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College of Life Sciences and Agriculture

What's in Your Milk?

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Outline

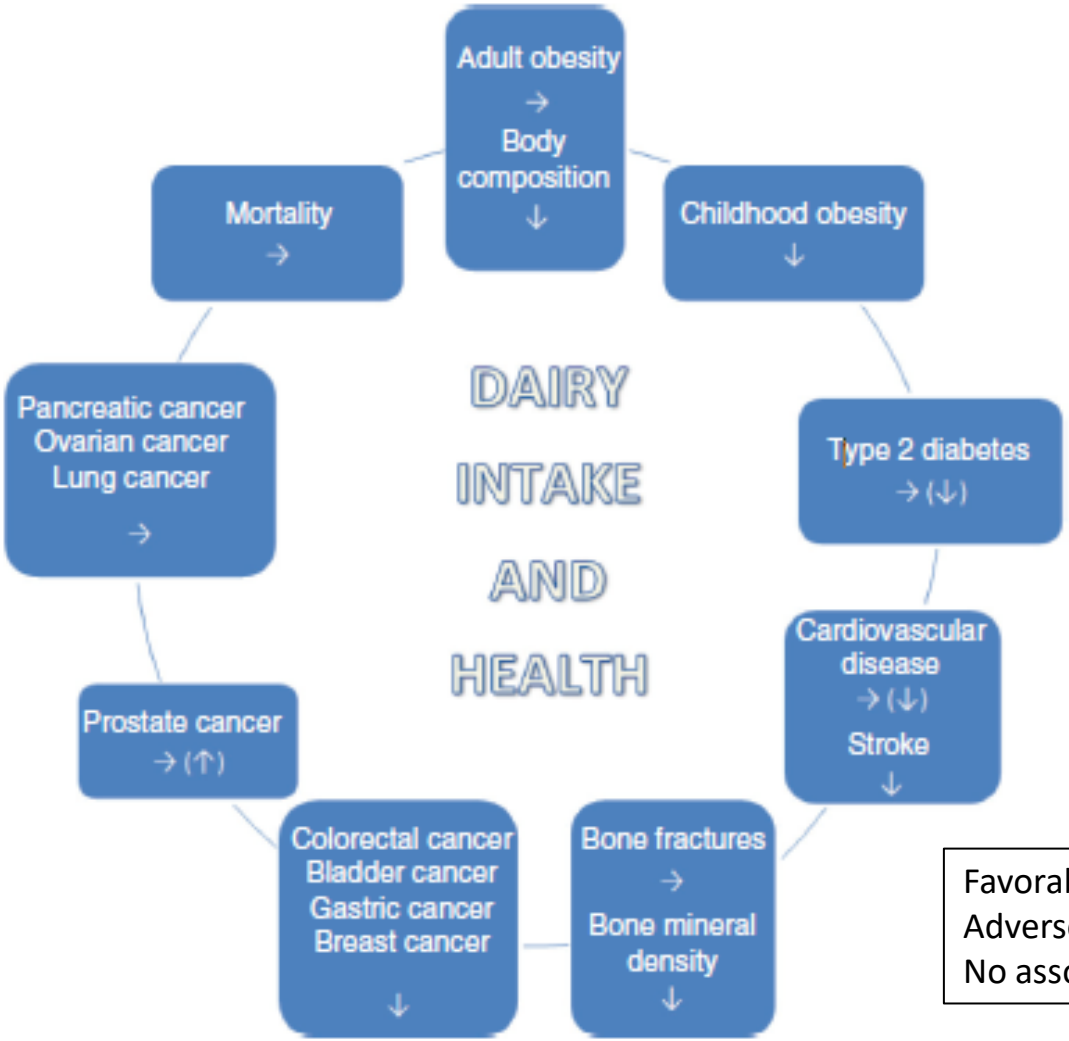
- Market and consumption of milk and plant-based drinks
- Nutritional composition of milk and plant-based drinks
- Kelp meal supplementation and milk iodine
- Final considerations

Workshop objectives

- Compare iodine content of milk vs. plant-based drinks relative to recommended dietary allowance (RDA)

- Compare the fatty acid profile of conventional, organic, and organic grass-fed milk

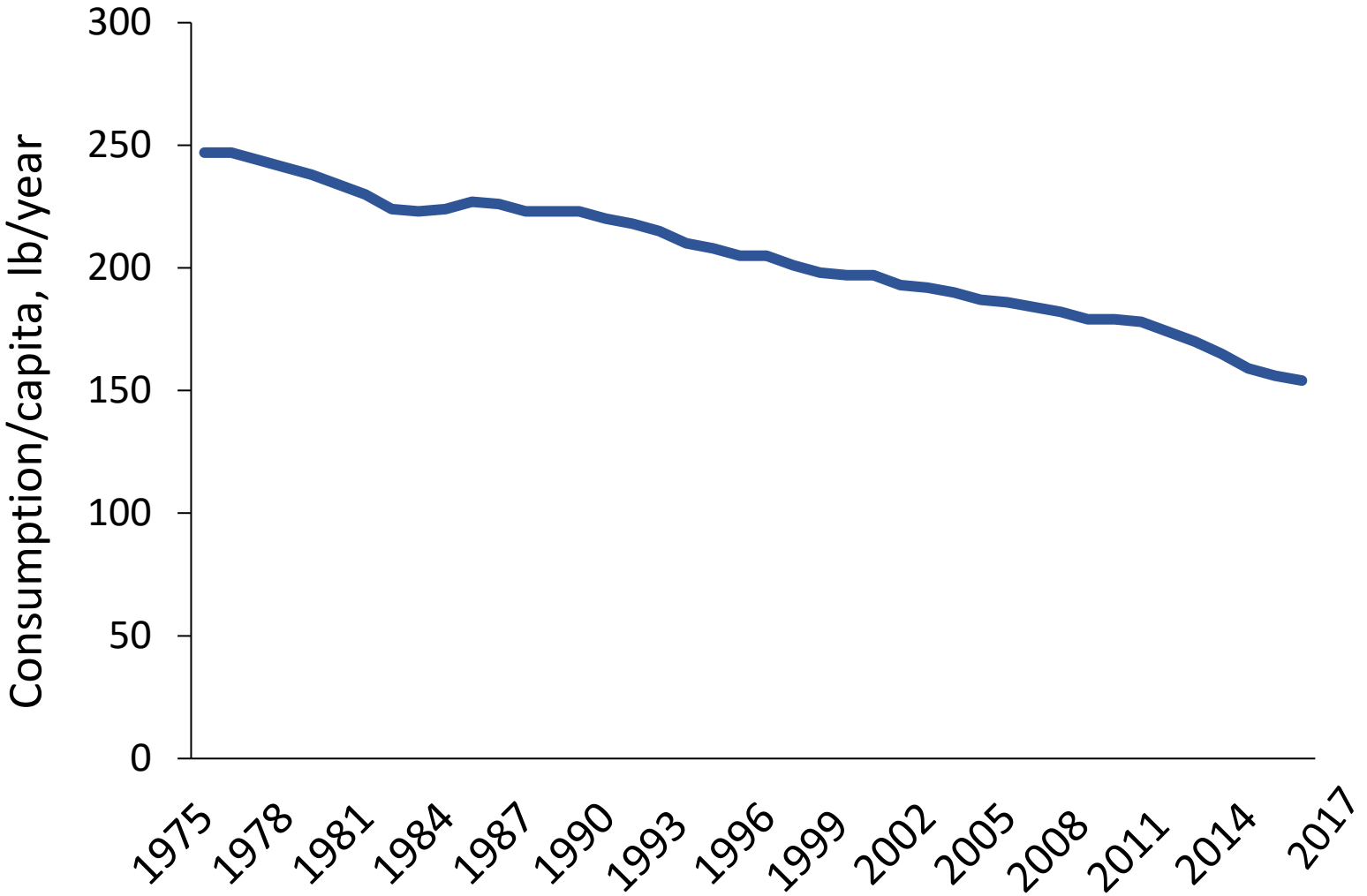
Association between dairy intake and health outcomes



Source: Thorning et al. 2016 (Food Nutr. Res. 60:32527)

How about consumption of milk and dairy products?

Consumption of fluid milk per capita in the US



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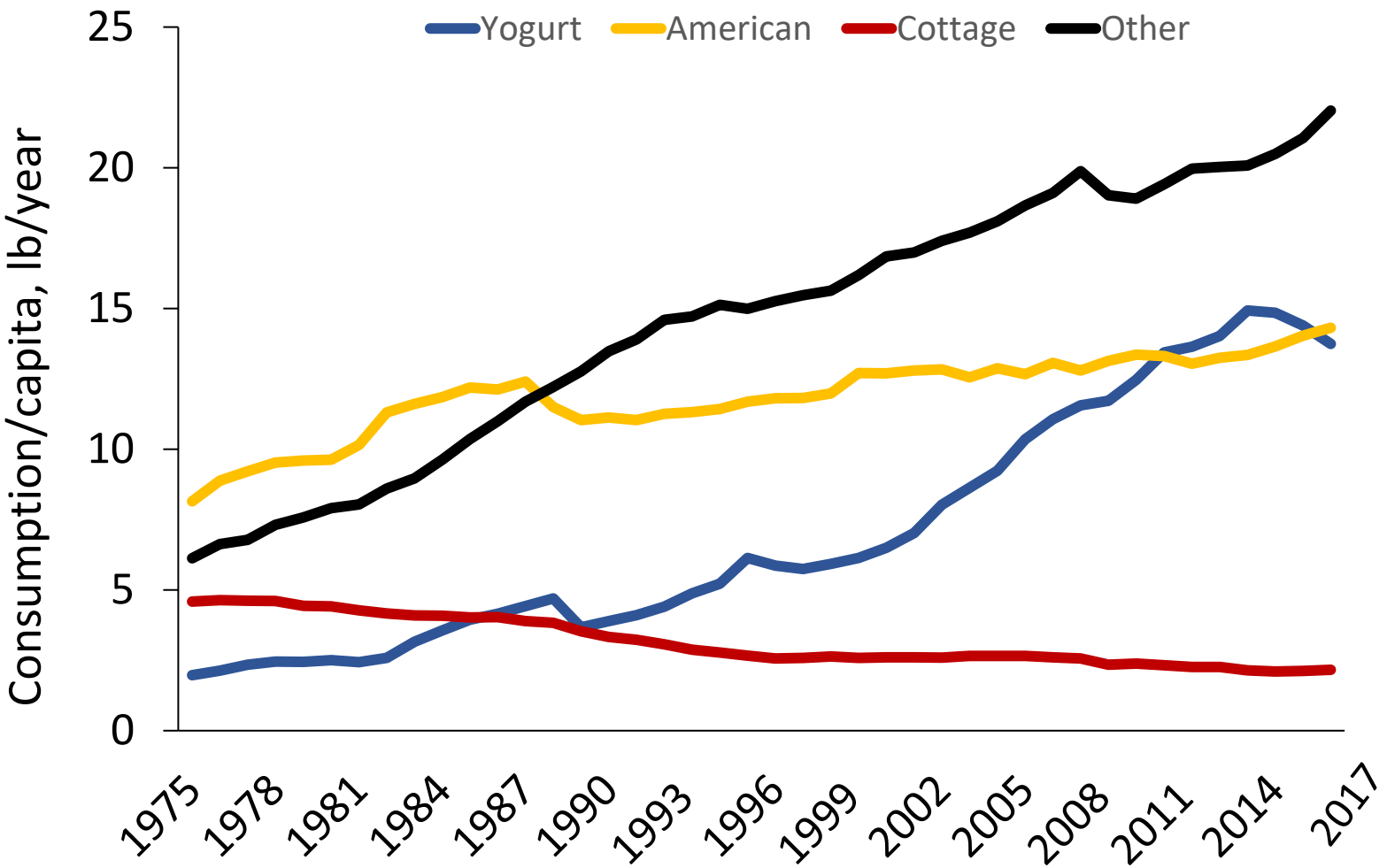
Source: USDA NASS-ERS

Dairy products consumption per capita in the US



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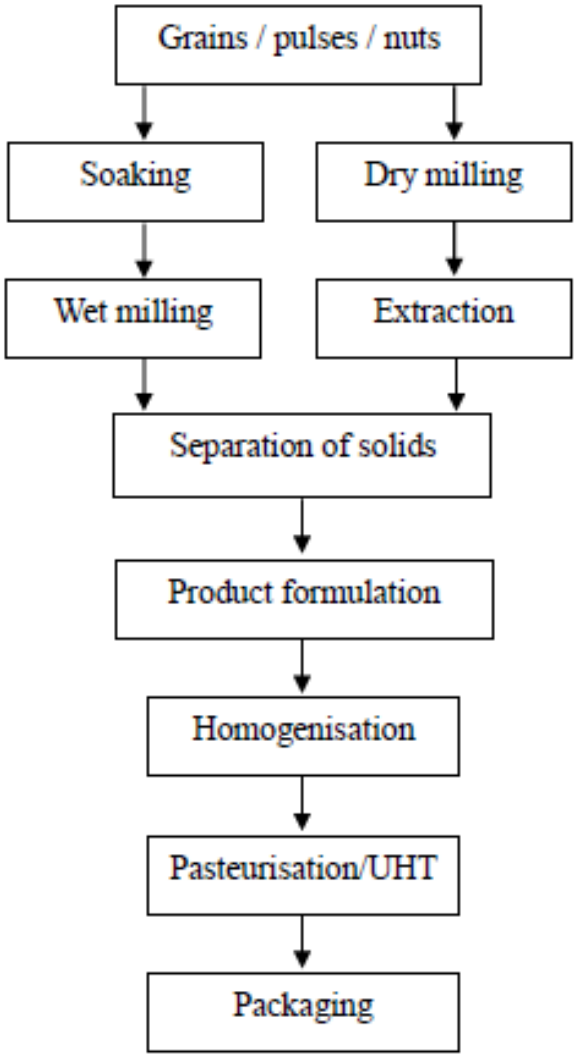
Source: USDA NASS-ERS

