Making Progress in Reducing the Environmental Impact of Dairy Production and Things to Think About

Mike Van Amburgh, Ryan Higgs, Larry Chase, Karl Czymmek and Quirine Ketterings

Dept. of Animal Science

Cornell University Founded A.D. 1865

Outline for this short talk:

- We are making significant progress, but…
- Need science to come to our rescue however, it needs to relate on an emotional level
- We eat for nutrients, but those are not fully described in the environmental battle
- Everything we eat has an environmental impact (almond vs dairy)
- Need to understand the whole food system (almond vs dairy)
- Net Zero is coming – both NY and Dairy Industry
- The nutrition supply chain (YOU) can help
- Need to be transparent

Table 5. Resource use and greenhouse gas emissions from U.S. dairy production in 2007 and 2017 per 1.0 MMT (million metric tonnes) of saleable energy-corrected milk

	2007	2017	2017 as a percentage of 2007
Resou			
Tota			
Cro			
N fe			
P fe			
K fe			
Herl			
Inse			
Foss			
Elec			
Catt			
Irrig			
San			
Tota			
Waste			
Nitr			
Pho			
Mar			
GHG			
Met			
Nitr			
GHC			
GHG from cropping, kg CO_2-eq	2.20×10^8	1.75×10^8	79.5
GHG from manure application, kg CO_2-eq	4.77×10^7	3.93×10^7	82.5
GHG from transport[3], kg CO_2-eq	7.41×10^6	8.30×10^6	112
Total GHG[4], kg CO_2-eq	2.10×10^9	1.70×10^9	80.8

Capper and Cady – 2007 to 2017

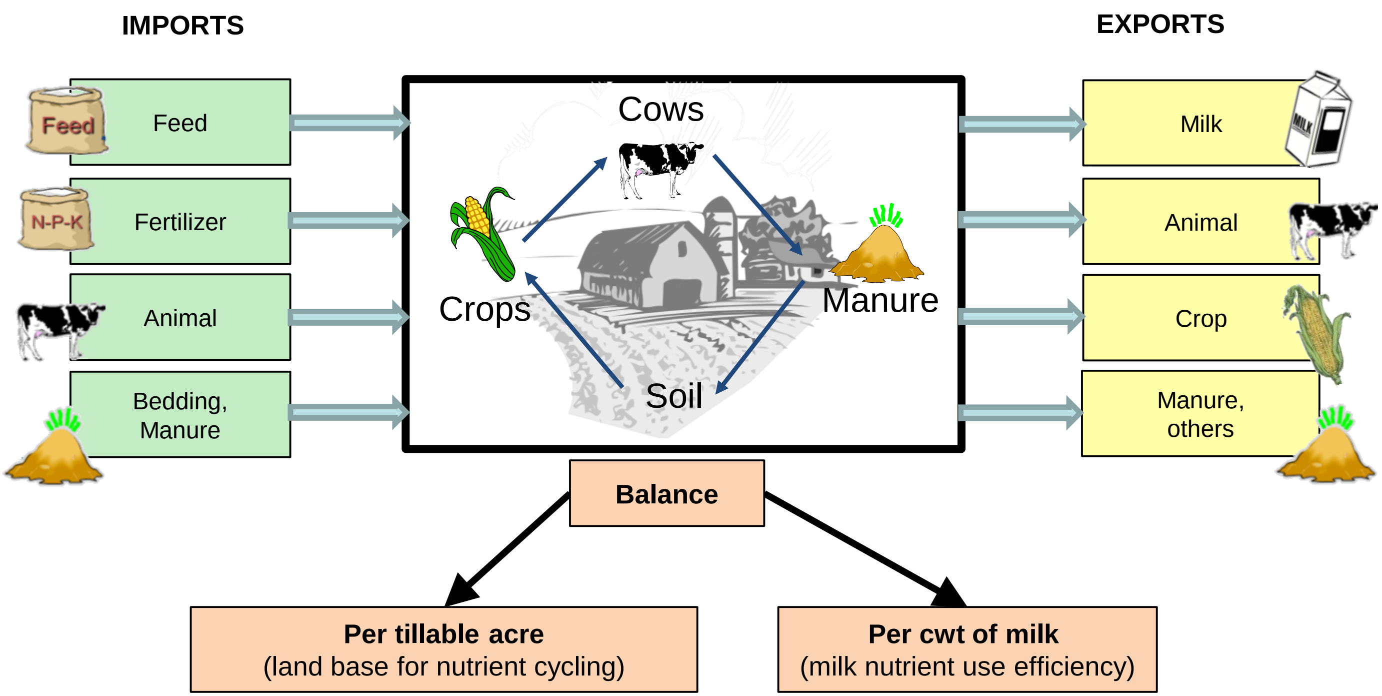
The industry is doing great things

All categories reduced by 15 to 31% except for transport which increased by 12%

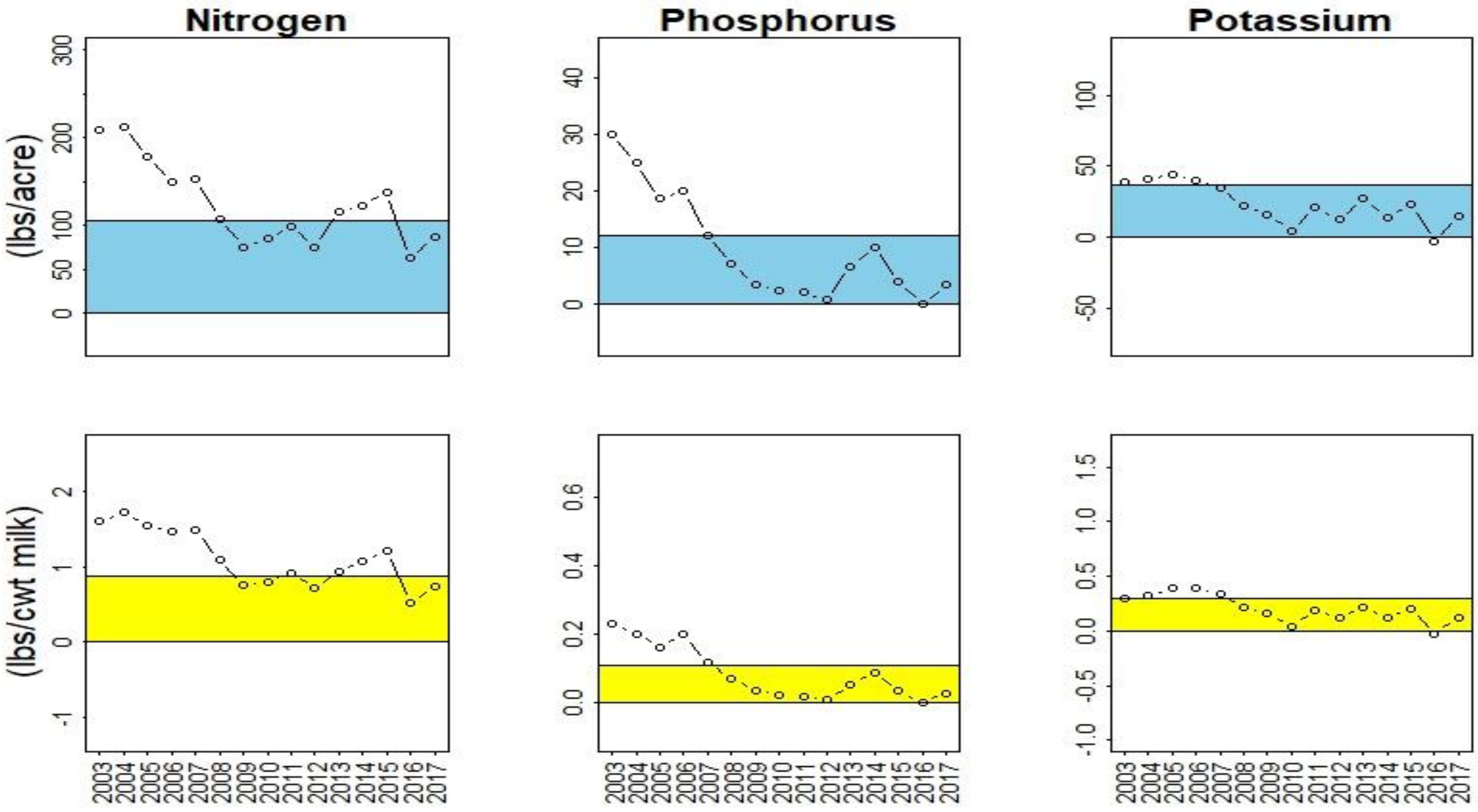
That is amazing progress over 10 years!

Capper and Cady, J. Anim. Sci. 2020

Whole-Farm Nutrient Mass Balances (NMBs)



Whole-Farm Feasible Nutrient Balances – 2003 to 2017



Cornell Net Carbohydrate and Protein System (CNCPS)

- Cattle nutrition model – any cow, anywhere

Year	Paper
1992	A net carbohydrate and protein system for evaluating cattle diets: I. Ruminal fermentation
1992	A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availability
1992	A net carbohydrate and protein system for evaluating cattle diets: III. Cattle requirements and diet adequacy
1993	Net Carbohydrate and Protein System for Evaluating Cattle Diets: IV. Predicting Amino Acid Adequacy
2004	The Cornell Net Carbohydrate and Protein System model for evaluating herd nutrition and nutrient excretion
2008	Cornell Net Carbohydrate and Protein System: A model for precision feeding of dairy cattle

NY PFM Project – 3 years

- Herds selected in several counties
- PFM guidelines described – needed to meet NRCS 592 Feed Management Standards
- Extension personnel and Feed Industry Professionals involved
- Herd visits conducted
- Forages sampled and analyzed routinely
- Cattle descriptions characterized (BW, etc)
- Diets analyzed through CNCPS 6.1 and 6.5

Initial and Final Diet Crude Protein and CNCPS Predicted Manure Nitrogen Excretion by Herd

Herd	Initial CP, %	Final CP, %	Initial Manure N Excretion, g/cow/d	Final Manure N Excretion, g/cow/d	Manure N Excretion Change, %	Manure N Excretion Change, kg/herd/yr
A	16.0	14.9	358	323	-9.7	-383
B	16.3	14.9	319	282	-11.5	-730
C	20.5	16.0	510	362	-29	-4755
D	17.1	16.0	385	344	-10.6	-1138
E	19.0	16.2	465	370	-20.4	-6520
F	17.4	16.5	456	423	-7.2	-5241
G	16.7	15.7	424	345	-18.6	-16,296
H	16.9	16.2	422	400	-5.2	-2128

Milk income, total feed cost and income over feed cost, $/cow/day

Item	Herd A	Herd B	Herd C	Herd D	Herd E	Herd F	Herd G	Herd H
Milk Income, $	9.67	12.65	13.30	16.73	14.63	16.97	16.75	13.80
ITFC, $	4.86	4.80	5.30	5.41	6.45	6.49	6.64	5.62
FTFC, $	4.69	4.80	4.84	5.21	5.63	6.44	6.18	5.53
IOTFC, $	4.81	7.85	8.00	11.32	8.18	10.48	10.11	8.18
FIOTFC, $	4.98	7.85	8.46	11.52	9.00	10.53	10.57	8.27
IOTFC Change, $/cow/year	62	0	168	73	299	18	168	33
IOPFC Change, $/cow/year	77	76	277	37	219	18	361	33

Dairy industry pushes back against livestock emissions reporting with new bill

By Mary Ellen Shoup
20-Feb-2018 - Last updated on 20-Feb-2018 at 09:45 GMT

POST A COMMENT

Animal agricultural organizations argue that they shouldn't have to submit GHG emissions reports under CERCLA. ©GettyImages/Bestgreenscreen

As part of the FARM Act, a new bipartisan bill was introduced in the US Senate that would exempt farms, ranches, and other agricultural operations from having to report animal waste emissions data required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

Objectives

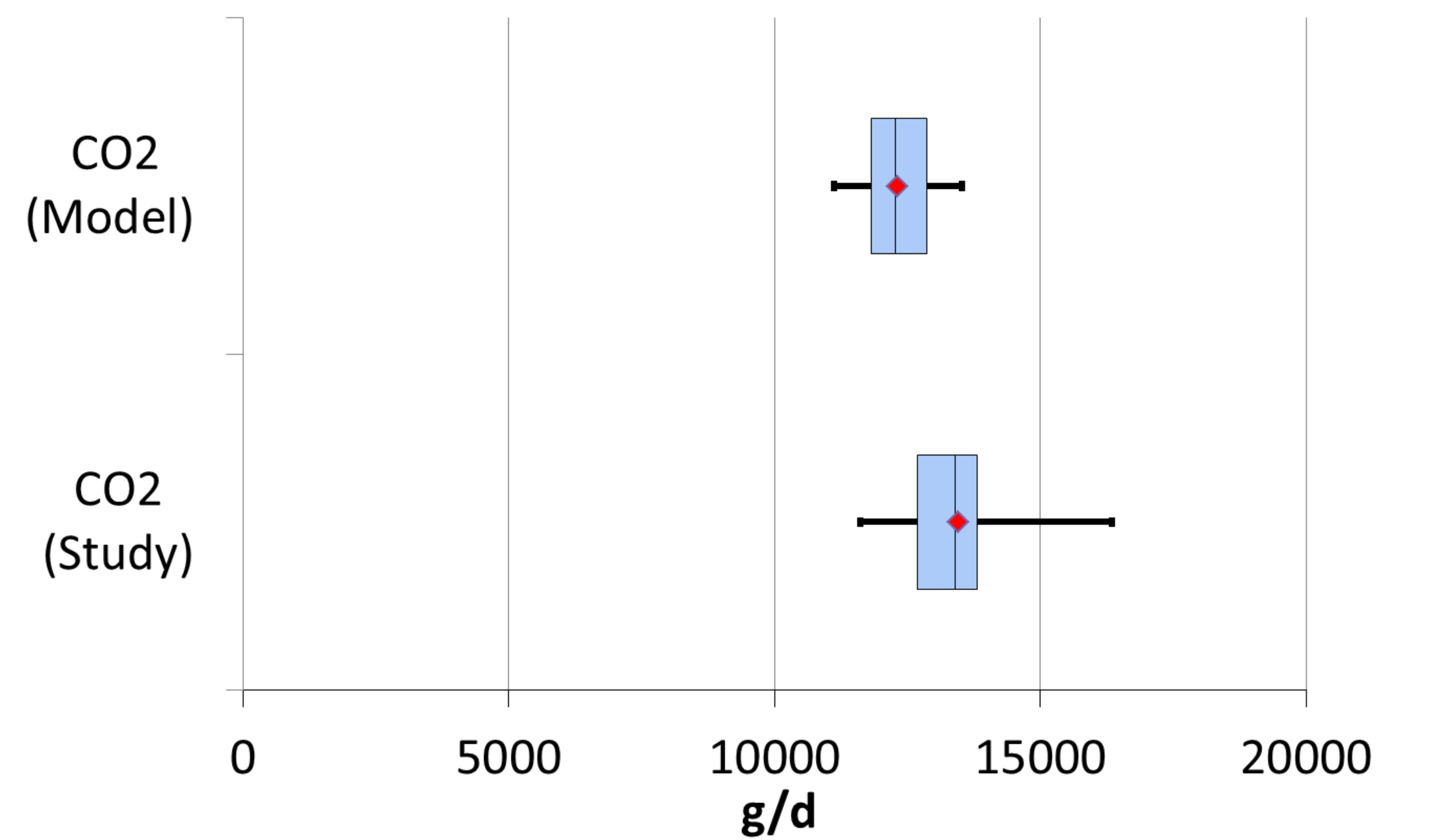
1. Develop the CNCPS to predict carbon dioxide and methane emissions per cow per day and per unit of milk production

