

Comparison of Calcium and Vitamin D Content in a Market Basket Survey of Plant-based Milk Alternatives

Benjamin Redan, PhD
Research Chemist
CFSAN/Office of Food Safety

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Background

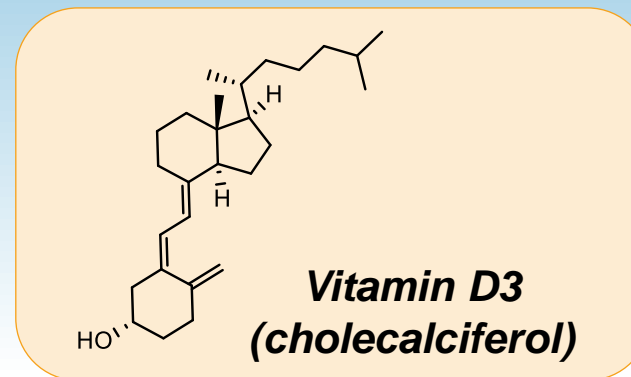
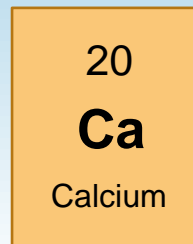
- Although fluid milk consumption has been declining in the US, there has been an increase in consumers including plant-based milk alternatives (PBMAs) in their diets [1]
- The *Dietary Guidelines for Americans* has identified the dairy group as being a key source of calcium and vitamin D in the American diet [2]
- Calcium and vitamin D are essential micronutrients with roles in maintaining immune function, bone health, and a number of other biological functions [2,3]



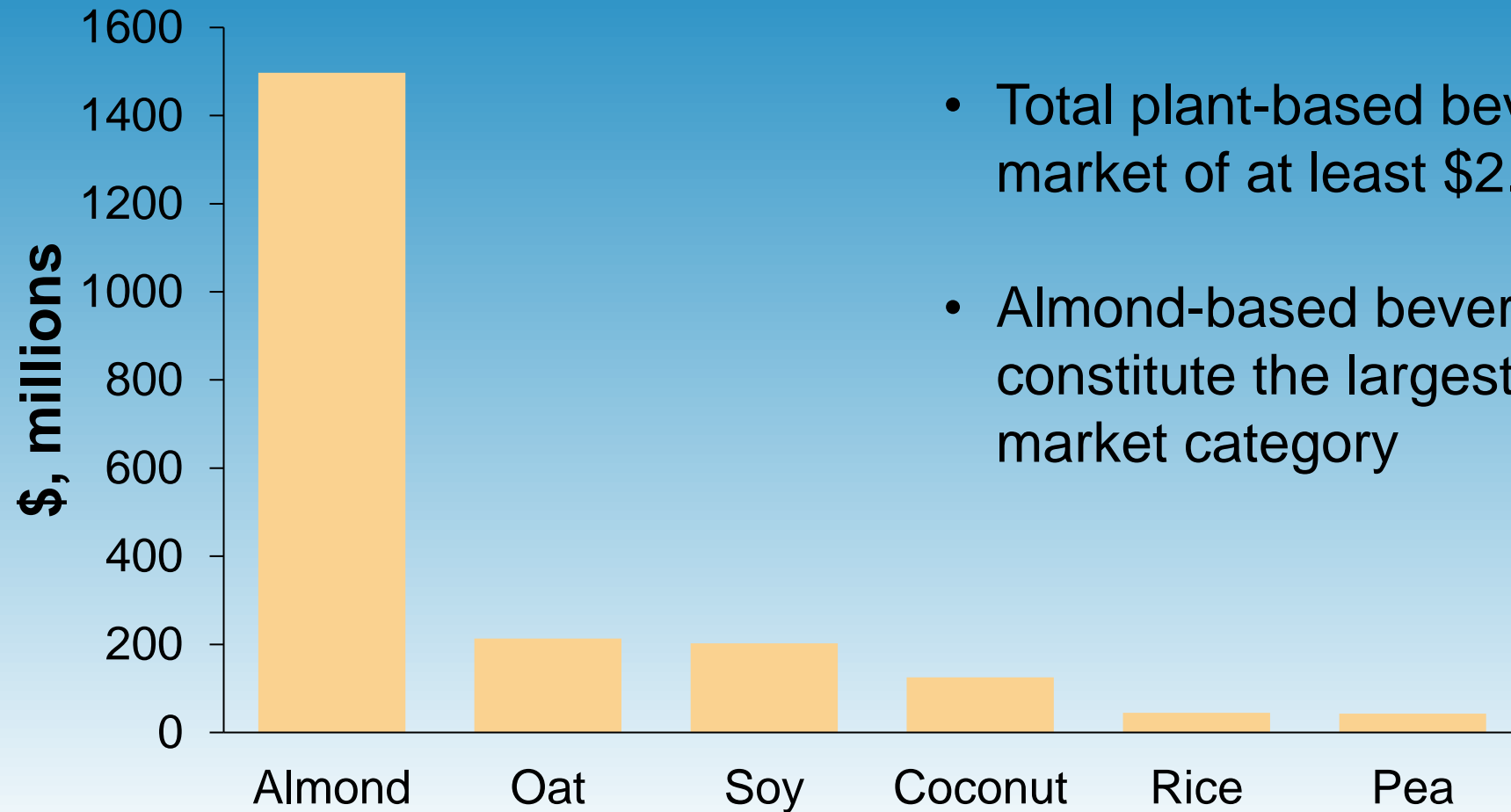
1. Stewart et al. (2020) Are plant-based analogues replacing cow's milk in the American diet? *J. Agric. Appl. Econ.*, 52, 562-579.
2. USDA and HHS. (2015). *Dietary Guidelines for Americans 2015-2020*. (8th ed.). Washington, DC: GPO.
3. Institute of Medicine, Food and Nutrition Board. *Dietary Reference Intakes*.

