LCA of environmental footprints of diets including wheat middling and DDGS for swine production in USA

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Background

- High feed cost and environmental footprint are two major challenges for the US pork industry.
- Energy and protein are the main nutrient components in swine diet. Energy represents the largest cost contribution to the finished diet followed by protein. Corn and soybean blend to produce a well-balanced diet
- Byproducts such as wheat middling and distillers dried grain with solubles (DDGS) from the supply chain of human food and biofuels are being used recently to formulate swine diets to reduce cost and waste.

Background

- As livestock production is one of the major causes of the world's environmental impacts including agricultural land use, water depletion, and climate change, researchers are looking for alternative diets that will lower environmental footprints of swine production.
- Our purpose is to assist swine producers to choose not only a cost-effective but also an environmentally benign alternative diet.

Objectives

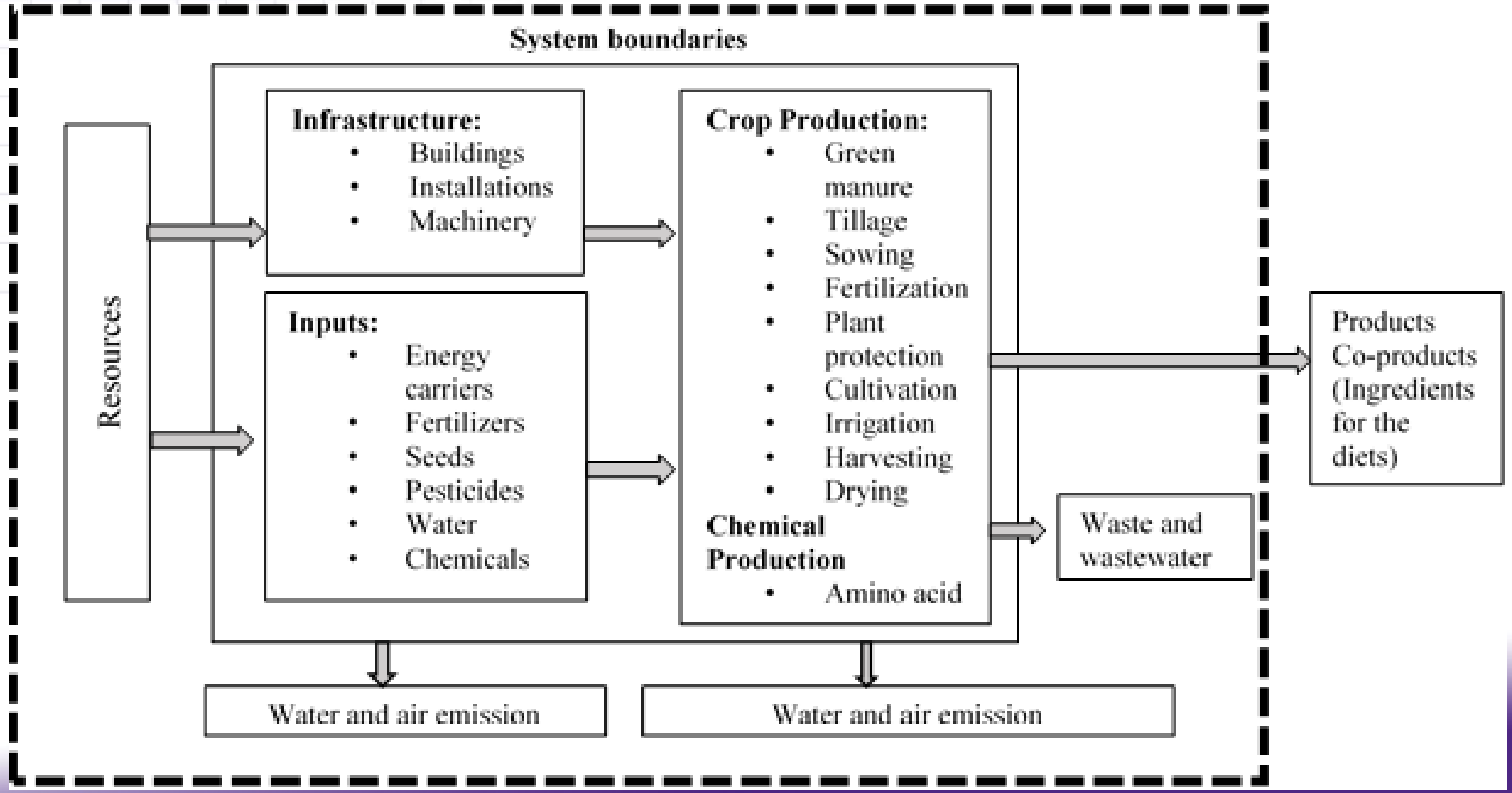
- Quantify the carbon, water and land footprint of a standard corn-soybean finishing swine diet and alternative diets through a synthetic life cycle assessment (LCA) .