2. Evaluate the models' ability to predict these greenhouse gases

3. Develop a database of diets and the level of byproducts fed to dairy cattle

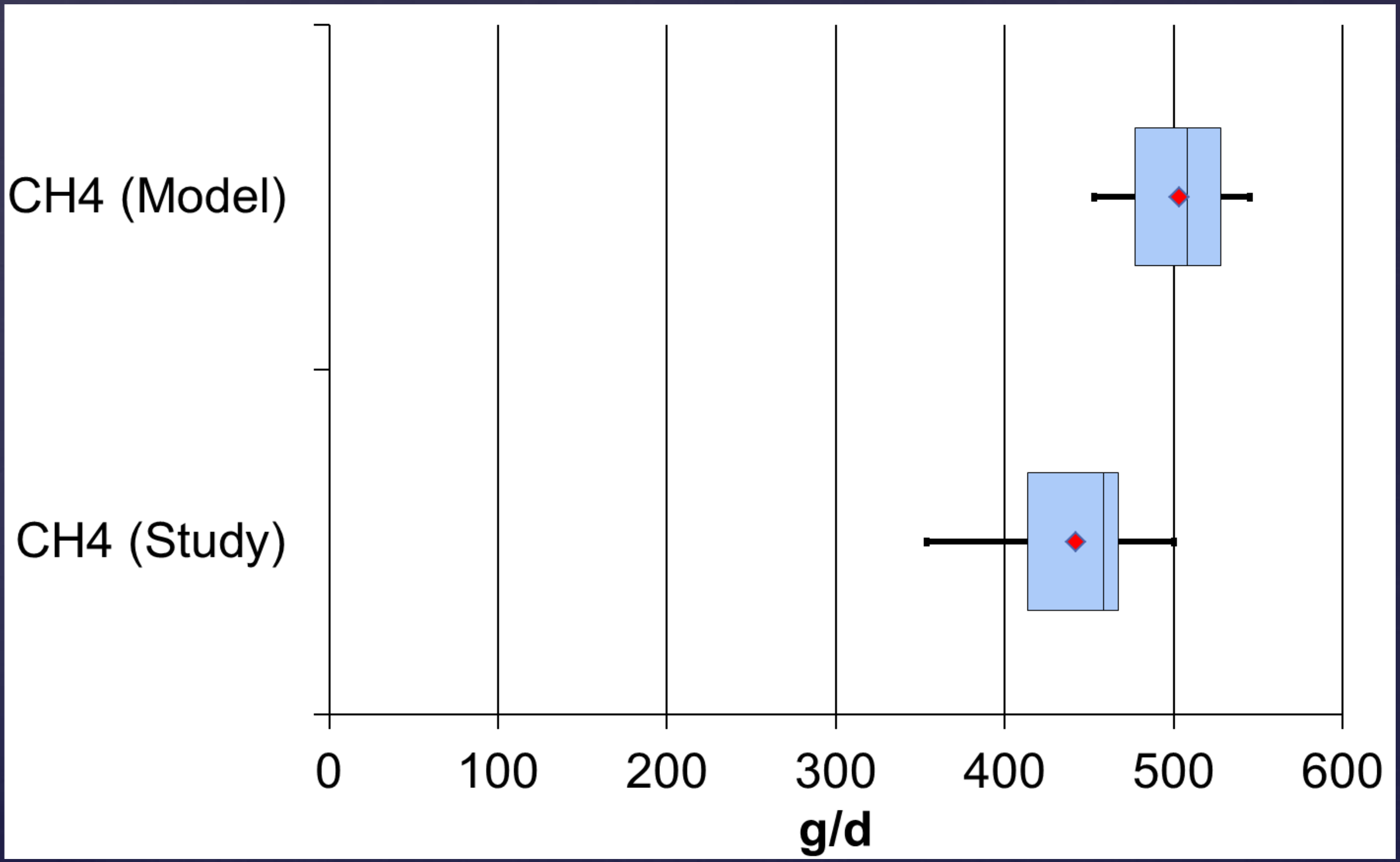
4. Characterize the diets to evaluate the impact of feeding byproducts on greenhouse gas emissions compared to a discrete carbon release – combustion

CO_2 production predicted by the CNCPS compared with observed from 5 studies and 22 treatments



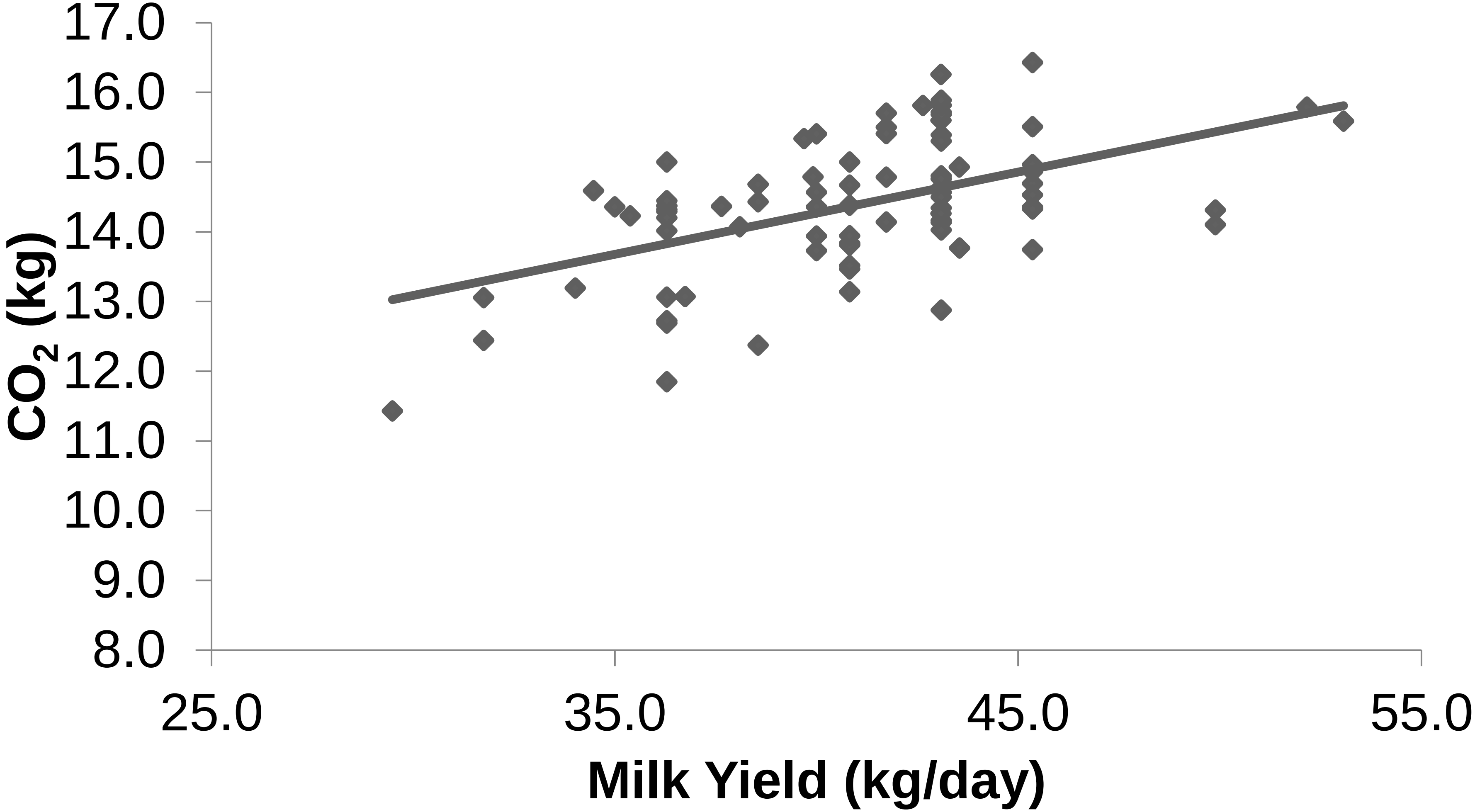
Van Amburgh et al., 2015

CH_4 production predicted by the CNCPS compared with observed from 5 studies and 22 treatments



