The Effect of Different Beef Cuts on the Processing, Compositional, and Sensory Properties of Beef Bacon

by

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ABSTRACT

The effect of different beef cuts on the sensory, processing, and compositional properties of beef bacon.

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Beef bacon is an unexplored product without a standard identity. A market evaluation of beef bacon products being sold in southern Ontario found a great deal of variation in the processing methods being used in manufacturing beef bacon. The greatest source of variation was the cut used. This prompted a controlled investigation into the differences between beef bacon products manufactured from seven different cuts; brisket (IMPS#120), clod heart (IMPS#114E; divided horizontally into two halves; silverskin side and non-silverskin side), flank (IMPS#193), outside flat (IMPS#171B), and short plate (IMPS#121A; cut into a deboned short rib half and navel half). Differences were identified between and within cuts used for processing, compositional, and sensory properties. These data allow the beef industry to tailor their cut selection for beef bacon to an identity found to be most agreeable with the consumer base they wish to target.
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1 Introduction

Beef bacon is presently both a familiar and unfamiliar product. The name implies that it is a beef product similar in form and processing technique to pork bacon, however with no standard cut from which it is manufactured, no distinct image of beef bacon comes to mind when the product is referenced. With no standard of identity or significant market presence, the potential of beef bacon for widespread use as a value-added product for the beef industry remains untapped.

This lack of a standard identity remains an impediment to the success of beef bacon, as different processors using different cuts of beef for manufacture, lends to a drastically different product appearance, shape, and flavour every time the product is encountered by the retailer and the consumer. Any references to the consumption of beef bacon products are specific to the source from which it was purchased or otherwise obtained, and as such, widespread recommendations for its purchase, use, or consumption cannot be suggested. Furthermore, academic and industrial investigations into the optimization of beef bacon processing parameters cannot be currently performed, as there is no base identity or formulation for which modifications can be applied to and compared against.

Although the lack of standard identity for beef bacon currently poses impediments to the widespread market success of beef bacon, this dilemma is not without any advantages. With no standard identity, a unique opportunity presents itself, where a thorough analysis of many different formulations that optimize sensorial and economical
properties, can be manufactured before ascribing an identity to “beef bacon”. Of the many potential parameters that could be ascribed to beef bacon, the cut of beef from which it is manufactured from is most critical to its success as it will dictate the form, composition, and most of the flavour of the beef bacon product. For this reason, the aim of this research was to compare the sensory, processing, and compositional properties of beef bacon manufactured with different cuts of beef, in order to aid the beef industry in selecting the superior cut of beef for which to ascribe to beef bacon’s standard identity.

2 Literature Review

The literature surrounding beef bacon is very sparse, both from an academic and regulatory point of view, such that it is possible to cover all scientific (academic) references to beef bacon in this review. In addition to exploring the literature surrounding beef bacon, a review on the existing definitions, compositional and sensorial properties, as well as market data, for pork bacon and other bacon alternatives, will aid in determining the properties of beef bacon.

2.1 Beef Bacon

2.1.1 Regulatory Information

Whereas bacon is consistently manufactured from the belly primal of pork, there is no standard cut ascribed to the identity of beef bacon (Canadian Food Inspection Agency,
There is also a lack of other formulation and processing requirements, which can lead to a great deal of variation even where the same cut is used.

**2.1.1.1 Regulatory Definitions of Beef Bacon**

In Canada, there exists no reference to beef bacon in the 1990 Meat Inspection Regulations or other, more recent regulatory documents (Meat Inspection Regulations, 1990; Safe Food for Canadians Regulations, 2018). Furthermore, there is no category of “bacon-like” or “bacon-style” meat products for which it may fall under for identification purposes. Despite not possessing a defined identity, the newly introduced (as of January 15, 2019) Safe Food for Canadians regulations provide package content weights for “sliced bacon”, which beef bacon would presumably fall under alongside other “bacon-style” meat products (Safe Food for Canadians Regulations, 2018). The lack of definition of beef bacon was the motivation for the first study which was a retail assessment of different beef bacon products in southern Ontario in an attempt to identify the different cuts and processing techniques used to create products being labelled as “beef bacon”.

In the USA, the USDA’s Food Standards and Labeling Policy Book, beef bacon is listed under “Bacon-Like Products” which indicates that bacon-like products must adhere to the same requirements as those applied to pork bacon, namely those that restrict certain ingredients, and the requirement that the bacon must return to green weight of the belly after processing (USDA, 2005).
Relative to Canadian regulations, the regulations in the US provide for greater product consistency and ensures that consumers understand the cut of meat from which their beef bacon is derived from. Unlike pork bacon, the USDA does not ascribe the root name of “beef bacon” to any specific cut of beef, instead allowing any cut to be used, provided that it is indicated on the package under a common name (USDA, 2005).

Beef bacon is specifically described by the USDA as:

A cured and smoked beef product sliced to simulate regular bacon. It is prepared from various beef cuts and offered with a variety of coined names, including “Breakfast Beef,” “Beef bacon,” etc. A common or usual name is required, e.g., “Cured and Smoked Beef Plate,” and should be shown contiguous to the coined name. (USDA, 2005)

The labeling convention used in the US provides consumers with a better understanding of the product they are purchasing. The drawback in the US however, is that the “beef bacon” name is never used, which is a simple and memorable term that is very easy to market and simple for consumers to understand and reference in conversation; as opposed to always referencing the coined and common name. Flooding the market with a wide variety of cured and/or smoked beef products, with lengthy labels, all of which the consumer may end up referencing as “beef bacon” anyway, is not conducive to market success of beef bacon. It would be more advantageous for the beef industry to agree upon a standard cut and processing methodology for a product that consumers can quickly reference as “beef bacon”. After a standard cut has been selected for the manufacture of beef bacon, it would be worthwhile to require additional labeling and
specifics when beef bacon is manufactured with other cuts; as is the case with bacon manufactured with other cuts, such as the jowl, must be called “jowl bacon”.

2.1.2 Academic Studies Involving Beef Bacon

2.1.2.1 Effect of Enzymatic Tenderization, Blade Tenderization, or Precooking on Sensory and Processing Characteristics of Beef Bacon (Bruggen, McKeith, and Brewer, 1993)

In this study beef bacon was manufactured from trimmed beef Plates to examine the effects of enzymatic tenderization, blade tenderization, and precooking on beef bacon. Beef plates were halved and modified in this experiment to analyze the effect of a treatment, and provided little information regarding a market-ready beef bacon product that has not been subjected to any of these treatments.

When examining enzymatic tenderization, 18 boneless, trimmed Plates were obtained from nine beef cattle, and cut in half, lengthwise, in order to obtain four “half-plates” from each animal. Of these four half-Plates, one was assigned to a control, another to a 10 ppm bromelain treatment, another to 20 ppm bromelain treatment, and the last to 30 ppm bromelain treatment. Bromelain was added to the cure solution and Plates were pumped to 110% of initial weight, resulting in a product containing 2% salt, 120 ppm nitrite, and 550 ppm erythorbate. Plates rested for 48 hours before cooking and smoking to an internal temperature of 55°C. 2.5 mm thick slices were manufactured from the smoked plate, vacuum-packaged, and refrigerated at 4°C.
When examining the effect of blade tenderization, short plates were halved into a blade half and a flank half. One half was randomly assigned as the control, the other was blade tenderized. Cuts were smoked, cooked, sliced, packaged, and stored, in the same manner as with the previous treatment.

In the final experiment on precooking, beef plates were cut in half length-wise once again and processed similarly to the experiment analyzing enzymatic tenderization.

In each experiment, plates were halved (either length-wise or width-wise), and the halves were randomly assigned to each treatment. Although this may have been appropriate for the analysis of each treatment, it offered no information on the characteristics of those halves; which are likely to be significantly and consistently different, regardless of whether they were cut length-wise or width-wise. Apart from analyzing the differences between several different primal cuts, one of the objectives of this current study is to quantify the differences of these “half-plates”, as well as to fabricate them into Institutional Meat Purchase Specifications (IMPS) standardized halves; an IMPS #121A boneless short plate will be cut into an IMPS #121G boneless, short ribs removed half, and an IMPS #123D boneless short ribs half (NAMI, 2014).

2.1.2.2 Processing and Palatability Characteristics of Round Beef Bacon

(Bruggen, McKeith, Brewer, Stites, and Betchel 1993)

The term “round beef bacon” is a bit misleading in the title of this study as beef bacon was manufactured from the Plate, rather than the round primal. Beef Plates were deboned, trimmed, cured, pumped to 110% of green weight, and a product containing
2% salt, 120 ppm sodium nitrite, and 550 ppm sodium erythorbate. Rather than halving the plate (which is presumed to be the short plate not the full plate with the brisket attached), plates were rolled longitudinally and stuffed into 23 cm diameter fibrous casings after receiving their treatments; which were either vacuum-tumbling, maceration and vacuum-tumbling, emulsion coating and vacuum tumbling, or maceration, emulsion coating, and vacuum-tumbling. The product was then smoked and cooked to an internal temperature of 55°C.

The curing, cooking, and smoking process were akin to traditional pork bacon, the stuffing of the entire plate into a casing and processing steps were not representative to a traditional sliced bacon product that most consumers are familiar with. The objectives of the present study being undertaken will remain true to the whole muscle form commonly associated with bacon in order to identify a true pork bacon alternative.

2.2 Pork Bacon

Bacon has been consumed for thousands of years, with the first known recorded consumption of salted pork dating back to 1500 BCE in China (Kim, 2013). The word “bacon” is of English origin, and was originally used as early as the 1st millennium AD to refer to modern day rashers sold in the UK, which is bacon manufactured from the loin with a portion of the belly still attached (Bule, 2018). Today, in North America, “bacon” is identified as the cured boneless pork belly consumed both as a convenient, savoury, fatty, and salty breakfast food item, as well as an ingredient and complement to many dishes. Its form and sensory properties are well recognized by consumers, and the
processing methodologies and formulations are well established by the industry and regulatory agencies alike.

2.2.1 Regulatory Definitions

In Canada, the 1990 Meat Inspection Regulations indicate that bacon must be cured and manufactured from the boneless pork belly, and must include salt and preservatives (Meat Inspection Regulations, 1990). The regulation allows for the addition of water, seasonings, and phosphates. The 1990 Meat Inspection Regulations defines “cured” as salt together with at least 100 ppm of sodium nitrite, potassium nitrite, sodium nitrate, potassium nitrate, or any combination thereof that has been added to the meat product during its preparation.

In the USA, the USDA’s Food and Labeling Policy Book describes bacon as:

… the cured belly of a swine carcass. If meat from other portions of the carcass is used, the product name must be qualified to identify the portions, e.g., “Pork Shoulder Bacon.” (USDA, 2005)

Under 9 CFR 319.107, the FSIS states that:

The weight of cured pork bellies ready for slicing and labeling as “Bacon” shall not exceed the weight of the fresh uncured pork bellies.
Under FSIS Directive 7620.3, the Processing Inspectors' Calculations Handbook identifies minimum limits are indicated for the use of sodium nitrite along with sodium erythorbate or sodium ascorbate.

An amount of 120 ppm sodium nitrite [to a maximum of 200 ppm] (or 148 ppm potassium nitrite), ingoing, is required in pumped and/or massaged bacon, except that 100 ppm sodium nitrite (or 123 ppm potassium nitrite) is permitted with an appropriate partial quality control program, and except that 40 - 80 ppm sodium nitrite (or 49 - 99 ppm potassium nitrite) is permitted if sugar and a lactic acid starter culture are used. 550 ppm sodium ascorbate or sodium erythorbate (isoascorbate), ingoing, is required in pumped and massaged bacon, in addition to any prescribed amount of nitrite.

2.2.1.1 Other Pork Bacon Products

Although pork bacon is understood to be manufactured from the belly, other cuts are used to make “bacon”, with the cut or kind of bacon labelled as such. In Canada, back bacon is popular and is defined as bacon from the boneless pork loin (Meat Inspection Regulations, 1990). The Canadian Meat Inspection Regulations define Wiltshire Bacon, also known as “rashers” in the UK, as bacon manufactured from the boneless pork loin with a portion of the belly still attached (Meat Inspection Regulations, 1990). In the US, there are many more unique types of bacon, including Arkansas/Shoulder bacon, Canadian/back bacon, Dixie/jowl bacon, and more. Ideally, beef bacon would have a similar regulatory framework, with standard cut from which it can be marketed and
understood called “beef bacon”, with other cuts requiring labelling similar to that currently seen in the US (USDA, 2005).

2.2.2 Sensory Properties and Shelf-life of Pork Bacon

Bacon has gained a reputation of a highly palatable and popular product because of its savoury taste, along with its high fat and salt content. When developing an alternative bacon product, it is necessary to more precisely identify the degree to which consumers prefer these and other sensory characteristics. A study by Saldaña et al. (2019) utilized the Ideal Profile Method (IPM) as described by Worch et al. (2013) in order for habitual consumers of bacon to create a profile of the ideal bacon product using 32 descriptors. This ideal profile was then compared to commercial bacon and it was found that more consumers desire a bacon product that is lower in fat and fatty taste. However, the same study also found that juiciness was the most commonly used descriptor for the ideal bacon product. Since juiciness is heavily reliant on the fat content, this seeming adumbration of preferences in the ideal bacon product is problematic since it suggests that consumers desire a bacon product with significantly less fat, while still remaining juicy. It would be very difficult and costly to offer consumers a pork bacon product that possesses a significantly lower fat content, but still possesses the same form and sensory properties of traditional pork bacon manufactured from the belly. Back bacon is very lean, and possesses very little fat. Although consumers desire less fat, too little would presumably have negative impacts on the sensory properties of the bacon. Back bacon is also significantly different in form from belly bacon. Wiltshire bacon (also known as rashers in the UK), manufactured from the loin with a small
portion of the belly attached, would offer an intermediate fat content between back and
belly bacon, however it’s overall form and the distribution of fat and collagen, creates
asymmetrical sensory properties across the slice that may not be desirable.

Furthermore, the cut required to create rashers is not well suited to the primal cuts of
pork that dominate the North American market (i.e. the separation of the loin and belly
primals). The success of poultry bacon, despite being an emulsified and formed
product, may largely be due to its lower fat content, indicating the degree to which
consumers are willing to sacrifice traditional bacon sensory properties for perceived
nutritional advantages.

Bacon manufactured from beef, even when manufactured from the plate, may prove to
be leaner than pork bacon, while still maintaining the traditional pork belly bacon
appearance and distribution of fat, muscle, and collagen. This would meet consumer
preferences for a lower fat bacon product, without having to rescind on traditional bacon
form and texture. Other primals apart from the plate, such as the brisket and flank, are
much leaner than both pork bacon and beef bacon manufactured from the plate, while
maintaining the traditional bacon shape that consumers would expect from a bacon
alternative. Despite not having the same distribution of fat and protein that pork bacon
possesses, beef that is heavily marbled may be the key to striking the balance between
delivering on the much-desired juiciness along with the much lower fat content that
consumers also desire. Thus, it is worth examining a variety of different beef cuts, even
traditionally leaner, but well-marbled cuts, to determine which cuts of beef would be
best-suited for the marketing of a lean, but still juicy, bacon alternative.
The main caveat with beef bacon, across all cuts, is likely due the higher intramuscular and intermuscular collagen content found in beef. This could potentially lead to tougher and more rubbery sensory properties, which consumers in the study by Saldaña et al. (2019) identified as undesirable properties in their ideal bacon product. Thus, it would be pertinent to identify the perceived tenderness of the muscle fiber component, along with the amount of connective tissue in beef bacon manufactured with a variety of cuts in order to determine the degree to which the increased collagen in beef would impact the sensory properties of the bacon.

In terms of stability, many studies have examined the shelf life of pork bacon as it pertains to lipid oxidation. A study by Leick et al. (2010) reported lipid oxidation in vacuum-packaged bacon as measured by TBARS, more than doubled after just 14 days of storage at 2°C followed by 14 days of storage under fluorescent lighting. Another study by Lowe et al. (2014) reported that the oxidation (as measured by a trained sensory panel and by TBARS) of bacon manufactured from fresh bellies, was significantly greater (more oxidized) after just 60 days of dark storage at 2°C. Dry-cured and dry-ripened bacon shows even more susceptibility to lipid oxidation, where a fourfold increase in TBARS values was observed at the end of the two week dry-ripening process (Yang et al., 2017). As lipid oxidation involves the degradation of unsaturated fatty acids, it is anticipated that beef bacon, with its greater proportion of saturated fatty acids, would be more resistant to lipid oxidation, and thus experience a longer shelf-life when compared to pork bacon (Aberle et al., 2001). In addition to the greater proportion of non-oxidizing saturated fats, the leaner cuts of beef would likely
experience an even longer shelf life as evaluated by lipid oxidation, as the lower fat content may not be high enough for consumers to detect significant oxidation even if a large proportion of that fat has been oxidized.

2.2.3 Bacon Consumption Trends

The bacon industry provides a substantial source of revenue for the pork industry. Sales in the US for 2018 totaled USD$6.56 billion and 1.47 billion units (Fox, 2018). In spite of the widespread reporting of the WHO’s statement on bacon and colorectal cancer, refrigerated bacon sales grew by 3.5% from July 2017 to July 2018 (Fox, 2018). According to Mordor Intelligence, the global bacon market is estimated to be USD$55.76 billion in 2016, with a forecasted growth of 3.13% between 2018 and 2023 (Mordor Intelligence, 2017). The same report indicates that bacon accounts for as much as 19% of in-home pork consumption. Such a high proportion of consumption for a value-added product is highly advantageous for the pork industry when compared with the beef industry. Excluding minced meat preparations, the beef industry is dominated by whole-muscle cuts which are difficult to add value to. By shifting consumption away from whole muscle cuts, towards value-added products with the same dominance as pork bacon, the industry can experience greater profitability while providing consumers with highly palatable products.
2.3 Poultry Bacon

Poultry bacon is an emulsified and formed bacon alternative. Thigh, breast, and skin are used in its fabrication. The thigh meat are coarsely ground and treated independently; the thigh meat is cured with a brine whereas the breast is prepared with ingredients without the use of nitrite; skin paste is blended in with the thigh and breast meats, and the resulting mixture is then smoked, cooked, and sliced (Baumgart et al., 1980; Walters et al., 1992). It offers several advantages over pork bacon. Poultry bacon can be both kosher and halal, and is also a leaner cut that may be of interest to those looking to consume fewer calories and more protein (USDA, 2018a, 2018b). Its main shortcoming is its lack of whole muscle form that is traditionally associated with bacon.

