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Opportunities for Strengthening Organic Dairy in the Northeast: From Kelp to Grass Fed to Human Health

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Workshop outline

- Use of kelp meal as a supplement for grazing dairy cows
- Kelp meal supplementation and milk iodine
- Grass-fed milk and milk fatty acids concentration
- Final considerations and questions

Workshop objectives

- Present research data regarding the use of kelp meal as a supplement for dairy cows and associated implications on milk production, milk iodine, and animal and human health

- Present research data about the concentration of beneficial fatty acids in organic milk

UNH Burley-Demeritt Organic Dairy Research Farm

Credit: Scott Ripley/UNH Communications and Public Affairs

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UNH Burley-Demeritt Organic Dairy Research Farm

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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)

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

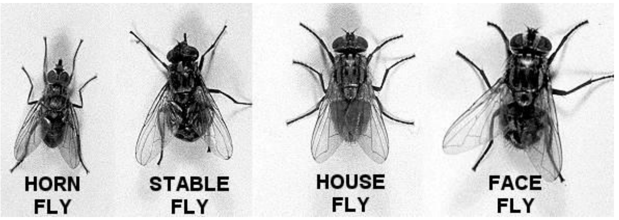
- 59% of organic dairy farmers feed kelp meal in the Northeast (Antaya et al., 2015)
- 49% of organic dairy farmers feed kelp meal in Wisconsin (Hardie et al., 2014)
- 83% of organic dairy farmers feed kelp meal in Minnesota (Sorge et al., 2016)

Why organic dairy farmers feed kelp meal in the Northeast?

- It improves body condition 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)

1 2 3 4



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

Source: Denning et al. 2014

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Frequency of pastures that did not meet minimum requirements

Item	Animal requirements according to Dairy NRC (2001), % of total diet, unless otherwise noted		Samples not meeting min animal requirements, %, unless otherwise noted	
	680-kg Holstein,[1] 25 kg/d milk	454-kg Jersey,[2] 25 kg/d milk	680-kg Holstein,[1] 25 kg/d milk	454-kg Jersey,[2] 25 kg/d milk
Forage quality				
CP	14.1	16.1	9.21	20.8
ADF	17–21 min	17–21 min	0.00	0.00
NDF	25–33 min	25–33 min	0.00	0.00
NE_l, Mcal/kg	1.37	1.54	35.5	85.8
Macrominerals				
Calcium	0.62	0.57	30.8	22.1
Phosphorus	0.32	0.33	19.2	26.1
Magnesium	0.18	0.18	2.89	2.89
Potassium	0.24	0.24	0.00	0.00
Sulfur	0.22	0.20	11.1	6.58

n = 380 pasture samples collected from 2012-1015 in organic dairies in NH, VT, ME, NY, and PA
CP = crude protein, ADF = acid detergent fiber, NDF = neutral detergent fiber, NE_l = net energy of lactation; Source: Hafla et al. (2016)

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)

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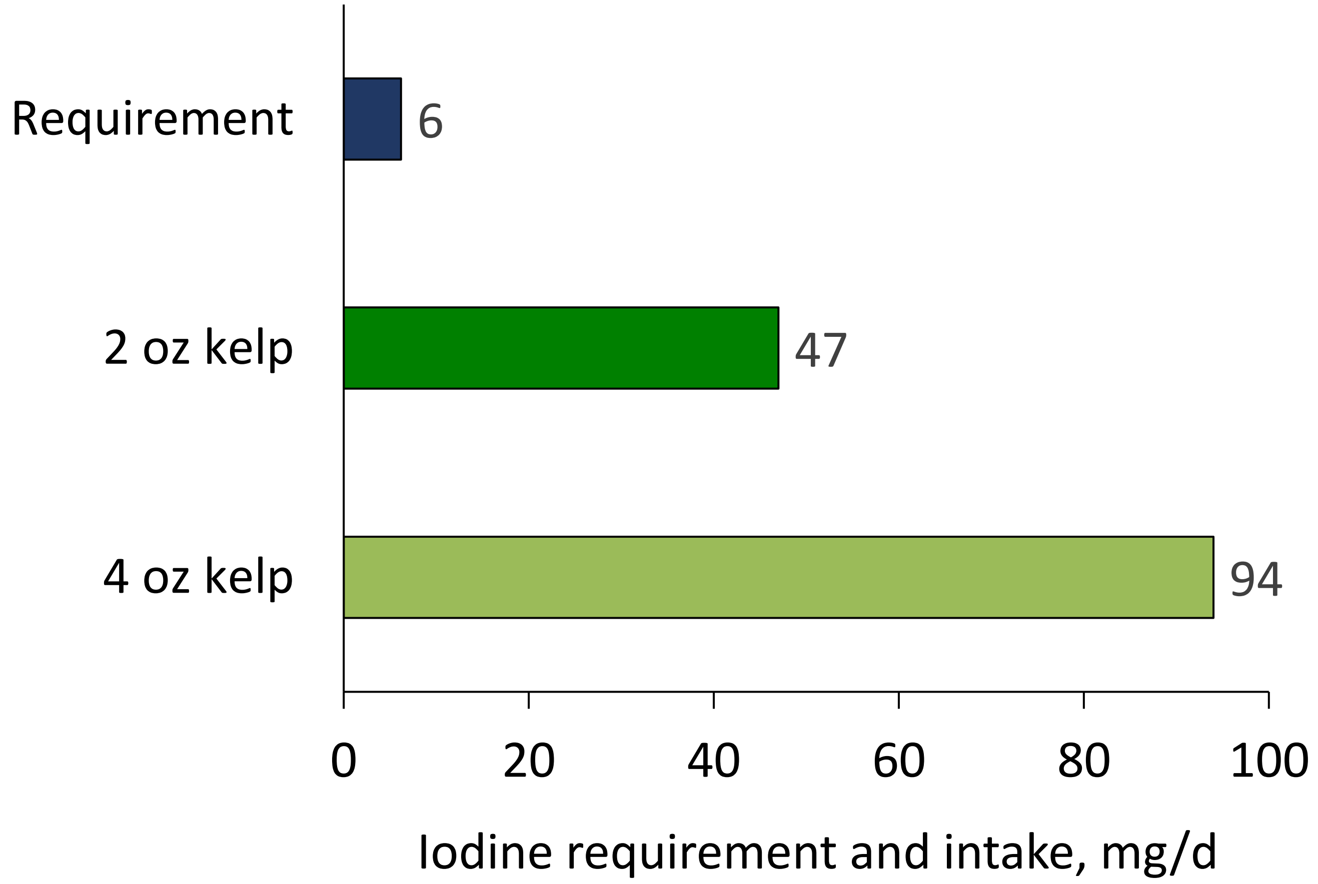
Nutritional comparison of kelp meal products

	Kelp meal products				
Item	**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)

Iodine intake with feeding 2 oz or 4 oz of kelp meal relative to iodine requirement of lactating dairy cows



Sources: NRC (2001); Antaya et al. 2015

Kelp meal studies objectives at UNH

- Investigate the impact of kelp meal supplementation on milk production, nutrient digestibility, animal health, and methane (CH_4) emissions during the grazing and winter seasons

- Improving the understanding of iodine metabolism in dairy cows fed kelp meal year-round

General study procedures

- Twenty lactating Jersey cows averaging 175 days in milk, 45 lb/d of milk production, and 972 lb of BW in the beginning of the study were used
- Cows were randomly assigned to 1 of 2 diets: **0 or 4 oz of kelp meal**
- Cows were milked twice daily and have access to a new strip of fresh pasture after every milking
- TMR was supplemented twice daily after milking
- Feeds, milk, blood, feces, and urine samples were collected monthly throughout the study
- Gaseous measurements were taken using the GreenFeed system

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Vertical mixer

TMR mixer

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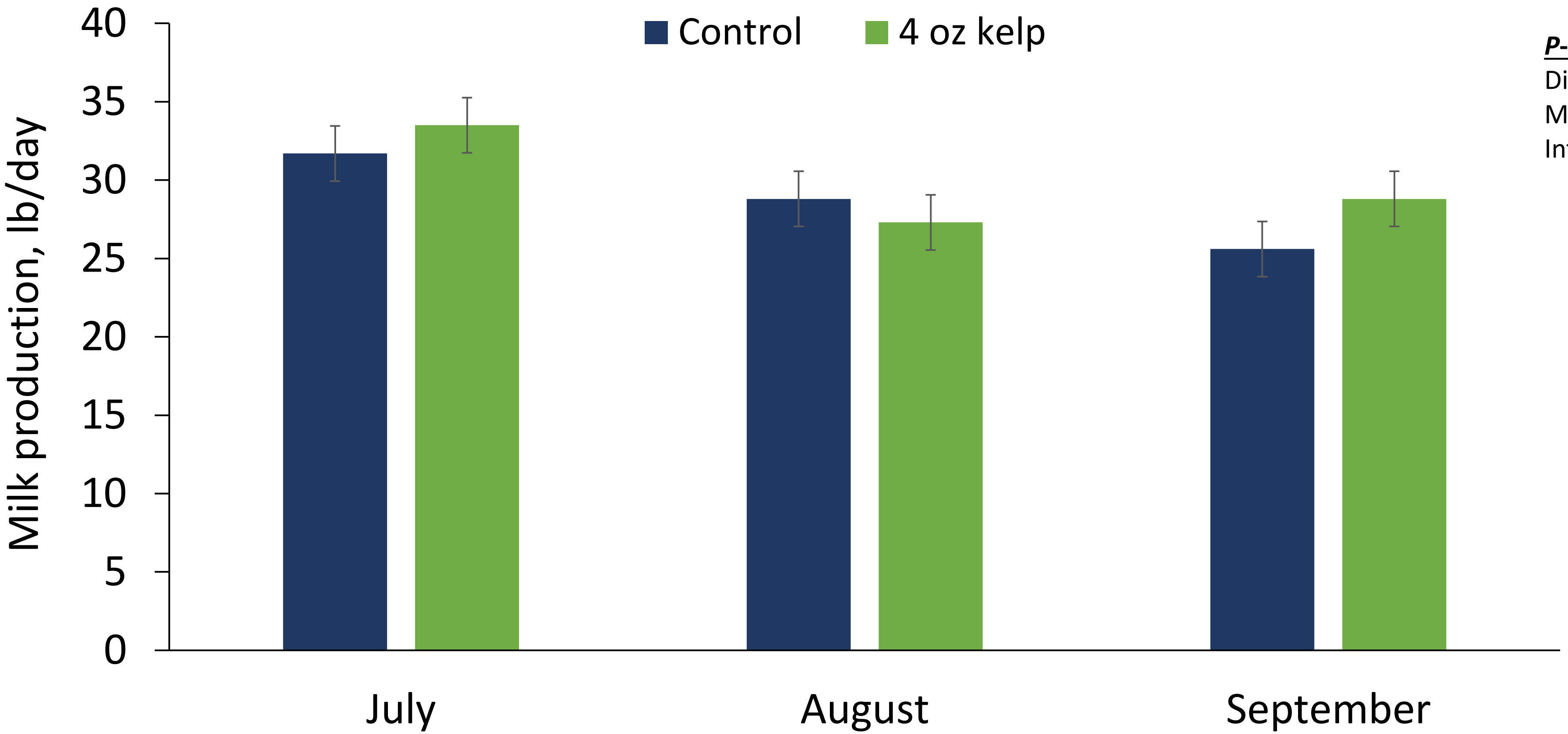
Calan doors system

Milk production in grazing cows fed kelp meal



***P*-values**
Diet ($P = 0.59$)
Month ($P < 0.001$)
Interaction ($P = 0.19$)

Source: Brito et al. (unpublished)

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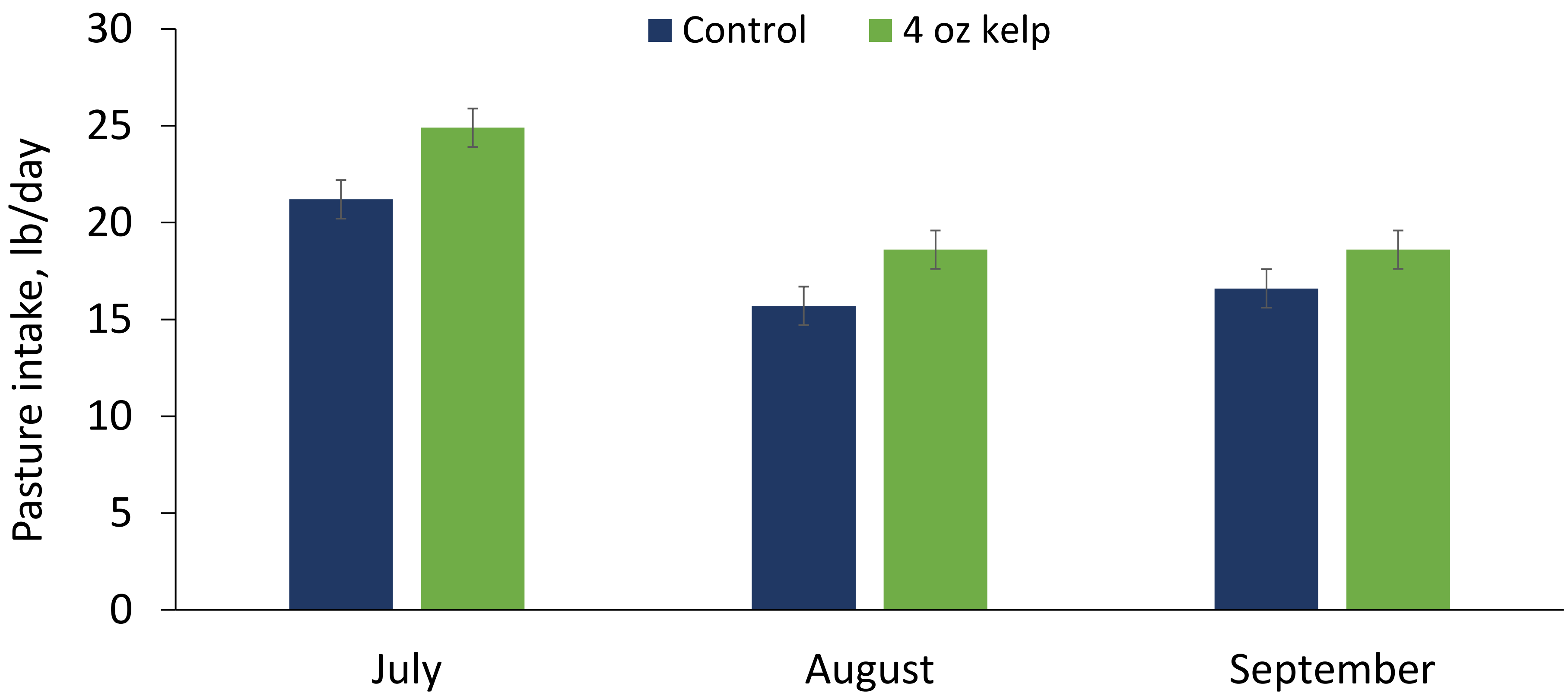
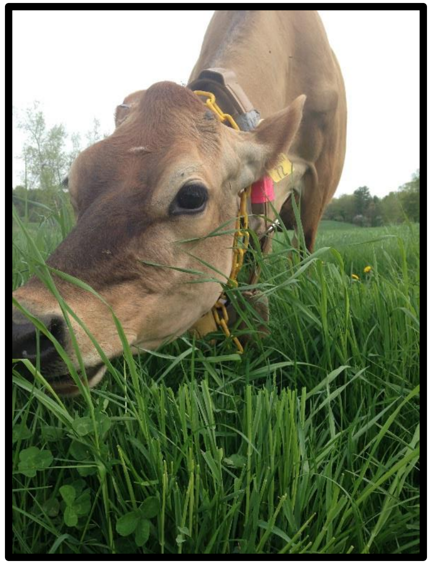
Pasture intake in grazing cows fed kelp meal