Methods

- LCA is a tool to evaluate environmental footprints of a product or process throughout the entire life cycle.
- The system boundaries for the LCA model were cradle to farm-gate; the functional unit was 1 kg diet at the feed production stage.
- Inventories of LCA were from DATASMART-2017 (SimaPro 8.5.2.0), USDA, and RIA-GREET 2018, etc.
- Four impact categories: global warming potential (GWP), land use (LU), water consumption (WC), and fossil resource scarcity (FR).

Methods

Process flow chart of feed ingredients with their system boundary



Methods

Environmental footprints by mass and economic allocation

- Agricultural LCA is often more complex than of industrial LCA. In addition to the main agricultural product, there are usually coproducts, so that appropriate environmental impacts need to be assigned to each product, a process known as allocation.
- The choice of the allocation methods is essential in determining the environmental footprints of feed that include byproducts such as wheat middling or DDGS. Generally, a byproduct has a relatively lower price comparing with the main products, and thus its allocation by economic value is often lower than that by mass. Consequently, the environmental footprints of the low-value byproducts (such as DDGS and wheat middling) based on economic allocation are generally lower than that based on mass allocation.
- The allocation between ethanol and DDGS is based on the economic value of the products, except that the energy for drying the distiller's grains to facilitate longer distance transport is allocated entirely to the DDGS.

Methods

Selection of representative swine diets

We identified the following 18 potential ingredients for alternative diets formulation.

1. Corn
2. Distillers dried grains with soluble (DDGS)
3. Barley
4. Oats
5. Sorghum
6. Triticale
7. Wheat-soft white winter variety
8. Wheat-soft red winter variety
9. Wheat, hard red spring
10. Wheat, hard red winter
11. Wheat middlings
12. Soybean meal
13. Meat and bone meal
14. Canola meal
15. Sunflower meal
16. Peas
17. Synthetic amino acids
18. Animal fat or vegetable oil

Diet formulation

- All the major ingredients including corn, SBM, DDGS, bakery meal and, wheat middling used in this study are grown or produced in the US crop production region 3 and were assumed representative for the USA.
- Formulations of the diets were based on a survey from experts and the least cost formulation principles.

Methods

Wheat as feed ingredient in swine diet

- Generally, wheat is produced for human consumption over the decades. Utilization of wheat as swine feed ingredients is limited to times when wheat is competitively priced with corn or other grains.
- Wheat contains less energy but more protein and lysine than corn.
- By-products of milling wheat for flour consist primarily of the bran and aleurone layers of the kernel and the germ. Wheat flour by-products are generally identified by their fiber level. A wheat milling byproduct with 7-9.5% fiber may be classified as wheat middlings.

Methods

Distiller dried grains with soluble (DDGS)

- DDGS is a common byproducts of the commercial ethanol industry.
- It is approximately equal to corn as an energy source, and although DDGS is quite high in protein (27%) it retains the poor amino acid balance;
- By supplementing swine diets with synthetic amino acids, DDGS can work well in swine diets.

