ENERGY VALUES FOR HUMAN MILK

U.S. and Canadian Human Milk Composition Initiative (HMCI)

Agenda

- **HMCI Overview (Ashley Vargas)**
- Historical data sources for energy for human milk (Kellie Casavale)
- New data sources for energy for human milk (Kathryn Hopperton)

Goal of The Human Milk Composition Initiative (HMCI)

Support coordination of the development of human milk composition data in the U.S. and Canada for use by federal policy, program, and other stakeholders.

Purpose: To support nutrition and dietary monitoring, guidelines, education, and other policy, programs, and regulations in maternal and child health.

HMCI Leadership

National Institutes of Health

Ashley Vargas, PhD, MPH, RDN *U.S. Coordinator
Kimberlea Gibbs, MPH, RDN, CHES *Executive Secretary
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Agenda

- HMCI Overview (Ashley Vargas)
- **Historical data sources for energy for human milk (Kellie Casavale)**
- Factors influencing the energy content for human milk (Kathryn Hopperton)

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FDA U.S. FOOD & DRUG ADMINISTRATION

Energy Values for Human Milk Used in Current DRIs

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Food and Drug Administration, HHS

Icie Macy Hoobler – An Exemplar of Strength and Excellence

FDA

1920
Received a PhD from Yale (4th woman to receive a degree in Physiological Chemistry)

1923
In World War II, was a member of the National Research Council's Food and Nutrition Board

1892 – 1984

1946
Francis P. Garvan Medal honoring women in Chemistry and for her investigations on the effect of diet on the composition of mother's milk

Awards
22 citations, awards, and honors including the Mendel Award by the Nutrition Foundation, Inc.

A Pioneer

- ✓ Determined the most effective means of enhancing dairy milk with Vitamin D which proved essential to the fight against Rickets.
- ✓ Her analysis of human milk composition unveiled its vitamin and antibody content, and uncovered the lack of a mother-baby boundary for artificial compounds like alcohol or drugs
- ✓ Carried out experiments in nutrition that allowed the government to formulate meals for children that curbed scurvy and growth irregularities
- ✓ Through her studies of the mother-fetus dyad, determined the crucial role of pre-natal care in child and mother health

Sources: Dale Debakcsy; Article in print on Jan. 13, 1984, Section D, Page 15 of the National edition with the headline: Icie Macy Hoobler dies at 91; nutrition studies

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Background

FDA

- DRIs - Infants mostly HM composition from 1970s to early 1990s
  - All AIs and EAR for zinc and iron (with additional considerations for iron)
  - Exception – EAR for protein
  - No AMDRs for infants

Basis for most DRIs for infants
- 75 kcal/ 100 mL

Used in DRI for Energy - Lactation
- 69 kcal/ 100 mL

www.fda.gov

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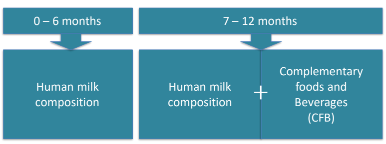
Background

- Basis for most DRIs for infants



Adequate Intakes (7 – 12 months)

Estimated energy intake from HM

$$75\ kcal/100\ mL \times 600\ mL/d = 450\ kcal/d$$

Caloric density HM — Volume HM

Estimated energy intake from CFB

$$845\ kcal/d - 450\ kcal/d = 395\ kcal/d$$

Average energy intake — Energy from HM

Estimated total nutrient intake for Adequate Intakes

Mean nutrient concentrations in HM and CFB

$$[\bar{X}]_{HM} + [\bar{X}]_{CFB} = AI$$

Mean concentration 600 mL HM — Mean concentration 395 kcal CFB

Key factors
AIs for 7 – 12 mo

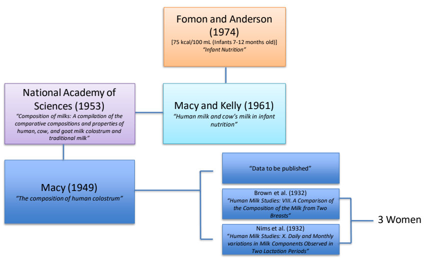
- **Caloric value of human milk**
- Mean concentration value used for the nutrient of exposure
  - Human milk
  - Complementary foods and beverages