Background, cont'd

- For those >18 years old, the recommended daily allowances (RDA) are **1,000-1,200 mg/day for calcium** and **15-20 µg/day for vitamin D** [1]
- Data on the calcium and vitamin D amounts in PBMA are necessary when comparing the nutritional content in milk to PBMA
- *However, there is limited publicly available information on the amounts and variability of these micronutrients in PBMA*



Overview of the PBMA Market in the US



- Total plant-based beverage market of at least \$2.36 billion
- Almond-based beverages constitute the largest PBMA market category

Data spans conventional multioutlet channels for 52 weeks to Sept 2020.

FoodNavigator-USA. "Oatmilk edges past soymilk for #2 slot in US plant-based milk retail market"

Overview of PBMA Product Sampling

Almond Cashew Coconut Hemp Oat Pea Rice Soy



Brands ($n=2-3$)

Within a Lot ($n=3-5$)

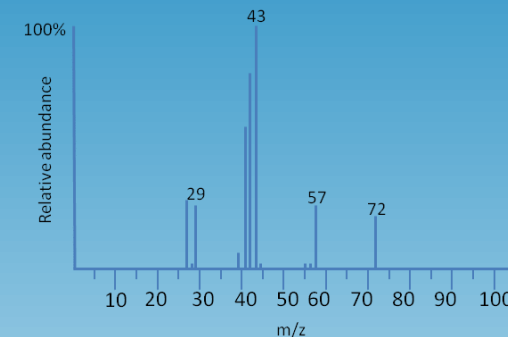
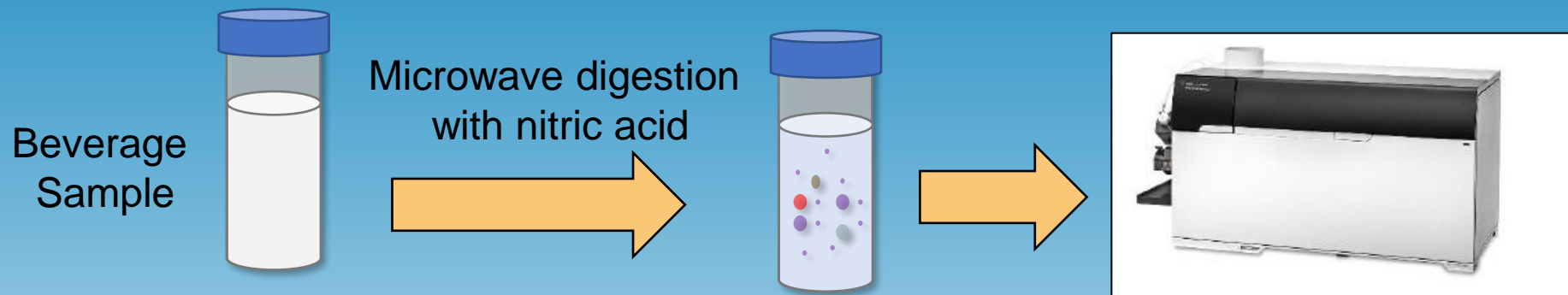
Across Three Lots
for Almond

- Samples from 10 retail markets in the greater Chicago area plus an online retailer