Methods

Formulation of the byproducts diet and standard Corn-SBM diet

Ingredient use, from 50 to 280 lb body weight	Standard corn-SBM diet		Byproducts diet	
	lb/pig	Inclusion rate	lb/pig	Inclusion rate
Corn	520.1	79.3%	364.6	55.0%
Soybean meal	119.7	18.3%	91.4	13.8%
Corn DDGS, 7.5% Oil	0.00	0.0%	66.3	10.0%
Bakery Meal	0.00	0.0%	57.6	8.69%
Wheat Middlings	0.00	0.0%	68.7	10.37%
Calcium carbonate	5.45	0.83%	6.73	1.01%
Calcium phosphate (monocalcium)	2.94	0.45%	0.41	0.06%
Sodium chloride	3.28	0.50%	3.31	0.50%
L-Lys-HCl	1.82	0.28%	2.02	0.30%
DL-Met	0.18	0.03%	0.05	0.01%
L-Thr	0.44	0.07%	0.29	0.04%
L-Trp	0.05	0.01%	0.00	0.00%
Vitamin premix with phytase	0.76	0.12%	0.77	0.12%
Trace mineral premix	0.76	0.12%	0.77	0.12%
Total	655.5	100%	663.0	100%

Results

The mass and economic allocation of wheat middling, DDGS, and SBM

Grain	Items	Unit price ($/kg)	Mass allocation (%)	Economic allocation (%)
Wheat processing	Wheat flour	1.05	73	65
	Wheat bran	0.978	12	9.9
	Wheat middling	0.168	12.5	1.8
	Wheat germ	13.70	2	23.2
Corn processing	Ethanol	0.466	46.8	85.5
	DDGS	0.09	53.2	14.5
Soybean processing	Crude soy oil	0.597	21.7	49.2
	Soy hulls	0.143	7.4	1.2
	SBM	0.322	70.9	49.6

Results

Environmental footprints of individual feed ingredients (per kg ingredients)

Ingredients	Allocation methods	GWP kg CO_2 eq.	LU m^2 yr. crop eq.	WC m^3	FR kg oil eq.
Wheat middling	Mass	0.737	1.11	0.501	0.14
	Economic	0.105	0.159	0.072	0.02
SBM	Mass	0.714	1.78	0.819	0.145
	Economic	0.50	1.25	0.573	0.101
DDGS	Mass	1.35	1.45	0.563	0.397
	Economic	0.747	0.397	0.154	0.241
Bakery meal		0.38	-	-	-
Corn		0.311	1.02	0.394	0.054
Amino acids:	L-Lysine-HCl	4.06	3.34	1.49	0.757
	Methionine	9.06	0.73	4.93	2.94
	Threonine	8.14	5.07	2.90	2.0
	*Tryptophan	9.62	-	-	-

Results

Environmental footprints of individual feed ingredients (per kg ingredients)

- The environmental footprints of the byproducts (such as wheat middling, DDGS) by economic allocation were generally lower than that by mass allocation, due to relatively low prices of these byproducts.
- By economic allocation, wheat middling had the lowest environmental footprints in all the four categories of GWP, LU, WC, and FR.
- GWP: DDGS > SBM > corn > wheat middling

Results

Major contributors to the environmental footprints for individual feed ingredients

- Fertilizer was the major contributor (12-20%) to GWP for corn, SBM, and wheat middling.
- Non-renewable natural gas was the major contributor (67%) to GWP for DDGS. Wet distiller grain soluble (WDGS) requires drying process to produce DDGS, and consumes huge energy.