General outline of the manufacturing process of plant-based drinks

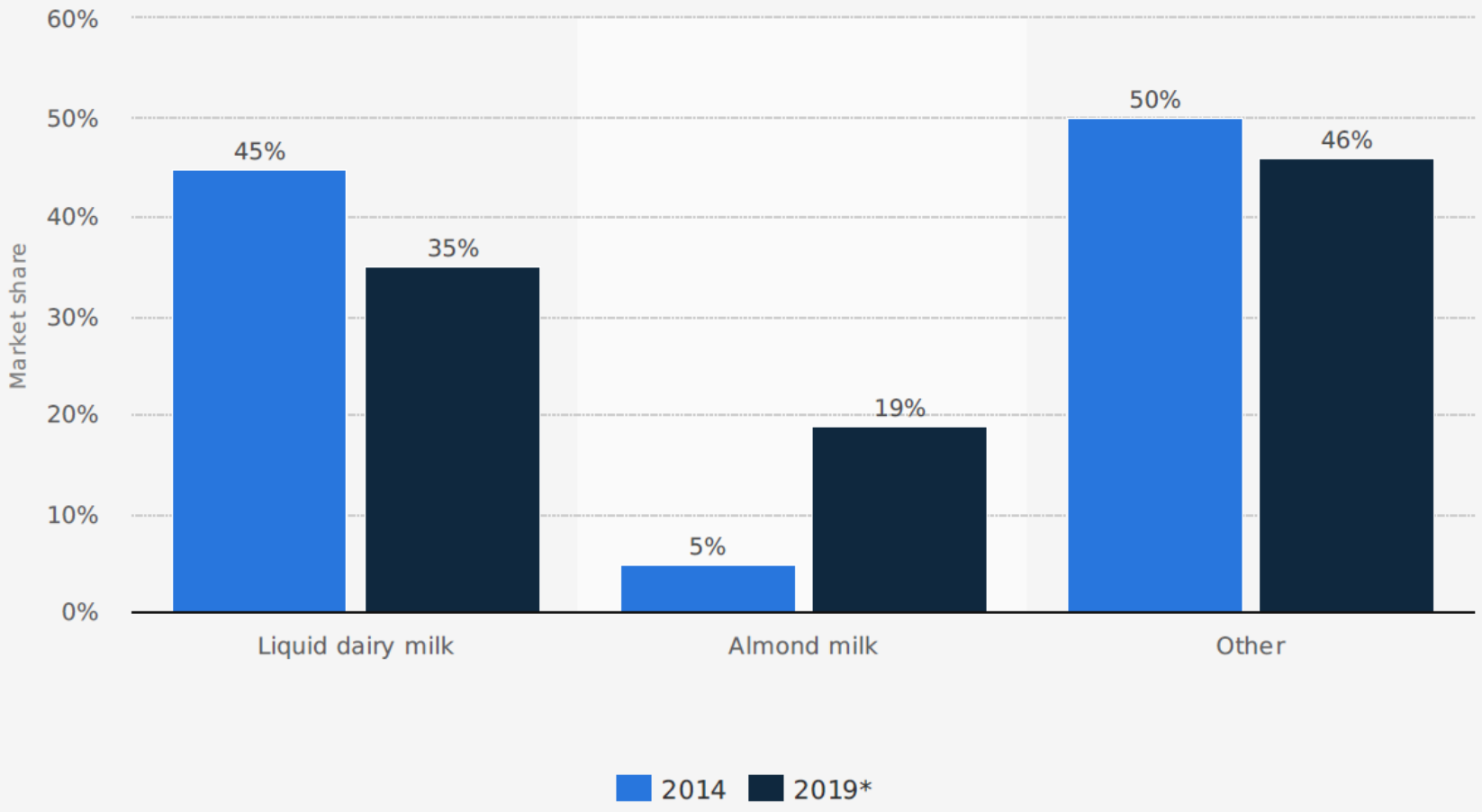


Source: Mäkinen et al. 2016 (Crit. Rev. Food. Sci. Nutr. 56:339-349)

Plant-based drinks market

- Global market reached ~$16.3 billion in 2018, up from $7.4 billion in 2010 (Innova Market Insights, 2017)
- Leading this market growth are companies dedicated to develop innovative processes and formulations featuring hemp, flax, pistachio, hazelnuts, almond among others (Innova Market Insights, 2017)
- China showed a compound annual growth rate of 19% between 2010 and 2018 compared with 10% in the US (Innova Market Insights, 2017)
- A key factor in this growth is continued consumer desire for lactose-free, dairy-free, plant-based, and vegan options (Innova Market Insights, 2017)

Market share of dairy and dairy alternative beverages in the United States in 2014 and 2019, by category

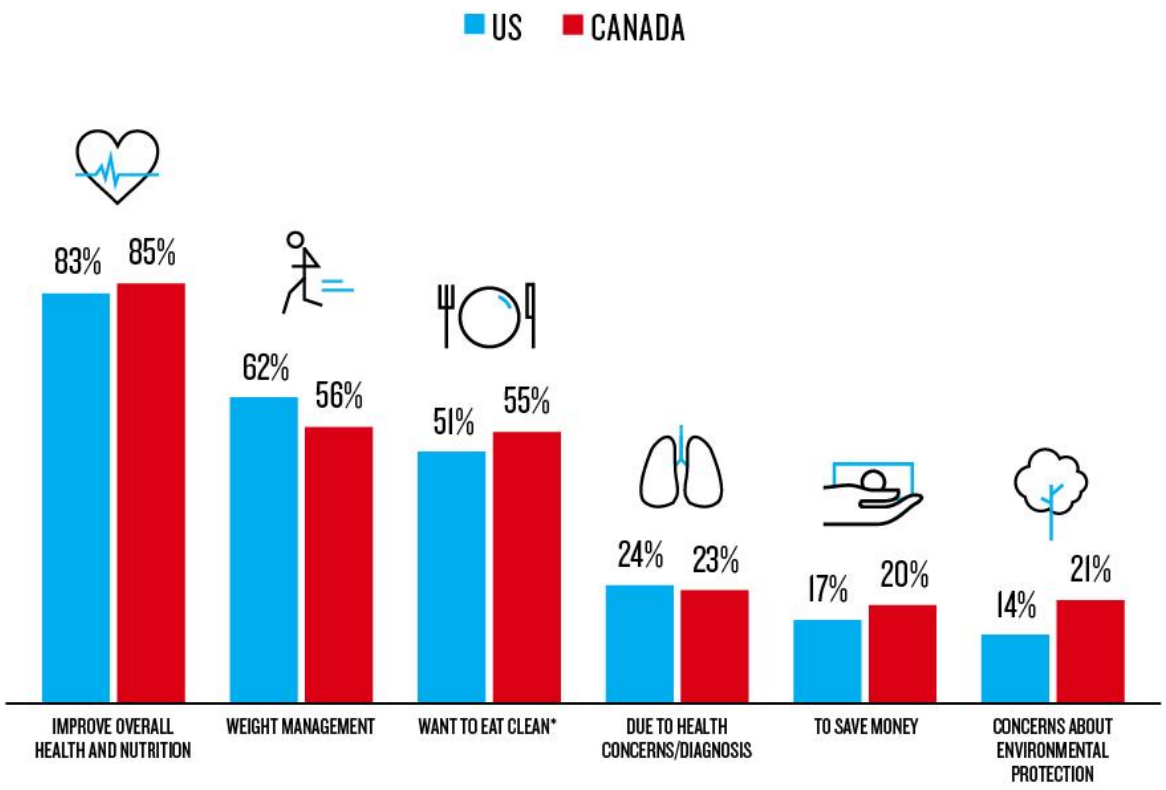


Source
Packaged Facts; Website (ticgums.com)

Additional Information:
United States; Packaged Facts; 2014

NUTRITION AND WEIGHT CONTROL ARE THE TOP REASONS TO INCLUDE MORE PLANTS

Top reasons from those wanting to incorporate more plant-based foods

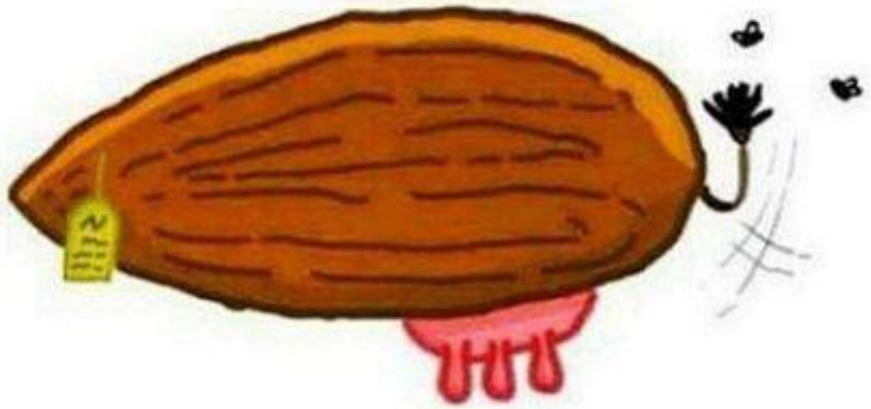


*Incorporate more foods that are unprocessed or minimally processed
Source: Nielsen, Homescan Panel Protein survey, April 2017 (U.S.)
Source: Nielsen Panelviews survey, March 2017 (Canada)

Incidence of lactose intolerance (LI) in different ethnic races

Ethnicity/ Geographic region	% population with LI
East Asian	90–100
Indigenous (North America)	80–100
Central Asian	80
African American (North America)	75
African (Africa)	70–90
Indian (Southern India)	70
French (Southern France)	65
Ashkenazi Jew (North America)	60–80
Balkans Region	55
Latino/Hispanic (North America)	51
Indian (Northern India)	30
Anglo (North America)	21
Italian (Italy)	20–70
French (Northern France)	17
Finnish (Finland)	17
Austrian (Austria)	15–20
German (Germany)	15
British (U.K.)	5–15

Source: Kumar et al. 2015 (J. Food Sci. Technol. 52:6112-6124)



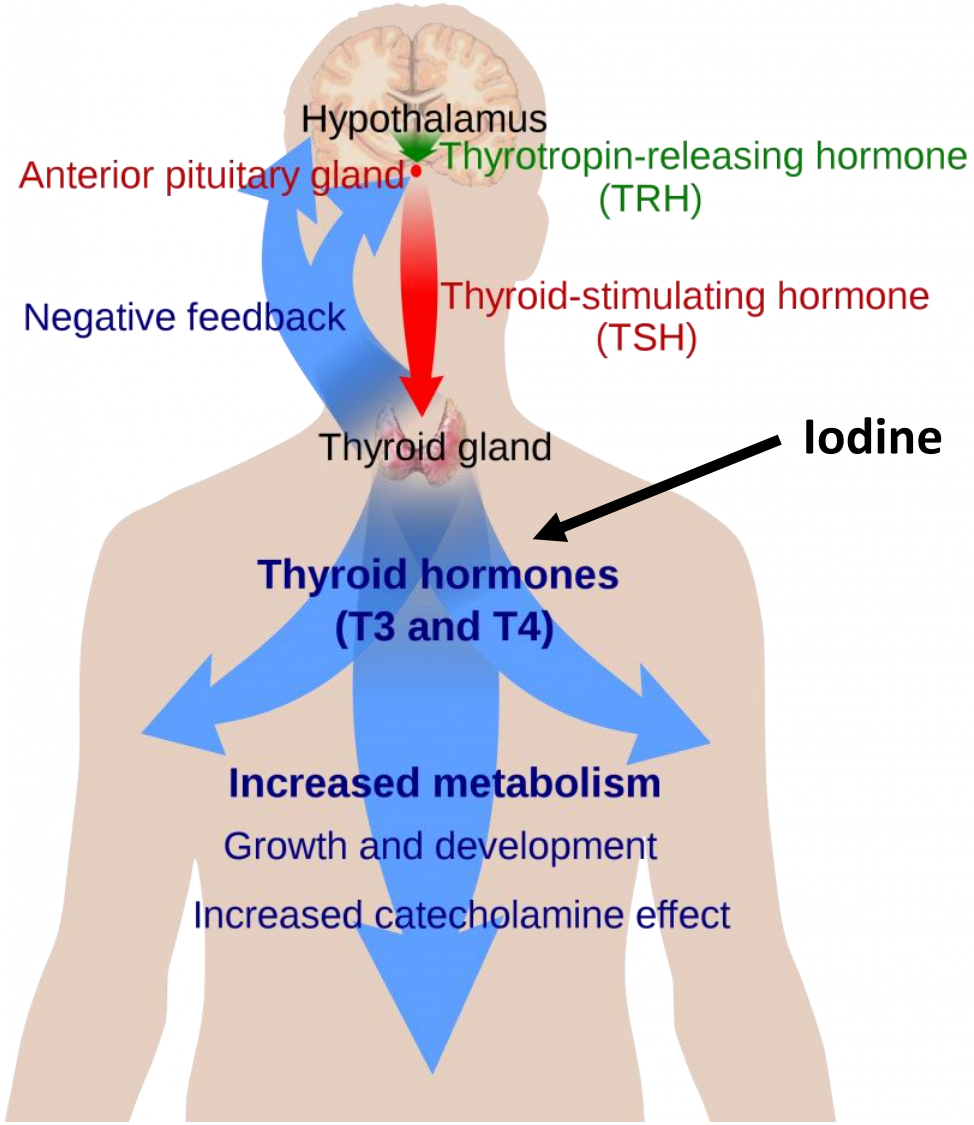
The most difficult part of being vegan is waking up at 5am to milk the almonds...