2020
Dietary Guidelines Advisory Committee

Did not use	Instead used
• **75 kcal/100 mL** (DRI Reports) • **74 kcal/100 mL** (Standard Reference legacy nutrient profile)	• **68 kcal/100 mL** • Metabolizable energy of human milk* • Align energy contributions from human milk and infant formula

*Reilly JJ, Ashworth S, Wells JC. Metabolisable energy consumption in the exclusively breast-fed infant aged 3--6 months from the developed world: a systematic review. Br J Nutr. 2005;94(1):56-63. doi:10.1079/bjn20051464.

Energy Content of Human Milk in DRI Reports as 75 kcal/100 mL
Citation Tree



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Evidences cited for Energy Content of Human Milk in DRI Reports continued

- Brown et al. (1932)

TABLE 1.—*History of Subjects*

Observation	Subject 6, Lactation A	Subject 6, Lactation B	Subject 7, Lactation A	Subject 8, Lactation B
Age	25	27	33	29
Height, inches	62.2	62.2	68.5	62.6
Pregnancy	3	4	2	2
Birthweight of baby	7 lb., 8 oz.	8 lbs., 10 oz.	8 lbs., 3 oz.	6 lbs., 12 oz.
Date of birth of baby	Oct. 13, 1926	Aug. 20, 1928	Nov. 20, 1926	July 16, 1928
Date of study	(a) Feb. 15, 1927, 18th week (b) Dec. 8, 1927, 60th week	(c) Oct. 21, 1929, 63rd week	(a) Feb. 1, 1927, 10th week (b) Nov. 1, 1927 50th week	(a) Sept. 24, 1929, 63rd week
Weight at time of study, Kg.	(a) 63.4 (b) 64.0	(c) 63.4	(a) 65.0 (b) 64.0	(a) 81.3
Average daily milk output	2,600 cc.	3,134 cc.	2,000 cc.	1,419 cc.

Overproducing milk
~47 – 104 oz/d

Source: Brown M, Macy IG, Nims B, and Hunscher HA. Human Milk Studies: VIII. A Comparison of the Composition of the Milk from Two Breasts, Am. J. Dis. Child. 43:40-561 (Jan) **1932**.

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Evidence cited for Energy Content of Human Milk in DRI Reports continued

TABLE 2.—*Comparative Percentage Composition of Human Milk Representative of Twenty-Four Hour Production, Collected at Four Hour Intervals Simultaneously from the Right and the Left Breasts**

Subject	Study	Fat Left	Fat Right	Fat Per Cent Difference	Lactose Left	Lactose Right	Lactose Per Cent Difference	Protein Left	Protein Right	Protein Per Cent Difference	Total Solids Left	Total Solids Right	Total Solids Per Cent Difference	Calories per 100 Cc. Left	Calories per 100 Cc. Right	Calories per 100 Cc. Per Cent Difference
6	(a) av. 4 hr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	77	77	...
6	(b) 24-hr.	[illegible]	[illegible]	...	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...
6	(c) av. 4 hr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	71	1.4
7	(a) av. 4 hr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	(b) 24-hr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	(a) av. 4 hr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Average per cent difference				[illegible]			[illegible]			[illegible]			[illegible]			[illegible]

Subject	Study	Solids Not Fat Left	Solids Not Fat Right	Solids Not Fat Per Cent Difference	Total Ash Left	Total Ash Right	Total Ash Per Cent Difference	Calcium Left	Calcium Right	Calcium Per Cent Difference	Phosphorus Left	Phosphorus Right	Phosphorus Per Cent Difference	Ca:P Ratio Left	Ca:P Ratio Right	Ca:P Ratio Per Cent Difference
6	(a) av. 4 hr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...
6	(b) 24-hr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...
6	(c) av. 4 hr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	(a) av. 4 hr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	(b) 24-hr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...
8	(a) av. 4 hr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Average per cent difference				[illegible]			[illegible]			[illegible]			[illegible]			[illegible]

Source: Brown M, Macy IG, Nims B, and Hunscher HA. Human Milk Studies: VIII. A Comparison of the Composition of the Milk from Two Breasts, Am. J. Dis. Child. 43:40-561 (Jan) **1932**.