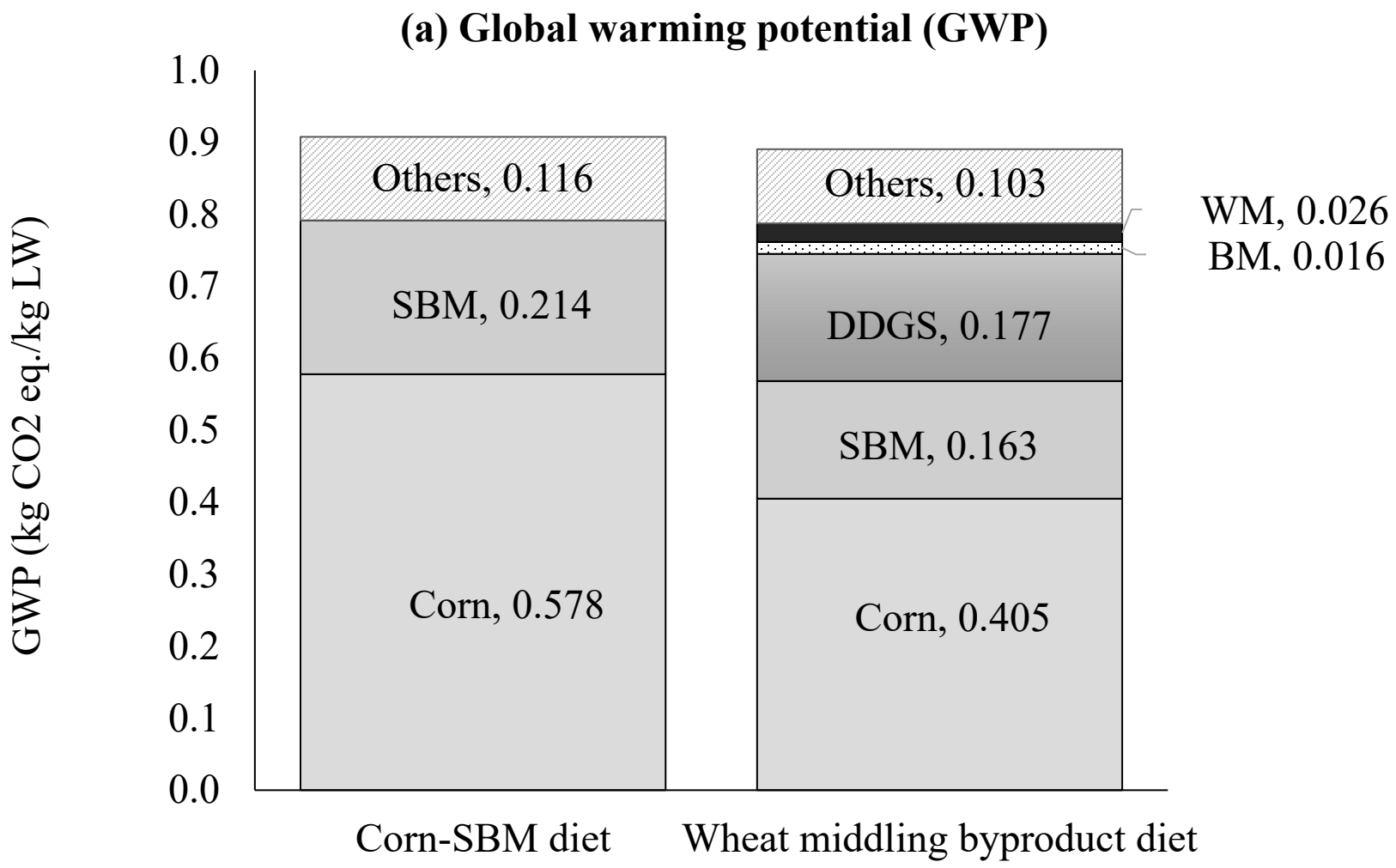
Results

Environmental footprints of individual feed ingredients in literature

- GWP of corn ranges 0.226-0.650 kg CO_2 eq. per kg corn. Temperature and fertilizer influence the variation of corn GWP both in North and Latin American. High GWP for corn production in Europe is caused by relatively low nitrogen use efficiency.
- GWP of SBM ranges 0.362-1.87 kg CO_2 eq. /kg SBM. High GWP of European SBM is due to transportation from Brazil and Argentina to Europe, and the association of deforestation in SBM production.
- GWP of DDGS ranges 0.66-1.1 kg CO_2 eq. /kg DDGS. By replacing non-renewable energy (natural gas) required for drying with alternative renewable energy (nuclear energy), the GWP of DDGS could be reduced by about 50%.
- GWP of wheat in this study is higher than the European wheat, due to relative low yield of wheat in USA.