Workshop objectives

- Compare iodine content of milk vs. plant-based drinks relative to recommended dietary allowance (RDA)

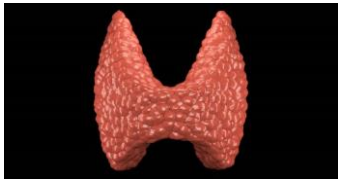
- Compare the fatty acid profile of conventional, organic, and organic grass-fed milk

Thyroid system



Thyroid hormone functions

- Regulation of metabolic processes essential for normal growth and development (Oetting and Yen, 2007; Cheng et al., 2010; Brent, 2012)
- Regulation of metabolism in adults (Oetting and Yen, 2007; Cheng et al., 2010; Brent, 2012)
- Stimulation of lipogenesis and lipolysis (Oppenheimer et al., 1991)
- Influence key metabolic pathways that control energy balance by regulating energy storage and expenditure (Oetting and Yen, 2007; Liu and Brent, 2010; Iwen et al., 2013)



Recommendations for iodine intake (µg/d) by age or population group

US Institute of Medicine[1]		World Health Organization[2]	
Age or population group	RDA[3]	Age or population group	RNI[4]
Infants (0-12 months)	110-130	Children (0-5 yr)	90
Children (1-8 yr)	90	Children (5-10 yr)	120
Children (9-13 yr)	120		
Adults (≥ 14 yr)	150	Adults (> 12 yr)	150
Pregnancy	220	Pregnancy	250
Lactation	290	Lactation	250

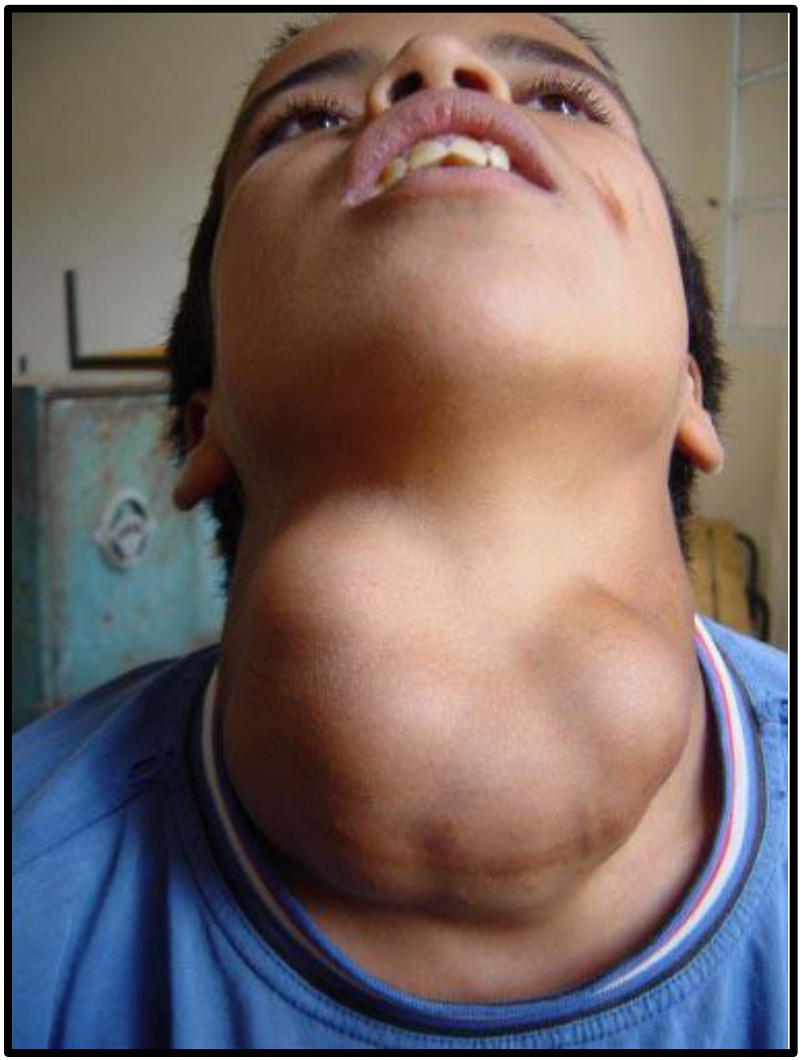
[1]US Institute of Medicine, Academy of Sciences (2001)
[2]World Health Organization (2007)
[3]RDA = recommended dietary allowance
[4]RNI = recommended nutrient intake

Spectrum of iodine deficiency disorders

PHYSIOLOGICAL GROUPS	HEALTH CONSEQUENCES OF IODINE DEFICIENCY
All ages	Goitre Hypothyroidism Increased susceptibility to nuclear radiation
Fetus	Spontaneous abortion Stillbirth Congenital anomalies Perinatal mortality
Neonate	Endemic cretinism including mental deficiency with a mixture of mutism, spastic diplegia, squint, hypothyroidism and short stature Infant mortality
Child and adolescent	Impaired mental function Delayed physical development Iodine-induced hyperthyroidism (IIH)
Adults	Impaired mental function Iodine-induced hyperthyroidism (IIH)

Source: Hetzel 1983 (Lancet 2:1126–1129)

Large nodular goiter in a 14-year old boy



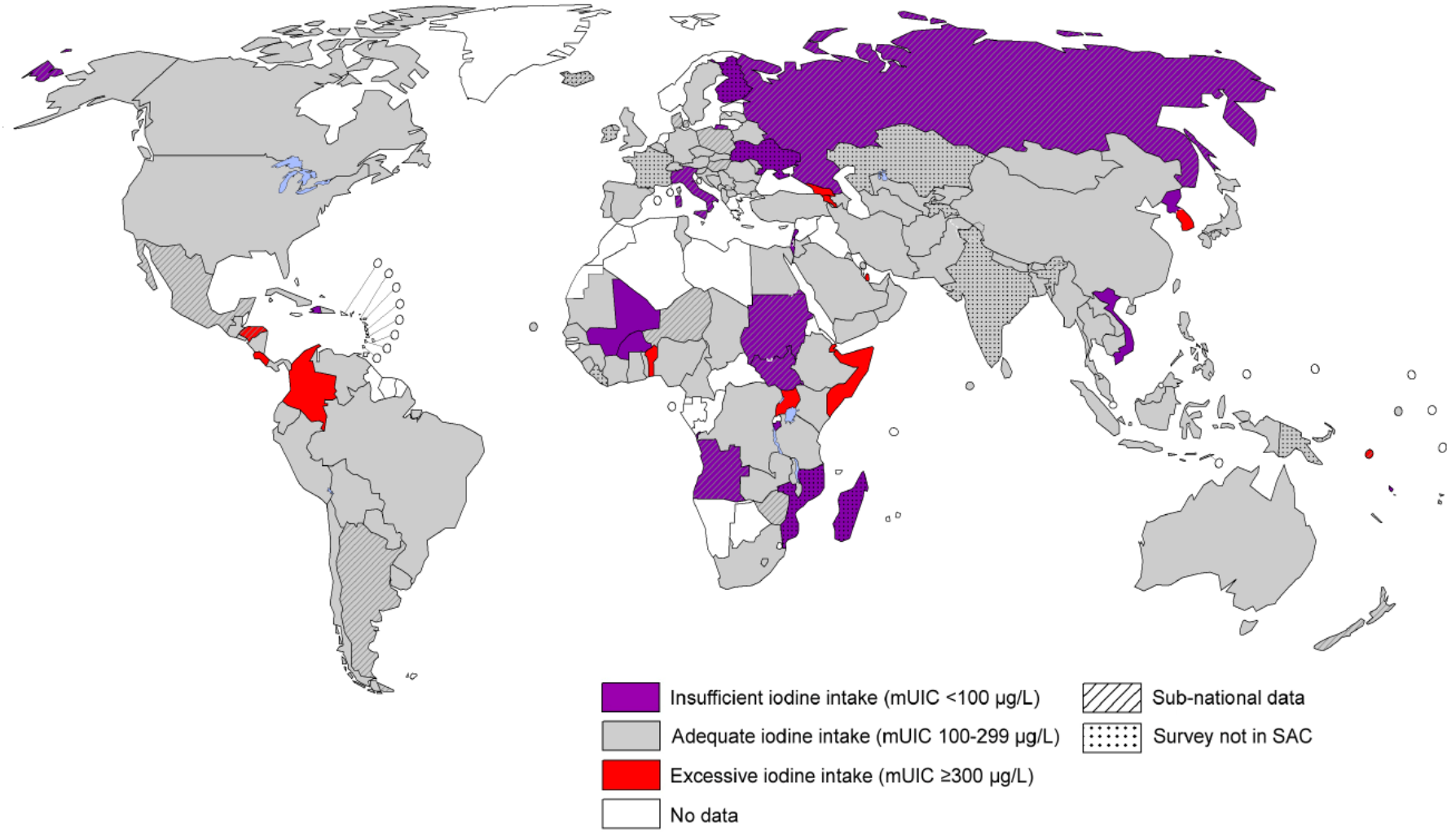
Source: Zimmermann 2009 (Endoc. Rev. 30:376–408)

Neurological cretinism (A) and myxedematous cretinism (B)

Source: Zimmermann, 2009 (Endoc. Rev. 30:376–408)

Global Scorecard of Iodine Nutrition 2017

Based on median urinary iodine concentration (mUIC) in school-age children (SAC) and adults



Source: The Iodine Global Network (2017)

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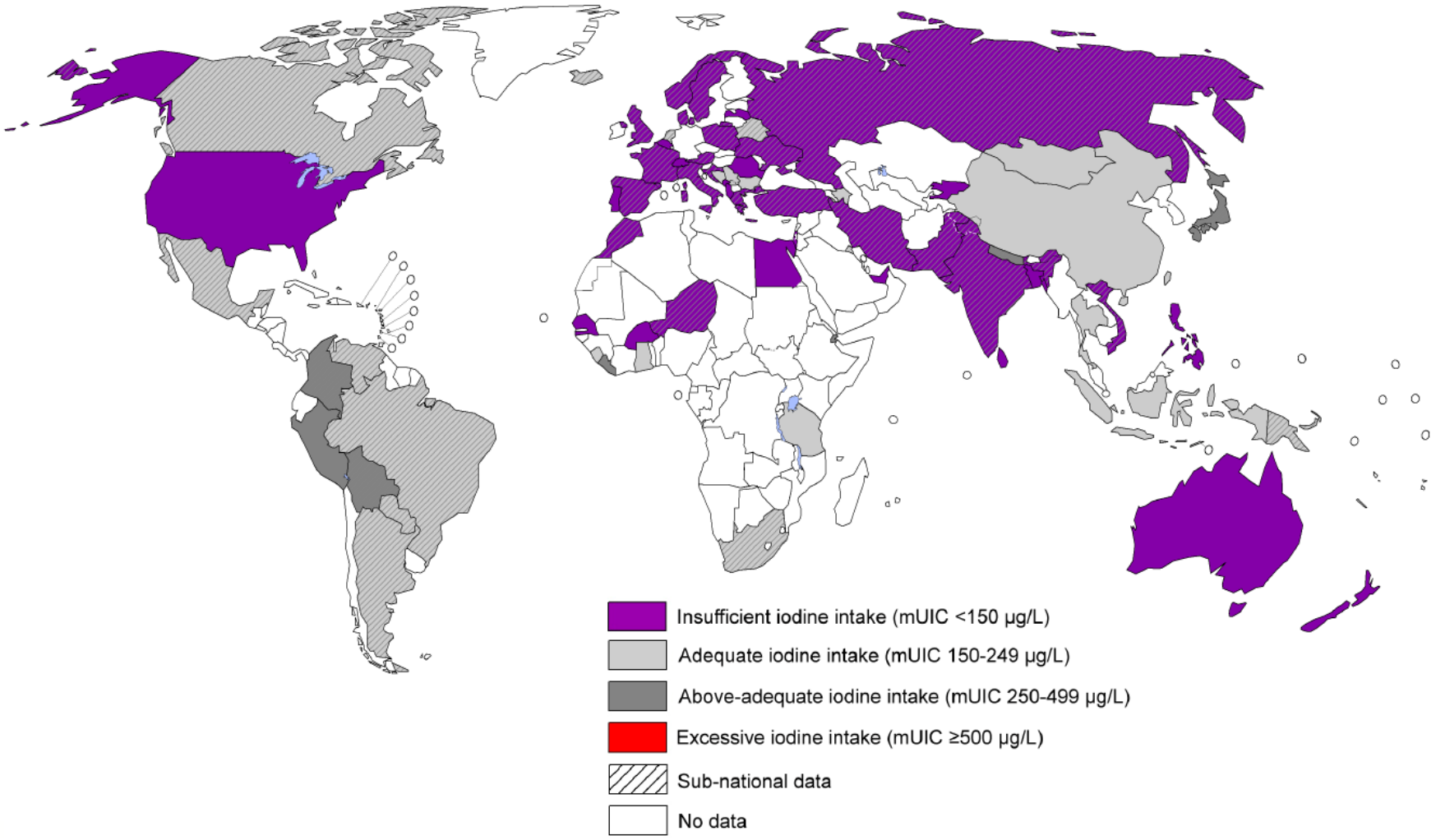
Global Scorecard of Iodine Nutrition 2017

Based on median urinary iodine concentration (mUIC) in pregnant women



Source: The Iodine Global Network (2017)

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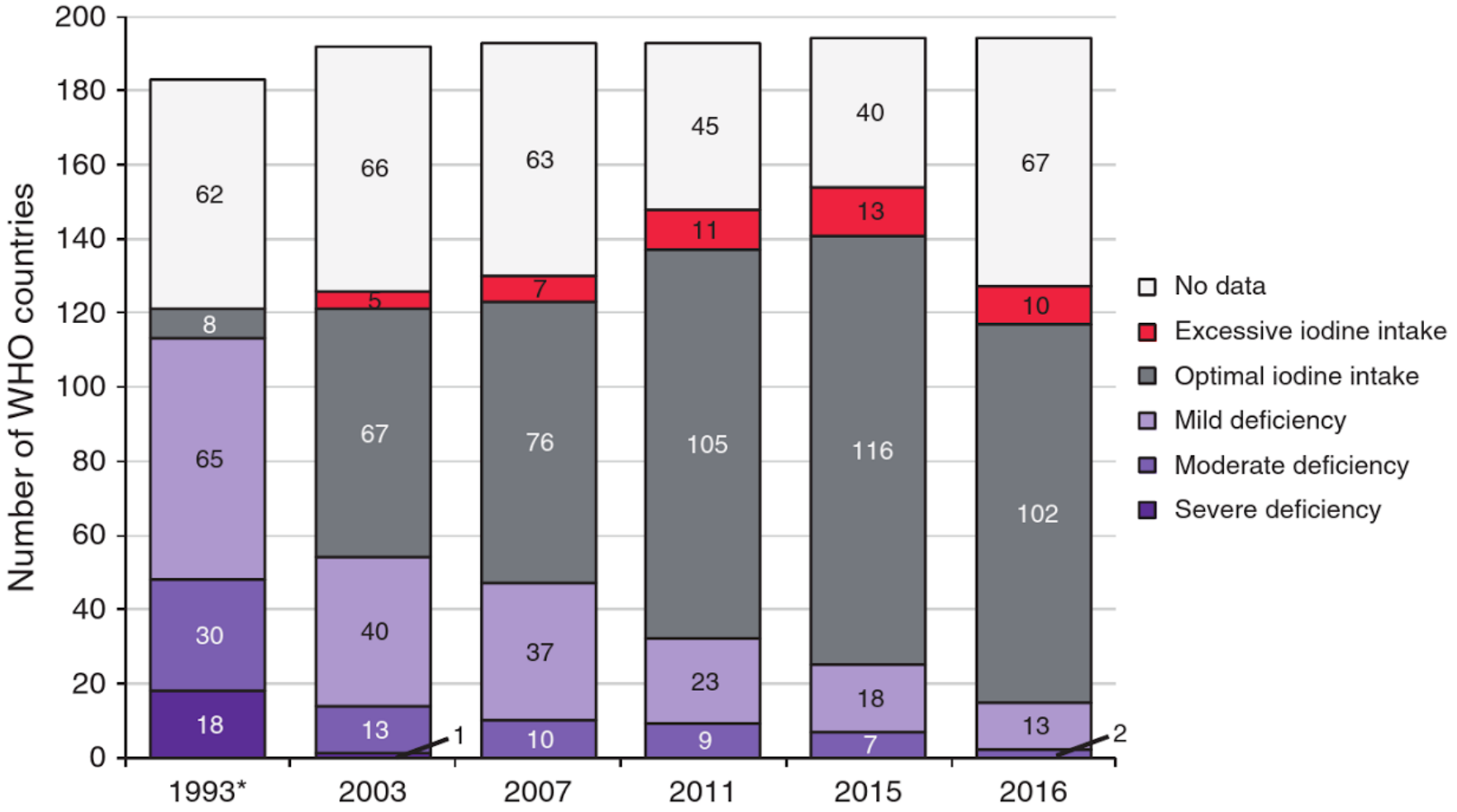
Estimated iodine intake over time



