IT IS POSSIBLE TO GENETICALLY CHANGE THE NUTRIENT PROFILE OF BEEF

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Introduction

For the last 25 years health professionals have encouraged people to reduce their intake of red meat as a means of reducing saturated fat intake with the goal of decreasing serum cholesterol level and, hence, the risk of atherosclerosis and cardiovascular disease (CVD) (Mensink, 2011). This recommendation is based on the perception that red meat is the major contributor to both total fat and saturated fat in the Western diet and that animal fat is a high risk factor for these diseases. Although this perception was seldom questioned, it is recently coming under increasing scrutiny and recent studies show that reducing intake of meat may not reduce the risk of CVD (McNeill and Van Elswyk, 2012). In this context, reducing the intake of red meat would only result in reducing the intake of a food with the highest nutritional value per unit of energy (nutritional density) as well as many bioactive components with important health promoting properties.

Modern consumers are increasingly aware of the relationship between diet and health and this awareness is responsible for the trend toward consumption of food perceived to be safe, nutritious and promoting good health and wellbeing. Meat provides valuable amounts of high quality protein containing several essential amino acids, fatty acids, vitamins (E and B complex, being major sources of B12) and minerals (USDA/HHS Dietary guidelines Americans, 2010). Equally important, meat is also a source of many bioactive components with health promoting properties such as conjugated linoleic acid, minerals of high bioavailability such as iron, zinc and selenium, peptides (carnitine, creatine, creatinine, carnosine and anserine), choline, etc. Therefore, beef industry is in a good position to respond to the demands of health-conscious consumers. To capitalize on this trend, the industry needs to focus its research and promotion efforts toward nutritional and health benefits of meat consumption.

A strategy designed to ensure that meat plays the role it deserves as a major component of a healthy diet should include research designed to document the relationship between meat consumption and specific health benefits, to develop the genetic or management tools needed to increase the components with positive and reduce those with negative health consequences, and to develop consumer education programs to promote nutritional and health benefits of meat consumption. The industry should also emulate the fruit and vegetable blueprint in pursuing scientific evidence on positive aspects of meat consumption on human health.

Why is the nutrient profile of beef important?

While the prevalence of obesity is rapidly increasing (Flegal et al., 2012) and has reached a 33.8% high among US adults (Shields et al., 2011), many Americans are not meeting the recommended daily intake for many nutrients (USDA-ARS, 2011), i.e., they are "overfed and undernourished". Among all diet components, meat has the unique status of providing per unit of energy high amount of high quality protein along with many nutritive factors and other components important for human health. Given its high nutrient density, red meat can, and should, play a critical role in meeting the nutritional needs of the consumers. Beef is already an important food group in the diet of many consumers and improvement of its healthfulness will be an efficient way to provide health benefits to a large proportion of the population, without dramatically changing dietary habits or affecting food quality, convenience and costs.

Animals and sample collection.

A total of 2,285 Angus sired bulls (n = 540), steers (n = 1,311), and heifers (n = 434) were used in this study. All cattle were finished on concentrate diets in Iowa (n = 1,085), California (n = 360), Colorado (n = 388), or Texas (n = 452). Animals were harvested at commercial facilities when they reached typical US market endpoints with an average age of 457 ± 46 days. Production characteristics including detailed sample collection and preparation of these cattle were reported previously (Garmyn et al., 2011). Briefly, external fat and connective tissue were removed from 1.27-cm steaks for nutrient and other bioactive compounds composition and 2.54-cm steaks were removed for Warner-Bratzler shear force (WBSF) and sensory analysis. All steaks were vacuum packaged, aged for 14 d from the harvest date at 2°C and frozen at -20°C. Steaks were cooked and subjected to WBSF and sensory analysis at Oklahoma State University Food and Agricultural Products Center. Nutrient and bioactive compounds composition analysis was conducted at Iowa State University.