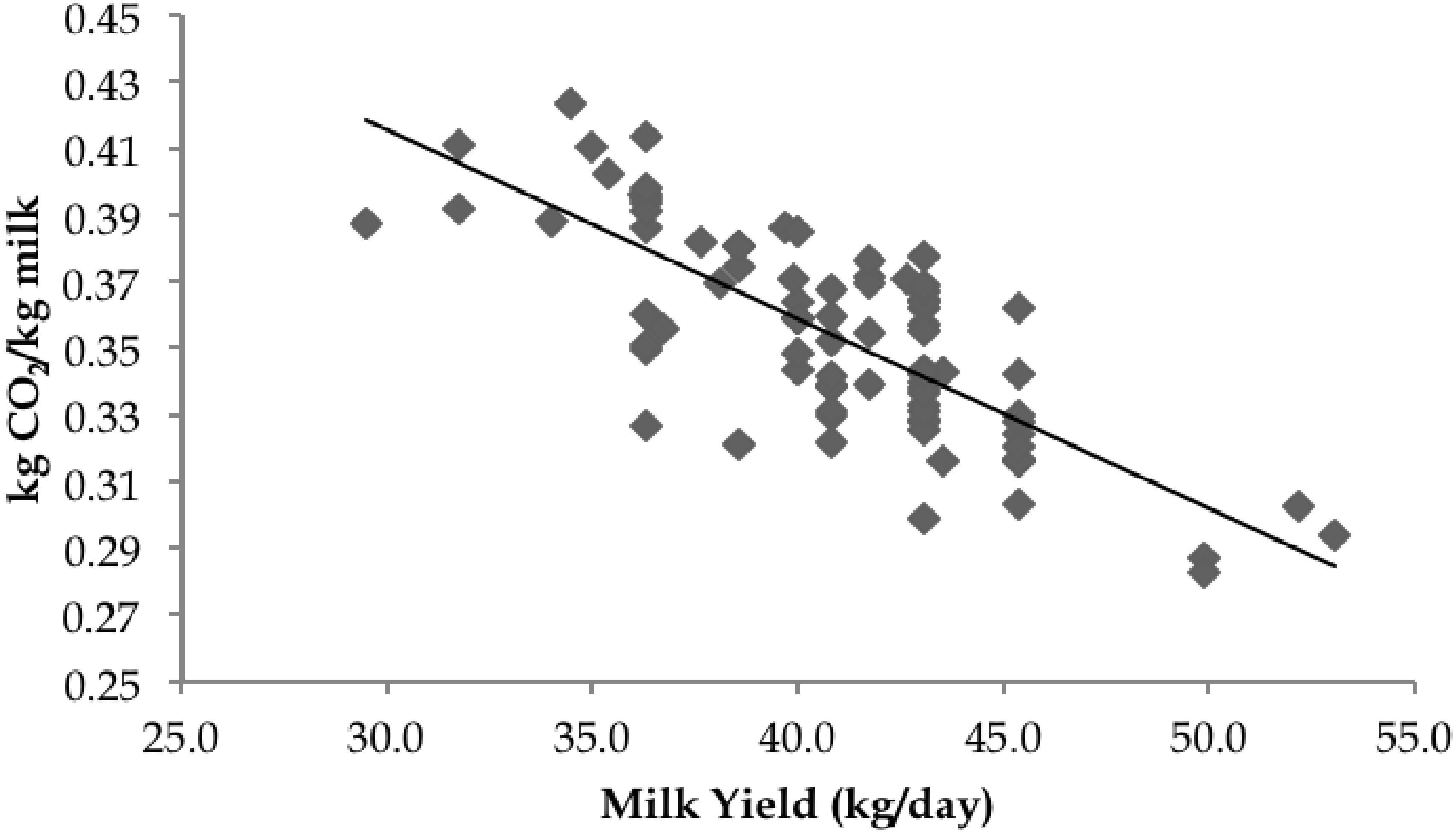
Van Amburgh et al., 2015

Predicted CO_2 emissions versus Milk Yield



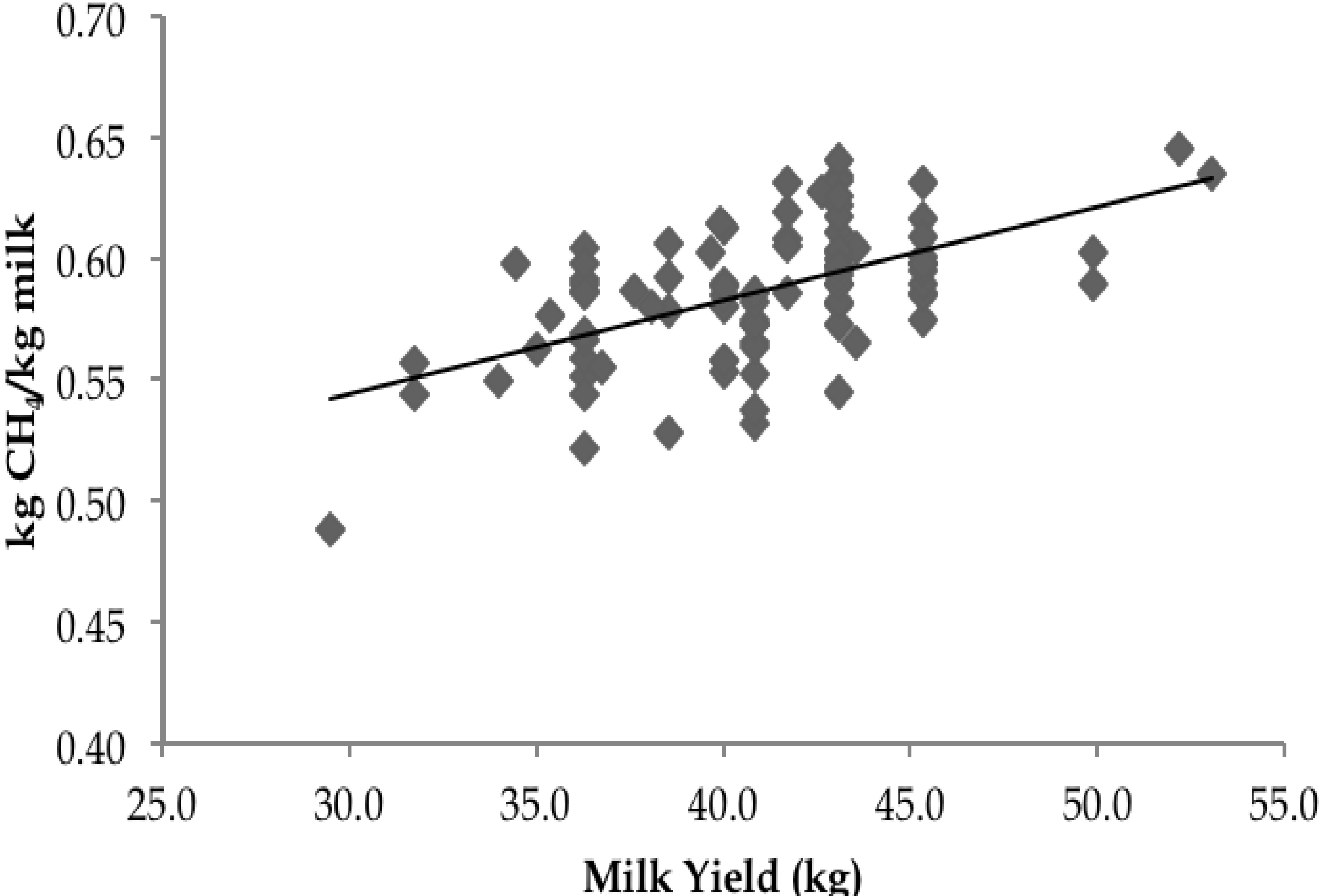
CO_2 (kg/d) = 0.12 × milk yield (kg/d) + 9.69 (R^2 = 0.69; RMSE = 0.64 kg/d)

Predicted CO_2 emissions per kg of milk versus milk yield



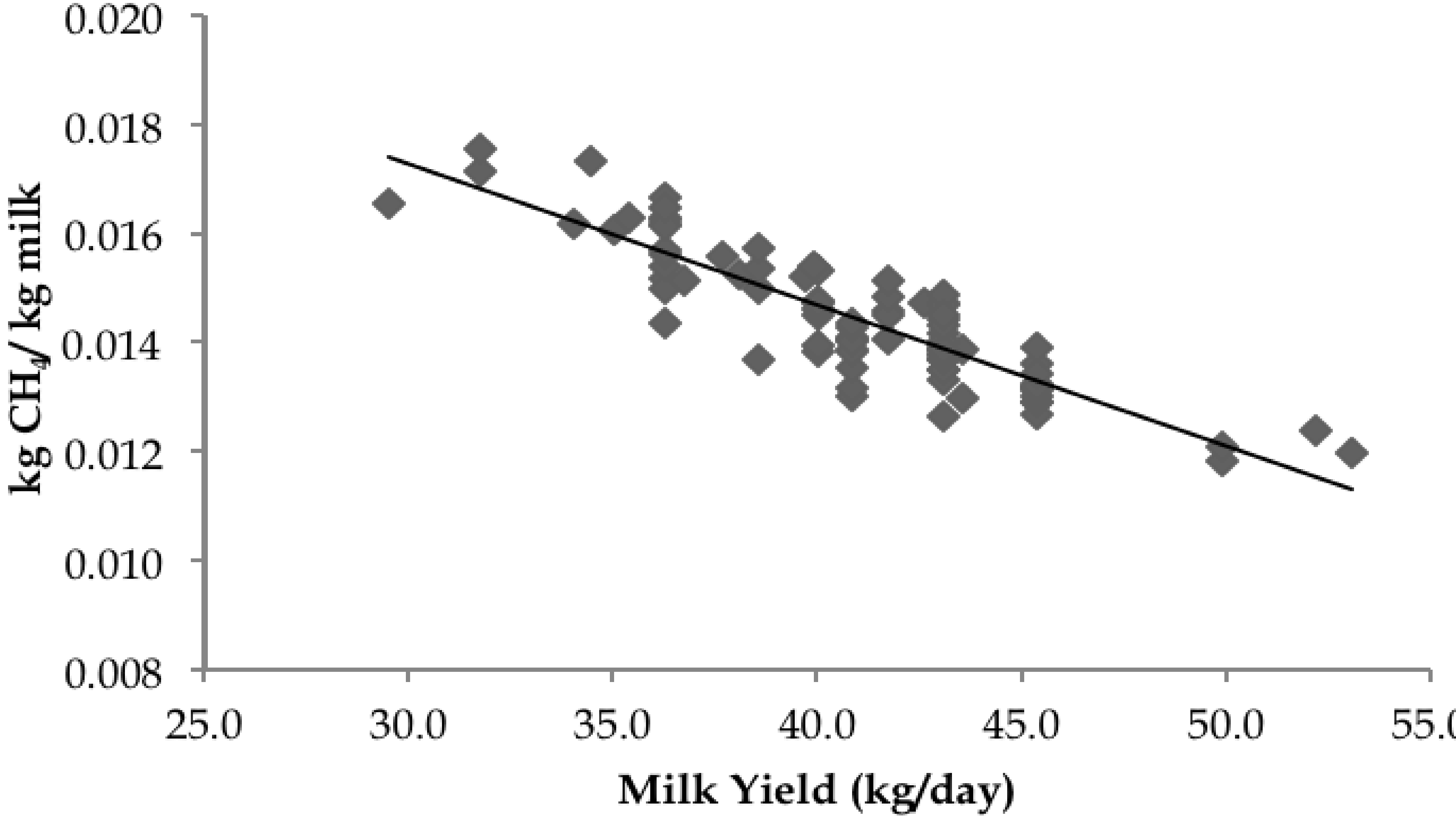
CO_2 Kg/kg milk = -0.006 × milk yield (kg/d) + 0.59 (R^2 = 0.81; RMSE = 0.02 kg CO_2/ kg milk.

Predicted CH_4 emissions vs milk yield



CH_4 (kg/d) = 0.004 × milk yield (kg/d) + 0.43 (R^2 = 0.75; RMSE = 0.02 kg/d)

Predicted CH_4 emissions per kg of milk versus milk yield



kg CH_4/Kg milk = -0.0003 × milk yield (kg/d) + 0.03 (R^2 = 0.89; RMSE = 0.0005 kg CH_4/ kg milk.

Comparison of gas released as CO_2 and CH_4 described as CO_2 equivalents of byproduct disposal when fed to dairy cows for milk production or incinerated as a discrete form of disposal for comparison of gaseous emissions

Variable		Mean	SD	Min	Max
Dietary byproduct inclusion	% ration DM	31	9	13	57
CO_2 from byproducts	kg CO_2 eq./cow/d	4.5	1.4	1.8	7.4
CH_4 from byproducts	kg CO_2 eq./cow/d	4.6	1.4	1.9	7.9
Total GHG gas release from digestion[1]	kg CO2 eq./cow/d	9	2.8	3.7	15.3
CO_2 incineration	kg	46.2	4.9	25	54.9

[1]Total gas release = CO_2 (kg/d) + CH_4 (kg CO_2 Eq./d)

Predicted carbon dioxide and methane release based on the total amount of dry matter consumed (DMI), byproduct inclusion (kg) and as a ratio of the milk yield

Variable	Mean	SD	Min	Max
DMI				
kg CO_2/kg DMI	0.576	0.011	0.557	0.618
kg CH_4/kg DMI	0.024	0.001	0.021	0.027
Byproduct				
kg CO_2/kg BP	0.050	0.018	0.029	0.117
kg CH_4/kg BP	0.002	0.001	0.001	0.005
Milk Yield				
kg CO_2/kg milk	0.353	0.031	0.283	0.423
kg CH_4/kg milk	0.014	0.001	0.012	0.018

Gas production and combustion of top 5 byproducts (% DM inclusion)

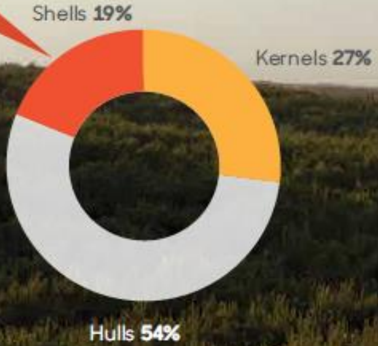
	% Diets with byproduct	Avg. Inclusion (% of diet)	BP DM fed (kg/cow)	Kg GHG/cow /d (CO_2 Eq.)	Kg GHG (CO2 Eq.)/kg milk
Corn Gluten Feed	37	8.0	2.0	2.32	0.057
Ethanol Distillers	48	5.3	1.3	1.55	0.038
SBM	63	5.6	1.4	1.61	0.039
Whole cottonseed	69	6.0	1.5	1.74	0.043
Canola Meal	66	8.1	2.0	2.29	0.056

2,263,500 tons hulls

crop year 2017/18

Almond Tree Fruit Weight

- 2.264 billion pounds of kernels
- 4.527 billion pounds of hulls
- 1.593 billion pounds of shells



Source: Kernel Weight–USDA Incomings received by Almond Board of California. Shell and Hull Estimations–Almond Alliance of California. August 2018.

The California almond industry generates **104,000 jobs** across California and **contributes $11 billion to the state's GDP.**

Source: University of California, Agricultural Issues Center. The Economic Impact of the California Almond Industry, December 2014.

crop years 2009/10–2018/19 | million pounds

California Almond Forecasts vs. Actual Production

http://www.almonds.com/sites/default/files/Almond_Almanac_2018_F_revised.pdf

What do you do with all of those hulls?

1.8 million dairy cattle in CA

5.2 million beef cattle

Assume ~70% consume hulls (7 million)

That’s 648 lb hull per cow or about 1.8 lb/cow/day

Bottom line: If you like your almond beverage, thank a cow for making it affordable and possible

JANUARY 22, 2020

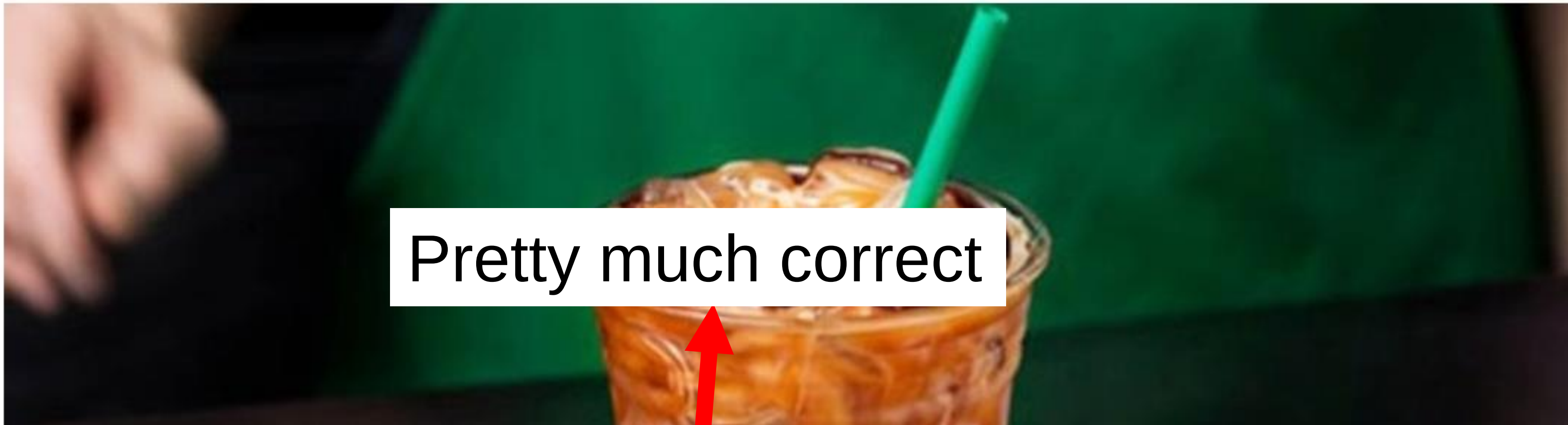
Starbucks Taking Aim at Milk Is Latest Blow to Beaten-up Dairy

BUSINESS | BY: BLOOMBERG NEWS

Share Tweet +

STARBUCKS MAY PHASE OUT DAIRY TO COMBAT CLIMATE CHANGE

Will Starbucks ditch dairy to fight climate change? CEO Kevin Johnson revealed the chain will introduce more plant-based alternatives for the environment.



Pretty much correct

Dairy has a significant environmental impact. According to the **World Wildlife Fund**, every day, a single **dairy** cow produces around 17 gallons of manure and urine. *"Improperly managed, manure emits greenhouse gases, pollutes water and air, and damages wildlife habitats,"* it says.

It ... of that wat... food.