Poultry bacon is not covered in Canada’s Meat Inspection Regulations and the pork industry has expressed concern with the use of the word “bacon” being applied to poultry products. In spite of this, the Canadian Food Inspection Agency (CFIA) announced that it would allow the use of “poultry-style bacon” and “poultry bacon-style” to be applied to poultry bacon products (Canada Gazette, 2000; Wilson, 2008).

In the USA, poultry bacon products are discussed under “bacon-like products”. In terms of labelling, the requirement is that a descriptive name must be contiguous to the kind of bacon, e.g. “Turkey Bacon-Cured Turkey Breast Meat-Chopped” (USDA, 2005). As with beef bacon, this is a lengthy labelling convention, and the poultry industry would benefit from the pursuit of a more simplified and standardized bacon product.
3 Market Evaluation of Beef Bacon Products Being Sold in Southern Ontario

3.1 Abstract

The lack of standard identity for beef bacon, and the sparse literature surrounding it, led to the undertaking of a preliminary study to identify the processing techniques and product identity that local beef bacon manufacturers were utilizing. Beef bacon was purchased at the retail level from six different meat processors in southern Ontario, Canada, and was analyzed for composition and for visual lean-to-fat ratio. A great degree of variability in the macronutrient composition was found. This suggested different processing techniques and utilization of different cuts were being used. Therefore, it was concluded that beef bacon was (and is) being treated as a value-added product that could be manufactured with cuts that were inexpensive or otherwise not selling well.

3.2 Introduction

A review of the Canadian standards of identity for meat products established the existence of only three bacon products; all manufactured from pork, and each with a standard cut from which it must be manufactured from (Canadian Food Inspection Agency, 2017). “Bacon” must be manufactured from the boneless pork belly, “Back Bacon” must be manufactured from the boneless pork loin, and “Wiltshire Bacon” must be manufactured from the boneless pork loin with a portion of the belly attached”; all
products must also contain salt and preservatives. There is no defined standard of identity for beef bacon products (Canadian Food Inspection Agency, 2017). Due to the lack of legislation and sparse market presence of beef bacon, meat processors are able to utilize any cut to manufacture bacon and utilize any type of processing method to manufacture a product that can be labeled as beef bacon. The brine uptake in the curing process can be used to improve the weight, palatability, storage time, and salability of virtually any cut of beef, including cuts that may otherwise not sell very well. The potential result of this lack of standard identity is poor product recognition among consumers, a paucity of scientific literature surrounding beef bacon, and ultimately, low process and profit optimization for meat processors. Safety is also a potential concern with a lack of standard identity and processing. There has been one instance where the CFIA has had to issue a public warning against the consumption of a particular brand of a beef bacon product due to potential contamination with *Listeria monocytogenes* (Canadian Food Inspection Agency, 2010). With no mandatory treatments or ingredients, it may be the case that this product did not contain the necessary preservatives that pork bacon would possess. On the other hand, it may instead be the case that it was manufactured like pork bacon, however, this method of processing may be insufficient for managing the risks associated with the different food matrices found in different cuts of beef. In order to understand the effect of a lack of standard identity on product variability, the objective of this study was to examine the composition of commercial beef bacon products sold in southern Ontario, Canada and further investigate the sources of variation in beef bacon products. It was hypothesized that
due to the lack of standard product identity, there would be a great degree of variability in the appearance and composition of products labelled as “beef bacon”.

3.3 Materials and Methods

3.3.1 Sample Collection and Storage

Butchers, meat processors, and retailers in southern Ontario were surveyed for beef bacon products. A total of six different beef bacon products were found and three packages of each brand (replications) were subsequently purchased, kept chilled during transport, and frozen at -20°C within 4 hours of purchase for further analysis.

3.3.2 Image Analysis

A visual analysis was conducted on two random slices of beef bacon from each of the three packages purchased for each brand; a total of six slices from each brand were analyzed. The method was adapted from the method prepared by Bohrer 2013 which can be found in Appendix A1. Slices were photographed using a Nexus 5 camera (LG Electronics Inc., Seoul, South Korea) against a black bristol board background alongside a 30 cm ruler. Adobe Photoshop CS5 (Adobe Systems Inc., San Jose, CA) was used to isolate the slices and ruler from the background to create a TIFF file of the slice and ruler layered on a transparent foreground. The TIFF files were then imported into the National Institutes of Health Image J software (Abramoff et al., 2004). Slice dimensions were determined by first defining the number of pixels in a centimeter using the Set Scale function, and then using the Threshold function to create a complete black
slice, and with the straight-line tool then being used to measure the slice dimensions. Total slice area was determined using the freehand selection tool along with the Analyze Particles function. High contrast black and white images of each bacon slice were created by converting each image to an 8-bit image and using the Threshold function to create black pixels for the lean portion of the slice, and white pixels for the fat portion of the slice. The Analyze Particles function was used to count the number of black (lean) pixels, which was then divided by the number of black pixels in a fully blackened bacon slice image; to determine the lean percentage of each slice. Refer to Appendix A1 for a step-by-step instruction of the Image Analysis procedure.

3.3.3 Proximate Analysis

A master batch was created from each brand, by mincing the six strips used for the image analysis in a food processor (KitchenAid 3.5 Cup Food Chopper Model KFC3516ER, Whirlpool Corporation, Michigan, USA) and then the homogenous blend was stored at -20°C until further analysis was conducted. Before further analysis was conducted, the homogenous blend of samples was thawed overnight in the refrigerator at 4°C. All proximate analyses were performed in duplicate on each brand’s master batch. Protein content was determined using the Dumas method (FP-528, Leco, St.Joseph, Michigan, USA). Moisture content by oven drying at 100°C for 24 hours, at which points samples were successively tested for their lipid content via Soxhlet. Other components were then determined by difference.
3.3.4 Statistical Analysis

Statistical analysis included determining descriptive statistics with the MEANS procedure of SAS and determining the fixed effect of brand using the MIXED procedure of SAS.

3.4 Results and Discussion

Table 3.1 presents the findings of the image analysis and proximate analysis performed on each of the six different brands. Brands are identified as Brand A-F instead of by their names to preserve the anonymity of each brand. Different brands of beef bacon ranged significantly in moisture content (45.6 – 66.6%; SEM = 0.4; P < 0.0001), lipid content (5.0 – 36.6%; SEM = 1.0; P < 0.0001), protein content (11.5 – 25.8%; SEM = 0.3; P < 0.0001), and other components (1.4 – 7.8%; SEM = 0.9; P = 0.01). Total slice area among different brands of beef bacon ranged (P < 0.0001) from 38.5 – 130.4 cm² with a SEM of 14.3 cm². Slice lean percentage among different brands of beef bacon ranged (P < 0.0001) from 51.1 – 94.8% with a SEM of 2.0%. Lean to fat ratios among different brands of beef bacon ranged (P < 0.0001) from 0.9 to 26.8 with a SEM of 1.7.
Table 3.1 Comparison of the visual and compositional properties between six different brands of beef bacon collected at the retail level in southern Ontario, Canada.

<table>
<thead>
<tr>
<th>Brand</th>
<th>Brand A</th>
<th>Brand B</th>
<th>Brand C</th>
<th>Brand D</th>
<th>Brand E</th>
<th>Brand F</th>
<th>SEM&lt;sup&gt;1&lt;/sup&gt;</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total slice area (cm&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>90.56&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>115.90&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>78.03&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>38.45&lt;sup&gt;c&lt;/sup&gt;</td>
<td>130.40&lt;sup&gt;a&lt;/sup&gt;</td>
<td>103.50&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>14.26</td>
<td>&lt;0.000 1</td>
</tr>
<tr>
<td>Slice lean percentage (%)</td>
<td>76.62&lt;sup&gt;b&lt;/sup&gt;</td>
<td>52.24&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>59.36&lt;sup&gt;c&lt;/sup&gt;</td>
<td>94.84&lt;sup&gt;a&lt;/sup&gt;</td>
<td>85.84&lt;sup&gt;a&lt;/sup&gt;</td>
<td>51.05&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.97</td>
<td>&lt;0.000 1</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>65.28&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>47.33&lt;sup&gt;d&lt;/sup&gt;</td>
<td>61.82&lt;sup&gt;c&lt;/sup&gt;</td>
<td>63.73&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>66.55&lt;sup&gt;a&lt;/sup&gt;</td>
<td>45.59&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.39</td>
<td>&lt;0.000 1</td>
</tr>
<tr>
<td>Lipid (%)</td>
<td>14.71&lt;sup&gt;b&lt;/sup&gt;</td>
<td>34.52&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18.87&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.04&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6.24&lt;sup&gt;c&lt;/sup&gt;</td>
<td>36.61&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.99</td>
<td>&lt;0.000 1</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>15.58&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14.41&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>11.51&lt;sup&gt;d&lt;/sup&gt;</td>
<td>25.60&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25.78&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.25&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.30</td>
<td>&lt;0.000 1</td>
</tr>
<tr>
<td>Other components (%)</td>
<td>4.43&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.73&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>7.80&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.63&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.40&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.57&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.89</td>
<td>0.01</td>
</tr>
</tbody>
</table>

<sup>1</sup>The maximum SEM (standard error of the mean) was reported.

<sup>a,b,c,d</sup>Least square means (n=6) lacking a common superscript letter within a row are different (P < 0.05).
Figure 3.1 Bacon slices obtained from each brand; images not to scale.

The results of the visual and compositional analyses in the market evaluation of beef bacon products sold in southern Ontario show a significant degree of variation in the processing techniques being used to manufacture beef bacon. The cut from which the beef bacon is manufactured from is identified as the greatest source of variation. Brand A appears to be an emulsion-based meat product manufactured similarly to how poultry bacon is manufactured. Brand B is hypothesized to be the navel end of the short plate, whereas brands C and D are not readily recognized. Brand E is not readily identifiable. Due to the high fat content, and the distribution of the fat, of Brand F, it is hypothesized to have been obtained from the short plate. Despite being manufactured from the same
cut, differences in processing methodologies lead to products with drastically different visual and compositional properties.

The drastic differences between different brands of beef bacon are undoubtedly tied to the lack of standard identity for beef bacon. It appears that some meat processors view beef bacon as an opportunity to add value to cuts that are otherwise not selling well. This lack of standardization leads to an inconsistent product without an identity. This means that unless a specific brand is referenced, consumers will identify a different product and eating experience when talking or reading about “beef bacon”. A standardized product would allow for easier product referencing and utilization in recipes and prepared food products.

3.5 Conclusions

The macronutrient composition and appearance of products that were labeled as “beef bacon” in southern Ontario, Canada, was highly variable. The variability was believed to be due to meat processors utilizing different value-added cuts of beef for the production of beef bacon. Further research is necessary to determine the utilization of different beef cuts for the manufacture of beef bacon and the associated effects on processing parameters, storage capabilities, product composition, and sensory characteristics.

3.6 References

4 Evaluation of Beef Bacon Manufactured with Different Cuts

4.1 Abstract

Beef bacon is an unexplored beef product without a standard identity. A market evaluation of beef bacon products being sold in southern Ontario found a great deal of variation in the processing methods being used to manufacture beef bacon. The greatest source of variation was the cut used. This prompted a controlled investigation into the differences between beef bacon products manufactured from seven different cuts; brisket (IMPS#120), clod heart (IMPS#114E; divided horizontally into two halves; silverskin side and non-silverskin side), flank (IMPS#193), the outside flat (IMPS#171B), and the short plate (IMPS#121A; cut into a deboned short rib half and navel half). Differences were identified between and within cuts for processing, compositional, and sensory properties. These data allow the beef industry to tailor their cut selection for beef bacon, to an identity found to be most agreeable with the consumer base they wish to target.
4.2 Introduction

Beef bacon is presently both a familiar and unfamiliar product. The name implies that it is a beef product similar in form and processing technique to pork bacon, however with no standard cut from which it is manufactured, no distinct image of beef bacon comes to mind when the product is referenced. With no standard of identity or significant market presence, the potential of beef bacon for widespread use as a value-added product for the beef industry remains untapped.

A preliminary study (Chapter 3), revealed a great deal of variation in the appearance and composition of beef bacon products sold in southern Ontario. The greatest source of variation was attributed to the cuts of beef being used to manufacture the beef bacon. This market variation due to differences in cut being used, stemming from a lack of regulated or commonly understood identity, remains an impediment to the success of beef bacon; as different processors using different cuts of beef for manufacture, lends to a drastically different product appearance, shape, and flavour every time the product is encountered. Any references to the consumption of beef bacon products are specific to the source from which it was purchased or otherwise obtained, and as such, widespread recommendations for its purchase, use, or consumption cannot be manufactured. Furthermore, academic and industrial investigations into the optimization of beef bacon processing parameters cannot be currently performed, as there is no base identity or formulation for which modifications can be applied to and compared against.
Although the lack of standard identity for beef bacon currently poses impediments to the widespread market success of beef bacon, this dilemma is not without any advantages. With no standard identity, a unique opportunity presents itself, where a thorough analysis of many different formulations that optimize sensorial and economical properties, can be manufactured before ascribing an identity to “beef bacon”. Of the many potential parameters that could be ascribed to beef bacon, the cut of beef from which it is manufactured from is most critical to its success as it will dictate the form, composition, and most of the flavour of the beef bacon product. For this reason, the aim of this study was to compare the sensory, processing, and compositional properties of beef bacon manufactured with different cuts of beef, in order to aid the beef industry in selecting the superior cut of beef for which to ascribe to beef bacon’s standard identity.

4.3 Materials and Methods

4.3.1 Beef Bacon Manufacture

Beef bacon was manufactured from the following cuts; the Institutional Meat Purchase Specifications (IMPS) cut identification number follows each cut name in brackets:

- Brisket (IMPS #120)
- Short Plate (IMPS #121A), divided vertically along the midsection, creating:
  - Deboned Short-rib half (Plate-SR)
  - Navel half (Plate-N)
- Flank (IMPS #193)
- Clod Heart (IMPS #114E), divided horizontally along the midsection, creating:
  - Wide, silverskin side half (Clod-S)
  - Narrow, non-silverskin side half (Clod-NS)
- Outside Flat (IMPS #171B)
Each of the cuts listed above were processed in replicates of six (the Plate-SR and Plate-N were processed in replicates of seven). The cuts were purchased from Ryding Regency Meat Packers Ltd. All the cuts arrived on the same day and were refrigerated at 4°C until further processing. The Brisket, Plate-SR, and Plate-N were processed first according to the following procedure, with the remaining cuts processed together thereafter.

Fat was trimmed to an eighth of an inch for all cuts. Cut dimensions (length, height, width) were measured after trimming. Length and height were measured along the longest and widest points, respectively, across the cut. Thickness was averaged across eight measurements (four measures along the length on each side) for the brisket, plate cuts, and outside flat. Thickness was averaged across four measurements (two measures along the length on each side) for the clod heart cuts and flank cut; as these were smaller. Each cut was weighed before being passed twice through an injector (Inject Star Pökelmaschinen Gesellschaft m.b.H; Hagenbrunn, Austria) to a pump uptake of approximately 20% (+/- 3%). The injection brine consisted of a standard commercial bacon cure (water, salt, corn syrup solids, sodium phosphate, sodium erythorbate, sodium nitrate, sodium bicarbonate, and glycerin; Herman Laue Spice Company Inc.; Uxbridge, Ontario, Canada) according to supplier recommendations. The composition of the injection brine along with the concentration of each of the components can be found in Appendix A2. Cuts were immediately weighed following injection and weighed again after a 30-min rest period. Cuts were then allowed to rest overnight at 4°C. The following day, cuts were weighed once more to obtain their rested
pump uptake as well as their pre-cook weight. Cuts were then smoked and cooked to
an internal temperature of 62°C in a smokehouse (Scott Mini Single Cage Vertical Air
Flow Smokehouse; ScottPec, Guelph, Ontario). Refer to Appendix A3 for the smoke
and cook cycle programmed into the smokehouse. After cooking, cuts were sprayed
with cold water and rested overnight at 4°C. Cooked cuts were then weighed prior to
being sliced into 4.0 mm slices using a deli slicer.

4.3.1.1 Sample Collection and Storage
Each cut was divided along its length into thirds, to create a back, center, and front (the
widest end of each cut was the “back”) section from which slices were collected,
vacuum-packaged, and stored in a sealed cardboard box. Sample storage temperature
and times were defined according to future analyses. Back, center, and front slices were
used for successive image analysis (4.3.3), proximate analysis (4.3.4), and fatty acid
analysis (4.3.7) and were immediately frozen and stored at -20°C. See Figure 4.1 for a
flow chart describing sample collection, storage, and utilization for the technical analysis
portion of this study. Only center slices were used for cook yield analysis (4.3.5) and
sensory evaluation (4.3.6). These slices were refrigerated at 4°C for 0, 30, 60, or 90
days, at which point they were stored at -20°C in order to delay lipid oxidation, microbial
growth, and enzymatic activity.
Seven different cuts were each processed in replicates of six.

Each cut was divided into three sections.

Three slices were saved from each section to create three replicates for the combined effect of: cut, cut replicate, and cut section.

Samples were vacuum-packed and stored in a sealed box at -20°C

**Image Analysis:**

3 slices × 3 sections × 7 cuts × 6 replicates
= 378 sampling units

Each sampling unit was individually minced and stored at -20°C for successive testing in proximate analysis.