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Evidence cited for Energy Content of Human Milk in DRI Reports continued

Unpublished data may be from:

Nutritional status of children. XII.
Evaluation by computing the food intake of a group and by weighing and analyzing foods eaten by representative subjects. Thomas RU, Rutledge MM, Moyer EZ, et al.
J Am Diet Assoc. 1950;26(10):788-798.

Nutritional status of children. XIII.
Accuracy of calculated intakes of food components with respect to analytical values.
Thomas RU, Rutledge MM, Beach EF, et al.
J Am Diet Assoc. 1950;26(11):889-896.

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Human Milk in the Energy DRI

EER Lactation (adult)
EER pre-pregn. + HM energy output – weight loss

1st 6 mo	**2nd 6 mo**
EER + 500 – 170	**EER + 400 – 0**

- 67 kcal/g (~69 kcal / 100 mL)*
- 0-6 mo lactation: 780 mL/ day
- 7-12 mo lactation: 600 mL/day

* Based on human milk density of 1.03 g/mL

Butte NF, Garza C, O'Brian Smith E, Nichols BL. 1984a. Human milk intake and growth in exclusively breast-fed infants. J Pediatr 104:187–195.
Butte NF, Garza C, Stuff JE, Smith EO, Nichols BL. 1984b. Effect of maternal diet and body composition on lactational performance. Am J Clin Nutr 39:296–306.
Neville MC. 1995. Determinants of milk volume and composition. In: Jensen RG, ed. Handbook of Milk Composition. San Diego, CA: Academic Press. Pp. 87–113.

Human Milk in the Energy DRI for Lactation

Energy Content					
	Sample Size	**Participant Demographics**	**Method Used**	**Collection Method**	**Result**
Butte, 1984	45	Single site, Caucasian, high education and socioeconomic class	Bomb calorimetry	Full-expression, single breast, over 24-hr	0.64-0.68 kcal/g
Nommsen, 1991	67	Single site, Caucasian, high education and socioeconomic class	Proximate composition	Full expression, 3 times over 24 hr	0.7-0.8 kcal/g
Butte, 1992	15	Single site, Mesoamerinfians with growth faltering	Bomb calorimetry	Full-expression, alternate breast, over 24-hr	0.53-0.56 kcal/g

Volume					
	Months	**Sample Size**	**Participant Demographics**	**Method**	**Results**
Allen, 1991	0 to 6	13	Single site, all Caucasian, parity > 1	Test weighing over 24 hours	700-800 ml/day
Dewey, 1984	7 to 12	10	Single site, ethnicity and income not reported, all with college education	Test weighing over 24 hours	578-875 ml/day

Methodologically rigorous
Small samples
Non-representative populations

References

Institute of Medicine 2000. *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids.* Washington, DC: The National Academies Press. https://doi.org/10.17226/9810.

Institute of Medicine 2001. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*. Washington, DC: The National Academies Press. https://doi.org/10.17226/10026.

Institute of Medicine 2005. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. Washington, DC: The National Academies Press. https://doi.org/10.17226/10490.

Butte NF, Garza C, O'Brian Smith E, Nichols BL. **1984a.** Human milk intake and growth in exclusively breast-fed infants. J Pediatr 104:187–195.

Butte NF, Garza C, Stuff JE, Smith EO, Nichols BL. **1984b.** Effect of maternal diet and body composition on lactational performance. Am J Clin Nutr 39:296–306.

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Fomon SJ and Anderson TA. 1974. *Infant Nutrition*, 2nd edition. Philadelphia: WB Saunders. pgs. 360 and 404.

Macy IG and Kelly HJ. *Human milk and cow's milk in infant nutrition. In* Kon SK and Cowie AT (eds.): *Milk: The mammary gland and its secretion.* Vol. II. Ch. 18 New York, Academic Press, **1961**, p. 267-9, 292.