Source: Brito et al. (unpublished)

***P*-values**
Diet (P = 0.05)
Month (P < 0.001)
Interaction (P = 0.73)



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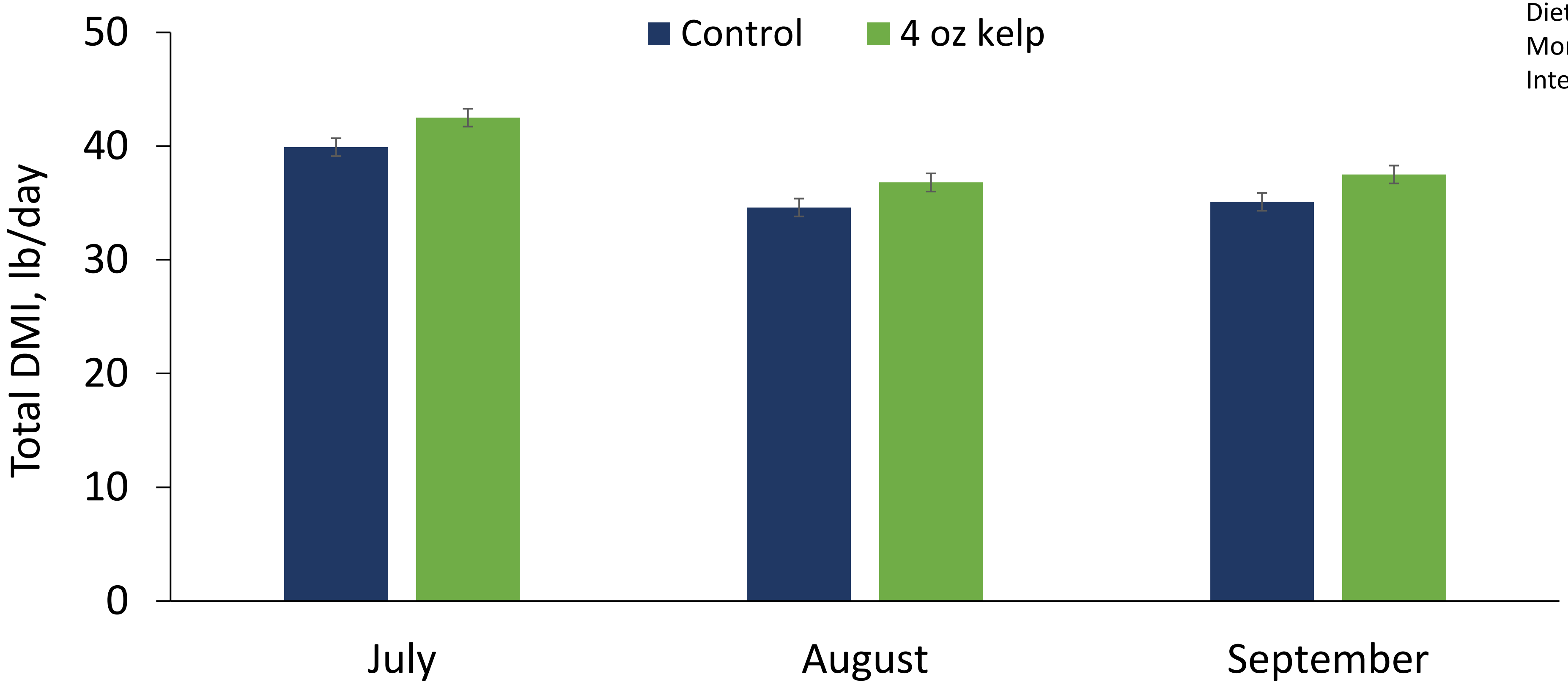
Total diet DMI in grazing cows fed kelp meal



***P*-values**
Diet ($P = 0.07$)
Month ($P < 0.001$)
Interaction ($P = 0.95$)

DMI = dry matter intake
Source: Brito et al. (unpublished)

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Milk composition and body condition score (BCS) in grazing cows fed kelp meal

	Diets			*P*-values		
Item	Control	Kelp meal	SEM	Diet	Month	Interaction
Milk fat, %	4.19	4.37	0.19	0.52	<0.01	0.85
Milk fat, lb/day	1.21	1.30	0.08	0.43	<0.001	0.40
Milk protein, %	3.41	3.40	0.06	0.93	<0.001	0.94
Milk protein, lb/day	0.97	1.01	0.02	0.50	0.02	0.25
MUN, mg/dL	12.5	13.2	0.47	0.35	0.08	0.09
BCS, point/28 days	3.33	3.30	0.11	0.83	<0.001	0.13

Source: Brito et al. (unpublished)

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Body temperature and respiration rate in grazing cows fed kelp meal

	Diets			*P*-values		
Item	Control	Kelp meal	SEM	Diet	Month	Interaction
Morning rectal temperature, °F	100	100	0.05	0.47	<0.001	0.69
Afternoon rectal temperature, °F	101.7	101.7	0.05	0.55	0.04	0.19
Morning respiration rate, no./min	36.4	36.5	1.00	0.54	<0.001	0.17
Afternoon respiration rate, no./min	61.2	62.0	2.31	0.80	<0.001	0.89

Source: Brito et al. (unpublished)

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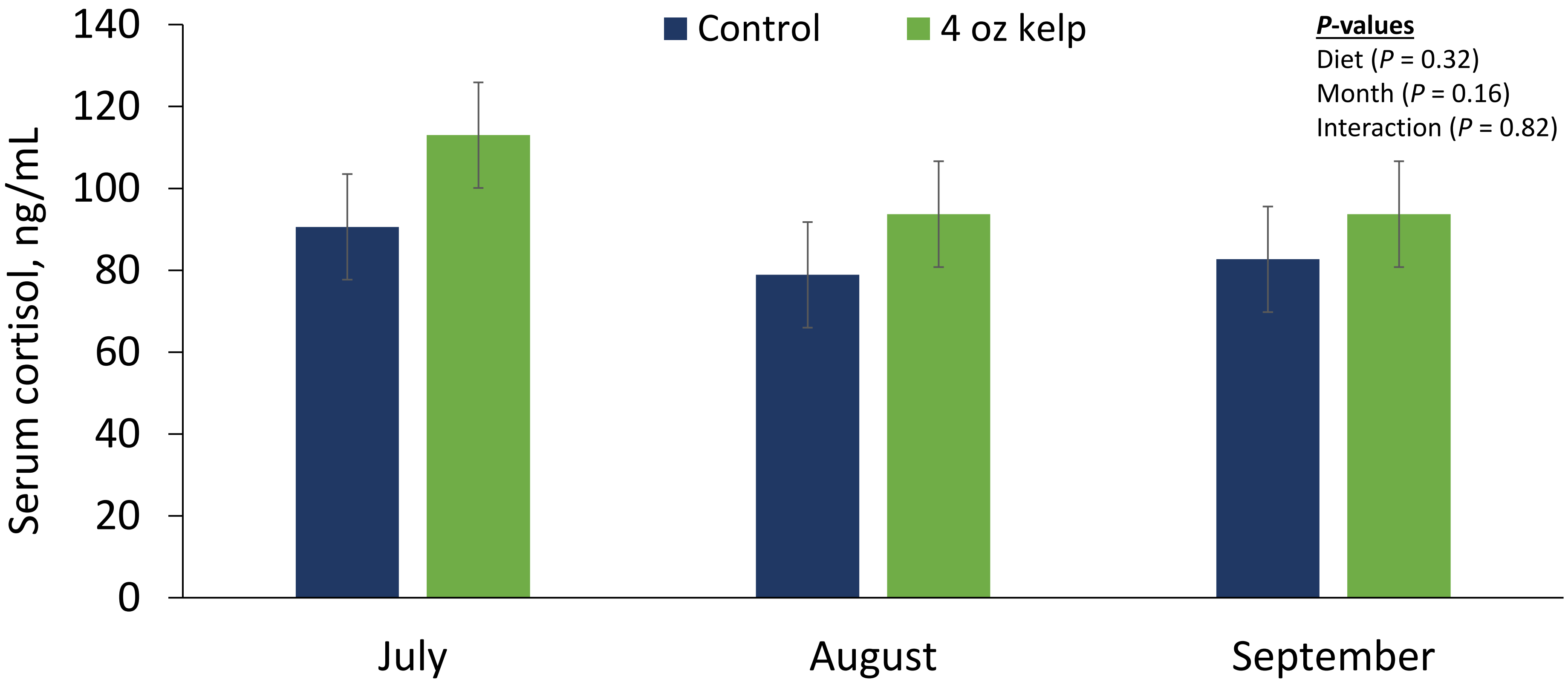
Serum cortisol in grazing dairy cows fed kelp meal



Source: Brito et al. (unpublished)

J. Dairy Sci. 98:1991–2004
http://dx.doi.org/10.3168/jds.2014-8851

Incremental amounts of *Ascophyllum nodosum* meal do not improve animal performance but do increase milk iodine output in early lactation dairy cows fed high-forage diets[1]

N. T. Antaya,* K. J. Soder,† J. Kraft,‡ N. L. Whitehouse,* N. E. Guindon,* P. S. Erickson,* A. B. Conroy,§ and A. F. Brito*[2]
*Department of Biological Sciences, University of New Hampshire, Durham 03824
†Pasture Systems and Watershed Management Research Unit, USDA-Agricultural Research Service, University Park, PA 16802
‡Department of Animal Science, University of Vermont, Burlington 05405
§Thompson School of Applied Science, University of New Hampshire, Durham 03824

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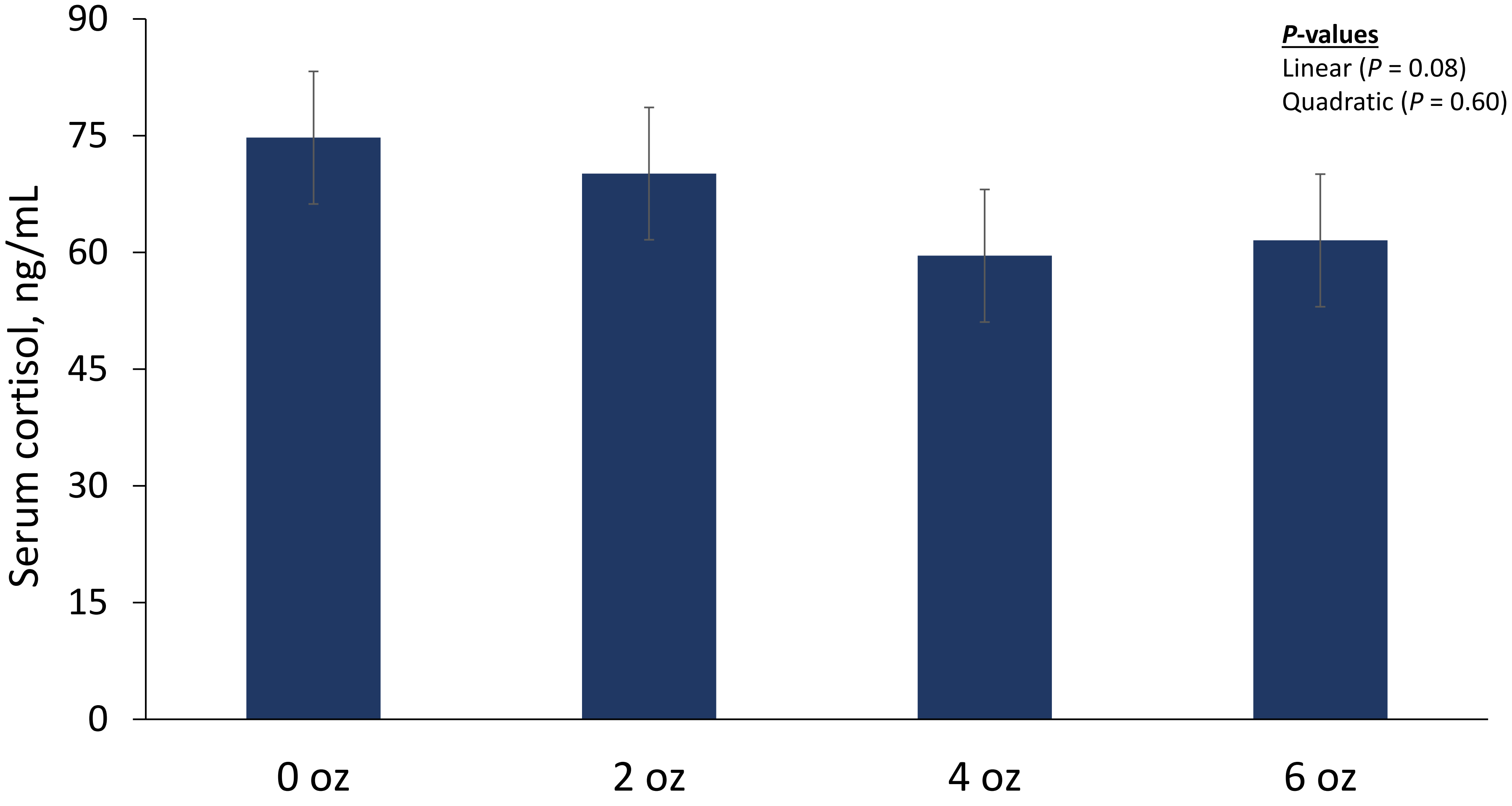
Serum cortisol in dairy cows fed kelp meal during the winter