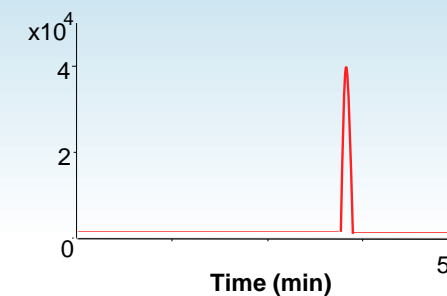
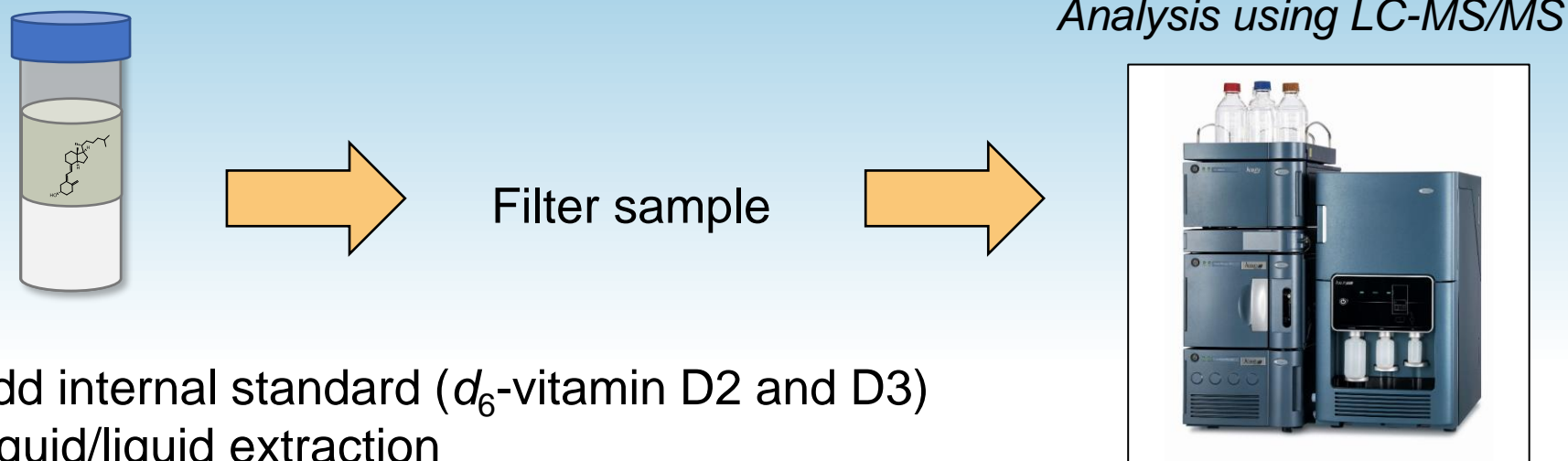
**Total of 85-90 unique
sample units**

