RESEARCH REPORT
HUMAN NUTRITION

Title: *Digestible indispensable amino acid score* (DIAAS) *for pork products at various stages of processing*. **NPB # 17-083**

Revised

Investigator: Eric P. Berg

Institution: North Dakota State University, Fargo

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Industry Summary:

Objectives: The objectives of this research were to test the hypotheses that meat products, in general, have digestible indispensable amino acid score (DIAAS) values that are greater than 100% and that cooking of ground or unground beef increases the ileal digestibility of the indispensable amino acids.

Outcomes: Using DIAAS cut-off values, protein quality can be described as 'Excellent' if DIAAS is greater than 100% and 'Good', if DIAAS is between 75% and 99% (FAO, 2013). For children from six months to three years of age, raw pork belly, smoked bacon, smoked-cooked bacon, non-cured ham, alternatively cured ham, conventionally cured ham, pork loin heated to (63ºC, 68ºC, or 72ºC), salami, beef/pork bologna, beef jerky, raw ground beef, as well as beef ribeye steaks cooked to medium rare (56°C) and medium (64°C) degree of doneness can be described as 'Excellent' quality proteins while cooked ground beef and well done ribeye would be classify as "good" quality protein sources. For the reference demographic representing persons three years or older, all meat categories but for cooked ground beef can be classified as "excellent" sources of indispensable amino acids.

Impact: Pork and beef products have the potential to compliment and balance a mixed-food diet with fewer calories providing nutrients necessary to fulfill the global undernutrition of indispensable amino acids for the prevention and (or) treatment of chronic disease prevention of the developmental conditions of wasting, stunting, and underweight as well as overweight and obesity.

Key Words: DIAAS, PDCAAS, beef, pork, amino acid digestibility

Scientific Abstract:

Calculation of the digestible indispensable amino acid score (DIAAS) is recommended by the Food and Agriculture Organization of the United Nations (FAO) for evaluating protein quality in human foods. The objectives of the present studies were to determine DIAAS values for pork and beef products, and to test the hypothesis that processing increases DIAAS. In Experiment 1, 10 ileal cannulated gilts were allotted to a 10 × 10 Latin square. In Experiment 2, 9 ileal cannulated gilts

were allotted to a 9 × 8 Youden square. The DIAAS was calculated using the FAO established reference patterns for children 6 mo to 3 yr and children > 3 yr, adolescents, and adults. In Experiment 1, DIAAS was greater than 100 for all pork products regardless of reference pattern. For both reference patterns, the DIAAS for smoked-cooked bacon was greater than for raw belly and smoked bacon, the two cured hams had numerically greater DIAAS than the non-cured ham, and loin heated to 63ºC had a greater DIAAS compared with loin heated to 68ºC or 72ºC. In Experiment 2, all products had a DIAAS value greater than 100, except cooked ground beef and ribeye roast heated to 72ºC. For both reference patterns, bologna and ribeye roast heated to 64ºC had the greatest DIAAS and cooked ground beef had the least DIAAS. In conclusion, meat products generally have DIAAS values greater than 100, and curing and cooking may increase DIAAS.

Introduction:

The definition of "protein quality" has long been defined by the protein digestibility corrected amino acid score (PDCAAS). In fact, it has been used for more than 20 years since first described in the Report of a Joint FAO (Food and Agriculture Organization)/WHO Expert Consultation (1991). Over this period of time, limitations in the PDCAAS procedure have been identified. In general, PDCAAS underestimates the value of high-quality proteins (meat) and overestimates the value of low-quality proteins (grains).

In an effort to rectify the flaws of the PDCAAS procedure, the FAO 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 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 body's demand for indispensable amino acids at various life stages. DIAAS should be calculated from amino acid digestibility (nutrient absorption) at the terminal ileum of the small intestine "*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)."

These statements from a branch of the United Nations and the World Health Organization are very notable because both have long been critical of muscle foods and the "*sustainability*" of producing livestock. Research of this nature will show that muscle foods and other animal proteins can provide an answer to three of the world's leading nutrient deficiencies; iron, B12, and indispensable amino acids. Furthermore, it will shift the plane of thought from crude protein to amino acids. For example, nutritionists may currently recommend a certain quantity of protein be consumed throughout the day. **The protein content listed on the food label is not indicative of the amino acid quality of the food,** and therefore, the individual may believe they are consuming adequate indispensable amino acids, when in fact they are not.

Objectives:

The objectives of this research were to test the hypotheses that meat products, in general, have DIAAS values that are greater than 100% and that cooking of ground or unground beef increases the ileal digestibility of the indispensable amino acids.

