Welcome to the 71st Reciprocal Meat Conference, and welcome to Kansas City!

The American Meat Science Association and our Kansas City based host committee could not be more excited to show you the rich traditions of Kansas City. From the stock yards and packing industry of years ago to the abundance of animal agriculture here today, the American Royal Stock Show, and, of course, barbeque, this city is truly a “Royal Choice” for our annual meeting.

Our week will be filled with an educational technical program and the best social venues that Kansas City has to offer. Kansas City Barbeque Society pit masters will help us kick off the week with the world’s best barbeque at the welcome reception held at the historic National WWI Museum and Memorial, Kansas City Live will show us the casual side of the town for our picnic, and Kansas City’s beautiful Union Station will serve as the venue for our awards banquet.

This year’s technical planning committee did an excellent job putting together an outstanding technical program that represents the timeliest and most relevant topics in our industry including industry updates, diet health, cultured sources of animal protein, food safety, research and development, live animal production, and even barbeque. Monday and Tuesday will highlight incredible keynote speakers, technical concurrent sessions, as well as our signature reciprocation sessions, and Wednesday will begin with a technical debate and finish with hands on workshops including barbeque, live cattle, carcasses, and the American Royal Stock Show. This year’s reciprocation grid provides one of the most diverse technical offerings to date with more than 40 individual sessions, speakers, and topics covering research and discussions for beef, pork, poultry, water buffalo, pet food, packaging, food safety, Spanish-speaking sessions, student sessions, omics, charcuterie, and more.

Of course, RMC would not be complete without both graduate and undergraduate student programs. This year we will see more abstracts and ePosters at RMC than ever before. Over 160 technical abstracts were submitted for presentation at RMC, and attendees will have many chances to engage with these presenters about their research. Just to name a few of the opportunities for students, there will be the Career Fair, Iron Chef Competition, Processed Meats Contest, student-dedicated reciprocation sessions, student social events, and many more.

On behalf of the entire host committee and the technical program committee, and as the 2018 RMC Chair, I want to thank you for attending the 71st Reciprocal Meat Conference. We are honored to have you here, and, if this is not your first RMC, we wish you the best RMC yet! If this is your first RMC, welcome, we know that it will not be your last! Have a wonderful RMC!

Sincerely,

Dale R. Woerner
Chair, 2018 Reciprocal Meat Conference
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Farming Cells: 
Opportunities and Advances in Clean Meat 

Liz Specht, Ph.D.

Clean meat—meat produced through farming animal cells (muscle cells, fat cells, connective tissue, etc.) rather than rearing and slaughtering animals—can dramatically reduce the environmental footprint of meat while alleviating the public health threats and animal welfare concerns posed by intensive, industrialized animal farming. Preliminary life cycle assessments indicate that clean meat production will require 10 to 100 times less land and water than conventional meat production, and will emit over 90% fewer greenhouse gas emissions (due in large part to the outsized contribution of gastric methane to warming potential). Land considerations alone make it clear that alternative production methods are needed in order to supply the projected increase in meat demand by the year 2050, much of which will come from developing countries.

In the last three years, over two dozen start-up companies have emerged to commercialize clean meat, relying heavily on recent advances in multiple fields including regenerative medicine and tissue engineering, cell-based therapies and drug manufacturing, industrial biotechnology, and food science. These companies have received funding from traditional technology venture capital funds as well as corporate venture funds within the meat industry. Many traditional meat companies are rebranding themselves as protein companies, and they are proactively embracing alternative production strategies that are more efficient and mitigate risks associated with the externalities of intensive animal agriculture. The strategic partnerships early in the development of the clean meat industry also enable clean meat companies to leverage the extensive meat science expertise within existing meat companies. Meat scientists are uniquely suited to articulate the design requirements and target parameters that characterize high-quality meats of various product types.

Furthermore, meat scientists are well versed in the downstream processing and handling occurring from slaughter to the consumer’s table, which will remain largely unchanged with clean meat (though clean meat is likely to exhibit higher stability and longer shelf life due to a lack of enteric pathogens as remnants of slaughter).

While many of the fundamental enabling technologies for cultivating and maturing animal cells drawn from the biomedical industry can already address areas of need within clean meat research and development, innovation is needed to optimize these processes for the cell types and structures that are relevant for clean meat—namely, muscle, fat, and connective tissue derived from livestock, poultry, and sea creatures. The fields of animal science and meat science increasingly leverage in vitro cell-based systems to accelerate targeted breeding and to garner 

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Figure 1. Schematic of a potential process design for large-scale clean meat production. The stirred-tank cell proliferation bioreactor feeds into tissue perfusion cultivators, in which cells are seeded onto scaffolds to differentiate and mature into the desired final cell types (muscle, fat, etc.). Some scaffolding materials can provide spatial cues to guide cellular differentiation in a designated pattern: for example, to produce a defined ratio and pattern of fat to muscle for a marbled product.
mechanistic insights into environmental conditions that affect meat quality. These species-specific insights will be critically important for the clean meat industry, in addition to the expertise surrounding high-quality definition at the molecular level and processing insights.

This talk will discuss the current state of the clean meat industry, opportunities to apply insights from meat science to active areas of clean meat research, and considerations for the meat industry as a whole regarding regulatory oversight, inspection, and food safety considerations. We will also discuss opportunities to accelerate the pathway to commercialization through partnerships between the meat industry and the emergent clean meat industry. As the demand for meat increases, clean meat presents a feasible alternative for producing real meat to satisfy this demand, and leveraging meat science insights and tools can hasten the development and commercialization of this sustainable alternative.
Production & Economic Balance in Domestic & Export Markets
Keith E. Belk, Ph.D.

PROSPECTS FOR MEAT TRADE
This presentation describes factors that will influence the ability of livestock and meat producers to be successful in a global market—a market that will likely offer significant sales opportunities in the future.

Projections for global human population growth suggest an “80% probability” that we will reach 9.6 to 12.3 billion people on planet Earth by the year 2100 (approximately 47% growth from the 7.5 billion of today), and that most growth will occur in Asia and Africa (Gerland et al., 2014). Such population growth, no matter where it occurs, offers mankind significant challenges. According to a recent FAO (2017) report on global food security, over 815 million people worldwide (11%) already were “undernourished” in 2016. Indeed, according to Global Food Stats (www.worldometers.info), almost 18,000 humans die each day from hunger. Imagine what that number will look like by the year 2100 without intervention.

While U.S. citizens enjoy multiple high-quality food options at retail for less than 7% of their disposable income (Economist, 2013), USDA data suggest that per capita consumption of beef, pork and chicken have leveled off in the U.S. since 2015 (USDA-ERS, 2016). In addition, U.S. population growth—other than that associated with immigration—will in the future reflect only a small fraction of the relative growth to be experienced by the rest of the world (Gerland et al., 2014). So, meat sales in the U.S. are not growing, and will not grow, when measured on a per capita basis—even though Americans spend very little of their income on food. The U.S. market, along with that in several other developed countries, appears to be mature.

But, it is well-established that, as financial strength improves in developing countries, demand for higher-quality protein increases. According to the Economist (2018), as one method of measuring availability of financial resources, global GDP is growing by 2.7% annually and only a few countries are performing poorly with respect to economic growth. Furthermore, based on United Nations (2017) data, global life expectancy is projected to increase to 77 years by 2050, and 83 years by 2100, which will result in greater lifetime spending on food. So, while there appears to be little opportunity for growth of meat sales in the U.S. (other than by the limited amount of population growth resulting from immigration), there will almost certainly continue to be opportunities for meat sales growth outside of the sovereign boundaries of the U.S., where over 95% of the world population resides (www.census.gov/popclock).

Therefore, several facts present themselves as favorable for the global meat industry: (a) Dramatic population growth will continue, mostly in Africa and Asia (requiring exports), that will require additional meat production. (b) There already exists a shortfall of nutrition in many parts of the world; nutrient-dense animal protein will certainly play a role in improving food security and life sustenance capabilities in many impoverished places. (c) Most countries are experiencing financial growth, allowing for increased spending on more nutrient-dense, higher quality products—except in the U.S. and a handful of countries where demand for meat appears to be mature regardless of price and the amount of income that must be spent on food. (d) People will, on average, live longer as time proceeds, thereby spending more on food over the course of their lifetime.

Exports of beef, pork and broilers have increased steadily for some time, helping to generate one of the few positive trade balances currently realized by U.S. industry business sectors (Manufacturing Institute, 2014). Forecasts for exports suggest a 5%, 1% and 2% growth in...
2018 for beef, pork and broilers, respectively (USDA-FAS, 2018), and there are no current reasons to believe that, with political and diplomatic effort, meat exports will not continue to grow. Sometimes, though, impediments to taking advantage of opportunities are outside the control of individual companies. The world needs to achieve consensus on the importance of trade in the future, utilize international standards to prevent barriers to trade, agree on scientific rules governing technical barriers to trade (TBT) and sanitary/phytosanitary (SPS) issues, and eliminate trade distorting subsidies and tariffs if global meat demand is to be satisfied in an efficient manner.

**GLOBALIZATION AND FREE TRADE**

According to the Merriam-Webster Dictionary, the term “globalization” was not used until the early 1950s. The word means “the act or process of globalizing”, and especially “the development of an increasingly integrated global economy marked by free trade . . .”. The concept of globalization has not always been popular. Although it appears that the majority of consumers appreciate access to products and services from all over the world (e.g., think wine, produce, etc.), many feel that trade jeopardizes their own personal livelihood because of additional competition, or their perceived safety, or that it compromises some other value(s) of importance; such beliefs reflect protectionism. It has led to riots and protests on more than one occasion (e.g., the Seattle riots in November of 1999). Nonetheless, it is likely that we are not turning back—international trade is becoming the norm. Mechanisms that have evolved to achieve “global trade” have been (a) the Free Trade Agreement (FTA) and (b) multinational businesses.

Free Trade is defined by the Merriam-Webster Dictionary as “trade based on the unrestricted international exchange of goods with tariffs used only as a source of revenue.” Initially, the concept became feasible at the end of the 19th century when vessel shipping costs for products that were exported were reduced to levels allowing reasonable pricing and transcontinental shipment; tariffs became the major impediment to trade at the time (Musa, 2000). Today, Free Trade Agreements are intergovernmental accords that can be bilateral or multilateral; those that have had the greatest impact have generally been the large, multinational agreements (e.g., GATT, WTO, NAFTA, etc.) that have striven to reduce or eliminate tariffs and internal support/subsidies for production that lead to distorted, artificial market values (WTO, 2018).

Currently, the U.S. has implemented 16 FTAs with 20 different countries (USTR, 2018). But, we are falling behind (USDA-FAS, 2016). The U.S. was in the process of developing another multilateral FTA—the Trans-Pacific Partnership (TPP)—when the new administration decided to exit the agreement in 2017; despite the U.S. exit, negotiations among the remaining partners continued and an agreement was achieved in March of 2018. Failure to establish a new U.S. agreement with at least some of the partners of TPP will have a negative impact on U.S. exports of meat to at least some countries (e.g., Japan) due to tariff benefits provided to the remaining members of TPP; tariff benefits will render their pricing of meat more favorable in those markets. The U.S. also has decided to re-negotiate two additional FTAs that have been advantageous to agriculture—the North American Free Trade Agreement (NAFTA) and the United States-Korea Free Trade Agreement (KORUS). While it is rumored that both agreements will be completed this year, and that both renegotiated agreements will benefit agriculture, finalized provisions have yet to be announced at the time of this presentation.

Probably the most important and potentially beneficial FTA that the U.S. has entered into was the agreement establishing the World Trade Organization (WTO), which resulted from several “Rounds” of negotiations in the General Agreement on Tariffs and Trade (GATT). Multinational negotiations (originally 115 countries, now 154 member countries; USTR, 2018) began during the first Round of GATT in 1948. The last (8th) Round was referred to as the “Uruguay” Round because it was initiated in Punta del Este, Uruguay, in 1986. The Uruguay Round was completed in 1994 (taking 8 years) and resulted in some truly transformational changes in global trade, including formation of the WTO, a body based in Geneva that theoretically should serve as the primary dispute resolution authority, and—significantly, for the first time in any of the GATT Rounds—inclusion of serious agricultural provisions that addressed both TBT and SPS considerations. Following congressional ratification, the WTO was officially accepted by President Clinton on behalf of the U.S. on December 23, 1994, and began operations in 1995 (WTO, 2018; USTR, 2018).

Implementation of FTAs has resulted in clear benefits for U.S. meat products. Potential exists for high-quality U.S. beef and pork exports to be used in increasingly popular foreign dishes. For example, consider: Yakiniku (Japan), restructured pork variety meat products (several locations), hot pot (Asia), rice bowl (Asia), and Shabu Shabu (Japan). According to the U.S. Meat Export Federation (USMEF, 2018), and just considering a few beef cuts that are not typically well-accepted in the U.S., exports of beef tongues, short plates, and short ribs/chuck short ribs have added $12.62/head, $27.36/head, and $19/head, respectively, to the total value of fed cattle. The value of exports to U.S. livestock producers is unquestionable; additional presentations in this session will illustrate this even further.

Perhaps the first truly ‘global’ livestock and meat company began operations long before the term “globalization” was used; in fact, in 1890. The Vestey Foods group, owned by William and Edmund Vestey, would become quite famous for producing feed, livestock and meat on several continents, and then transporting it around the world on ships operated by their own carrier line—the Blue Star fleet (which operated until 1998; Vestey Foods Group, Ltd., 2018). Today, and just to list a few, the fol-
lowing companies both operate production plants in multiple countries, and market products from those plants in even more countries: JBS S.A., Tyson Foods, WH Group (owner of Smithfield Foods), Cargill, Marfrig Global Foods, Brasil Foods (BRF), Danish Crown, Itoham Foods, Gruppo Cremonini, Teys Australia, Hormel Foods, SuKarne, Nippon Meat Packers, ANZCO Foods, Minerva Foods, Sigma Alimentos, OSI Group, and Maple Leaf Foods. The days of strictly-domestic commerce are over. This list is truly astounding for those that remember the U.S. domestic ‘anti-acquisition’ crusades of the 1980s; in which case some entities were concerned about domestic size of packing companies. This list reflects truly global, multinational companies that have evolved despite concerns for domestic company size: companies that can frequently overcome protectionism and barriers to trade.

In May of 2005, following full implementation of both NAFTA and the Uruguay round of GATT, USDA-FAS computed the apparent benefits to the U.S. of positive agricultural trade (particularly as a consequence of NAFTA), stating that “every $1 billion in exports creates 15,000 U.S. jobs,” and, at that time, “increased agricultural exports resulted in over 885,000 new U.S. jobs” (USDA-FAS, 2005). Moving forward in time, and depending on what happens with re-negotiations associated with NAFTA and KORUS, additional access opportunities are likely. Consider the ramifications to meat trade of BREXIT (i.e., the separation of the U.K. from the EU); the U.K. is expected (at least based on 2015 values) to import approximately 65% of its beef needs (AHDB, 2016). Their exit from the EU will change the meat marketing landscape of Europe.

Today, even when the U.S. does not agree with regulatory impositions of countries to which we wish to export, opportunities exist to conform to their wishes via USDA Export Verification Programs (EVP) that are implemented by the Agricultural Marketing Service and documented on export certificates by the Food Safety Inspection Service. While many have criticized such programs, there is no question that their existence has opened doors to many export opportunities without requiring the U.S. to adjust its domestic regulatory requirements. Availability of EVPs were particularly important after detecting bovine spongiform encephalopathy (BSE) in the U.S. to the >80 export markets that shut their doors as a consequence. Competition for U.S. exports will not decline—in fact, competition will increase on several fronts. The U.S. must be diligent and proactive if it wishes to have access to the markets in which it hopes to compete, and doing so will mean ‘meeting the requirements of the buyer.’ Use of EVPs can assist in that regard.

**BARRIERS TO TRADE**

As provisions of the Uruguay Round of GATT and other FTAs (e.g., NAFTA), TBT and SPS agreements were developed to convey fairness in import regulatory criteria for countries. Importing countries are essentially accountable—at least in theory—for implementing import regulatory requirements that are consistent with these agreements in the FTAs, and that are only based on true science to protect their citizens and animals. In other words, countries have a sovereign right in the FTAs to enforce science-based concerns for animal or human health, but not to use such barriers for protectionism. As a consequence, to facilitate trade and prevent artificial barriers from existing, several international organizations have positioned themselves to be considered as “international standards development bodies” that establish consensus on a plethora of scientific issues.

For example, the WTO recognizes Codex Alimentarius as the global food safety standard, the World Organization for Animal Health (OIE) as the global standard for animal health, and the FAO International Plant Protection Convention (IPPC) as the international standard for plant protection (WTO, 2018). The International Organization for Standardization (ISO), and other international standards-development bodies, also make a case for being useful in trade facilitation. By establishing international standards with significant global consensus, trade issues due to TBT and SPS issues can be prevented and/or rectified. The WHO has stated that “about 75% of the new diseases affecting humans . . . originate from an animal, or from products of animal origin” and that “All major zoonotic diseases prevent the efficient production of food of animal origin, particularly of much-needed proteins, and create obstacles to international trade in animals and animal products.” The U.S. must remain diligent and engaged in the standards development efforts of such organizations to continue to improve access to export markets.

Although several examples exist regarding the consequences that an animal health or food safety crisis can have on exports (e.g., avian influenza, porcine reproductive and respiratory system, etc.), the U.S. began the long process of learning about the ramifications of such a crises when bovine spongiform encephalopathy (BSE) was first detected in Mabton, WA on December 23, 2003. Immediately following the report of the detection, approximately 80 U.S. export markets closed their doors to U.S. beef. Through 2017, the U.S. is still working to recover some of those lost markets; access for beef products into the Chinese market was just re-established in May of 2017, but several markets remain closed to U.S. beef to this day (USMEF, 2018).

Initially, when the U.S. beef industry was struggling with market closures due to BSE, Cattle-Fax (using USDA pricing information) computed opportunity losses that were incurred by the industry as a consequence. On average, the beef industry lost $100/head for every fed steer and heifer marketed at the time, and those costs languished across many years as market access was re-established over time. As the percentage of U.S. market value for livestock that is comprised of exports continues to increase, the risk associated with such crises-like events in the future have even greater potential financial ramifications for the livestock industry.
One way that producers and processors may initiate programs to prevent loss of markets, or at least recovery of market access in the event of such crises, is via traceability—identification that is tied to information about production parameters for livestock. Interestingly enough, and despite the implementation of individual traceability systems worldwide by competitors, U.S. producers have been reluctant to implement similar programs (World Perspectives, Inc., 2018). A recent analysis of traceability for the National Cattlemen’s Beef Association by World Perspectives, Inc. (2018) showed that, had such mandatory traceability systems been in place in the U.S. following detection of BSE in Mabton, WA in 2003, recovery time would have been reduced and fed cattle would have been worth over $4.4 billion more in 2007-2009. And yet, despite such redundant evidence about the importance of providing traceability capabilities to export customers, roughly 60% to 80% of cow/calf, dairy, farmer-feeders, feedlot operators, seedstock producers, and stockers responded in the World Perspectives study that they would not voluntarily participate in such a traceability system. The U.S. must address this deficiency if it truly wishes to be an exporter of meat products; traceability that is tied to information about production parameters for livestock is expected in the export markets and is critical towards addressing perceived SPS issues.

As identified by the U.S. Meat Export Federation (US-MEF, 2018), potentially new SPS and TBT barriers on the horizon include provisions for product food safety (e.g., consider the zero-tolerance standard for presence of Salmonella spp. on products exported to China), prevalence of antimicrobial resistance, animal welfare issues (OIE had published a code addressing global animal handling expectations), policies reflecting the Precautionary Principle rather than science, domestic vs. Codex vs. zero tolerance policies for residues and/ or use of technologies, and continually improving sophistication of testing methodologies. Technical competency in trade negotiations will be increasingly important if the U.S. is to address barriers to trade.

**USE OF GROWTH TECHNOLOGIES**

One clear example of the complexity of SPS barriers is the case of impediments to trade that have developed as a consequence of using growth technologies in livestock production. Such technologies are used on a broader scope in North America than in similar production systems in other parts of the world. Use of the technologies leads to (a) clear improvements in production efficiencies and, hence, (b) improved sustainability and reduced environmental impact. Many have suggested that we MUST use such technologies if we plan to meet the needs of a growing global population (e.g., Jeff Simmons of Elanco; CAST, 2013). It is estimated that 90% of the growth in agricultural production, to feed the expanding population, must come from more intense production using technologies, or biotechnologies, that generate an equal nutrient density using the same land mass (Neumeier and Mitloehner, 2013).