**Proximate Analysis:**

378 minced sampling units × 2 technical replicates
= 756 samples

The three replicates for each section were placed in folded aluminum pans into a single soxhlet flask to collect a lipid sample for each section of each cut. Samples were stored in 1.5mL Eppendorf tubes at -20°C for successive fatty acid analysis.

**Fatty Acid Analysis:**

3 sections × 7 cuts × 6 cut replicates × 2 technical replicates
= 252 lipid samples

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Figure 4.1 Description of sample collection, storage, and utilization for image, proximate, and fatty acid analysis.
4.3.2 Processing Characteristics and Yield

During the manufacturing of beef bacon, the green weight, weight after injection with brine, weight after a 30-min rest period following injection, weight after a 24-h rest period following injection, and the weight after smoking and cooking; was collected for each cut. From these weights, the pump uptake, rested pump uptake, and smokehouse cook yield was calculated.

Equation 4.1 Pump uptake after brine injection.

\[
Pump\ uptake\% = \frac{Pump\ weight - Green\ weight}{Green\ weight} \times 100\%
\]

Equation 4.2 Rested pump uptake following a 30-minute rest period following brine injection.

\[
Reste\d pump\ uptake\% = \frac{Reste\d\ pump\ weight - Green\ weight}{Green\ weight} \times 100\%
\]

Equation 4.3 Smokehouse cook yield after smoking and cooking.

\[
Smokehouse\ cook\ yield\% = \frac{Cooked\ weight}{Green\ weight} \times 100\%
\]

4.3.3 Image Analysis of Individual Beef Bacon Strips

As shown in Figure 4.1, image analysis was performed on each of the three slices obtained from each front, center, and back section; or each replicate. Lean percentage, total area, length and width, and length to width ratio were evaluated. The image analysis method was adapted from the method prepared by Bohrer (2013) which can be found in Appendix A1. Slices were photographed using a Nexus 5 camera (LG
Electronics Inc., Seoul, South Korea) against a black bristol board background alongside a 30 cm ruler. Adobe Photoshop CS5 (Adobe Systems Inc., San Jose, CA) was used to isolate the slices and the ruler from the background of each image to create a TIFF file of the slice and ruler layered on a transparent background. The TIFF files were then imported into the National Institutes of Health’s Image J software (Abramoff et al., 2004). Slice dimensions were determined by first defining the number of pixels in a centimeter using the “Set Scale” function, and then using the “Threshold” function to create a complete black slice, and with the straight-line tool then being used to measure the slice dimensions. High contrast black and white images of each bacon slice were created by converting each image to an 8-bit image and using the Threshold function to create black pixels for the lean portion of the slice, and white pixels for the fat portion of the slice. The “Analyze Particles” function was used to count the number of black (lean) pixels, which was then divided by the number of black pixels in a fully blackened bacon slice image; to determine the lean percentage of each slice. Total slice area was determined using the freehand selection tool to slice made up of only black pixels, which was then measured with the “Analyze Particles” function. Refer to Appendix A1 for a step-by-step instruction of the image analysis procedure. All measured parameters were evaluated in duplicate, by two technicians, and are presented as averages of both evaluations. Length and width were obtained from the longest and widest points along each slice respectively.
4.3.4 Consumer Beef Bacon Impressions Survey

To determine consumer perception surrounding beef bacon, an online survey was distributed using the Qualtrics survey platform and circulated to University of Guelph students, as well as several online cooking forums, in order to gauge impressions that consumers may have of each of the seven different cuts from which beef bacon was manufactured in this study. In the survey, 83 participants were screened for bacon consumption frequency and familiarity with beef bacon. Participants were then asked to rank seven images based on their subjective opinion on what beef bacon should look like, on what looked most appetizing, as well as which they were most likely to purchase based. For each ranking, participants were asked to indicate which criteria most affected their ranking. Finally, consumers were asked to indicate whether or not the visual fat content would impact their choice to purchase the product. Refer to A7 for the questions circulated in the survey.

4.3.5 Proximate Analysis

Proximate analysis for the identification of moisture, lipid, protein, and ash content was performed in duplicate for all the beef bacon slices used in the image analysis as described above. Strips were minced individually in a food processor (KitchenAid 3.5 Cup Food Chopper Model KFC3516ER, Whirlpool Corporation, Michigan, USA) and stored at -20°C until further analysis was to be conducted, at which point samples were thawed in a refrigerator overnight.
Moisture content was determined by oven drying at 100°C for 24 hours, at which points samples were successively tested for their lipid content via Soxhlet, protein content via Dumas (FP-528, Leco, St. Joseph, Michigan, USA), and ash content by being placed in a muffle furnace at 550°C for 24 hours. Non-protein nitrogen as added in the curing solution was deemed negligible and not subtracted from total nitrogen content determined via the Dumas method.

4.3.6 Cook Yield

All bacon slices prepared for the sensory analysis (described below in 4.3.7), were gently pat down with a paper towel and individually weighed before and after cooking on wire rack bacon tray (Nordic Ware, Minneapolis, Minnesota, USA) in a convection oven at 204°C for 15 minutes.

4.3.7 Sensory Evaluation

To examine the differences between the cuts’ sensory properties and oxidative stability, a trained panel performed a descriptive analysis of each cut across four different storage times at 4°C (0, 30, 60, and 90 days). The sensory properties examined were muscle fiber toughness, connective tissue amount, beef flavour intensity, oxidation aroma, and oxidation flavour. Panelists were recruited with recruitment emails that were circulated in the Food Science and Animal Biosciences departments at the University of Guelph. The only exclusion criteria used was the inability to consume pork (due to religious restrictions). Panelists participated in two training sessions which trained them to recognize and quantify the sensory properties being examined in this study, which
was followed by a screening session which confirmed the panelists’ ability to adequately identify and quantify the sensory properties of interest. Approval from the Research Ethics Board at the University of Guelph was received (REB# 18-05-007).

4.3.7.1 Training Sessions

Upon arrival panelists received a consent form along with a guiding document for the training session (Appendix A4). The consent form was reviewed with the panelists, along with the purpose of the study and panelist expectations. Panelists had each of the sensory properties being examined described to them and were provided with samples that exhibited different degrees of intensity for each sensory parameter. With the guidance of the session instructor, trainees were instructed to consume the provided samples and describe the intensity of the sensory property being evaluated by arranging the samples on a line scale. The samples used to train panelists on beef flavour, were three different dilutions of Campbell’s beef broth (1:3, 1:1, 1:0) and Campbell’s chicken broth for contrast and comparison, along with an 80% lean ground beef sample cooked in a convection oven at 204°C to a 72°C internal temperature. To train panelists to recognize and quantify oxidative aroma, panelists were instructed to smell fresh soybean oil that was microwaved for zero, two, or five minutes. Oxidative flavour was taught to trainees by instructing them to consume the soybean oil samples described above, along with a freshly prepared 80% lean ground beef sample and 80% lean ground beef sample that was frozen at -20°C for 18 months; both ground beef samples were cooked in a convection oven set to 204°C to a 72°C internal temperature. Connective tissue was identified using thick-cut pork bacon samples of different
connective tissue amounts, along with connective tissue isolated from striploin steaks. Muscle fiber toughness was evaluated using an eye of round steak cooked to 85°C, a striploin steak cooked to 56°C, and a beef tenderloin steak cooked to 56°C; all samples were cooked in a convection oven set to 204°C.

4.3.7.2 Panelist Screening Session

Following the training sessions, panelists were tested on the sensory attributes described during the training sessions. The purpose of this testing was to screen panelists for their ability to understand and quantify differences between the sensory criteria being evaluated in the descriptive panel as well as to verify their ability to follow instructions. The testing form involved a series of questions that tested the panelists’ ability to identify and quantify the relevant sensory attributes (Appendix A5). Panelists were permitted to participate in the descriptive panel if they were able to correctly answer at least 4 of the 5 questions.

4.3.7.3 Descriptive Analysis Panel Sessions

Descriptive analysis panel sessions were conducted to evaluate the effect of each cut across the four different storage times; with each storage by cut treatment combination being performed in three replicate; and with the same cut being used across each storage time. The samples were presented to the panelists across 14 sessions in a balanced incomplete block design. A total of 11 panelists were recruited. Each descriptive analysis session consisted of six to eight panelists that were served six treatments labelled with random three-digit codes, under red light, along with saltine
crackers and water for palate cleansing. Panelists were provided with a form to guide
the descriptive analysis that can be found in Appendix A6.

Oxidative aroma and oxidative flavour were both evaluated using a 4-point nominal
scale. Panelists were provided with an oxidized vegetable oil sample each session to
recalibrate their senses and ensure that only oxidized characteristics were being
detected. Beef flavour intensity, connective tissue amount, and muscle fiber toughness
was evaluated using unipolar magnitude estimation; ASTM E1697 – 05 (ASTM, 2008).
The reference standard used for the purposes of magnitude estimation for beef flavour
intensity was 80% lean ground beef; which was used a middle anchor in the reference
standards developed for quantifying beef flavour identity by Adhikari et al. (2011). In
order to make quantitative comparisons between beef bacon and pork bacon, thick cut
pork bacon (President’s Choice Old-Fashioned Style Bacon; approximately 4mm in
width) was used as the reference standard used for the magnitude estimation of
connective tissue amount and muscle fiber toughness.

4.3.8 Fatty Acid Analysis

The fatty acid composition of beef bacon was determined using gas chromatography
(GC). Fat that was collected and saved from the Soxhlet lipid extraction portion of the
proximate analysis outlined in 4.3.4, underwent the transmethylation procedures
specified by Christie & Han (2010). Fatty acid methyl esters (FAME) were analyzed
using capillary GC equipped with a BPX 70 column, 60 m X 0.22 mm internal diameter
with 0.25 mm film thickness (SGE Inc., Austin, TX, USA). An Agilent 6890-series Gas
Chromatograph (Agilent Technologies, Inc., Wilmington, DE, USA) with a 7683-series auto-sampler was used to house the column. The oven temperature was programmed to increase from 110°C to 230°C at a rate of 4°C/min and maintained at 230°C for 10 min. The injector and detector temperatures were 240°C and 280°C, respectively. Helium was used as the carrier gas at an average velocity of 25 cm/s. Peaks were identified via comparison to FAME standards (Sigma Aldrich, St. Louis, Missouri, USA). No FAME standard was available for docosapentanoic acid (DPA), C22:5, and its peak was inferred from the analysis of FAMEs prepared from seal oil (SeaDNA, Verdun, Qc, Canada); seal oil possesses the highest concentration of DPA in any natural lipid extract.

4.3.9 Statistical Analysis
Statistical analysis was performed on the processing characteristics using the PROC GLIMMIX function in SAS (v9.4) with the fixed effect of cut and with the random effect replication. Statistical analysis was performed on the image and proximate analyses using the PROC GLIMMIX function in SAS (v9.4) with the fixed effect of cut and section, and with the random effect of cut replication and section replication. Sensory data for beef flavour intensity, muscle fiber toughness, and connective tissue amount, were analyzed as repeated measures using PROC GLIMMIX of SAS (v9.4) with fixed effect of cut, storage day, and their interaction, and random effects of session, panelist, and replication. Sensory data for oxidative aroma and oxidative flavour were analyzed with PROC FREQ of SAS (v9.4) along with Fisher’s Exact Test function under PROC FREQ. Statistical analysis was performed on the cook yield using the PROC GLIMMIX function.
in SAS (v9.4) with the fixed effect of cut, storage day, and their interaction, and with the random effects of session and replication. Statistical analysis was performed on the fatty acid analyses using the PROC GLIMMIX function in SAS (v9.4) with the fixed effect of cut and section, and with the random effect of cut replication.

4.4 Results and Discussion

4.4.1 Processing Characteristics and Yield

The dimensions of the raw, trimmed cuts, can be found in Table 4.1. Processing weights can be found in Table 4.2. As expected, dimensions and processing weights differed significantly ($P < 0.01$). The outside flat was the widest ($P < 0.05$) cut, and its thickness was about twice as great ($P < 0.05$) as the next thickest cut; the brisket. The outside flat also weighed the greatest ($P < 0.05$) at each processing stage. In terms of length the short plate cuts were longest ($P < 0.05$). Although each dimension is critical to the form of the entire product, the length dictates the number of slices that may be obtained from each cut; however, the advantage of length may be offset by differences in uniformity examined later on in this study. The clod heart cuts and the flank, were the smallest cuts in terms of length and width ($P < 0.05$), as well as processing weights at all stages ($P < 0.05$). The overall dimensions and size have important implications on the surface area to volume ratio of each cut. Since smaller cuts have larger surface area relative to their volume, there is a greater surface area for which heat exchange and evaporation to occur through; which can impact both cooking time (as samples
were cooked to a specific internal temperature rather than under a set cooking time) as well as cook yield.

**Table 4.1 Comparison of the dimensions of each raw, trimmed cut.**

<table>
<thead>
<tr>
<th></th>
<th>Brisket</th>
<th>Clod-S&lt;sup&gt;6&lt;/sup&gt;</th>
<th>Clod-NS&lt;sup&gt;6&lt;/sup&gt;</th>
<th>Flank</th>
<th>Plate-SR&lt;sup&gt;6&lt;/sup&gt;</th>
<th>Plate-N&lt;sup&gt;6&lt;/sup&gt;</th>
<th>Outside Flat</th>
<th>SEM&lt;sup&gt;1&lt;/sup&gt;</th>
<th>P-value&lt;sup&gt;2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length&lt;sup&gt;3&lt;/sup&gt; (cm)</td>
<td>47.36&lt;sup&gt;b&lt;/sup&gt;</td>
<td>27.62&lt;sup&gt;c&lt;/sup&gt;</td>
<td>29.18&lt;sup&gt;c&lt;/sup&gt;</td>
<td>30.53&lt;sup&gt;c&lt;/sup&gt;</td>
<td>55.49&lt;sup&gt;a&lt;/sup&gt;</td>
<td>52.30&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>48.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.50</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Width&lt;sup&gt;4&lt;/sup&gt; (cm)</td>
<td>26.52&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18.80&lt;sup&gt;c,d,e&lt;/sup&gt;</td>
<td>18.06&lt;sup&gt;d,e&lt;/sup&gt;</td>
<td>15.41&lt;sup&gt;e&lt;/sup&gt;</td>
<td>21.67&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>19.46&lt;sup&gt;c,d&lt;/sup&gt;</td>
<td>24.94&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>0.88</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Thickness&lt;sup&gt;5&lt;/sup&gt; (cm)</td>
<td>4.78&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.55&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.82&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>2.12&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4.34&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>4.01&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>9.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.28</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

1 The maximum SEM (standard error of the mean).
2 The maximum P-value for means estimate of each cut.
3 As measured at the longest point along the cut.
4 As measured at the widest point along the cut.
5 Average of the thickness measured at eight different points as described in Figure 4.1.
6 Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.

**Table 4.2 Comparison of processing weights.**

<table>
<thead>
<tr>
<th></th>
<th>Brisket</th>
<th>Clod-S&lt;sup&gt;7&lt;/sup&gt;</th>
<th>Clod-NS&lt;sup&gt;7&lt;/sup&gt;</th>
<th>Flank</th>
<th>Plate-SR&lt;sup&gt;7&lt;/sup&gt;</th>
<th>Plate-N&lt;sup&gt;7&lt;/sup&gt;</th>
<th>Outside Flat</th>
<th>SEM&lt;sup&gt;1&lt;/sup&gt;</th>
<th>P-value&lt;sup&gt;2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Weight (kg)</td>
<td>4.65&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>1.51&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.50&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.87&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.46&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.03&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.85&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.29</td>
<td>0.004</td>
</tr>
<tr>
<td>Pump Weight&lt;sup&gt;3&lt;/sup&gt; (kg)</td>
<td>5.81&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>1.86&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.86&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.18&lt;sup&gt;e&lt;/sup&gt;</td>
<td>5.64&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.20&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.27&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.36</td>
<td>0.0026</td>
</tr>
<tr>
<td>Rest Weight&lt;sup&gt;4&lt;/sup&gt; (kg)</td>
<td>5.54&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>1.78&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.76&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.07&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.37&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.87&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.33</td>
<td>0.006</td>
</tr>
<tr>
<td>Pre-smoke Weight&lt;sup&gt;5&lt;/sup&gt; (kg)</td>
<td>5.52&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>1.81&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.79&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.09&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.37&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.89&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.36</td>
<td>0.004</td>
</tr>
<tr>
<td>Smoked Weight&lt;sup&gt;6&lt;/sup&gt; (kg)</td>
<td>4.98&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.51&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.52&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.88&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.71&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.38&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.26&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.32</td>
<td>0.009</td>
</tr>
</tbody>
</table>

1 The maximum SEM (standard error of the mean).
2 The maximum P-value for means estimate of each cut.
3 Measured immediately after injection.
4 Measured 30 minutes after injection.
5 Measured after an overnight rest; prior to smoking.
6 Measured immediately after smoking.
7 Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.

Table 4.2 shows the changes in weight at each processing step. Pump uptake, rested uptake, and smokehouse yield for each cut is shown in Table 4.3. No significant difference (P = 0.29) was observed between cuts for rested uptake.
Smokehouse yield was greater \((P < 0.05)\) for the brisket, outside flat, and short plate (both halves) compared with the clod heart (both halves) and flank. The lowest yielding cuts (clod heart cuts and the flank) weighed the least and were smallest when compared to the other cuts. This may be due to a larger surface area to volume ratio creating a larger interface through which water evaporation can occur.