Vitamin and Mineral Analysis Methodology

Calcium Analysis



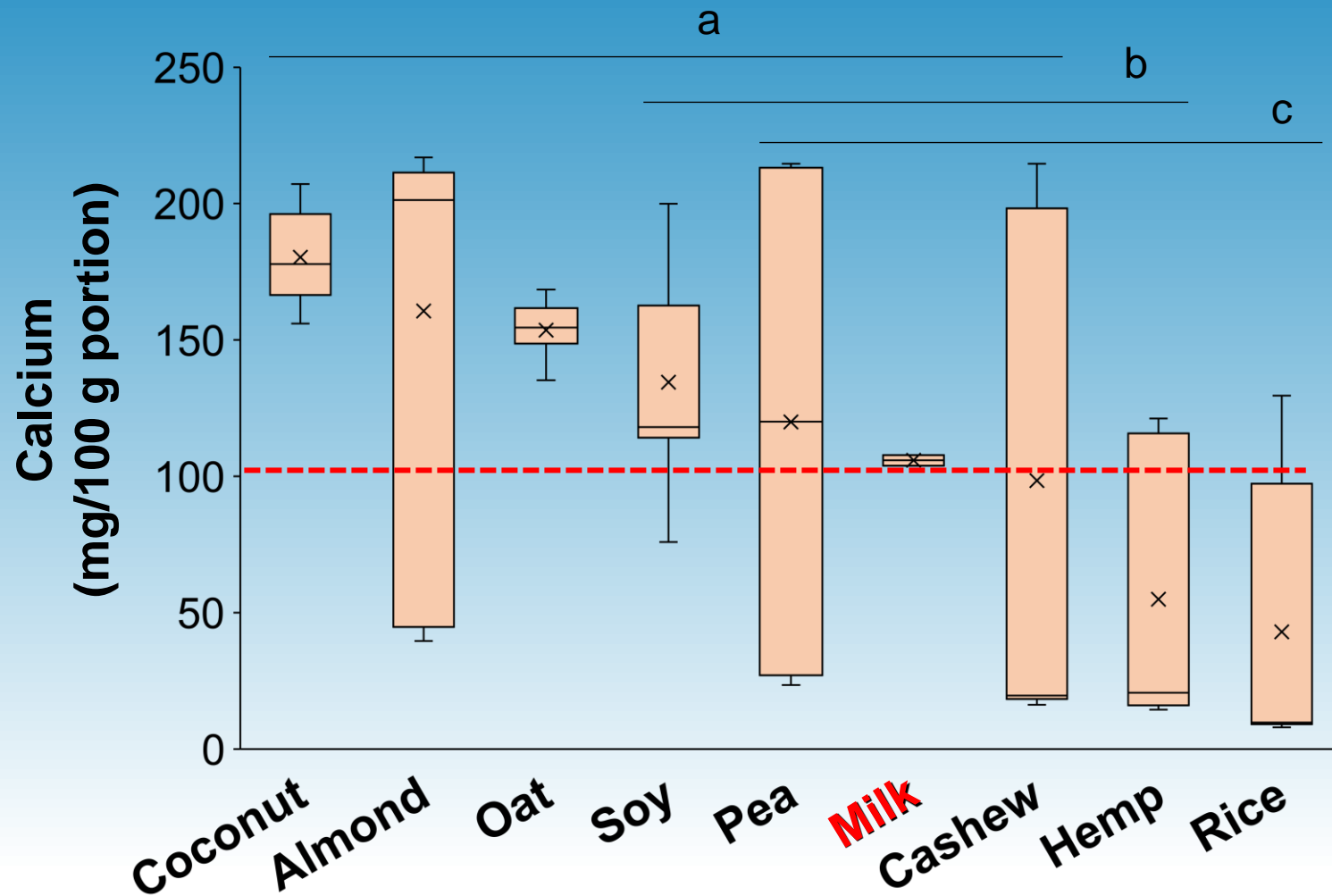
Vitamin D Analysis



- Add internal standard (d_6 -vitamin D2 and D3)
- Liquid/liquid extraction

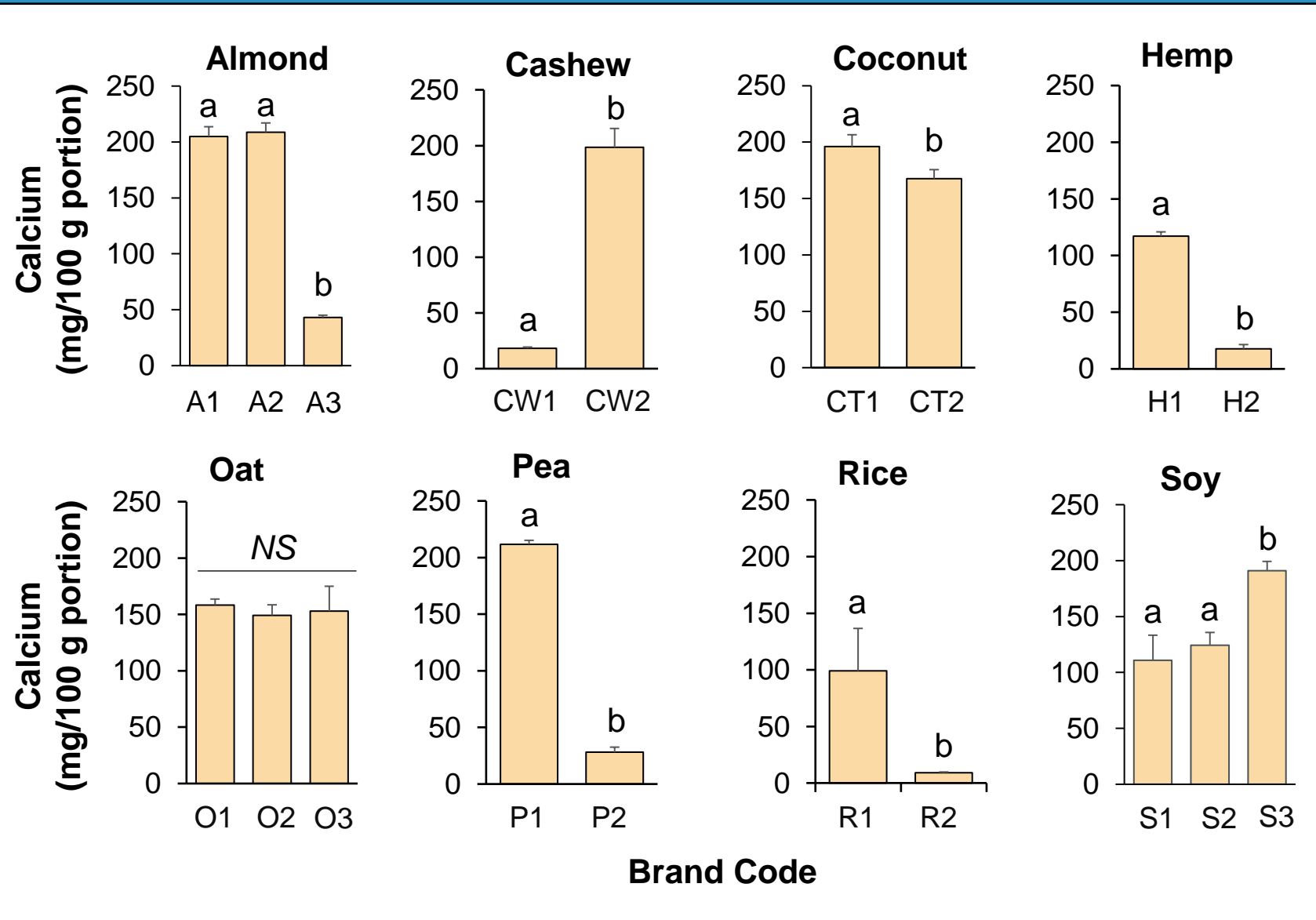
Calcium Analysis

Measured Calcium in a Market Basket of PBMA's



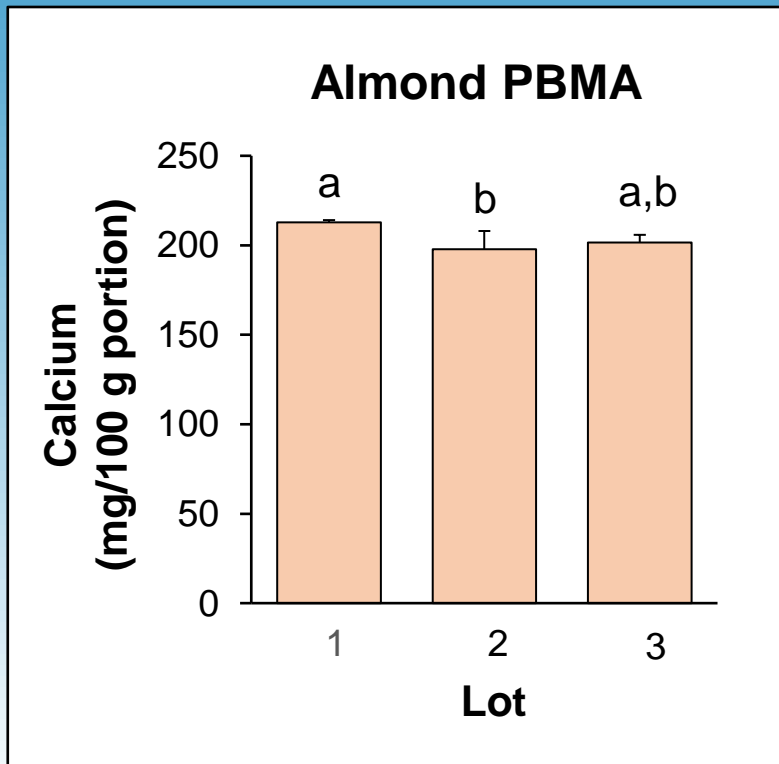
- 85 unique samples were analyzed using ICP-MS
- Sample data are grouped by PBMA type
- Nutrition Facts label declared that calcium was added to all PBMA's except for one rice brand
- Average calcium amounts in milk were not significantly ($P < 0.05$) different compared to any PBMA type

Calcium Variability Across Different Brands of PBMA



- PBMA formulated with added calcium appeared to be the major driver of calcium levels
- Only one brand did not contain added calcium (rice PBMA R2), which was ~90% lower than levels in milk.
- Only oat PBMA did not contain different amounts of calcium across brands
- Values not sharing the same letter within PBMA type contain significantly different ($P < 0.05$) calcium amounts as determined by Tukey's HSD post hoc test

Calcium Variability Across Different Lots of Almond PBMA



- There was a small but significant ($P < 0.05$) difference in calcium amounts across three lots of brand A almond beverage ($n = 10$)
- Values not sharing the same letter are significantly different ($P < 0.05$) as determined by Tukey's HSD post hoc test