Results

Environmental footprints of the byproducts diet and standard corn-SBM diet



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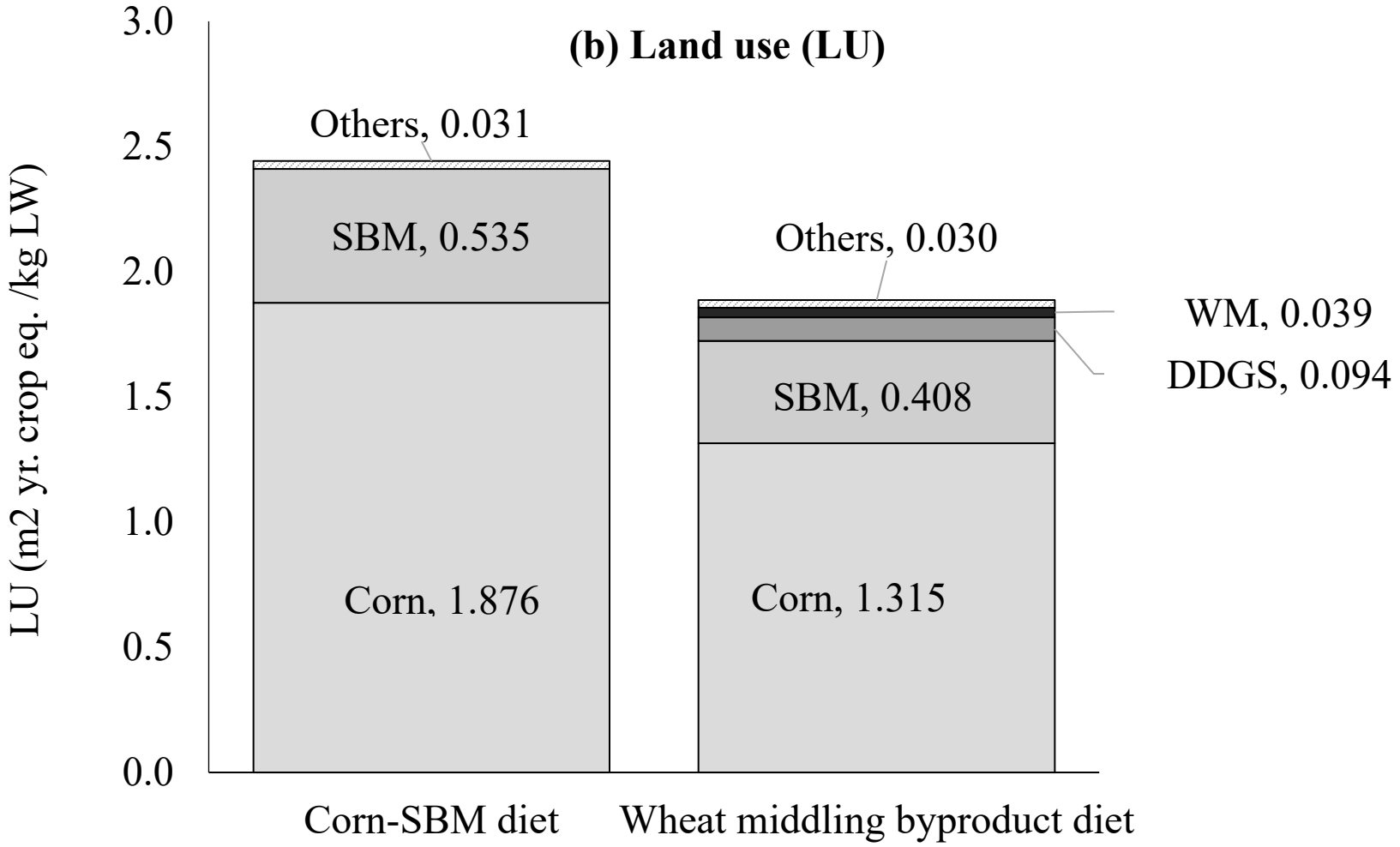