**Table 4.3 Comparison of pump uptake and smokehouse yield.**

<table>
<thead>
<tr>
<th></th>
<th>Brisket</th>
<th>Clod-S(^6)</th>
<th>Clod-NS(^6)</th>
<th>Flank</th>
<th>Plate-SR(^6)</th>
<th>Plate-N(^6)</th>
<th>Outside Flat</th>
<th>SEM(^1)</th>
<th>P-value(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump uptake(^3) (%)</td>
<td>26.08(^b)</td>
<td>24.00(^b)</td>
<td>25.83(^b)</td>
<td>33.33(^a)</td>
<td>27.83(^a,b)</td>
<td>30.36(^a,b)</td>
<td>25.57(^b)</td>
<td>1.78 (&lt;0.0001)</td>
<td></td>
</tr>
<tr>
<td>Rested uptake(^4) (%)</td>
<td>20.10</td>
<td>19.10</td>
<td>19.74</td>
<td>21.29</td>
<td>22.10</td>
<td>22.21</td>
<td>21.93</td>
<td>1.45 (&lt;0.0001)</td>
<td></td>
</tr>
<tr>
<td>Smokehouse yield(^5) (%)</td>
<td>106.78(^a)</td>
<td>99.10(^c)</td>
<td>101.18(^c)</td>
<td>98.84(^c)</td>
<td>105.61(^a,b)</td>
<td>108.54(^a)</td>
<td>106.95(^a)</td>
<td>1.20 (&lt;0.0001)</td>
<td></td>
</tr>
</tbody>
</table>

\(^{1}\)The maximum SEM (standard error of the mean).
\(^{2}\)The maximum \(P\)-value for means estimate of each cut.
\(^{3}\)(Pump weight – green weight) \(÷\) green weight \(×100\%\)
\(^{4}\)(30-minute rest weight – green weight) \(÷\) green weight \(×100\%\)
\(^{5}\)Smoked weight \(÷\) green weight \(×100\%\)
\(^{6}\)Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.

\(a,b,c\) Least square means \((N=6)\) lacking a common superscript letter within a row are different \((P < 0.05)\).

**4.4.2 Image Analysis**

An image of a slice derived from each cut and section within each cut can be seen in Figure Appendix A8. Tables 4.4, 4.5, 4.6, 4.7, and 4.8 show the differences in lean percentage, length, width, total slice area, and length to width ratio; respectively. Figures 4.2, 4.3, 4.4, 4.5, and 4.6 show differences in lean percentage, length, width, length to width ratios, and total slice area respectively.
Table 4.4 Lean percentage (%) for slices sourced from different locations along each cut\(^{1,2}\).

<table>
<thead>
<tr>
<th></th>
<th>Brisket</th>
<th>Clod-S(^5)</th>
<th>Clod-NS(^5)</th>
<th>Flank</th>
<th>Plate-SR(^5)</th>
<th>Plate-N(^5)</th>
<th>Outside Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>69.55(^a)</td>
<td>92.66(^{a,b})</td>
<td>93.00(^{a,b})</td>
<td>86.28(^{c,d})</td>
<td>60.28(^l)</td>
<td>66.15(^e)</td>
<td>89.61(^{a,b,c})</td>
</tr>
<tr>
<td>Center</td>
<td>82.42(^d)</td>
<td>93.60(^a)</td>
<td>89.76(^{a,b,c})</td>
<td>86.87(^{b,c,d})</td>
<td>56.79(^l)</td>
<td>60.10(^l)</td>
<td>88.74(^{a,b,c})</td>
</tr>
<tr>
<td>Back</td>
<td>71.98(^e)</td>
<td>91.46(^{a,b,c})</td>
<td>91.52(^{a,b,c})</td>
<td>88.60(^{a,b,c,d})</td>
<td>59.32(^l)</td>
<td>57.19(^l)</td>
<td>92.05(^{a,b,c})</td>
</tr>
<tr>
<td>Average</td>
<td>74.65(^y)</td>
<td>92.57(^w)</td>
<td>91.41(^w)</td>
<td>87.25(^x)</td>
<td>58.79(^z)</td>
<td>61.15(^z)</td>
<td>90.13(^w,x)</td>
</tr>
<tr>
<td>(F)-value(^3)</td>
<td>30.25</td>
<td>0.74</td>
<td>1.66</td>
<td>0.94</td>
<td>2.45</td>
<td>2.45</td>
<td>1.91</td>
</tr>
<tr>
<td>(P)-value(^4)</td>
<td>&lt;0.0001</td>
<td>0.4748</td>
<td>0.1910</td>
<td>0.3892</td>
<td>0.0868</td>
<td>&lt;0.0001</td>
<td>0.1492</td>
</tr>
</tbody>
</table>

\(^{a,b,c,d,e,f}\) Least square means lacking a common superscript letter within the front, center, and back rows are different \((P < 0.05)\).

\(^{w,x,y,z}\) Least square means \((n=18)\) lacking a common superscript letter with the row are different \((P < 0.05)\).

\(^1\) Maximum SEM for any Least squares means estimate done on sections = 1.34%, and 0.88% on averages.

\(^2\) \(P\)-value <0.001 for all least squares means estimates.

\(^3\) \(F\)-statistic on the effect of section along the cut.

\(^4\) For average of \(F\)-test statistic.

\(^5\) Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.
Figure 4.2 Visual lean percentage of bacon slices (n=18) sourced from the back, center, and front sections of each cut; with standard error bars.

With the exception of the brisket, image analysis revealed a clear separation of the cuts into two categories: a lean beef bacon product that appears to be approximately 90% lean and fairly homogenous in lean distribution along the different sections of the cut; and a fatty beef bacon product with approximately 60% lean, with a more heterogeneous lean distribution between the front, center, and back sections along the cut.

Lean ratios in pork bacon vary drastically, with consumers indicating a strong preference for leaner cuts (McLean, Hanson, Jervis, & Drake, 2017; Saldaña et al.,...
2019). A previous study which surveyed consumers for lean percentage preference in pork bacon, provided consumers with images of packages of pork bacon ranging from 48% to 81%, with consumers providing greater approval ratings the leaner the bacon was (McLean et al., 2017). A previous study which conducted the same image analysis on pork bacon from barrows found that lean percentages were approximately 48-53% (Kyle et al., 2014). All beef bacon slices averaged well above this range, with the lowest lean percentage being 57%; which was sourced from the center section of the Plate-SR cut. For consumers looking for a whole-muscle bacon alternative, beef bacon, regardless of the cut from which it was manufactured from, would offer a high-protein, low-fat alternative.

Table 4.5 Length (cm) for slices sourced from different locations along each cut$^{1,2}$.

<table>
<thead>
<tr>
<th>Location</th>
<th>Brisket</th>
<th>Clod-S$^5$</th>
<th>Clod-NS$^5$</th>
<th>Flank</th>
<th>Plate-SR$^5$</th>
<th>Plate-N$^5$</th>
<th>Outside Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>17.26$^{c,d,e,f}$</td>
<td>14.92$^{a,h}$</td>
<td>11.16$^{x}$</td>
<td>11.93$^{i,k}$</td>
<td>16.87$^{e,f}$</td>
<td>16.86$^{e,f}$</td>
<td>15.42$^{g}$</td>
</tr>
<tr>
<td>Center</td>
<td>21.56$^{b}$</td>
<td>16.39$^{e,f,g}$</td>
<td>14.52$^{h,i,j}$</td>
<td>13.16$^{u,l,j}$</td>
<td>16.16$^{e,f,g}$</td>
<td>18.87$^{c,d}$</td>
<td>21.04$^{k}$</td>
</tr>
<tr>
<td>Back</td>
<td>17.74$^{c,d,e}$</td>
<td>15.44$^{a,g}$</td>
<td>12.75$^{j,k}$</td>
<td>13.10$^{u,i,l,j,k}$</td>
<td>17.15$^{e,f,j}$</td>
<td>19.13$^{c}$</td>
<td>25.97$^{k}$</td>
</tr>
<tr>
<td>Average</td>
<td>18.86$^{w}$</td>
<td>15.58$^{v}$</td>
<td>12.81$^{z}$</td>
<td>12.73$^{w}$</td>
<td>16.73$^{x}$</td>
<td>18.29$^{w}$</td>
<td>18.86$^{w}$</td>
</tr>
<tr>
<td>$F$-value$^3$</td>
<td>37.79</td>
<td>3.80</td>
<td>19.11</td>
<td>3.26</td>
<td>2.06</td>
<td>12.19</td>
<td>189.54</td>
</tr>
<tr>
<td>$P$-value$^4$</td>
<td>&lt;0.0001</td>
<td>0.0227</td>
<td>&lt;0.0001</td>
<td>0.0390</td>
<td>0.1287</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

$^{a,b,c,d,e,f,g,h,i,j,k}$ Least square means (n=18) lacking a common superscript letter within the front, center, and back rows are different ($P < 0.05$).

$^{1}$ Maximum SEM for any Least squares means estimate done on sections is 0.47 cm, and 0.35 cm on averages.

$^{2}$ $P$-value <0.0001 for all least squares means estimates.

$^{3}$ $F$-statistic on the effect of section along the cut.

$^{4}$ For average of $F$-test statistic on the average.

$^{5}$ Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.
Figure 4.3 Length of bacon slices \((n=18)\) sourced from the back, center, and front sections of each cut; with standard error bars.

Length varied significantly \((P < 0.05)\) between the back, center, and front ends for every cut except the Plate-SR cut. As the widest ends of each cut were designated as the “back” section, it is expected that their strips would be longer in comparison to the front.

Slices of beef bacon are generally lesser than that of pork bacon; which for pork bacon was measured through the same image analysis procedure to be 23-24 cm (Kyle et al., 2014).

The clod-NS and flank cuts both were less than 15 cm in length, the outside flat back section, and center sections of the brisket and outside flat were greater than 20 cm. The
rest of the cuts fell between 15 and 20 cm in length. It is worth mentioning that although the short plate cuts were formed by creating a half sourced from the deboned, Short-rib half, and the remaining navel half; the trimming can be tailored to create other lengths.

Table 4.6 Width(cm) for slices sourced from different locations along each cut.1,2

<table>
<thead>
<tr>
<th>Location</th>
<th>Brisket</th>
<th>Clod-S5</th>
<th>Clod-NS5</th>
<th>Flank</th>
<th>Plate-SR5</th>
<th>Plate-N5</th>
<th>Outside Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>7.06b,c,d</td>
<td>4.83j,i,k</td>
<td>4.18k</td>
<td>2.77l</td>
<td>7.05b,c,d</td>
<td>7.56b,c</td>
<td>7.75b</td>
</tr>
<tr>
<td>Center</td>
<td>6.08a,f,g,h</td>
<td>4.59j,k</td>
<td>5.48h,i,j</td>
<td>2.91l</td>
<td>6.44d,e,f</td>
<td>6.91c,d</td>
<td>9.79a</td>
</tr>
<tr>
<td>Back</td>
<td>6.29d,e,j,g</td>
<td>4.35k</td>
<td>5.25h,i,j</td>
<td>2.93l</td>
<td>6.68d,e</td>
<td>6.30e,g,d</td>
<td>5.74i,g,h</td>
</tr>
<tr>
<td>Average</td>
<td>6.47x</td>
<td>4.59y</td>
<td>4.97y</td>
<td>2.87z</td>
<td>6.72x,y</td>
<td>6.92w</td>
<td>7.76v</td>
</tr>
<tr>
<td>F-value3</td>
<td>9.26</td>
<td>2.01</td>
<td>16.82</td>
<td>0.32</td>
<td>3.88</td>
<td>16.28</td>
<td>143.57</td>
</tr>
<tr>
<td>P-value4</td>
<td>0.0001</td>
<td>0.1349</td>
<td>&lt;0.0001</td>
<td>0.7262</td>
<td>0.0212</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

1 Least square means (n=18) lacking a common superscript letter within the front, center, and back rows are different (P < 0.05).
2 Least square means lacking a common superscript letter with the row are different (P < 0.05).

F-statistic on the effect of section along the cut.

For average of F-test statistic on the average.

Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.

Maximum SEM for any Least squares means estimate done on sections is 0.20 cm, and 0.15 cm on averages.
Figure 4.4 Width of bacon slices (n=18) sourced from the back, center, and front sections of each cut; with standard error bars.

The average width of pork bacon as determined by prior image analysis was revealed to be approximately 3.9-4.1cm (Kyle et al., 2014). With the exception of the flank, beef bacon slices are generally wider than that of pork bacon. Exceptionally wide cuts such as the center and front section of the outside flat could be suited for horizontal slicing prior to processing.
Table 4.7 Length to width ratio for slices sourced from different locations along each cut\(^1,2\).

<table>
<thead>
<tr>
<th></th>
<th>Brisket</th>
<th>Clod-S(^5)</th>
<th>Clod-NS(^5)</th>
<th>Flank</th>
<th>Plate-SR(^5)</th>
<th>Plate-N(^5)</th>
<th>Outside Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>2.57(^{d,e,f,g,h})</td>
<td>3.15(^{c,b})</td>
<td>2.70(^{c,d,e,f,g})</td>
<td>4.32(^{a})</td>
<td>2.46(^{f,g,h})</td>
<td>2.26(^{f,g,h})</td>
<td>2.12(^{h})</td>
</tr>
<tr>
<td>Center</td>
<td>3.58(^{b})</td>
<td>3.56(^{b})</td>
<td>2.66(^{c,d,e,f,g,h})</td>
<td>4.63(^{a})</td>
<td>2.54(^{e,f,g,h})</td>
<td>2.77(^{c,d,e,f})</td>
<td>2.19(^{g,h})</td>
</tr>
<tr>
<td>Back</td>
<td>3.07(^{b,c,d,e})</td>
<td>3.57(^{b})</td>
<td>2.44(^{f,g,h})</td>
<td>4.60(^{a})</td>
<td>2.63(^{c,d,e,f,g,h})</td>
<td>3.08(^{b,c,d})</td>
<td>4.67(^{a})</td>
</tr>
<tr>
<td>Average</td>
<td>3.07(^{y})</td>
<td>3.43(^{x})</td>
<td>2.60(^{z})</td>
<td>4.52(^{w})</td>
<td>2.54(^{z})</td>
<td>2.70(^{z})</td>
<td>2.99(^{z})</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.0001</td>
<td>0.01</td>
<td>0.20</td>
<td>0.10</td>
<td>0.55</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

\(^{a,b,c,d,e,f,g,h}\) Least square means (n=18) lacking a common superscript letter within the front, center, and back rows are different \((P < 0.05)\).

\(^{w,x,y,z}\) Least square means lacking a common superscript letter with the row are different \((P < 0.05)\).

\(^{1}\) Maximum SEM for any Least squares means estimate done on sections is 3.50 cm\(^2\), and 2.53 cm\(^2\) on averages.

\(^{2}\) P-value <0.0001 for all least squares means estimates.

\(^{3}\) F-statistic on the effect of section along the cut.

\(^{4}\) For average of F-test statistic on the average.

\(^{5}\) Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.

---

**Figure 4.5** Length to width ratio of bacon slices (n=18) sourced from the back, center, and front sections of each cut; with standard error bars.
Length to width ratio varied significantly ($P < 0.05$) along the back, center, and front sections for each the brisket, clod-S, plate-N, and outside flat. With the exception of the flank and back section of the outside flat, all cuts had a length to width ratio that fell between 2:1 and 3:1. All the cuts had a lower length to width ratio than conventional pork bacon. The clod heart was halved in order to create a greater length to width ratio, yet also falls short of pork bacon. In comparison to pork bacon was previously measured to possess an average length to width ratio of 5.8; approximately twice that of most of the slices created in this study (Kyle et al., 2014). The length to width ratio may be a critical parameter to consumer acceptance; a higher length to width ratio for beef bacon may reduce product unfamiliarity. Many cuts utilized here would yield a L:W ratio more akin to pork bacon if they were horizontally halved prior to processing.

Table 4.8 Area (cm²) for slices sourced from different locations along each cut$^{1,2}$.

<table>
<thead>
<tr>
<th></th>
<th>Brisket</th>
<th>Clod-S$^5$</th>
<th>Clod-NS$^5$</th>
<th>Flank</th>
<th>Plate-SR$^5$</th>
<th>Plate-N$^5$</th>
<th>Outside Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>81.95$^{d,e,f}$</td>
<td>50.77$^{h,i}$</td>
<td>38.01$^{j}$</td>
<td>24.36$^{j}$</td>
<td>90.92$^{b,c,d}$</td>
<td>100.27$^{b,c}$</td>
<td>86.72$^{c,d,e,f}$</td>
</tr>
<tr>
<td>Center</td>
<td>98.18$^{b,c}$</td>
<td>55.62$^{h}$</td>
<td>59.30$^{h,i}$</td>
<td>27.88$^{g}$</td>
<td>72.88$^{k}$</td>
<td>97.24$^{b,c}$</td>
<td>154.01$^a$</td>
</tr>
<tr>
<td>Back</td>
<td>76.09$^{g,f}$</td>
<td>50.32$^{h,i}$</td>
<td>50.22$^{h,j}$</td>
<td>27.94$^{i}$</td>
<td>80.93$^{d,e,f}$</td>
<td>89.67$^{b,c,d,e}$</td>
<td>102.07$^b$</td>
</tr>
<tr>
<td>Average</td>
<td>85.41$^x$</td>
<td>52.24$^y$</td>
<td>49.18$^y$</td>
<td>26.73$^z$</td>
<td>81.58$^x$</td>
<td>95.73$^v$</td>
<td>114.26$^v$</td>
</tr>
<tr>
<td>$F$-value$^3$</td>
<td>14.91</td>
<td>0.98</td>
<td>13.00</td>
<td>0.48</td>
<td>10.85</td>
<td>3.96</td>
<td>141.63</td>
</tr>
<tr>
<td>$P$-value</td>
<td>&lt;0.0001</td>
<td>0.3751</td>
<td>&lt;0.0001</td>
<td>0.6200</td>
<td>&lt;0.0001</td>
<td>0.0195</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

$^a,b,c,d,e,f,g,h,i,j,k,l$ Least square means (n=18) lacking a common superscript letter within the front, center, and back rows are different ($P < 0.05$).

$^{v,w,x,y,z}$ Least square means lacking a common superscript letter with the row are different ($P < 0.05$).

$^1$ Maximum SEM for any Least squares means estimate done on sections is 3.50 cm², and 2.53 cm² on averages.

$^2$ $P$-value <0.0001 for all least squares means estimates.