Nonetheless, and particularly due to the political policies that were implemented in the EU during the latter part of the 1980s, society appears to have developed (or has been convinced of the need for) a fear of consuming products that are derived from livestock in which such growth technologies were utilized—even in light of both science-based and international Maximum Residue Limits (MRLs) for such compounds. Or, in some cases (e.g., China), such policies are implemented because rigorous self-policing is necessary and, therefore, internal rules must also be applied to external exporters. In China, as one example, there is zero tolerance for a total of 146 compounds; many are simply banned from use in imported products because their use became problematic domestically.

Chinese and EU policies, along with those of some other markets (e.g., Taiwan), do not conform to requirements of the WTO, as was demonstrated via arbitration using WTO as the dispute resolution authority. Despite their implementation of zero tolerance policies regarding use of growth technologies, the EU (formerly the EEC) position was (a) firstly debunked in 1982 via their own research conducted by an EEC Scientific Working Group led by Professor G. E. (Eric) Lamming of the U.K., which clearly refuted any human health consequences of using anabolic growth technologies in livestock production, and (b) a ruling, and subsequent loss upon appeal, by the WTO regarding the EU ban on the use of growth promotants; the WTO referred to the ban as a “nontariff trade barrier that does not comply with global trading rules.” In fact, international standards exist regarding MRLs for these compounds that have not been fully endorsed or adopted by meat importing nations.

As one example of how such ‘zero-tolerance bans’ can become complicated, consider the estrogenic compound of Zeranol, which is sometimes used as an ear implant in beef cattle (i.e., Ralgro). Zeranol, a naturally-occurring, estrogenic mycotoxin, can be detected in beef (and particularly in livers) from cattle that never receive a zeranol implant because zearalenone (the mycotoxin) can be generated by certain Fusarium species in grains that are fed to the cattle (Kennedy, 1998). Therefore, despite meeting the import requirements of a particular market from a production-practice standpoint, some beef products and/or the processing plants that they were produced in may still be rejected/delisted as a consequence of a mere biological anomaly.

Use of beta-agonists in North America is especially problematic in beef and pork export markets. With respect specifically to ractopamine hydrochloride supplementation, export problems result from tissue concentrations detected with sophisticated testing methodologies (i.e., LC/MS-MS) that can be affected by both the meth-
Concentrations in tissues of “parent” ractopamine, detected using sophisticated methods, reflect the amount of compound resulting directly from feed supplementation; most MRLs (including those of the U.S., established by FDA, for the specific target tissues of liver and muscle) are based on testing for parent ractopamine to ascertain whether residue levels are ‘violative’ or not from a food safety perspective. But, some export markets are beginning to implement testing methodologies that result in measures of tissue concentrations of “total” ractopamine, and then are applying those test results using inappropriate MRLs to off-target tissues. Total ractopamine refers to the detected concentrations of “parent” ractopamine plus the concentrations of metabolites in tissues. Ractopamine metabolites can undergo enzyme hydrolysis, catalyzed by beta-glucuronidase, which falsely increases detected concentrations of parent ractopamine. In markets that test for tissue concentrations of total ractopamine, false levels of parent ractopamine concentrations—particularly in off-target tissues—can be detected which, in turn, can lead to rejection and plant delisting by the importing country.

As an example of how inappropriate sample-handling and testing methodologies might lead to rejections of product, consider the importance of the Egyptian market for livers. Today, over 64% of U.S. beef livers are exported to Egypt (USMEF, 2018). Sample handling in Egypt (where every container of product is sampled and tested), due to the ambient temperatures and the concentration of beta-glucuronidase in liver, is critical to export success if they test for either parent or total ractopamine concentrations at customs. It is imperative that technical experts work with the Egyptian government to insure use of appropriate protocols for receipt of imported beef livers; similar issues can easily be extended to several products being exported to many different countries.

In addition to issues that can result from sampling and testing methods, data collected in our laboratories concerning use of beta-agonists suggest that (a) some ractopamine may be recirculating in the production system via feed tallow, (b) processing plant cross-contamination is possible due to concentrations of ractopamine in rinsates from variety meat tissues, and (c) different tissues retain differing concentrations of ractopamine during depletion studies. All of these factors severely complicate trade when growth technologies are used and importing countries do not abide by international or scientific standards.

CONCLUSIONS

All signs point to optimism for global meat trade. However, for the potential opportunities to avail themselves, developed and developing countries must aggressively continue to strive for true free trade in agricultural products. Furthermore, international standards bodies must continue to apply true scientific knowledge as standards are developed and implemented, and independent sovereign markets must be willing to recognize and establish import regulatory policy based on those standards. The impact of WTO dispute resolution must be greater—even if punitive measures are necessary—so that countries will abide by their findings. The world must more carefully consider policies that ban the use of agricultural technologies as many believe that such use may be the only alternative if we are to feed a growing population—this could morph into a humanitarian issue. Negotiators from the U.S. must take a more aggressive and strategic position to address technical barriers that have arisen and that violate both TBT and SPS provisions of trade agreements, particularly as such tactics continue to be used by other trading blocs as surrogates for protectionism. Never has this been clearer than recently, given issues that have arisen in relation to use of growth promotion technologies in North America and the impact that their use has had on technical issues surrounding meat export trade.

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REFERENCES


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Kicking U.S. Pork Exports Up a Notch: Delivering Producer Returns During a Critical Time

Dr. Craig Morris

INTRODUCTION

As domestic pork production continues to outpace domestic consumption, there has never been a more critical time to expand opportunities for U.S. pork exports around the globe. In fact, as U.S. pork exports accounted for nearly 30 percent of pork and pork variety meat production in 2017, the importance of exports to the continued—and future—success of the pork industry only increases. The pork industry is not alone in its dependence on exports to bolster sales and use product that exceeds domestic demand: agriculture is hugely dependent on exports now and going forward.

According to recent data, Fiscal Year 2018 agricultural exports are projected at $139.5 billion, down $500 million from the November forecast, largely due to a six-percent decline in oilseed and product exports that is only partially offset by increases in livestock, cotton and grain. Livestock, poultry and dairy exports are raised $800 million to $30.5 billion, led by higher forecasts for beef and pork. Simply put, exports are critical to the livelihood of the U.S. agricultural sector because trade spurs economic growth for America’s farmers, ranchers and their corresponding rural communities. U.S. agriculture has become acutely aware that 95 percent of the world’s consumers live outside of the United States and more than 20 percent of U.S. farm income is based on exports: Fully one-fifth of U.S. agricultural production goes to export markets.

It would seem that the importance of cultivating new global markets has been critical to the U.S. for some time, in fact. In a 2011 Congressional report, the growing importance of exports was noted to underscore the continued need for proactive and positive trade agreements specifically that addressed the need for export growth for agriculture. The report reinforced the importance of exports for the American agricultural sector noting, even then, the changing landscape for American agricultural exports over the past 20 years. Specifically, the report detailed that just two decades ago, just one percent of U.S. agricultural export sales went to China. This total increased to four percent by 2002 but, by 2012, China was the top destination for U.S. agricultural products, purchasing more than $25 billion in products that accounted for more than 18 percent of total sales.

Since that report was authored, the international trade landscape has only become more complicated. Yet, exports have continued to increase, year after year. In order to maintain, and even increase this export growth trajectory, the pork industry—and frankly, all of agriculture—will become more reliant on proactive, comprehensive and incredibly strategic international market development and marketing activities. The success of such efforts will depend, in large measure, on our ability to harness consumer research and insights to understand the opportunities and predict the challenges so that we can navigate around them.

This paper will explore the current export landscape for U.S. pork, but, more critically, look to what will be needed to build upon the success of recent years to safeguard producer returns and kick our collective pork exports “up a notch.”

2017: A RECORD YEAR FOR U.S. PORK EXPORTS

Raising demand in both the domestic and export markets is the key to supporting pork prices, with a continued surge of pork production. The critical and strategic examination of export markets are critical to raising demand for pork; and there has never been a more critical time for U.S. pork exports.

As domestic pork production continues to surge, the critical need to expand existing export markets, and identify and target new ones has never been greater. Beef, pork, broilers and turkey are all expecting increased production in 2018, up an expected 3.85 billion pounds to 103.94 billion pounds. Pork production, in particular, is expected to increase to 26.96 billion pounds, up 1.38
billion pounds. Additionally, the U.S. hog herd is at an all-time high of 73.2 million head. Industry slaughter capacity grew another eight percent in 2017 and is expected to rise another six percent in 2018 to compensate for this increase in production.

Based on the February World Agricultural Supply and Demand Estimates (WASDE), it is safe to say that there will likely be record pork production in the European Union, United States and Canada, and a pork production rebound in China in 2018. Globally, there could be more than two percent more pork produced, bringing global production to 113.5 million metric tons. There are several factors fueling this expansion in pork production, including good economic growth in both developing and developed markets, dietary pattern shifts in Latin America, continued low feed costs and a sustained period of relatively limited live animal disease impacts.

This is the fourth consecutive year of strong production growth for the major exporters and, as was the case for 2017, the U.S. will lead the major pork exporters in both domestic production grown and export volume growth in the 4.8 percent range, respectively. Global pork exports are expected to set another new record in 2018, up another one percent led by demand in Mexico, Philippines, Taiwan, Central and South America—offsetting continued export slowdowns in China, Hong Kong and Russia.

Last year was a record year for U.S. pork exports, which accounted for roughly 26.6 percent of pork and pork variety meat production. U.S. pork exports recorded the largest year ever in volume in 2017, selling more than 5.3 billion pounds of pork and pork variety meats, worth 6.48 billion dollars. Export value returned an average $53.47 per head back to producers in 2017, up six percent from 2016.
The United States is the second-largest pork exporter in the world, behind the European Union. Last year, U.S. pork exports accounted for fully 31 percent of the world’s pork exports. More specifically, however, 2017 was a record year for pork variety meat exports. 2017 was the first year that the value of U.S. pork edible variety meat exports surpassed 1.17 billion dollars—setting a new record. Last year, the U.S. exported 82 percent of its edible pork variety meat production, including hearts, livers and kidneys—products not typically consumed in the U.S.

Exports of pork, and more critically, pork variety meats, delivered incredible value to U.S. pork producers last year. Specifically, pork edible variety meat exports to China and Hong Kong equated to more than six dollars for every pig marketed in the U.S. Interestingly, in China, stomachs and ears receive a higher price than loins. In total, edible pork variety meat exports averaged $9.67 for every hog marketed—an incredible value for U.S. producers.

Perhaps more critical than simply moving volume of product overseas is ensuring that the U.S. pork industry is also diversifying its global market opportunities so as not to “put all of the U.S. bacon in one basket”—and 2017 proved the importance of that very concept. Specifically, the top markets for U.S. pork in 2017 included Mexico, China/Hong Kong and Japan. And though exports were down overall to China last year, U.S. pork variety meat exports still tied the 2011 export record and set a total value record, surpassing $1 billion.

Emerging markets in Honduras, Venezuela, and the Dominican Republic show some promise for U.S. pork sales as the diets of the consumers in those markets shift toward a more protein-rich diet. Further, as these countries’ consumers get more disposable income, they look to upgrade their diet, providing great opportunities for versatile proteins like U.S. pork. More of a selling feature: the price of domestic pork products—U.S. pork has a great price point, and it’s a safe, versatile product.
More than $53.47 per hog comes from these markets.

In 2017, export value averaged $53.47 for every U.S. hog marketed.

**TOP PORK EXPORTERS**
The U.S. accounts for fully 31% of all of the world’s pork exports.

1️⃣ E.U.  
2️⃣ U.S.

2017 was the 1st year the value of U.S. pork edible variety meat exports surpassed $1.17 BILLION RECORD BREAKING!
There are certainly challenges and opportunities for U.S. exports in the current global trade environment. Certainly, a slower demand for pork in China is likely to continue this year. Competitive pressure from the European Union is expected to continue, yet, Mexico is projected to boost its imports of U.S. pork due to our lower pork prices and strong processing demand. For the United States, exports to Korea, Mexico, Japan, Canada, Central and South America, will all serve as key markets to watch in 2018 given the challenges in China/Hong Kong and Brazil’s loss of the Russian market.

According to the February World Agriculture Supply and Demand Estimates (WASDE) report, both pork muscle cut and pork muscle cut plus pork variety meat export set records for the month of February on a volume and value basis. The growth in year over year pork muscle cut exports was led by Korea (more than the next four markets combined), South America, Canada, Central America, China/Hong Kong and the Caribbean. Unfortunately, the U.S. had reduced shipments to Mexico, Australia/New Zealand and just slightly to Japan.

Exports of pork muscle cuts to Canada were actually the highest since 2013 and South America set records with larger volumes to Columbia, Chile and Peru (setting a record month). Central America set records as well, led by the top market, Honduras, as well as impressive growth to Panama, El Salvador and Nicaragua. In total, the record February export numbers for pork and pork variety meats mean that exports accounted for fully 27.8 percent of U.S. production valued at fully $56.78 per head processed. This is up fully $4.84 per head from a year ago, or nine percent.
It is clear from February data that U.S. pork exports will continue to set records in both volume and value this year. Despite a projected challenging trade environment, international marketing efforts for our U.S. pork products will continue to make advancements in new and emerging markets abroad—and goals for our exports are lofty in terms of continued growth and delivery against producer investment in such efforts.

**ELEVATING INTERNATIONAL MARKETING**

Coming off a record 2017 for U.S. pork exports, U.S. pork producers and pork industry leadership are seeing a need for increased investment in, and prioritization of, international marketing efforts. For the first time, the National Pork Board (NPB) has included international marketing as one of its four focused organizational goals. This critical inclusion is a recognition of the important role effective international marketing will play in U.S. producer profitability during 2018 and the ability of our industry to sustainably grow in the future.

There is no doubt that the trade policy environment will be a challenging one for the United States, arguably for the foreseeable future. While the National Pork Board works closely with the National Pork Producers Council (NPPC) as they lead on trade policy issues, it’s important that advancement of export growth isn’t stymied by a lack of free trade agreements (FTAs), challenging trade restrictions or market access issues. International marketing efforts play a critical role in ensuring that despite any current or emerging trade policy issues, we can continue to foster growth in existing export markets and identify new potential homes for our U.S. products abroad.

As the National Pork Board has placed increased emphasis on international marketing, so too has it defined metrics for success for 2018 and beyond. Specifically, success will be measured by NPB’s ability to maximize the return on increased Checkoff investment in international marketing as well as by driving accountability with NPB’s strategic partners, including the U.S. Meat Export Federation (USMEF). Tactics to accomplish this lofty goal will include leveraging the U.S. pork packers, streamlining and harnessing the power of NPB’s new International Marketing Committee, and further leveraging the U.S. Meat Export Federation’s staff to maximize in-country investment.

First and foremost, NPB will work to build on the expertise of the pork packer community. All of the major U.S. pork packers are already engaged in comprehensive and strategic marketing efforts abroad. Success will lie in NPB’s ability to develop a comprehensive marketing plan that assesses current packer export tactics and goals, and then determines how the Pork Checkoff can best support U.S. pork export efforts for each packer. Stakeholder interviews will be conducted with each packer to determine where they are currently engaged, tactics being utilized and what further research, insights or aid would be necessary to continue increasing U.S. pork exports in 2018 and beyond. Such information will be critical in harnessing the current power of the industry, avoiding duplication and driving accountability forward for the entire U.S. pork industry.

Second, NPB restructured its former Trade Committee to be a committee now focused specifically on international marketing. In doing so, the NPB wisely reduced the committee size and augmented committee membership with representatives from all facets of the industry. This smaller, but more experienced, committee will be leveraged throughout 2018 and beyond at key international trade and export events, on international mission trips and in-country meetings with key industry partners and stakeholders. Most critically, the Committee will be utilized to help drive accountability and provide key guidance on
investment activities of the U.S. Meat Exports Federation and the National Pork Producers Council—as well as other partners—to help determine where resources should be invested, measure return on that investment and support decisiveness in decision making and accountability.

Critically, NPB will also work to significantly leverage its strategic partner, USMEF, in its international marketing activities. Specifically, the USMEF will integrate its in-country marketing staff into the Checkoff’s programs, providing a greater understanding and opportunity for synergies between the domestic marketing and multicultural strategies and opportunity for shared learnings. For 2018, NPB’s investment in International Market Promotion, Development and Research will fund the partnership with the USMEF to elevate U.S. pork as the global protein of choice. Specifically, USMEF will conduct Pork Checkoff-funded activities in 13 different regions, representing 80 markets. U.S. Pork will be represented at 26 World Trade Show events scheduled in 2018. Pork Checkoff dollars are also being leveraged to conduct 466 retail events, 235 Food Service events, 201 e-commerce & world consumer activities and 1,442 further processing and trade show events. All these activities help promote the unique value and quality of U.S. pork products in new, emerging and growing markets.

With the Pork Checkoff funded activities, USMEF forecasts U.S. pork exports to increase five percent in volume in 2018. Throughout the year we will communicate these significant returns to our membership, helping producers better understand their investment and the continued importance of exports in producer returns. Finally, this partnership with USMEF will be leveraged to help inform our NPB Domestic Marketing Program of the pork demand drivers of the various immigrant populations that are a significant component to the growing fabric of the U.S. marketplace.

All of these efforts, combined, will be utilized as tactics towards the ultimate goal of elevating international marketing in an effort to increase U.S. pork exports and deliver impressive, and increasing, returns on producer investment. Key to all of these tactics is research and insight meant to identify challenges and opportunities for U.S. pork products in global markets—research that will be critical to overcoming obstacles and growing demand for U.S. pork abroad.

**DOMESTIC INSIGHTS AND U.S. PORK PRODUCTION ADVANTAGES**

The NPB approved $8.77 million for 2018 international marketing activities, a significant increase in the investment in marketing activities overall, and an even greater investment in international versus domestic. Perhaps this ten percent increased investment in international marketing is a reflection of the potential growth in global pork consumption as compared to the relatively flat year-over-year domestic pork consumption. That said, NPB is still looking to find ways to increase pork consumption in the United States.

Compared to insights on global consumers, however, NPB’s investment over the last decade into informative consumer research and insights has yielded impressive results and provided critical data needed to help market pork domestically and provide consumers answers to their burning questions about pork production. Over the years, countless studies have been done showing that consumers’ desire to understand more about food and agriculture production—from farm to fork—has only continued to increase. Radical transparency became the advice for agriculture; telling our story in an open, honest and realistic way about how food is raised and produced. As such, research was conducted about how to tackle tough topics like antibiotic use, farm size and housing issues like gestation crates.
Such studies were conducted on a domestic basis, looking to examine how the U.S. consumer wanted to be communicated to, about what, and in what manner would make the most impact. That research has segmented, and re-segmented the consumer, drawing lines for which messages work for which audiences and how those messages should be delivered for maximum impact. The results of such studies have been critical in guiding how pork has been marketed to our domestic consumer.

For example, according to a recent “consumer perception study” conducted by the U.S. Farmers and Ranchers Alliance (USFRA), animal care concerns are on the rise—and potentially the biggest threat to long-term consumer trust, while other topics of recent interest, like genetically modified ingredients (GMOs) appear to be declining or leveling off, based on year-over-year trendlines.10 Animal Care perceptions—including those around antibiotic use—are potentially the biggest threat to long-term trust in the agriculture industry today. According to the same study, consumers in the U.S. are also highly motivated by absence claims or “no” language. Consumers are focused on the absence of things in very specific ways – no antibiotics, no hormones, no GMOs, etc. This trend even dominates over the broad category of organics.

These examples of consumer insights in the U.S. serve to illustrate how the pork industry is working to market product and be proactive in answering questions on how pigs should be raised today. For example, such insights—nearly ten years ago—led, in part, to the development of the We Care® initiative by the NPB. The We Care® initiative was launched in 2008 as a joint effort of the NPB, the National Pork Producers Council and state organizations representing farmers. We Care® is a proactive, multifaceted initiative to promote responsible practices in all areas of farming and is a commitment to continuously evaluate and improve pork production methods.

The effort has two fundamental messages: First, it strongly encourages farmers and employees to understand and consistently use best practices in raising animals. Second, We Care® is a promise to the public that as an industry, America’s pig farmers are committed to responsible and ethical animal agriculture. Pork producers understand trust is something that must be earned. Through the We Care® initiative, they hope to earn the public’s trust by making this industry better for all concerned — animals, farmers, food industry partners and consumers worldwide. To further demonstrate that commitment, the pork industry already offers numerous programs, including Pork Quality Assurance® Plus (PQA Plus®) and Transport Quality Assurance® (TQA®), to support animal well-being and maintain a safe, high-quality supply of pork. The We Care® initiative ties everything together to help the public view the pork industry as a self-regulated business that earns the trust of others.