Source: Antaya et al (2015)

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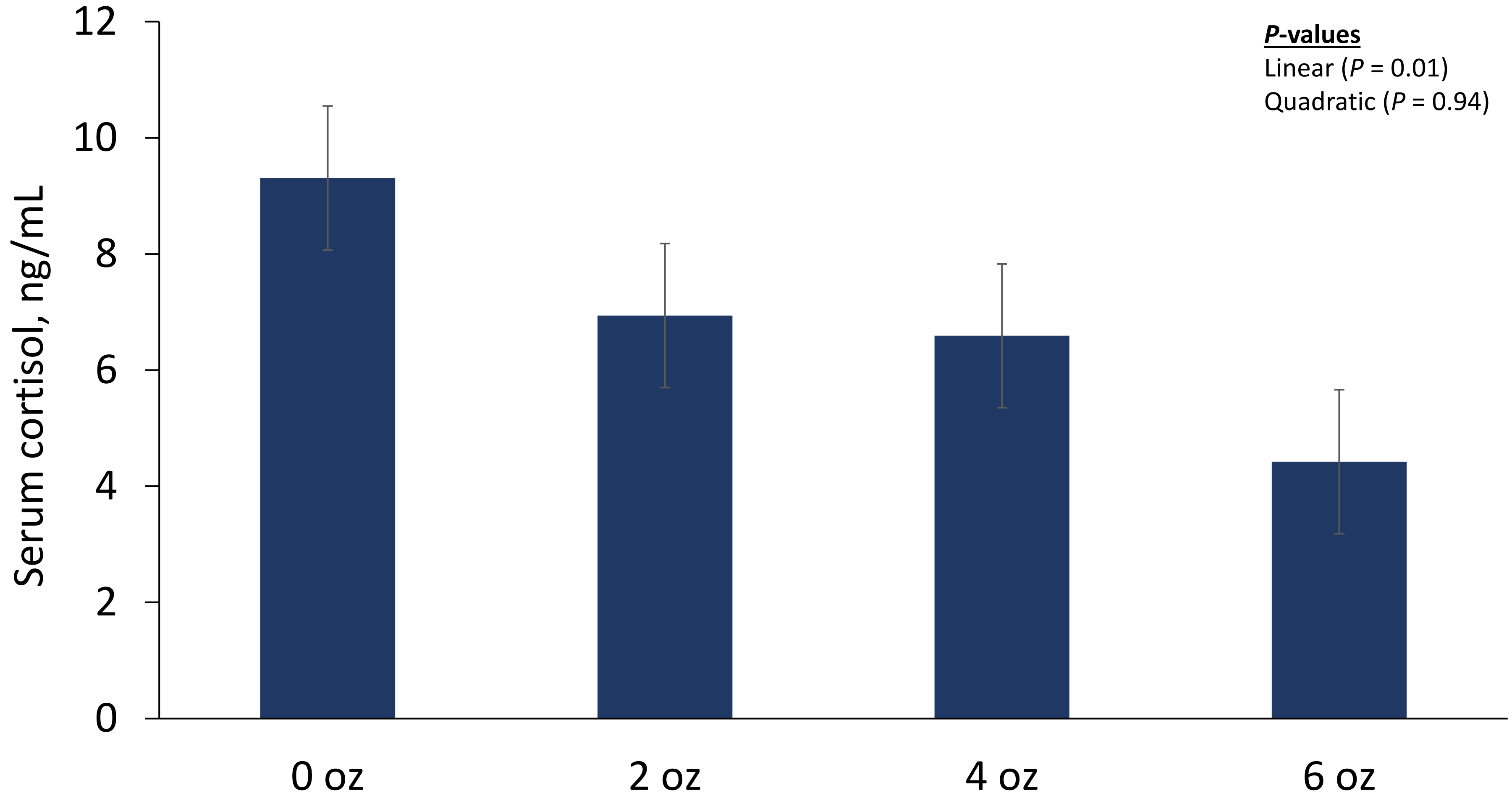
Serum cortisol in conventional dairy cows fed kelp meal during the summer



Source: Brito et al. (unpublished)

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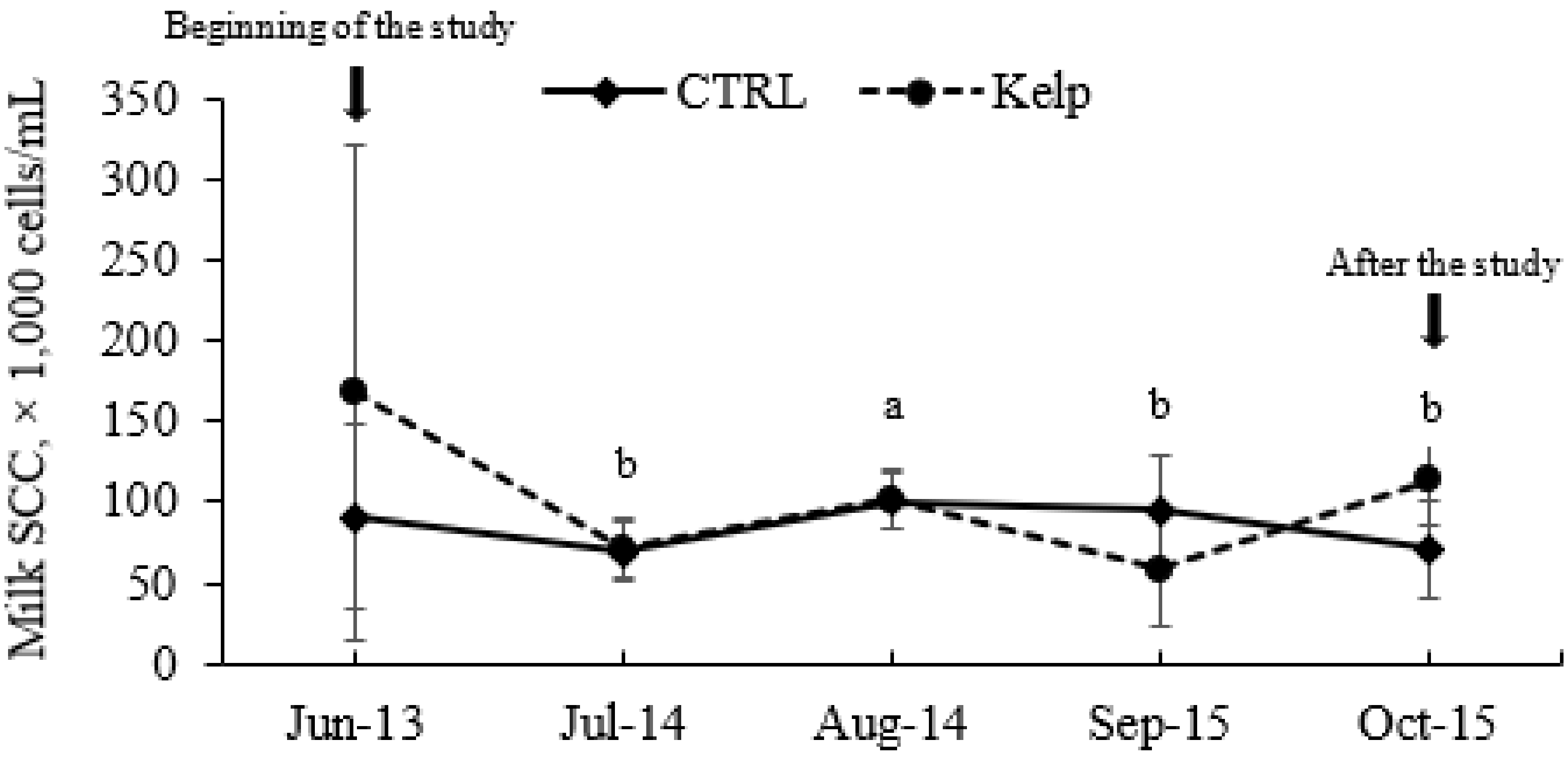
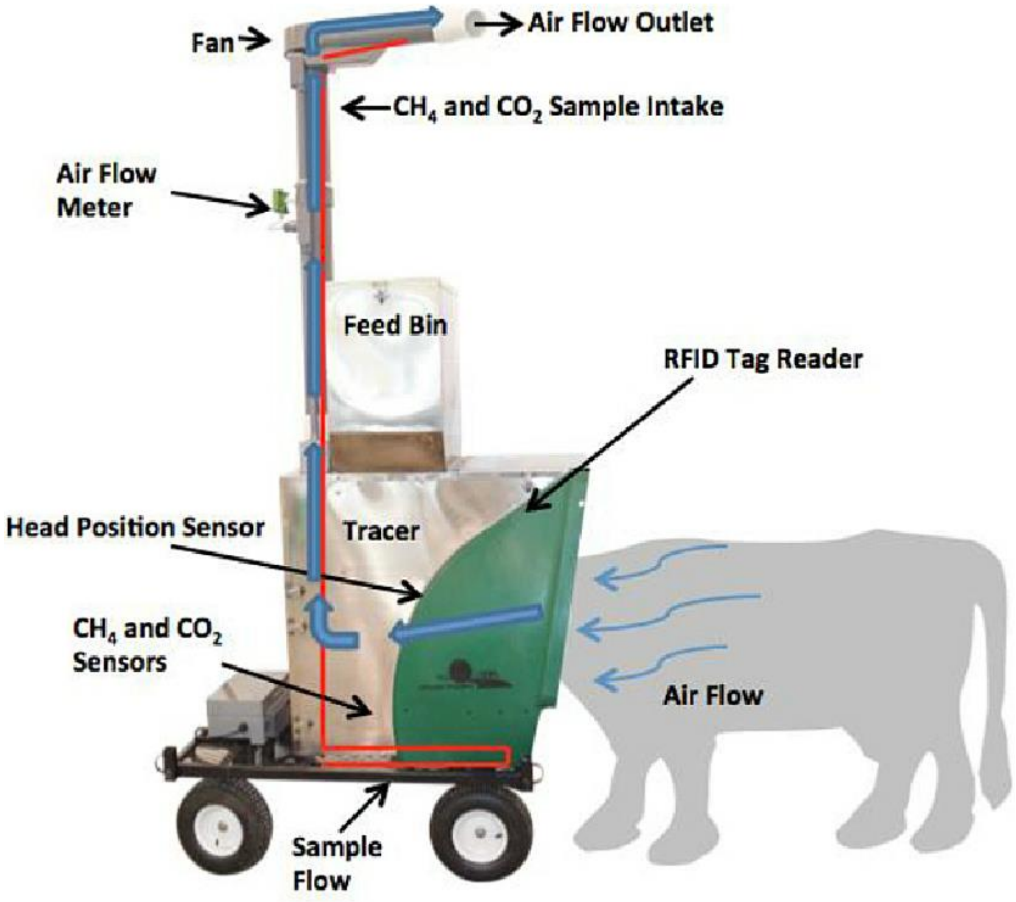
Milk somatic cell count (SCC) in grazing cows fed kelp meal



***P*-values**
Diet (*P* = 0.92)
Month (*P* < 0.05)
Interaction (*P* = 0.29)

Source: Brito et al. (unpublished)