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Source: The Iodine Global Network (2017)
WHO = World Health Organization

British Journal of Nutrition (2017), **118**, 525–532
doi:10.1017/S0007114517002136

Iodine concentration of milk-alternative drinks available in the UK in comparison with cows' milk

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[2]*LGC Limited, Queens Road, Teddington, Middlesex TW11 0LY, UK*

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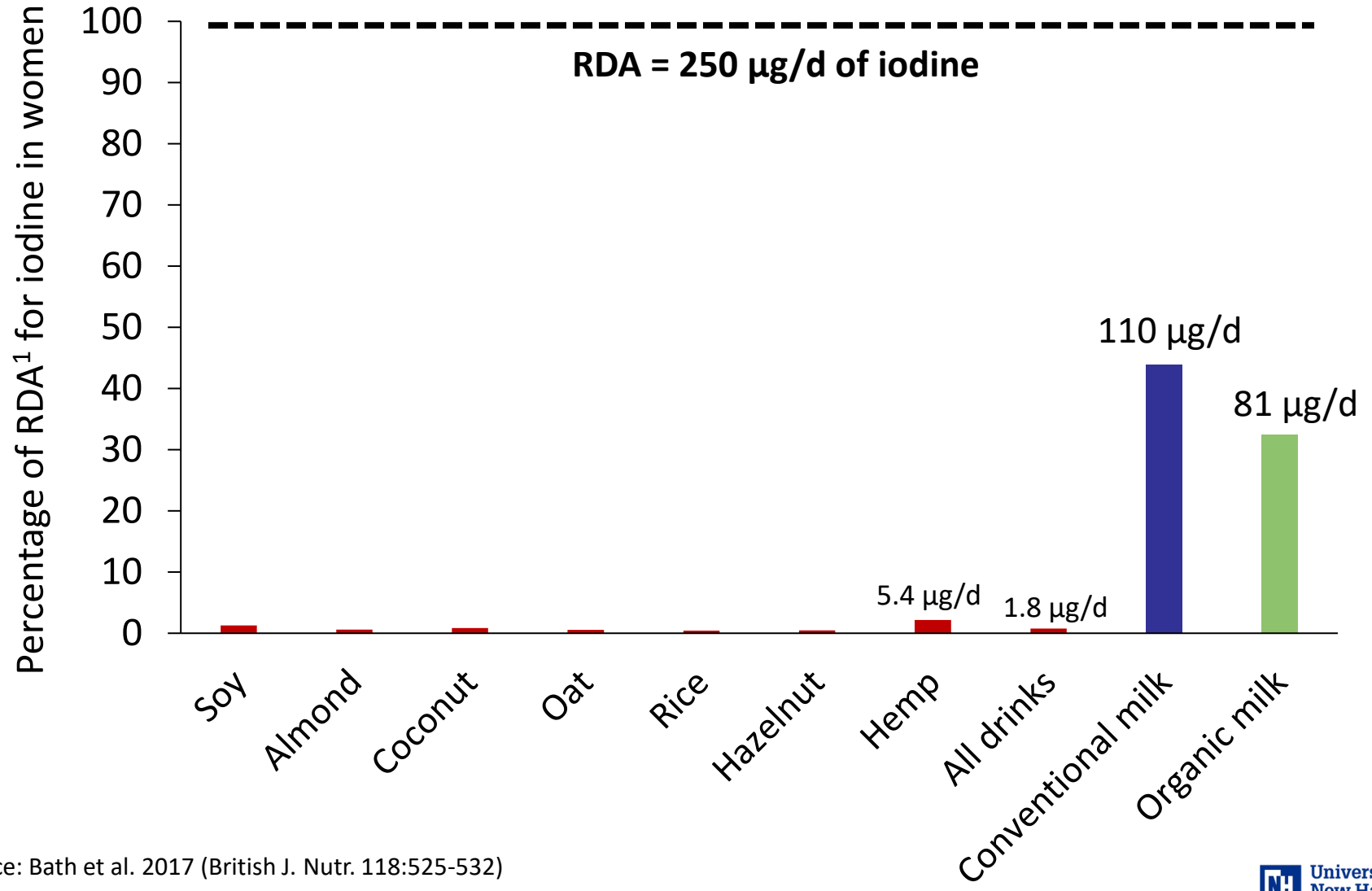
Bath et al. (2017) study methods

- The initial survey included 20 grocery stores and 28 brands of plant-based drinks were identified
- Iodine concentration of 7 types of plant-based drinks (i.e., soy, almond, coconut, oat, rice, hazelnut, and hemp) was determined chromatographically in 47 products
- For comparison, winter samples of conventional (n = 5) and organic (n = 5) cows' milk were included

Iodine intake per serving of milk and plant-based drinks relative to RDA for pregnant and nursing women



Source: Bath et al. 2017 (British J. Nutr. 118:525-532)

[1]RDA = recommended dietary allowance based on the World Health Organization (2007)

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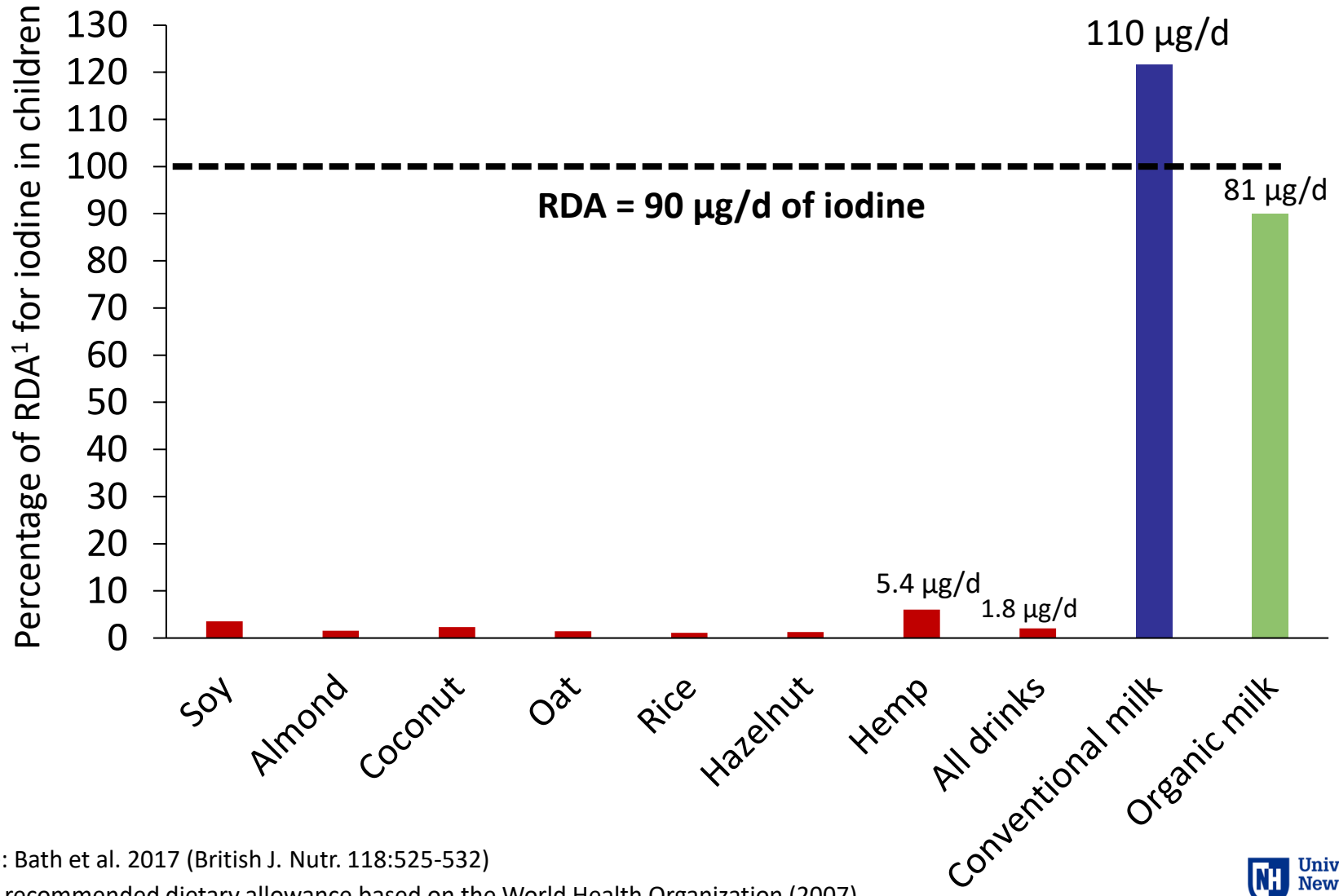
Iodine intake per serving of milk and plant-based drinks relative to RDA for children (0-5 yr)



Source: Bath et al. 2017 (British J. Nutr. 118:525-532)

[1]RDA = recommended dietary allowance based on the World Health Organization (2007)

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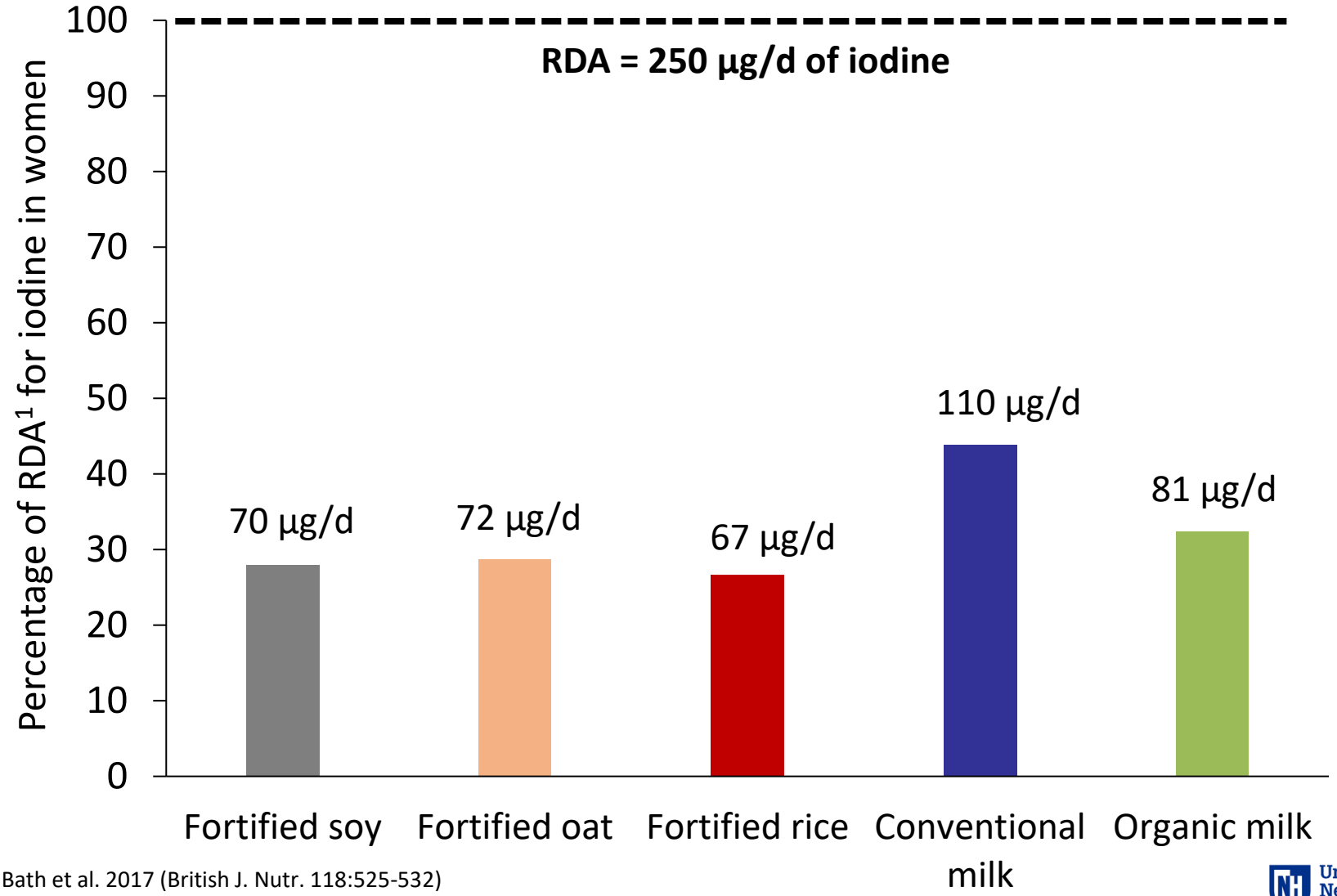
Iodine intake per serving of milk and iodine-fortified plant-based drinks relative to RDA for pregnant and nursing women



Source: Bath et al. 2017 (British J. Nutr. 118:525-532)

[1]RDA = recommended dietary allowance based on the World Health Organization (2007)