The We Care® initiative not only helps to improve animal care and handling on U.S. pork farms, but more critically it helps answer the questions on the minds of consumers—in an open, transparent and honest manner. Domestic insights for years have indicated that consumers don’t want sound bites, they want a depth and breadth of truthful information available, should they seek it out. That information needs to be credible, and factual and provide the assurances necessary to consumers so that they have the permission to enjoy pork products. Simultaneously, there is much work being done to provide consumers with information about pork taste, quality, cooking recommendations and recipes as well.

This year, $3 million is budgeted for a partnership with YouTube and Google, which will help provide insight as to how consumers are searching for pork, and ways the NPB can reach more customers. The NPB is working with Yummly®, a mobile phone app, to direct consumers on ways to cook and use more pork. These efforts are a way to help customers get back to the basics and reiterate the lower cooking temperature of pork, which helps improve flavor and eating experience. Yummly™ will utilize the nearly 30 years of recipes that the NPB has compiled to deliver to its 20 million monthly users.

Research has indicated that focus should be placed on the pork loin, for example, which is known to be lean and quite often overcooked by consumers. While there are some consumers who understand how to properly cook a pork loin—and celebrate those efforts on social media and other platforms—there are many others who indicated a fear or risk in purchasing pork loin, driven by a misunderstanding or lack of knowledge in how to properly prepare it.

Consumer outreach often allows for NPB to reiterate the cooking temperature of 145 degrees with a 3-minute rest to ensure a better eating experience. New photos of the pork loin cooked at a medium-rare appearance, in an upcoming campaign for example, will help show that the loin can be juicy and delicious.

While there is certainly much work being done domestically by NPB, and others, to provide information to consumers about recipes and cooking methods for pork products, these simultaneous efforts to provide information on the social responsibility of the U.S. pork industry are critical—and are happening thanks to valuable domestic consumer insights gleaned from years of research and study.

**FOOD FORESIGHT AND PORK 2040**

While more than a decade of in-depth, comprehensive research exists for how to motivate and engage the domestic consumer, significantly less research and insights exist for the global consumer. Perhaps this is due to a more complicated study need to map consumer preferences across countries and continents—each diverse markets and likely accompanying consumer preferences. Nevertheless, this data and research are invaluable as international marketing is elevated and the value of exports is higher than ever before.

In 2018, NPB will again make a significant investment in the International Trade Market Access Research and Analysis to support the industry’s investment in the American
Pork Export Trading Company (APEX) in defense of current market access in Canada (predicted to increase +3 percent in volume), Mexico (predicted to increase +5 percent in volume), Korea (predicted to increase +4 percent in volume), Japan (predicted to increase +4 percent in volume) and China (predicted to increase +3 percent in volume); industry efforts to grow market access in Australia, South Africa, Thailand, Taiwan, Singapore; and industry efforts to obtain new market access in Brazil, India, Jamaica, Nigeria and Paraguay.

Overall, this partnership is expected to increase exports in South America by 10 percent, Central America by 11 percent, Oceania by six percent and the ASEAN region by 13 percent, respectively in volume. Importantly, this investment will also help support advocacy for the development and/or maintenance of science- and risk-based international standards with Codex and the World Organization for Animal Health (OIE)—working in close concert with our strategic partners at the NPPC to ensure that the Pork Welfare Chapter under development incorporate We Care® principles and that any food safety standards under development within Codex respect the quality standards we adhere to domestically. Lastly, NPB will partner in exploratory trips, including one to the European Union to discuss African swine fever, and ensure that we hold imports to science-based standards.

But this research is only the tip of the iceberg compared to what is needed to dramatically increase exports of U.S. pork—and more critically, global consumption of pork and pork products. The pork industry has committed, through NPB and its strategic partner USMEF, to engage in a comprehensive research study, termed “Pork 2040” that will dramatically increase the valuable global consumer insights we have and need in the future. Pork 2040 is a line of research that could identify large, sweeping ideas of change in the various export markets for U.S. pork that will have an impact on pork demand over the course of the next 20-plus years.

In 2018, NPB will aim to better understand Pork 2040, set research goals for the coming years, leverage new insights to realign strategic partners around export goals and become thought leaders in the field. This international marketing study will go beyond the quantitative numbers of demand, production and market access and will look at other relevant factors that shape consumers’ opinions, and hence the markets, for pork and pork products over the next several decades. In addition to analyzing linear consumer trends, this research will also look at trends in the development of new production and marketing technologies, new environmental concerns and new legal, trade and regulatory regimes around the globe.

This research will examine factors like housing and, specifically, kitchen layout and size in global markets. Specific data-points like that, which go beyond basic trend and consumption information, will help international marketing efforts by being more targeted. For example, if the research shows that Asian developers are no longer building kitchens in new high-rise apartment complexes, not only does that indicate a decrease by that population in a desire to cook and prepare home-cooked meals, but it also indicates a necessity to focus pork marketing efforts on restaurants and meal preparation/delivery services as opposed to in-store retail displays and recipes developed for the home cook. Such insights are invaluable as the NPB and its partners look to deploy resources in the most strategic and meaningful way—maximizing return on producer investment.

Comprehensive research like this is vital to our international marketing efforts—both this year and in the future—as we need to stay ahead of the curve and make sure we can take proactive steps to market products in new and emerging markets for years to come.

**CONCLUSION**

Last year, 2017, was a record year for U.S. pork exports—and such records were set amid a backdrop of surging domestic pork production and steady, if not slightly declining, domestic pork consumption. As a result, investment in international marketing efforts has never been higher, and pork industry leadership recognizes the critical role that exports will play in the continued success of the U.S. pork industry. While expectations are high, there are challenges to overcome as international marketing is elevated as a key industry-wide goal.

Specifically, a challenging trade environment for the foreseeable future means that international marketing efforts are even more critical—increasing demand and consumption for U.S. pork in emerging and developed global markets will be key. But perhaps the most critical need is that of focused, insightful and comprehensive research about the global consumer so that resources can be deployed strategically to yield maximum value and return on producer investment. Contrasted with the breadth and depth of domestic consumer data and insights that we currently have, we lack such a repository of information on the global consumer and global market trends. NPB and others are working to address this critical need in 2018 and beyond—working to blend the domestic insights and research we have, leverage our domestic programs like We Care® and more to tell our story and market our products abroad.

**ENDNOTES**

1. The Economic Contribution of America’s Farmers and the Importance of Agricultural Exports, 2011, Congressional Report
2. US Meat Export Federation Data
3. USDA & US MEF Export Data
4. US Meat Export Federation Data
5. U.S. Meat Export Federation Data
6. U.S. Meat Export Federation Data
7. U.S. Meat Export Federation Data
8. WASDE Report February 2018
9. WASDE Report February
10. USFRA Consumer Perception Study
The Effects Of Genetics and Nutrition on the Incidence of Woody Breast Meat and Proteomic Methods to Characterize Poultry Meat Quality Defects

Xue Zhang, Jasmine Hendrix, Wei Zhai, Surendranath Suman, and M. Wes Schilling*

INTRODUCTION
Woody breast (WB) and pale, soft, and exudative (PSE) meat are quality defects associated with breast meat from approximately 30-50% of broilers harvested in the United States since 2016. PSE meat has an undesirable pale color, soft texture, and surface moisture that leads to an unacceptable appearance at retail display (van Laack et al., 2000). Woody breast meat has a hard, tough texture at the cranial and/or caudal portions of the breast. The WB defect results in reduced water holding/binding capacities in fresh and marinated broiler breast meat. Mudalal et al. (2015) reported that WB fillets had less marinade uptake and greater cook loss in both non-marinated and marinated broiler breast meat. Kuttappan et al. (2017) reported that the expression of severe WB was associated with a greater broiler age at the time of slaughter and a greater live bird weight. These researchers also stated that severe WB fillets were thicker, lighter in color and lower in water holding capacity in comparison to normal meat. Instrumental texture measurements of cooked breast meat suggested that fillets with the severe WB condition were harder, chewier, more crunchy and fibrous than normal breast fillets (Aguirre Cando, 2016; Chatterjee et al., 2016).

Previous research demonstrated that there was a correlation between the abundance of certain proteins in the breast meat tissue and whether broiler breast meat was PSE, WB, or normal (Desai et al., 2016; Cai et al., 2018). Research is being conducted to build upon this knowledge using proteomic tools, including two-dimensional gel electrophoresis and mass spectrometry to evaluate the evolution of the proteome from live muscle to both pre-rigor and post-rigor meat. This paper briefly describes the effect of genetics and nutrition on the incidence of PSE and WB meat, the use of proteomic tools to determine biochemical pathways associated with PSE and WB meat development, and provides a synopsis of the relationships between the gut microbiome, proteomics, and meat quality to assist the poultry industry in minimizing the incidence of quality defects.

INITIAL RESEARCH ON GENETIC AND NUTRITION EFFECTS ON PSE AND WB INCIDENCE
A total of 1,200 broilers (5 breeds that are currently used in commercial poultry production: A1, A2, A3, B1, B2) were raised for 8 weeks at the Poultry Research Farm at Mississippi State University. Commercial and reduced essential amino acid diets (20% reduction of digestible lysine, total sulfur amino acids, and threonine) were fed to broilers. Post slaughter, 32 broilers from each treatment was evaluated for live weight, carcass weight, part weight, breast pH, and breast color. The quality defects [PSE and WB] of chicken breasts were also evaluated where 0 = normal, 1 = slight, 2 = moderate, and 3 = severe. The pH was measured at 15 min and 24 h post processing, and color was measured 24 h post processing.

When broilers were harvested at 6 weeks (Table 1), 81% of B1 broiler birds that were fed the control diet expressed the WB condition, with an average value of 1.8. This value was similar (P>0.05) to that of A1 which scored 1.7. In addition, feeding an amino acid limiting diet led to large reductions in WB incidence in B1 and B2 (P<0.05) but had minimal impact on WB incidence in the 3 A breeds that were evaluated. This indicates that WB incidence is impacted predominantly by genetics in both cases, but that nutrition has more of an impact on WB incidence.
Table 1. Average woodiness scores for broiler breast meat, carcass and breast weights of broilers from 5 genetic strains of commercially available broilers that were 6 weeks in age and fed a typical industry diet and a diet that was reduced in concentrations of essential amino acids (digestible lysine, total sulfur amino acids, and threonine).

<table>
<thead>
<tr>
<th>Breed</th>
<th>Diet</th>
<th>Woodiness</th>
<th>Carcass (kg)</th>
<th>Breast (g)</th>
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<td>A1</td>
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</tr>
<tr>
<td>A1</td>
<td>Reduced</td>
<td>1.56&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>1.93&lt;sup&gt;de&lt;/sup&gt;</td>
<td>555&lt;sup&gt;c&lt;/sup&gt;</td>
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<tr>
<td>A2</td>
<td>Control</td>
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<td>564&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
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<td>Reduced</td>
<td>1.06&lt;sup&gt;ab&lt;/sup&gt;</td>
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<td>497&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
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<sup>abcd</sup> superscripts with different letters indicate differences (P<0.05) within each column.

Woodiness Scale: 0 = normal, 1 = slight, 2 = moderate, and 3 = severe

in B2 and B1 broilers than in the A genetic strains. For the control diet, B1 had greater breast weight (P<0.05) than the other treatments with the exception of A1. For the A breeds, breast meat correlated with carcass weight. For B broilers that were fed with control diet, B1 had a similar carcass weight to B2, but had a greater amount of breast meat (P<0.05) than B2. Similar results were seen for the 8 week old broilers. For 8 week old broilers, the B1 had greater (P<0.05) breast weight than all other treatments. However, feeding the reduced diet caused greater than 200 g less breast weight in the B1 when compared to the control diet and 140 g less for the B2. In addition, the breast weight differences between the control and reduced diet treatments was much greater in the B breeds than the A breed.

Differences existed among treatments (P<0.05) with respect to cooking loss, shear force, pH and lightness, but all samples were tender (<45 N) and average shear force for each treatment was much less than 45 N. In addition, pH and cooking loss values were similar to those reported in literature (Cai et al., 2018). CIE L* values (lightness) were greater than what is typically reported in literature (Cai et al., 2018) but still had a low incidence of PSE meat.

For 6 week old broilers there was greater than 15% severe WB in the A1 and B1 control diet treatments and the A1 reduced diet treatments. Feeding a reduced diet to B1 led to a decrease from 62.5% of moderate and severe WB to 25%. In addition, the A3 and B2 had the least incidence of WB meat, which was minimized with the reduced diet. Similar results were seen for the 8 week old broilers. However, the only treatments that had a relatively low incidence of WB meat was the B1 and the B2 reduced diets. B1 and A1 breeds had the greatest incidence of WB meat. Feeding a diet that was rate limiting in amino acid density led to greater reductions in WB incidence in B but not in A breeds. In addition, when a diet with reduced essential amino acids was used, the reduction in breast meat was much greater in B breeds in comparison to A breeds.

**PROTEIN MARKERS ASSOCIATED WITH MEAT QUALITY DEFECTS OF BROILERS**

Proteomics is a tool that is used to study a set of proteins which contains information on gene expression and protein translation (Petracci and Cavani, 2012). Two analytical procedures are commonly used in proteomics: two-dimensional gel electrophoresis for protein separation and mass spectrometry for protein identification. In recent years, proteomics has been applied to detect proteomes as protein biomarkers of poultry and to elucidate the link between proteome biomarkers and poultry meat quality (Molette et al., 2005; Mekchay et al., 2010; Paredi et al., 2012, Schilling et al., 2017).

In a study conducted by Desai et al. (2016), 15 proteins were expressed differently in normal and PSE chicken breast meat. Compared with normal breast meat, 11 proteins [actin alpha, myosin heavy chain (in 2 different spots), phosphoglycerate kinase, creatine kinase M type (in 2 different spots), beta-enolase, carbonic anhydrase 2, proteasome subunit alpha, pyruvate kinase, and malate dehydrogenase] were over-expressed and 4 proteins (phosphoglycerate mutase-1, alpha-enolase, ATP-dependent 6-phosphofructokinase, and fructose 1,6-biphosphatase) were under-expressed in PSE meat. These proteins are known to be involved in glycolysis, proteolysis, muscle contraction and ATP generation.

Cai et al. (2018) observed the differences between the whole muscle proteomes of woody and normal breast meat samples. They found that 6 proteins (myosin regulatory light chain 2, 14-3-3 protein gamma, serum albumin, protein deglycase DJ-1, phosphoglycerate mutase 1, and carbonic anhydrase III) were over-expressed and 2 proteins (creatine kinase M-type and triosephosphate isomerase) were under-expressed in WB when compared to normal breast meat. The differences in proteomes between normal and WB meat indicated that there was an increased oxidative stress in WB when compared to normal breast meat. Overall, proteomics has been observed to be a promising tool to detect and identify protein biomarkers associated with PSE and WB meat. This technology offers information pertaining to biochemical pathways and genetic variation of meat quality.

**APPLICATION OF PROTEOMICS AND METAGENOMICS IN UNDERSTANDING BROILER MEAT QUALITY**

The quality traits of muscle foods are influenced by genetics, nutrition, environmental factors, and processing conditions (Mekchay et al., 2010; Paredi et al., 2012;
Zapata et al., 2012; Marino et al., 2014; Canto et al., 2015; Franco et al., 2015;). However, the underlying molecular mechanisms are far from understood. Current research includes the effect of genetic strain and diet on the development of PSE and WB meat. In addition, proteomics is being utilized to meet the following 2 objectives: 1) To characterize biochemical pathways in live muscle, pre-rigor meat and post-rigor meat to explain the biochemical pathways associated with woody breast meat development and mechanisms for the whole muscle proteomes in woody breast meat; 2) To evaluate biochemical and proteomic differences in genetic strains that produce woody breast meat to characterize the genetics and biochemical pathways that are consistent with the production of woody breast meat. To elucidate the impact of nutrition and genetic strain on broiler breast meat quality, transcriptomics is being conducted on muscle tissue that was excised at the time of slaughter. In addition, samples were taken from the cecum of the broilers at the time of slaughter and the microbiota is being used to determine differences in gut health between broilers that produced woody breast meat and broilers that produced normal meat (Brisbin et al., 2008; Stanley et al., 2014). The cecal microbiota is being elucidated based on the 16S rRNA gene sequence to evaluate the impact of microbiota on broiler growth and the development of WB meat.

CONCLUSIONS

The differences in proteomes of (normal and PSE, normal and woody) broiler breast meat are being elucidated. Characterizing the differential abundance of proteome components and the biochemical pathways (in the muscles from harvest to rigor mortis) associated with those components will identify potential biomarkers for PSE and woody broiler breast and can help develop strategies to minimize the incidence of these quality defects in the poultry industry. In addition, we will be able to determine how proteome abundance correlates to the transcriptome, gut microbiota and instrumental analysis, sensory properties, and consumer acceptability of broiler breast meat.

LITERATURE CITED

INTRODUCTION
Dark cutting beef is considered a meat quality defect because its increased pH (> 5.8) is conducive to microbiological growth, decreased shelf-life, and decreased food safety (Tarrant, 1989), and its dark colour is unfamiliar and unappealing to most consumers (reviewed by Ponnampalam et al. 2017). An increased pH has also been associated with decreased palatability through increased toughness and/or reduced flavor (Dransfield 1981; Jeremiah et al., 1991; Purchas 1990; Purchas and Aungsupakorn 1993; Holdstock et al. 2014; Mahmood et al. 2017); hence penalties are applied to dark cutting carcasses in North America.

Dark cutting is caused by depletion of glycogen in muscle from ante-mortem stress or activity. Bulls (Warris et al., 1994) and heifers (Mahmood et al. 2016a) have been identified as having an increased likelihood of producing a dark cutting carcass although there is evidence to the contrary (Lorenzen et al. 1993; Mach et al. 2008), but even with mindful management of these populations, dark cutting persists and pervades all sexes including male castrates (steers). This pervasive persistence may be due to glycogen in muscle being used when animals brace during transport (Immonen et al. 2000) or due to the stress that may be associated with loading and unloading (Pettrford et al. 2008). It may also be due to the widespread use of growth promoting technologies (steroids, ractopamine), which have been associated with increased likelihood of dark cutting (Scanga et al. 1998).

Sub-populations of dark cutting carcasses have been identified that have muscle pH values below 5.9 (Page et al. 2001), which Holdstock et al. 2014 found to be significantly tougher than normal beef and dark cutting beef with pH values above 6.0 (Jeremiah et al. 1991; Purchas 1990; Holdstock et al. 2014). Putative dark cutting categories are atypical (AT) dark cutters with m. longissimus thoracis (LT) pH of less than 5.8, borderline (BD) dark cutters with LT pH of between 5.8 and 6.0, and typical or classic (CL) dark cutters which have an LT pH of greater than 6.0. The sub-population of AT and BD dark cutting carcasses accounted for about 28% of the 179 dark cutters carcasses surveyed by Holdstock et al. (2014), with 6% being AT and 21% being BD of the 28% (Holdstock 2012). The AT and BD carcasses appear to have sufficient glycogen to produce beef of normal colour, but either do not achieve or require much longer than ‘normal’ carcasses to achieve an intramuscular pH less than 5.8 and a lightened colour (Holdstock et al. 2014; Mahmood et al. 2017).