Methane emission measurements



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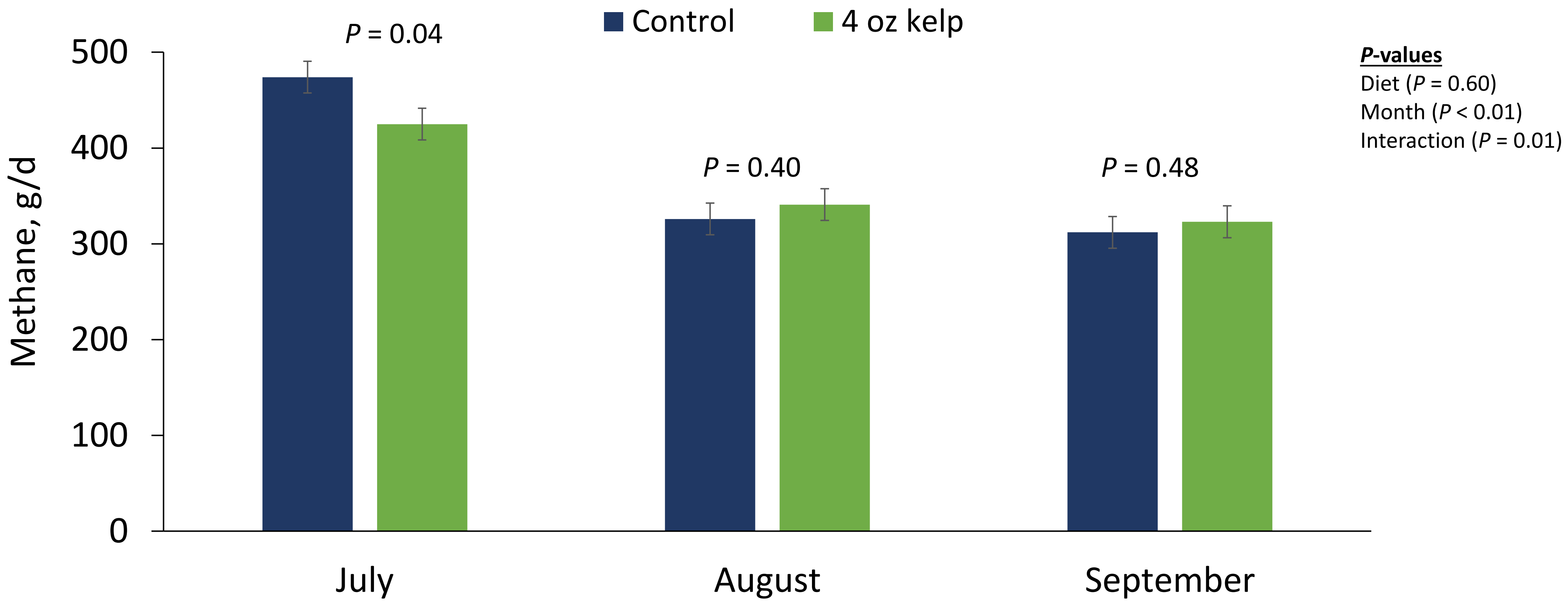
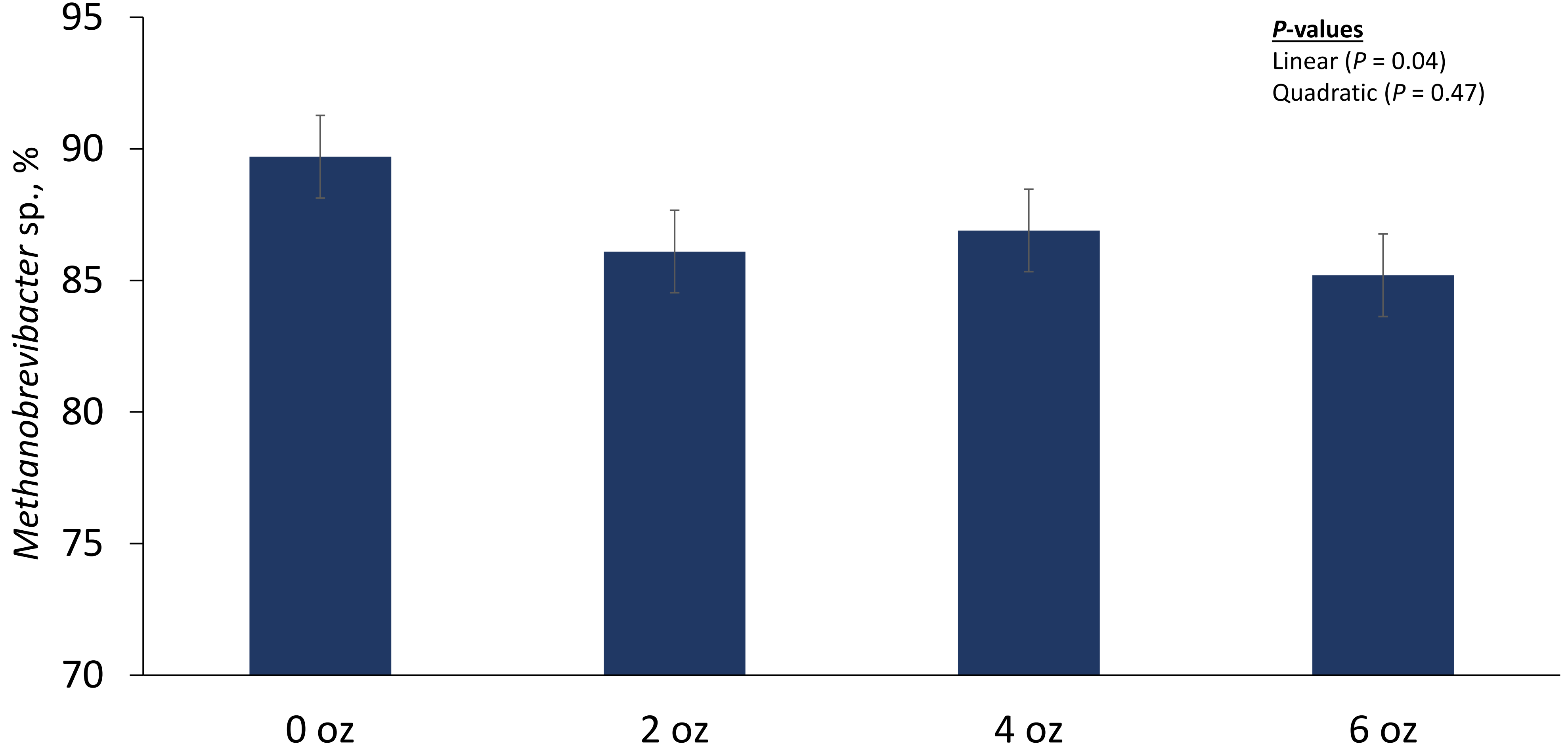
The portable GreenFeed gas emission monitoring system

Methane emissions in grazing dairy cows fed kelp meal



Source: Brito et al. (unpublished)

Proportion of *Methanobrevibacter* sp. in rumen fluid of confined dairy cows fed kelp meal during the summer



Source: Brito et al. (unpublished)

Summary

- Kelp meal supplementation maintained or slightly improved production of milk and milk components during the grazing season

- Effects of kelp meal supplementation of blood cortisol, milk SCC, and methane emissions deserve further investigations

Kelp meal studies objectives at UNH

- Investigate the impact of kelp meal supplementation on milk production, milk components, animal health, and methane (CH_4) emissions during the grazing and winter seasons

- Improving the understanding of iodine metabolism in dairy cows fed kelp meal year-round

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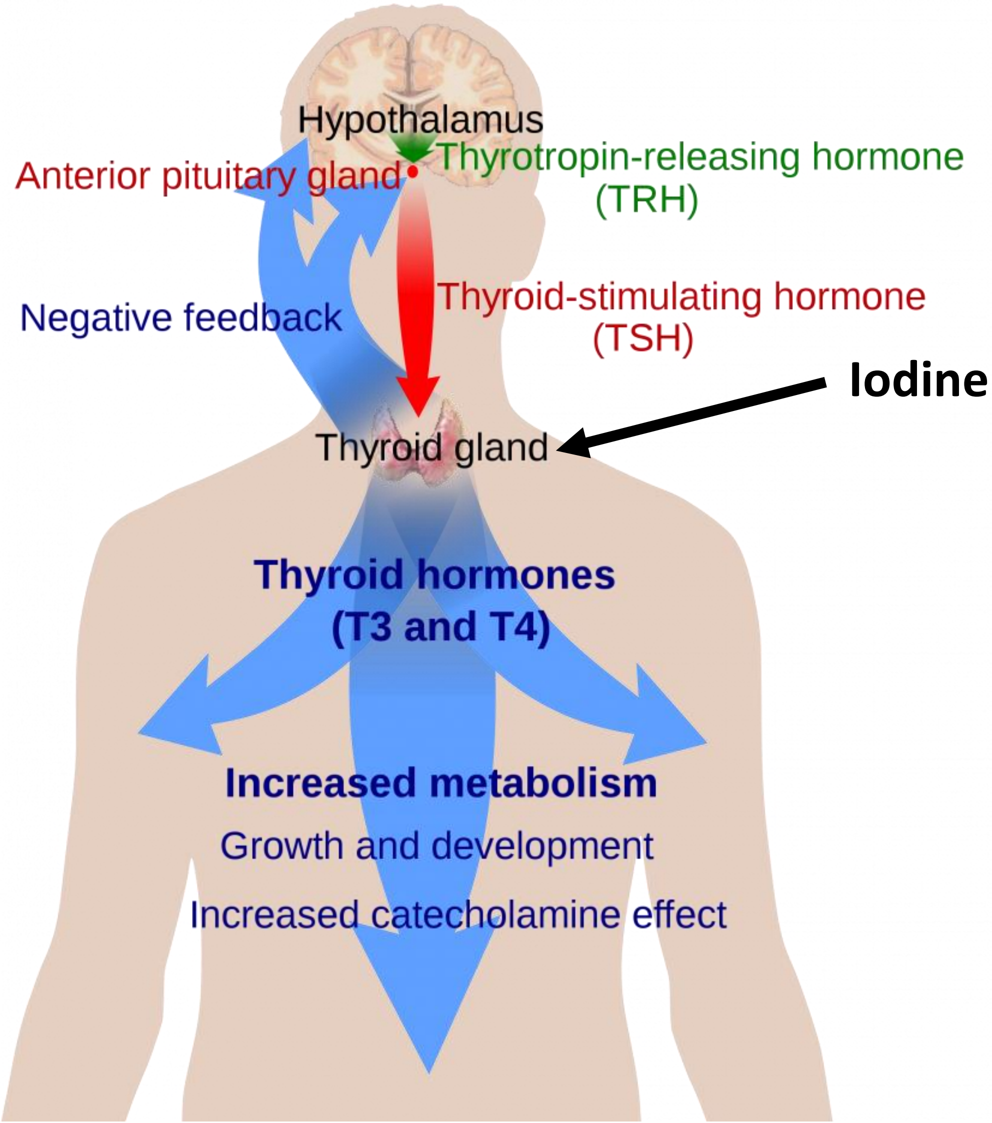
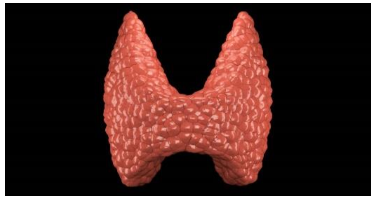
Thyroid system



Iodine

Tyroide 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

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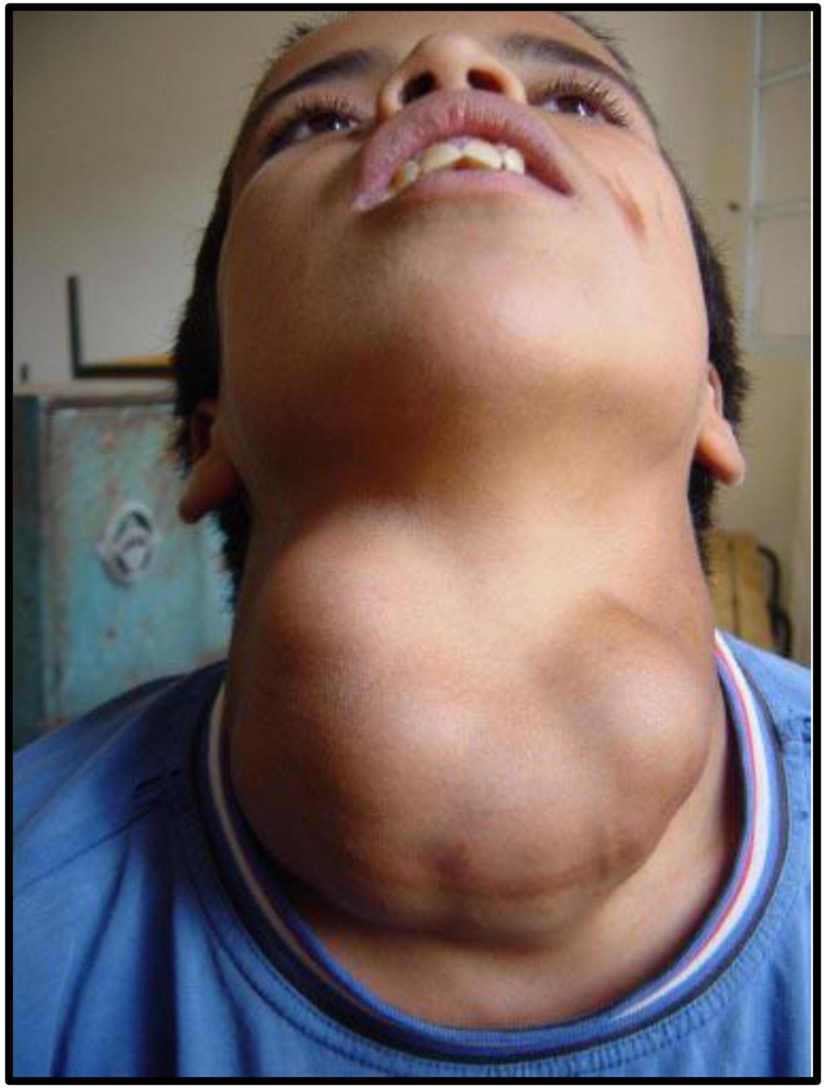
Spectrum of iodine deficiency disorders

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)