$^3$ $F$-statistic on the effect of section along the cut.

$^4$ For average of $F$-test statistic on the average.

$^5$ Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.
Slice area varied significantly ($P < 0.05$) along the back, center, and front sections for every cut except for the clod-S. Slice area was generally lower than that of pork bacon which was previously found to be approximately 100 cm$^2$ (Kyle et al., 2014).

The visual properties of the raw, packaged beef bacon product is likely to heavily impact consumers’ initial evaluation of the product and the product’s functionality in recipes. The large area and dimensions of the outside flat make it conducive to the creation of a lean, whole-muscle sandwich meat.
The visual properties of packaged, unprepared beef bacon strips, such as the percentage of lean muscle tissue, size, and dimensions, are the first properties of beef bacon that consumers will observe when encountering beef bacon in a retail setting. These properties can have a critical impact on consumers' first impressions of the product, as they can be used to infer the product's nutritional composition, flavour, and cooking functionality; which can result in consumer acceptance or denial before cooking and consuming the product.

4.4.3 Consumer Survey

The visual appearance of the uncooked beef bacon will be the first impression of the beef bacon product that consumers observe in a retail setting. Their initial visual impressions are likely to dramatically affect first time consumer purchasing decisions. Consumers may use the visual properties of beef bacon's fat content, fat distribution, texture, and shape, to infer their eating experience as well as the nutrition of the product.

A total of 83 responses were collected from the survey, a full report can be found in Appendix A9. 77 of 83 participants were regular bacon consumers (consumed at least once a month). Religious restrictions were the most commonly cited reason for not consuming bacon. 23% of participants reported consuming bacon made from beef in the past. The plate-N and brisket were ranked highest for ranking of what image best represents beef bacon identity; plate-N (ranked 1st by 40% participants, 2nd: 25%), brisket (1st: 25%, 2nd: 35%). Fat distribution was the primary determinant for ranking...
beef bacon identity, followed by amount of fat, and shape. For palatability, the plate-N and brisket were once again the highest ranking; plate-N (1st: 41%, 2nd: 24%), brisket (1st: 24%, 2nd: 34%). Distribution and amount of fat was again the primary criteria used evaluating palatability, however texture was more important than shape; colour was also more impactful. A similar cut ranking was observed for purchase likelihood. Flavour, and then texture were the primary determinants for the determining purchase likelihood. 57% of respondents indicated that they would be more likely to purchase a beef bacon product with less fat and more protein.

4.4.4 Proximate Analysis

The macronutrient content of beef bacon is likely to affect consumer acceptance of the product and will have to be identified for nutritional labeling and marketing purposes. In addition to analyzing the nutritional differences between different cuts, the variation observed between replicates of each cut was also determined, as well as the variation within the back, center, and front sections of each cut.

Table 4.9 Moisture percentage (%) for slices sourced from different locations along each cut1,2.

<table>
<thead>
<tr>
<th></th>
<th>Brisket</th>
<th>Clod-S5</th>
<th>Clod-NS5</th>
<th>Flank</th>
<th>Plate-SR5</th>
<th>Plate-N5</th>
<th>Outside Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>58.53a</td>
<td>67.70ab</td>
<td>69.50a</td>
<td>63.51af</td>
<td>53.65h</td>
<td>53.40h</td>
<td>65.29cde</td>
</tr>
<tr>
<td>Center</td>
<td>65.31bc</td>
<td>68.80a</td>
<td>69.82a</td>
<td>64.99de</td>
<td>50.30h</td>
<td>54.62h</td>
<td>66.28bcd</td>
</tr>
<tr>
<td>Back</td>
<td>61.59i</td>
<td>67.56abc</td>
<td>69.11a</td>
<td>64.57de</td>
<td>53.22h</td>
<td>58.21g</td>
<td>67.53abc</td>
</tr>
<tr>
<td>Average</td>
<td>61.81x</td>
<td>68.02v</td>
<td>69.48u</td>
<td>64.36x</td>
<td>52.39z</td>
<td>55.41y</td>
<td>66.37w</td>
</tr>
<tr>
<td>F-value3</td>
<td>54.62</td>
<td>2.24</td>
<td>0.59</td>
<td>2.77</td>
<td>18.68</td>
<td>35.00</td>
<td>6.10</td>
</tr>
<tr>
<td>P-value4</td>
<td>&lt;0.0001</td>
<td>0.1070</td>
<td>0.5521</td>
<td>0.0631</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.0024</td>
</tr>
</tbody>
</table>

1 Maximum SEM for any Least squares means estimate done on sections = 0.67%, and 0.55% on averages.
2 P-value <0.0001 for all least squares means estimates.
3 F-statistic on the effect of section along the cut.
4 For average of F-test statistic.
Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.

Figure 4.7 Moisture content of bacon slices (n=18) sourced from the back, center, and front sections of each cut; with standard error bars.

Moisture content in pork bacon is approximately 48-52% (Kyle et al., 2014). Only the center section of the plate-SR cut fell into this range, with all other cuts exceeding it. This is likely due to the greater proportion of lean which retains moisture. The brisket and short plate cuts all showed a significant degree of variation for the back, center, and front sections of each cut for moisture content.
Table 4.10 Fat percentage (%) for slices sourced from different locations along each cut\(^{1,2}\).

<table>
<thead>
<tr>
<th></th>
<th>Brisket</th>
<th>Clod-S(^5)</th>
<th>Clod-NS(^5)</th>
<th>Flank</th>
<th>Plate-SR(^5)</th>
<th>Plate-N(^6)</th>
<th>Outside Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>21.61(^c)</td>
<td>5.27(^{a,h,i})</td>
<td>3.51(^l)</td>
<td>9.71(^{e,f})</td>
<td>26.71(^b)</td>
<td>22.59(^b)</td>
<td>9.77(^{a,f})</td>
</tr>
<tr>
<td>Center</td>
<td>11.58(^a)</td>
<td>4.62(^{h,j})</td>
<td>3.63(^i)</td>
<td>7.69(^{g,h})</td>
<td>30.66(^a)</td>
<td>26.97(^b)</td>
<td>9.55(^{a,f})</td>
</tr>
<tr>
<td>Back</td>
<td>15.89(^d)</td>
<td>5.66(^{g,h,i})</td>
<td>4.01(^l)</td>
<td>8.34(^{j,g})</td>
<td>27.27(^b)</td>
<td>28.40(^{a,b})</td>
<td>7.29(^{g,h})</td>
</tr>
<tr>
<td>Average</td>
<td>16.36(^c)</td>
<td>3.71(^{k})</td>
<td>5.18(^{k})</td>
<td>8.58(^{r})</td>
<td>28.21(^{w})</td>
<td>25.99(^{r})</td>
<td>8.87(^{y})</td>
</tr>
</tbody>
</table>

F-value\(^3\) | 64.99 | 0.72 | 0.17 | 2.80 | 13.88 | 27.91 | 4.93 |

P-value\(^4\) | <0.0001 | 0.4889 | 0.8400 | 0.0613 | <0.0001 | <0.0001 | 0.0075 |

\(^{a,b,c,d,e,f,g,h,i}\) Least square means (n=18) lacking a common superscript letter within the front, center, and back rows are different (P < 0.05).

\(^{w,x,y,z}\) Least square means lacking a common superscript letter with the row are different (P < 0.05).

\(^{1}\) Maximum SEM for any Least squares means estimate done on sections = 0.89%, and 0.73% on averages.

\(^{2}\) P-value <0.0001 for all least squares means estimates.

\(^{3}\) F-statistic on the effect of section along the cut.

\(^{4}\) For average of F-test statistic.

Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.

**Figure 4.8** Fat content of bacon slices (n=18) sourced from the back, center, and front sections of each cut; with standard error bars.
Fat content in pork bacon was previously found to be 31-37\% (Kyle et al., 2014). Only the center cut of the plate-SR cut fell into this range, with all other sections of each cut possessing a much lower fat content. Thus, in agreement with the image analysis performed above, beef bacon is consistently lower in fat than pork bacon, regardless of cut used. Cuts with lower lean percentages as judged by image analysis, also possessed a greater degree of variation in fat content across the entire cut; brisket and short plate cuts. In the brisket fat content differed by as much as 10\% across the cut, 6\% across the plate-N, and 4\% across the plate-SR; the brisket was the only cut to exhibit significant differences between all three sections ($P < 0.05$).

### Table 4.11 Protein percentage (%) for slices sourced from different locations along each cut$^{1,2}$.

<table>
<thead>
<tr>
<th>Location</th>
<th>Brisket</th>
<th>Clod-S$^5$</th>
<th>Clod-NS$^5$</th>
<th>Flank</th>
<th>Plate-SR$^5$</th>
<th>Plate-N$^5$</th>
<th>Outside Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>15.69$^a$</td>
<td>21.38$^{a,b}$</td>
<td>21.26$^{a,b}$</td>
<td>20.74$^{a,b,c,d}$</td>
<td>15.57$^g$</td>
<td>15.41$^g$</td>
<td>20.23$^{b,c,d,e}$</td>
</tr>
<tr>
<td>Center</td>
<td>19.19$^{f,e}$</td>
<td>21.42$^{a}$</td>
<td>21.50$^{a}$</td>
<td>21.49$^a$</td>
<td>15.05$^{g,h}$</td>
<td>14.56$^{g,h}$</td>
<td>20.03$^{c,d,e}$</td>
</tr>
<tr>
<td>Back</td>
<td>18.47$^l$</td>
<td>21.56$^a$</td>
<td>21.60$^a$</td>
<td>21.14$^{a,b,c}$</td>
<td>15.34$^{g,h}$</td>
<td>14.28$^h$</td>
<td>19.76$^{d,e}$</td>
</tr>
<tr>
<td>Average</td>
<td>17.78$^x$</td>
<td>21.46$^{v}$</td>
<td>21.45$^{v}$</td>
<td>21.12$^{v}$</td>
<td>15.32$^v$</td>
<td>14.75$^v$</td>
<td>20.01$^w$</td>
</tr>
<tr>
<td>$F$-value$^3$</td>
<td>61.45</td>
<td>0.16</td>
<td>0.55</td>
<td>2.53</td>
<td>1.43</td>
<td>7.51</td>
<td>1.01</td>
</tr>
<tr>
<td>$P$-value$^4$</td>
<td>&lt;0.0001</td>
<td>0.8480</td>
<td>0.5765</td>
<td>0.0806</td>
<td>0.2402</td>
<td>0.0006</td>
<td>0.3638</td>
</tr>
</tbody>
</table>

$^a,b,c,d,e,f,g,h$ Least square means (n=18) lacking a common superscript letter within the front, center, and back rows are different ($P < 0.05$).

$^{1,2}$ Least square means lacking a common superscript letter with the row are different ($P < 0.05$).

$^1$ Maximum SEM for any Least squares means estimate done on sections = 0.28\%, and 0.20\% on averages.

$^2$ $P$-value <0.0001 for all least squares means estimates.

$^3$ $F$-statistic on the effect of section along the cut.

$^4$ For average of $F$-test statistic.

$^5$ Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.
Figure 4.9  Protein content of bacon slices (n=18) sourced from the back, center, and front sections of each cut; with standard error bars.

Protein content was greater than 20% for the clod heart cuts, flank, and outside flat; which coincided with the higher lean percentages that were evaluated by image analysis. The short plate cuts, which were the lowest protein slices, still yielded a protein content of 15%.
Table 4.12 Ash percentage (%) for slices sourced from different locations along each cut\(^1,2\).

<table>
<thead>
<tr>
<th></th>
<th>Brisket</th>
<th>Clod-S(^5)</th>
<th>Clod-NS(^5)</th>
<th>Flank</th>
<th>Plate-SR(^5)</th>
<th>Plate-N(^5)</th>
<th>Outside Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>2.92(^a),(^g),(^h)</td>
<td>4.05(^a),(^b),(^c),(^d)</td>
<td>4.03(^b),(^c),(^d)</td>
<td>4.49(^a)</td>
<td>2.82(^g),(^h)</td>
<td>2.50(^h)</td>
<td>3.28(^e),(^f)</td>
</tr>
<tr>
<td>Center</td>
<td>2.77(^g),(^h)</td>
<td>3.62(^d),(^e)</td>
<td>3.63(^d),(^e)</td>
<td>4.30(^a),(^b)</td>
<td>2.78(^g),(^h)</td>
<td>2.70(^g),(^h)</td>
<td>2.98(^g)</td>
</tr>
<tr>
<td>Back</td>
<td>2.69(^g),(^h)</td>
<td>3.85(^d)</td>
<td>3.83(^d)</td>
<td>4.47(^a),(^b)</td>
<td>2.87(^g),(^h)</td>
<td>2.80(^g),(^h)</td>
<td>3.85(^c),(^d)</td>
</tr>
<tr>
<td>Average</td>
<td>2.80(^x)</td>
<td>3.84(^x)</td>
<td>3.83(^x)</td>
<td>4.42(^x)</td>
<td>2.82(^x)</td>
<td>2.67(^z)</td>
<td>3.37(^y)</td>
</tr>
<tr>
<td>F-value(^3)</td>
<td>1.74</td>
<td>6.01</td>
<td>5.09</td>
<td>1.42</td>
<td>0.31</td>
<td>3.37</td>
<td>25.02</td>
</tr>
<tr>
<td>P-value(^4)</td>
<td>0.1763</td>
<td>0.0026</td>
<td>0.0064</td>
<td>0.2413</td>
<td>0.7348</td>
<td>0.0351</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

\(^a,b,c,d,e,f,g,h\) Least square means (n=18) lacking a common superscript letter within the front, center, and back rows are different (\(P < 0.05\)).

\(^w,x,y,z\) Least square means lacking a common superscript letter with the row are different (\(P < 0.05\)).

\(^1\) Maximum SEM for any Least squares means estimate done on sections = 0.18%, and 0.17% on averages.

\(^2\) P-value <0.0001 for all least squares means estimates.

\(^3\) F-statistic on the effect of section along the cut.

\(^4\) For average of F-test statistic.

\(^5\) Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.

Figure 4.10 Ash content of bacon slices (n=18) sourced from the back, center, and front sections of each cut; with standard error bars.
Ash content was generally lower for cuts with greater fat contents as much of the inorganic material in the curing solution would have been taken up in the lean portion of the bacon.

Figure 4.11 Proximate composition of bacon slices (n=18) sourced from the back, center, and front sections of each cut.
Table 4.13 P-values for F-test determining the significance of slice location (back, center, front) along the cut as a source of variation for the criteria measured in proximate analysis and image analysis.

<table>
<thead>
<tr>
<th></th>
<th>Brisket</th>
<th>Clod-S&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Clod-NS&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Flank</th>
<th>Plate-SR&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Plate-N&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Outside Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Proximate Analysis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture</td>
<td>&lt;0.0001</td>
<td>0.1070</td>
<td>0.5521</td>
<td>0.0631</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.0024</td>
</tr>
<tr>
<td>Fat</td>
<td>&lt;0.0001</td>
<td>0.4889</td>
<td>0.8400</td>
<td>0.0613</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.0075</td>
</tr>
<tr>
<td>Protein</td>
<td>&lt;0.0001</td>
<td>0.8480</td>
<td>0.5765</td>
<td>0.0806</td>
<td>0.2402</td>
<td>0.0006</td>
<td>0.3638</td>
</tr>
<tr>
<td>Ash</td>
<td>0.1763</td>
<td>0.0026</td>
<td>0.0064</td>
<td>0.2413</td>
<td>0.7348</td>
<td>0.0351</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Image Analysis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lean Percentage</td>
<td>&lt;0.0001</td>
<td>0.4748</td>
<td>0.1910</td>
<td>0.3892</td>
<td>0.0868</td>
<td>&lt;0.0001</td>
<td>0.1492</td>
</tr>
<tr>
<td>Area</td>
<td>&lt;0.0001</td>
<td>0.3751</td>
<td>&lt;0.0001</td>
<td>0.6200</td>
<td>&lt;0.0001</td>
<td>0.0195</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Length</td>
<td>&lt;0.0001</td>
<td>0.0227</td>
<td>&lt;0.0001</td>
<td>0.0390</td>
<td>0.1287</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Width</td>
<td>0.0001</td>
<td>0.1349</td>
<td>&lt;0.0001</td>
<td>0.7262</td>
<td>0.0212</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Length to Width Ratio</td>
<td>&lt;0.0001</td>
<td>0.01</td>
<td>0.20</td>
<td>0.10</td>
<td>0.55</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

<sup>1</sup> Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.

Section along the cut was a source of variation for every component measured in the plate-N cut, and for every component except ash, for the brisket. In terms of proximate composition, the clod heart cuts and flank showed the least variability along the cut.

Overall, the flank showed the least variability along the cut in terms of both proximate and visual analysis; which only varied in length. Aside from the flank, all other cuts varied significantly along the cut for two or more visual criteria.

### 4.4.5 Cook Yield

Table 4.14 Slice cook yield after cooking in a convection oven at 204°C for 15 minutes.

<table>
<thead>
<tr>
<th></th>
<th>Brisket</th>
<th>Clod-S&lt;sup&gt;4&lt;/sup&gt;</th>
<th>Clod-NS&lt;sup&gt;4&lt;/sup&gt;</th>
<th>Flank</th>
<th>Plate-SR&lt;sup&gt;4&lt;/sup&gt;</th>
<th>Plate-N&lt;sup&gt;4&lt;/sup&gt;</th>
<th>Outside Flat</th>
<th>SEM&lt;sup&gt;1&lt;/sup&gt;</th>
<th>P-value&lt;sup&gt;2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slice Cook Yield (%)</td>
<td>44.45&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>48.44&lt;sup&gt;b&lt;/sup&gt;</td>
<td>46.73&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>46.46&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>39.56&lt;sup&gt;d&lt;/sup&gt;</td>
<td>42.24&lt;sup&gt;c,d&lt;/sup&gt;</td>
<td>54.76&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.14</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

<sup>1</sup> The maximum SEM (standard error of the mean).
<sup>2</sup> The maximum P-value for means estimate of each cut.
<sup>3</sup> Pre-cook weight ÷ post-cook weight ×100%
<sup>4</sup> Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.