Mineral and peptide content of Angus beef

Dietary minerals are essential components of human diets, and most dietitians recommend that these minerals be supplied from foods in which they occur naturally. Meat provides valuable amounts of important minerals but limited information is available regarding their content and natural variation in beef, the extent to which that variation is the result of genetic differences or if it is associated with meat palatability traits. The objectives of our study were to quantify the genetic and environmental components of observed variation in the concentrations of several minerals and peptides in LM of Angus beef cattle, to estimate genetic parameters and their associations with a wide portfolio of beef palatability traits. The concentrations for several minerals and peptides are shown in **Table 1**.

Table 1. Simple statistics for calcium, copper, iron, magnesium, manganese, phosphorus, potassium, sodium and zinc concentrations (µg/g muscle), and carnitine, creatine, creatinine, carnosine and anserine concentrations (mg/g muscle) of steaks from Angus cattle.

Trait	N[1]	Mean	SD[2]	CV[3]
Calcium	2,260	38.71	19.79	0.51
Copper	1,980	0.78	0.85	1.09
Iron	2,259	14.44	3.03	0.21
Magnesium	2,274	254.54	43.06	0.17
Manganese	2,000	0.07	0.04	0.57
Phosphorus	2,271	1,968.02	278.36	0.14
Potassium	2,225	3,433.54	494.27	0.14
Sodium	2,273	489.44	92.92	0.19
Zinc	2,261	38.96	7.90	0.20
Carnitine	2,248	3.16	0.94	29.75
Creatine	1,835	5.26	0.53	10.08
Creatinine	2,161	0.21	0.11	52.38
Carnosine	2,140	3.72	0.46	12.37
Anserine	2,139	0.67	0.13	19.40

[1]Number of cattle
[2]Standard deviation
[3]Coefficient of variation

Iron and Zinc

Iron deficiency is one of the most common and widespread nutritional disorder in the world affecting both developing and industrialized nations (WHO, 2006). In the U.S. and Europe the iron deficiency is greater particularly in pregnant women and infants living in lower socioeconomic groups (Agostoni et al., 2008). A recent study from Australia (Samman, 2007) indicates that ~30% of young women had mean daily iron intakes of less than 70% of the recommended daily intake and among young female athletes was even higher at 51%. The intake of iron was inversely correlated with the amount of red meat consumed on the day of the survey (Baghurst, 1999). The picture is similar in the US with iron deficiency anemia being identified by the Centers for Disease Control & Prevention as the most common nutritional deficiency.

The iron concentration in our data set was 14.44 µg/g muscle, representing on average 1.44 mg iron per 3.5 oz serving of beef. The current recommended daily allowance varies depending on gender and age from 8 to 18 mg per day. In this context, a 3.5 oz serving of beef would provide between 8 and 18% of the recommended daily allowance. The amount of iron absorbed compared with the amount ingested is typically low, and the source of iron is an important factor determining the efficiency of absorption (Kapsokefalou and Miller, 1993; Andrews, 2005; West and Oates, 2008; Han, 2011). Of particular importance are the results reported by Etcheverry and co-workers (2006) which indicate that, in adolescents, non-heme iron and zinc absorption from a beef meal is significantly greater than that from a meal providing soy protein.

The obvious and probably most effective dietary strategy to improve iron status in population groups exhibiting iron deficiency (especially infants, growing children and young women) is to increase intake of absorbable iron by increasing consumption of meat and the concentration of iron in meat. Both strategies represent opportunities for the beef industry by developing programs focusing on the benefits of meat consumption targeting segment of the population at risk of iron deficiency and implementing genetic programs to increase iron content.

Zinc is an essential nutrient involved in a number of metabolic processes, including protein and nucleic acid synthesis, insulin and other enzymes, growth and immunity, therefore, critically important for good health. The World Health Organization (WHO) considers zinc deficiency to be a major contributor to the burden of disease in developing countries, especially in those with a high mortality rate. Based on WHO estimates, it appears that 25% of the populations of South and South-East Asia and Latin America are at risk of inadequate zinc intake, compared with 10% of the population of Western Europe and North America. Similar to iron, zinc in animal products is more readily absorbed than from plant foods. Beef is the major source of zinc in the diet.