Materials & Methods:

In Exp. 1, 10 gilts (initial BW: 26.63 ± 1.62 kg) were fitted with a T-cannula in the distal ileum (Figure 1 and 2) and allotted to a 10 × 10 Latin square with 10 diets and ten 7-d periods. Nine pork products were evaluated (i.e., raw belly, smoked bacon, smoked-cooked bacon, non-cured ham, alternatively cured ham, conventionally cured ham, and loin heated to 63ºC, 68ºC, or 72ºC). In Exp. 2, 9 ileal cannulated gilts (initial BW: 35.50 ± 3.77) were allotted to a 9 × 8 Youden square with 9 diets and ten 7-d periods. Eight meat products were evaluated (i.e., salami, bologna, beef jerky, raw ground beef, cooked ground beef, and ribeye roast heated to 56ºC, 64ºC, or 72ºC). For both experiments, each meat product was used in one diet as the sole source of AA, and ileal digesta were collected on d 6 and 7 of each period. DIAAS values were according to FAO (2013).

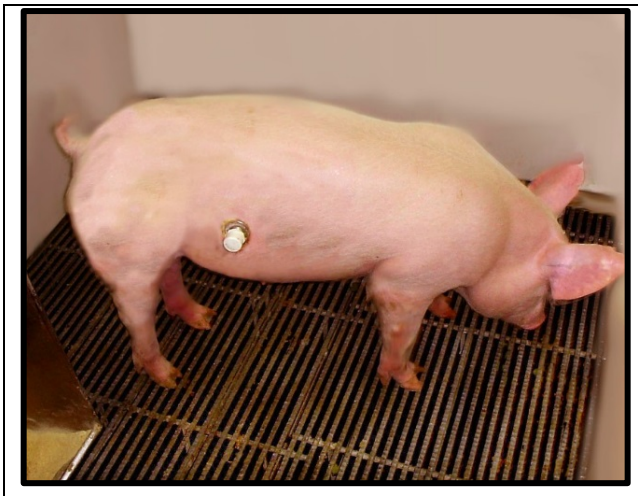

Figure 1. Research gilt that has been fitted with an ileal cannula.

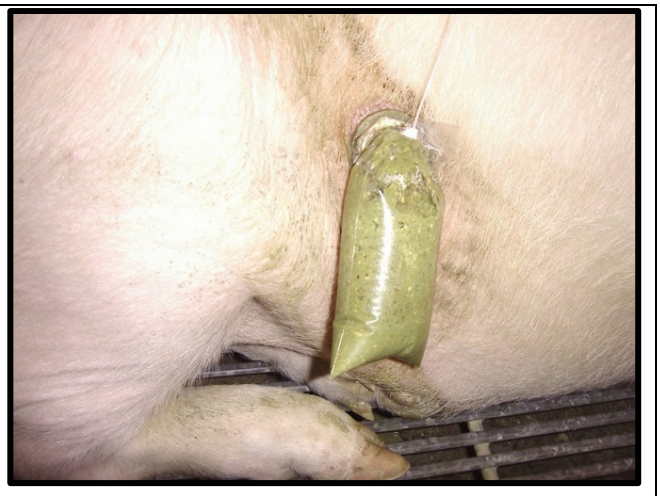

Figure 2. Collection of fecal digesta from the ileal cannula.

Results:

All pigs remained healthy throughout the experiment and readily consumed their daily feed allowance.

In experiment 1 (Table 1), all pork products had a DIAAS value greater than 100, regardless of the reference pattern and method of processing. This indicates that pork products are excellent quality proteins and have the potential to complement lower quality proteins, such as cereal grains and some plant proteins (FAO, 2013). For both reference patterns, smoked-cooked bacon had a greater DIAAS compared with smoked bacon and raw belly, and alternatively cured ham (cured with celery salt) and conventionally cured ham (cured with Prague powder) had greater DIAAS values than non-cured ham. Loin heated to 63ºC had a greater DIAAS value than the other 2 loins. The AA in least concentration (limiting IAA) when compared with the 2 human IAA reference patterns was Trp for smoked-cooked bacon and Val for all pork products. In experiment 2 (Table 2), ribeye

roast heated to 72ºC and cooked ground beef had DIAAS less than 100, but all other meat products had DIAAS greater than 100. For both reference patterns, bologna had a greater DIAAS than salami and beef jerky; raw ground beef had a greater DIAAS than cooked ground beef; and the ribeye roast heated to 64ºC had a greater DIAAS value than the other 2 ribeye roasts. The limiting AA for children older than 3 yr was sulfur for beef jerky, Leu for bologna, raw ground beef, and cooked ground beef, and Val for salami and the 3 ribeye roasts. In conclusion, meat products are generally excellent quality proteins with DIAAS values greater than 100. In addition, curing and moderate heating may increase DIAAS, whereas grinding meat prior to some processing methods may expose a greater surface area to heating resulting in overcooking that may reduce the DIAAS value.