Not entirely sure of their math, per gallon seems high – definitely counting rain water

In a statement sent to LIVEKINDLY, Starbucks said that it has not *"announced plans to 'phase out' dairy as part of its strategy to become a resource positive company."* Instead, it will *"expand plant-based options, migrating toward a more environmentally friendly menu."*

Cows and Water

- 1,650 lb cow making 88 lb milk in 70°F weather consuming 53 lb dry matter
- Will consume approximately 33 to 38 gallons of water
- Need to decide how much water is necessary to grow crops – Starbucks is implying at least 111 gallons (921 lb) to grow the forage and grain she eats and they allocate all of this to one gallon (8.6 lb) of milk (107:1) – seems high if you count rainwater
- This ignores the byproducts and upcycling of nutrients and associated water

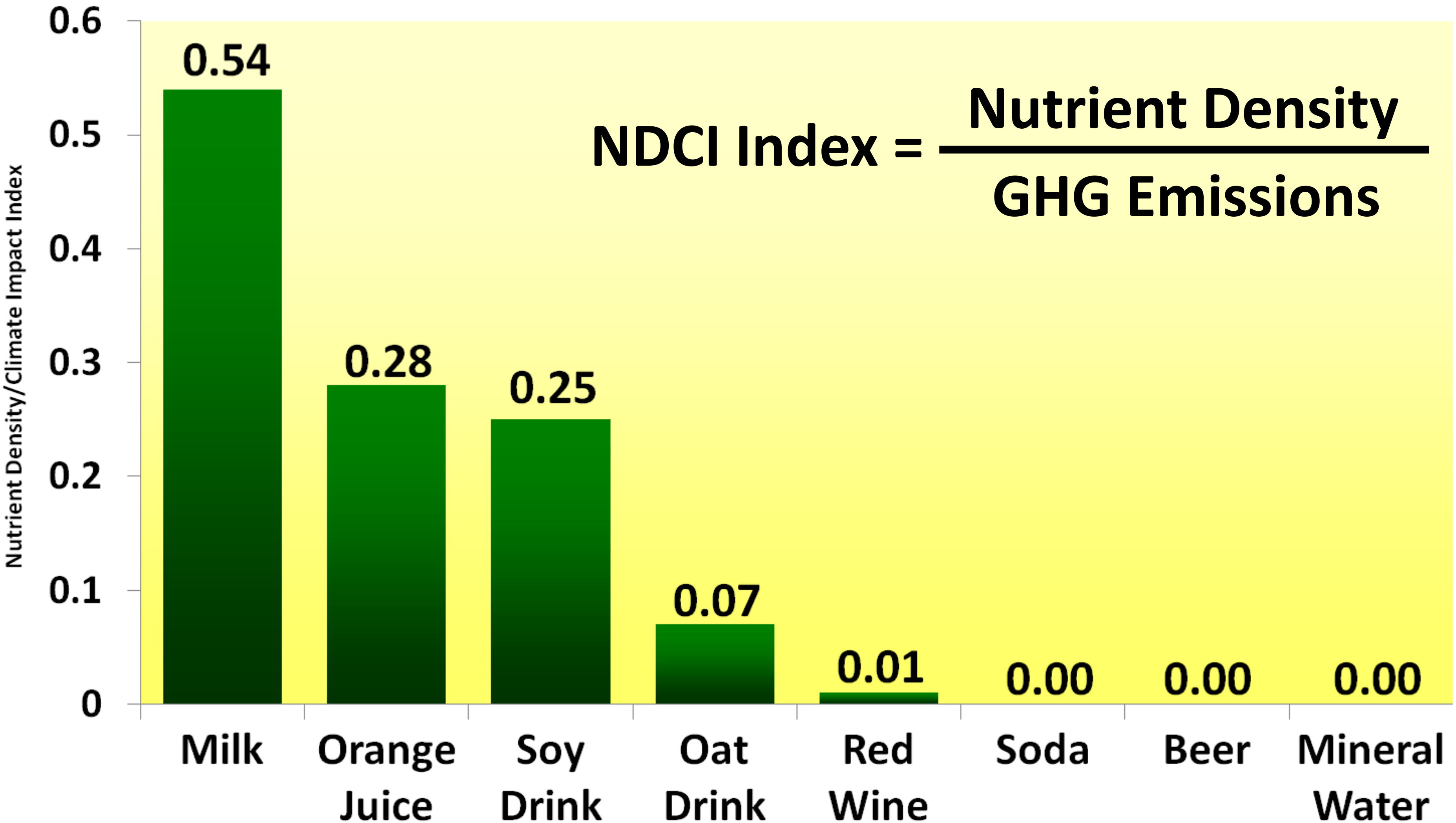
Beverages Vary in Nutrient Density and Greenhouse Gas Emissions

	% NNR in 100g product	Nutrient Density	GHG Emissions gCO2-eq/g product
Milk	126	53.8	99
Orange juice	90	17.2	61
Soy drink	53	7.6	30
Oat drink	32	1.5	21
Red wine	24	1.2	204
Soda	7	0	109
Mineral water	2	0	10
Beer	18	0	101

NNR – Nordic Nutrient Recommendations

Smedman et al. 2010 Nutrient density of beverages in relation to climate impact. Food & Nutr.

Nutrient Density Must Be Included When Assessing Environmental Impact



Based on Smedmen et al. 2010

ENVIRONMENTAL ENGINEERING SCIENCE
Volume 35, Number 11, 2018

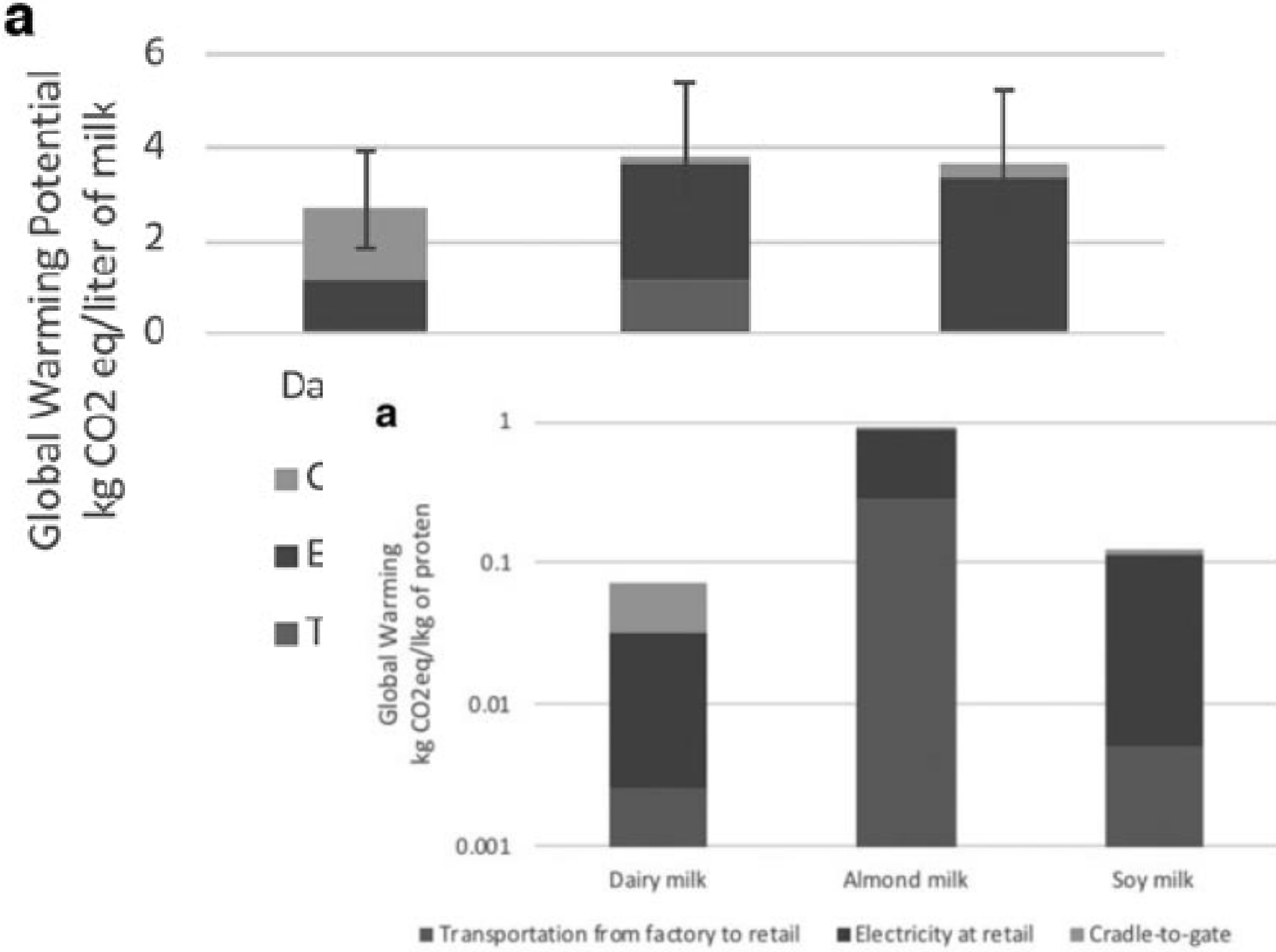
DOI: 10.1089/ees.2018.0233

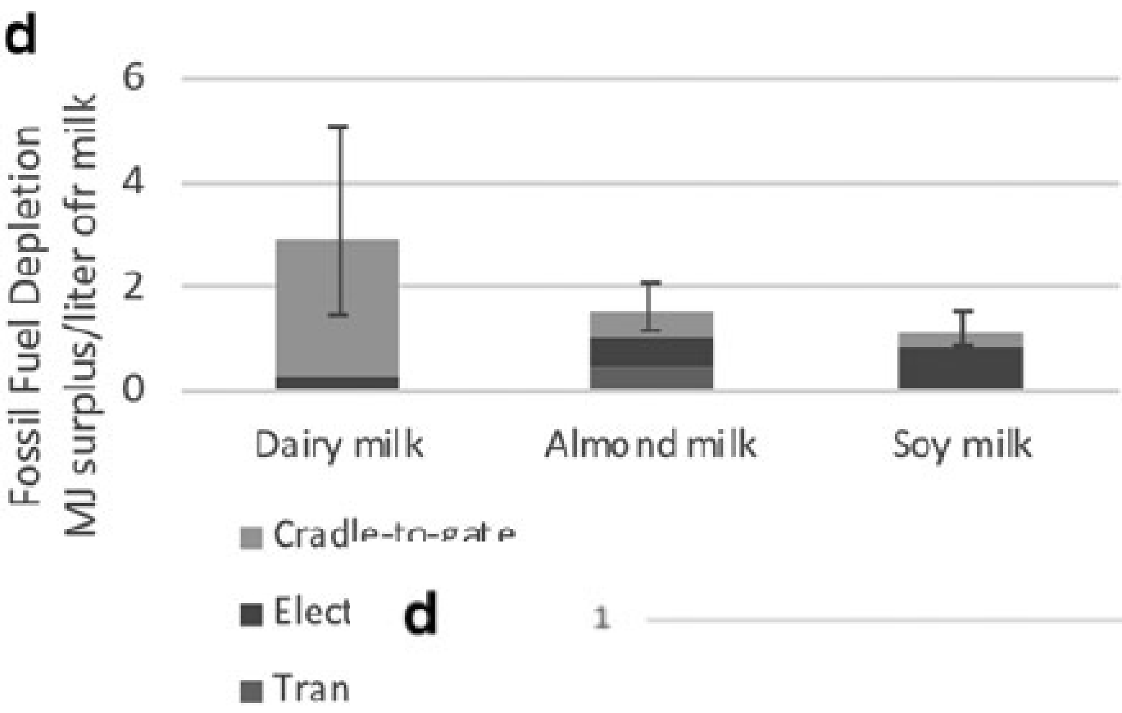
Comparative Life Cycle Assessment of Milk and Plant-Based Alternatives

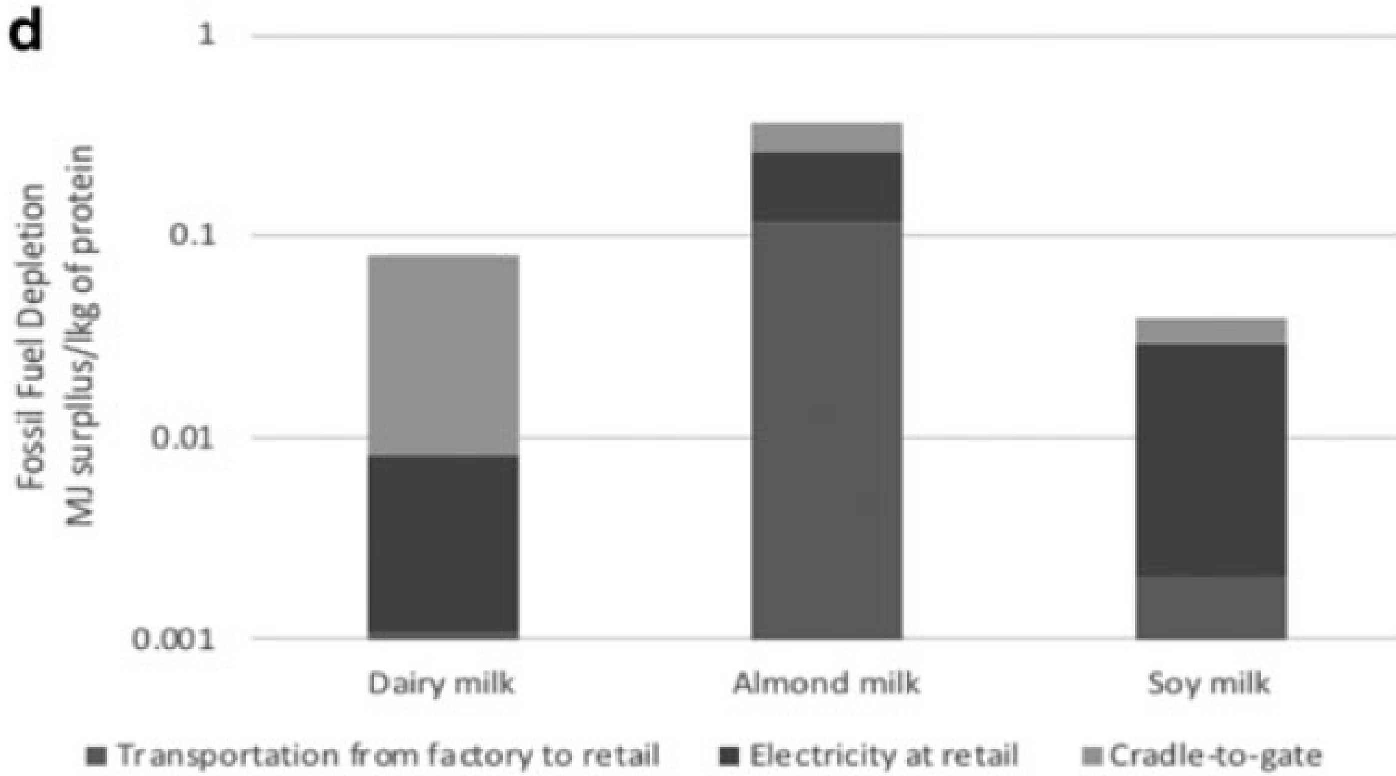
Courtney A. Grant and Andrea L. Hicks*,†

Department of Civil and Environmental Engineering, University of Wisconsin-Madison, Madison, Wisconsin.