Relatively high heritability for iron (**Table 2**) and moderate heritability for zinc along with their positive genetic correlation (0.49) indicate that a selection program with emphasis on increasing the beef content for these two minerals is feasible and permanent and cumulative genetic improvement should be successful. The associations of iron and zinc concentrations with several palatability traits (tenderness, juiciness and flavor) were all low indicating that increasing the iron and zinc content, no negative consequences on palatability traits are expected (Mateescu et al., 2013a).

Table 2. Genetic (σ^2_a) and residual (σ^2_e) variance and heritability (h^2) estimates with SE for calcium, copper, iron, magnesium, manganese, phosphorus, potassium, sodium and zinc concentrations (µg/g muscle) and carnitine, creatine, creatinine, carnosine and anserine concentrations in LM from Angus cattle obtained by single trait REML analysis.

Trait[1]	σ^2_a	σ^2_e	$h^2 \pm$ SE
Calcium	0.00003	277.74	0.000 ± 0.03
Copper	0.00025	0.49	0.000 ± 0.04
Iron	3.69	3.09	0.544 ± 0.09
Magnesium	36.78	530.83	0.065 ± 0.04
Manganese	0.00006	0.007	0.009 ± 0.03
Phosphorus	1105.10	29630.5	0.036 ± 0.03
Potassium	3989.63	104989.0	0.037 ± 0.03
Sodium	591.32	2574.71	0.187 ± 0.06
Zinc	4.73	47.10	0.091 ± 0.04
Carnitine	0.0055	0.350	0.015 ± 0.03
Creatine	0.0974	0.127	0.434 ± 0.10
Creatinine	0.0001	0.002	0.070 ± 0.05
Carnosine	0.0557	0.089	0.383 ± 0.07
Anserine	0.0076	0.007	0.531 ± 0.08

Genome-wide association study for iron concentration

Given the difficulty of collecting records for these traits in selection candidates, implementation of a selection program would require identification of genetic markers associated with iron and zinc content to be used in marker-assisted selection programs. Toward this end, a genome-wide association study using the Bovine SNP50 Infinium II BeadChip was conducted to identify chromosomal regions associated with concentrations of iron in LM of Angus beef cattle, to estimate genomic breeding values for iron concentration and assess their accuracy, and to determine how other economically important traits might be affected by genomic selection to improve iron concentration (Mateescu et al., 2013b).

Seven regions on six chromosomes (1, 2, 7, 10, 15 and 28) were identified to have major effect on iron content of LM in Angus cattle. Many of these chromosomal regions contain, or are in close proximity to, genes associated with iron homeostasis or iron metabolism, providing strong candidate genes for further investigation as well as confirming the validity of the genome-wide association results. The proportion of phenotypic variance of iron concentration in muscle explained by SNP genotypes (genomic heritability) was 0.37 and the accuracy of genomic breeding value (GEBV) was 0.59. This level of accuracy indicates that selection based on genomic merit for iron concentration would be as efficient as selection based on individual phenotype for a trait with heritability of 0.35. We estimated that in a selection program to improve iron concentration based on GEBV, and for each unit (µg/g of meat) improvement in iron GEBV, 0.73 units (µg/g of meat) improvement in the actual iron concentration is expected.

To assure long-term sustainability of the industry, a beef cattle improvement program should consider traits that influence production efficiency, traits that influence quality of the eating experience, traits that influence animal health and well-being, and traits that would provide health benefits to humans consuming the product. Increasing the concentration of iron and zinc in beef muscle through selection should benefit the beef cattle industry as well as consumers by producing meat that is healthier for humans to eat and, therefore, encouraging consumption. In addition, increasing iron concentration in muscle would contribute to improved functionality of beef (defined as retention of red color at days 3-4 of retail display) and improved beef flavor. Vitamin E and iron content in muscle are the most important factors determining the functionality of meat, with redness being positively related to both vitamin E and heme iron content in lamb meat (Ponnampalam et al., 2012). Increasing iron content in muscle is expected to also improve color stability (shelf life) of beef at retail display. A significant genetic and phenotypic correlation was reported recently (Garmyn et al., 2011; Mateescu et al., 2013a) between beef flavor and iron concentration, indicating an increase in iron concentration would contribute toward an improved beef flavor.