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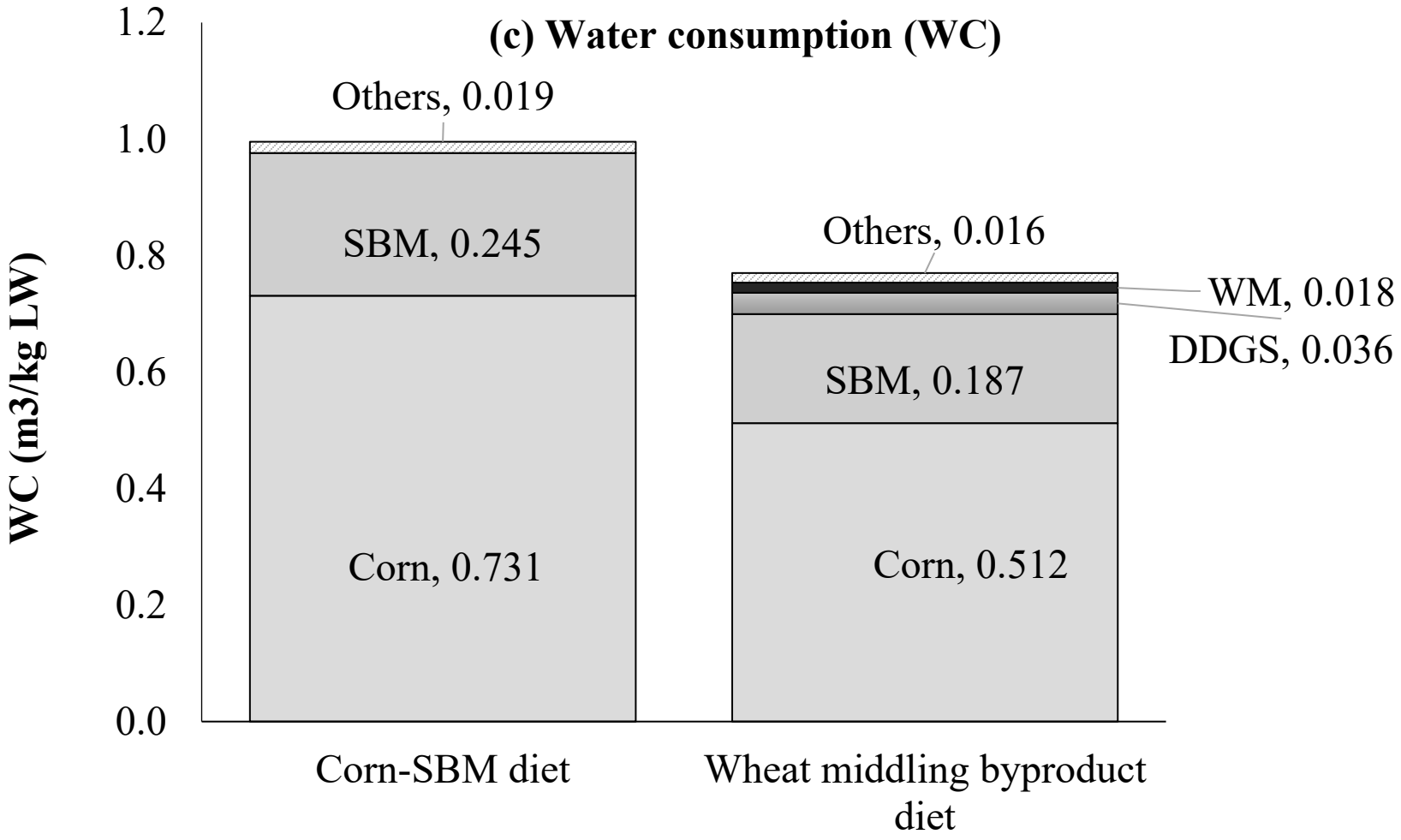