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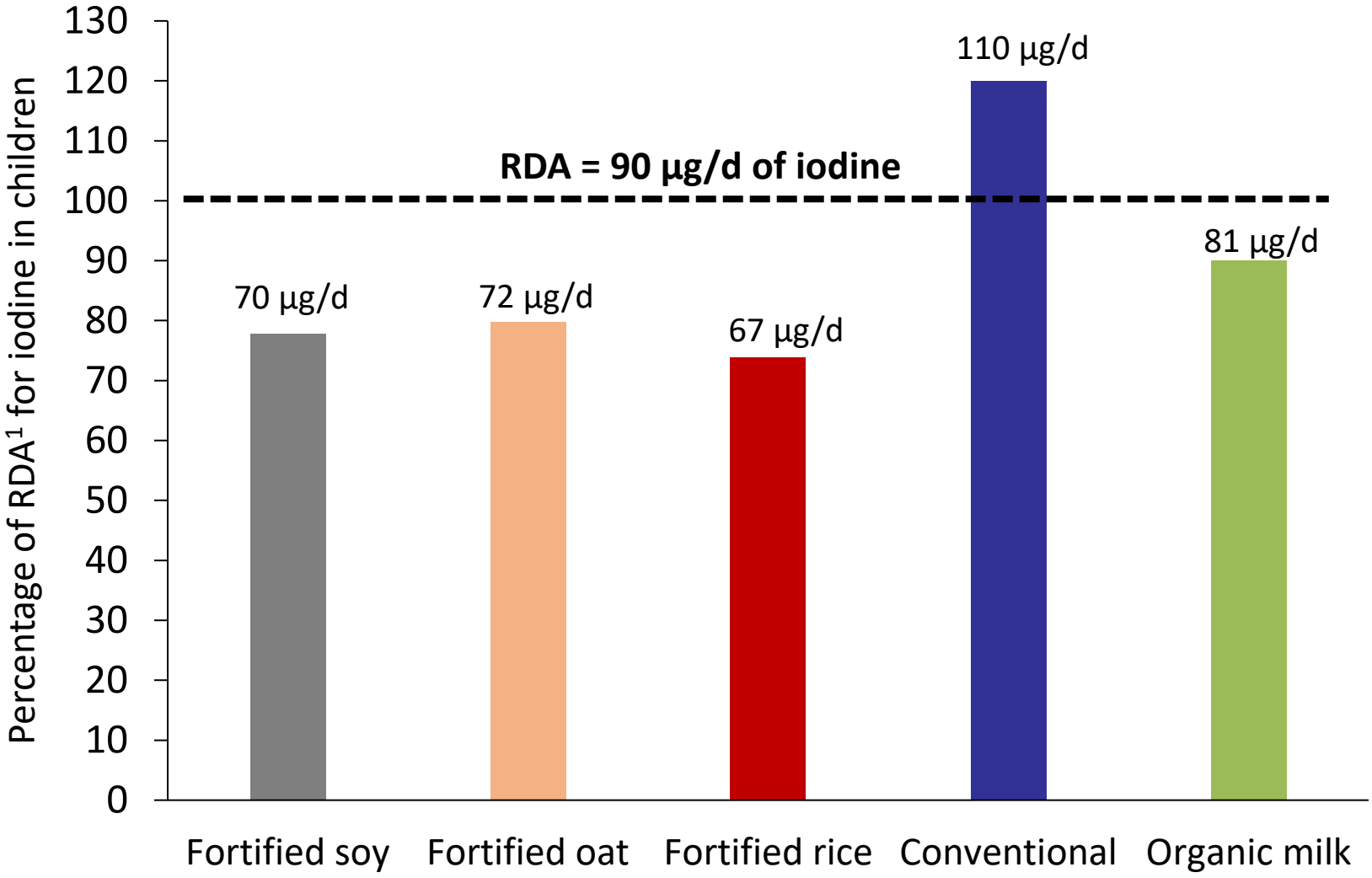
Iodine intake per serving of milk and iodine-fortified plant-based drinks relative to RDA for children (0-5 yr)[1]



Source: Bath et al. 2017 (British J. Nutr. 118:525-532)

[1]RDA = recommended dietary allowance based on the World Health Organization (2007)

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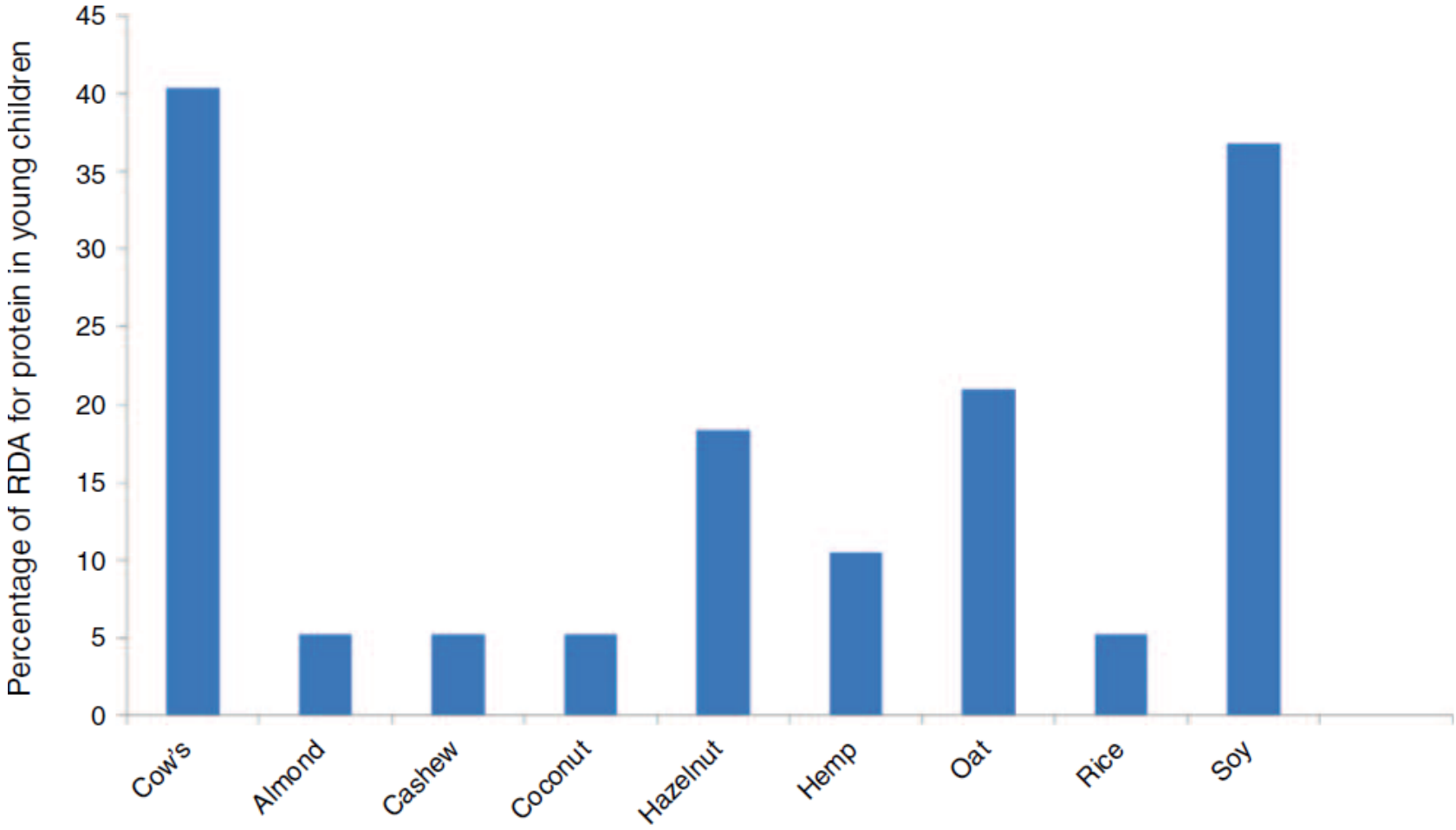
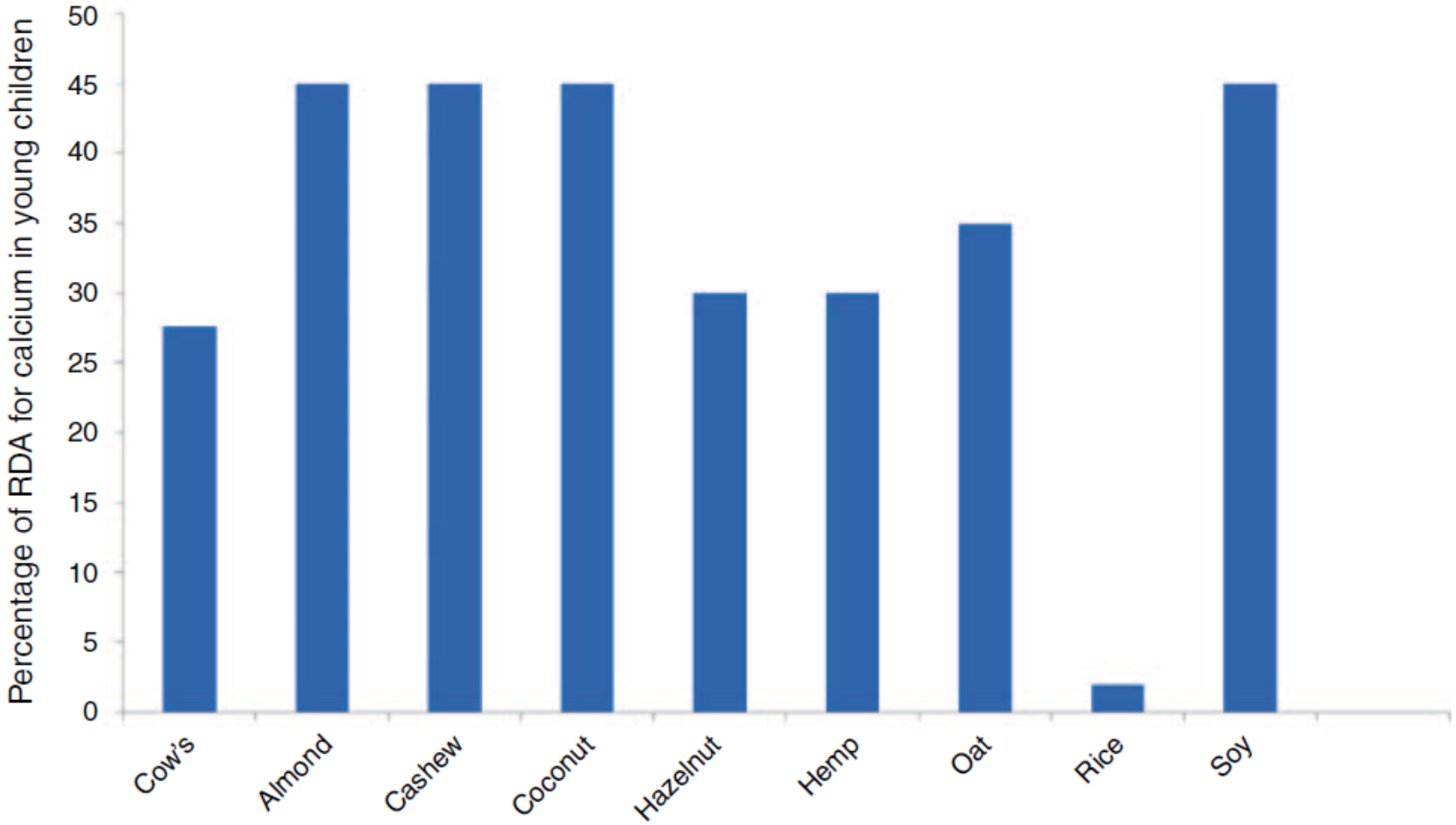
Protein content per serving of milk and plant-based drinks compared with RDA for young children



Source: Singhal et al. 2017 (JPGN 64:799–805)
RDA = recommended dietary allowance

Calcium content per serving of milk and fortified plant-based drinks compared with RDA for young children



Source: Singhal et al. 2017 (JPGN 64:799–805)
RDA = recommended dietary allowance

Nutritional composition of soymilk vs. cow's milk (content/serving)

	Fat (gr)	Fatty acid (gr)	Fiber (gr)	Protein (gr)	Carbohydrate (gr)	Lactose (gr)	Ca (mgr)	Fe (mgr)	P (mgr)	Calories (Kcal)
Soymilk	4.67	0.52	3.18	6.73	4.43	0	9.8	1.4	120.05	79
Cow milk	8.15	5.07	0	8.02	11.37	4.27	290.36	0.12	226.92	150

Source: Hajirostamloo, 2009 (Int. J. Nutr. Food Eng. 3:455–457)

Kelp meal supplementation

Kelp meal nutritional properties

- Brown seaweed (*Ascophyllum nodosum*) rich in minerals, particularly iodine (Antaya et al., 2015)
- Contains a wide spectrum of nutritional compounds including polyunsaturated fatty acids (PUFA), polyphenols, bioactive peptides, and vitamins (Kumari et al., 2010; Tierney et al., 2010; Fitzgerald et al., 2011)
- Rich in phlorotannin, a polyphenol similar to terrestrial tannins known to affect carbohydrate and protein utilization, and to inhibit bacterial growth (Ragan and Glombitza,1986; Wang et al., 2008, 2009)
- High concentrations of antioxidants such as β-carotene and fucoxanthine, which may improve animal health (Haugan and Liaaen-Jensen, 1994; Allen et al., 2001)

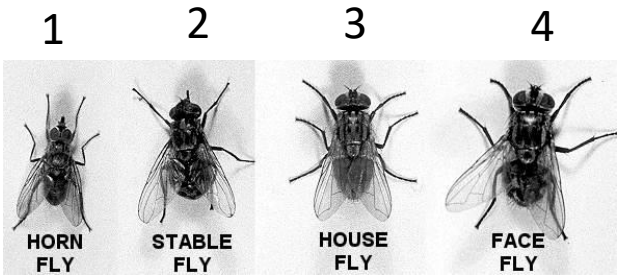
Use of kelp meal in organic dairy farms in the Northeast and Midwest US

- 59% of organic dairy farmers feed kelp meal in the Northeast (Antaya et al., 2015)
- 49% of organic dairy farmers feed kelp meal in Wisconsin (Hardie et al., 2014)
- 83% of organic dairy farmers feed kelp meal in Minnesota (Sorge et al., 2016)

Why organic dairy farmers feed kelp meal in the Northeast?