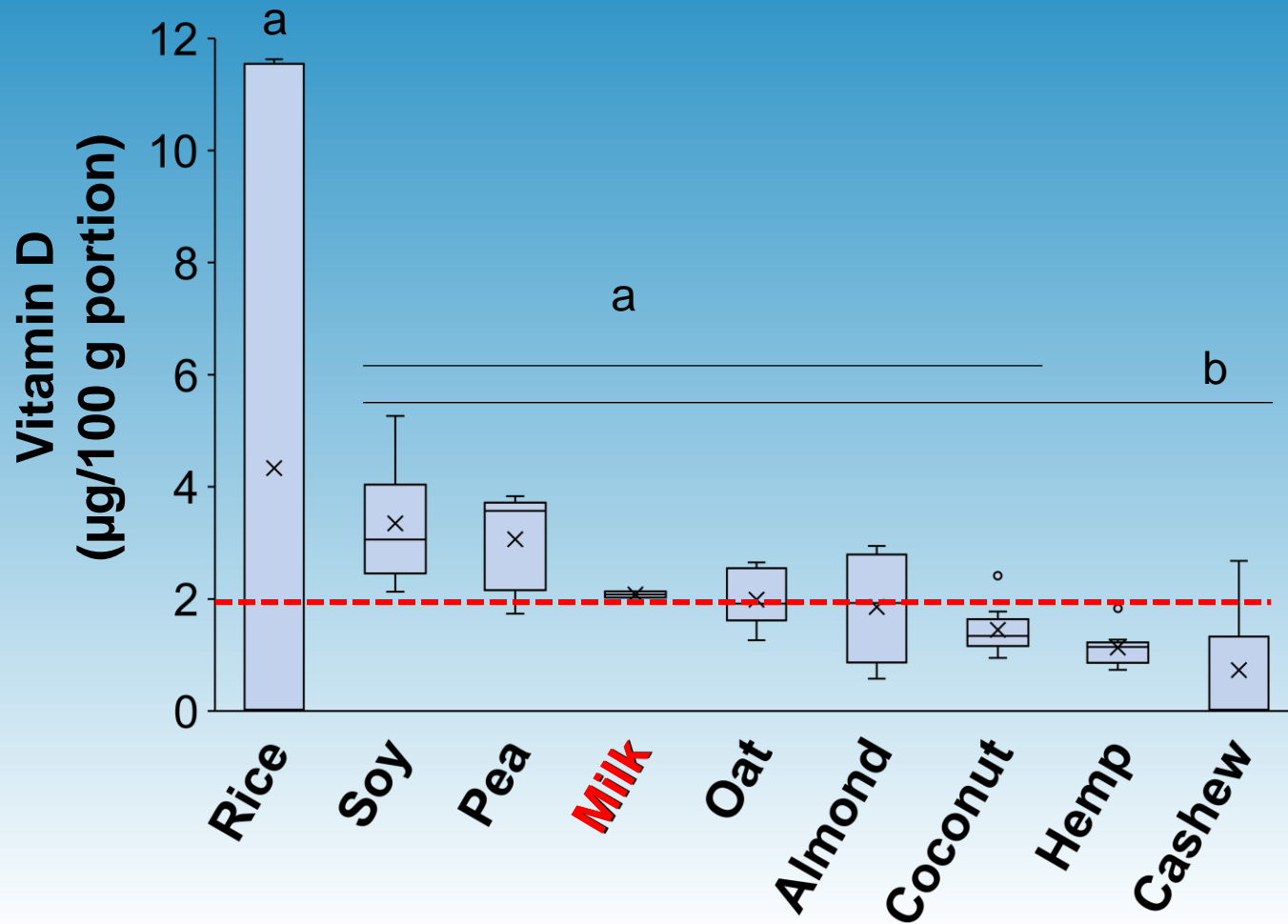
Type/brand code	% Difference from Declared Value for Calcium	Calcium Ingredient(s) on Nutrition Facts Label
Milk	-9.4	-
Almond		
Almond/A1	+9.0	calcium carbonate
Almond/A2	+11.2	calcium carbonate
Almond/A3	-20.2	calcium carbonate
Oat		
Oat/O1	+8.2	calcium carbonate
Oat/O2	+14.6	calcium carbonate; tricalcium phosphate
Oat/O3	+4.8	calcium carbonate; tricalcium phosphate
Soy		
Soy/S1	-11.2	calcium carbonate
Soy/S2	-0.8	calcium carbonate
Soy/S3	+1.6	calcium carbonate; tricalcium phosphate

Calcium

- % difference of the average measured amount of calcium vs. declared value on the Nutrition Facts label
- All 9 brands were within ~20% of the declared value
- 6/9 brands were above the declared value