FACTORS AFFECTING THE INCIDENCE OF DARK CUTTING
The accepted cause of dark cutting is the depletion of glycogen in the muscle, but the factors that affect its incidence are difficult to define. The incidence of dark cutting and whether it is typical or atypical dark cutting may not be related to muscle fiber type as Holdstock et al. (2014) showed no differences existed in muscle fiber area or proportion of type between normal and atypical and typical dark cutting m. longissimus thoracis, although others (Hunt and Hedrick 1977; Wegner et al. 2000; Zeroula and Stickland 1991) have found associations. The incidence of dark cutting may be affected by dry matter intake, because Mahmood et al. (2016a) found that as dry matter intake increased, the likelihood of cutting dark decreased; however, dry matter intake was not a factor affecting the incidence of dark cutting in a population of heifers subsequently studied (Mahmood et al. 2016b). Dark cutting carcasses have been noted to have lighter weights than normal carcasses (McGilchrist et al. 2012; Holdstock et al. 2014), with McGilchrist et al. (2012) finding that dark cutting carcasses exhibited a lack of muscling as well. McGilchrist et al. (2016) found that increased muscling was not associated with increased glycolytic potential; rather it was associated with increased oxidative capacity, suggesting that the oxidation of lipids may be favored thus sparing glycogen (Mahmood et al. 2016b). Results
from Mahmood et al. (2016a, b) supported previous research that indicated that the incidence of dark cutting was highest in heifers and also agreed with the results of McGilchrist et al (2012) by finding that cattle with small rib eye areas had an increased likelihood of producing a dark cutting carcass. Mahmood et al. (2016a) also found that the likelihood of producing a dark cutting carcass decreased as animal live and carcass weight, and age daily gain increased, suggesting that cattle with the greatest potential for dark cutting were cattle that were small and growing slowly. The results of Mahmood et al. (2016a) also indicated that different carcass characteristics were associated with the incidence of dark cutting in heifers and steers, with the carcasses of heifers that dark cut being low in fat depth, marbling score, carcass weight and rib eye area, while steers producing dark cutting carcasses had bimodal characteristics of either low or high carcass weight and rib eye area. These and other results of Mahmood et al. (2016a) suggested that there is not one phenotype reliably related to the occurrence of dark cutting, as decreased live weight in heifers and depressed carcass weights in both sexes appeared to be related to dark cutting. Mahmood et al. (2017) found that the relationship between phenotype and the incidence of dark cutting could be superseded by handling conditions prior to slaughter, with typical dark cutting carcasses arising primarily from cattle held in lairage for 72 h (a weekend) prior to slaughter, and atypical dark cutting carcasses being produced by cattle held in lairage between 5 and 8 h prior to slaughter. These results suggested that establishing a particular phenotype at risk of dark cutting would be difficult and perhaps only achievable on a situation by situation basis.

PROTEOMICS OF DARK CUTTING BEEF

Proteomic analyses by Mahmood et al. (2018) indicated that in typical dark cutting carcass LT muscle, actin, glycogenin-1, isoform beta-2 of protein phosphatase, and ras-related nuclear protein (RAN) abundances were increased relative to LT from normal carcasses. Glycogenin-1 is a muscle-specific glycosyl-transferase that binds glucose to itself and serves as the protein anchor for initiating glucose polysaccharide chains. Once the polysaccharide chains are 10 to 20 glucose residues long, glycogen synthase elongates them by continuing to add glucose, binding to glycogenin in the process (Testoni et al. 2017). Isoform beta-2 of protein phosphatase (PPM1B) is a de-phosphorylating enzyme with broad specificity. Among its targets are PRKAA1 and PRKAA2 which encode AMP-activated protein kinase (AMPK), the energy sensor of the cell, the de-phosphorylation of which would reduce AMPK activity (Ross et al. 2016), but this de-phosphorylation can be overridden by auto-phosphorylation at other phosphorylation sites within AMPK (Woods et al. 2003). It may also simply be upregulated in readiness for binding to the ATP site 3 on AMPK once AMP levels are reduced, which removes steric hindrance of the Thr172 phosphorylation site making it vulnerable to phosphatases (Ross et al. 2016), allowing cell metabolism to be quickly switched away from glycogenin-driven glycogen accretion. PPM1B also reduces necroptosis by dephosphorylating receptor-interacting protein 3 (Rip3) in mice (Chen et al. 2015), suggesting that profound reduction in cellular energy source puts cells at risk of programmed death. RAN is a small GTP binding protein that is essential for the translocation of RNA and proteins into the cell nucleus, and is involved in the control of DNA synthesis and the cell cycle (https://www.ncbi.nlm.nih.gov/gene/5901).

Mahmood et al. (2018) also found that in the soluble protein fractions from AB and TB muscles, myomesin-1, adenylate kinase isoenzyme 1, peroxiredoxin-1, desmin, and spermine synthase abundances were reduced relative to normal LT muscle. Myomesin-1 is a protein associated with stabilizing thick filaments within the sarcomere at the M-line and so is located in the sarcoplasm (Reddy et al. 2008). Desmin is also a major cytoskeletal protein that provides mechanical strength throughout the sarcomere and costamere (Costa et al. 2004), and the presence of both myomesin-1 and desmin in the cytosol may reflect increased release from the cytoskeleton pre- or post-mortem. It may also indicate that the muscle is undergoing degradation, as desmin is up-regulated during muscle degeneration (Costa et al. 2004). Adenylate kinase isoenzyme 1 (myokinase) reversibly catalyzes the reaction 2ADP to ATP and AMP, thereby minimizing the concentration of ADP. Peroxiredoxin-1s is a second messenger in redox signaling, and its reduced abundance may allow for increased oxidation and activation of target proteins by free peroxide through disulfide bond formation (Jarvis et al. 2012). Spermine synthase catalyzes the synthesis of spermine from spermidine, which may enable atrophic processes as spermidine has been associated with reducing sarcopenia (reviewed by Cervelli et al. 2018).

Mahmood et al. (2018) observed increased abundances in the atypical LT muscle of alpha-crystallin-B chain, protein Dj-1, phosphotidylethanolamine-binding protein 1, heat shock 27 kDa protein 1 (HSPB1) and thioredoxin-dependent peroxide reductase relative to normal LT. Protein Dj-1 is a multi-functional protein that regulates transcription and oxidative stress, and can act as a chaperone and a protease (Ariga et al. 2013). In what capacity protein Dj-1 is acting in atypical dark cutting muscle is unclear, but if it is acting as a chaperone it may be another protein associated with tough beef. Phosphatidylethanolamine-binding protein 1 (PEBP1) is a serine protease inhibitor (Hengst et al. 2001) and its increased abundance suggests that it also may be involved in the reduced tenderness of atypical dark cutting beef. PEBP1, also known as Raf kinase inhibitory protein (RKIP), may be increased in atypical dark cutting beef muscle as it enhances the activity of glycogen synthase kinase-3 (GSK-3)(Al-Mulla et al. 2011). Thioredoxin-dependent peroxide reductase is another enzyme that protects cells against oxidants (Chae...
et al. 1994), and has been associated with color stability of lamb (Gao et al. 2016).

That the abundances of the small heat shock proteins alpha-crystallin-B and HSPB1 were increased in the soluble protein fraction of the tougher atypical LT but not normal or typical LT agrees with the results of Bernard et al. (2007), who found positive associations between cooked meat toughness and these proteins. Pulford et al. (2009) also found that the reduced tenderness of beef with pH values between 5.8 and 6.3 was related to increased abundances of heat-shock proteins, which can bind to myofibrillar proteins; however, if they were bound to proteins, they would not be in the soluble portion of the muscle. In contrast, Mahmood et al. (2018) found that alpha-crystallin B chain and HSP27 abundances were reduced in the insoluble protein fraction relative to normal LT in both atypical and typical dark cutting LT muscles, indicating that a lower concentration of heat shock proteins were bound to proteins in the dark cutting LT than in normal LT. These results suggested that the presence of heat shock proteins in the insoluble myofibrillar protein portion was not indicative of cooked beef toughness, but rather that their presence in the soluble portion was. Ding et al. (2018) found that unbound HSP27 reduced the degradation of troponin-T and desmin by μ-calpain and the degradation of troponin-T by caspase-3, providing evidence to support this hypothesis.

Mahmood et al. (2018) also noted that abundances of soluble glyceraldehyde-3-phosphate dehydrogenase, L-lactate dehydrogenase, glycerol-3-phosphate dehydrogenase, and creatine kinase, all of which are proteins associated with glycolysis and energy conservation were reduced in atypical dark cutting beef post mortem. These results indicated that glycolytic potential was compromised in the atypical dark cutting beef population only, and may indicate that the rate of glycolysis in this population would be compromised; indeed, it was in this population only that intramuscular pH continued to decline up to 7 days post mortem (Mahmood et al. 2018). The rate of glycolysis would also be depressed during glyco gen replenishment by decreased glycogen phosphorylase activity as glycogen phosphorylase would be inhibited by glycogen synthase (Bräu et al. 1997).

Genetics of Dark Cutting Beef

Given that only a proportion of the slaughter cattle population produces dark cutting carcasses, there is the possibility that some cattle are more prone to dark cutting than others due to genetic differences. If cattle are assumed to experience the same amount of physical stress ante-mortem, then it would be the rate of recovery from the stress that could be potentially affected by animal genetics. Holdstock et al. (2014) hypothesized that the rate of recovery from stress varied with animal, and Mahmood et al. (2016b) recognized that resistance to stress may lie in the availability of liver glycogen (Gardener et al. 2014) for repletion of muscle glycogen (Jacob et al. 2009). Consequently, dark cutting carcasses may arise from cattle that are genetically predisposed to slow glycogen synthesize or reduced ability to store liver glycogen.

Genomic analyses to date in my laboratory in collaboration with Livestock Gentec have indicated that genetic influence on the incidence of dark cutting is most likely limited, although single nucleotide polymorphisms were observed in genes associated with molecular transport, cell growth and proliferation, and carbohydrate metabolism. Single nucleotide polymorphisms specifically related to carbohydrate metabolism identified were involved in metabolism, synthesis and quantity of glycogen, suggesting that there may be differences in energy storage and metabolism between animals.

Conclusions

Management of cattle to prevent dark-cutting should therefore focus on supplying sufficient energy prior to transport and reducing the cumulative effects of stressful production practices by ensuring complete payout of steroids and minimizing loading and unloading and handling of cattle in the days prior to slaughter.

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INTRODUCTION

Marination originated to provide a consistent positive eating experience along with economic benefits. However, marination or enhancement has a plethora of uses and benefits. We will take a journey through examples of how marinades have evolved and are used in industry and will troubleshoot along the way.

OVERVIEW

Quality

Meat palatability traits of tenderness, flavor, and juiciness attribute to the consumer eating experience and hence meat cuts are classified as low or high value cuts basis the delivery of these traits. The muscle anatomical location and genetics are two significant factors affecting palatability. Because of the variation presented between and within muscles, marination is used to deliver consumers a desirable eating experience with greater consistency in tenderness (Grobbel et al. 2008), juiciness, color stability, cooking, and flavor. However, visual defects may arise from variation in muscles and result in observed striping or two-toning along with a soft and weeping appearance. Hence a balance is needed in providing eating consistency without an undesirable appearance.

Ingredients

Over thirty-years, marinade research has been conducted evaluating ingredient functionality and impact on palatability traits. Initial marinades were water and salt, then water, salt, and polyphosphates, advancing to addition of lactates and antioxidants, and evolving to clean label along with flavors and sweeteners. The marinade functionality and consumer appeal are dependent on the ingredient inclusions. Examples of functional ingredients are curing aids, enzymes, or greater functionality with a higher pH marinade that improves tenderness through increased water holding capacity and for eating experience sensory ingredients such as flavors and spices appeal to consumers. Additionally, marinade processes have been developed for fat (Reed Jr. et al., 2017) and meat trim inclusions (Cozzini & Walker, 1990) to enhance juiciness and water holding capacity, respectively. Product use, nutritional needs and labeling requirements are key considerations when developing a marinade. Available ingredients and flavorings and their combinations along with marination technologies provide boundless marinade solutions. It is important that proper order of ingredient addition and thorough mixing occurs in marinade preparation or products may result with inaccurate nutrition facts panels because of inconsistent ingredient concentrations.

MARINATION

Injection, Massaging, and Tumbling

Multi-needle and needless injection, massaging, and tumbling are processes utilized to enhance the marinade absorption. Species, muscle size and profile, desired retention level, and end product use are aspects to consider in selecting the appropriate marinade mixing and injection, massaging, and tumbler equipment. Additionally, marinade mixer shear level, mechanical action, bed height, type of heads and needles, pressure, as well as tumbler size, type of baffles, and required vacuum level are key equipment attributes to understand to attain optimal quality and efficiency. Routine maintenance and specialized sanitation are required to reduce the likelihood of marinade challenges of ingredient separation, striping, discoloration, food safety, and off-flavors. In the past few years, there has been considerable advances in marination processes with brines and injection (Crow et al., 2010; Reed Jr. et al., 2017), massaging, and tumbling technologies.
CONCLUSION

Since the introduction of food processing marination, much knowledge has been gained on equipment, marinate composition, processing technologies and techniques to provide a consistent performing product. Hence, it is key to utilize these learnings in developing strategies to improve overall meat palatability and add value through marination.

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**U.S. Dietary Guidelines for Health: Getting to the Meat of the Matter**

Wayne W. Campbell, PhD*, Lauren E. O’Connor, PhD

**INTRODUCTION**

This proceedings paper of the 2018 Meat Reciprocal Conference will present how common recommendations to reduce red meat consumption may be inconsistent with emerging research suggesting that unprocessed red meat consumption is neutral to cardiovascular disease development and associated risk factors. First, a quick overview will be provided of the Dietary Guidelines for Americans (DGA) congressionally mandated process and how definitions of ‘meat’ and ‘red meat’ influence DGA recommendations. An important concern regarding red and processed meat consumption is increased risk of developing cardiovascular disease (CVD). Therefore, the last section of this paper will address statements from the 2015-2020 DGA regarding red and processed meat consumption and CVD risk and associated risk factors, emphasizing results from recent randomized controlled trials.

**DIETARY GUIDELINES FOR AMERICANS PROCESS**

Goals of the DGA include helping Americans establish healthier eating patterns to decrease risk for chronic diseases such as CVD, type 2 diabetes, and cancers (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015a, Executive Summary). The United States Department of Agriculture (USDA) and the Department of Health and Human Services (HHS) update the evidence-based recommendations of the DGA every five years. First, an advisory committee of nationally recognized scientists is chartered to review available evidence pertaining to nutrition and human health. The committee, or the Dietary Guidelines Advisory Committee (DGAC), is divided into subcommittees to form and address questions of public health concern related to nutrition. All communications among DGAC subcommittees are monitored by USDA or HHS officials and all full committee meetings are broadcasted live and available for public comment. Toward the end of the DGAC appointment, DGAC members summarize the process and results in a Scientific Advisory Report which is presented to the USDA and HHS Secretaries for review. The DGAC is disbanded upon acceptance of the Scientific Advisory Report and members of this committee have no role in formulating the DGA policy document. The Scientific Advisory Report is used by government officials as one of several resources to form the final policy document. The recommendations in the final DGA policy document are then implemented through federal nutrition programs, including the National School Lunch Program and the Supplemental Nutrition Assistance Program, and used to create educational public health tools (Office of Disease Prevention and Health Promotion, 2018).

**WHAT IS ‘RED MEAT’?**

In nutrition research and dietary guidance, protein-rich foods are often grouped broadly into categories such as ‘meats’, ‘red and processed meat’ or ‘meats, poultry and eggs’. While regulatory agencies such as the United States Department of Agriculture provide concise definitions of each individual term and corresponding subcategories, researchers often rely on their own categorization methods to determine relationships between protein-rich foods and health (Gifford and O’Connor et al., 2017). The method in which dietary intake data are recorded often dictates how researchers can categorize or group protein-rich foods to assess associations between protein-rich foods and human health. For example, red meats (including unprocessed red meats such as pork chops or beef tenderloin) are historically grouped with processed meats (such as bacon and sausage) as a “red and processed meat” category. The “red and processed meat” category likely emerges from the inability to completely separate these food groups in dietary intake datasets collected from...
food frequency questionnaires. This broad categorization does not account for differences in macro-, micro-, and non-nutritive compositions of red meats and processed meats, confounding the health implications of consuming these meat types independent of one another (Gifford and O’Connor et al., 2017).

Without a universal approach to categorizing protein-rich foods across the field of nutrition science, it is difficult to interpret and compare results from studies in order to provide dietary recommendations about consuming red meat. This problem was first noted in the Scientific Report of the 2015 Dietary Guidelines Advisory Committee which highlighted that the issue of variability across food groupings/categories was particularly apparent in the meat group. The report reads “for example, ‘total meat’ may have been defined as ‘meat, sausage, fish, and eggs’, ‘red meat, processed meat, and poultry’ or various other combinations of meat”. The DGAC provided a general label, ‘meat’, in conclusion statements (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015b). The ambiguous term ‘meat’, rather than the more specific term ‘red meat’ as used in the definitions shown below, was included in the final DGA policy document, as it has in the previous seven editions. Variability in how meats are categorized, particularly red meat, can lead to ambiguous dietary recommendations and public health messages about implications of consuming red meat and CVD risk.

The 2015-2020 Dietary Guidelines for Americans’ definitions of red and processed meats will be used in this article. The term ‘meat’, otherwise known as red meat, includes beef, pork, lamb, veal, goat, and non-bird game. Processed meats are defined as meat products preserved by smoking, curing, salting, and/or the addition of chemical preservatives such as sausage, luncheon meats, bacon, and beef jerky (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015a, Appendix 6: Glossary of terms).

**RED MEAT CONSUMPTION AND CARDIOVASCULAR DISEASE RISK**

As stated in the 2015-2020 DGA, there is strong evidence that eating patterns that are low in red and processed meats are associated with a reduced risk for developing CVD (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015a, Chapter 1, A closer look inside healthy eating patterns). This statement is supported mainly by prospective cohort studies that follow a group of people over time and assess whether their eating habits at baseline are related to disease development or death decades later. Prospective cohort studies are foundational for dietary recommendations (Satija et al., 2015) but are not without limitations. This type of observational study design assesses associations, not causality, between red meat and disease onset and is confounded by lifestyle factors that are related to high red meat consumption (such as smoking, poor dietary habits, and low physical activity) (Klurfeld, 2015). The statement from the 2015-2020 DGA states that there is also evidence from some randomized controlled trials to support that eating patterns low in red meat reduce the risk of CVD (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015a, Chapter 1, A closer look inside healthy eating patterns). While randomized controlled trials are rarely conducted long enough to assess the onset of CVD, the use of a randomized controlled trial design allows researchers to assess cause and effect between red meat consumption and CVD risk factors, such as blood lipoproteins or blood pressure (Barton, 2000).

A commonly recommended red meat intake amount included in heart healthy eating patterns is <0.5 servings of total red meat (~35-40g or ~1.5 oz) per day which equates to about three to four 3 ounce servings per week (Karanja et al., 1999, Swain et al., 2008). This restrictive recommendation is supported by an analysis of two high-quality observational prospective cohort studies, the Health Professionals Follow-up Study and the Nurses’ Health Study (Pan et al., 2012). The results of this analysis show that 8.6% and 12.2% of CVD-related deaths in men and women, respectively, could have been prevented if they were consuming <0.5 servings of total red meat per day, inclusive of unprocessed and processed red meat. However, a recent meta-analysis of randomized controlled trials showed that consuming >0.5 servings of total red meat, but mainly unprocessed beef and pork, did not affect changes in blood lipids, lipoproteins, or blood pressures compared to consuming <0.5 servings of total red meat per day (O’Connor et al., 2017a). Further, several other meta-analyses that assess the associations between unprocessed red meat independent of processed meat show that unprocessed red meat consumption does not increase the risk of developing CVD. A detailed summary of these meta-analyses was previously published (O’Connor et al., 2017b).

The 2015-2020 DGA states that lean red meats, as well as processed meats and processed poultry, can contribute important nutrients to an omnivorous eating pattern when consumed in recommended amounts, provided that total daily sodium and saturated fat intakes do not exceed recommendations (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015a, Chapter 1, A closer look inside healthy eating patterns). Previous research, published before the 2015-2020 DGA process began, showed that consuming 4 to 6 ounces of lean unprocessed beef or pork per day did not hinder the effectiveness of a Dietary Approaches to Stop Hypertension eating pattern to improve CVD risk factors (Sayer et al., 2015, Roussell et al., 2012, Roussell et al., 2014). Similarly, one study compared the effects of energy-restricted Dietary Approaches to Stop Hypertension eating patterns substituting plant protein with beef (12, 139, or 196 g of lean unprocessed beef) combined with exercise on metabolic syndrome outcomes (Hill et al., 2015). The researchers concluded that weight loss was the primary
modifier of metabolic improvements, independent of protein source. A new study showed that a Mediterranean-style eating pattern containing about one serving (~3 ounces) of lean unprocessed red meat per day had cardiometabolic benefits for adults who are overweight or obese (O’Connor et al., 2018). There are no randomized controlled trials to date assessing the effects of consuming processed red meat or processed poultry independent of or in the context of a healthy eating pattern on CVD risk factors. Observational evidence suggests that consuming processed meats increases the risk for developing CVD up to 42% while consuming unprocessed red meats does not increase risk of developing CVD (Micha et al., 2012, O’Connor, 2017, Micha et al., 2010).

CONCLUSIONS

Evidence from observational research as well as randomized controlled trials support that unprocessed red meat is neutral to CVD development and associated risk factors. Further, consuming lean unprocessed red meat in the context of a healthy eating pattern, such as a Dietary Approaches to Stop Hypertension or a Mediterranean-style eating pattern, has cardiometabolic benefits for adults who are overweight or obese and choose to consume an omnivorous eating pattern. The 2015-2020 DGA states that it is important to consume a variety of protein-rich foods that do not exceed sodium or saturated fat recommendations.