<sup>a,b,c</sup> Least square means (n=18) lacking a common superscript letter within a row are different (P < 0.05).
Slice cook yield was lowest for higher fat slices such as the short plate cuts, and highest for the outside flat, which was a lean cut and the largest in terms of area.

### 4.4.6 Trained Panel Descriptive Analysis

#### Table 4.15 Comparison of the effect of cut on sensory attributes.

<table>
<thead>
<tr>
<th>Cut</th>
<th>Brisket</th>
<th>Clod-S&lt;sup&gt;5&lt;/sup&gt;</th>
<th>Clod-NS&lt;sup&gt;5&lt;/sup&gt;</th>
<th>Flank</th>
<th>Plate-SR&lt;sup&gt;5&lt;/sup&gt;</th>
<th>Plate-N&lt;sup&gt;5&lt;/sup&gt;</th>
<th>Outside Flat</th>
<th>SEM&lt;sup&gt;1&lt;/sup&gt;</th>
<th>P-value&lt;sup&gt;2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef Flavour Intensity&lt;sup&gt;3&lt;/sup&gt;</td>
<td>1.94&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>2.11&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>1.67&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.10&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>2.19&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>2.04&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>0.15</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Muscle Fiber Toughness&lt;sup&gt;4&lt;/sup&gt;</td>
<td>2.30&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>2.33&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>2.40&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>2.51&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.36&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>1.35&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.93&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>0.16</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Connective Tissue Amount&lt;sup&gt;4&lt;/sup&gt;</td>
<td>0.60&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.71&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>0.64&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.51&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.93&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>1.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.89&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>0.08</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

<sup>1</sup>The highest SEM (standard error of the mean).  
<sup>2</sup>The highest P-value for the least squares means estimate of each cut.  
<sup>3</sup>Magnitude estimation score relative to a medium ground beef sample anchored at 1  
<sup>4</sup>Magnitude estimation score relative to a thick-cut pork bacon sample anchored at 1  
<sup>5</sup>Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.  
<sup>a,b,c</sup>Least square means (n=6) lacking a common superscript letter within a row are different (P < 0.05).  

As whole muscle products are generally more flavorful than ground products, it was unsurprising to see that beef flavour intensity was generally twice as great in comparison to the reference ground beef sample with the exception of the clod-NS cut. Beef flavor intensity only significantly differed between the most and least flavorful cuts; flank and clod-NS respectively. Thus, leaner cuts do not sacrifice flavor intensity with lower fat contents. Flavor development in leaner cuts may in part be due to the fat that is still present in the marbling of the leaner cuts.

Muscle fibre toughness was generally 2-2.5 times as tough as the reference thick-cut pork bacon sample, with the exception of the outside flat and the plate-N cuts. Connective tissue amount was lower than the reference pork thick-cut pork bacon
sample for all cuts except for the plate-N cut; which had an equal amount. Thus, in terms of texture, the plate-N cut is most similar to thick-cut pork bacon. All other cuts may be advantageous towards thick-cut pork bacon in terms of overall texture as the elastic and gummy texture of the connective tissue is often seen as the least desirable property of pork bacon (McLean et al., 2017; Saldaña et al., 2019). A future consumer evaluation would be needed to determine if the increased toughness of the muscle fiber component is offset by the lower connective tissue amount; as well the lower fat content.

Table 4.16 Comparison of the effect of storage time at 4°C on sensory attributes.

<table>
<thead>
<tr>
<th>Days at 4°C</th>
<th>0</th>
<th>30</th>
<th>60</th>
<th>90</th>
<th>SEM</th>
<th>P-value²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef Flavour Intensity³</td>
<td>2.05</td>
<td>2.06</td>
<td>1.86</td>
<td>2.18</td>
<td>0.13</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Muscle Fiber Toughness⁴</td>
<td>2.39ᵃ</td>
<td>2.27ᵃᵇ</td>
<td>2.05ᵃᵇ</td>
<td>1.97ᵇ</td>
<td>0.14</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Connective Tissue Amount⁴</td>
<td>0.71</td>
<td>0.73</td>
<td>0.87</td>
<td>0.71</td>
<td>0.07</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

¹ The highest SEM (standard error of the mean).
² The highest P-value for the least squares means estimate of each cut.
³ Magnitude estimation score relative to a medium ground beef sample anchored at 1
⁴ Magnitude estimation score relative to a thick-cut pork bacon sample anchored at 1
ᵃᵇ Least square means (n=18) lacking a common superscript letter within a row are different (P < 0.05).

A wet-aging effect is seen during storage, as muscle fiber toughness decreased with each successive increase in storage, whereas beef flavour intensity and connective tissue showed no significant difference during storage.
Table 4.17 Frequency table displaying the percent distribution of oxidation aroma scores for each cut and Fisher’s exact test p<0.0001.

<table>
<thead>
<tr>
<th>Oxidation Aroma Score</th>
<th>1 – None</th>
<th>2 – Trace</th>
<th>3 – Some; Acceptable</th>
<th>4 - Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brisket</td>
<td>48.78%</td>
<td>36.59%</td>
<td>12.20%</td>
<td>2.44%</td>
</tr>
<tr>
<td>Clod-S(^1)</td>
<td>54.43%</td>
<td>30.38%</td>
<td>13.92%</td>
<td>1.27%</td>
</tr>
<tr>
<td>Clod-NS(^1)</td>
<td>42.11%</td>
<td>36.84%</td>
<td>17.11%</td>
<td>3.95%</td>
</tr>
<tr>
<td>Flank</td>
<td>49.38%</td>
<td>32.10%</td>
<td>14.81%</td>
<td>3.70%</td>
</tr>
<tr>
<td>Plate-N(^1)</td>
<td>48.10%</td>
<td>31.65%</td>
<td>13.92%</td>
<td>6.33%</td>
</tr>
<tr>
<td>Plate-SR(^1)</td>
<td>48.78%</td>
<td>37.70%</td>
<td>12.20%</td>
<td>1.22%</td>
</tr>
<tr>
<td>Outside Flat</td>
<td>50.63%</td>
<td>30.38%</td>
<td>17.72%</td>
<td>1.27%</td>
</tr>
</tbody>
</table>

\(^1\) Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.

Table 4.18 Fisher’s exact test P-values for each cut on the effect of storage time at 4°C on oxidation aroma for each cut.

<table>
<thead>
<tr>
<th></th>
<th>Brisket</th>
<th>Clod-S(^2)</th>
<th>Clod-NS(^2)</th>
<th>Flank</th>
<th>Plate-SR(^2)</th>
<th>Plate-N(^2)</th>
<th>Outside Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisher’s Exact Test P-value(^1)</td>
<td>0.1359</td>
<td>0.5832</td>
<td>0.8465</td>
<td>0.0343</td>
<td>0.3040</td>
<td>0.6747</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) P<0.05 indicates a significant effect of storage time on oxidation aroma.

\(^2\) Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.

Although the plate-SR cut revealed a significant effect of storage time on oxidation aroma, the frequency table indicates that this was due to a different distribution in scores that were still acceptable; not due to an increase in unacceptability scores.

Table 4.19 Frequency table displaying the percent distribution of oxidation flavour scores for each cut; Fisher’s exact test p<0.0001.

<table>
<thead>
<tr>
<th>Oxidation Aroma Score</th>
<th>1 – None</th>
<th>2 – Trace</th>
<th>3 – Some; Acceptable</th>
<th>4 - Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brisket</td>
<td>58.54%</td>
<td>26.83%</td>
<td>14.63%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Clod-S(^1)</td>
<td>37.97%</td>
<td>35.44%</td>
<td>25.32%</td>
<td>1.27%</td>
</tr>
<tr>
<td>Clod-NS(^1)</td>
<td>39.47%</td>
<td>28.95%</td>
<td>25.00%</td>
<td>6.58%</td>
</tr>
<tr>
<td>Flank</td>
<td>43.21%</td>
<td>35.80%</td>
<td>14.81%</td>
<td>6.17%</td>
</tr>
<tr>
<td>Plate-N(^1)</td>
<td>31.65%</td>
<td>34.18%</td>
<td>21.52%</td>
<td>12.66%</td>
</tr>
<tr>
<td>Plate-SR(^1)</td>
<td>53.66%</td>
<td>32.93%</td>
<td>7.32%</td>
<td>6.10%</td>
</tr>
<tr>
<td>Outside Flat</td>
<td>37.97%</td>
<td>39.24%</td>
<td>17.72%</td>
<td>5.06%</td>
</tr>
</tbody>
</table>

\(^1\) Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.
Table 4.20 Fisher’s exact test P-values for each cut on the effect of storage time at 4°C on oxidation flavour for each cut.

<table>
<thead>
<tr>
<th></th>
<th>Brisket</th>
<th>Clod-S²</th>
<th>Clod-NS²</th>
<th>Flank</th>
<th>Plate-SR²</th>
<th>Plate-N²</th>
<th>Outside Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisher’s Exact Test P-value¹</td>
<td>0.4475</td>
<td>0.0221</td>
<td>0.0624</td>
<td>0.8502</td>
<td>0.4037</td>
<td>0.5999</td>
<td>0.2165</td>
</tr>
</tbody>
</table>

¹ P<0.05 indicates a significant effect of storage time on oxidation flavour.
² Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.

Unlike with oxidative aroma, the plate-SR did not show a significant effect of storage time on oxidative flavor. The clod-S cut was the only cut to see an effect of storage time on oxidative flavor, however this again was due to the distribution among acceptable scores, as the unacceptability scores were still very low. The results of the sensory evaluation indicate that beef bacon is stable under refrigeration up to at least 90 days.

4.4.7 Fatty Acid Analysis

Tables 4.21, 4.22, and 4.23 show, respectively, the saturated (SFA), monounsaturated (MUFA), and polyunsaturated (PUFA) fatty acid distribution between each of the cuts, as well as between their front, center, and back sections. As the carcasses from which the cuts were derived from were not controlled for, a high standard error of the mean for the least squares means estimate was expected. Despite this, cut was still a source of significant variation (P < 0.001) for SFA, MUFA, and PUFA content; and Tukey-Kramer’s test still identified significant differences (P < 0.05) between cuts for every fatty acid.

The SFA content is of critical importance for the storage potential of beef bacon. As the sensory oxidation tests only evaluated the center portions of each cut, ensuring that
SFA content is equal or greater across the front and back sections would strongly suggest that slices derived from all along the cut would be just as stable. Despite the Tukey-Kramer’s least squares means comparison between the brisket sections not showing statistical significance between the sections ($P > 0.05$) the center portion of the brisket still trended towards having less SFA then its front and back sections. This trend would indicate that the resistance to oxidation conferred by the saturated fat content, is present across the entire brisket. As section was not a significant source of variation for SFA content for all other cuts ($P > 0.05$), this would indicate that beef bacon slices would exhibit similar oxidative stability regardless of the location along the cut from which they may be sourced from. Overall, SFA content was much greater than that of pork bacon, irrespective of cut and section; which has been reported as being 32-24% (Kyle et al., 2014).

### Table 4.21 Saturated fatty acid percentage (%) for slices sourced from different locations along each cut$^1$.$^2$.

<table>
<thead>
<tr>
<th></th>
<th>Brisket</th>
<th>Clod-S$^5$</th>
<th>Clod-NS$^5$</th>
<th>Flank</th>
<th>Plate-SR$^5$</th>
<th>Plate-N$^5$</th>
<th>Outside Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>52.12$^{a,b,c}$</td>
<td>45.30$^{c,d,e,f}$</td>
<td>44.83$^{c,d,e,f}$</td>
<td>50.98$^{a,b,c,d}$</td>
<td>53.80$^{a,b}$</td>
<td>45.69$^{c,d,e,f}$</td>
<td>42.30$^f$</td>
</tr>
<tr>
<td>Center</td>
<td>44.83$^{c,d,e,f}$</td>
<td>45.77$^{c,d,e,f}$</td>
<td>45.00$^{c,d,e,f}$</td>
<td>49.73$^{a,b,c,d,e}$</td>
<td>54.21$^a$</td>
<td>48.92$^{a,b,c,d,e}$</td>
<td>43.30$^{e,f}$</td>
</tr>
<tr>
<td>Back</td>
<td>48.20$^{a,b,c,d,e,f}$</td>
<td>45.52$^{c,d,e,f}$</td>
<td>46.32$^{c,d,e,f}$</td>
<td>48.90$^{a,b,c,d,e,f}$</td>
<td>53.95$^{a,b}$</td>
<td>46.35$^{b,c,d,e,f}$</td>
<td>40.87$^f$</td>
</tr>
<tr>
<td>Average</td>
<td>48.39$^{x,y}$</td>
<td>45.53$^{y,z}$</td>
<td>45.38$^{y,z}$</td>
<td>49.87$^x$</td>
<td>53.99$^w$</td>
<td>46.98$^{y-z}$</td>
<td>42.16$^z$</td>
</tr>
<tr>
<td>$F$-value$^3$</td>
<td>6.17</td>
<td>0.02</td>
<td>0.26</td>
<td>0.51</td>
<td>0.02</td>
<td>1.43</td>
<td>0.54</td>
</tr>
<tr>
<td>$P$-value$^4$</td>
<td>0.0025</td>
<td>0.9765</td>
<td>0.7696</td>
<td>0.6021</td>
<td>0.9773</td>
<td>0.2422</td>
<td>0.5829</td>
</tr>
</tbody>
</table>

$^{a,b,c,d,e,f}$ Least square means (n=6) lacking a common superscript letter within the front, center, and back rows are different ($P < 0.05$).

$^{x,y,z}$ Least square means lacking a common superscript letter with the row are different ($P < 0.05$).

$^1$ Maximum SEM for any Least squares means estimate done on sections = 1.80%, and 1.26% on averages.

$^2$ $P$-value <0.0001 for all least squares means estimates.

$^3$ F-statistic on the effect of section along the cut.

$^4$ For average of $F$-test statistic.

$^5$ Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.
MUFA content followed a similar trend to SFA content where only the brisket showed section as a source of variation ($P < 0.0026$). Again, Tukey-Kramer’s test failed to show significant differences ($P > 0.05$) between the sections, however the center portion trended towards having a higher MUFA content. MUFA content has been positively correlated with flavour, juiciness, tenderness, and overall palatability (Hwang & Joo, 2017). Although there are many factors that contribute to the sensory characteristics of beef bacon, a uniform MUFA content throughout the entire cut would indicate that each section along the cut offers not only similar stability, but a similar eating experience; with the exception of the brisket.

As with previous analyses in this study, the clod heart cuts showed a great degree of similarity between one another as well as between each of their sections for MUFAs, SFAs, as well as PUFAs; most likely due to being manufactured from the same cut. The plate-SR cut and plate-N cuts however, did not show a great deal of similarity despite both being manufactured from the same plates. SFA content was about 7% greater in the plate-SR cut than the plate-N cut, and MUFA content was approximately 7% lesser in the plate-SR cut.
Table 4.22 Monounsaturated fatty acid percentage (%) for slices sourced from different locations along each cut$^{1,2}$.

<table>
<thead>
<tr>
<th></th>
<th>Brisket</th>
<th>Clod-S$^3$</th>
<th>Clod-NS$^5$</th>
<th>Flank</th>
<th>Plate-SR$^5$</th>
<th>Plate-N$^5$</th>
<th>Outside Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>44.54$^{a,b,c,e,f}$</td>
<td>50.22$^{a,b,c}$</td>
<td>51.27$^{a,b,c}$</td>
<td>46.14$^{b,c,d,e,f}$</td>
<td>41.73$^{e,f}$</td>
<td>51.16$^{a,b,c}$</td>
<td>54.69$^{a,b}$</td>
</tr>
<tr>
<td>Center</td>
<td>52.10$^{a,b,c}$</td>
<td>49.63$^{a,b,c,d,e}$</td>
<td>50.27$^{a,b,c}$</td>
<td>47.14$^{b,c,d,e,f}$</td>
<td>41.06$^{f}$</td>
<td>47.43$^{b,c,d,e,f}$</td>
<td>54.16$^{a,b}$</td>
</tr>
<tr>
<td>Back</td>
<td>48.74$^{a,b,c,d,e}$</td>
<td>49.86$^{a,b,c,d}$</td>
<td>49.71$^{a,b,c,d,e}$</td>
<td>48.10$^{a,b,c,d,e,f}$</td>
<td>42.10$^{x,y,d,f}$</td>
<td>50.62$^{a,b,c}$</td>
<td>55.96$^{a}$</td>
</tr>
<tr>
<td>Average</td>
<td>48.46$^y$</td>
<td>49.90$^y$</td>
<td>50.57$^y$</td>
<td>47.12$^y$</td>
<td>41.63$^e$</td>
<td>49.74$^y$</td>
<td>54.94$^x$</td>
</tr>
<tr>
<td>$F$-value$^3$</td>
<td>6.11</td>
<td>0.03</td>
<td>0.23</td>
<td>0.41</td>
<td>0.14</td>
<td>1.85</td>
<td>0.28</td>
</tr>
<tr>
<td>$P$-value$^4$</td>
<td>0.0026</td>
<td>0.9664</td>
<td>0.7942</td>
<td>0.6630</td>
<td>0.8728</td>
<td>0.1603</td>
<td>0.7536</td>
</tr>
</tbody>
</table>

$^{a,b,c,d,e,f}$ Least square means (n=6) lacking a common superscript letter within the front, center, and back rows are different ($P < 0.05$).

$^{x,y,z}$ Least square means lacking a common superscript letter with the row are different ($P < 0.05$).

$^1$ Maximum SEM for any Least squares means estimate done on sections = 2.08%, and 1.37% on averages.

$^2$ $P$-value <0.0001 for all least squares means estimates.

$^3$ $F$-statistic on the effect of section along the cut.

$^4$ For average of $F$-test statistic.

$^5$ Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.