Other nutrients

Meat also contains many other compounds with human health importance. Among these components, some of which are not generally recognized as nutrients, we evaluated carnitine, creatine, creatinine, carnosine and anserine. There is growing evidence regarding the positive effect these meat bioactive compounds play in human health and wellbeing. They are powerful antioxidants and play important roles in muscle metabolism and other metabolic functions. The focus in this paper will be on the role meat, with its quality protein and bioactive compounds, can play in preventing and reversing muscle wasting diseases such as sarcopenia.

Sarcopenia refers to the gradual loss of muscle mass and strength at a rate of about 1% per year that accompany the aging process. Sarcopenia leads to reduced mobility and weakness, increased risk of diabetes and weight gain, poor quality of life and morbidity. The underlying mechanism is unknown but age-associated changes in diet and exercises are primary suspects. The 'National Health & Nutrition Examination Survey' estimated that about 25% of adults over age 50 have low levels of B12 vitamin, strongly suggesting inadequate amount of animal products in their diet. What is known is that physical exercise, particularly weightlifting, and adequate nutrition can prevent and reverse the syndrome. A recent study compared the acute muscle protein synthetic response occurring at rest and following resistance exercise in middle-aged men following the ingestion of 4 oz (113 g) of beef protein or an equivalent amount of soy-based protein marketed and sold as a bona-fide replacement for beef (Phillips, 2012). The results show that meat, with its quality protein and bioactive compounds, is better than plant protein at promotion of myofibrillar (the contractile protein of skeletal muscle) protein synthesis at rest and also following resistance exercise. Based on these results men over 50 should include lean beef in their diet to prevent or delay the onset of muscle loss. The inclusion of a serving of beef would also provide substantial amounts of iron, zinc, vitamin B-12 as well as carnatine, creatine, creatinine, carnosine, anserine and other nutrients and bioactive compounds that are missing or present in small amounts and with low bioavailability in plant-based proteins.

Our study found creatine, carnosine and anserine to be moderately heritable (**Table 2**) whereas almost no genetic variation was observed in carnitine and creatinine. The additive genetic variation for some of these traits is large enough to be exploited in selection or management if changing the concentration of these compounds is contemplated but at this point in time such a program may not be necessary. The natural concentrations of these components in beef seem adequate to enhance the protein quality and prevent the onset of sarcopenia in the segment of the population at risk. Few associations between these compounds and WBSF or meat quality assessed by sensory panels were detected, and these associations were favorable, suggesting that palatability would not be compromised if the nutritional profile of beef would be improved by altering the concentration of these compounds.

Conclusions

Following recent trends, consumers are likely to continue to pay increased attention to the effect of diet on health. Red meat is a very nutritious food and contains numerous compounds with positive health effects but, unfortunately, the average consumer is not familiar with these benefits. An online poll conducted for American Meat Institute by Harris Poll revealed that most consumers do not fully recognize the unique nutritional benefits that beef has to offer. For example, only 12% of consumers correctly identified animal products like beef and poultry as the only natural source of vitamin B12. In the same poll, 20% of the consumers said cruciferous vegetables such as broccoli and cauliflower while 13% said citrus fruit were the natural source of vitamin B12, when in fact neither of these types of foods contains vitamin B12.

The beef industry needs to increase its efforts to document and promote the nutritional and health benefits of beef in order to capitalize on the consumer trend. The most convincing way to demonstrate the positive effects of meat consumption on health is via well designed human intervention studies and the beef industry should take a proactive role and increase its efforts to promote/support studies addressing the most prevalent chronic diseases, in which dietary intervention using red meat would reduce risks or improve quality of life.

In this paper two important human health issues, iron deficiency and sarcopenia, were discussed. In both cases, increasing consumption of red meat to meet the recommended daily intake would mitigate the health problem given that the segments of the population affected (young women and elderly people), have a relatively low red meat consumption. This represents a golden opportunity to improve human health and increase red meat consumption.

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