REFERENCES


Can Meat Consumption Improve Global Quality of Life?

Eric P. Berg*, Hans H. Stein1, Kimberley A. Vonnahme2, Korry J. Hintze3

CURRENT STATUS OF THE PROBLEM

The human body deals with high blood sugar by releasing insulin produced in the beta cells of the pancreas. Insulin binds to its insulin receptors on the liver, muscle, and (or) fat cells to serve as a key to unlock the cells ability to store energy (glucose or triglyceride) inside the cell. Under normal physiological conditions, insulin does its job by replenishing energy stores of glucose (glycogen) in the liver and muscle and triglycerides in adipose. However, when blood sugar (serum glucose) is chronically elevated, the pancreas will respond with increased insulin secretion. Chronic insulinism can ultimately lead to the down-regulation of insulin receptors on target tissues. The tissue is effectively saying “I’m full, thank you” and over time, the hormone has less and less of an effect. Liver and muscle are the most metabolically active of the tissues, so when liver and muscle glucose (glycogen) stores remain chronically overloaded, the insulin receptors down-regulate (mechanistic response to glycogen saturation). This leaves the adipose tissue as the only remaining viable cells accepting glucose. The glucose returns to the liver where it is converted to triglycerides. This results in yet another symptom of chronic disease; elevated serum triglycerides and can cause non-alcoholic, fatty liver disease. With now elevated triglycerides and elevated insulin, insulin binds its receptor on adipose and facilitates triglyceride storage as fat. Since muscle tissue is the largest disposal site of circulating blood glucose, muscle tissue-specific down-regulation of insulin receptors initiates the metabolic pathways that lead to obesity and obesity-related metabolic disorders (Taubes, 2007, 2011).

Muscle tissue specific insulin resistance is a phenomenon that has been identified in the literature. The high incidence of type II diabetes and metabolic syndrome in the Pima Indian tribe has been evaluated by Lillioua and Bogardus (1988) and Youngren et al. (1997). Youngren et al. (1997) reported that obesity in the Pima Indian population was associated with diminished function of skeletal muscle insulin receptors in response to insulin-mediated disposal of circulating blood glucose. This impairment led to disproportionate disposal of glucose as fat in adipocytes leading to obesity and subclinical detection of the onset of type II diabetes (or metabolic syndrome). This was further substantiated by Beck-Nielsen et al. (1992) and Bogardus and Lillioja (1992) who indicated that defects in insulin-stimulated muscle glycogen synthesis are responsible for insulin resistance in type II diabetic patients.

While muscle-specific insulin resistance is the basis of our hypothesis for the obesity-related disorders suffered globally, the human dietary condition is much more complicated than simply eating too many carbohydrates. Our working hypothesis is this: humans consuming an unbalanced diet that over-indexes on high-glycemic carbohydrates and under-indexes the nutritional requirements for essential (indispensable) amino acids results in liver and muscle glycogen saturation, muscle-specific insulin resistance, hyperglycemia, hyperinsulinemia, muscle wasting, and obesity.

SWINE AS A MODEL FOR HUMANS

Controlled scientific studies regarding human diet and health are difficult to manage and very expensive. A large sample size is necessary to filter the error (confounding factors) associated with different genetics (race), environment, physical activity, socio-economic status, age, gender, and every interaction of these factors. Also, finding human subjects willing to adhere to a strict research diet for prolonged duration is extremely difficult. The use of an appropriate animal model can control for these confounding factors. Like humans, pigs are omnivores and their anatomy and physiology are very similar. A pig’s gastrointestinal system, body composition, and nutrient requirements favor the use of the pig as a model for evaluation of how diet influences physiological responses to growth and development (Tumbleson, 1986; Tumbleson...
The rational for using the pig as a biomedical model to study obesity-related metabolic disorders has been previously described by Bellinger et al. (2006).

Table 1 is adapted from data published from 10 research projects utilizing the swine model at various life stages. These researchers compared diets that were either adequate or deficient in just one indispensable amino acid; lysine. Lysine deficient swine averaged 19.3% more subcutaneous fat and had 8.1% smaller cross-sectional area of the longissimus dorsi muscle. The most dramatic effect was seen in an 89.2% increase in intramuscular fat; fat located between the muscle fibers in the longissimus dorsi. In the developmental stages of chronic disease progression, central adiposity and accumulation of intramuscular triglyceride are well documented. The accumulation of intramuscular fat (triglyceride) fits with the hypothesis of tissue-specific insulin resistance. The muscle becomes resistant to insulin, while the adipocytes located between the muscle fibers are not. In these swine studies, a deficiency of lysine in a high starch (high glycemic), corn-based diet resulted in muscle attenuation (wasting) and increased adiposity indicative of human metabolic syndrome, pre-diabetes, and type II diabetes.

Based on the swine models above, the dietary advice requiring plant-based foods will require an education effort to avoid perpetuation and escalation of obesity and obesity related metabolic disorders. Foods of animal origin, including muscle foods, are the most bioavailable source of indispensable amino acids. Our research has focused on how diets that overemphasize carbohydrate at the expense of high quality protein (those containing a large proportion of bioavailable indispensable amino acids) can lead to a progression of physiological events resulting in tissue-specific insulin resistance.

### EVALUATION OF THE TOTAL WESTERN DIET

The National Health and Nutrition Examination Survey (NHANES) is arguably the most detailed survey information of the dietary habits of American children and adults. These data are used to identify nutritional deficiencies and relationships between diet and disease. Our collaborator, Dr. Korry Hintze (Utah State University) has developed a Total Western Diet (TWD) designed for swine by selecting the average (50th percentile) daily intake for nutrients reported to the NHANES What We Eat in America 2007-2008 (CDC, 2011) for individuals age two and older. Hintze translated the human NHANES diet into a dietary ration suitable for swine which served as the base diet for the TWD treatments.

We recently utilized swine as a biomedical model for humans to determine if replacing sugar present in the TWD (average American diet) with ground beef would alter developmental body composition and susceptibility to obesity-related metabolic disorders. Twenty-four Berk-

Table 1. Comparison of swine diets that were either adequate or deficient for the indispensable amino acid lysine fed at various stages of development.

<table>
<thead>
<tr>
<th>Dietary protein (lysine level), %</th>
<th>Duration fed</th>
<th>Subcutaneous fat depth, cm</th>
<th>Intramuscular fat, %</th>
<th>Longissimus dorsi cross sectional area, cm²</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adequate</td>
<td>Deficient</td>
<td>Adequate</td>
<td>Deficient</td>
<td>Adequate</td>
</tr>
<tr>
<td>18.5 (0.96)</td>
<td>13.1 (0.64)</td>
<td>Fed to 103 kg</td>
<td>NR</td>
<td>NR</td>
<td>1.5</td>
</tr>
<tr>
<td>17.6 (0.81)</td>
<td>11.9 (0.48)</td>
<td>25-98 kg Fed for 82 d</td>
<td>2.44</td>
<td>2.68</td>
<td>1.4</td>
</tr>
<tr>
<td>25 (NA)</td>
<td>10 (NA)</td>
<td>Fed to 104 kg</td>
<td>3.4</td>
<td>3.7</td>
<td>3.4</td>
</tr>
<tr>
<td>16.0 (0.82)</td>
<td>12.0 (0.55)</td>
<td>10-101 kg</td>
<td>3.0</td>
<td>3.8</td>
<td>5.5</td>
</tr>
<tr>
<td>20.5 (1.05)</td>
<td>16.6 (0.70)</td>
<td>Not reported (NR)</td>
<td>NR</td>
<td>NR</td>
<td>1.2</td>
</tr>
<tr>
<td>14.0 (0.56)</td>
<td>10.0 (0.40)</td>
<td>80-110 kg Fed for 35 d</td>
<td>NR</td>
<td>NR</td>
<td>3.8</td>
</tr>
<tr>
<td>10.4 (0.64)</td>
<td>10.4 (0.48)</td>
<td>89-126 kg Fed for 48 d</td>
<td>1.85</td>
<td>2.11</td>
<td>2.9</td>
</tr>
<tr>
<td>10.4 (0.69)</td>
<td>10.4 (0.57)</td>
<td>75-106 kg Fed for 42 d</td>
<td>1.5</td>
<td>1.7</td>
<td>3.5</td>
</tr>
<tr>
<td>18.7 (NA)</td>
<td>16.9 (NA)</td>
<td>24-104 kg Fed for 91 d</td>
<td>1.2</td>
<td>1.9</td>
<td>1.3</td>
</tr>
<tr>
<td>11 (0.68)</td>
<td>11 (0.40)</td>
<td>62-110 kg</td>
<td>2.4</td>
<td>2.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Summary of research findings:

- Lys deficient pigs had 19.3% more subcutaneous fat
- Lys deficient pigs had 89.2% more intramuscular fat
- Lys deficient pigs had 8.1% smaller longissimus muscle cross-sectional area
shire gilts were sorted, blocked by litter and weight, and penned individually. Gilts were assigned a treatment (sugar [SUG] vs. ground beef [GB]) and pair-fed at 3.7% of body weight (BW) for 93 d. The SUG diet was the standard TWD developed by Hintze using the 2007-08 NHANES with micronutrients corresponding to average daily American intakes at the 50th percentile when adjusted for nutrient density. For the corresponding GB treatment, cooked ground beef (70:30 lean:fat) replaced sugar in TWD-SUG diet on a kcal basis. Blood samples were collected on d 0 (start of treatment) and then every 28 d. Weekly BW were taken; subcutaneous fat depth (FD) and longissimus muscle area (LMA) were measured at the 10th rib on d 42, 56, 70, and 93. Fat-free lean as a percentage of BW (FFL%) was calculated using FD, LMA, and BW. The GB gilts had superior BW gain over time (P < 0.0001) and finished an average of 27.63 kg heavier than their TWD-SUG counterparts (Figure 1). Muscle deposition in TWD gilts appeared to attenuate by day 42 on test and then declined through day 93. The TWD-GB possessed 17.6% more fat-free lean mass at the end of test (Figure 2).

![Figure 1](https://example.com/figure1.png)

**Figure 1.** Weekly body weight disparity between gilts consuming a total western diet (TWD) with sugar (SUG) versus a TWD where cooked ground beef (GB) replaced dietary sugar on a kcal for kcal basis. *Treatments were different (P < 0.05) on these days.

![Figure 2](https://example.com/figure2.png)

**Figure 2.** Fat-free carcass lean mass (% of live body weight) over time for gilts consuming a total western diet (TWD) with sugar (SUG) versus a TWD where cooked ground beef (GB) replaced dietary sugar on a kcal for kcal basis. *Treatments were different (P < 0.05) on these days.
Figure 3 compares the body cross-section (divided at the 10\textsuperscript{th} and 11\textsuperscript{th} thoracic vertebra) for two sets of litter mates matched for pair-feeding. Items #4 and #12 represent the SUG treatment while #3 and #11 represent GB. Numbers 3 and 4 are full sisters as are 11 and 12. The muscle attenuation and increased adiposity is evident for the SUG treatments (items #4 and #12). Deposition of adipose between muscle fibers and central adiposity have been identified as a risk factor for metabolic syndrome. The SUG gilts possessed 7.34\% intramuscular fat (IMF) and 2.55\% peri-renal fat compared to 2.93\% IMF and 1.32 \% peri-renal fat in the GB group (\textit{P} < 0.001).

Compared to conventional swine diets, the TWD diet was much lower in several minerals resulting in both treatments exhibiting brittle bones. One gilt representing the GB diet was removed from the study on d 76 because she became non-ambulatory and reacted in pain when prompted to move. Veterinary diagnosis was that the case was consistent with metabolic bone disease which resulted in early termination of the research project. This non-ambulatory condition was much more evident in the GB gilts who became less ambulatory by d 93. Postmortem densitometry (DXA) analysis was performed on humerus and femur samples collected during fabrication. Total volumetric bone mineral density (mg/mm\textsuperscript{3}) in mid-shaft femur diaphysis was more dense for TWD-SUG than GB (\textit{P} = 0.002). No differences were observed for bone mineral density in the humerus. Further analysis is being conducted to determine if the subsequent increase in lean body mass of the GB gilts is somehow competitive with normal bone development. It can be concluded that swine cannot thrive consuming an average American diet and while the replacement of dietary sugar with ground beef improves body composition, it does not correct for the nutritional deficits necessary for healthy bone development.

**DIETARY PROTEIN: HIGH QUALITY SHOULD NOT BE CONFUSED WITH HIGH CONSUMPTION**

We have established that swine cannot thrive on the Total Western Diet. Referring back to our hypothesis, muscle foods possess nutrient density that should be ideal for avoiding food-related glucose/insulin spikes, glycogen saturation in tissues, and the eventual insulin resistant condition. That said, is there a potential negative implication of overconsumption of such a nutrient dense food product? What happens when the Adkins, Paleo, or ketogenic dieters take it to the extreme and essentially turn carnivorous? According to the American Diabetes Association (2018) “Meats and fats don’t have a glycemic index because they do not contain carbohydrate.” We tested the idea of an all-beef diet using female pigs as a model for humans. Yorkshire × Duroc × Hampshire gilts (\textit{N} = 21) born over a five-day period from the same sire were provided \textit{ad libitum} access to a low lysine diet (total Lys = \textit{0.45}\%) to promote hyperphagia and adiposity. Upon reaching 3 cm subcutaneous backfat, diets were assigned across body weight and backfat with treatments designated as ground beef (GB; \textit{n} = 5) or con-
The ad libitum consumption of high-fat ground beef (complete diet of 99.9% cooked ground beef [GB; 63:37 lean:fat blend] and 0.1% Ca-carbonate) in the absence of carbohydrates did result in an increase in insulin receptors on the gracilis myofibers of mature gilts fed for 84 days (Figure 4) versus CON diet consisting of 70.5% ground corn, 15% vegetable oil, 8.5% distillers dried grains plus solubles, and 4.25% soybean meal. Furthermore, pigs fed the GB diet ate an average of 2,500 more kcals per day, gained less body weight (BW; P < 0.05), and tended (P = 0.09) to deposit less subcutaneous (SQ) fat expressed as a percentage of initial BW and (or) SQ fat over the time on trial (Figure 5). The HDL/LDL cholesterol ratio was slightly higher (P = 0.04) for CON (0.67 ±0.03) versus GB (0.55 ±0.04), however, no differences were seen across diets for circulating triglycerides or for oil red staining intensity for identification of atherosclerotic plaque.

These findings are supportive of our hypothesis given increases in insulin receptor density and a reduction in adiposity. However, these positive results do not appear to be sustainable as the GB gilts acclimated to the calorically extreme diet and after 28 d, body weight and subcutaneous fat deposition paralleled that of the CON group. The American Diabetes Association notes that meat does not have a glycemic index because meat contains no carbohydrates, however in the present study, the GB gilts tended to average a higher concentration of circulating serum glucose (95.5 mg/dL) than CON (89.3 mg/dL; P = 0.06). Because sugar was absent in the GB diet it is assumed that gluconeogenic amino acids are being converted to glucose. Glucose is needed for biological processes and is especially important to the brain as its primary fuel. Non-carbohydrate precursors, such as amino acids, can be converted into glucose via the gluconeogenic pathway.

**THE RATIONALE FOR HIGH QUALITY PROTEIN**

The Food and Agriculture Organization (FAO) branch of the United Nations convened a consortium of nutrition experts at the *Expert Consultation on Protein Quality Evaluation in Human Nutrition* in Auckland New Zealand (March 31 to April 1, 2011). The Proceedings and recommendations of the Expert Consultation can be found in *Dietary Protein Quality Evaluation in Human Nutrition; Report of an FAO Expert Consultation* (FAO, 2013). The key findings were as follows:

1. **Dietary amino acids should be treated as individual nutrients.** Food tables (labels) should include information about digestible or bioavailability of individual amino acids.

2. **Quality of protein will be defined as a measure of digestible indispensable amino acid score (DIAAS).** The DIAAS is based on how well a food protein can meet the bodies demand for indispensable amino acids at various life stages.
   a. DIAAS should be calculated from amino acid digestibility (nutrient absorption) in the terminal ileum of the small intestine.
   "Digestibility should be based on the true ileal digestibility of each amino acid preferably determined in humans, but if this is not possible, in growing pigs or in growing rats in that order (FAO, 2013)."

The conclusions of the FAO Expert Consultation should be considered by those responsible for establishing human dietary guidelines. Dietary recommendations often support the recommendation to eat more food of plant origin.
Figure 5. Body weight (A) and subcutaneous backfat (B) change expressed as the percentage change from day 0 (start on test) for gilts fed ad libitum corn-soybean control (CON) and 63:37 (lean:fat) ground beef (GB) dietary treatments (TRT).
and limit or avoid meat. Foods of animal origin are a high quality, complete source of indispensable amino acids with the closest plant source being processed soy-protein isolate. **In order to obtain the necessary dietary complement of indispensable amino acids, different plant-based foods must be combined.** For example, beans (legumes) possess a higher concentration of the amino acid lysine and are lower in sulfur-containing amino acids. Beans are a fine compliment to corn which is deficient in the indispensable amino acid lysine, yet high in sulfur-containing amino acids. Those choosing to eliminate or limit foods of animal origin will need to be taught how to combine and balance the indispensable amino acids that are uniquely available from various plant foods. Current food labels do not list amino acid content, but rather show only the level of total (crude) protein.

Crude protein (CP) is not an indication of protein quality as now defined by the FAO Expert Consultation. By way of an example, let’s examine two common breakfast protein foods (Table 2); a plain grain bagel [USDA Nutrient Database, nutrient data for: 18406, Bagels, plain, enriched, without calcium propionate (includes onion, poppy, sesame)] or ham [USDA Nutrient Database, nutrient data for: 10153, Pork, cured, ham, whole, separable lean only, roasted].

The crude protein (CP) for the 100g portion of ham is roughly 2.4 times that of the CP in the bagel of comparable size. If an individual wished to consume comparable amounts of CP from the bagel “meal”, they would be consuming 2.4 times the calories. Now if we consider that the ileal digestibility of whole wheat found in the bagel possesses a DIAAS of 43 (Cervantes-Pahn et al., 2014), the actual crude protein consumed (based on what is reported on the food label) will be 58.26 g CP and accompanying 1,526 kcals. If we follow the same process for lysine equivalents, an individual would consume roughly 5,412 kcals. Putting this in further perspective, the daily lysine requirement for a 75 kg human age 18 or older as recommended by the FAO Expert Consultation is 30mg/kg of body weight per day; or 2.25 grams of lysine per day. This amount is roughly equivalent to the 100 gram sample of ham in Table 2.

The mathematical manipulation of protein equivalents presented in Table 2 must be supported by data through determination of the actual DIAAS score for these ham and bagel products. Our lab is currently collaborating with the lab of Dr. Hans Stein (University of Illinois) to determine the DIAAS score of several beef and pork products (including comparisons of fresh pork leg, conventionally cured/smoked ham, and so-called “natural cured”/smoked ham). It will be hard to deny malnourished individuals access to meat if scientific data concludes that 100 g of processed pork is sufficient to meet the daily requirement for indispensable amino acids.

**CONCLUSION**

Most often we associate malnutrition with undernutrition. The World Health Organization (WHO, 2018) describes undernutrition as wasting (low body weight relative to height), stunting (low height relative to age), and underweight (low body weight for a given age). However, the WHO also classifies malnutrition as inadequate or excess vitamins/minerals, overweight, and obesity. It is interesting to note that “meat” is mentioned only once in the 79

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### Table 2. Protein and caloric equivalents for pork (cured, ham, whole, separable lean only, roasted) and bagel (plain, enriched, without calcium propionate (includes onion, poppy, sesame) per 100g sample.

<table>
<thead>
<tr>
<th>CP per 100g of food product</th>
<th>Ham, g</th>
<th>Ham, kcals</th>
<th>Bagel, g</th>
<th>Bagel, kcals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ham, g</td>
<td>25.05</td>
<td>157</td>
<td>10.5</td>
<td>275</td>
</tr>
<tr>
<td>Bagel CP adjusted to meet Ham CP</td>
<td>25.05</td>
<td>157</td>
<td>25.05</td>
<td>656</td>
</tr>
<tr>
<td>Bagel CP adjusted for DIAAS (43%) to meet Ham CP</td>
<td>25.05</td>
<td>157</td>
<td>58.26</td>
<td>1,526</td>
</tr>
<tr>
<td>Lys per 100g of food product</td>
<td>2.124</td>
<td>157</td>
<td>0.251</td>
<td>275</td>
</tr>
<tr>
<td>Bagel Lys adjusted to meet Ham Lys</td>
<td>2.124</td>
<td>157</td>
<td>2.124</td>
<td>2,327</td>
</tr>
<tr>
<td>Bagel Lys adjusted for DIAAS (43%) to meet Ham Lys</td>
<td>2.124</td>
<td>157</td>
<td>4.94</td>
<td>5,412</td>
</tr>
</tbody>
</table>

*a The DIAAS for ham is not available. The DIAAS for foods of animal origin are often higher than 100 and therefore the protein and lysine content will remain unadjusted for ease of calculation.