- It improves body condition score and overall animal appearance
- It decreases milk somatic cell count, reproductive problems, and incidence of “pinkeye” (i.e., infectious bovine keratoconjunctivitis)
- It helps with control of nuisance flies during the grazing season

Source: Antaya et al. 2015 (J. Dairy Sci. 98:1991–2004)



1. *Haematobia irritans* L.,
2. *Stomoxys calcitrans* L.
3. *Musca domestica*
4. *Musca autumnalis*, De Geer

Source: Denning et al. 2014 (J. Dairy Sci. 97 :4624–4631)

Pasture vs. kelp meal nutritonal composition

Item	Feeds	
	Pasture	Kelp meal
	-----% of dry matter (unless otherwise noted)-----	
Crude protein	19.5	10.2
Neutral detergent fiber	51.0	53.9
Acid detergent fiber	31.4	39.9
Ca	0.76	1.31
P	0.36	0.25
Mg	0.28	0.69
K	2.68	3.53
S	0.28	2.84
I, ppm	0.62	820

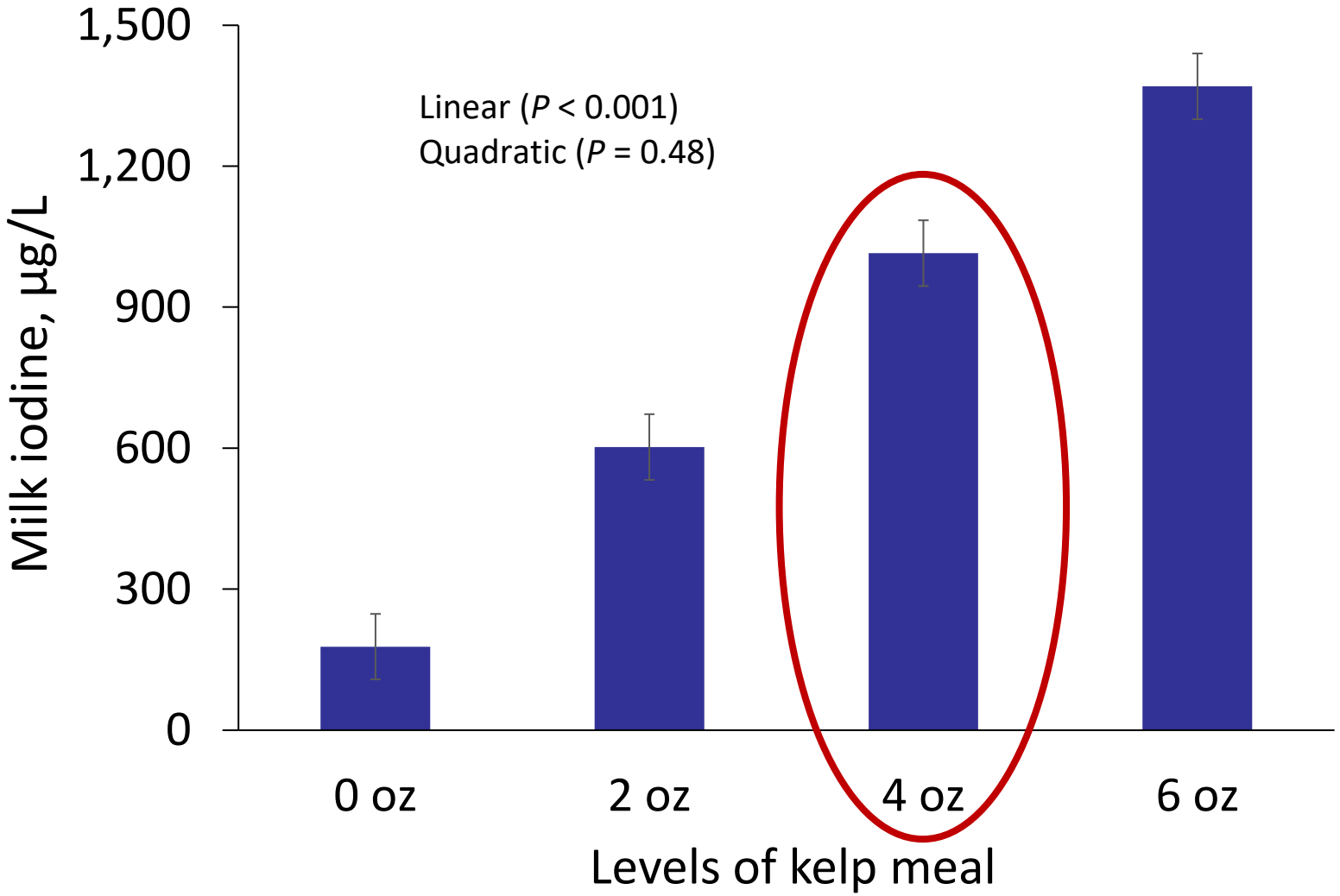
Sources: Antaya et al. 2015; Hafla et al. (2016); Brito et al. (unpublished)

Nutritional comparison of different kelp meal products

Item	Kelp meal products				
	Thorvin 1	Thorvin 2	TASCO 1	TASCO 2	Sealife
	--------% of dry matter (unless otherwise note)--------				
Ca	1.31	1.28	1.12	1.19	1.13
P	0.25	0.21	0.16	0.16	0.15
Mg	0.69	0.80	0.89	0.84	0.79
K	3.53	2.57	2.51	2.37	1.76
S	2.84	2.71	3.37	3.30	3.27
Na	3.90	3.59	3.42	3.39	3.14
Cl	4.70	4.73	3.18	3.30	2.95
Se	<0.041	-	-	0.025	-
I, ppm	820	727	356	775	-

Sources: Antaya et al. 2015; Brito et al. (unpublished)

Milk iodine increased linearly in organic dairy cows fed kelp meal during the winter season



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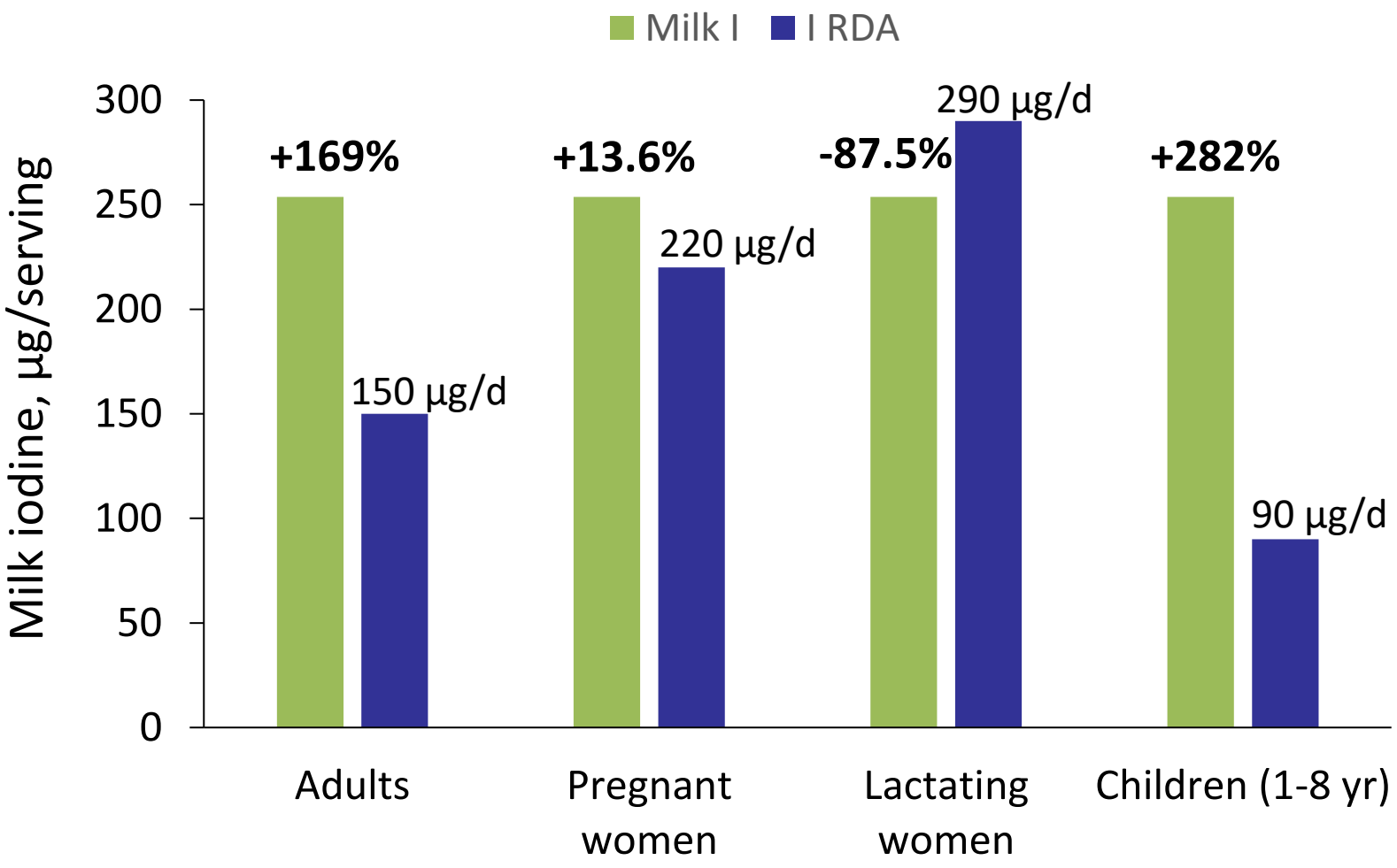
Source: Antaya et al. 2015 (J. Dairy Sci. 98:1991-2004)

Iodine intake per serving of milk from cows fed 4 oz of kelp meal relative to iodine RDA[1]



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[1]Based on the US Institute of Medicine (2001) recommendations
RDA = recommended dietary allowance

Tollerable upper limits for iodine intake

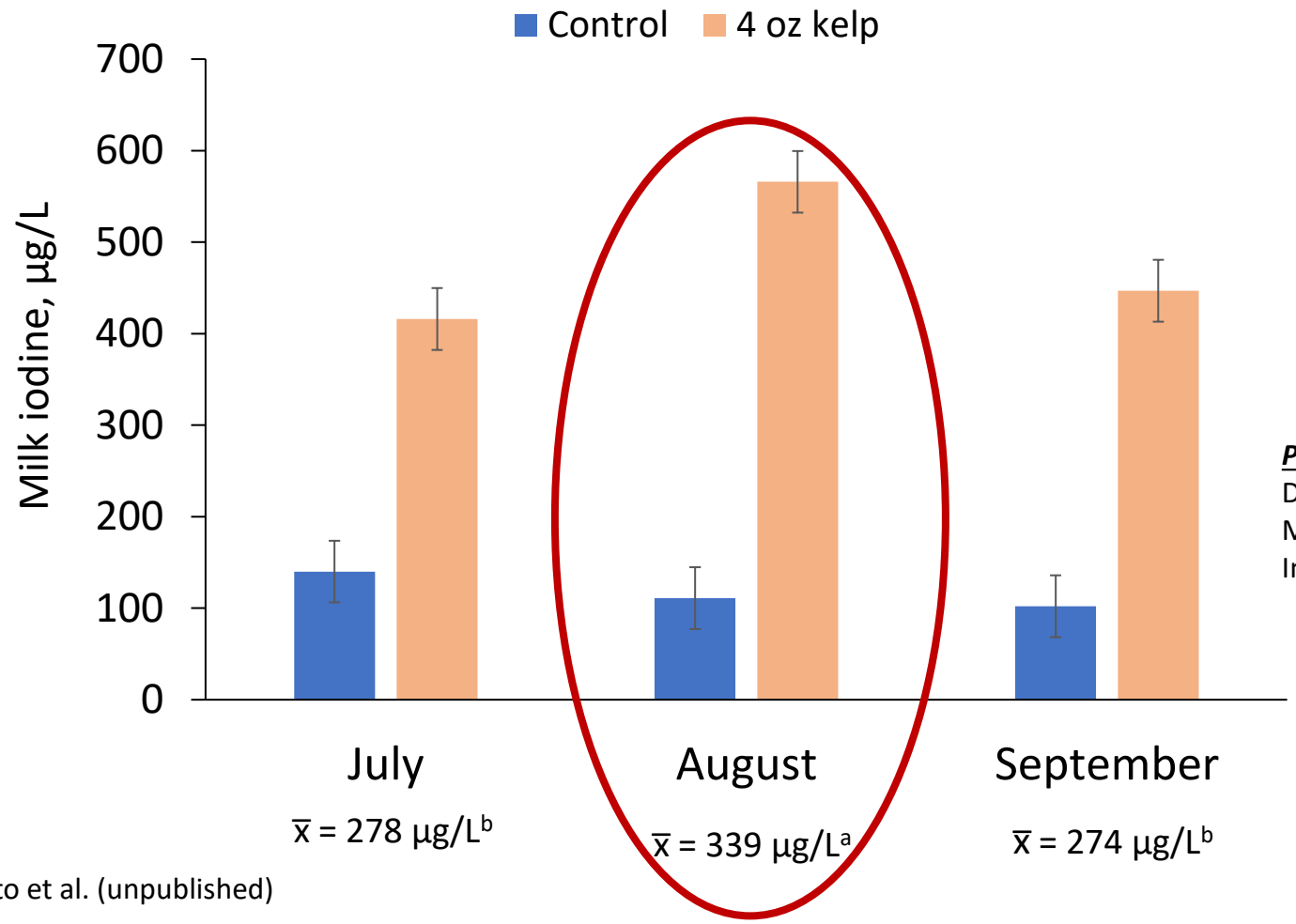
US Institute of Medicine[1]		World Health Organization[2]	
Age or population group	µg/d	Age or population group	µg/d
0-12 months	Unknown	Infants	180
1-3 years	200	Pregnancy	500
4-8 years	300	Lactation	500
9-13 years	600		
14-18 years	900		
19-50 years	1,100		

[1]US Institute of Medicine, Academy of Sciences (2001)
[2]World Health Organization (2007)

Excess iodine intake and human health

- Hyperthyroidism (Sun et al., 2014; Katagiri et al., 2017)
- Hypothyroidism (Sun et al., 2014; Katagiri et al., 2017)
- Thyroid nodules (Katagiri et al., 2017)
- Autoimmune thyroiditis (Sun et al., 2014)
- Goiter (Katagiri et al., 2017)

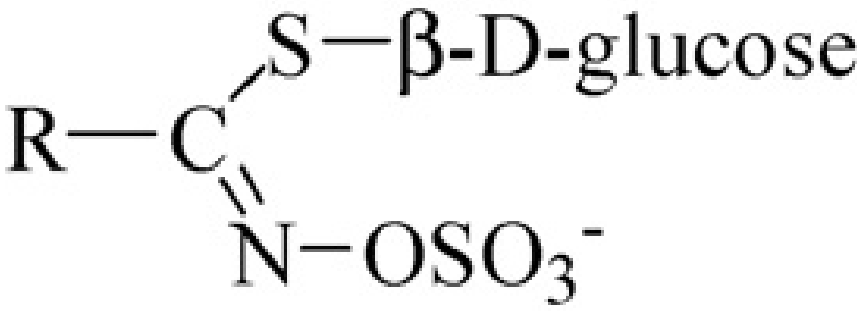
Milk iodine concentration in grazing cows fed kelp meal