In addition to being most susceptible to oxidation, PUFAs are also associated with lower sensory scores for flavour, juiciness, tenderness and overall palatability (Hwang & Joo, 2017). Only the plate-SR cut showed section as a significant source of variation ($P < 0.05$) for PUFA content; the plate-N cut almost reached significance ($P < 0.05$). On average, the PUFA content was lowest for the brisket, plate-N, and outside flat cuts. The clod heart cuts once again showed no significant variation between them ($P > 0.05$), however the plate-SR and plate-N cuts did show significant differences in PUFA content ($P < 0.05$); as was seen with the SFA and MUFA content. Despite being sourced from the same plate, and with carcass being controlled for, this shows that way that the plate is cut to form bacon may have significant implications on stability and eating experience.
Table 4.23 Polyunsaturated fatty acid percentage (%) for slices sourced from different locations along each cut\(^{1,2}\).

<table>
<thead>
<tr>
<th></th>
<th>Brisket</th>
<th>Clod-S(^5)</th>
<th>Clod-NS(^5)</th>
<th>Flank</th>
<th>Plate-SR(^5)</th>
<th>Plate-N(^5)</th>
<th>Outside Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>3.07(c,d)</td>
<td>4.47(^a)</td>
<td>3.89(^{a,b,c})</td>
<td>2.87(^{c,d})</td>
<td>4.43(^a)</td>
<td>3.14(^{b,c,d})</td>
<td>2.99(^{c,d})</td>
</tr>
<tr>
<td>Center</td>
<td>3.05(^{c,d})</td>
<td>4.58(^a)</td>
<td>4.27(^{a,b})</td>
<td>3.13(^{c,d})</td>
<td>4.61(^a)</td>
<td>3.65(^{a,b,c})</td>
<td>2.53(^d)</td>
</tr>
<tr>
<td>Back</td>
<td>3.05(^{c,d})</td>
<td>4.60(^a)</td>
<td>3.95(^{a,b,c})</td>
<td>2.98(^{c,d})</td>
<td>3.93(^{a,b,c})</td>
<td>3.04(^{c,d})</td>
<td>3.16(^{b,c,d})</td>
</tr>
<tr>
<td>Average</td>
<td>3.06(^{a})</td>
<td>4.55(^y)</td>
<td>4.03(^y)</td>
<td>2.99(^{c,d})</td>
<td>4.32(^y)</td>
<td>3.28(^{a})</td>
<td>2.89(^{a})</td>
</tr>
</tbody>
</table>

\(^{a,b,c,d,e}\) Least square means (n=6) lacking a common superscript letter within the front, center, and back rows are different (\(P < 0.05\)).

\(^{y}\) Least square means lacking a common superscript letter with the row are different (\(P < 0.05\)).

\(^{1}\) Maximum SEM for any Least squares means estimate done on sections = 0.19%, and 0.21% on averages.

\(^{2}\) \(P\)-value <0.0001 for all least squares means estimates.

\(^{3}\) \(F\)-statistic on the effect of section along the cut.

\(^{4}\) For average of \(F\)-test statistic.

\(^{5}\) Clod-S: Clod Heart half with silverskin, Clod-NS: Clod Heart half with no silverskin, Plate-SR: deboned, Short-rib half of Short Plate, Plate-N: remaining half cut off from Short-rib half.

4.5 Conclusions

An analysis of the processing characteristics showed that dimensions and processing weights were significantly different between cuts. The outside flat was the largest cut, followed by the brisket; the flank and clod heart cuts were the smallest. No significant differences were present between cuts for rested pumped uptake. Smokehouse yield was greater for the brisket, outside flat, and short plate (both halves) compared with the clod heart (both halves) and flank; likely due to the larger surface area to volume ratio of the smaller cuts resulting in a greater rate of heat transfer and evaporation. Slice cook yield was lowest for higher fat slices such as the short plate cuts, likely as a result of more fat rendering out during cooking, and highest for the outside flat, which was a lean cut and the largest in terms of area.

The consumer survey of images of uncooked beef bacon slices showed that the plate-N and brisket were ranked highest for beef bacon identity, palatability, and purchase.
likelihood. Fat distribution was the primary determinant for ranking beef bacon identity and palatability. 57% of respondents indicated that they would be more likely to purchase a beef bacon product with a lower fat content.

Various significant differences were found between and within cuts subjected to visual and compositional analysis. The short plate cuts as well as the brisket contained the greatest fat content; the flank, outside flat, and clod heart cuts contained less than 9% fat. All cuts showed that the section along the cut was a source of variation for two or more criteria evaluated during proximate and visual analysis; with the exception of the flank, which only showed length as the visual criteria affected by cut section. The plate-N was the only cut that showed section to be a source of variation for every criteria evaluated during proximate and image analysis; the brisket showed variation for every criteria except ash. SFA and MUFA content only varied between sections for the brisket; PUFA content only differed between sections for the plate-SR cut.

Beef flavour intensity was generally about twice as great as the reference of ground beef sample used as an anchor point, and only differed significantly between the clod-NS (least flavourful) and the flank (most flavourful). Connective tissue amount was lower than the reference pork thick-cut pork bacon sample for all cuts except for the plate-N cut; which had an equal amount. Muscle fibre toughness was generally 2-2.5 times as tough as the reference thick-cut pork bacon sample, with the exception of the outside flat and the plate-N cuts, which contained approximately 0.9x the connective tissue of thick-cut pork bacon. All cuts were resistant to oxidation for the 90 day duration of this study.
The data quantified in this study elucidate the differences in the processing, visual, compositional, and sensory properties of beef bacon made with seven different cuts. These data allow the beef industry to tailor their cut selection to an identity most agreeable with the consumer base they wish to target. Leaner cuts also show the possible introduction of new whole-muscle, high-protein, and low-connective tissue bacon-style products. Future work should examine differences in processing parameters and conduct large-scale consumer panels to identify acceptance within the categories of the higher fat and leaner cuts used in this study.

4.6 References


Saldaña, E., Saldarriaga, L., Cabrera, J., Behrens, J. H., Selani, M. M., Rios-Mera, J., &
5 Summary and Conclusions

The results of the market of evaluation of beef bacon being sold in southern Ontario showed that the lack of standard identity of beef bacon has led to a wide variety of processing techniques being utilized to manufacture the product. The greatest source of variability between beef bacon products was the cut from which the bacon was manufactured from. This variability is believed to stem from meat processors utilizing bacon processing as a means to add value to poorer selling cuts.

Many differences and similarities regarding processing, compositional, and sensory characteristics, were identified between cuts and within different sections of the cuts, when beef bacon was manufactured in a controlled processing environment, with cut as the controlled variable.

An analysis of the processing characteristics showed that no significant differences were present between cuts for rested pump uptake, however smokehouse yield was greater for the brisket, outside flat, and short plate (both halves) compared with the clod heart (both halves) and flank. Cook yield of individual slices being prepared for sensory analysis, was lowest for higher fat slices such as the short plate cuts, and highest for the outside flat, which was a lean cut and the largest in terms of area.
The consumer survey of images of uncooked beef bacon slices showed that the plate-N and brisket were ranked highest for beef bacon identity, palatability, and purchase likelihood. Fat distribution was the primary determinant for ranking beef bacon identity and palatability. 57% of respondents indicated that they would be more likely to purchase a beef bacon product with a lower fat content.

There were many significant differences found between and within cuts during visual and compositional analysis. The short plate cuts as well as the brisket contained the greatest fat content; the flank, outside flat, and clod heart cuts contained less than 9% fat. All cuts showed that the section along the cut was a source of variation for two or more criteria evaluated during proximate and visual analysis; with the exception of the flank, which was most consistent throughout the cut and showed length as the only criteria affected by cut section. The plate-N was the only cut that showed section to be a source of variation for every criteria evaluated during proximate and image analysis; the brisket showed variation for every criteria except for ash. SFA and MUFA content only varied between sections for the brisket; PUFA content only differed between sections for the plate-SR cut.

A trained descriptive panel that scored attributes of beef bacon relative to a reference sample found that beef flavour intensity was generally about twice as great as the reference ground beef sample, and only differed significantly between the clod-NS (least flavourful) and the flank (most flavourful). Connective tissue amount was found to be lower than the reference pork thick-cut pork bacon sample for all cuts except for the plate-N cut; which had an equal amount. Muscle fibre toughness was generally 2-2.5
times as tough as the reference thick-cut pork bacon sample, with the exception of the outside flat and the plate-N cuts, which contained approximately 0.9x the connective tissue of thick-cut pork bacon. By evaluating oxidation aroma and flavour, all cuts were found to be resistant to oxidation for the 90 day duration of this study.

This study elucidated the differences of the visual and compositional differences of beef bacon being sold in southern Ontario, as well as the visual, compositional, and sensory differences between cuts manufactured in a consistent and controlled environment. The data quantified in the processing, visual, compositional, and sensory properties of beef bacon made with seven different cuts, allows the beef industry to tailor their cut selection to an identity most agreeable with their target market. The analyses support the creation of new, low-connective tissue and lean bacon-style products, alongside a more “traditional” beef bacon product. Future work should examine differences in processing parameters and conduct large-scale consumer panels to identify acceptance within the categories of the higher fat and leaner, low-connective tissue cuts used in this study.


Resources. https://doi.org/10.5851/kosfa.2017.37.2.153


APPENDICES

Appendix

A1. Image Analysis

Beef Bacon Slice Image Analysis

Prepared by: Sebastian Chalupa-Krebsdak

Summary:

Slices were photographed using a Nexus 5 camera (LG Electronics Inc., Seoul, South Korea) against a black bristol board background alongside a 30 cm ruler. Adobe Photoshop CS5 (Adobe Systems Inc., San Jose, CA) was used to isolate the slices and ruler from the background to create a TIFF file of the slice and ruler layered on a transparent foreground. The TIFF files were then imported into the National Institutes of Health Image J software (Abramoff et al., 2004). Slice dimensions were determined by first defining the number of pixels in a centimeter using the Set Scale function, and then using the Threshold function to create a complete black slice, and with the straight-line tool then being used to measure the slice dimensions. Total slice area was determined using the freehand selection tool along with the Analyze Particles function. High contrast black and white images of each bacon slice were created by converting each image to an 8-bit image and using the Threshold function to create black pixels for the lean portion of the slice, and white pixels for the fat portion of the slice. The Analyze Particles function was used to count the number of black (lean) pixels, which was then divided by the number of black pixels in a fully blackened bacon slice image; to determine the lean percentage of each slice.

Equipment:

- Black background (matte); resistant to glare
- Ruler
- Uniform, low-glare lighting
- Adobe Photoshop, GIMP, or other image editing software able to create TIFF image files of isolated slices with transparent backgrounds
- Image J software

Procedure:

Creating the Image

1. Place thawed bacon slice(s) against a black background under lighting that is uniform across the slice(s); must not be any glare present on sample.
2. Place a label in the image to identify the slice.
3. Place a ruler in the image space.
4. Take an image of the workspace using similar lighting and distance for each image.
Isolating Slices

1. Open each image in Adobe Photoshop, GIMP, or other image editing software.
2. Click on the lock icon beside the “Background” layer to unlock the layer.
3. Use the quick selection or magic wand tool to select non-slice, non-label, and non-ruler area.
4. Press Delete to remove the background; revealing the transparent background.
5. (Optional) Use the lasso selection tool, Levels function, Curves function, and Exposure function as needed to darken the lean portion of each slice; lean should have few very white-pink areas.
6. Save image as a TIFF file.

Performing Image Analysis

1. Open TIFF file in Image J.
2. Using the straight line tool, select a distance of at least 15 cm along the rule.
3. Analyze > Set Scale…
   a. Enter the distance selected with the straight line tool beside “Known distance”
   b. Enter the units of measure beside “Unit of length”
   c. Press OK.
4. Image > Type > 8-bit
5. Image > Adjust > Threshold… or press Ctrl + Shift + T
   a. Adjust sliders to ensure black pixels best represent the proportion of lean and white pixels represent the proportion of fat.
   b. Press Apply and close the Threshold window.
6. Analyze > Set Measurements…
   a. Ensure that Area and Limit to threshold are checked.
   b. Press OK.
7. Using the freehand selection tool circle the slice of interest.
8. Analyze > Analyze Particles…
   a. Ensure that Size is set to 0-Infinity
   b. Ensure that Display results is checked.
   c. Press OK.
9. Analyze > Measure To obtain the lean area of the selected slice.
10. Close the image and perform steps 1 through 4 once more; you may manually enter the scale distance to be identical to the scale used to analyze the lean portion.
11. Image > Adjust > Threshold… or press Ctrl + Shift + T
    a. Adjust sliders to ensure the entire slice is made up of black pixels.
    b. Press Apply and close the Threshold window.
12. Analyze > Set Measurements…
    a. Ensure that Area and Limit to threshold are checked.
    b. Press OK.
13. Using the freehand selection tool circle the slice of interest.
14. Analyze > Analyze Particles…
    a. Ensure that Size is set to 0-Infinity
b. Ensure that *Display results* is checked.
c. Press OK.

15. **Analyze > Measure** To obtain the total area of the selected slice.
16. Use the *straight line tool* to select the conduct length and width measurements. The length will be displayed below the tool icons while the distance is being selected.

**Calculations**

\[
\text{Lean percentage} = \frac{\text{Lean area}}{\text{Total area}} \times 100\
\]

\[
\text{Length to width ratio} = \frac{\text{Length}}{\text{Width}}
\]
A2. Hela Brine and Cure Unit Composition

Table 5.1 Composition of Hela Brine and Cure Unit obtained from product specification sheet; used to create the injection solution in the manufacture of beef bacon.

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity (% in curing solution)</th>
<th>Quantity (% in product at 20% targeted injection)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt</td>
<td>60.056</td>
<td>1.74%</td>
</tr>
<tr>
<td>Sugar</td>
<td>28.957</td>
<td>0.75%</td>
</tr>
<tr>
<td>Disodium phosphate</td>
<td>10.939</td>
<td>0.32%</td>
</tr>
<tr>
<td>Sodium erythorbate</td>
<td>0.993</td>
<td>0.03% (287 ppm)</td>
</tr>
<tr>
<td>Cure accelerator</td>
<td>0.993</td>
<td>0.03% (287 ppm)</td>
</tr>
<tr>
<td>Sodium nitrite</td>
<td>0.437</td>
<td>0.01% (126 ppm)</td>
</tr>
</tbody>
</table>
A3. Smokehouse Cook Cycle for the Manufacture of Beef Bacon

Table 5.2 Scottpec smokehouse cycle used for the manufacturing of beef bacon.

<table>
<thead>
<tr>
<th>Stage Name</th>
<th>Time (hours: minutes)</th>
<th>Temperature (°C)</th>
<th>Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREHEAT</td>
<td>0:10</td>
<td>54</td>
<td>0</td>
</tr>
<tr>
<td>DRYING 2</td>
<td>1:15</td>
<td>54</td>
<td>0</td>
</tr>
<tr>
<td>SG IGNITION 2</td>
<td>0:04</td>
<td>54</td>
<td>0</td>
</tr>
<tr>
<td>SMOKING</td>
<td>0:14</td>
<td>54</td>
<td>0</td>
</tr>
<tr>
<td>SMK DISCHARGE 2</td>
<td>0:05</td>
<td>54</td>
<td>0</td>
</tr>
<tr>
<td>SMOKING 3</td>
<td>0:18</td>
<td>54</td>
<td>0</td>
</tr>
<tr>
<td>SMK DISCHARGE 3</td>
<td>0:08</td>
<td>54</td>
<td>0</td>
</tr>
<tr>
<td>COOK 1</td>
<td>0:15</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td>COOK 1</td>
<td>0:15</td>
<td>65</td>
<td>40</td>
</tr>
<tr>
<td>COOK 1</td>
<td>0:15</td>
<td>69</td>
<td>50</td>
</tr>
<tr>
<td>COOK 1</td>
<td>0:15</td>
<td>70</td>
<td>60</td>
</tr>
<tr>
<td>COOK 1</td>
<td>Until core temperature of 62°C was achieved</td>
<td>72</td>
<td>60</td>
</tr>
</tbody>
</table>
A4. Training Session Guiding Document

Sensory Attribute Training for the Descriptive Analysis of Beef Bacon

Beef Flavour

Beef has a very distinct flavour. This flavour is complex and different from other food products and even other meat products. You are provided with various dilutions of beef broth and ground beef. Use the line scale below to rank them based on the intensity of beef flavour:

Least intense---------------------------------------------------------------Most Intense

Oxidation Aroma

Many fats and oils will undergo oxidation after prolonged storage. This results in a cardboard-like odour and flavour that is often used to indicate the end of a food item’s shelf life. Smell the following oils and ground beef samples and rank them based on the intensity of the oxidation odour:

Least intense---------------------------------------------------------------Most Intense

Oxidation Flavour

Taste the following samples and rank them based on the intensity of the cardboard-like, oxidized flavour. It is important to ignore all other flavours and perceptions you may have when analyzing this property. Rank the intensity of oxidation below:

Least intense---------------------------------------------------------------Most Intense

Connective Tissue

The connective tissue in meat products is very elastic and gummy. It takes a long time to chew and is distinct from the toughness of the muscle fibre component. Focus only on this elastic and gummy component when chewing the following samples and rank the samples based on how much connective tissue you felt was present:

None---------------------------------------------------------------------A lot

Muscle Fibre Toughness

Another component of meat that affects the ease of chewing, is the tenderness of the muscle fibre component. Chew the following samples, and notice the force and time it takes to chew before swallowing. Rank them based on the ease of chewing for ONLY the muscle component:

Very Tender---------------------------------------------------------------Very Tough
A5. Testing Form for Descriptive Panel Screening Session

Sensory Attribute Testing for the Descriptive Analysis of Beef Bacon

Sample the following broths and rank them in order of beef flavour intensity by placing a number from 1 to 4, beside each of the samples (1- Least intense flavour, 4- Most intense flavour):

52 38 21 14

Smell the following samples and rank them based on the intensity of the oxidation aroma by placing a number from 1 to 3 beside the samples (1-Least oxidized, 3-Most oxidized)

71 87 65

Taste the following samples and circle which possesses the oxidation flavour:

90 16 34

Taste the following beef and bacon samples. Circle the beef sample that has the MOST connective tissue, then circle the bacon sample that has the MOST connective tissue:

15 22 77 10

Taste the following samples and rank them based on the difficulty chewing based only on the muscle fiber component by placing a number from 1 to 3 beside the samples (1-Most TENDER, 3-Most TOUGH):

42 54 61
A6. Example of Descriptive Analysis Panel Form

Descriptive Analysis of Beef Bacon

You will be provided with a reference sample for each criteria you will be evaluating. Each sample that you are evaluating will be scored with the reference sample as a guide. Please start each test by evaluating the reference sample and remember to cleanse your palate often and refer to the reference sample as often as you see fit to ensure accurate testing.