Goiter

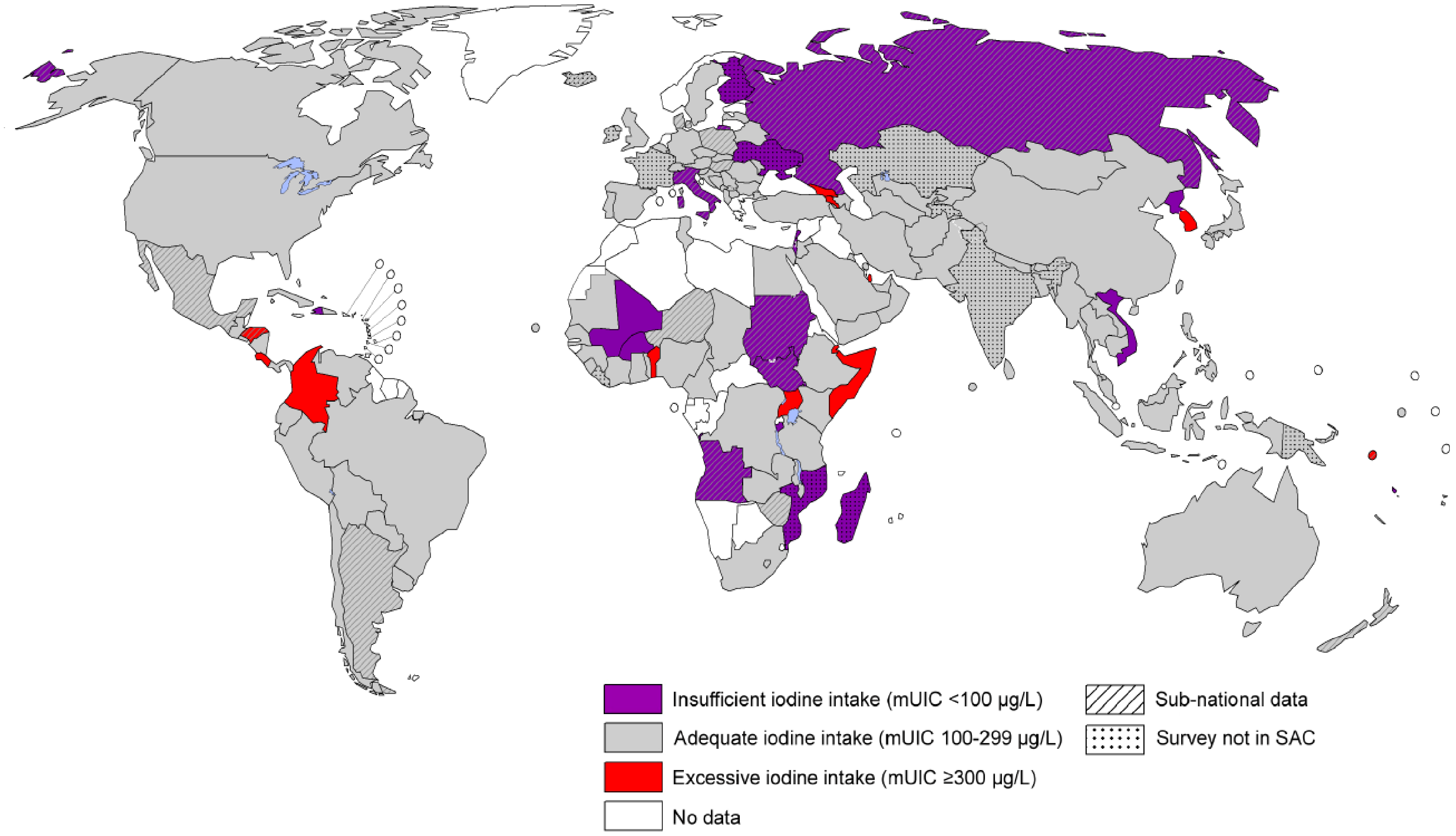


Cretinism

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



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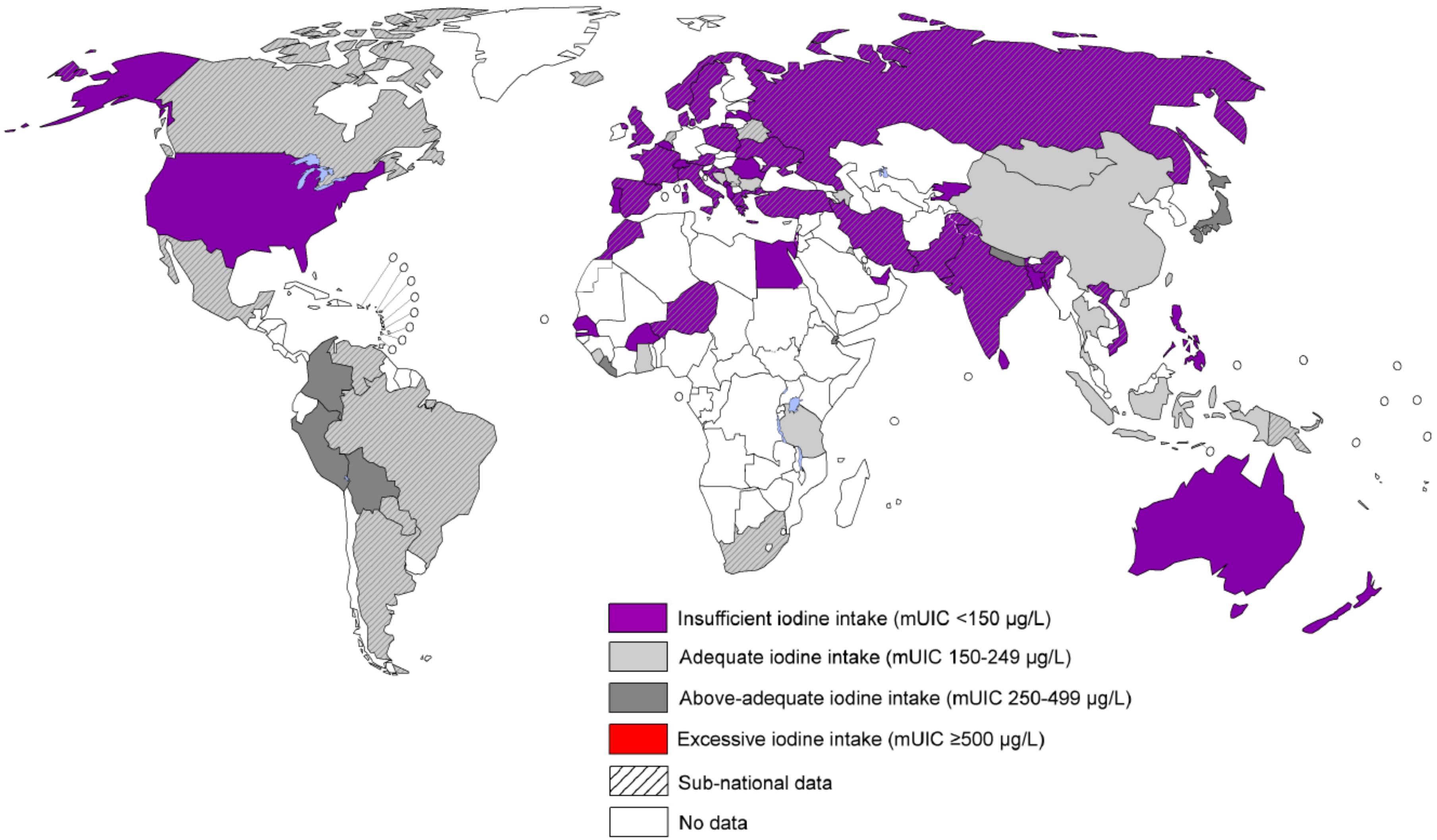
Source: The Iodine Global Network (2017)

Global Scorecard of Iodine Nutrition 2017

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



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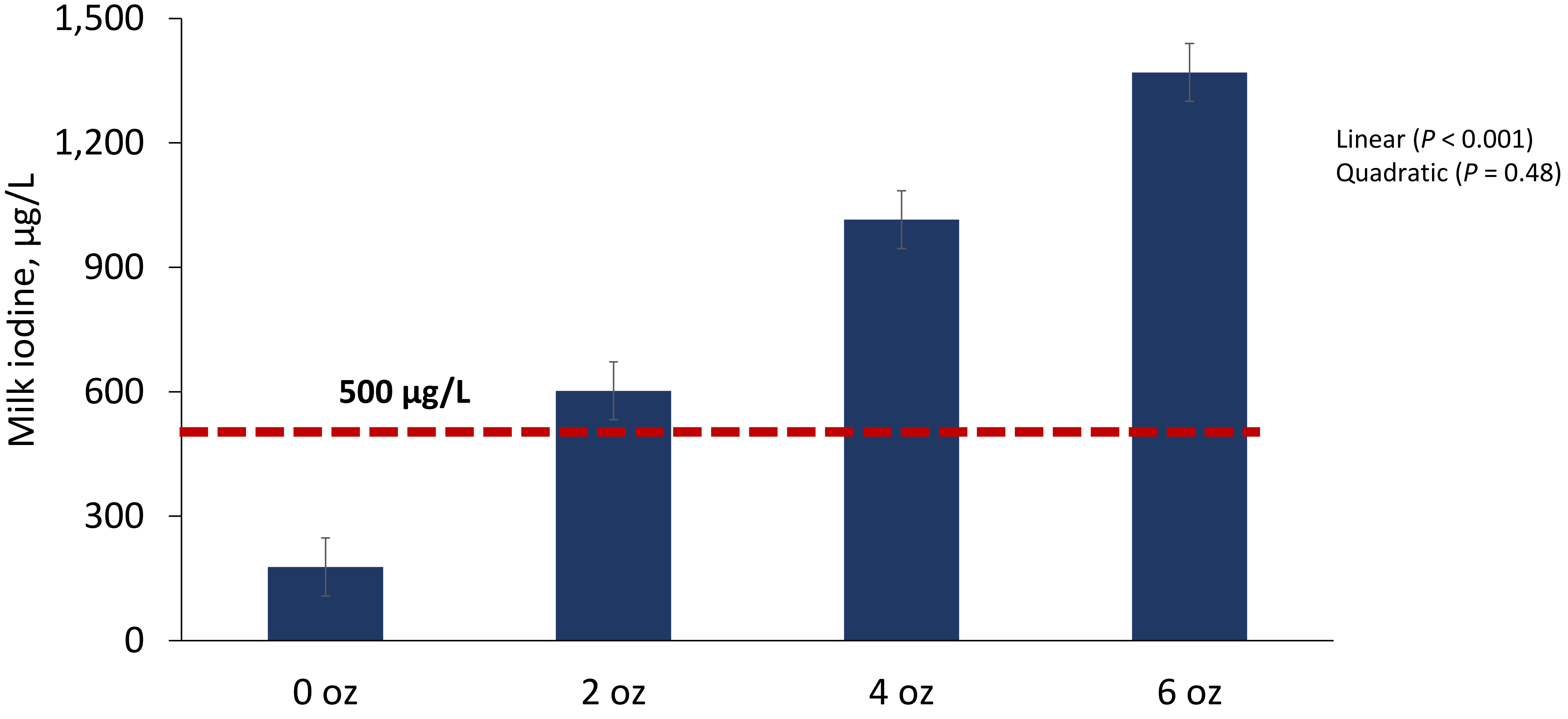
Source: The Iodine Global Network (2017)

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



Source: Antaya et al. 2015

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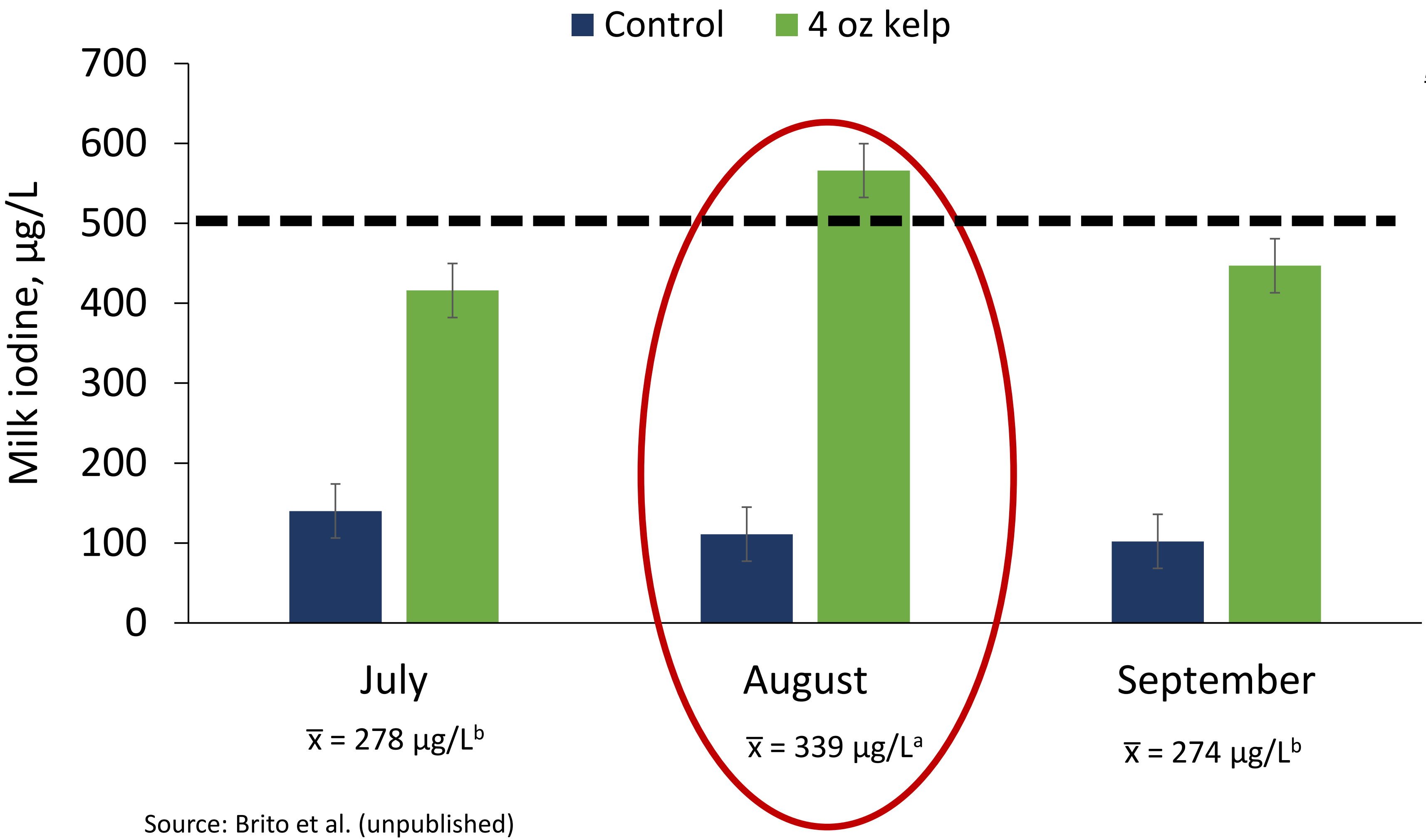
Excess iodine intake and human health

- 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)

