowed for there to be an increase in percentage yield of tenderloins in ALT carcasses. This helps limit the impact on supply of demanded loin retail cuts—center-cut chops and tenderloins—in the domestic market.

In summary, alternative fabrication methods of pork carcasses to be more similar to key export markets has the potential to increase the value of carcasses. Losses in loin and belly weights should not affect premium cuts such as center-slice bacon or center-cut pork loin chops.

LITERATURE CITED

Cravens, J.W. 2001. U.S. pork in the international marketplace. AMSA 54th Reciprocal Meat Conference Proceedings; pp. 28–39.

Harsh, B.N., B. Cowles, R.C. Johnson, D.S. Pollmann, A.L. Schroeder, A.C. Dilger, and D.D. Boler. 2017. A summary review of carcass cutability data comparing primal value of immunologically and physically castrated barrows. Transl. Anim. Sci. 1:77–89. doi:10.2527/tas2016.0009

Igoe, M. 2017. Strong momentum continues for red meat exports. USMEF. [accessed September 9, 2017] https://www.usmef.org/news-statistics/member-news-archive/strong-momentum-continues-for-red-meat-exports-2/.

Lowell, J.E., B.M. Bohrer, K.B. Wilson, M.F. Overholt, B.N. Harsh, H.H. Stein, A.C. Dilger, and D.D. Boler. 2018. Growth performance, carcass quality, fresh belly characteristics, and commercial bacon slicing yields of growing-finishing pigs fed a subtherapeutic dose of an antibiotic, a natural antimicrobial, or not fed an antibiotic or antimicrobial. Meat Sci. 136:93–103. doi:10.1016/j.meatsci.2017.10.011

NAMP (North American Meat Institute). 2014. NAMP Meat Buyer's Guide. 8th rev. ed. Washington (DC): North American Meat Association.

Oh, S.H., and M.T. See. 2012. Pork preference for consumers in China, Japan and South Korea. Asian-australas. J. Anim. Sci. 25:143–150. doi:10.5713/ajas.2011.1368

Person, R.C., D.R. McKenna, D.B. Griffin, F.K. McKeith, J.A. Scanga, K.E. Belk, G.C. Smith, and J.W. Savell. 2005. Benchmarking value in the pork supply chain: processing characteristics and consumer evaluations of pork bellies of different thicknesses when manufactured into bacon. Meat Sci. 70:121–131. doi:10.1016/j.meatsci.2004.12.012

Swatland, H.J. 2000. Meat cuts and muscle foods. Thrumpton, Nottingham: Nottingham University Press.

United States Department of Agriculture (USDA). MPR data mart, national weekly negotiated pork report-FOB plant. [accessed April 10, 2017] https://mpr.datamart.ams.usda.gov/results.do.

United States Department of Agriculture Economic Research Service (USDA ERS). 2017. Hogs & pork: sector at a glance. [accessed September 6, 2017] https://www.ers.usda.gov/topics/animal-products/hogs-pork/sector-at-a-glance/.

United States Meat Export Federation (USMEF). 2017. Total U.S. pork exports 2007–2016. [accessed September 6, 2017] http://www.usmef.org/downloads/Pork-2007-to-2016.pdf.