***P*-values**
Diet ($P < 0.001$)
Month ($P < 0.01$)
Interaction ($P < 0.01$)

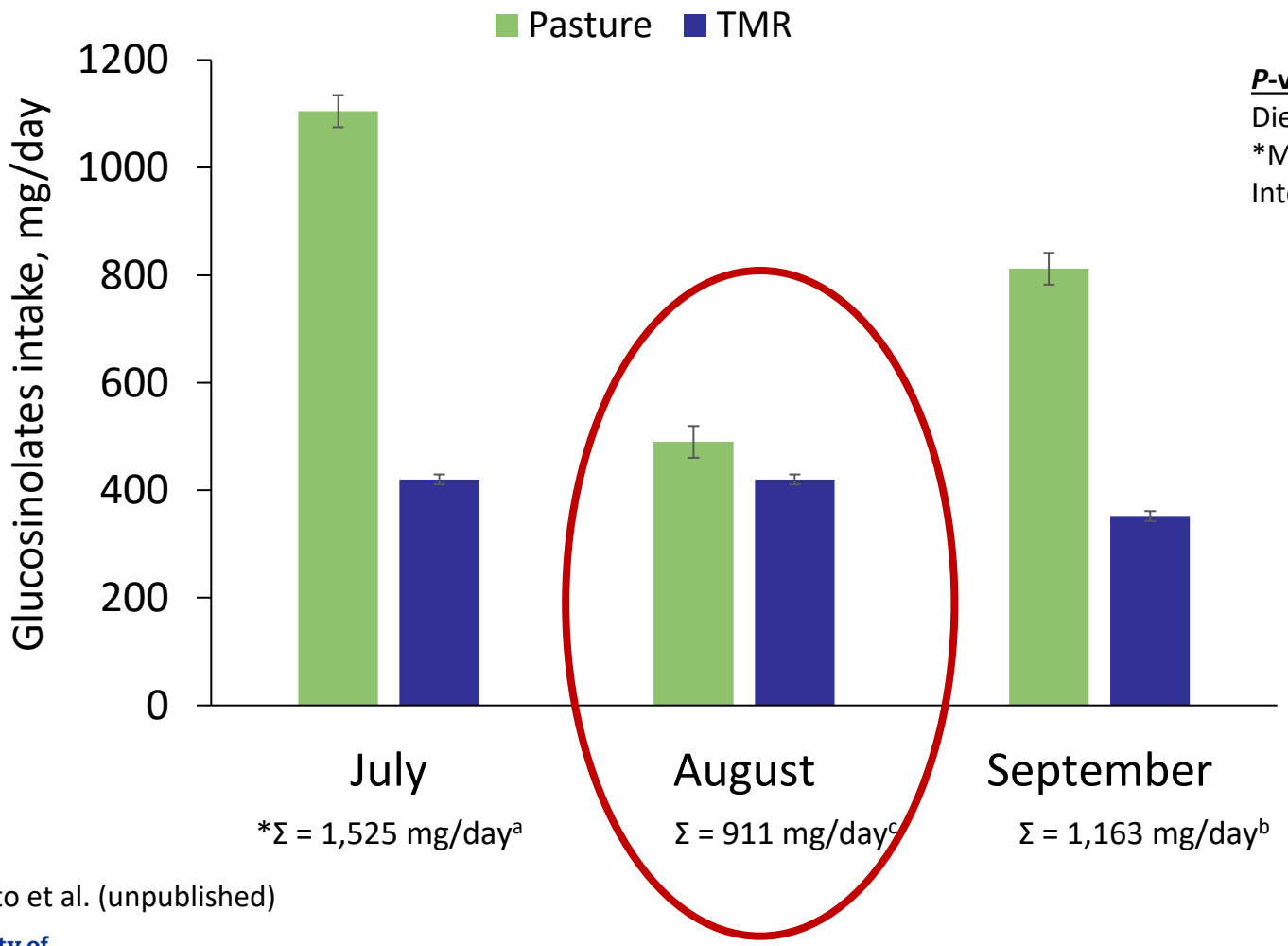
Source: Brito et al. (unpublished)

General structure of glucosinolate



Source: Tripathi and Mishra (2007)

Glucosinolates intake during the grazing season



***P*-values**
Diet ($P = 0.09$)
*Month ($P < 0.001$)
Interaction ($P = 0.40$)

Source: Brito et al. (unpublished)

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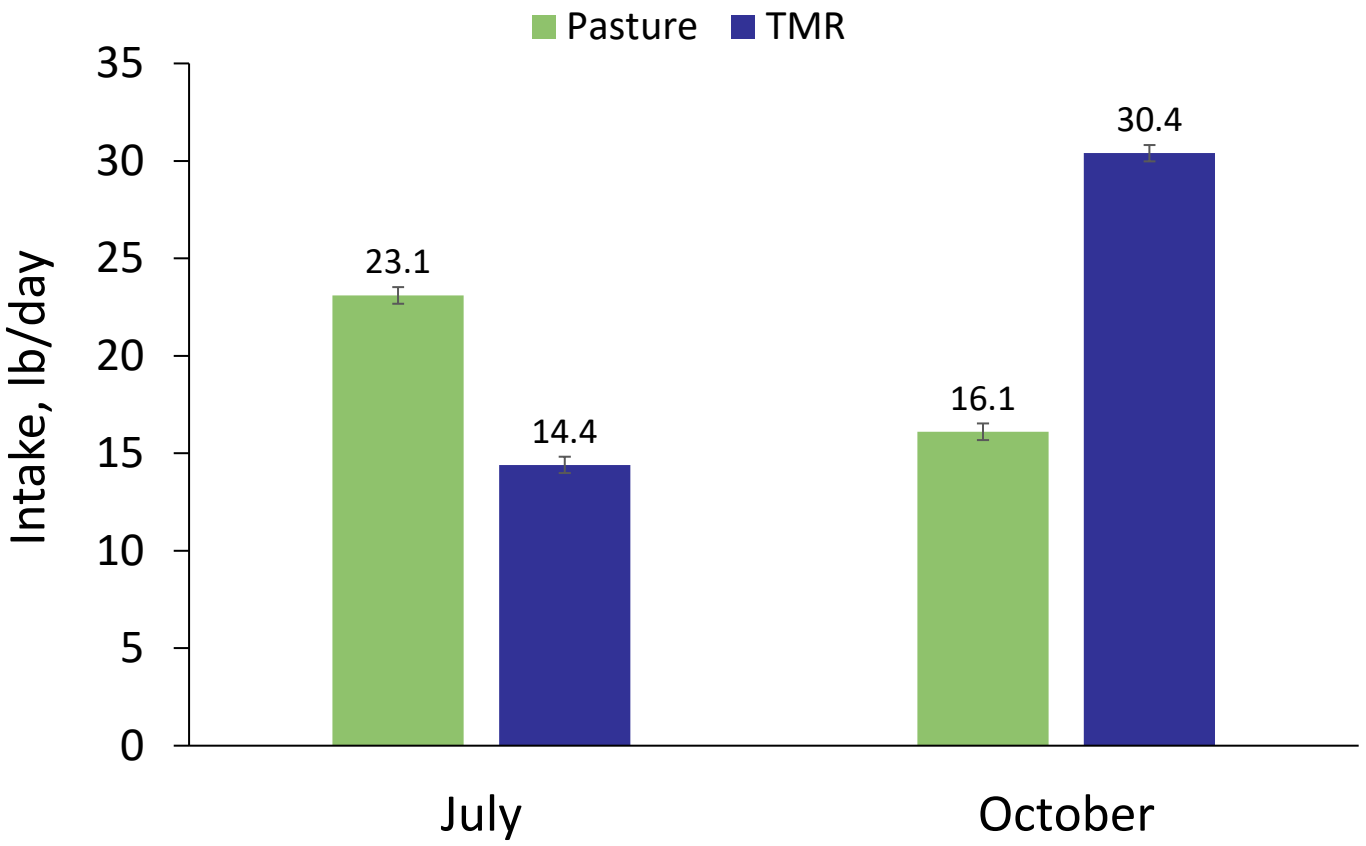
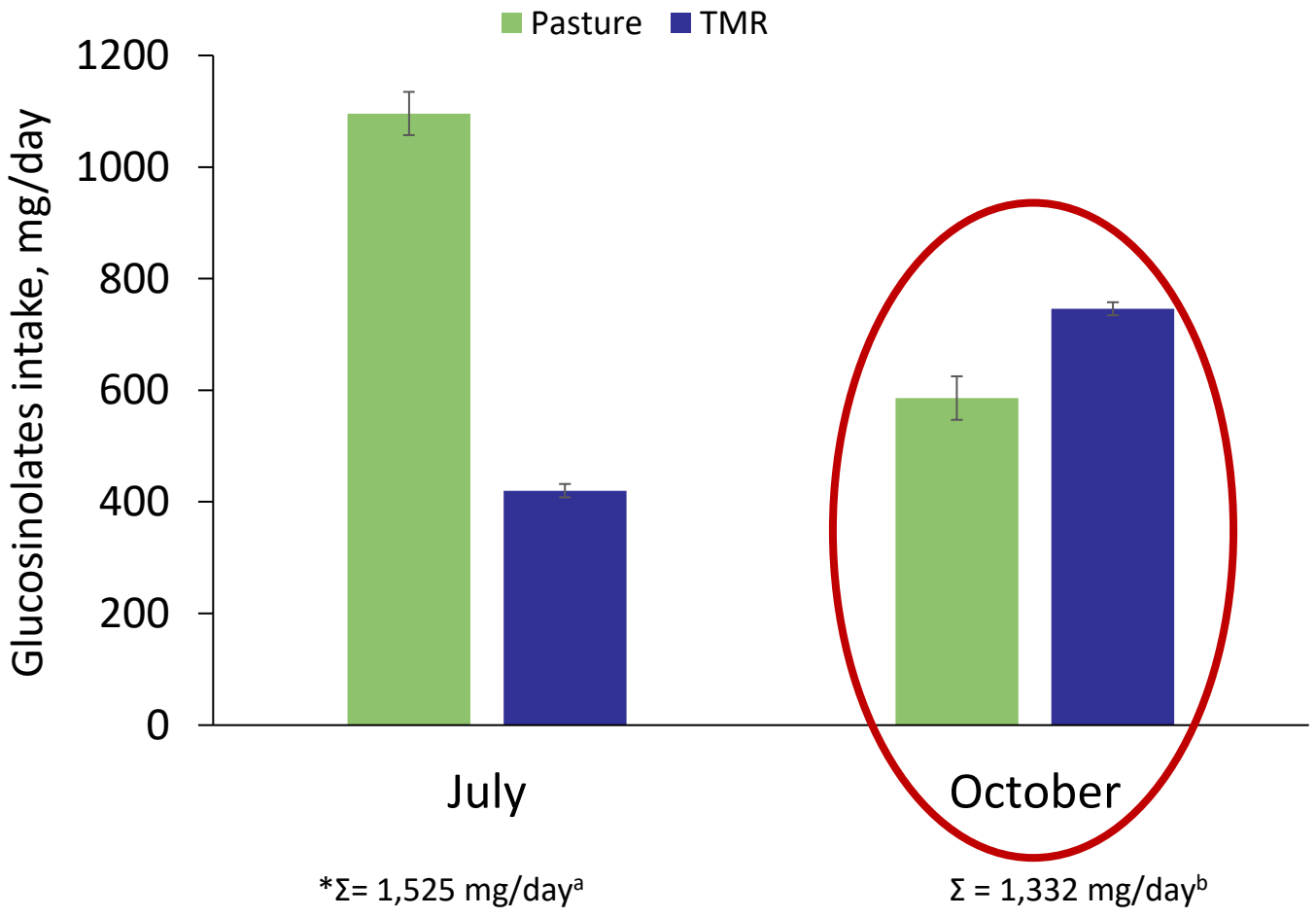
Pasture and TMR intake during the grazing season



***P*-values**
Diet ($P = 0.32$)
Month ($P < 0.001$)
Interaction ($P = 0.13$)

Source: Brito et al. (unpublished)

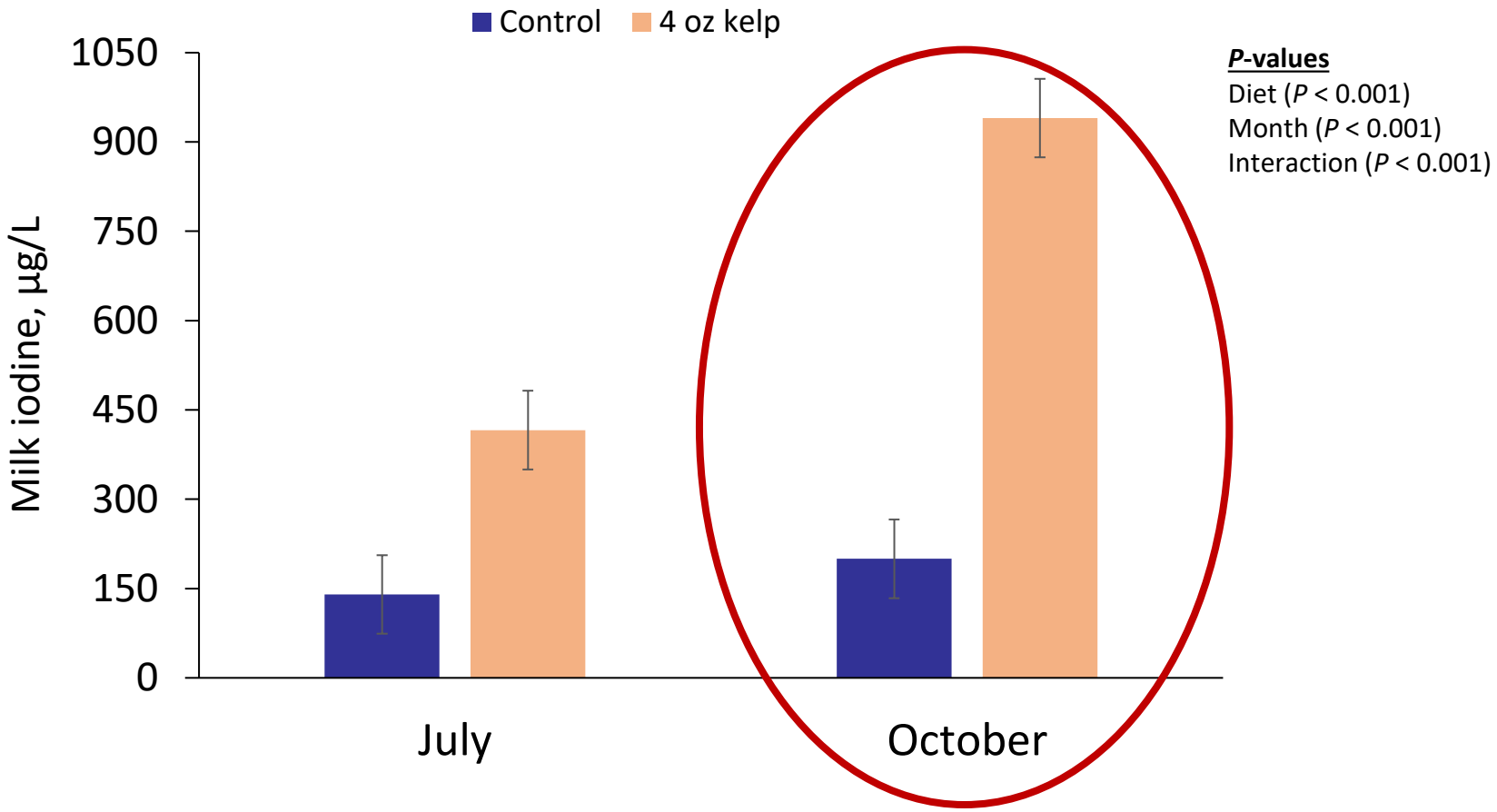
Glucosinolates intake during the grazing season