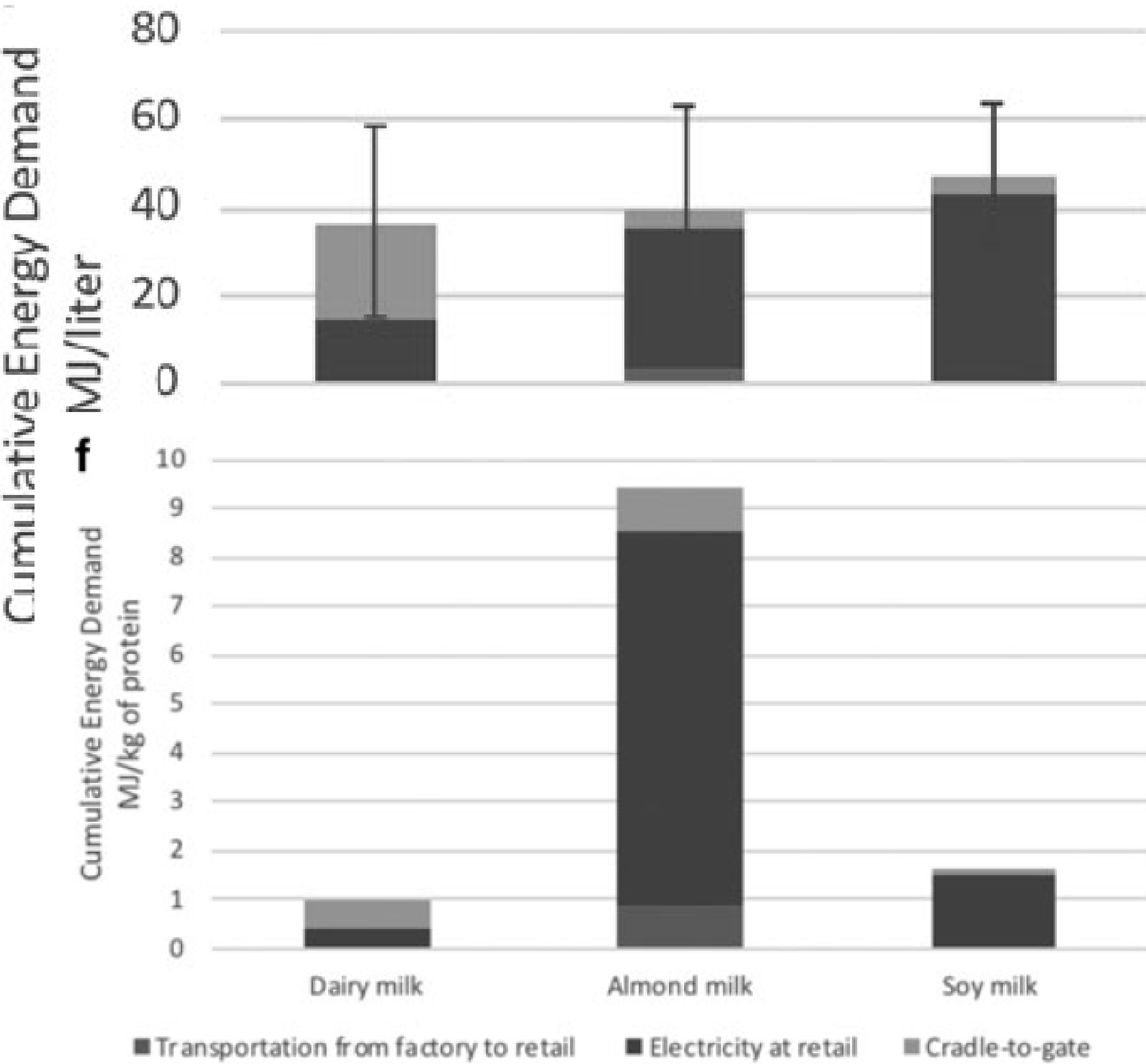
Received: May 21, 2018   *Accepted in revised form: August 30, 2018*


a
6
4
2
0
Global Warming Potential
kg CO2 eq/liter of milk
Da
C
E
T
a
1
0.1
0.01
0.001
Global Warming
kg CO2eq/lkg of proten
Dairy milk
Almond milk
Soy milk
Transportation from factory to retail
Electricity at retail
Cradle-to-gate

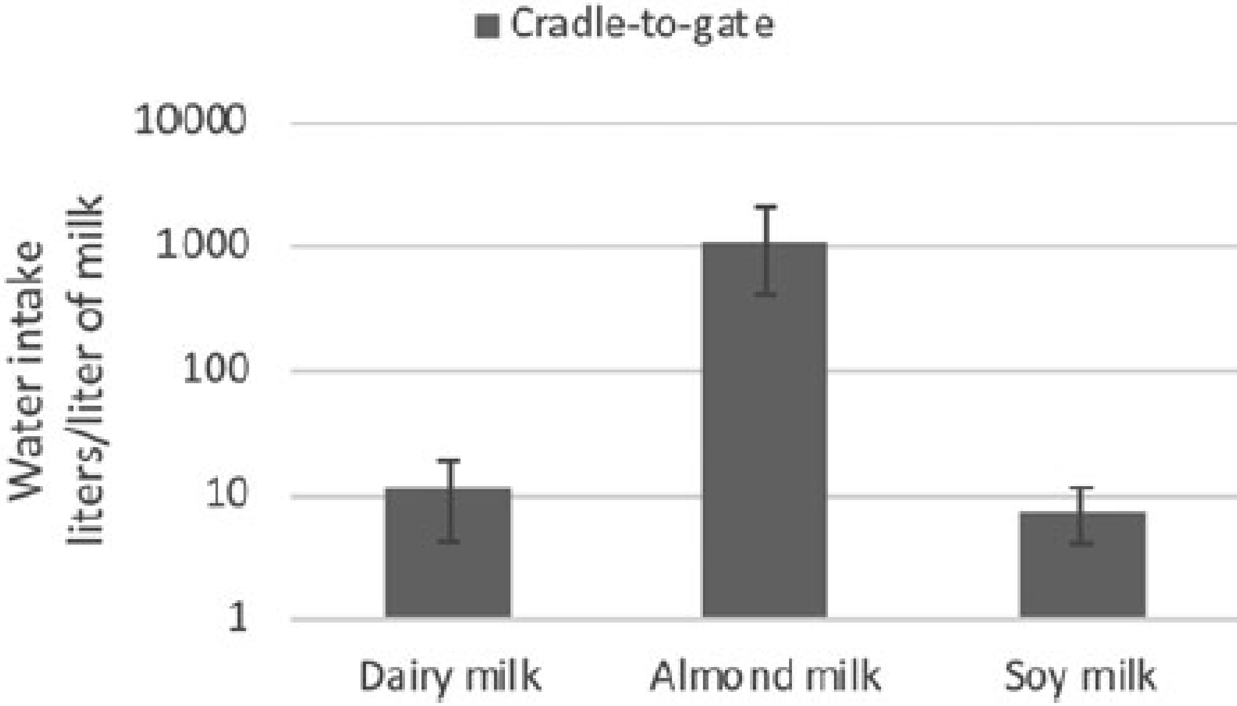

d
6
4
2
0
Fossil Fuel Depletion
MJ surplus/liter ofr milk
Dairy milk
Almond milk
Soy milk
Cradle-to-gate
Elect
Tran

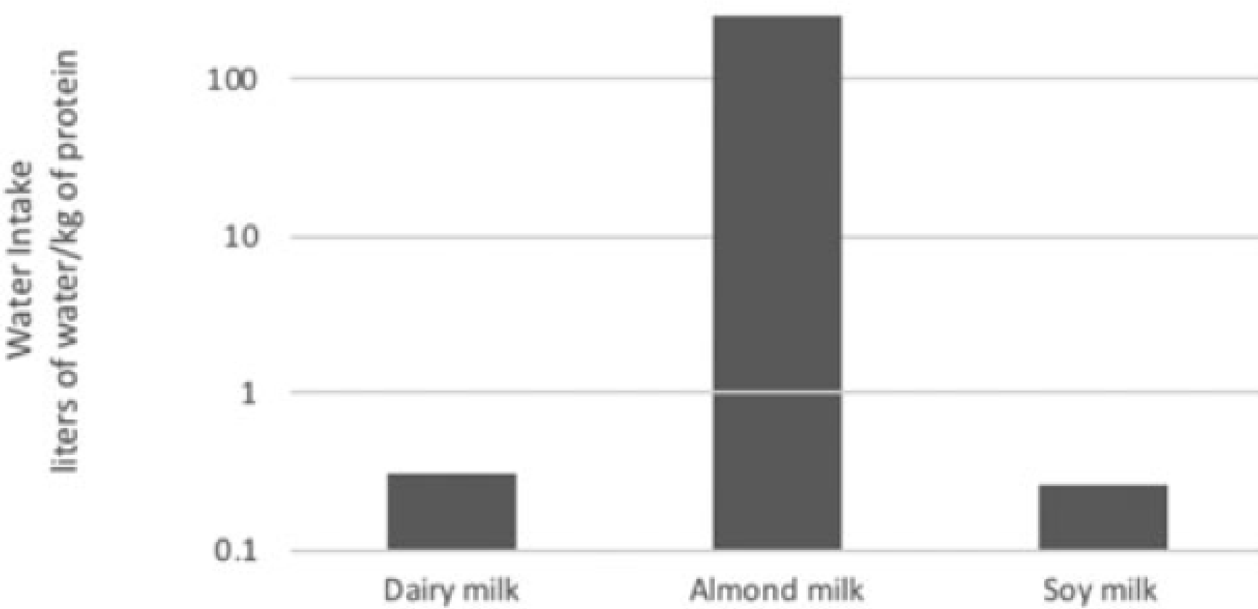

d
1
0.1
0.01
0.001
Fossil Fuel Depletion
MJ surplus/kg of protein
Dairy milk
Almond milk
Soy milk
Transportation from factory to retail
Electricity at retail
Cradle-to-gate

Grant and H



80
60
40
20
0
Cumulative Energy Demand
MJ/liter
f
10
9
8
7
6
5
4
3
2
1
0
Cumulative Energy Demand
MJ/kg of protein
Dairy milk
Almond milk
Soy milk
Transportation from factory to retail
Electricity at retail
Cradle-to-gate





Grant and Hicks, 2018

AUGUST 9, 2019

Your Dairy Can Get To Net Zero GHG Emissions

BUSINESS | BY: MIKE OPPERMAN

How Can the Supply Chain Help?

- Here is an idea borrowed from Europe:
- Record and report the amount of C, N, P, and K sold to the dairy or business every year so they can document what was supplied to them
- This helps in at least two ways:
  - Provides documents about the tons of nutrients coming onto the farm
  - Provides opportunity to understand how efficient the nutrients are being used

22,000 lactating cows – one site with all the heifers and dry cows

Milk processed and packaged on site

EVERYTHING is transparent


加工
养殖
种植
现代牧业
纯牛奶


2016-01-22 10:33:08
蚌埠2号搅拌站出料口

Summary

- We are making significant progress
- Need science to come to our rescue however, it needs to relate on an emotional level
- We eat for nutrients, but those are not described in the environmental battle
- Everything we eat has an environmental impact
- Need to understand the whole food system – what to do with byproducts of the human food system
- Net Zero is coming
- The nutrition supply chain (YOU) can help
- Need to be transparent

Outline

- Brief history of CNCPS
- Concept of precision feeding
- Modifications to the CNCPS
- Application of CNCPS in Precision Feed Management (PFM)
- Greenhouse gas, dairy and byproducts
- Use of CNCPS to predict and evaluate GHG emissions at farm level
- Summary

CNCPS Quick History –

A Net Carbohydrate and Protein System for Evaluating Cattle Diets: I. Ruminal Fermentation

J. B. Russell[*,†], J. D. O'Connor[†,1], D. G. Fox[†], P. J. Van Soest[†], and C. J. Sniffen[†,2]

[*]U.S. Dairy Forage Research Center, ARS, USDA, Madison, WI 53706 and U.S. Plant, Soil, and Nutrition Laboratory, Ithaca, NY 14853 and [†]Department of Animal Science, Cornell University, Ithaca, NY 14853

A Net Carbohydrate and Protein System for Evaluating Cattle Diets: II. Carbohydrate and Protein Availability

C. J. Sniffen[*,1], J. D. O'Connor[*,2], P. J. Van Soest[*], D. G. Fox[*], and J. B. Russell[*,†]

[*]Department of Animal Science, Cornell University, Ithaca, NY 14853 and [†]U.S. Dairy Forage Research Center, ARS, USDA, Madison, WI 53706 and U.S. Plant, Soil, and Nutrition Laboratory, Ithaca, NY 14853

A Net Carbohydrate and Protein System for Evaluating Cattle Diets: III. Cattle Requirements and Diet Adequacy[1]

D. G. Fox[*], C. J. Sniffen[*,2], J. D. O'Connor[*,3], J. B. Russell[*,†], and P. J. Van Soest[*]

[*]Department of Animal Science, Cornell University, Ithaca, NY 14853 and [†]U.S. Dairy Forage Research Center, ARS, USDA, Madison, WI 53706 and U.S. Plant, Soil, and Nutrition Laboratory, Ithaca, NY 14853

A Net Carbohydrate and Protein System for Evaluating Cattle Diets: IV. Predicting Amino Acid Adequacy

J. D. O'Connor[1], C. J. Sniffen[2], D. G. Fox[3], and W. Chalupa[4]

Department of Animal Science, Cornell University, Ithaca, NY 14853

The Cornell Net Carbohydrate and Protein System model for evaluating herd nutrition and nutrient excretion

D.G. Fox[a,*], L.O. Tedeschi[a], T.P. Tylutki[a], J.B. Russell[b], M.E. Van Amburgh[a], L.E. Chase[a], A.N. Pell[a], T.R. Overton[a]

Cornell Net Carbohydrate and Protein System: A model for precision feeding of dairy cattle☆

T.P. Tylutki[a,*], D.G. Fox[a], V.M. Durbal[a,1], L.O. Tedeschi[b], J.B. Russell[c], M.E. Van Amburgh[a], T.R. Overton[a], L.E. Chase[a], A.N. Pell[a]

J. Dairy Sci. 98:6340–6360
http://dx.doi.org/10.3168/jds.2015-9379

Updating the Cornell Net Carbohydrate and Protein System feed library and analyzing model sensitivity to feed inputs

R. J. Higgs, L. E. Chase, D. A. Ross, and M. E. Van Amburgh[1]

J. Dairy Sci. 98:6361–6380
http://dx.doi.org/10.3168/jds.2015-9378

The Cornell Net Carbohydrate and Protein System: Updates to the model and evaluation of version 6.5