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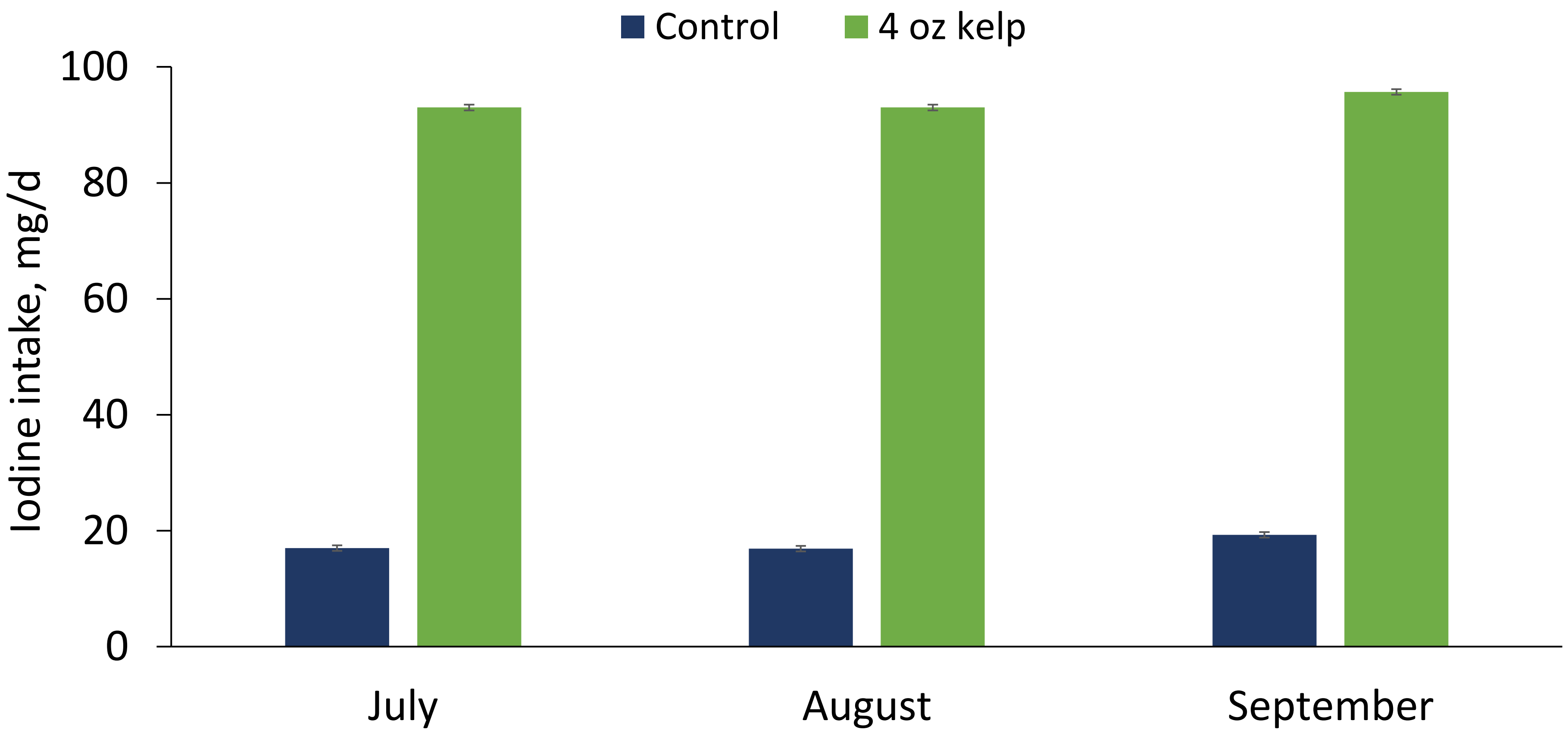
Iodine intake in grazing cows fed kelp meal



***P*-values**
Diet ($P < 0.001$)
Month ($P < 0.001$)
Interaction ($P = 0.59$)

Source: Brito et al. (unpublished)

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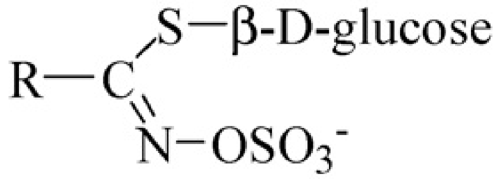
Glucosinolates and hydrogen cyanide



$H-C\equiv N$

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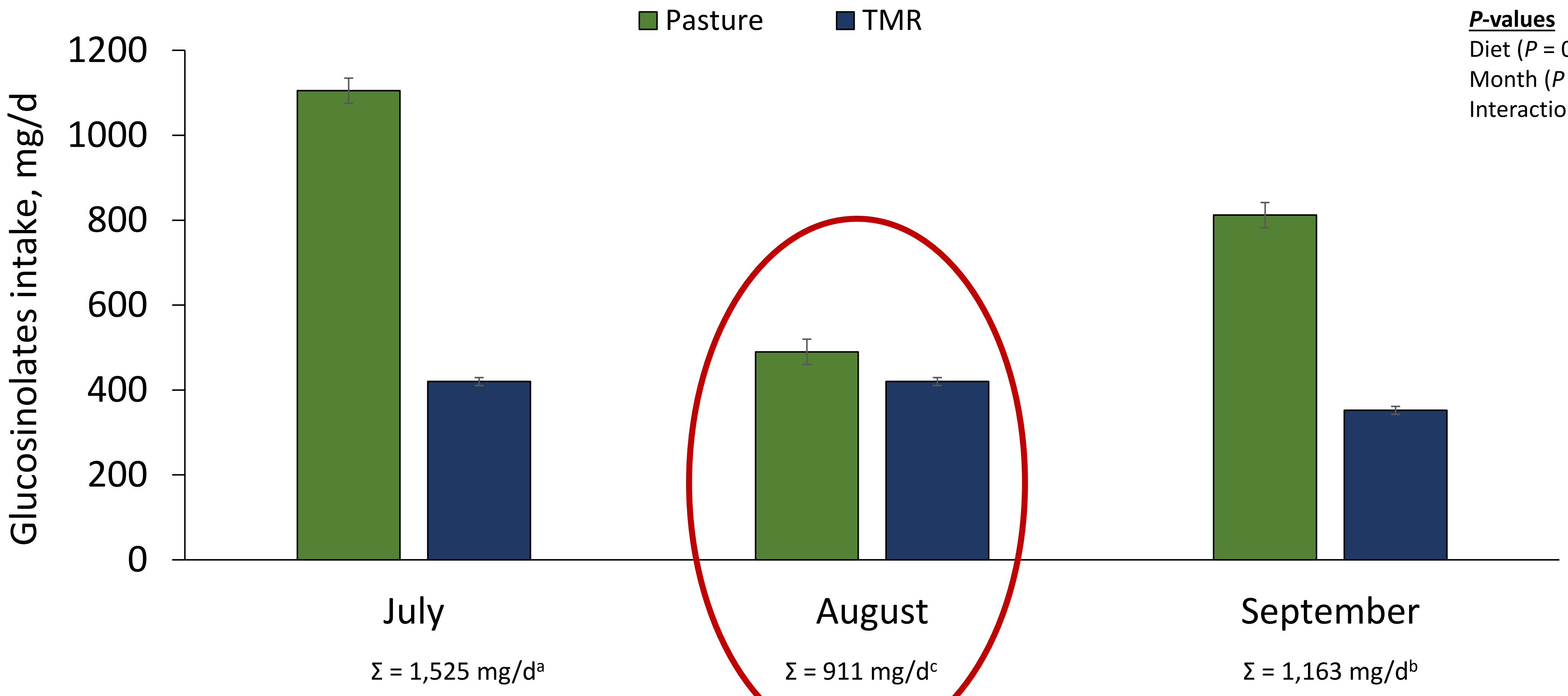
Source: Tripathi and Mishra (2007)

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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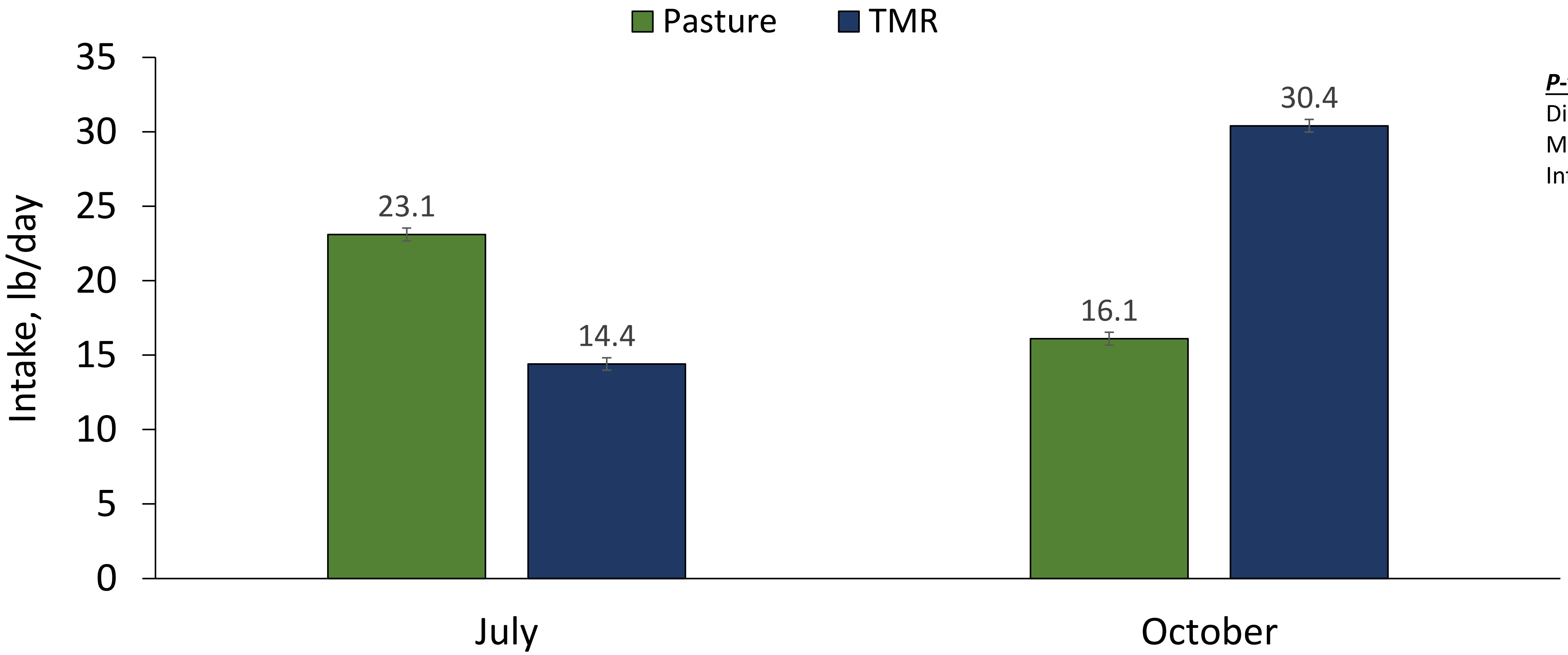
Pasture and TMR intake during the grazing season



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

Source: Brito et al. (unpublished)

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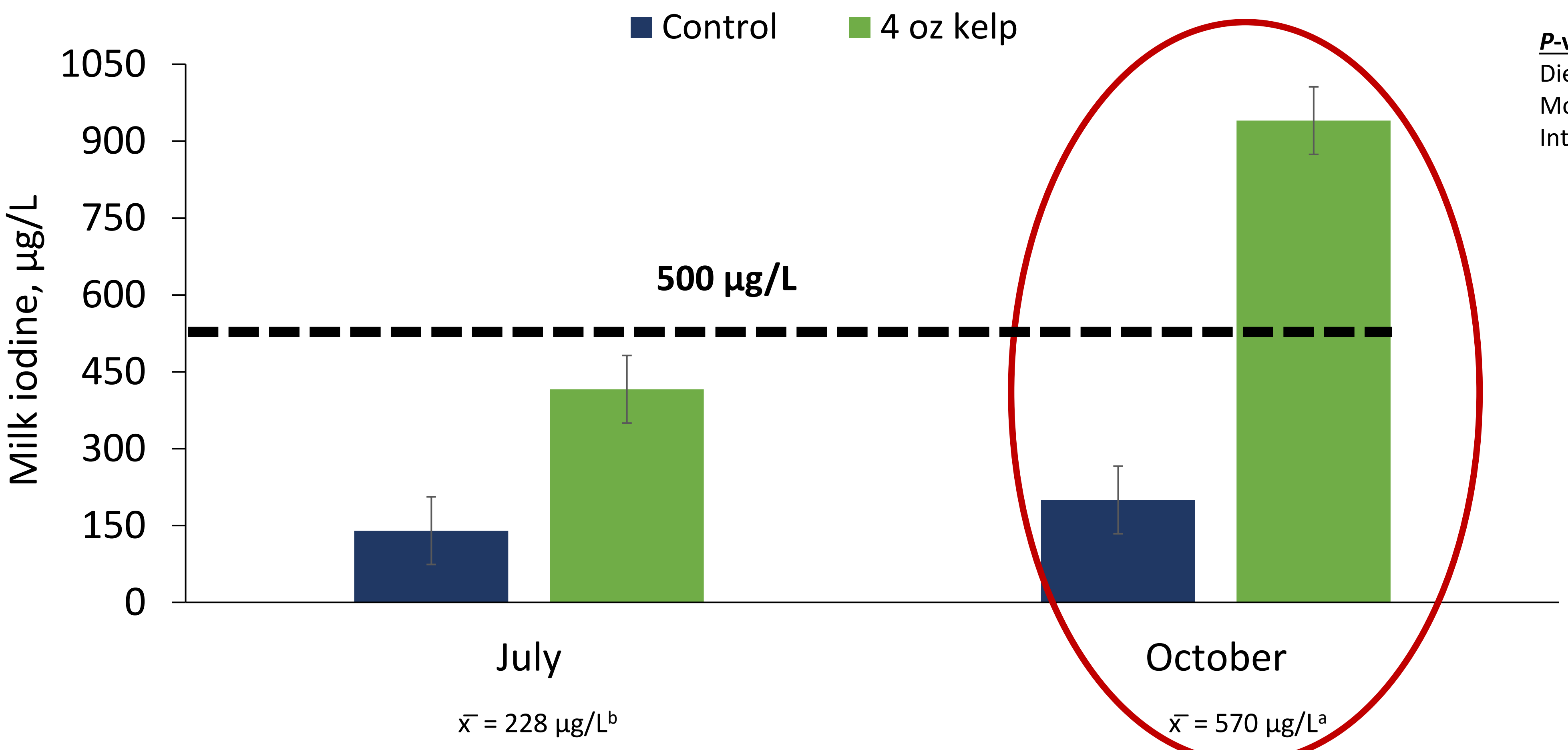
Milk iodine concentration in grazing cows fed kelp meal