*b Ham CP 25.05/Bagel CP 10.5 which would equal 2.39 times the kcal consumption.

*c DIAAS adjusted Bagel CP based on a DIAAS of 43. To obtain 25.05 grams of digestible CP, an individual would consume 58.26 grams of wheat bagel CP which would equal 5.55 times the kcal consumption.

*d Ham Lys 2.124/Bagel Lys 0.251 which would equal 8.46 times the kcal consumption.

*e DIAAS adjusted Bagel Lys based on a DIAAS of 43. To obtain 2.124 grams of digestible Lys, an individual would consume 4.94 grams of wheat bagel Lys which would equal 19.7 times the kcal consumption.
page FAO (2012) publication Dietary Protein Quality Evaluation in Human Nutrition: report of an FAO Expert Consultation. The report makes reference to analysis of net postprandial protein utilization (NPPU) of milk, soya protein isolate, wheat and meat. The report then provides the NPPU values for milk, soya, and wheat, but not for meat. Reference is made to “high quality” diets of other foods of animal origin, namely eggs and milk, yet muscle foods are absent. Beef, pork, lamb, chicken, poultry, or even fish are not referenced. Anemia (iron and B12 deficiency) and indispensable amino acid malnutrition are physically manifested as wasting, stunting, and underweight as well as overweight and obesity. Meat that is often referred to as red meat has the nutrient density to prevent/cure these most common global nutrition-related conditions. Determination of the DIAAS for muscle foods at various stages of processing is necessary to establish the role of meat in healthy dietary patterns.

LITERATURE CITATIONS


MEAT & NUTRITION – SUSTAINING HEALTHY PROTEIN SOURCES

How are Plants Competing with Meat for the Center of the Plate

Rody Hawkins, Ph.D.

WHAT IS CHANGING?
The plant protein food industry has made a big push in the last six years. A survey by 210 Analytics had found that three out of five millennials consume plant-based meat. Food Management found in their survey that 34 percent of consumers eat a totally vegan meal at least once a week. In a 2018 research survey from sales and marketing agency Acosta, 18 percent of shoppers are buying more fresh meat versus last year, but plant-based meat alternatives are growing 11 percent in units, year-over-year. Surprisingly, 71 percent of shoppers who purchase plant-based meat alternatives also eat meat. A 2018 Data Essential report notes that 83% of consumers believe plant-based foods can be just as satisfying as animal proteins. A growing number of Canadians are embracing alternative proteins with 53 percent of Canadian consumers reporting they eat meat alternatives including 18 percent who say they eat them at least a few times a week, according to 2018 Mintel research. According to a Markets and Markets estimate, the plant-based global meat market is about $4.6 billion with an annual growth of 6.8%. This market segment is one of the fastest growing segments in the food industry.

WHAT ARE THE FACTORS FUELING THIS GROWTH?
Consumers are searching for a way to impact their quality of life and health. Surveys have broken down these searches, changes, and quests into the following categories:

- Health – Wellness
- Environmental – Sustainability
- Social Concerns – Animal Welfare
- Financial – Investment

All the elements are here to grow the market: emotion, purpose, personal stake, and money. These categories explain the growth of the plant protein market and combine to assure that this market will continue to grow far into the future.

Health - Wellness: According to the 2018 Food & Health Survey (2018 FHS) conducted by the International Food Information Council Foundation, cardiovascular health and weight loss are the two most desired nutritional benefits of interest to consumers (Chart 1). Almost half of the respondents indicated that foods that contribute to heart health were a factor in their selection for food benefits. Also, research indicates that 40% of consumers are seeking to reduce meat consumption with a focus on improved health (2017 Nielsen and Markets to Markets research). In the 2018 FHS, 73 percent of consumers perceive “Protein from Plant Sources” as healthy while only 38 percent of consumers perceive “Animal Protein” as healthy (Chart 2). What is driving this perception of less healthy which is leading the quest to reduced meat consumption?

Studies are published every year that show some adverse effect of eating meat. In 2012 study from Harvard School of Public Health (HSPH) researchers found that red meat consumption is associated with an increased risk of total, cardiovascular, and cancer mortality. The results also showed that substituting other healthy protein sources, such as fish, poultry, nuts, and legumes, was associated with a lower risk of mortality (Archives of Internal Medicine, March 12, 2012). Then in November of 2015, the International Agency for Research on Cancer (IARC), a specialized cancer agency of the World Health Organization a group of the United Nations, issued a report concluding that there is enough scientific evidence to conclude that eating red and processed meats can be considered a cancer hazard. This announcement, although reputed by many agencies, set in motion the world opinion that lower meat consumption would be prudent. Personally, I had many customers asked about reducing meat in various products and moving quickly to remove nitrites from processed meats.
Many books have been published promoting a vegetarian diet or a “plant-based” diet. Books like *The China Study*, *Proteinaholic*, *Whole*, and *The Low-Carb Fraud* are just some of the books discussing the science behind a “Plant-Based Diet”. *The China Study* has had over 850,000 copies sold, has been hailed as one of the most important health and nutrition books ever published. Written by T. Colin Campbell, Ph.D. and Thomas M. Campbell II, MD (his son), the book is based on an extensive and ongoing study in rural China. T. Colin Campbell has great credentials as the Jacob Gould Schurman Professor Emeritus of Nutritional Biochemistry at Cornell University. They conclude that the traditional Western diet has led to our modern health crisis and the widespread growth of obesity, diabetes, heart disease, and cancer; while the plant-based, high caloric diet in rural China does not have the same effect (Table 1).

He explains that the best diet is one of
- Complete carbohydrates and whole plants
- Low in Protein
- No refined oils, sugars and starches
Table 1: Chinese and American Dietary Intakes*

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>China</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories (kcal/day)</td>
<td>2641</td>
<td>1989</td>
</tr>
<tr>
<td>Total Fat (% of calories)</td>
<td>14.5</td>
<td>34-38</td>
</tr>
<tr>
<td>Dietary Fiber (g/day)</td>
<td>33</td>
<td>12</td>
</tr>
<tr>
<td>Total Protein (g/day)</td>
<td>64</td>
<td>91</td>
</tr>
<tr>
<td>Animal Protein (% of calories)</td>
<td>0.8</td>
<td>10-11</td>
</tr>
<tr>
<td>Total Iron (mg/day)</td>
<td>34</td>
<td>18*</td>
</tr>
</tbody>
</table>

Calorie intake in China is for a 65 kg adult male doing “light physical work.” Comparable data for the American male is adjusted for a body weight of 65 kg.

In the book *The Low-Carb Fraud*, Dr. Campbell explains some of the biochemical pathways of why he promotes a plant-based diet. He does agrees with Gary Taubes, author of the books *Good Calories, Bad Calories* and *Why We Get Fat*, that calories do not count and that refined sugars and starches are bad; however, he differs in his conclusions on what would be the best diet. He concludes the following:

- Americans did not ever get to a low fat diet. The consumption of fats and oils did not decrease and even in closely controlled studies, the reduction was minimal.
- Complex carbohydrates creates more energy through increased body heat called “metabolic thermogenesis” or voluntary physical activity. Also, the fat produced with this type of diet is different and is called “brown adipose tissue”. This fat is more readily available for energy metabolism.
- High animal protein is associated with an increase in cancer and heart disease. In his book *Whole, Re-thinking the Science of Nutrition*, Dr. Campbell uses his research in the mechanism of cancer to explain how proteins promote the onset and growth of cancer.
- Whole plants contain many beneficial antioxidants, besides beta carotene, and other botanicals that we have yet to identify. These beneficial plant-based nutrients are what our metabolism uses to protect itself and keeping them whole in plant foods assures that they will always be available. He uses the increasing complexity of the Krebs cycle over the past 5 decades as an example of how complex is our metabolism. Thus a diet containing many nutrients, known and unknown, is the best course.

Dr. Campbell uses his book *Whole* to contrast the dietetic philosophies of “Reductionist” and “Wholist”. He defines reductionist as looking at diet by conducting research about specific nutrients. The view of the diet defined by level of specific nutrients and the subsequent fortification ends up missing many important minor nutrients. He professes that a diet is something that should be studied as a whole and studying specific nutrients and their effects will lead to false conclusions, unnecessary fortifications, and less than optimum outcomes. Conclusion, eating whole plant-based foods will give you all the nutrients you need.

Finally, both Dr. Campbell and Dr. Garth Davis, in his book *Proteinaholic*, push the research and correlation of how an animal protein diet is associated with cancer and heart related diseases. The mechanism that Dr. Campbell uses is one of how the enzyme “mixed function oxidase” (MFO) contributes to developing carcinogens and subsequent cancer. MFO is responsible for catalyzing oxidations of substrates and handles two different substrates simultaneously. The mold *Aspergillus flavus* produces a very powerful aflatoxin (AF) that is a carcinogen. In his studies with mice, he defined the final model for how MFO removes the AF from infected mice.

$$\text{AF Substrate} \xrightarrow{\text{MFO}} \text{[AF Epoxide]} \xrightarrow{\text{AF Product}}$$

During this removal process, the toxic AF Substrate is converted into a carcinogenic intermediate, AF Epoxide, before it is oxidized into the AF Product for removal. This intermediate substrate, AF Epoxide has been shown to bind to DNA to initiate cancer.

So what does all this have to do with a high protein diet? A high protein diet increases MFO activity, leading to less substrate, more epoxide, and an increased possibility of the epoxide binding to DNA and subsequently creating cancer. This is just one mechanism that is under investigation.

**Environmental - Sustainability:** “How do you feed 9.5 billion by the year 2050 with limited land and water,” was the challenge posed by Jack Bobo from the US State Department at the 2014 RMC (Chart3). The challenge presented seemed particularly ominous despite all of the advancements in agriculture over the past century, future major strides need to be made, not just incremental increases. While I was participating in a roundtable panel at the Concordia 2017 Annual Summit on the Campaign for a Sustainable Global Food Supply, the discussion moved from animal agriculture efficiencies to a plant-based diet for food security. These meetings were held during the opening of the United Nations General Assembly and included stakeholders both domestically and internationally. The shift to a more plant based diet is beneficial in the use of our resources in the way of water efficiency, land
utilization, and green-house gas (CO₂) reduction (Chart 4). Pulses, including soybeans, are the most efficient sources for quality protein and healthy food.

A varieties of pulses can be grown in many different geographical regions and even survive various minor drought conditions. Soybeans are the most efficient source of protein per unit of energy input (Chart 5). In addition, soybeans are the most efficient use of land in the production of protein (Chart 6). Greater utilization of this amazing plant could solve the future global food crisis.

Social Concerns: Reducing the reliance on using animals to feed the planet as the population grows is becoming a global concern, according to a UN FAO Global Agricultural Study. This is evident by the

• Supported conferences around the United Nations and other groups, like Concordia and Future-Food Tech,
• Increased activity in and formation of trade organizations, like Plant Based Foods Association, The Good Food Institute, and the Sustainable Food Trade Association,
• Increased number of venture funds formed to address these concerns, like The Glass Wall Syndicate, Khosla Ventures, Coller Capital, S2G Ventures, and many others,
• Many companies forming departments around sustainability and redefining their mission, i.e. Cargill Meat Solutions to Cargill Protein Solutions.

In March 2016, the first-ever plant food trade association, Plant Based Foods Association, was formed by leading Plant Based Food Companies. Their mission was to promote the plant-based foods industry by removing obstacles to a fair and competitive marketplace for alternatives to animal ingredients and products.

In February 2016, The Good Food Institute was formed with the mission to promote meat replacement with plants stating “By bringing together the brightest innovators, forward-thinking investors, and food marketing visionaries, we can produce food in a new and better way.” They blame the way we eat as causing:

• Environmental Degradation
• Global Poverty
• Animal Welfare Issues
• Human Health Problems

This organization has help support the formation of food companies to make better tasting and more nutritious plant-based foods. Since then, many other groups were formed with roots in the animal rights groups of The Humane Society of the United States (HSUS), American Society for the Prevention of Cruelty to Animals (ASPCA), Mercy for Animals (MFA) and other animal rights groups.

Previous to the organization of these groups, capital started coming from Silicon Valley to promote innovation in this category. Beyond Meat lured high profile investors like Bill Gates, Leonardo DiCaprio, and Twitter co-founders Biz Stone and Evan Williams to help fund this
Chart 4. Plant-Based Proteins More Beneficial to the Planet
Source: Shifting Diets for a Sustainable Food Future. World Resources institute 2016

Chart 5. Protein Efficiency Per Unit Energy (g Protein/MJ)
Source: Protein efficiency per unit energy and per unit greenhouse gas emissions, Gonzalez et al. Food Policy, 2011.
mission and bring attention to this category. Other impact investors began to fund startups like Impossible Foods and Memphis Meats as they developed better and interesting technologies. These products were an improvement over the textured vegetable products of the previous decades.

**Financial – Investment:** An investor report called “Plant-Based Profits” urges global food companies to diversify their protein sourcing away from a reliance on animal proteins. They analyze how 16 multinational companies are positioned to transition to alternative plant-based proteins. The report was created by FAIRR (Farm Animal Investment Risk & Return), an investor initiative that aims to raise awareness of “factory” farming and animal welfare. Investors working on this report are concerned over the risks of food companies relying on animal protein and want to see companies investing in the growing plant-based food market to diversify their portfolio and protect their stock price. The concerns focus on disruption in the animal food supply by disease, drought, and push for sustainability. The report finds that the market for alternative proteins is predicted to expand by over 8% a year and to reach $5.2 billion by 2020. They report retail sales of plant-based foods that directly replace animal products grew 8.1% in the 12 months to August 2017.

A meat based diet is expensive. According to a 2018 study published in the *Journal of Nutrition*, the UK could cut its healthcare and societal costs – such as absenteeism from work—by €5.87bn ($6.89bn) if 10% of the population would emphasize plant-based foods in their diets over the next 20 years. The study examined the health and economic consequences of two plant-based eating patterns: a diet with a daily proportion of soya foods and a Mediterranean-style diet. The Ghent University researchers concluded savings would rise as high as €8.49bn ($9.96bn) if 10% of the UK population incorporated soya products into their daily diets. This emphasis is already published in the UK government’s *Eat Well* guidance.

HOW HAS THE FOOD INDUSTRY RESPONDED?

With the mission defined and the emotion channeled, the money for innovation materialized. The current meat alternative company products were just not good enough, so new companies responded to the challenge by four different action plans:

1. **Celebrate Ingredients** – Combine whole, natural, organic, and ancient grains to form plant protein products that did try to completely duplicate meat in looks and taste, but provided a different, fulfilling eating experience. Amy’s and Gardein are examples of some of the companies in this category.

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**Chart 6. Efficiency of Protein Production per Acre of Land Utilized**

*Source: USDA; FAO/WHO/UNICEF Protein Advisory Group (2004).*
2. Create through Technology
– Using a variety of the ingredients and technology, develop a formula and process to manufacture products out of protein that have a similar look and taste as the meat item it is intending to replace. Beyond Meat (BM) and Impossible Foods (IF) are the two main examples of this category. Their products have gotten so close to meat products that the National Cattleman’s Beef Association is using its political power to try and regulate this movement. One downside of these items is some of the ingredients they use are not very appealing: i.e. titanium dioxide (BN) and leghemoglobin (IF).

3. Plant Duplicates – Use plants, or fungi, that have similar eating qualities of meat. Quorn and The Jack Fruit Company are two examples of this innovation. Quorn has its roots in the UK and is composed mainly of mycoprotein. This protein is held together by egg whites and calcium chloride. Jack Fruit is the bulbous fruit that can be used for both savory and sweet dishes depending on its ripeness.

4. Cultured “Clean” Meat – Though technically not a plant and not on the market, this technology gets combines with the plant protein movement. This product is where you actually grow meat as a culture in a controlled environment; they produce “meat” without sacrificing the animal. Memphis Meats, Mosameat, Just, Finless Foods, SuperMeat, Future Meat Technologies, and Aleph Farms (Meat the Future) are all companies receiving money to further develop this technology. The three incubator “hot” spots for this technology are Silicon Valley, the UK, and Israel. This initial thought was that they were years away from a commercially viable product, but with the influx of capital from China, Tyson, Cargill, Richard Branson and Bill Gates, this timeline to market may have been accelerated.

HOW DO YOU IMPROVE(D) NATURE?

Once IN sets the texture, the protein fibers are as resilient as meat and can survive freezing and thawing, the microwave, fry lines and even the retort. The texture is set in the initial proprietary process and it can survive the reheat and cooking stages to deliver its texture in the final product. In addition, when you use soy protein, the nutritional profile is very similar to meat with a complete amino acid profile and a PDCAAS score of .99. The IN product has a similar protein value as meat with more fiber, potassium, calcium, and iron, coupled with no cholesterol.

Create through Technology had to use a variety of questionable ingredients to deliver their texture, look, and color. Some of these ingredients are not very desirable, like titanium dioxide, or creates a very long and cumbersome ingredient statement. Also, the texture that is initially set by the products does not always transfer to the finish product after shipping and reheating.

Plant Duplicates have different issues, depending on the plant used. Quorn has protein amount and bite that is somewhat supplier by the egg whites, but the texture is still lacking. Jack Fruit has a good texture but very little protein to claim in its move to the center of the plate.

Cultured “Clean” Meat still has to deal with the “yuck” factor of being grown from live tissues and the efficiencies of scale. Many companies and investors are betting that they can overcome these issues and objections with marketing, education, and technology.

Improved Nature (IN) address all the above concerns by asking the question: What if you could have a simple labeled plant protein that would look like meat, eat like meat, cook like meat, and have a similar nutritional profile as meat? Can we do all this with a price point similar to meat? This is what Improved Nature did. IN took plant protein and made fibers, like meat, and then turned those fibers into discrete units with heat and pressure (i.e, strips, chunks, filets, etc.) that could seamlessly replace meats and provide the same eating experience. This proprietary process produces the finished base product with no additional ingredients. Just like meat protein, the IN product called PrimeProTex has little to no flavor; but also like meat, it will quickly absorb any flavor and seasoning that you like to add. The product is so versatile in its use that you can create a flakey texture like fish or a firmer bite like beef. You can even make jerky out of PrimeProTex and you still have only the ingredients of plant protein and water; just add seasoning for flavor.

Once IN sets the texture, the protein fibers are as resilient as meat and can survive freezing and thawing, the microwave, fry lines and even the retort. The texture is set in the initial proprietary process and it can survive the reheat and cooking stages to deliver its texture in the final product. In addition, when you use soy protein, the nutritional profile is very similar to meat with a complete amino acid profile and a PDCAAS score of .99. The IN product has a similar protein value as meat with more fiber, potassium, calcium, and iron, coupled with no cholesterol.
There are many stakeholders that have come together to support this market. Lately, the fight has moved into the legislative realm. While the State of Missouri was passing legislation to define meat, the New York Legislature introduced New York Plant-Based Requirement SB 8517 and companion bill AB 10600; these New York bills would require public schools to offer plant-based food options for every meal or snack offered in food service to the student. The plant-based option must be offered at no additional cost to the student. With all this activity the future of plant-based foods is here to stay.
Identification and Characterization of Bacteria Using Mass Spectrometry

Jessica Prenni, Ph.D.

INTRODUCTION

Chemical based approaches to bacterial identification can offer advantages in throughput, cost, and ease of use as compared to traditional microbiological techniques. This presentation will include an overview of microbial identification using mass spectrometry as well as examples of advanced applications for strain and serotype characterization.

Traditionally, microbial identification is performed using various morphological, staining, and physiological and/or biochemical tests. These methods tend to be laborious, time intensive and can be subjective, requiring trained technicians. Microbial diagnostics can also include genotypic methods, such as 16S rRNA sequencing and pulsed field gel electrophoresis (PFGE). However, while genotypic methods can improve resolution beyond the species level, they require additional extraction and purification steps as well as informatics analysis to process and interpret the data.