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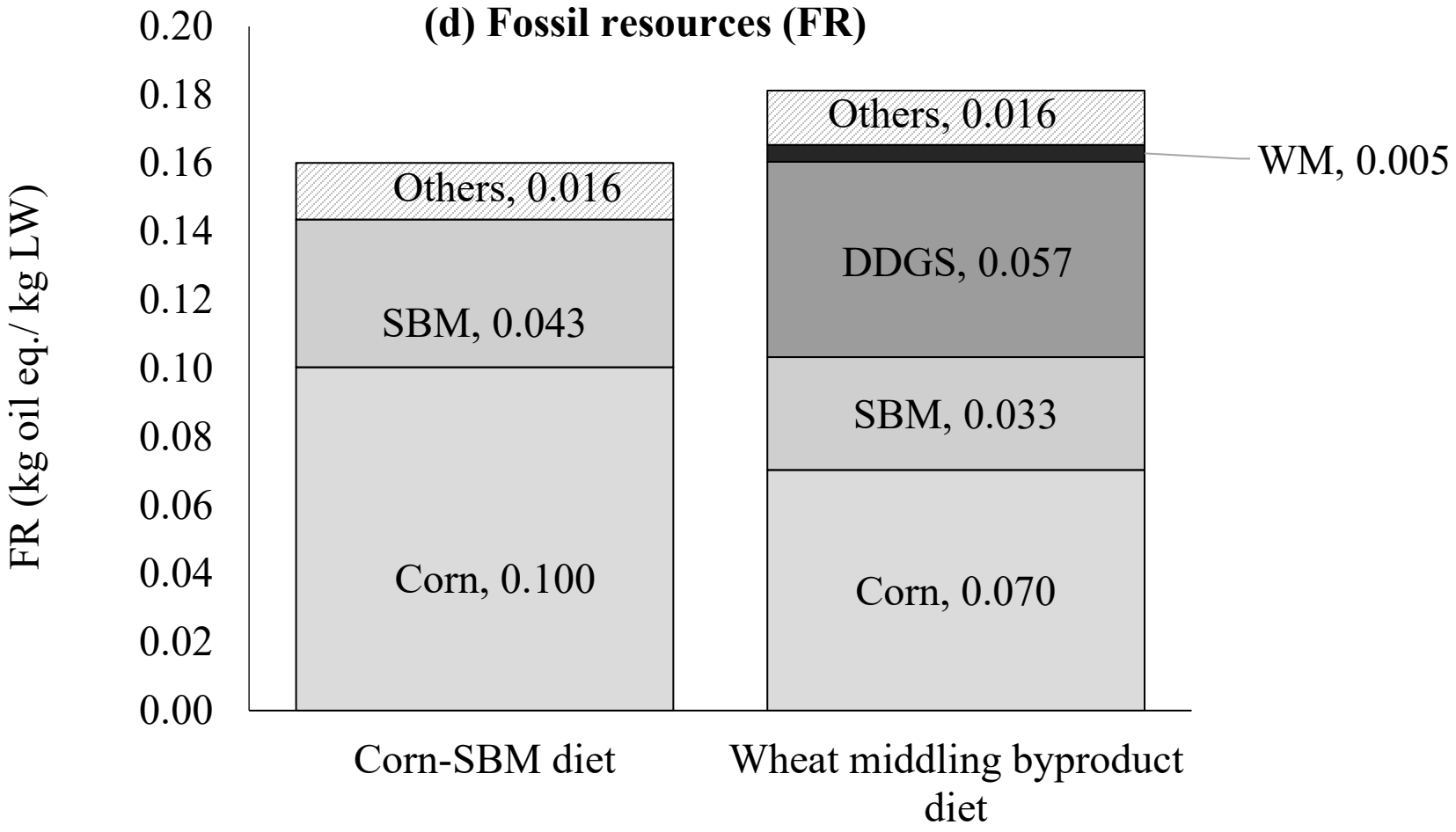