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

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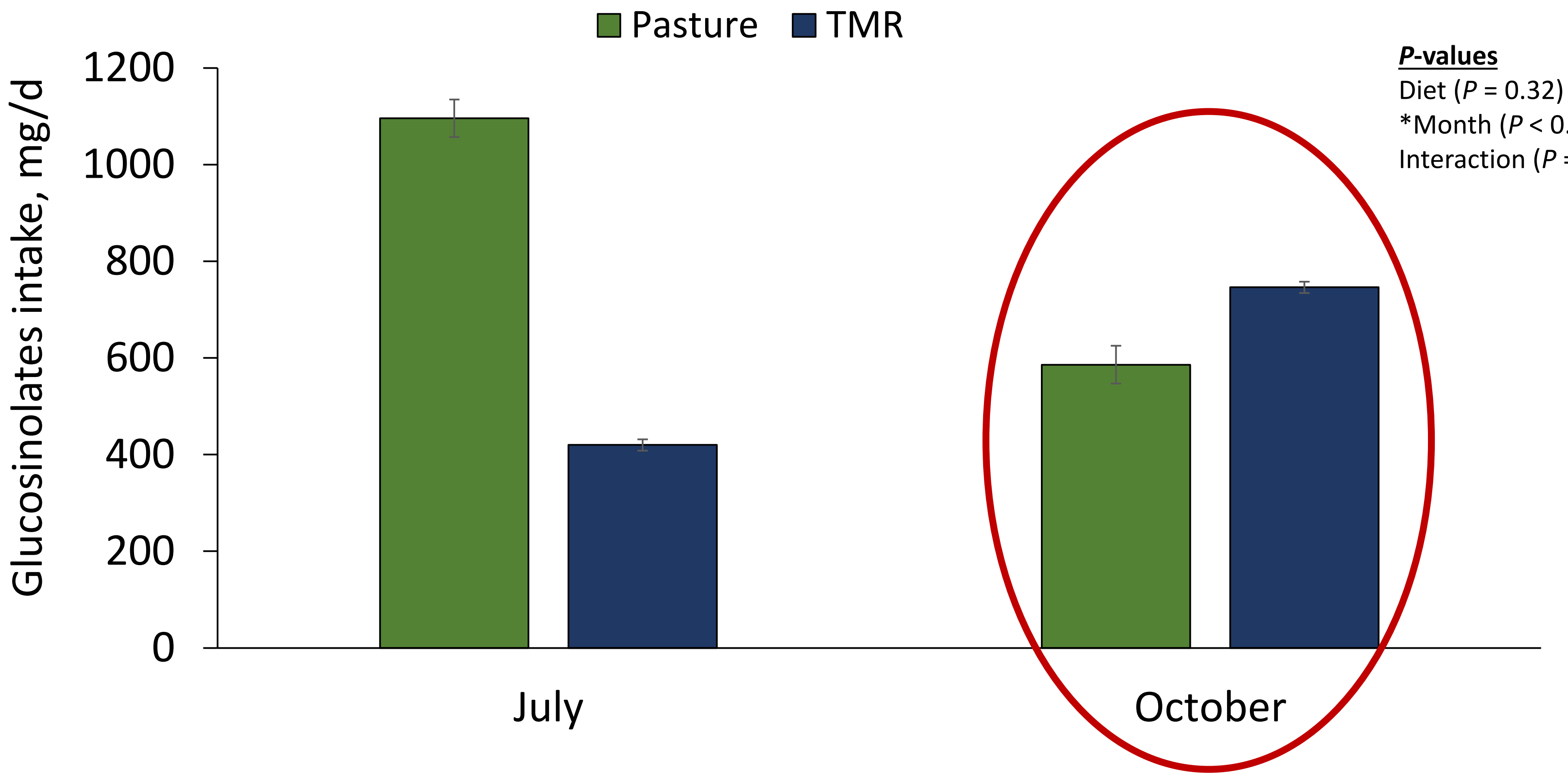
Source: Brito et al. (unpublished)

Glucosinolates intake during the grazing season



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

Σ= 1,525 mg/d[a]

Σ = 1,332 mg/d[b]

Source: Brito et al. (unpublished)

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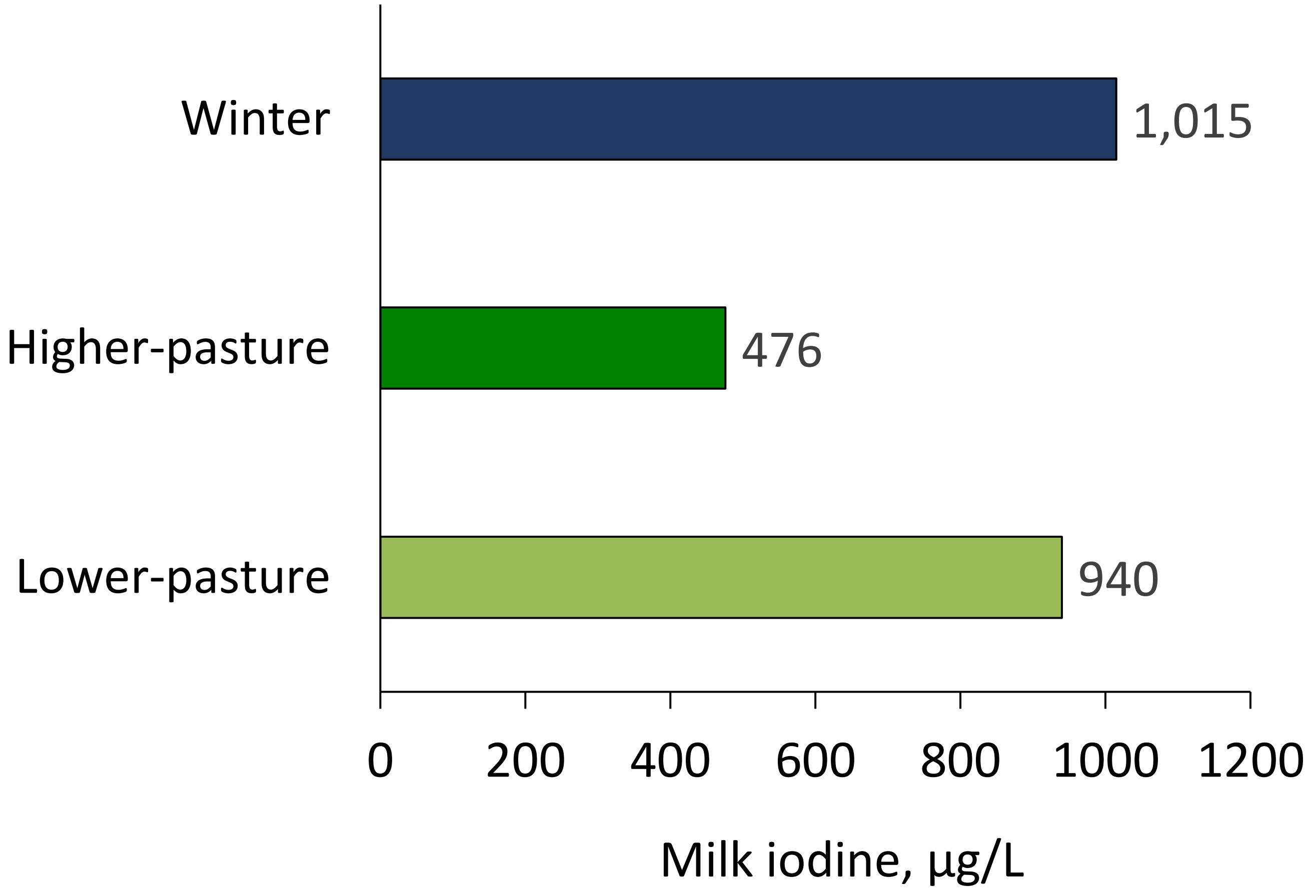
Milk iodine concentration in dairy cows fed 4 oz of kelp meal during the winter[1] and summer seasons[2]



[1]Winter study: Antaya et al. 2015
[2]Summer study: Brito et al. (unpublished)

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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

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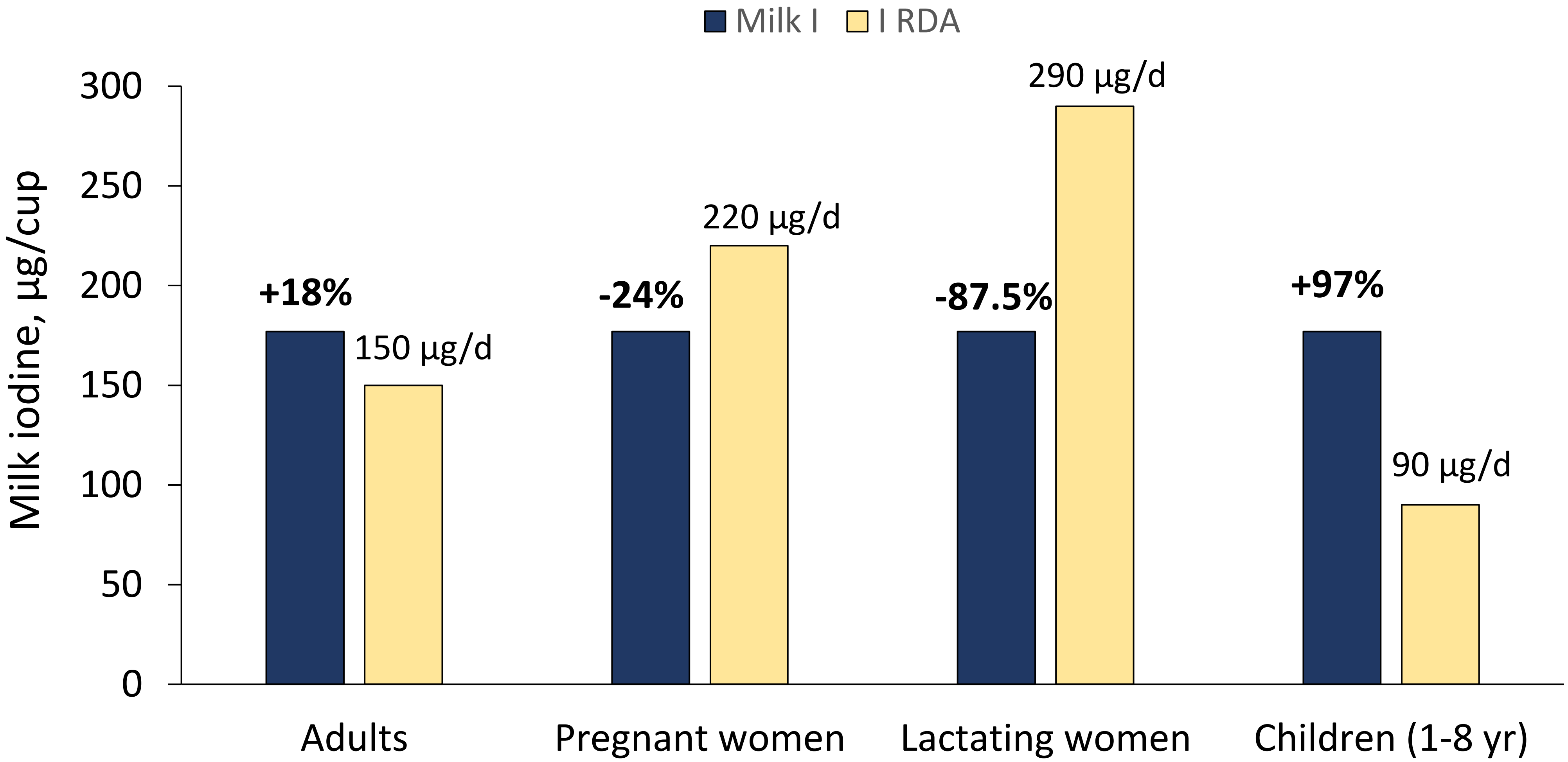
Iodine intake per cup of milk from cows fed 4 oz of kelp meal during the summer relative to iodine RDA[1]