Vitamin D Analysis

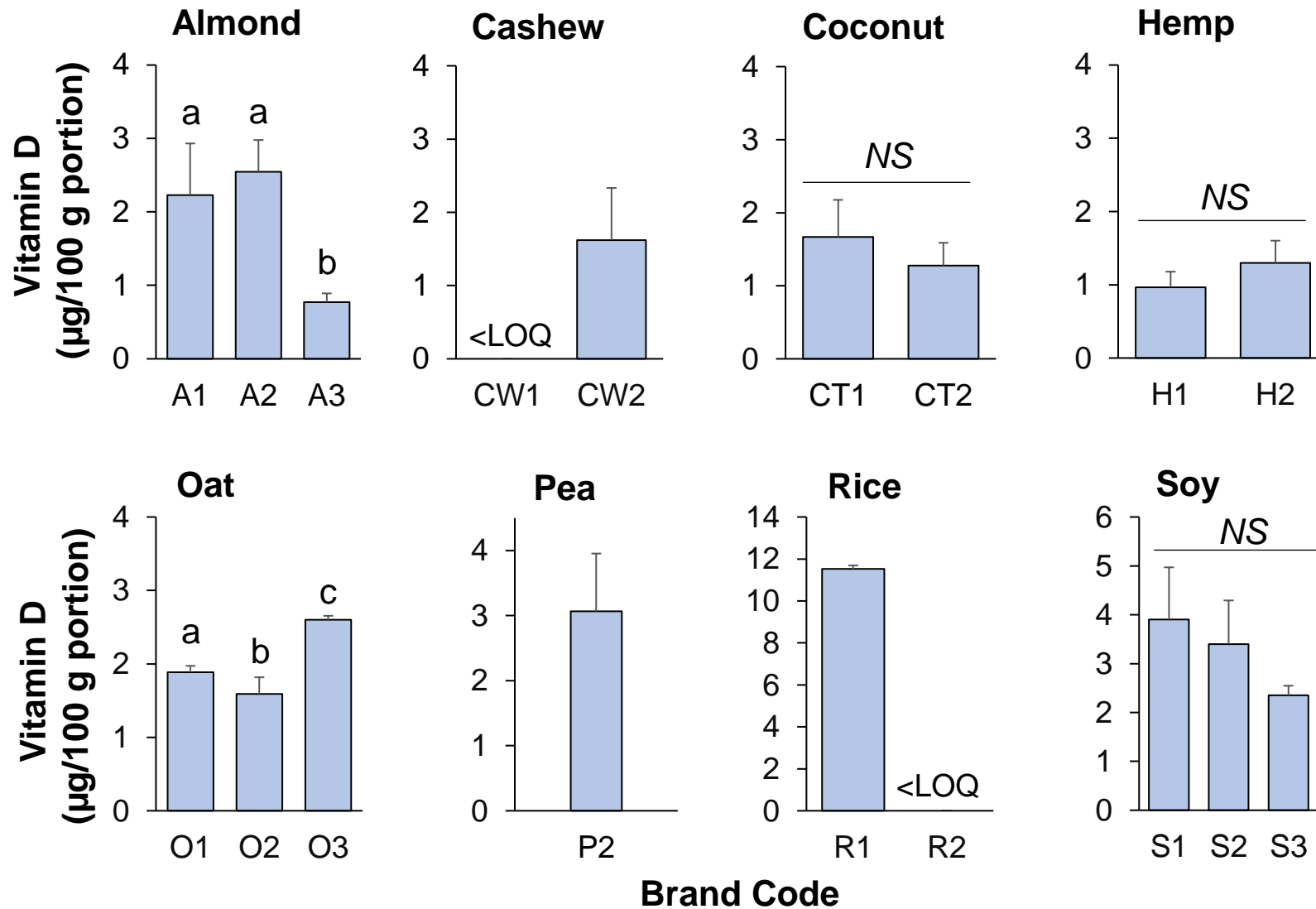
Measured Vitamin D in a Market Basket of PBMA



- Samples ($n=90$) were analyzed for vitamins D2 and D3 using LC-MS
- Sample data are grouped by PBMA type
- PBMA with vitamin D added by the manufacturer contained the D2 form except for one brand of oat and pea PBMA (O2 and P2), which contained D3
- Average vitamin D amounts in milk were not significantly ($P<0.05$) different compared to any PBMA type

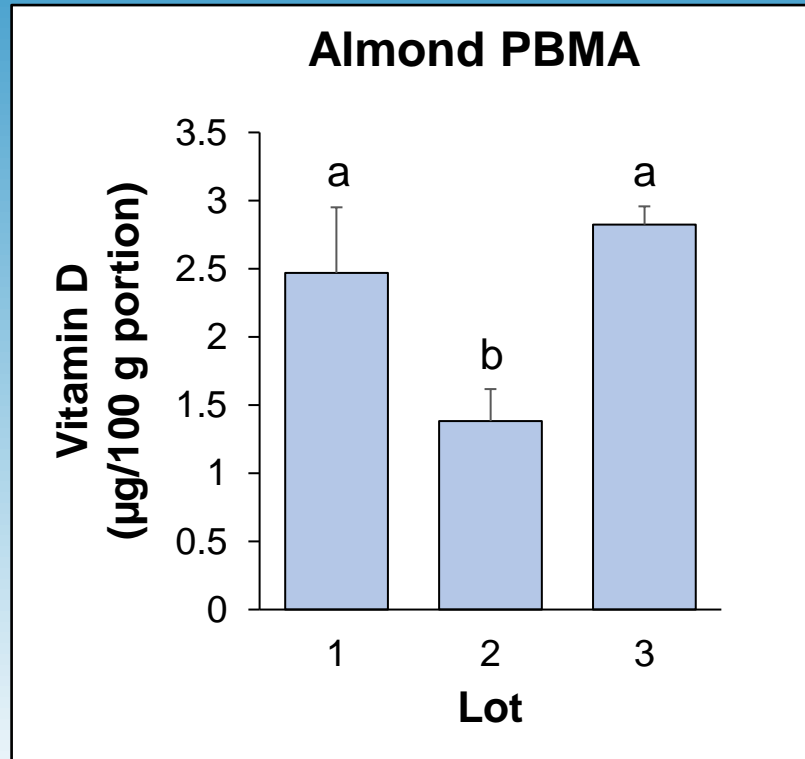
Values not sharing the same letter are significantly different ($P<0.05$) as determined by Tukey's HSD post hoc test.
1µg vitamin D=40 IU.