M. E. Van Amburgh,[*1] E. A. Collao-Saenz,[†] R. J. Higgs,[*] D. A. Ross,[*] E. B. Recktenwald,[*] E. Raffrenato,[‡] L. E. Chase,[*] T. R. Overton,[*] J. K. Mills,[§] and A. Foskolos[*]

Evaluating and Predicting N Excretion

- Urinary N is main form of excreted N
- Fecal N is fairly constant

Reference	Intake N (g/d)	Fecal N (g/d)	Urinary N (g/d)
Kauffman and St-Pierre, 2001	429	178	93
	460	184	101
	572	198	190
Hristov and Ropp, 2003	658	208	233
	754	176	279

Fecal, Urinary and Total Manure Nitrogen Excretion Predictions in CNCPS

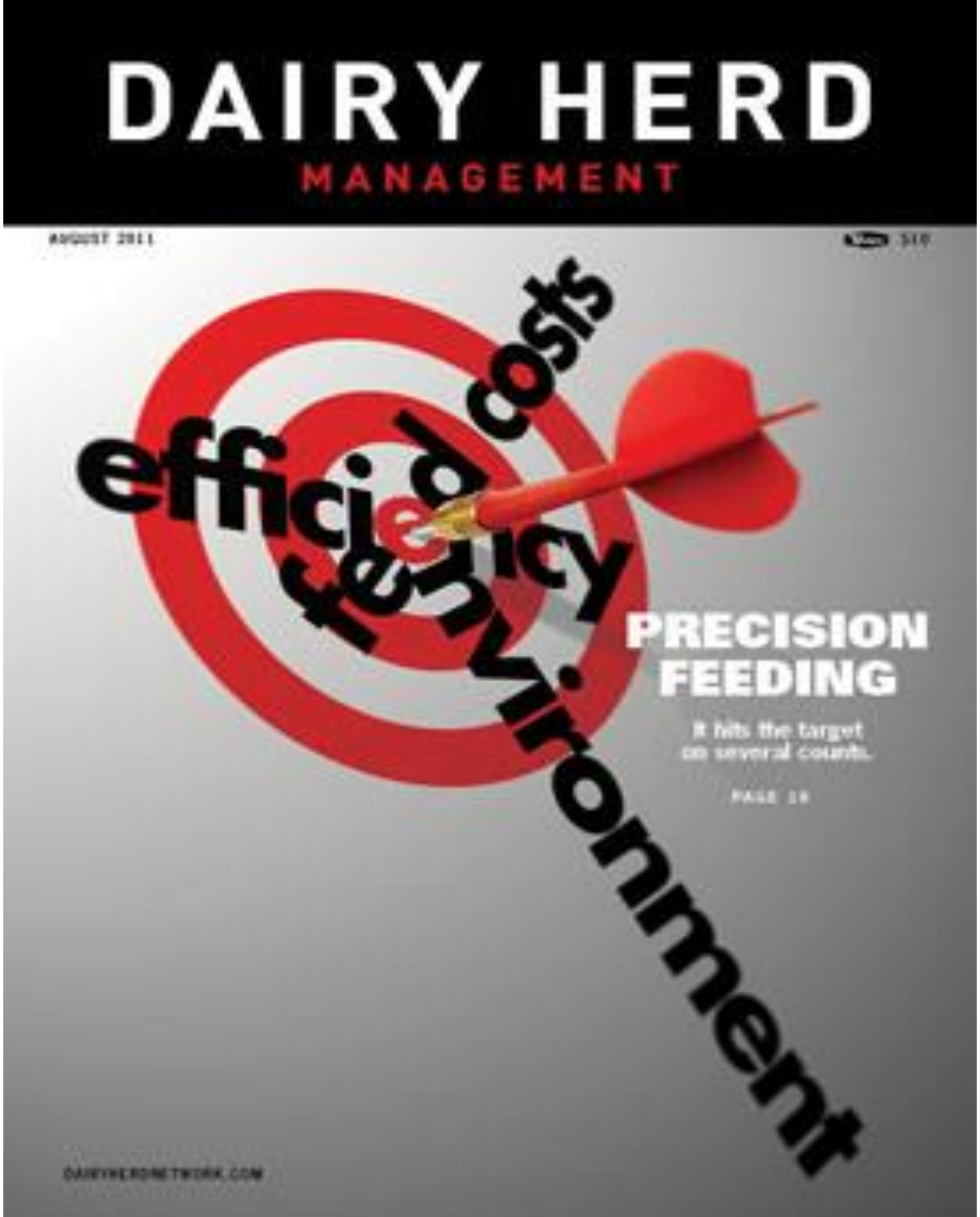
Equation	Slope	R^2	MSE	Variance component, (%)		
				Study	Slope	Residual
Fecal N	1.00	0.97	107.66	85.33	0.01	14.66
Urinary N	0.93	0.97	162.17	70.79	0.01	29.20
Manure N	0.97	0.99	154.14	56.82	0.00	43.17
Total N	1.00	1.00	0.05	72.20	0.00	27.80

Higgs et al., 2012, J. Dairy Science

Excretion Report – Fecal, Urine and Total Manure N

- 1820 total animals

Feces Total MT	Urine Total MT	Manure Total MT	Fecal N Total MT	Urine N Total MT	Manure N Total MT
19732.87	9771.42	29504.28	99.28	55.95	155.23


DAIRY HERD
MANAGEMENT
AUGUST 2011
efficiency
feed costs
environment
PRECISION FEEDING
It hits the target on several counts.
DAIRYHERDNETWORK.COM

Why Precision Feed Management?

1. Improve dairy farm profitability.
2. Improve the efficiency of nutrient use.
3. Decrease nutrient excretion into the environment (soil, water, air).
4. Help to comply with environmental regulations.

- NY currently concerned with N and P, and methane is on the short list

What is Precision Feed Management (PFM)?

- Definition by NY PFM Working Group
- “The continual process of providing adequate, but not excess, nutrients to the animal and deriving a majority of nutrients from homegrown feeds through the integration of feeding and forage management for the purpose of maintaining environmental and economic sustainability”

NY PFM Project

- Diets were evaluated with CNCPS v6.1 or 6.5
- Diets were formulated to reduce excess feed N – three phase approach – reduce rumen N balance, reduce urinary N excretion, improve efficiency of meeting MP supply
- Phosphorous was already low in these herds so difficult to reduce – at NRC, 2001 lower limits
- Forage analysis didn't inlcude aNDFom digestibility for first 1.5 yr, but did measure and use the second half of study
- All prices (feed and milk) held constant for evaluation to understand management changes

Herd information for the precision feed management study

Herd	Cow number	Barn Type#	Milking, times/d	Feeding System	DHI§	Milk, $/cwt.
A	30	TS	2	Component	No	19.34
B	54	TS	2	Component	No	19.46
C	88	TS	2	TMR	Yes	20.46
D	76	TS	2	TMR	Yes	22.31
E	188	FS	2	TMR	Yes	19.77
F	435	FS	3	TMR	Yes	19.73
G	565	FS	3	TMR	Yes	19.25
H	265	FS	2	TMR	No	18.41

Diet phosphorus and manure phosphorus excretion by herd

Herd	Initial Diet P, g/day	Final Diet P, g/day	Initial Manure P, g/day	Final Manure P, g/day	Manure P, Excretion, % Change	Manure P Excretion, kg/herd/yr
A	0.39	0.36	51.2	46.1	-10	-55.8
B	0.43	0.38	52.1	42.8	-17.8	-185.1
C	0.38	0.36	51.0	43.7	-14.3	-234.6
D	0.35	0.36	46.4	48.1	+3.7	47.2
E	0.34	0.33	58.2	53.3	-8.4	-336.2
F	0.36	0.38	52.3	55.6	+4.3	365.2
G	0.32	0.31	36.4	31.2	-14.3	-1072.6
H	0.37	0.38	50.1	52.0	+3.8	183.8

PFM and CNCPS

- Implementation of a PFM program can have positive impacts on N and P utilization and increase income to the dairy
- The CNCPS was an effective formulation tool to reduce dietary N and P without losing productivity and reducing the environmental impact of milk production
- Further, the predictions of the CNCPS allow the user to quantify those changes for use by CAFO planners

Dairy industry pushes back against livestock emissions reporting with new bill

By Mary Ellen Shoup
20-Feb-2018 - Last updated on 20-Feb-2018 at 09:45 GMT

POST A COMMENT

Animal agricultural organizations argue that they shouldn't have to submit GHG emissions reports under CERCLA. ©GettyImages/Bestgreenscreen

As part of the FARM Act, a new bipartisan bill was introduced in the US Senate that would exempt farms, ranches, and other agricultural operations from having to report animal waste emissions data required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

Byproduct feeding and the Environmental Impact of Dairy Cattle

- There is a significant misunderstanding of the role dairy cows play in utilization of byproducts of the human food chain

Cows Fed Candy Instead Of Corn On Kentucky Ranch Affected By Drought

Posted: 08/21/2012 3:38 pm Updated: 08/21/2012 3:46 pm

Like 4,788 people like this.

www.huffingtonpost.com/.../**cows-fed-candy**-drought_n_1819366.html

Flash

WHO KNEW?

EAT LIKE A COW
They chow down on 50+ pounds of food a day—that's like 7,250 gummies.

HOLY WOW!

Was this your dinner's dinner?

Farmers are giving cattle stuff like stale candy and cookies instead of pricey feed. So even if you're avoiding junk, your beef probably isn't. The sweets don't alter the food's nutritional value (or even hurt the animals' health), but still....

Source: Michael Van Amburgh, Ph.D., associate professor of Animal Science at Cornell University

SELF PLUS
Hold your device over this page to tell us whether this weirds you out or is NBD. Get the app—details, page 12.

JONATHON KAMBOURIS; FOOD STYLING, ED GABRIELS FOR HALLEY RESOURCES.

Self Magazine
March '13

By-product Utilization in Dairy Cattle Diets

- Mowrey et al., 1999 characterized byproduct feeds around the country
  - 21.7% in SE region fed citrus pulp
  - 13.3% in NW and 16.7% in SW area of the country fed almond hulls

- There is no single database or reference at this time

- USDA did keep track at one time, but that service is now non-existent

- Contacted AFIA and they did not have this type of data

Carbon Dioxide Prediction

- Casper and Mertens, 2010 ADSA abstract
- Based on the measurements at the USDA-Beltsville Energy Metabolism Unit

$$CO_2 = (821.3 + (126.0 \times DMI) – (1.18 \times milk)) / 0.27$$

- Also evaluated the equation of Kirchengessner et al, 1991 for comparison:

$$CO_2 = (-1.4 + (0.42 \times DMI) + (0.045 \times BW^{0.75}))/0.27$$

USDA-Beltsville Energy Metabolism Unit - dataset

- 3,018 individual digestion metabolism balance trials
- 1,351 balance trials involving lactating cows
- Lactating Beef Cow study excluded (milk yield)
- Ruminal infusion study (Orskov) excluded
- 1,252 individual metabolism trials with milk production being > 5 kg/d were used in the data analysis

Casper and Mertens, 2010

Comparison of CO_2 emissions from dairy cows between Casper and Mertens (2010) and Kirchengessner et al, (1991) prediction equations

	Casper and Mertens, 2010	Kirchgessner et al., 1991
	CO_2 (g/cow/d)	
Mean	14,281	14,775
SD	1,181	1,244
Min	9,172	9,059
Max	16,429	17,187

Methane Equations

- For dairy cattle: CH_4 (MJ/d) = 45.98 – (45.98e$^{(-1*(((-0.0011*starch/ADF)+0.0045*MEintake,}$ where starch and ADF are kg of dry matter consumed and ME intake is in megajoules

(Mills et al. 2003)

- For beef cattle: CH_4 (MJ/d) = 2.94 + 0.0585 * ME intake (MJ/d) + 1.44 * ADF (kg/d) – 4.16 * lignin (kg/d). (Ellis et al. 2007; equation 14b)
- Both equations chosen due to high R^2 and low RMSE

Van Amburgh et al., 2015

Data for analysis using CNCPS:

- Lactating dairy cattle diets were requested from professional nutritionists around the U.S.
- Received 91 diets from 70 different farms from 10 states across the U.S. from the following states: AZ, CA, FL, ID, MI, NY, PA TX, VT, and WI
- Almost all diets came in a CNCPS format
- Complete set of diet ingredients, including chemical analysis of individual ingredients as well as a complete diet nutrient summary

Description of the data used in this study for input into the CNCPS v6.5. Data from 91 farms in 10 states around the U.S.