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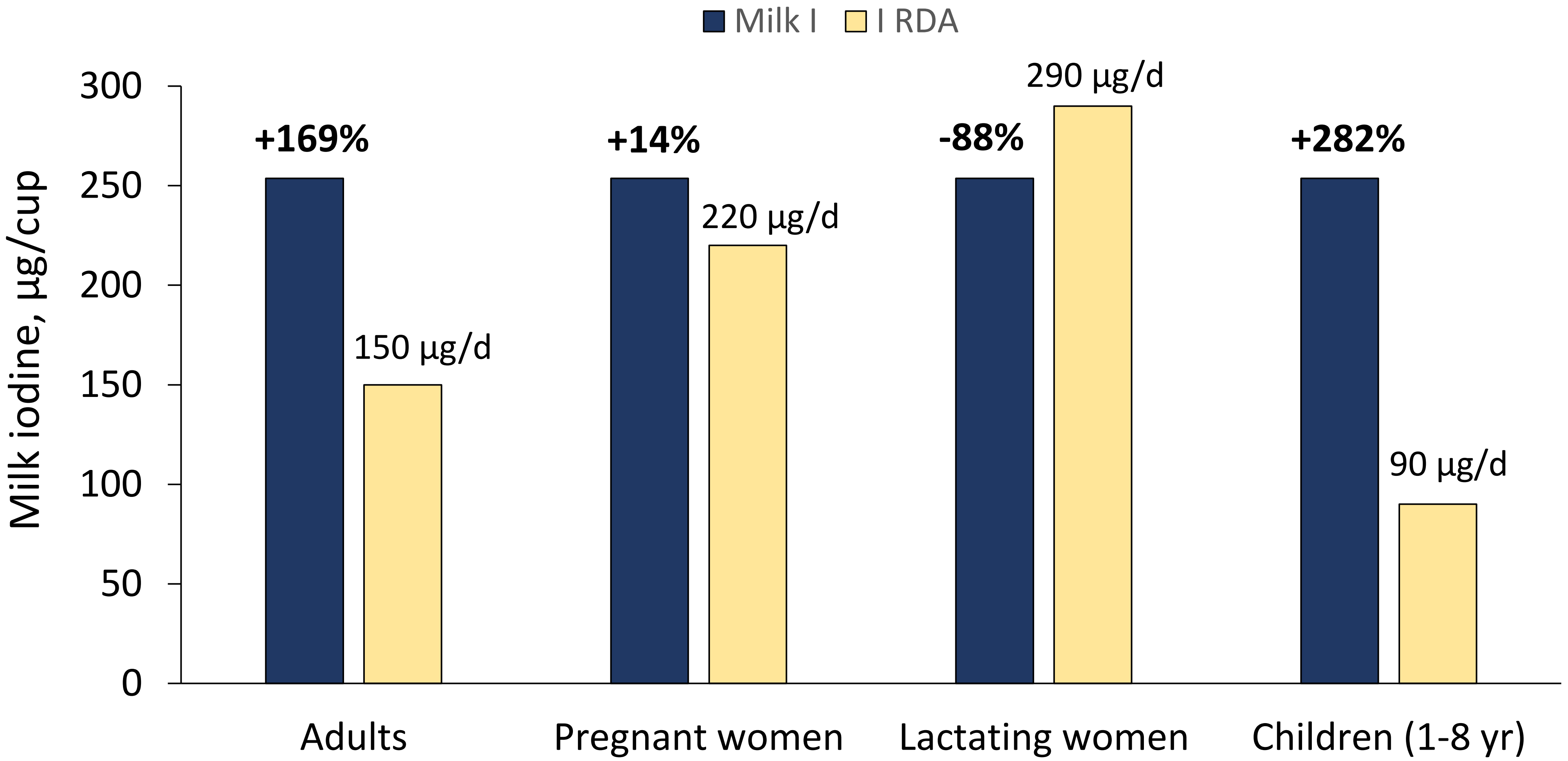
[1]Based on the US Institute of Medicine (2001) recommendations
RDA = recommended dietary allowance

Iodine intake per cup of milk from cows fed 4 oz of kelp meal during the winter 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)

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

Sarah C. Bath[1], Sarah Hill[2], Heidi Goenaga Infante[2], Sarah Elghul[1], Carolina J. Nezianya[1] and Margaret P. Rayman[1]*

[1]*Department of Nutritional Sciences, Faculty of Health and Medical Sciences, University of Surrey, Guildford, Surrey GU2 7XH, UK*

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

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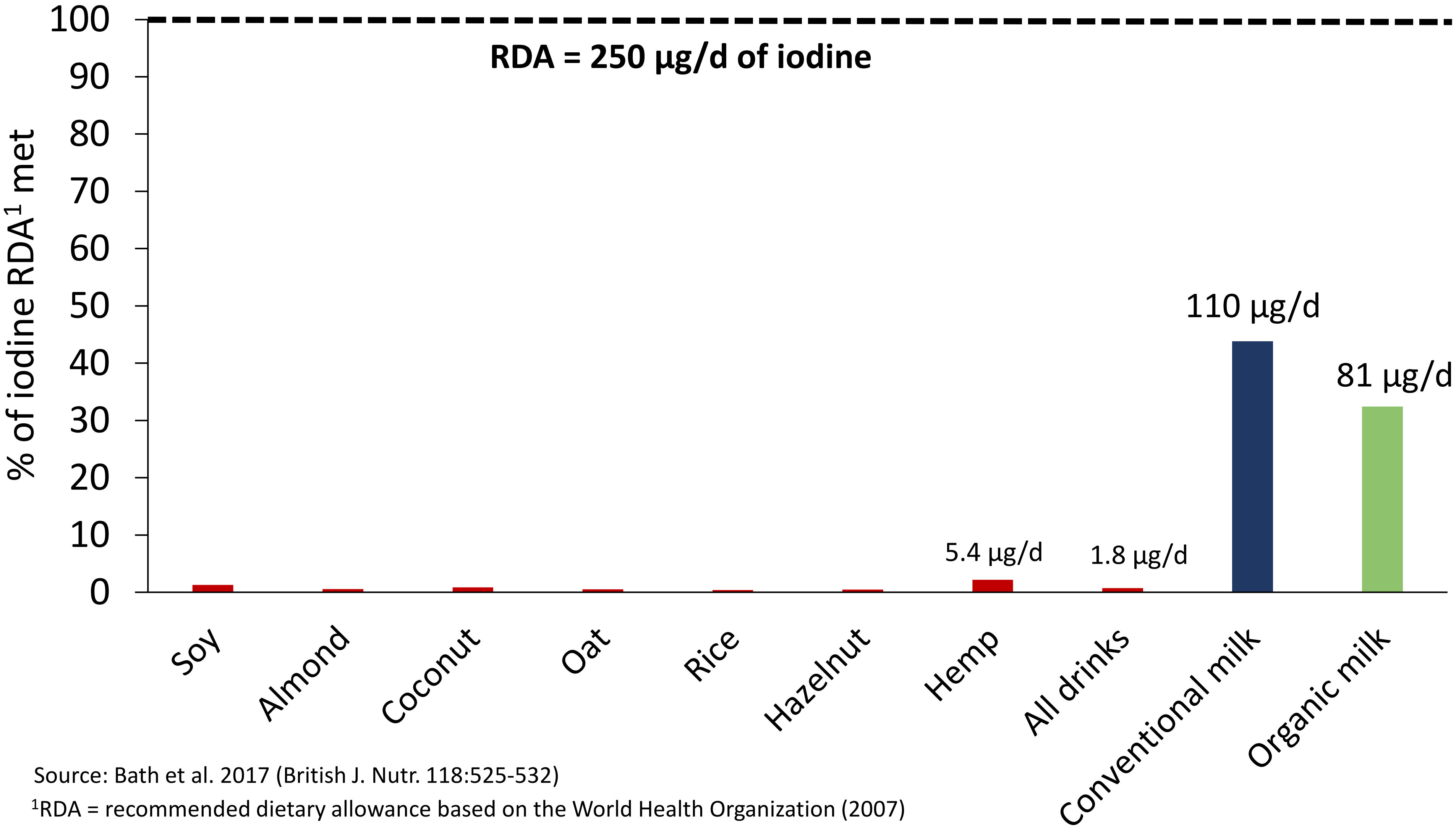
Iodine intake per cup of cow's milk and plant-based drinks relative to RDA for pregnant and nursing women



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

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

Summary

- Kelp meal supplementation effectively increases the concentration of iodine in milk
- However, there are concerns and opportunities regarding the impact of iodine in human health

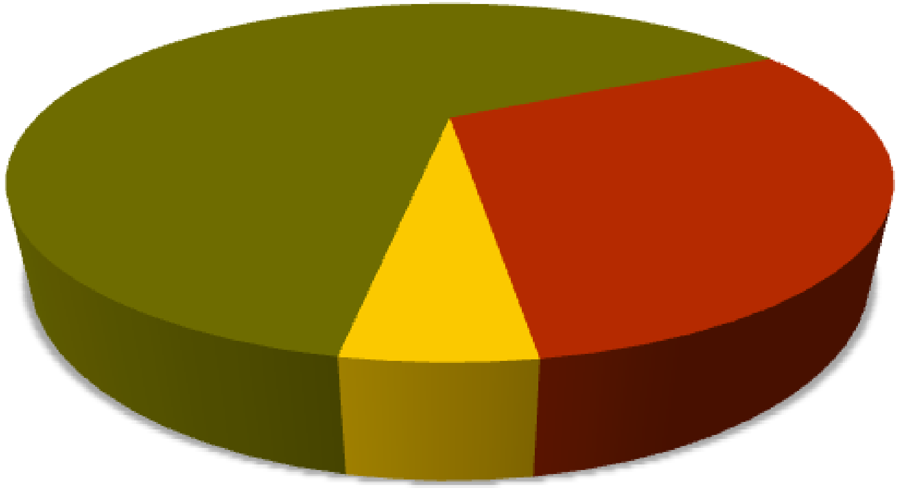
Workshop objectives

- Present research data regarding the use of kelp meal as a supplement for dairy cows and associated implications on milk production, milk iodine, and animal and human health

- Present research data about the concentration of beneficial fatty acids in organic 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



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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

WILEY Food Science & Nutrition Open Access

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)

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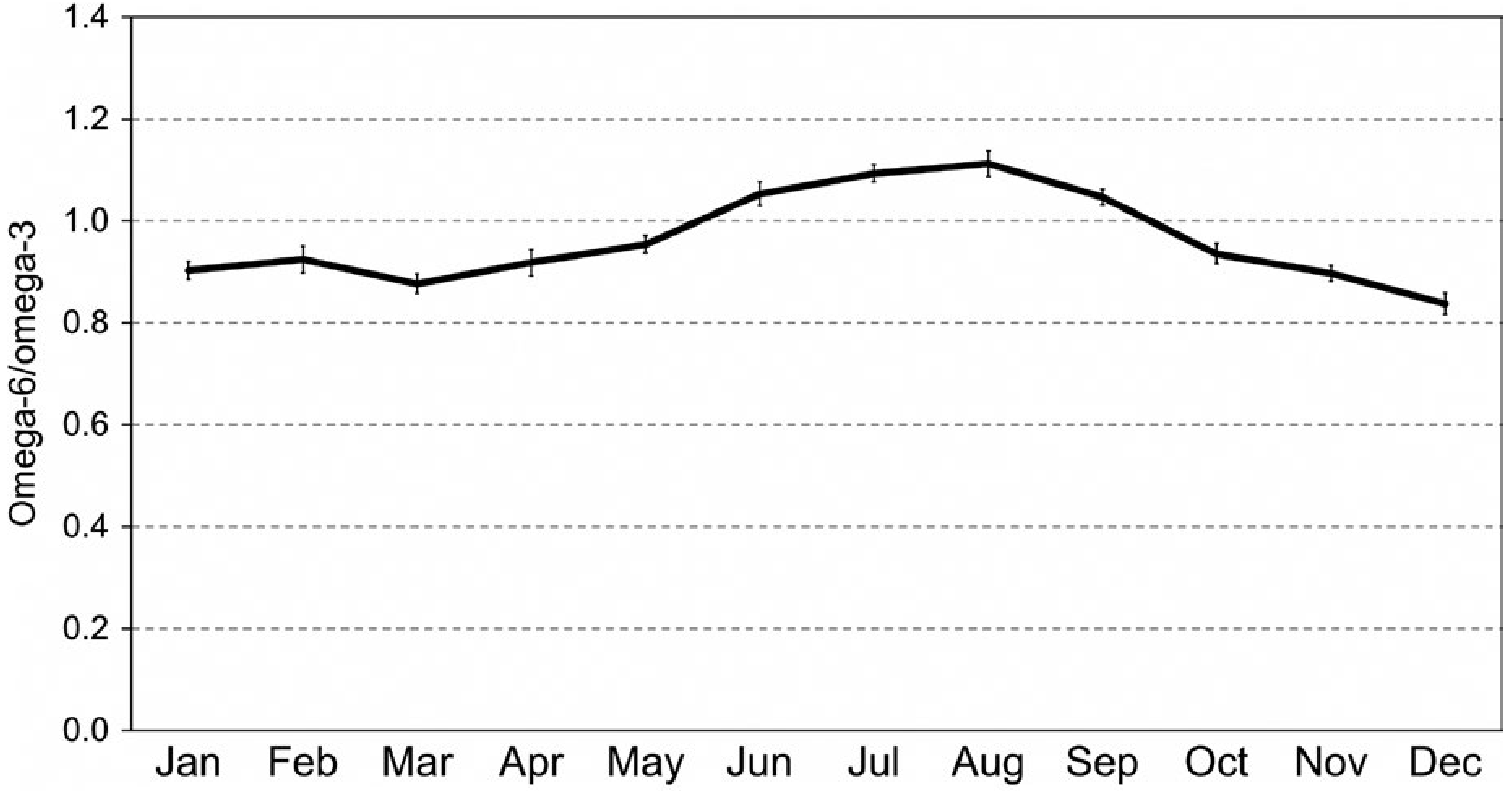
Comparison of key fatty acids (% of total) obtained from conventional, organic, and organic grass-fed whole milk (Grassmilk™)

	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



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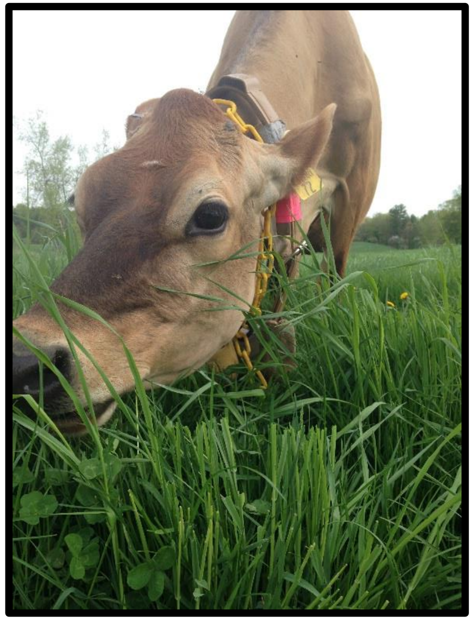
Source: Benbrook et al. 2018 (Food Sci Nutr. 6:681–700)

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 milk



- Regional and temporal variation in ω-3 fatty acids, CLA, and ω-6/ω-3 ratio was relatively small so that consumers are ensured to purchase a consistent product

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Final considerations

- Kelp meal supplementation may provide farmers with opportunities to improve animal health, but further research is needed
- Kelp meal is a high cost supplement ($50-60/50-lb bag)
- There is a critical need for developing a comprehensive evaluation of iodine concentration of retail organic milk
- Organic milk, particularly grass-fed is an excellent source of ω-3 fatty acids and CLA implying that management strategies to increase forage intake in organic and conventional sector should be implemented

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Acknowledgments

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