Recently, the use of matrix assisted laser desorption ionization—time of flight mass spectrometry (MALDI-TOF MS) has been developed as a fast, easy and effective alternative for the identification of microbial isolates. The MALDI-TOF-MS approach is based on the detection of spectral features reflective of intact proteins. The resulting MS patterns represent a “protein fingerprint” that is unique to an individual sample. These protein fingerprints are then compared to a library of spectra from known isolates and pattern recognition algorithms are utilized to determine the species of the unknown based on the best match to the library. This technique has multiple advantages over pheno- and geno-type based diagnostics including throughput, reduced cost, independence of biological reagents such as antibodies and genetic primers, and ease of use. Over the last two decades, MALDI-TOF MS has been successfully used for identification at the species level over several genera of bacteria, as well as fungi and viruses. At the species level, the identification rate by MALDI-TOF MS has proven to be similar to the gold standard typing method, 16S rRNA sequencing and to be robust across laboratories.

Microorganisms often have many subtypes within a species. Subtypes are the result of minor genetic variation but can greatly influence the virulence among different hosts (e.g. plasmids containing virulence genes). Subtypes are often not resolved by 16S rRNA sequencing and require higher resolution genomic approaches for discrimination. There has been considerable interest in expanding the utility of MALDI-TOF MS to the subtype level but this is difficult due to the extreme similarity of the spectra across subtypes of the same species. Specifically, the current informatics approaches are biased towards using only the most abundant and reproducible protein peaks detected by MALDI-TOF MS. While this approach has been demonstrated to result in robust classification at the species level, it is not sufficient or sensitive enough to enable classification at the subtype level.

One approach to differentiate subtypes by MALDI-TOF MS is to identify unique biomarker peaks. For example, this approach has been recently demonstrated for the identification of a methicillin-resistant Staphylococcus aureus (MRSA) subtype characterized by the production of a specific toxin, phenol-soluble moduline (PMS-mec). While this approach can be successful, initial biomarker discovery and validation requires significant research and development and biomarker databases are highly specific to the species of interest. Furthermore, the likelihood of unique biomarker peaks for each subtype decreases as the number of subtypes increases.
Commercial MALDI-TOF MS microbial typing software relies on spectral similarity algorithms to match a spectrum from an unknown isolate to a library of previously collected spectra. This approach works very well for species level characterization but fails when spectra are too similar, as within subtypes of a given species. Our group has developed a novel approach which utilizes multivariate statistical methods to differentiate subtypes based on spectral fingerprints. Specifically, we have recently published an application of this approach that demonstrates successful strain-level characterization of *Xanthomonas axonopodis*, a bacterial plant pathogen that infects food and forage crops such as alfalfa, onion and citrus. Results demonstrating the potential of this approach for identification of serotypes of *Salmonella enterica* subsp. *enterica* will also be presented.
Developing the Developer:
How to be RTE (Ready-to-Employ) on Day One

Rodrigo Tarté, Ph.D.

Organizations are, above all, collections of people. While factors such as organizational structure, strategy, and operational and other assets are important elements of any organization’s success, it is people who actually do the work and turn these elements into success factors. Like all other assets, these most important human assets are effective to the degree that they are suitable (they’re the right asset for the job), reliable (they can perform consistently with minimal breakdowns), durable (they have staying power, patience and perseverance) and cost-effective (they’re a good value for the money). Unlike physical inanimate assets, however, people assets have the capability of improving over time to become more suitable, more reliable, more durable and more cost-effective. This is what is known as potential.

As with all other assets, organizations spend a significant amount on their human assets, or resources. Although much effort is expended during talent recruitment to ensure the selection of the best possible new talent, no organization I know of truly expects that their new employees will be fully ready on day one to perform to their fullest. Rather they take great care to ensure that their new employees possess the aforementioned attributes to some degree and, importantly, the potential to improve on them over time. The latter may involve, from the organization’s perspective, costly training and onboarding programs, and some amount of time, all of which delay the return on their investment. The sooner, however, an employee gets up-to-speed and starts making significant contributions, the better of an investment he/she will be for the organization and the greater his/her prospects will be for future success and advancement. And this will depend, to a large extent, on how prepared the employee is to begin with.

This is not unlike other assets, such as a piece of manufacturing machinery, which needs to be observed, tested and adjusted before being put into full production, but can never do so unless it’s been properly manufactured, assembled and installed in the first place. So, what are some of the things that differentiate new employees who are RTE (“Ready-to-Employ”) from those who will require more training and time to come up to speed? We will focus here on three aspects: college coursework, skills and an understanding of the differences between academic research and industrial research & development (R&D).

COLLEGE COURSEWORK
Most new R&D employees in the meat and food industries are hired from the most relevant scientific disciplines, primarily animal science, food science, biology/microbiology and engineering. These individuals should possess the basic knowledge and hard skills to do the job effectively. However, for a student to be better prepared on day one, there some university courses a student could take, most of which are not typically requirements of the aforementioned courses of study. Some of these are cost accounting, finance, marketing and communication (business communication is recommended). These courses are not recommended to make one’s résumé look better, but to actually learn very valuable business skills.

SKILLS
The skill set an employee brings to the workplace is, obviously, of fundamental importance. In the world of human resources, these are generally subdivided into hard and soft skills.

Hard Skills
Hard skills are behaviors that are generally tangible, quantifiable and easy to measure. They generally comprise an individual’s technical and academic qualifications, and are typically acquired through formal and intensive training, such as a university course of study, training courses and self-learning activities. In an academic environment
they are measured by diplomas and grade transcripts, which are used by employers precisely for this purpose. Most hard skills are strongly correlated to analytical intelligence and are essential for professional success. However, they are not the sole determinant of success nor always the best predictors of excellent employee performance. Universities generally do an excellent job of providing students with a good set of hard skills.

Soft Skills

Soft skills are behaviors that are intangible and tend to be attributes of an individual's personality. They are more related to emotional intelligence and, though they can be taught, they are generally refined and perfected through experience and practice. Many soft skills can be acquired in college, sometimes in class but more often in extracurricular activities. This is a major reason why students should seek a diverse college experience that includes out-of-the-classroom experiences. This doesn't necessarily mean being president of every student club a student joins but does imply active participation and assumption of some responsibility. Given individuals with a similar set of hard skills; soft skills can often make the difference between someone who is an excellent performer and someone who is just good enough. As a result, many employers also weigh soft skills heavily during a new employee's hiring and onboarding process and provide numerous on-the-job training opportunities in this area. The number of soft skills one could acquire is quite large and beyond the scope of this writing. In my opinion, the following are some of the most important ones. This is by no means an exhaustive list and represents my opinion, as derived from my own experiences. There are some soft skills that work effectively in conjunction with a good set of hard skills (problem-solving and execution, for instance) — further underscoring the importance of possessing both types of skills, — while some are independent of the hard skills.

Ability to Execute

A good product developer and R&D professional needs to be able to transform his/her technical knowledge (i.e., the hard skills) into executable plans that align with business goals and strategies; and execute them. This is a critically important skill, which also feeds off other soft skill in other to become perfected.

Critical Thinking and Problem-Solving

This involves the ability to analyze and assess a problem or situation and to find creative and unique ways to resolve them.

Time Management

Effective and wise use of limited time resources is critical for success. This involves knowing how to prioritize activities in the short-, mid-, and long-term. While there is much talk of multitasking as the ability to deal with more than one issue or problem at the same time, in actuality one can only do one thing in any instant of time. The ability to multitask effectively, then, is dependent on the ability to properly prioritize in “the moment” (e.g., should I be reading the literature, writing a report, running a pilot plant trial, or having lunch? What’s most important to do this moment?). Remember time is nothing more than a collection of instants.

Leadership

Much research has been done in the area of leadership and there is a wealth of literature on the subject. One definition of leader that I particularly like is “a person who has commanding authority or influence” (Merriam-Webster’s Dictionary). I like this definition because it embodies two different types of leadership that I think are critical in any organization. Commanding authority type of leadership is typically assigned formally by the organization. Every organizational or project team will have a commanding leader or manager assigned by upper management. Whether that individual can exert influence is another question. A truly influential leader is, in my view, someone who is able to earn the trust and respect of those he/she works and interacts with. Some commanding leaders have it and some don’t. Being an influential leader does not have to go hand in hand with being a commanding leader. One can be a leader without an official mandate from upper management, and this is the type of true leadership I’m referring to. We’ve all most likely met people who seem to be “born leaders.” However, for most of the rest of us, this is a skill that we must deliberately hone and develop. One can do so by being trustworthy (e.g., meet deadlines, keep one’s word), empathic (e.g., identify with the feelings and needs of others), a servant (e.g., roll up one’s sleeves and get dirty with the rest of the team; lend a helping hand to a team member who needs assistance), respectful (e.g., treat others with respect and as valued team members) and self-assured (e.g., show confidence), among others.

Self-learning

This is one of the biggest challenges of the transition from college to the business world, for those who wish to take it on. Also called “lifelong learning,” it is the ability to continue to learn in a very deliberate and meaningful way without a formal teacher, teacher-imposed deadlines or the specter of a grade at the end of the academic term. Science and technology continue to advance and evolve over time and much of the knowledge that is learned in college eventually becomes obsolete as it’s replaced by new discoveries and understanding. So, to avoid becoming obsolete oneself, it is critical to develop a lifelong habit of learning.

Communication

It cannot be said enough times. Communicate, communicate, communicate. Without effective communication, effort in other areas will oftentimes become detrimentally diluted. It is important to understand the rules and eti-
quette of communication, both within and outside one’s organization. This includes all forms of written (e.g., reports, email) and spoken (e.g., presentation skills, the “elevator speech”) communication.

**Confidence**

Not to be confused with self-esteem, confidence relates to how sure an individual is of his/her thoughts or judgements. While confidence can come from any number of places (beware of false confidence), in a work setting it usually develops as a result of mastery of a subject matter and/or a track record of achievement. While the track record within the organization may take some time to develop, some level of mastery of technical subjects is something an employee can work to bring to the job once hired. Some level of technical expertise is expected of hiring organizations; yet the more the new employee brings with him/her the better. Overall, however, a solid level of confidence will require time to attain, but such attainment should be an employee’s goal from day one. Confidence is important because, as Dr. Richard Petty of Ohio State University has been quoted as saying, it “is the stuff that turns thoughts into action” (Kay and Shipman 2014).

**Adaptability**

Situations, deadlines, and objectives oftentimes change, and sometimes without much notice or time to react. It is important to remain flexible and be willing to change directions without a negative effect on performance.

**Teamwork**

The ability to work effectively in teams is highly desired in the industry. An effective team can leverage and multiply the talents of its team members, but it can be effective only when all its members bring their best effort, value and respect each other, keep each other accountable, and place the needs of the team ahead of their own. Product development work is almost always done by multidisciplinary teams, so seeking opportunities in college to work in diverse teams is highly recommended.

**R AND D: WHAT’S THE DIFFERENCE AND DOES IT MATTER?**

This applies mostly to those students who have engaged in academic research, either as a graduate or undergraduate student. While research in its most basic form is driven primarily by scientific inquiry and the quest for knowledge and discovery. It generally seeks to test a hypothesis or answer a research question by systematically investigating a specific topic. Studies are carefully designed and controlled, and data are analyzed in the same way. Publication of academic research must almost always pass critical peer review. Development can be defined as the application of “scientific or engineering knowledge, to expand it, to connect the knowledge in one field...” and “seeks to move product or process concepts through a series of definite stages to prove, refine, and ready them for commercial application” (Roussel et al. 1991); it therefore involves the application of existing knowledge. In academic settings, most of the R&D effort takes the form of research, whereas development is more prevalent in industrial R&D, which is typically driven by short- or long-term business strategies. In the food industry research is generally a costly, time-consuming and financially risky endeavor, which underscores why many companies don’t engage in it at all. Others do, but to different degrees, most opting for a combination of some in-house research and the application of publicly-available (i.e., academic) research. One major advantage of in-house research is that it can lead to discoveries that a company can own and either disclose in the form of patents or retain in-house as trade secrets. Development projects, on the other hand, involve much less uncertainty, clearer project objectives and much shorter execution timelines. Development projects, due to their short-term nature, are not generally designed nor executed with the same degree of scientific rigor as research projects and oftentimes rely on a fair amount of consumer research to go along with the science.

It should be obvious by now that the approach to these types of projects would be very different and that they would require slightly different skills. Students coming out of university who have engaged in academic research can sometimes be taken aback by the fast-paced nature of industrial product development, and early success may depend on how quickly they can adopt a product development mindset. One very effective way to do this is to participate in R&D internship or co-operative education programs prior to beginning full-time employment.

**SEEK ANSWERS BEFORE STARTING**

It is very important to clearly understand what the employer’s expectations are. If in doubt, one should ask. It must be remembered that organizations hire new talent with the objective of seeing them succeed. Their success is the organization’s success, so they will do what is necessary to ensure it. The first few weeks and months on the job should be dedicated to careful observation and analysis of the organization, its policies, procedures and expectations. This is the best time to ask basic questions.

**CONCLUSION**

Early success as a meat or food product developer is dictated by several factors. By preparing for these ahead of time as much as possible and going into the first day on the job with clear expectations of what the responsibilities are and what success looks like, the new industry scientist can be as ready as possible and be on his/her way to long-term career success.

**REFERENCES**

INTRODUCTION
The product portfolio of the small to medium meat processor tends to show a large range of product types and flavors. These products can often include unique, traditional, and ethnic products such as Souse, Headcheese, and Chourico. Small businesses use their distinctive product range to set themselves apart from the large retail stores, which effectively gives each processor their own unique identity. The small processor typically has simple Research and Development processes that are dictated by the technology that is available to them, the extension information that they can obtain, and the technical training that they inherent. As these businesses grow, they ultimately are challenged with staffing issues and the conversion to corporate processes.

BUSINESS DEVELOPMENT DEFINES PROCESSES
The origin of the modern small meat processing business plays a role in how they go about developing products. Typically, the processing business is an older business with the original founder still running operations or has sold the business to their children or to a plant employee. In this instance, the formulations are handed down to the next generation. In most instances with the business staying in the family, the new owners have spent a life time training in their processes. Alternatively, if the plant is sold to an employee, the previous owner usually takes the time to train in their processes. Business owners who come through this route of ownership generally know the basics of manufacturing and have a diverse line of product types including bacon, bone-in hams, boneless hams, turkeys, snack sticks, jerky and various types of fresh and cooked sausages. Research and Development for processors in this category will generally be more focused on product extensions (new flavors) and increasing efficiency (through technology).

Alternative to the older established meat processing businesses, many new small businesses are forming across the United States. While it is not uncommon for new business owners to build their meat processing business from the ground up, it is currently more common for business owners outside the meat industry to enter the industry to diversify their current business holdings. Entrepreneurs of this type generally form their businesses in one of two ways. They sell their old business in favor of a new challenge developing a meat business or they develop a meat business to develop the community into a destination location. Many winery owners see a charcuterie and high end meat business as the natural progression to their business. Many chefs partner with brewing companies for an exquisite pairing with their brats. Examples of these type of business exist very commonly in California and the upper east coast. A big segment of new meat processors are livestock owners. Many people that own heritage breeds or that are marketing natural, organic, or grass/pasture raised animals find that after they sell the middle meats, they have left over product that remains to be utilized. To maximize profits, several of these producers in states such as Virginia, Illinois, Oklahoma, and California build facilities for further processing. The R&D processes of people in this group generally focus on new product development and processes to manufacture those products.

PRODUCT DEVELOPMENT PROCESSES
As a community, the small to medium sized business owners generally have simple product development processes. In most cases, these business owners have direct access to their customers making it easy to evaluate the demands of their customer base. In the case of established processors looking to expand their selection of flavors, many will create a product and submit it to the product competition at their state meat processors convention or the American Cured Meat Championship at the American Association of Meat Processors convention. These contests have score
sheets that encourage feedback from the judges. The processors will then take the feedback and adjust the product accordingly. Another common method for evaluating a new product is to simply place it in their retail cases. It is very common for small processors to have frozen retail displays and they will display the product for several months to evaluate how it sells.

Small processors new to the business can take a slightly different approach, especially if they are new to creating formulations. In many instances customers want to start making Ham, Bacon, or Pepperoni but don’t know what ingredients should be added. They then would approach companies such as Ultrasource that sell pre-mixed spice blends or companies like Excalibur Seasonings and AC Legg who will develop custom spice blends. The processor then would use the spice pack as is or add spices to meet their desired flavor profile.

Pursuing Education

Many small meat processors whether they are new or established will always look for help developing processing methods or improving efficiency. One product that is particularly troublesome for many processors is boneless hams because they have issues with jelly pockets or holes forming in the center of their hams. To troubleshoot these type of problems, processors will consult with extension specialists or seek help from companies like Ultrasource that have food application scientists dedicated to helping them. In fact, small processors that operate in states with established extension programs experience great benefits to their business while those that don’t have extension programs that are immediately accessible to them have to pursue other means to troubleshoot processing issues.

Regardless of background, the community of small processors actively pursues new product ideas and training in new processes. The processing short courses put on by the Iowa State University, the Master Meat Crafter training course by the University of Wisconsin, the Northwest Meat Processing School and the Ultrasource Academy are all valuable tools for processors to processors develop their processes. In lieu of these short courses, the small processor community is very supportive to members of this community. Members of the American Association of Meat Processors such as Doug Hankes (Immediate Past President of AAMP) of Thrushwood Farms and Jesse Smith of the Diller Locker Company take time out of their schedules to assist members with their business.

Conversion to Corporate Entity

Many small to medium processors are experiencing great success at growing their business. The success is such that many processors are discarding the slaughter and fabrication component of their business in favor of further processing and developing a co-packing business. The current market for meat based protein snacks has been a huge advantage to the small processor who has the capacity to co-pack for other companies. Shelf stable meat snacks such as the Caveman Bar, Epic Bar, and Cro-Magnon snacks that have volumes low enough to be by-passed by larger co-packers have provided massive business growth to the small processor. This leads to investments in more smokehouses, grinders and stuffers with bigger capacity, packaging loaders, and roll-stock packaging machines.

Eventually the business grows big enough to require role specialization. Previous to this point a small business owner fills multiple rolls such as formulator, HACCP expert, manager, meat buyer, marketing, and human resources. This role specialization can have a significant impact on the R&D processes. As the company moves towards the division of labor, this means that people that have been involved in product development may no longer be involved. If management hasn't carefully defined the roles, it is possible the excess contributions will delay the development process. Issues can also arise by bringing in personnel to manage the non-manufacturing roles that don’t understand the business or don’t communicate using the same terminology. In both of these instances it is important to define a strong process for product development.

Most large businesses have a well-defined map of processes they use to develop products. These processes typically start with some type of concept summary. This summary would contain a product description and ideal price point. It is important that this description is detailed and goes through an approval process that is approved by managers in multiple departments. As an example, if a high end meat and cheese product was the goal, it would be very important to describe the cheese. There would be a big difference in processing capabilities, price point, labeling requirements, and nutrition profile between a product like Velveeta cheese and a hard sharp cheddar. If the raw material is not specified there could be significant challenges further in the development process such as inability to manufacture the product or wasted investments in processing machinery that is unable to process the raw materials.

After the concept summary is approved it would have to go through some type of market assessment before being approved to move into an evaluation of costs for production. At this point pilot plant work would commence and evaluations would be made on the sensory aspects of the product. If approved, packaging for the product would be developed, shelf life tests would be conducted, and labels will be submitted to USDA. After proper authorization at each stage, the new product would then be moved into plant testing. After the scale up has been improved full production can be begin.

Summary

In general the product development practices of the small processor are relatively simple. Due to control of their
retail store, processors can put new product directly into their markets or compete in product competitions to obtain decision making feedback for their new products. Many new processors utilize external resources such as extension programs to improve the quality and efficiency of manufacturing their products. As these companies grow, the current success of the snacking market provides huge opportunities for small processors to grow their businesses.

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INTRODUCTION

Meat is a suitable candidate for investing in advanced protective packaging, because it costs more than most other foods, has high carbon dioxide emissions and requires substantial resources for production. Avoiding food waste of meat is overshadowing the relatively smaller environmental cost of packaging. Proper packaging is securing a red stable color, long microbiological shelf life and high eating quality, so that meat does not end up as undesired food waste.