Item	Mean	SD	Min	Max
Dietary Characteristic				
DMI (lb per cow/day)	55.1	4.62	40.8	65.0
ADF (%DM)	19.3	1.5	15.7	23.4
NDF (%DM)	34.5	3.2	16.1	31.6
CP (%DM)	17.1	1.3	14.7	23.2
Starch (%DM)	24.5	3.2	16.1	31.6
By-Products (%DM)	31.2	9.4	9.4	56.7
Animal Characteristic				
BW (lb)	1427	95	969	1662
Milk yield (lb/day)	90.4	9.2	65.0	117.0
Milk fat (%)	3.7	0.2	3.3	4.5
Milk protein (%)	3.0	0.1	2.8	3.2

Carbon Dioxide from Combustion

Carbon composition and ash content of each byproduct was calculated using the equation of Adams et al. (1951):

$$\%C = \%VS/1.8$$

Where VS = volatile solids and %VS = 100-%ash, (attributing to carbon, oxygen and nitrogen)

Ash = mineral elements that will not oxidize upon combustion and C= carbon

Summary

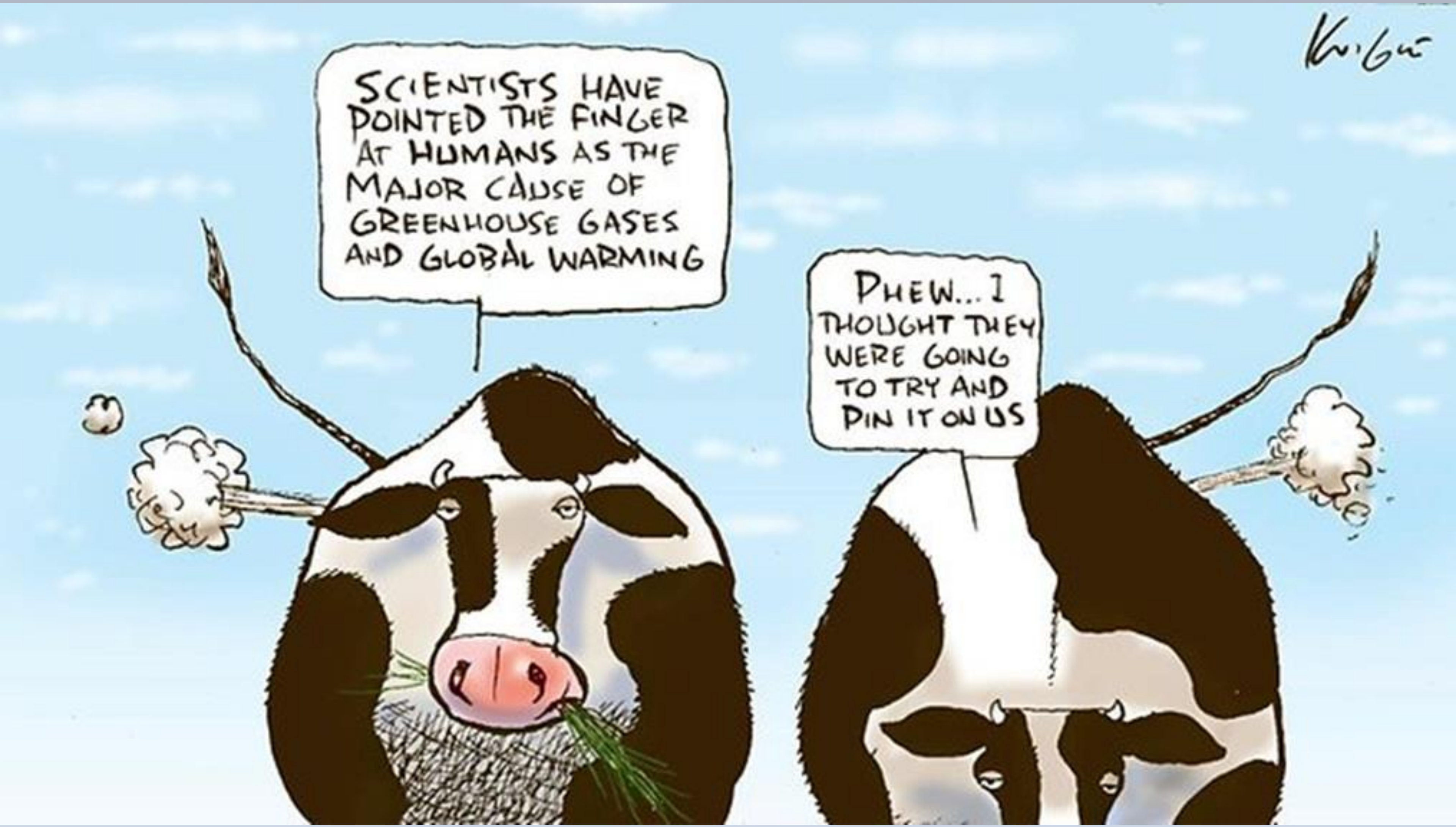
- A practicing nutritionist can evaluate the environmental impact of a particular diet, group or herd on an N, P or GHG basis.

- This can be useful to both dairy producers and CAFO planners in the preparation and deployment of nutrient management plans

Summary

- Total amount of N and P consumed and excreted can be forecasted given a specific set of forages, byproducts, concentrates and animals at the pen, barn or farm level
- The same calculations can be made for GHG, although there is no current regulatory demand for that information
- The cow fulfills a role in society by upcycling byproducts of the human food chain into high quality nutrient source which also reduces the costs of the primary product

Thank you for your attention



Credit for Use of Human Food & Fiber By-products Further Reduces the Carbon-Footprint of Milk

Oil extraction
- Almond hulls
- Canola meal
- Cotton hulls
- Cotton seed meal
- Linseed meal
- Peanut meal
- Soy hulls & meal
- Sunflower hulls & meal

Brewing & Spirits
- Brewers grains
- Brewers solubles
- Brewers yeast
- Distillers grains

Grain milling
- Bran (corn, wheat, rice)
- Cereal fines
- Midds (corn, wheat, barley)

Clothing
- Whole cotton seed

Fruit/Vegetable processing
- Pomace (apple, tomato, carrot)
- Vine silage (peas & legumes)
- Corn stover
- Potato peels

Citrus processing
- Citrus pulp

Ethanol production
- Distillers grains (corn, milo, barley, sorghum)

Dry corn milling for corn flour & grits
- Corn bran
- Hominy feed

Wet corn milling for starch, sweeteners & oil
- Corn germ meal
- Corn gluten feed

Sugar processing
- Beet pulp
- Molasses

Fish processing
- Fish meal

Cheese manufacturing
- Whey

Baking industry
- Bakery by-products
- Expired product

Chocolate manufacturing
- Candy by-products
- Confectionary waste

Human foods that fail grading
- Starches, oils
- Grains, flour
- Vegetables

Nutritional and greenhouse gas impacts of removing animals from US agriculture

Robin R. White[a,1,2] and Mary Beth Hall[b,1,2]

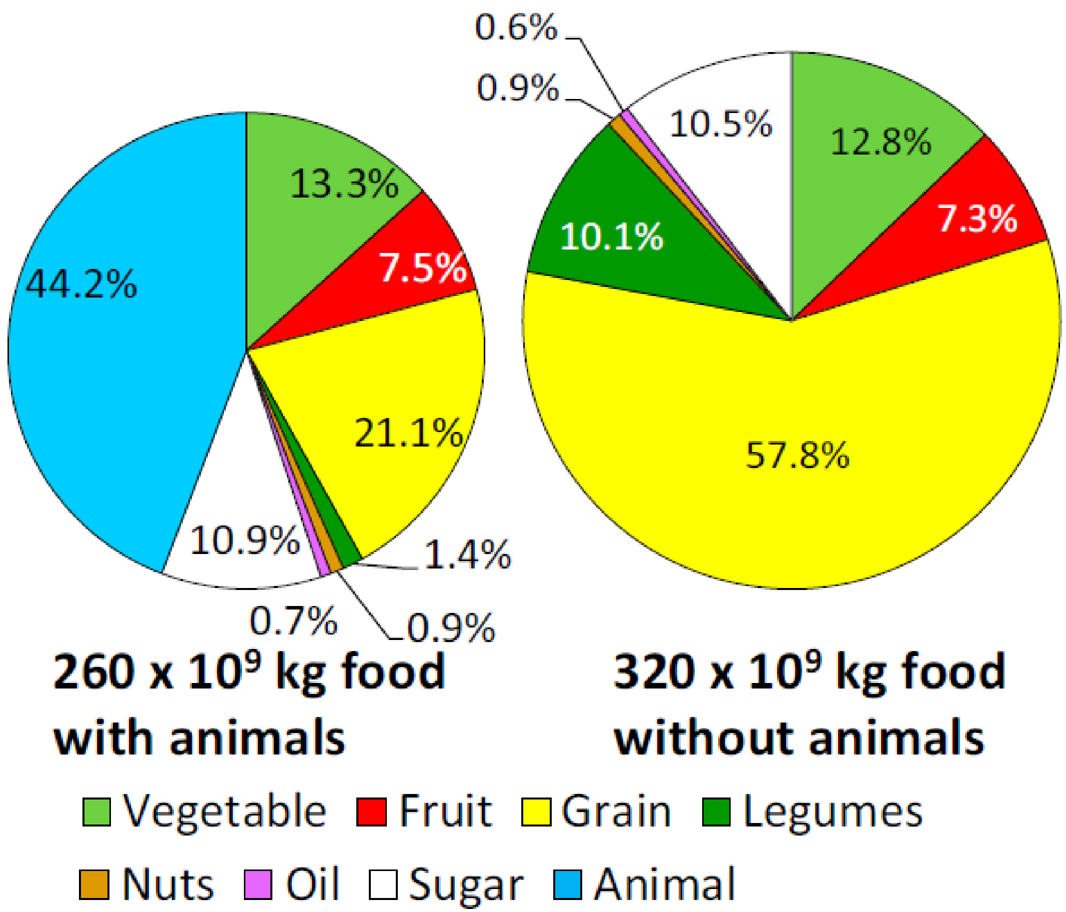
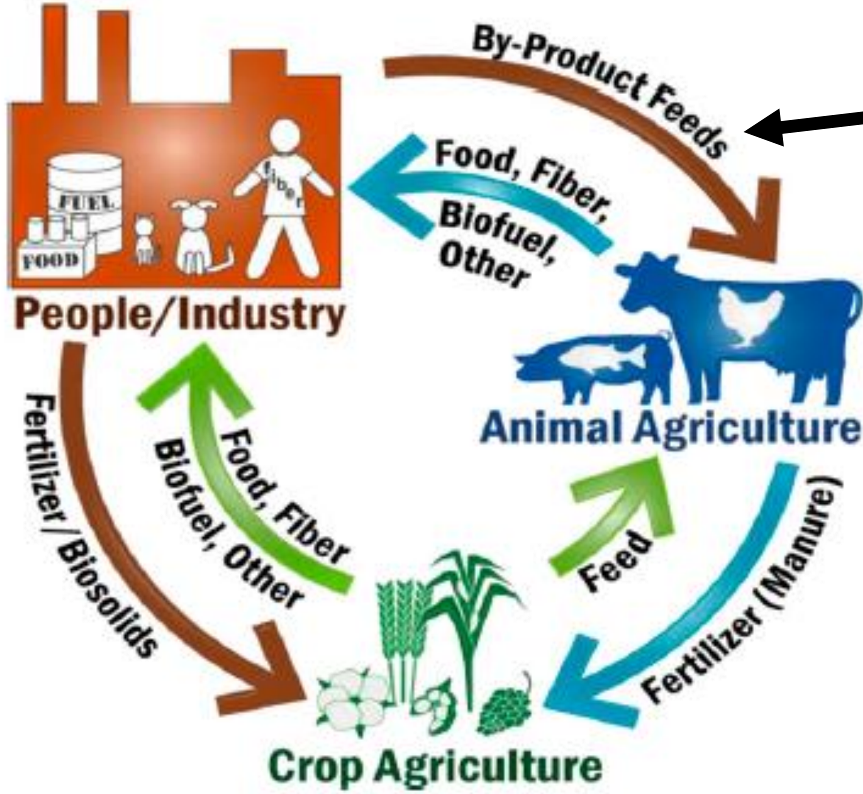


Fig. 3. Amounts and proportions of foods available in systems with and without animal inputs. Graphs are sized proportionally to the amounts of food available.

PNAS, 2017



This part is actually a big deal economically and environmentally

Their calculation is 4.32×10^{10} kg

That is 43,200,000 metric tons of byproducts

Yearly Contributions, kg

People/Industry
To Animal Agriculture:
By-product feed: 4.32×10^{10}

Crop Agriculture
To People/Industry:
- Food: 1.72×10^{11}
- Non-food: 1.28×10^{11}

To Animal Agriculture:
- Crops: 1.12×10^{11}

Animal Agriculture
To People/Industry
- Food: 1.20×10^{11}
- Non-food: 1.22×10^{10}

To Crop Agriculture
- Manure N: 4.01×10^{9}
- Manure P: 1.69×10^{9}
- Manure K: 1.88×10^{9}
- Manure S: 2.84×10^{8}

In 2014, in the **United States**, about 258 million **tons** of municipal solid waste (MSW) were generated.
EPA data

Over 89 million **tons** of MSW were recycled and composted
https://www.epa.gov/smm/advancing-sustainable-materials-management-facts-and-figures

White and Hall, PNAS 2017

White and Hall, PNAS 2017

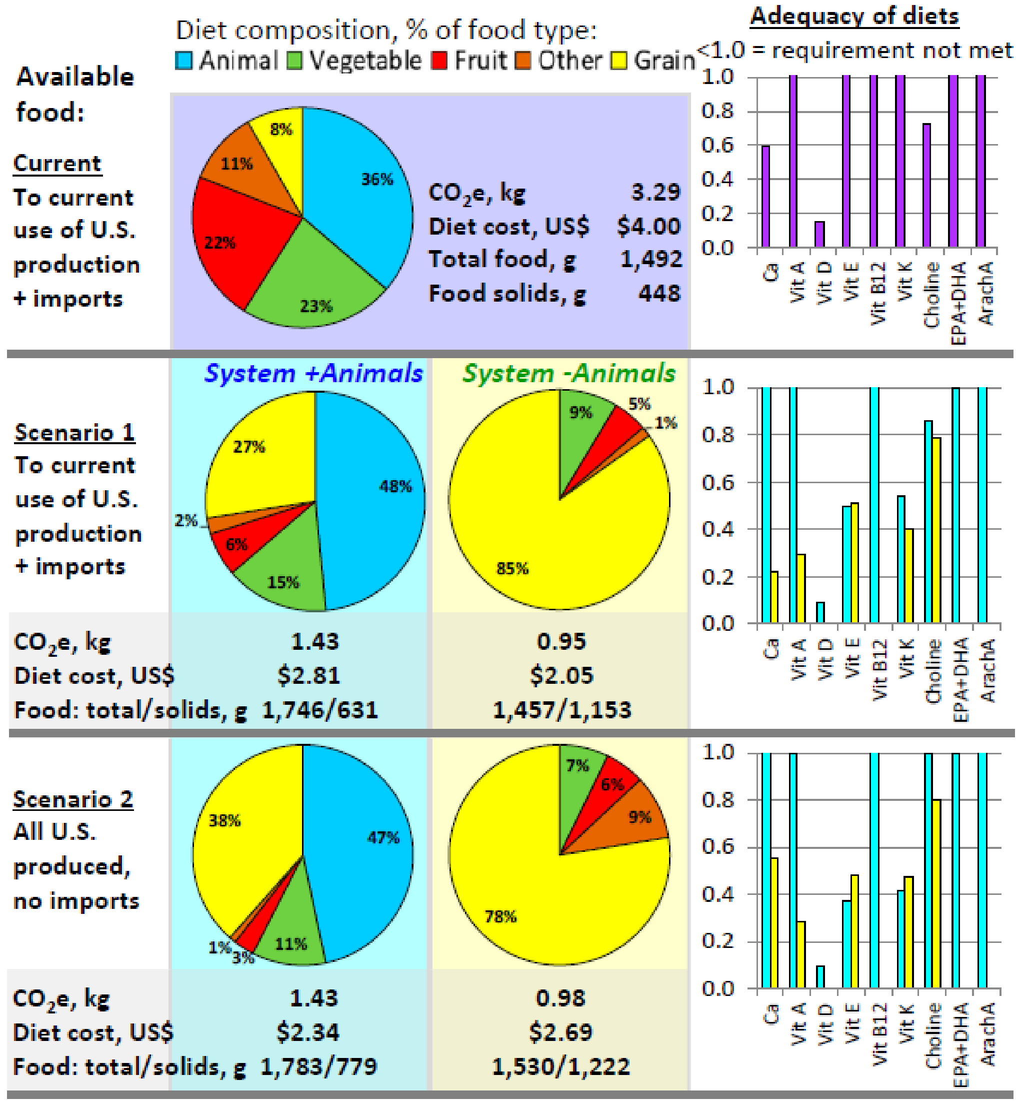


Fig. 4. Comparison of the daily diet composition, CO_2e emissions, intake, cost, and nutrient adequacy of the current US diet compared with a series of optimized diets with and without (modeled) animal-derived foods. Bar graphs indicate dietary adequacy of specific nutrients by scenario; purple indicates current diet, blue indicates diet with animals, yellow indicates plants-only diet. "Other" represents nuts, legumes, fats, and sweeteners. ArachA, arachidonic acid.