Vitamin D Variability Across Different Brands of PBMA



- There was no detectable vitamin D unless added to the product by the manufacturer
- Three PBMA types (coconut, hemp, soy) did not have significantly ($P < 0.05$) different vitamin D amounts across brands
- Vitamin D in brand P1 could not be determined due to poor analyte recovery
- Values not sharing the same letter within PBMA type are significantly ($P < 0.05$) different as determined by Tukey's HSD post hoc test

Vitamin D Variability Across Different Lots of Almond PBMA



- Significant ($P<0.05$) difference in vitamin D amounts across three lots of brand A almond PBMA ($n=10$)
- Values not sharing the same letter are significantly different ($P<0.05$) as determined by Tukey's HSD post hoc test

Type/brand code	% Difference From Declared Nutrition Facts Label Value for Vitamin D
Milk	-1.0
Almond	
Almond/A1	+6.2
Almond/A2	+154.0
Almond/A3	-63.3
Oat	
Oat/O1	+11.2
Oat/O2	+22.3
Oat/O3	+73.3
Soy	
Soy/S1	+56.0
Soy/S2	+36.0
Soy/S3	+80.8

Vitamin D

- % Difference of the average measured amount of vitamin D vs. declared value for the top three most popular PBMA's
- Only 2 brands were within 20% of declared value on Nutrition Facts panel
- 8/9 brands were above the declared value

Conclusions

- There were differences in the amounts of vitamin D and calcium **declared on the Nutrition Facts label** and the **measured content** in some PBMA brands
- **All brands** in the three most popular PBMA types (almond, soy, oat) contained calcium levels **within 20%** of declared value. Added calcium appeared to be the major driver of calcium levels in PBMA
- **In the majority of PBMA brands** formulated with added vitamin D, the measured amount **differed by >20%** compared to the declared amounts
- Only **two brands** in the top three most popular PBMA types (almond, soy, oat) contained vitamin D within 20% of the declared value. Measured vitamin D levels in PBMA **tended to be higher** than the declared value



Ongoing and Future Work

- Perform analysis on PBMA for **additional micronutrients**, including trace minerals (e.g., zinc and selenium), choline, vitamin A, and B vitamins
- Perform experiments in GMP pilot plant examining the **effect of HTST processing** (high-temperature short-time) on retention of micronutrients in an in-house formulated almond PBMA

Batching of
almond PBMA
in Breddo Likwifier



MicroThermics
unit for HTST
treatment

Acknowledgements

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Thanks for listening!

Contact: Benjamin.Redan@fda.hhs.gov



Supplemental Slides

NIST Reference Material

- NIST SRM 1869 reference material (Infant/Adult Nutritional Formula) was used for quality control
- Calcium recovery (n=3) was $104 \pm 1.7\%$
- Mean recovery (n=3) was $92.7 \pm 1.4\%$ for D2 and $102 \pm 4.3\%$ for D3
- Precision (%CV) over 5 non-consecutive days was 10.0% for D2 and 4.5% for D3

Recommended Dietary Allowances (RDAs) for Calcium

Age	Male (mg/d)	Female (mg/d)
0-6 mo*	200	200
7-12 mo*	260	260
1-3 y	700	700
4-8 y	1,000	1,000
9-13 y	1,300	1,300
14-18 y	1,300	1,300**
19-50 y	1,000	1,000**
51-70 y	1,000	1,200
>70 y	1,200	1,200

*Adequate Intake (AI)

**RDA is the same during pregnancy or lactation

Institute of Medicine. Dietary Reference Intakes for Calcium and Vitamin D. Washington, DC: The National Academies Press; 2011.

Recommended Dietary Allowances (RDAs) for Vitamin D

Age	Male (µg/d)	Female (µg/d)
0-12 mo*	10	10
1-13 y	15	15
14-18 y	15	15**
19-50 y	15	15**
51-70 y	15	15
>70 y	20	20

*AI (adequate intake)

**RDA is the same during pregnancy or lactation

Institute of Medicine, Food and Nutrition Board. Dietary Reference Intakes for Calcium and Vitamin D. Washington, DC: National Academy Press, 2010.