Results

Environmental footprints of the byproducts diet and standard corn-SBM diet

- Corn was the major part of the diets and contributed the most to environmental footprints in both diets. In the Corn-SBM diet, corn and SBM comprised almost 87% of the total GWP, while in the byproducts diet it was about 63%. Inclusion of by-products replaced corn and SBM, and thus reduced its contribution to the overall environmental footprints.
- The GWP of the two diets were similar at a point of about 0.9 kg CO_2 eq. /kg LW. The by-product wheat middling diet has lower WC and LU.
- When mass allocation was used, the GWP of the byproducts diet was about 39.4% higher than the standard Corn-SBM diet.

GWP from feed production kg CO_2 eq.	Total GWP kg CO_2 eq.	Land use m^2 yr. crop eq.	Diet	Region
0.91		2.44	Standard corn-SBM	USA
0.89		1.9	Byproducts	USA
1.54* (58%)	2.66		Barley based	UK
1.09 (65%)	1.67*		Corn based	Canada
0.90 (61%)	1.48*		Wheat shorts	Canada
	2.37-2.45		-	Brazil
2.11* (79%)	2.66*	11.4*	Corn & Soybean meal	Brazil
1.63-1.92	2.24-2.53		Corn & Soybean meal	Brazil
1.3 (50-52%)	2.5	3.8-4.4	Corn & Wheat	Netherlands
1.58 (70%)	2.25	4.13	Conventional	Europe
(52-77%)	2.26-4.14	3.90-4.02	Cereals & soybean meal	France
1.71 (54%)	3.16		Corn & Soybean meal	Japan
1.54* (63%)	2.45*		Wheat & Barley	German
	4.15*	8.52*	-	Dutch
	1.98*		-	Belgium
1.05		3.6	Corn & Barley	Europe
1.14-1.48		3.27-3.94	Cereals & soybean meal	France
1.28 (54%)	2.36*	4.41*	Wheat & Barley	Denmark
1.20 (42%)	2.87		Corn based	USA
	2.5		-	USA
	3.66*		-	Europe
	2.8-3.3		-	Denmark
	2.36-4.18*		Conventional	Australia
	3.12-4.33*		-	UK
	2.66-2.81*		Conventional	Europe
	3.28			UK
	3.3-3.4			Denmark
1.82*	2.74*		Soybean meal & grain	Denmark
	4.86*	5.62*	-	UK
	2.3	5.4	Conventional	France
	1.3-1.5		Barley & Wheat	Sweden
	2.76-3.37*	8.59-9.45*	Wheat & Barley	Sweden

Conclusions

- Relatively low price in comparison with SBM and the requirement of no additional step for wheat middling resulted in the lowest environmental footprint among all the ingredients.
- Land and water-saving benefits and the low price of DDGS make it as a potential feed ingredient in the US livestock both environmentally and economically.
- GWP of DDGS could be potentially reduced with alternative drying energy implementation.
- Although the environmental footprints of synthetic amino acids were much higher than that of corn, SBM, DDGS, and wheat middling, their contributions to the overall environmental footprints of the diets were limited due to the low inclusion rates.
- Environmental footprints of the byproducts diet by economic allocation were not sensitive to the potential price changes of wheat middling or DDGS at the proposed inclusion rates of these byproducts.

Acknowledgement

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Thank you!