Carbon: Ingredient values for formulation in swine diets

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Pork products are a vital protein source for the global population; however, an increased focus on sustainability throughout the swine industry has led to efforts to find substantial reductions in the environmental impact per kg of pork produced. Measuring the environmental impact of an industry or production practice can occur in a variety of forms, including assessment of carbon utilization, greenhouse gas emissions, and excretion of undigested nutrients into manure (Andretta et al., 2021). Each of these addresses a specific concern based on the resulting impact on the environment. Ultimately, the most comprehensive way to evaluate the environmental impact of the swine industry is through a Life Cycle Assessment which attempts to quantify the inputs and outputs of a system for a comprehensive understanding of a particular practice or industry segment.

Importance of Carbon

Crop cultivation (44.50%) and manure management (42.19%) have been identified as the two largest contributors to C emissions, accounting for over 86% of the total C emissions from swine production systems (Yu et al., 2024). When translating these factors into considerations for formulating swine diets, C emissions will largely be affected by initial ingredient selection and retention efficiencies. This fact sheet will specifically focus on the C associated with the feed ingredient itself; however, additional knowledge on the ingredient's production and transportation are needed to understand the full impact of the ingredient's C value.

NRC carbon values for ingredients

For ingredient selection, understanding C content of each feed ingredient is vital. Although currently underutilized, the National Research Council (NRC, 2012) provides C values for commonly used swine feed ingredients including cereal grains, protein sources, and fats. These values were established using the following equation, which can be updated using actual ingredient analytical values:

Calculated carbon of ingredients (as-fed)

carbon content (g/kg) = (crude protein content (g/kg) × 0.53) + (crude fat content (g/kg) × 0.76) + (starch content (g/kg) × 0.44) + (sugar content (g/kg) × 0.42) + (remaining organic material content (g/kg) × 0.45)

Analyzed carbon values for ingredients

For a more accurate determination of the C content of each feed ingredient, it can be directly measured utilizing the procedures described below:

Combustion elemental analysis is conducted using a Thermo Scientific FlashSmart Elemental Analyzer. The samples are weighed out into pressed tin capsules in triplicate using 1 to 3 mg of material per replicate. Vanadium pentoxide is added as a combustion aid, in quantities of 8 to 12 mg per replicate. Five standard samples of 2,5-Bis(5-tert-butyl-benzoxazol-2-yl)thiophene (BBOT) are prepared in the same fashion, in addition to two sample blanks that contain no organic material or vanadium pentoxide. The replicates are loaded into an autosampler and dropped into a combustion furnace held at 950 °C. The combustion tube

contains copper oxide and electrolytic copper. UHP helium is used as the carrier gas and UHP oxygen is used to support combustion. When the combusted sample vapors interact with the electrolytic copper and high oxygen atmosphere, the elemental nitrogen, carbon, hydrogen, and sulfur are oxidized into NO_2, CO_2, H_2O, and SO_2. These components flow through a gas chromatography column to separate them based on their chemical properties, and then through a flame ionization detector to determine the concentration of the component gases. The resulting chromatogram is then integrated, and the results are compared to a calibration curve that is generated based on the integration of the BBOT standards that were run prior to unknown sample analysis. Additional information on these procedures can be found at: https://www.cif.iastate.edu/other-insts/pe2100/qaqc.

Table 1 compares C values of commonly used feed ingredients obtained from NRC (2012) to analyzed values using the procedures mentioned above.

Table 1. Comparing carbon values (%) for common feed ingredients from NRC (2012) versus analyzed values.		
Ingredient[1]	NRC	Analyzed[2]
Corn	40.26	40.40
Distiller's Dried Grains with Solubles	43.24	44.21
Soybean meal	41.48	42.34
Hard Red Winter Wheat	40.14	41.12

[1]Percentages are on an as-fed basis.
[2]Analyzed at Iowa State University utilizing procedures found at https://www.cif.iastate.edu/other-insts/pe2100/qaqc.

Table 2. Additional values for feed ingredients from the NRC (2012) that currently do not have analyzed values.	
Ingredient[1]	NRC
Bakery Meal	42.51
Barley, Hulless	40.90
Blood Plasma	42.78
Canola Meal, Solvent Extracted	41.94
Whey Permeate, 80% lactose	37.80
Whey Protein Concentrate	47.31
Oats	41.44
Oat Groats	40.59
Sorghum	40.60
Soybean Meal, Dehulled, Expelled	45.85
Soybean Hulls	39.94
All varieties of vegetable or animal derived oils and fats	73.72

[1]Percentages are on an as-fed basis.

Main Takeaways
Currently, producers and nutritionists have three available options for determining the C values of their feed ingredients: NRC (2012) book values, utilizing the NRC (2012) equation with analyzed nutrient values, or utilizing values directly analyzed for C. As additional samples are directly analyzed for C, this database will continue to grow providing more accurate information for use in diet formulation.

Literature cited

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