There are two parts to this analysis: aroma and flavour, and texture. After completing the first page of the evaluation wait for the other panelists to complete it as well. When everyone is finished, the second page will be provided along with the new reference sample and additional beef bacon. Please do not rush the evaluation.

**Oxidation Aroma**

Reference Sample: *Oxidized vegetable oil*

Assign one of the following values to each beef bacon sample based on the amount of oxidation aroma you can detect; an unacceptable amount of oxidation aroma is one that you feel is simply too dominant and masks the other aromas in the beef too much:

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>Trace</td>
</tr>
<tr>
<td>3</td>
<td>Some but still acceptable</td>
</tr>
<tr>
<td>4</td>
<td>Unacceptable</td>
</tr>
</tbody>
</table>

Oxidation Aroma Scores:

<table>
<thead>
<tr>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
<th>Sample 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>421</td>
<td>317</td>
<td>517</td>
<td>695</td>
<td>342</td>
</tr>
</tbody>
</table>

**Oxidation Flavour**

Reference Sample: *Oxidized vegetable oil*

Assign one of the following values to each beef bacon sample based on the amount of oxidation flavour you can detect; an unacceptable amount of oxidation flavour is one that you feel is simply too dominant and masks the other flavours in the beef too much:

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>Trace</td>
</tr>
<tr>
<td>3</td>
<td>Some but still acceptable</td>
</tr>
<tr>
<td>4</td>
<td>Unacceptable</td>
</tr>
</tbody>
</table>

Oxidation Flavour Scores:

<table>
<thead>
<tr>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
<th>Sample 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>421</td>
<td>317</td>
<td>517</td>
<td>695</td>
<td>342</td>
</tr>
</tbody>
</table>

**Beef Flavour Intensity**

Reference Sample: *Ground beef*

Taste the ground beef reference sample and note its flavour intensity. Give it a value of 10 for its flavour. Then rate each beef bacon sample in proportion to the ground beef’s flavour intensity. If the sample is twice as flavourful as the ground beef, assign a value of 20. If it is half, assign a value of 5. If it is 0.75 as flavourful, assign a value of 7.5. If it is 3.5 times as flavourful, assign a value of 35. Feel free to use any value you think best describes the proportion you perceive.

Beef Flavour Intensity Scores:

<table>
<thead>
<tr>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
<th>Sample 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>421</td>
<td>317</td>
<td>517</td>
<td>695</td>
<td>342</td>
</tr>
</tbody>
</table>
**Muscle Fibre Toughness**  **Reference Sample: Pork Bacon**

Taste the pork bacon reference sample and note the toughness of the *muscle fibre component*; ignoring the gummy, stringy, elastic connective tissue component for this evaluation. Assign a value of 10 to the muscle fibre toughness of the pork bacon. As before, rate each beef bacon sample in proportion to the pork bacon’s muscle fibre toughness. If the beef bacon sample is 1.5 times as tough as the pork bacon, give a value of 15; if it is 0.6 times as tough, assign a value of 6; 4.5 times as tough, assign a value of 45. Feel free to use any value you think best describes the proportion you perceive.

<table>
<thead>
<tr>
<th>421</th>
<th>317</th>
<th>517</th>
<th>695</th>
<th>342</th>
<th>221</th>
</tr>
</thead>
</table>

**Connective Tissue Amount**  **Reference Sample: Pork Bacon**

Taste the pork bacon sample and note the amount of connective tissue in it. This is the gummy, stringy, elastic component. Ignore the toughness of the muscle fibre component. As before, assign a value of 10 to the pork bacon for its amount of connective tissue, and rate each beef bacon sample in proportion to it. If it has two times the amount of connective tissue, assign a value of 20; if it has half the connective tissue, assign a value of 5; if it has 1.5 times the connective tissue, assign a value of 15. Feel free to use any value you think best describes the proportion you perceive.

| 421 | 317 | 517 | 695 | 342 | 221 |
A7. Beef Bacon Consumer Impressions Survey Questions

How often do you consume bacon?

- Never
- Once a month
- Few times a month
- Every week
- Several times a week

If you do not consume bacon at least once a month, please indicate why not.

- High fat content
- Vegetarian/Vegan
- Religious Restrictions
- I do consume bacon at least once a month
- Other ______

Have you ever consumed bacon made from beef?

- Yes
- No

Rank the following images based on what you think best matches the identity of "beef bacon". (1 - This product looks most like what I would consider to be beef bacon; 7 - This product looks least like what I would consider to be beef bacon)

____ Image:Brisket.jpg
____ Image:Clod Heart Silverskin Half.jpg
____ Image:Clod Heart Non-Silverskin Half.jpg
____ Image:Flank.jpg
____ Image:Short Plate Navel Half.jpg
____ Image:Outside Flat.jpg
____ Image:Short Plate Short Rib Half.jpg
What criteria did you use to rank the images in the previous question? (select one or more)

- Color
- Texture
- Amount of fat
- Distribution of fat
- Overall shape
- Other: __________

Rank the following images based on what you think would be most palatable (flavour, texture, colour, etc.). (1 - most palatable)

_____ Image: Brisket.jpg
_____ Image: Clod Heart Silverskin Half.jpg
_____ Image: Clod Heart Non-Silverskin Half.jpg
_____ Image: Flank.jpg
_____ Image: Short Plate Navel Half.jpg
_____ Image: Outside Flat.jpg
_____ Image: Short Plate Short Rib Half.jpg

What criteria did you use to rank the images in the previous question? (select one or more)

- Color
- Texture
- Amount of fat
- Distribution of fat
- Overall shape
- Other: __________

Based on your own perceptions of texture, flavour, nutrition, colour, and any other criteria you find important, rank the following images based on your likelihood to purchase and consume each product; given the same price. (1 - most likely to purchase/consume)

_____ Image: Brisket.jpg
_____ Image: Clod Heart Silverskin Half.jpg
_____ Image: Clod Heart Non-Silverskin Half.jpg
_____ Image: Flank.jpg
_____ Image: Short Plate Navel Half.jpg
_____ Image: Outside Flat.jpg
_____ Image: Short Plate Short Rib Half.jpg
Rank the criteria that most influenced your likelihood to purchase each product in question 7. (1 - most important)

- Texture
- Flavour
- Nutrition
- Colour
- Other

Would you be more, or less likely to purchase a beef bacon product with less fat and more protein?

- Less likely
- More likely
A8. Images of Slices Derived from Back, Center, and Front Sections of each Cut

Front  |  Center  |  Back

Brisket
Clod-S
Clod-NS
Flank
Plate-N
Outside
Plate-SR
A9. Consumer Survey Report as Exported by Qualtrics

Beef Bacon Impressions Survey

Q1 - How often do you consume bacon?

<table>
<thead>
<tr>
<th>Answer</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>7.32%</td>
</tr>
<tr>
<td>Once a month</td>
<td>31.71%</td>
</tr>
<tr>
<td>Few times a month</td>
<td>36.59%</td>
</tr>
<tr>
<td>Every week</td>
<td>14.63%</td>
</tr>
<tr>
<td>Several times a week</td>
<td>9.76%</td>
</tr>
</tbody>
</table>

Q2 - If you do not consume bacon at least once a month, please indicate why not.

<table>
<thead>
<tr>
<th>Answer</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>High fat content</td>
<td>6.06%</td>
</tr>
<tr>
<td>Vegetarian/Vegan</td>
<td>0.00%</td>
</tr>
<tr>
<td>Religious Restrictions</td>
<td>6.06%</td>
</tr>
<tr>
<td>I do consume bacon at least once a month</td>
<td>75.76%</td>
</tr>
<tr>
<td>Other</td>
<td>12.12%</td>
</tr>
</tbody>
</table>
Q2 - Other

**Other - Text**

- avoiding most red meat
- High price
- Don’t have access to it
- not the fat, but calories
- It's expensive, and you don't get that much meat out of it. It's kind of a luxury for me, as I don't consider it a real breakfast item like a sausage
- I just don't regularly eat it
- Bacon expensive
- Too expensive, too much fat and salt.

Q3 - Have you ever consumed bacon made from beef?

<table>
<thead>
<tr>
<th>Answer</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>22.89%</td>
</tr>
<tr>
<td>No</td>
<td>77.11%</td>
</tr>
</tbody>
</table>
Q4 - Rank the following images based on what you think best matches the identity of "beef bacon". (1 - This product looks most like what I would consider to be beef bacon; 7 - This product looks least like what I would consider to be beef bacon)

<table>
<thead>
<tr>
<th>Cut</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>6th</th>
<th>7th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brisket</td>
<td>24.6%</td>
<td>34.57%</td>
<td>18.52%</td>
<td>7.41%</td>
<td>8.64%</td>
<td>6.17%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Clod-S</td>
<td>14.81%</td>
<td>4.94%</td>
<td>8.64%</td>
<td>14.81%</td>
<td>17.28%</td>
<td>28.40%</td>
<td>11.11%</td>
</tr>
<tr>
<td>Clod-NS</td>
<td>0.00%</td>
<td>14.81%</td>
<td>9.88%</td>
<td>6.17%</td>
<td>11.11%</td>
<td>24.69%</td>
<td>33.33%</td>
</tr>
<tr>
<td>Flank</td>
<td>7.41%</td>
<td>3.70%</td>
<td>8.64%</td>
<td>43.21%</td>
<td>16.05%</td>
<td>7.41%</td>
<td>13.58%</td>
</tr>
<tr>
<td>Plate-N</td>
<td>39.51%</td>
<td>24.69%</td>
<td>11.11%</td>
<td>0.00%</td>
<td>8.64%</td>
<td>12.35%</td>
<td>3.70%</td>
</tr>
<tr>
<td>Outside</td>
<td>4.94%</td>
<td>3.70%</td>
<td>9.88%</td>
<td>17.28%</td>
<td>32.10%</td>
<td>17.28%</td>
<td>14.81%</td>
</tr>
<tr>
<td>Flat</td>
<td>8.64%</td>
<td>13.58%</td>
<td>33.33%</td>
<td>11.11%</td>
<td>6.17%</td>
<td>3.70%</td>
<td>23.46%</td>
</tr>
</tbody>
</table>

Q5 - What criteria did you use to rank the images in the previous question? (select one or more)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>7.18%</td>
</tr>
<tr>
<td>Texture</td>
<td>8.13%</td>
</tr>
<tr>
<td>Amount of fat</td>
<td>28.71%</td>
</tr>
<tr>
<td>Distribution of fat</td>
<td>34.45%</td>
</tr>
<tr>
<td>Overall shape</td>
<td>20.57%</td>
</tr>
<tr>
<td>Other</td>
<td>0.96%</td>
</tr>
</tbody>
</table>
Q5 - Other

**Other - Text**

<table>
<thead>
<tr>
<th>lean ratio</th>
<th>size</th>
</tr>
</thead>
</table>

Q6 - Rank the following images based on what you think would be most palatable (flavour, texture, colour, etc.). (1 - most palatable)

<table>
<thead>
<tr>
<th>Cut</th>
<th>1&lt;sup&gt;st&lt;/sup&gt;</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt;</th>
<th>3&lt;sup&gt;rd&lt;/sup&gt;</th>
<th>4&lt;sup&gt;th&lt;/sup&gt;</th>
<th>5&lt;sup&gt;th&lt;/sup&gt;</th>
<th>6&lt;sup&gt;th&lt;/sup&gt;</th>
<th>7&lt;sup&gt;th&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brisket</td>
<td>23.75%</td>
<td>33.75%</td>
<td>18.75%</td>
<td>8.75%</td>
<td>8.75%</td>
<td>3.75%</td>
<td>2.50%</td>
</tr>
<tr>
<td>Clod-S</td>
<td>13.75%</td>
<td>6.25%</td>
<td>11.25%</td>
<td>22.50%</td>
<td>25.00%</td>
<td>16.25%</td>
<td>5.00%</td>
</tr>
<tr>
<td>Clod-NS</td>
<td>1.25%</td>
<td>17.50%</td>
<td>6.25%</td>
<td>10.00%</td>
<td>13.75%</td>
<td>27.50%</td>
<td>23.75%</td>
</tr>
<tr>
<td>Flank</td>
<td>2.50%</td>
<td>3.75%</td>
<td>16.25%</td>
<td>23.75%</td>
<td>18.75%</td>
<td>13.75%</td>
<td>21.25%</td>
</tr>
<tr>
<td>Plate-N</td>
<td>41.25%</td>
<td>23.75%</td>
<td>11.25%</td>
<td>7.50%</td>
<td>6.25%</td>
<td>8.75%</td>
<td>1.25%</td>
</tr>
<tr>
<td>Outside Flat</td>
<td>1.25%</td>
<td>3.75%</td>
<td>10.00%</td>
<td>18.75%</td>
<td>21.25%</td>
<td>20.00%</td>
<td>25.00%</td>
</tr>
<tr>
<td>Plate-SR</td>
<td>16.25%</td>
<td>11.25%</td>
<td>26.25%</td>
<td>8.75%</td>
<td>6.25%</td>
<td>10.00%</td>
<td>21.25%</td>
</tr>
</tbody>
</table>
Q7 - What criteria did you use to rank the images in the previous question? (select one or more)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>11.37%</td>
</tr>
<tr>
<td>Texture</td>
<td>16.11%</td>
</tr>
<tr>
<td>Amount of fat</td>
<td>25.59%</td>
</tr>
<tr>
<td>Distribution of fat</td>
<td>30.81%</td>
</tr>
<tr>
<td>Overall shape</td>
<td>14.22%</td>
</tr>
<tr>
<td>Other</td>
<td>1.90%</td>
</tr>
</tbody>
</table>

Q7 - Other

**Other - Text**

<table>
<thead>
<tr>
<th>lean ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>The very small piece looks like it will just shrivel up and burn</td>
</tr>
<tr>
<td>Bacon needs fat to be proper bacon. Using teres major wouldn't be economical either.</td>
</tr>
<tr>
<td>size</td>
</tr>
</tbody>
</table>
Q8 - Based on your own perceptions of texture, flavour, nutrition, colour, and any other criteria you find important, rank the following images based on your likelihood to purchase and consume each product; given the same price. (1 - most likely to purchase/consume)

<table>
<thead>
<tr>
<th>Cut</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>6th</th>
<th>7th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brisket</td>
<td>21.79%</td>
<td>33.33%</td>
<td>17.95%</td>
<td>11.54%</td>
<td>7.69%</td>
<td>6.41%</td>
<td>1.28%</td>
</tr>
<tr>
<td>Clod-S</td>
<td>15.38%</td>
<td>14.10%</td>
<td>11.54%</td>
<td>12.82%</td>
<td>30.77%</td>
<td>8.97%</td>
<td>6.41%</td>
</tr>
<tr>
<td>Clod-NS</td>
<td>3.85%</td>
<td>15.38%</td>
<td>8.97%</td>
<td>11.54%</td>
<td>14.10%</td>
<td>30.77%</td>
<td>15.38%</td>
</tr>
<tr>
<td>Flank</td>
<td>6.41%</td>
<td>2.56%</td>
<td>10.26%</td>
<td>29.49%</td>
<td>10.26%</td>
<td>11.54%</td>
<td>29.49%</td>
</tr>
<tr>
<td>Plate-N</td>
<td>42.31%</td>
<td>19.23%</td>
<td>8.97%</td>
<td>12.82%</td>
<td>8.97%</td>
<td>5.13%</td>
<td>2.56%</td>
</tr>
<tr>
<td>Outside Flat</td>
<td>0.00%</td>
<td>3.85%</td>
<td>12.82%</td>
<td>14.10%</td>
<td>20.51%</td>
<td>24.36%</td>
<td>24.36%</td>
</tr>
<tr>
<td>Plate-SR</td>
<td>10.26%</td>
<td>11.54%</td>
<td>29.49%</td>
<td>7.69%</td>
<td>7.69%</td>
<td>12.82</td>
<td>20.51</td>
</tr>
</tbody>
</table>

Q9 - Rank the criteria that most influenced your likelihood to purchase each product in question 7. (1 - most important)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture</td>
<td>28.57%</td>
<td>41.43%</td>
<td>18.57%</td>
<td>11.43%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Flavour</td>
<td>60.00%</td>
<td>24.29%</td>
<td>12.86%</td>
<td>2.86%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Nutrition</td>
<td>7.14%</td>
<td>10.00%</td>
<td>38.57%</td>
<td>34.29%</td>
<td>10.00%</td>
</tr>
<tr>
<td>Colour</td>
<td>2.86%</td>
<td>18.57%</td>
<td>25.71%</td>
<td>48.57%</td>
<td>4.29%</td>
</tr>
<tr>
<td>Other</td>
<td>1.43%</td>
<td>5.71%</td>
<td>4.29%</td>
<td>2.86%</td>
<td>85.71%</td>
</tr>
</tbody>
</table>
Q10 - Would you be more or less likely to purchase a beef bacon product with less fat and more protein?

<table>
<thead>
<tr>
<th>Answer</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less likely</td>
<td>43.37%</td>
</tr>
<tr>
<td>More likely</td>
<td>56.63%</td>
</tr>
</tbody>
</table>