Packaging provides basic protection against outer contamination, physical damage and drying of the products. In modern distribution of meat with vacuum and modified atmosphere packaging (MAP), it is difficult for the consumer to assess the quality of the meat by smelling, tasting or feeling the texture. Therefore, consumers frequently base their choice of purchase on color. Discolored meat cannot be sold and contributes substantially to food waste, even if the color is not always a reliable indicator of eating quality. Although recent research and industry experience has yielded a considerable pool of knowledge about color, discoloration is still common and remains a frequent subject for trouble-shooting in the meat industry. Of no less importance, is the continuous work to extend and secure the microbiological shelf life of meat. Packing is not the only solution to long shelf life, but must be combined with thorough raw material or product hygiene, as well as temperature control along the chill chain.

The requirement for packaging differs with the items, like fresh meat of beef, lamb, pork and poultry, including whole muscle meat and ground meat, in addition to processed meat like cooked cold cuts, dry cured sausages and dried meat. The various products groups have different requirements on how to maximize color, shelf life and quality with minimum food waste, and will be addressed from both a research and industrial perspective.

PACKAGING METHODS

The four gases currently used for packaging of meat and meat products are carbon dioxide (CO₂, antimicrobial), nitrogen (N₂, inert filler), oxygen (O₂, profound effect on color and quality), and carbon monoxide (CO, color). These gases are seldom used alone, but in combinations adapted to the specific product and packaging needs. The following gas mixtures and packaging methods are options.

Fresh chilled meat of beef, pork, lamb and poultry (whole muscle and ground):

- high oxygen mixture of 60 to 80 % O₂ / 20 to 40 % CO₂ (worldwide, common in Europe)
- low carbon monoxide mixture of approximately 0.4 % CO / 30 % CO / 70 % N₂ (USA and more)
- low oxygen or oxygen-free mixture of 60 % CO₂ / 40 % N₂ (Norway)
- vacuum, skin-packages and chub packages (the lat- ter for ground meat)
- wrapping in oxygen permeable film.

Cooked or cured meat products with nitrite/nitrate:

- gas blends of 20 to 30 % CO₂ / 70 to 80 % N₂
- for dry cured meat products, alternatively use 100 % N₂
- vacuum and skin-packaging.

PACKAGING OF RETAIL MEAT IN SCANDINAVIA

A variety of packaging methods for fresh raw meat can be found in these countries. Commercial packaging with a CO gas mixture of 0.4 % CO / 60 % CO₂ / 40 % N₂ was first introduced in Norway in 1985 and lasted to 2004, when CO was prohibited due to adaption of European Union trade agreements. The CO mixture was successfully used for more than 60 % of the Norwegian retail meat, including red meats and poultry. From 2004, ground meat, pork, poultry and bone-in meat has been packaged in the same...
gas mixture without CO (60 % CO₂ / 40 % N₂), while retail cuts like steaks and boneless pieces of meat of beef, pork and lamb are often sold in skin-packages. Ground beef has the ability to remove low levels of detrimental residual O₂ in the headspace (Sørheim et al., 2009). Whole muscle meat like beef steaks seems to be lacking the ability to rapidly remove residual O₂ and therefore is not suitable for low O₂ gas packaging, but should be packaged in vacuum or skin-packages. In the period 2012 to 2014 the retailer NorgesGruppen temporarily used high O₂ for its private label meat, but returned to the 60 % CO₂ / 40 % N₂ gas mixture and skin-packaging as being more cost-effective. All Norwegian meat producers and retailers are now using O₂-free packaging for all types of raw meat. In the Swedish retail market for meat some of the high-O₂ packaging has been replaced with packaging in vacuum, skin-packages and chub packages. High-O₂ packaging of meat is still the most common method in Denmark, in accordance with many countries in the European Union.

**COMPARISON OF DIFFERENT PACKAGING FOR FRESH MEAT**

Color is the basis for consumer acceptance of meat. Traditionally, the opinion of consumers, retailers and industry has been that meat should be presented in the bright red oxymyoglobin state. Meat in the discolored metmyoglobin state has definitely been perceived as unacceptable and impossible to sell. However, many markets seem to have a growing acceptance of purple meat in the deoxymyoglobin state. In Norway, ground beef for retail is packaged in an atmosphere of CO₂/N₂ with low O₂, and in which the color usually changes from oxy-, via transient met- to final deoxymyoglobin (Sørheim et al., 2009). Grinding of beef helps by increasing the O₂ consumption rate, possibly due to tissue disruption (Madhavi & Carpenter, 1993). The key to succeeding in a rapid transformation of myoglobin forms is using raw materials with a high enzymatic activity, and that not have been frozen and is obtained shortly after slaughter. Using a low gas to meat ratio yields less volume of residual O₂ to remove from the headspace. A predominantly purple color can be achieved by storage of ground beef in atmospheres with residual O₂ below 0.1 % for at least two days. Avoiding an early accumulation of excessive metmyoglobin in ground meat is best achieved by rapid removal of residual O₂, which is temperature dependent and faster at 4 than 0 ºC (Bendall & Taylor, 1972). When inherent processes in the meat are not sufficient to remove residual O₂, applying O₂ scavengers can be a viable option, as demonstrated for master bag packaging of beef (Limbo et al., 2013).

Oxy- and carboxymyoglobin are visually and spectrally very similar, as described by the bright red or cherry red color (Suman et al., 2006). Carboxymyoglobin is more resistant to oxidation than oxymyoglobin, owing to the stronger binding of CO to the iron-porphyrin site on the myoglobin molecule. The redness of meat displayed in high-O₂ is reduced over time, while meat in low CO atmospheres remains stable red. Therefore, low CO packaging is contributing to meat being sold, consumed and ultimately not going to waste.

Premature browning of cooked meat is a condition in which the inner parts of the meat appears brown/gray and fully cooked without having achieved a safe core temperature of 71 ºC (Hague et al., 1995; Hunt et al., 1999). Ground beef that has been stored in high O₂ is turning brown/gray internally at temperatures of less than 60 ºC. At this temperature, shigatoxigenic Escherichia coli can survive and cause a food safety risk without the expected change in internal color (Røssvol et al., 2014).

In a consumer at-home study of different packaging for beef steaks with approximately 400 respondents each in Norway, Sweden and Denmark, meat in O₂-free packaging of gas and skin-packages was preferred over high-O₂ packaging (Aaslyng et al., 2010). Beef steaks in packages with low CO received a higher preference than with high-O₂ in tests in Denmark and Norway. In support of these findings, a comparison of attitudes to meat packaging by German and US consumers confirmed a high level of acceptance of CO inclusion in meat packaging, due to a cherry red color and long microbiological shelf life of the meat (Grebitus et al., 2013). In a study of ground beef in the USA, CO-MAP meat exhibited more desirable color and higher consumer desirability throughout display than from alternative packaging, including high O₂ (Røgers et al., 2014). In a recent consumer study in Australia, beef steaks in skin-packaging or overlap packaging scored higher than in high O₂ packaging for the attributes tenderness, juiciness, flavor and overall acceptability (Pollinghorne et al., 2018). These studies all point to O₂-free packaging, with or without CO₂ as being superior to high O₂ packaging in consumer preference of meat.

The amount of food waste may be influenced by the length of the shelf life. In a comparison from the Netherlands, high O₂ packaging had higher direct packaging costs than traditional film wrapping, but diminished food waste and improved the environmental impact (Velzen & Linnenmann, 2008). Commercial ground beef in high O₂ usually has a microbiological shelf life of 8-10 days compared to 16-18 days in the CO₂/N₂ gas blend. In Norway, the percentage of food waste for ground meat at retail display was registered in two periods, each of 8 months, comparing packages with high O₂ and CO₂/N₂ in 630 food stores by the retailer NorgesGruppen (Møller et al., 2016). The average number of packages of waste for ground meat in the stores in these two periods was 8.7 % in high O₂ and 2.5 % in CO₂/N₂, leading to a substantial difference in cost and environmental impact.

Numerous benefits of O₂-free packaging, either with gas or vacuum/skin-pack, versus high O₂ packaging have been demonstrated:
• a purple color that is stable throughout display and largely unaffected by light
• avoid the food safety risk of premature browning in the core of cooked meat
• no bone blackening (Cornforth & Hunt, 2008)
• no or very limited lipid oxidation, and no need for using antioxidants (John et al., 2004; Lagerstedt et al., 2011)
• tenderization is not restricted by protein oxidation (Rowe et al., 2004; Zakrys-Waliwander et al., 2012)
• extended microbiological shelf life with lower counts of spoilage bacteria (Sørheim et al., 1999; Rogers et al., 2014)
• reduction of growth of certain pathogenic bacteria (Nissen et al., 2000)
• simplified packaging with no use of flammable O₂
• substantial reduction of food waste, due to longer shelf life and less quality deterioration.

When accepting a purple color of meat at display, gas blends with CO/N₂ is a viable choice. Steaks and other whole muscle meat of beef and other red meats are suitable for skin-packaging, a technology that has become increasingly popular in Europe. CO in a level of 0.4 % is permitted as a packaging gas for bulk and retail red meats in the USA, but CO is not allowed in the European Union. Additional benefits of using CO/N₂ gas blends with low levels of CO (0.4 % or less) includes a stable cherry red color and a high protection against oxidation of heme pigments and lipids (Sørheim et al., 1997, Cornforth and Hunt, 2008; Rogers et al., 2014). The inclusion of low CO in MAP favors red color formation in meat, in particular beef, when variable redox status between muscles and insufficient reducing capacity are at risk. Low CO packaging is safe to use and represent no toxicological treat to consumers (Cornforth & Hunt, 2008). O₂-free packaging with low CO in gas blends of CO₂ and N₂ probably represents an ideal packaging solution for many markets, either for direct retail display or temporarily storage in master bag, in particular for dark meats like beef and lamb meat with high pigment contents.

However, experience from the Norwegian market have demonstrated that lighter types of meat like pork and chicken, even whole muscle meat, can do well with O₂-free packaging without CO and still maintain an acceptable pale red color at retail display. Using high O₂ packaging for chicken meat is not advisable, because of the risk of developing rancidity. In some markets, the use of high O₂ packaging for meat is combined with addition of antioxidants, which are not so needed in O₂-free packaging. The increasing trend of consumers looking for “clean label” with no or less additives can better be obtained with O₂-free packaging.

The main advantage with high O₂ packaging is the bright red color, in particular at early display, but gradually becoming less red over time. High O₂ packaging is still a method of choice for chilled retail meat packaging in many markets in the world. With agreements between industry and retail, and with open information to consumers about the above-mentioned benefits, it should be possible to change to O₂-free packaging. When high O₂ packaging was introduced in Europe about 40 years ago, the technology had clear benefits over simple oxygen-permeable cling film wrapping. Taking into account the knowledge having been acquired about high O₂ packaging, it is time to consider better alternatives to packaging of raw chilled meat for retail.

PACKAGING OF COOKED OR DRY CURED MEAT PRODUCTS

For the consumer, MAP with a high fraction of N₂ is facilitating the separation of slices from stacks of these products. Processed meat products with addition of nitrite and/ or nitrate differs from fresh meat in being more vulnerable to discoloration or fading by light at display, in combination with residual O₂ in the headspace of the packages. The levels of residual O₂ that causes light-induced oxidation of nitrosoheme vary between product groups. Sliced, cooked ham packaged in modified atmospheres should have < 0.15 % residual O₂ in headspace at start of illumination (Larsen et al., 2006). The cooked ham has no internal consumption of residual O₂ until late at display when bacteria increase in numbers. The requirements for very low residual O₂ in the packaging of cooked, cured meat products has led to increased use of light-proof top films.

Raw, fermented salami sausage could tolerate approximately 0.4 % residual O₂ in packages with sliced products at start of illumination (Sørheim et al., 2017). When salami contains active bacteria from added starter cultures, these are likely to contribute to removal of O₂. The consumption of residual O₂ in salami was much higher at 20 than 4 °C. In a test with MAP of sliced, cooked salami the benefit of O₂ removal was completely lost, because the added lactic acid bacteria were eliminated by heat treatment at 75 °C (unpublished results). The US summer sausage typically has a processing step with heating.

Light at retail display is aiming at presenting meat products in an attractive way to the consumers and stabilizing color and other quality attributes over time (Krof, 1980; Barbut, 2003). All over the world, energy-efficient light emitting diode (LED) light is replacing traditional fluorescent and incandescent light, so also in display cases and cabinets for meat products. Fluorescent light often is broad-spectra, with many small peaks in the range 400 to 700 nm of the visible light range, while LED light often has two peaks at the lower and upper parts of the spectra, which is near blue and yellow. In a study of sliced bologna sausage packaged in nitrogen with 0.5 % residual O₂ and exposed to different separate fractions of spectra by LED light for 24 hours, the blue and green fractions resulted in 2-3 times higher loss of redness compared to red
light (Böhner & Rieblinger, 2016). In support of these findings, the blue and green fractions of the spectra and wavelengths below 580 nm resulted in more product discoloration (Kropf, 1980). Increasing color stability of cooked ham, bologna, dry cured sausages, dry cured hams and similar products by choosing the right illumination can reduce food waste. Retailers should invest in research for finding the best possible spectra for various products under LED or other light. When conducting such light research, it is important to measure and report the specific spectra and light intensities obtained at the surface of the products along with a detailed temperature history.

**REDUCING FOOD WASTE AND LOSSES WITH BETTER PACKAGING**

Plastics in general and packaging materials for foods have been targeted as a source for pollution on land and in water, in particular. Packaging of meat is challenging, because the way meat is distributed in industrialized societies often requires protection of the products by using multi-layer high O₂ barrier materials, which are not easily characterized as environmental-friendly.

Roughly one third of the food produced in the world for human consumption is lost or wasted. As mentioned initially, reducing the amount of waste from meat is more important than the relatively low environmental contribution from plastic packaging materials. Even if much of the waste in industrialized countries is occurring in the households, the meat packaging should facilitate minimum waste, for example by offering correct package sizes, reclosing of packages, and with the best possible labelling and information to the consumers about shelf life and product handling. Packaging methods for extending microbiological shelf life, for example by applying high CO₂ gas blends, can reduce the amount of food waste. However, the food industry, including the meat sector, is now looking for alternative packaging that is recyclable, biodegradable and originate from non-fossil resources. The daily media attention on environmental issues keeps the consumers alert. The innovation in finding new materials and handle these is a best possible way is already huge and increasing.

In developing countries, much of the food is distributed from producers to consumers with little or no use of processing and packaging for extending shelf life. The loss of food is mainly occurring in harvesting and pre-handling of the food, and less at the household level. A pre-condition for investing in MAP or advanced packaging of fresh meat is a well-functioning chill chain from slaughter up to the consumers, in addition to proper hygiene during slaughter and handling of the meat. When proper value chains for meat are in place, opportunities for more and better packaging exist.

**CONCLUSIONS**

- For fresh raw meat at retail, replacing high O₂ packaging with high CO₂ packaging without residual O₂ would benefit the overall quality, shelf life and food safety
- Inclusion of low CO (0.4 % or less) packaging is favorable for stabilizing color of fresh red meats
- Controlling and rapidly reducing the level of residual O₂ in the headspace is paramount to stabilize color in MAP of many types of meat and meat products, with a high O₂ consumption rate found in ground meat and raw fermented sausage, and a low rate in whole muscle meat and cooked meat products
- The introduction of energy-saving LED light in display cabinets for meat products opens for adjusting light spectra in a favorable way to minimize surface discoloration
- Reducing food waste has become a driving force in selection of packaging methods for fresh meat and meat products, in the direction of longer shelf life
- A strong international trend to reduce the amount of plastics and change to fossil-free, recyclable and biodegradable packaging materials will affect future packaging of meat.

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Recently, the topic of “cultured meat” has led to many questions relating to its definition and regulation. This interactive debate was developed to engender lively discussion on the protein products being developed by the meat and poultry industry and the complexity of the challenges the industry faces with these topics. During the debate, speakers presented “for” and “against” the following two topics:

1. Should the regulatory definition of meat (9 C.F.R. § 301.2) include “cultured meat” products?
2. Should non-animal protein products be held to the same regulatory requirements as meat and poultry products?

To evaluate whether audience views had changed following the debate, electronic polling was conducted that allowed for a yes/no vote on each topic question prior to and following the discussion. Results of the pre-debate survey found:

1. Should the regulatory definition of meat (9 C.F.R. § 301.2) include “cultured meat” products?
   - 43% responded “yes”; 57% responded “no”
2. Should non-animal protein products be held to the same regulatory requirements as meat and poultry products?
   - 79% responded “yes”; 21% responded “no”

During the session, two speakers presented either a “yes” or “no” position during a 7-minute presentation, and each presenter conducted a 3-minute rebuttal. Concluding the rebuttal, a 6-minute question and answer session was allowed for audience participation. Discussion among topics advanced audience knowledge on the subject matter and awareness of concerns presented by each speaker. An overview of the presented evidence per topic by “yes” then “no” is provided. It is important to note, the speakers’ views given in this session may not have been reflective of personal or professional positions as this was purely an academic discussion.

**Topic 1, Should the regulatory definition of meat (9 C.F.R. § 301.2) include “cultured meat” products?**

**Presented evidence for “yes”:**

The presentation began with a congressional statement of findings which read, “It is essential in the public interest that the health and welfare of consumers be protected by assuring that meat and meat food products distributed to them are wholesome, not adulterated, and properly marked, labeled, and packaged.” In law (21 U.S.C. 601 (j)), meat food products are described as any article capable of use as human food. These products must be derived either wholly or in part from any meat or other portion of the carcass. “Cultured meats” are taken from a small sample of muscle tissue, and so, are derived from the carcass. Furthermore, the American Meat Science Association (AMSA) stated, “Historically, terms used in the meat industry were never created using a single systematic method...They were, instead, created in a more empirical fashion...to describe an industry and its related practices encompassing a variety of species, processes, technologies, and products all evolving over time.” The method of production is not a regulatory criterion in determining a product’s safety, hence cultured meat food products should be subject to equivalent food safety standards as the product that they are emulating.

**Presented evidence for “no”:**

The speaker-against prompted the audience with an initial question, asking “When do cultured cells become muscle and then meat?”. A portion of the regulatory definition of meat states, “The part of the muscle of any cattle, sheep, swine, or goats which is skeletal...in the process of dressing.” The Food and Drug Administration (FDA) defines food as articles used for food or drink for man or other animals (21 U.S.C. § 321(f)). The Center for Biologics Evaluation and Research specializes in conducting inspections, investigations, and compliance activities for blood and tissue products and works hand in hand with federal agencies to increase competency and consistency.
of inspections. Following these discoveries, it is possible that it would be most appropriate for FDA to have jurisdiction of foods produced by using animal cell culture technology.

**Post-Debate Results**

The live-polling post-rebuttal and after interactions with the audience changed results to 57% “yes” and 43% “no.” Therefore, the pre-debate poll response shifted as there were more “yes” responses and a decrease in “no” responses by 14%. Overall, the majority of responses indicate that the regulatory definition of a meat food product should include “cultured meat” products.

**Topic 2, Should non-animal protein products be held to the same regulatory requirements as meat and poultry products?**

**Presented evidence for “yes”:**

The FDA and the United States Department of Agriculture (USDA) have regulations on misbranding of food that are very similar in their context. FDA’s regulation (21 CFR § 101.18) reads, “Among representations in the labeling of a food which render such food misbranded is false or misleading representation with respect to another food...”. While USDA’s regulation (9 CFR § 301.2) reads, “Misbranded. This term applies to any carcass, part thereof, meat or meat food product under one or more of the following circumstances: (1) if its labeling is false or misleading in any particular...”. An example of misbranding of meat products given was a bag of chips labeled as “Bacon Habanero” in large text, however, in fine print across the side of the bag is a label stating, “vegan bacon”. The labeling of “cultured meat” as meat would be consistent with this type of misbranding.

**Presented evidence for “no”:**

Since the FDA regulates pharma and beer, it is the belief of the speaker-against that non-animal protein should also be included. In addition to pharma, FDA is responsible for medical devices which are required to be suitable for use inside the human body. Those same governing principles and production requirements are how non-animal protein products are produced. The FDA regulates products such as baby formula, cancer drugs, and adult beverages. Therefore, the speaker-against stated that the FDA is well suited to assess the safety and is the logical regulator for “cultured meat”.

**Post-Debate Results**

The live-polling post-rebuttal and after interactions with the audience changed results to 88% “yes” and 12% “no.” Therefore, the pre-debate poll “yes” responses increased by 9% over the “no” responses. The debate further cemented the audiences’ stance, in that non-animal protein products should be held to the same regulatory requirements as meat and poultry products.
RMC is Hosted By
Smithfield Foods, Inc. and the AMSA Members in the Greater Kansas City Area

2019-2020 RMC/ICoMST

June 23-26, 2019
Colorado State University,
Fort Collins, Colorado

August 2-7, 2020
Disney Coronado Springs Resort
Lake Buena Vista, Florida

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