***P*-values**
Diet ($P = 0.32$)
*Month ($P < 0.001$)
Interaction ($P = 0.13$)

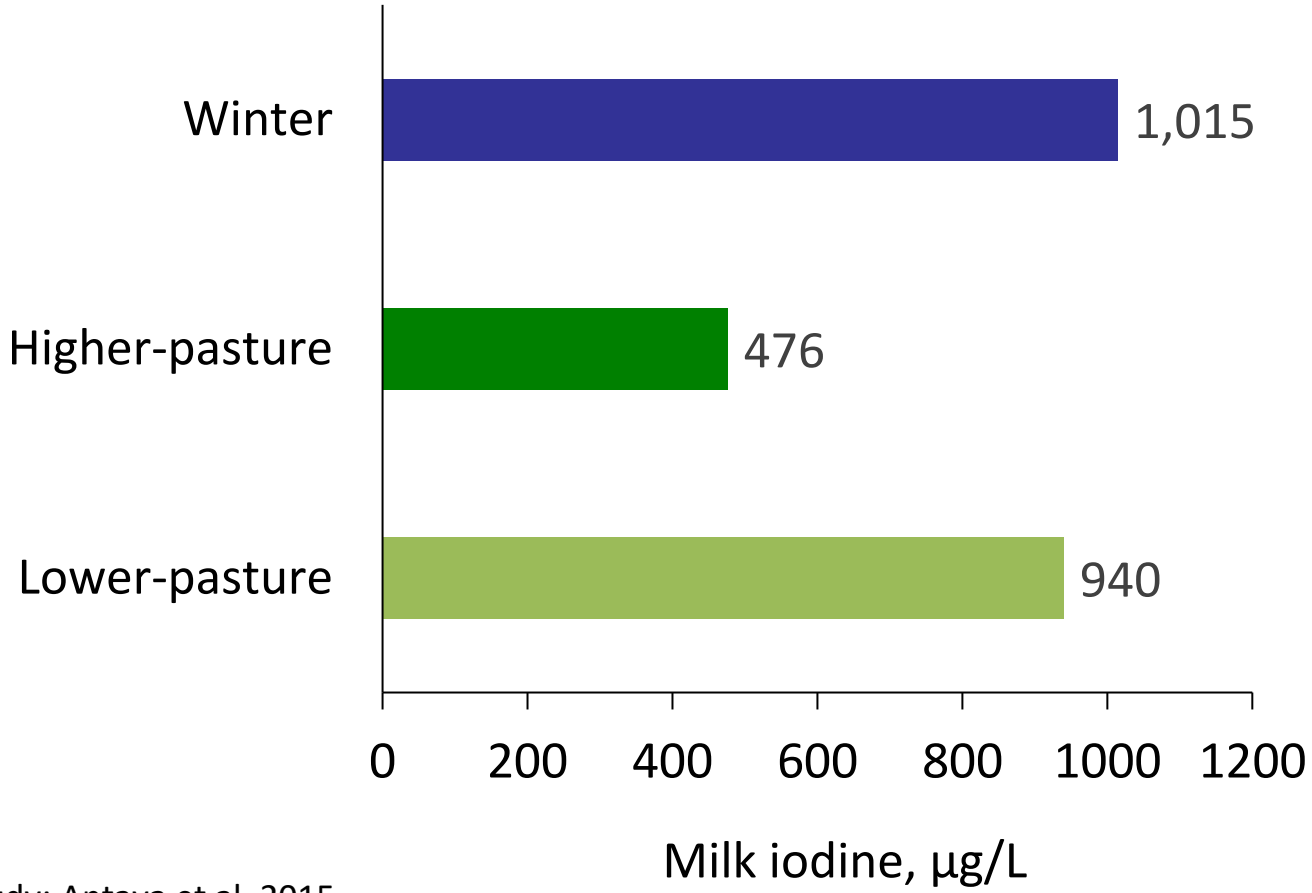
Source: Brito et al. (unpublished)

Milk iodine concentration in grazing cows fed kelp meal



Source: Brito et al. (unpublished)

Milk iodine concentration in dairy cows fed 4 oz of kelp meal during the winter[1] and summer seasons[2]



[1]Winter study: Antaya et al. 2015

[2]Summer study: Brito et al. (unpublished)

Summary

- Plant-based drinks are poor sources of iodine and must be fortified to meet recommended dietary allowance (RDA) for humans

- Kelp meal is an excellent source of iodine, but a comprehensive evaluation of iodine content in retail organic milk is needed

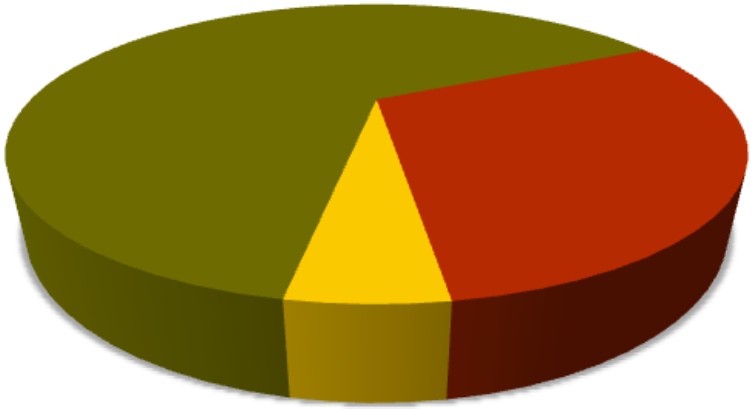
Workshop objectives

- Compare iodine content of milk vs. plant-based drinks relative to recommended dietary allowance (RDA)

- Compare the fatty acid profile of conventional, organic, and organic grass-fed milk

Fatty acid classes in milk fat

- Saturated fatty acids
  - 55 - 80% of total fatty acids
- Monounsaturated fatty acids
  - 15 - 30% of total fatty acids
- Polyunsaturated fatty acids
  - 3 - 6% of total fatty acids



Milk fatty acids affected by:

- Fresh forage and concentrate eaten
  (Croissant et al., 2007; Coppa et al., 2013)
- Differences within and between breed
  (Soyeurt et al., 2008; Maurice-Van Eijndhoven et al., 2011)
- Season (Heck et al., 2009)
- Climate (Kamleh et al., 2010)
- Stage of lactation (Craninx et al., 2008)
- Management (Fall et al., 2008)

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ORIGINAL RESEARCH

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Enhancing the fatty acid profile of milk through forage-based rations, with nutrition modeling of diet outcomes

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Comparison of key fatty acids obtained from conventional, organic, and organic grass-fed whole milk (Grassmilk™)

	Types of Milk			% Difference[1]	
Fatty acids, % total	Conventional	Organic	Grassmilk™	GM vs. CONV	GM vs. ORG
Total ω-6	3.06	2.28	1.46	-52%	-36%
Total ω-3	0.64	1.03	1.58	+147%	+52%
ω-6/ω-3	5.78	2.28	0.95	-83%	-58%
Total CLA[3]	0.62	0.73	1.39	+125%	+90%
ALA (ω-3)	0.51	0.82	1.23	+141%	+50%

[1]CONV = conventional milk; ORG = organic; GM = Grassmilk™
ALA = α-linolenic acid
Source: Benbrook et al. 2018 (Food Sci Nutr. 6:681–700)

University of New Hampshire

Comparison of key fatty acids (% of total) obtained from conventional, organic, and organic grass-fed whole milk (Grassmilk™)

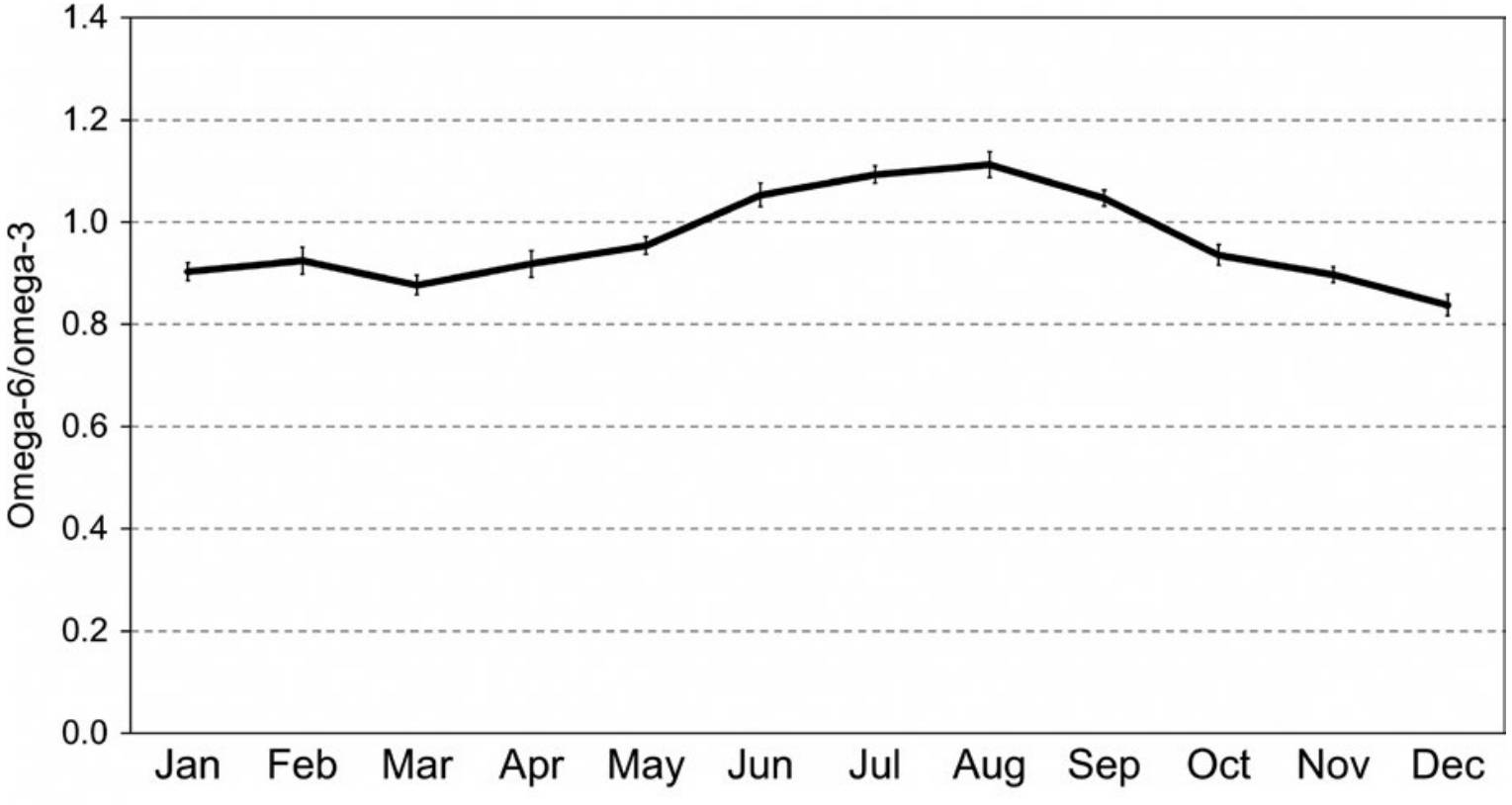
	California	Mideast	Midwest	Northeast	*SEM*	*p*-value
Observations	85	54	582	442		
Total ω-3	1.40^{c}	1.434^{bc}	1.601^{a}	1.575^{ab}	0.04	.002
Total ω-6	1.364^{ab}	1.309^{b}	1.477^{a}	1.495^{a}	0.04	.002
Total CLA	1.282	1.165	1.300	1.379	0.07	.09
LA/ALA	1.091	1.022	1.035	1.047	0.03	.62
ω-6/ω-3	1.189	1.232	1.206	1.151	0.07	.75

*Least square means. Means within a row without common superscripts are different at $p < .05$. Means were evaluated using Tukey's multiple comparisons test.

Source: Benbrook et al. 2018 (Food Sci Nutr. 6:681–700)

LA = linoleic acid; ALA = α-linolenic acid

Monthly variation in mean ω-6/ω-3 ratio of Grassmilk™ over all US geographical regions from 2014 to 2016



Source: Benbrook et al. 2018 (Food Sci Nutr. 6:681–700)

Comparison of fatty acid profile between Grassmilk™ and soymilk

	Product	
Fatty acids (FA), % total FA	Grassmilk™	Soymilk
Oleic acid (ω-9)	20.2	20.4
Linoleic acid (ω-6)	1.25	54.8
α-Linolenic acid (ω-3)	1.23	7.53
Saturated FA	66.9	15.3
MUFA	28.1	22.1
PUFA	6.61	62.4
ω-6/ω-3 ratio	0.95	7.28
Total *trans* FA	5.39	0.03

Sources: Benbrook et al. 2018 (Food Sci Nutr. 6:681–700)
Penalvo et al. 2004 (Eur. Food Res. Technol. 219:251–253)

Summary

- Grass-fed organic milk (Grassmilk™) resulted in greater proportion of ω-3 fatty acids and CLA and lower ω-6/ω-3 ratio than conventional and traditional organic

- All cow milk types (i.e., conventional, organic, and grass-fed organic/Grassmilk™) led to lower ω-6/ω-3 ratio compared with the plant-based dairy alternative (i.e., soymilk)

Final considerations

- Globally, 29.8% of school-age children (246 million) and 30% of the world population (~2.2 billion) are estimated to have insufficient iodine intake

- In the US, consumption of plant-based drinks is increasing at expense of milk, which may have implications to the iodine status of vulnerable populations (e.g., children, pregnant and lactating women, vegans)

- Organic milk, particularly grass-fed is an excellent source of human-healthy fatty acids implying that management strategies to increase forage intake in organic and conventional sector should be implemented

- Nutritionally, cow's milk and plant-based drinks are completely different foods, and an evidence-based conclusion on the health value of the plant-based drinks requires more studies in humans

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Questions?


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