Macy IG, Kelly HJ, and Sloan RE. Composition of Milks: A compilation of the Comparative Composition and Properties of Human, Cow, and Goat Milk Colostrum, and Traditional Milk. Publ. No. 254, Washington, DC, **National Academy of Sciences - National Research Council, 1953.**

Macy IG. The composition of human colostrum and milk. Am. J. Dis.Child. 78: 589, **1949**. PMID: 18141078 DOI: 10.1001/archpedi.1949.02030050604009.

Looking Forward
Human Milk Data for DRIs

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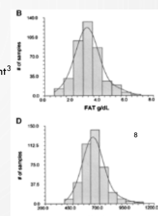
Factors That May Influence Human Milk Energy Content

- Time post-partum[1]
  - Higher fat, lactose and energy, lower protein in mature milk
- Socioeconomic status
  - Associated with higher total fat[2]
- BMI
  - Positively correlated with total fat content, in some studies with energy content[3]
- Volume of production
  - Negatively correlated with energy density[4]
    - Human milk feeding exclusivity
      - ~28% non-exclusive at 1 month, 47% by 5 months[5]
    - Infant energy requirements (sex, growth rate)[6]
- Maternal diet
  - Higher in high fat, low carbohydrate diet[7]
- Ethnicity and genetic factors



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1 Gidrewicz and Fenton, BMC Pediatr (2014) 14:216
2 Hopperton et al. AJCN (2021) 114:1523
3 Daniel et al. AJCN (2021) 113:1009
4 Nommsen et al. AJCN (1991) 53:457
5 https://www.cdc.gov/breastfeeding/data/nis_data/results.html
6 Hosseini et al. Breastfeed Med. (2020) 5:341
7 Mohammad et al. AJCN (2009) 89:1821
8 Wokcik et al. J Am Assoc (2009) 109:137

Sources of New Data – Upcoming Literature

- **International milk Composition Consortium – IMiC – expected 2022-2023**
  - 1200 dyads from Tanzania, Pakistan, Burkina Faso and Canada
  - Milk collected 3-4 months post partum, not full expression
  - Macronutrients by mid-infrared analyzer
  - Canadian subjects from the CHILD cohort, n=400
  - Associations with infant growth and developmental outcomes
  - IMiC: https://www.milcresearch.com/imic.html
- **Mothers, Infants and Lactation Quality study – MILQ – Expected completion December 2022**[1]
  - 1000 subjects, 250 each from Bangladesh, Brazil, Denmark and the Gambia
  - Milk collected at 4 time points: 24-48 hr, 1-3 months, 3.5-5.9 months, and 6-8.5 months
  - Full breast expression
  - Milk volume – mother to child deuterium method or 24 hr test weighing (Denmark)
  - Macronutrients by mid-infrared analyzer
  - Aims to establish reference ranges for nutrients

Methods not intended for energy quantification, but will provide information on milk volume and sources variability in large multiethnic cohorts

Allen *et al.* Curr Dev Nutr (2021) 5:116

Sources of New Data

HMCI is conducting a scoping review
for completion in the fall of this year to determine
which nutrients have enough publications that they could benefit from a
systematic review for potentially generating an interim human milk
reference for federal food composition databases

Will identify publications that have kcal data for human milk,
but only from U.S. and Canadian populations

NIH's National Institute on Child Health and Human Development recently
received scientific concept clearance to move forward on an early life
nutrition study called
"PRiMORDIAL"
that includes a deep characterization of human milk
Awaiting availability of funds in FY23
https://www.nichd.nih.gov/about/advisory/council/archive/202110/PRIMORDIAL-PGNB-202110

For more information about either project: ashley.vargas@nih.gov

Conclusions

- The energy content of human milk is variable
- Parent and infant characteristics likely affect the energy content of human milk
  - More research is needed to understand the impact
- New studies reporting in the next two years will provide new data on volume of human milk production and sources of variability in macronutrient composition of human milk from large multi-ethnic cohorts

THANK YOU AND QUESTIONS

U.S. FOOD & DRUG ADMINISTRATION ODPHP Office of Disease Prevention and Health Promotion NIH National Institutes of Health USDA United States Department of Agriculture Agricultural Research Service Canada