Table 1. Experiment 1 digestible indispensable amino acid score (DIAAS) calculated for each pork product using the standardized ileal digestibility of amino acids from the Food and Agriculture (FAO) division of the United Nations established reference protein patterns.

DIAAS for a child six months to 3 years old[1]										
	Bacon			Ham			Loin				
Raw belly	Smoked	Smoked-cooked	Non-cured	Alt. cured[2]	Conv. cured[3]	Rare (63 °C)	Medium (68 °C)	Well (72 °C)	Pooled SEM	P-value
119[e] (Val)	117[e] (Val)	142[a] (Val)	124[d] (Val)	133[c] (Val)	126[d] (Val)	139[b] (Val)	118[e] (Val)	117[e] (Val)	1.08	<0.001
DIAAS for older child, adolescent or adult[2]										
111[e] (Val)	109[e] (Val)	126[b] (Trp)	115[d] (Val)	123[c] (Val)	117[d] (Val)	129[a] (Val)	109[e] (Val)	109[e] (Val)	0.99	<0.001

[a-f]Means within a row lacking a common superscript letter differ ($P < 0.05$).
[1]DIAAS calculated using the FAO recommended amino acid scoring pattern for a child (6 m to 3 y).
[2]DIAAS calculated using the FAO recommended amino acid scoring pattern for older child, adolescent, and adult.

Table 2. Experiment 2 digestible indispensable amino acid score (DIAAS) calculated for each meat product using the standardized ileal digestibility of amino acids from the Food and Agriculture (FAO) division of the United Nations established reference protein patterns.

DIAAS for a child six months to 3 years old[1]									
			Ground beef		Ribeye roast				
Pork Salami	Beef/Pork Bologna	Beef Jerky	Raw	Cooked	Rare (56°C)	Medium (64°C)	Well (72°C)	Pooled SEM	P-value
107[c]	118[a]	102[d]	111[b]	92[f]	104[d]	121[a]	99[e]	1.02	<0.0001
DIAAS for older child, adolescent or adult[2]									
120[b]	128[a]	120[b]	121[b]	99[e]	111[c]	130[a]	107[d]	0.97	<0.0001

[a-f]Means within a row lacking a common superscript letter differ ($P < 0.05$).
[1]DIAAS calculated using the FAO recommended amino acid scoring pattern for a child (6 m to 3 y).
[2]DIAAS calculated using the FAO recommended amino acid scoring pattern for older child, adolescent, and adult.

Discussion:

Processed meats have been targeted as a global cause of obesity-related disorders and (or) cancer. The further processing of smoked then baked bacon, cured ham, salami, bologna, and jerky improved DIAAS scores. This is important to note as several of these products are derived from less expensive lean trimmings making them an inexpensive food source of indispensable amino acids that appeal to a wide range of consumers (even kids). The increased digestibility may be attributed to grinding. Grinding of whole muscle foods may have an impact similar to chewing which increases the surface area of proteins during digestion. Also, the addition of ingredients that prevent oxidation during heat processing may also be having an effect on maintaining the integrity of proteins prior to digestion in the small intestine. The decrease in DIAAS of cooked ground beef from raw ground beef supports this observation. Grinding the beef increases the DIAAS, yet the high cooking temperature in a relatively short period of time in the absence of oxidation preventing

ingredients results in a lower DIAAS; especially the reference demographic of children under three years of age. It is apparent that heating pork and beef to a higher temperature has a negative impact on DIAAS as seen with cooked ground beef and well-done ribeye roast.

Implications/Industry Impact:

Most often we associate malnutrition with undernutrition. The World Health Organization (WHO, 2018) described 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 page FAO (2012) publication titled: **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 (such as pork and beef) has the nutrient density to prevent/cure these most common global nutrition-related conditions. Red meat products, naturally high in the indispensable amino acid lysine, have the potential to compliment cereal grains and balance the amino acid profile of a mixed diet. This is especially important considering the nutrient density of pork and beef and the ability to fulfill the global undernutrition of indispensable amino acids, iron, and vitamin B12 by providing these nutrients from fewer dietary calories.