LETTER

In PNAS - response to White and Hall

Causing confusion in the debate about the transition toward a more plant-based diet

Koenraad Van Meerbeek[a,b,1] and Jens-Christian Svenning[a,b]

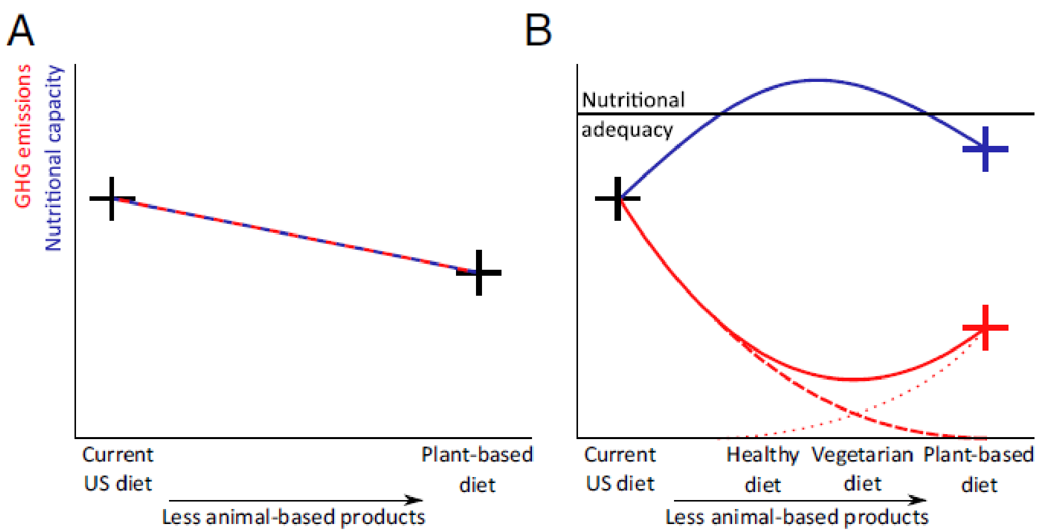


Fig. 1. (*A*) Implicitly assumed linear relationship between the share of animal-based products in the American diet and GHGE (in red) and nutritional capacity (in blue) by White and Hall (1). The black crosses represent results for GHGE and nutritional capacity of the considered diets, as calculated in their analysis. (*B*) More likely (although uncertain) relationships (solid lines), with the optimum not situated in one of the two considered scenarios. Red and blue cross indicate more likely levels of GHGE and nutritional capacity of a plant-based diet. The net GHGE (solid red line) achieve a minimum and increase again when the indirect adverse effects on emission reduction of the removal of animals from agriculture (dotted red line) outweigh the gross emission reduction (dashed red line). Given the highly complex nature of the GHG balance, the shape of the GHG emission curve is uncertain. The position of the maximum and minimum of the curves on both axes are purely illustrative. Only relative positions are considered. Healthy diet limits the consumption of sugar, oil, meat, and dairy, as recommended by the Harvard Medical School (3). Vegetarian diet is without meat or fish consumption. Plant-based or vegan diet is without any animal-based products.

Integration of Health, Environment and Nutrient Supply: Milk Example

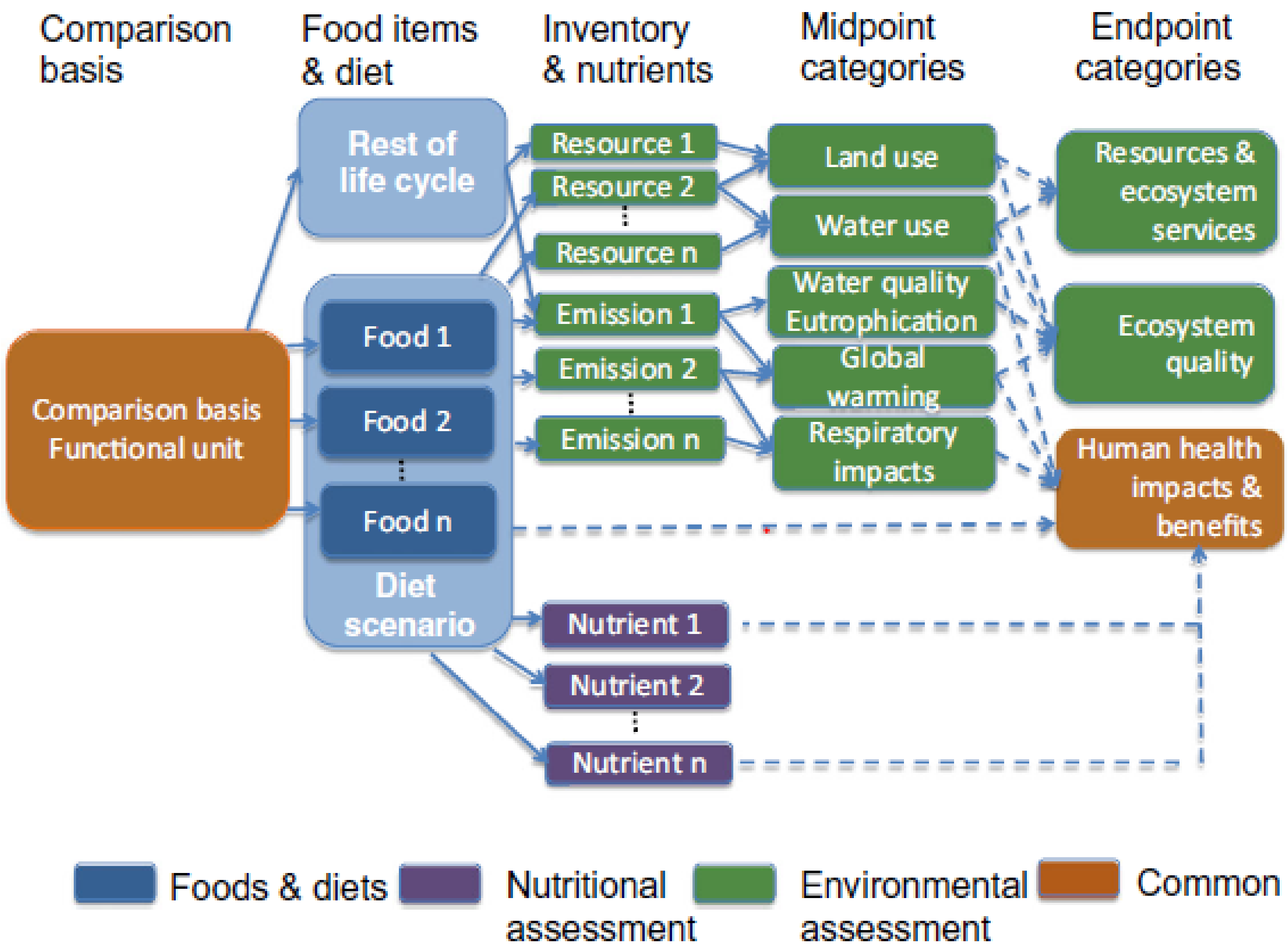
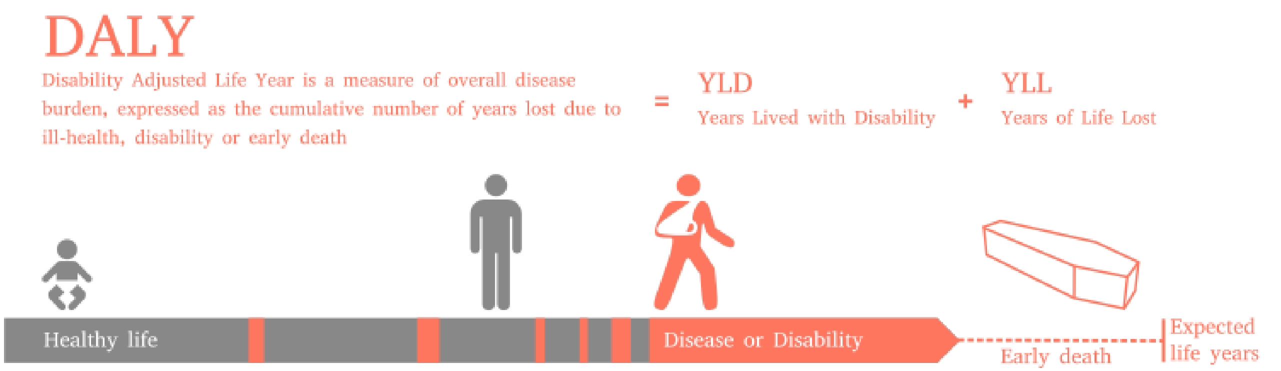


Fig. 1 Graphical representation of the combined nutritional and environmental health impact LCA framework. *Dashed lines* represent links between midpoint and endpoint categories that are useful to interpret impact scores, but whose quantification is also associated with a high degree of uncertainty

Stylianou et al. Int J Life Cycle Assess (2016) 21:734–746

What's a DALY?

- The **disability-adjusted life year** (**DALY**) is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death. It was developed in the 1990s as a way of comparing the overall health and life expectancy of different countries.
- The DALY relies on an acceptance that the most appropriate measure of the effects of chronic illness is time, both time lost due to premature death and time spent disabled by disease. One DALY, therefore, is equal to one year of healthy life lost.



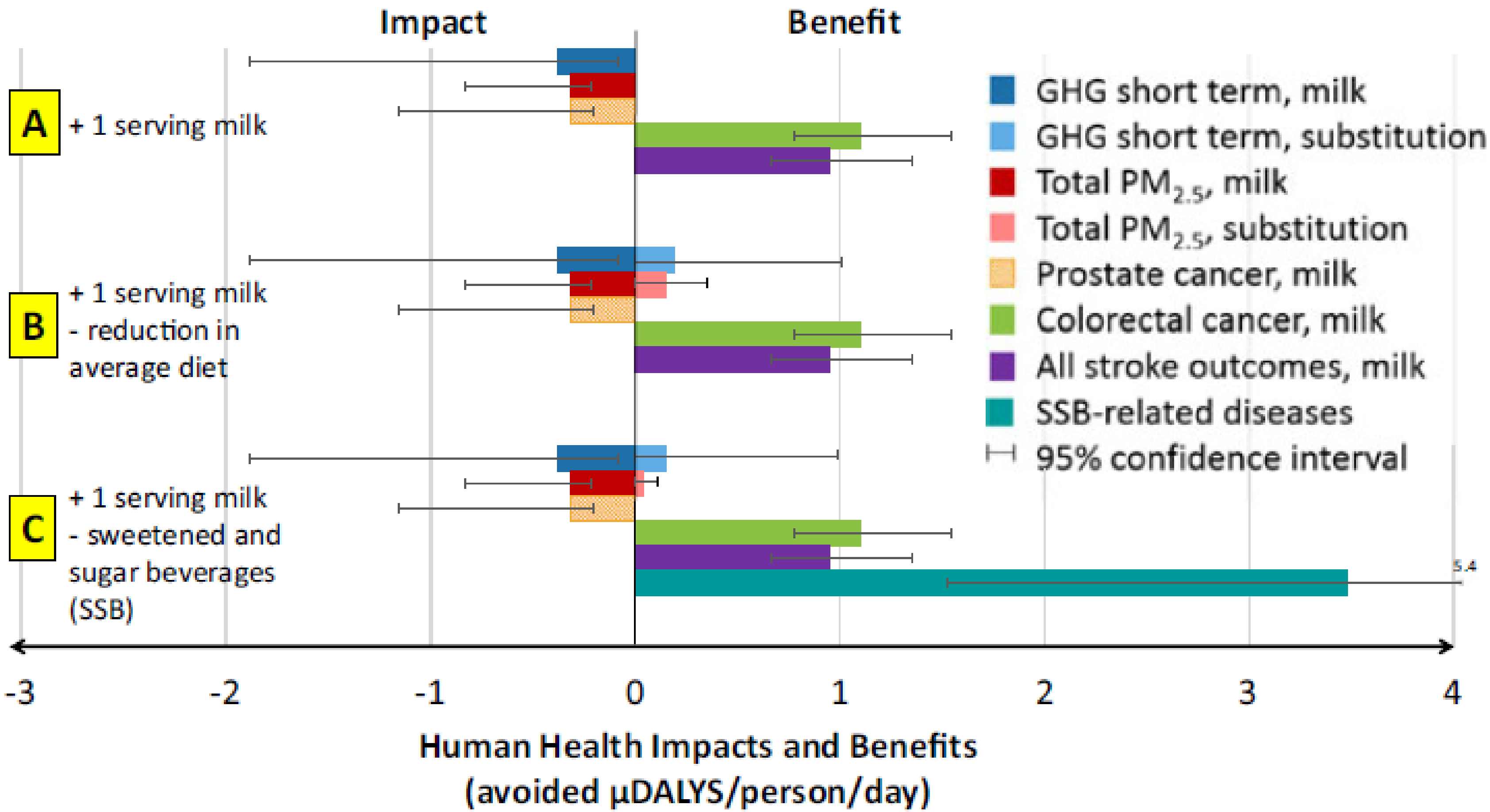
https://en.wikipedia.org/wiki/Disability-adjusted_life_year

Comparison made of current U.S. diet and alternatives adding or exchanging a 119 kcal serving of milk

The width of food groups corresponds to their caloric contribution to the total average US diet

Stylianou et al. Int J Life Cycle Assess (2016) 21:734–746

Outcomes in Health Benefits (µDALY) Compared to the Standard U.S. diet by Addition or Exchange of 1 serving Fluid Milk



DALY = Disability Adjusted Life Years – gap between current health status and ideal health status

Stylianou et al. Int J Life Cycle Assess (2016) 21:734–746