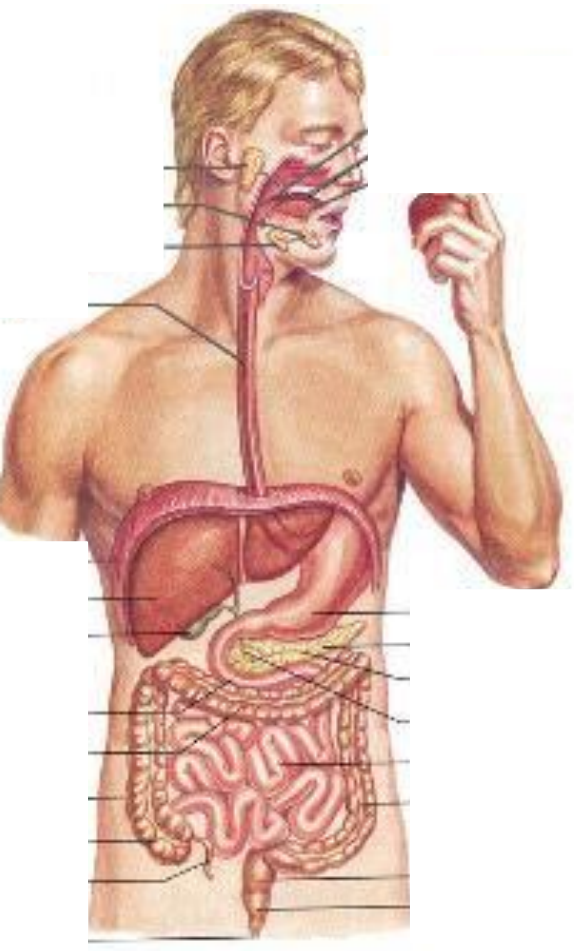
Maximization of Vitamin A, Folic Acid, and Other Essential Micronutrient Utilization in the Body

Michael I McBurney, PhD
Twitter: @MIMcBurney

IFT, Las Vegas, NV
June 25, 2017

Utilization of Essential Nutrients in the Body

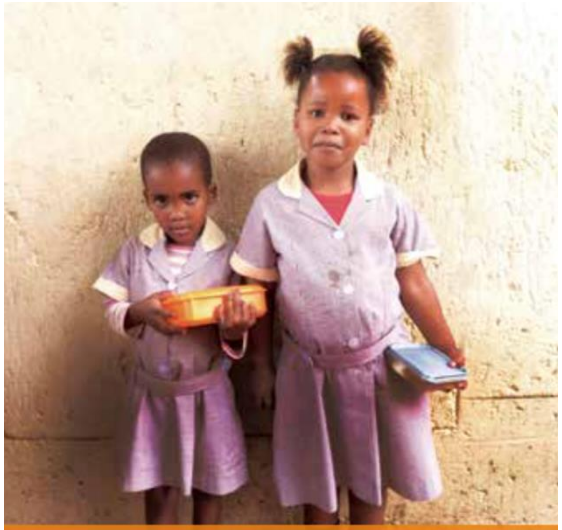


- Previous intake & body nutrient ‘status’
  - First-pass metabolism
- Ingested food matrix
  - Concentration
  - Other products in food matrix and diet
    - Tannins, phytates, some minerals, fat
  - Treatment of the food before consumption
    - Storage and cooking
- Efficiency of digestion & absorption
  - Quantity and concentration ingested
  - Gastro-intestinal function
    - Transit time
    - Stomach pH
    - Digestive enzymes

DSM
BRIGHT SCIENCE. BRIGHTER LIVING.

What is the Purpose of the Assessment?

- Acute bioavailability outcomes
  - Product A vs B
  - Ingredient form A vs B



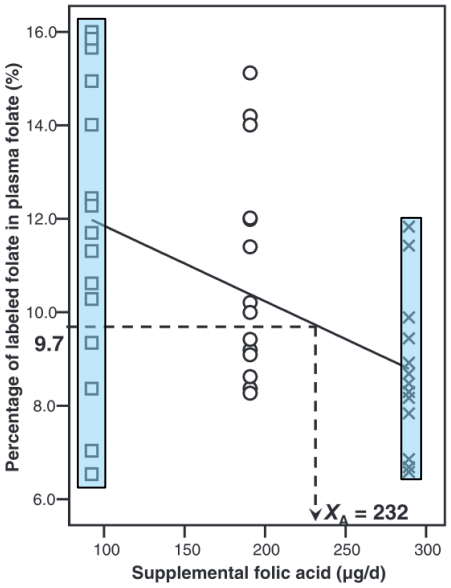
Two girls aged seven, one showing the dramatic effects of stunting.

- Chronic nutritional status outcomes
  - Structure/function measures
  - Disease incidence

DSM
BRIGHT SCIENCE. BRIGHTER LIVING.

Vitamin Bioavailability

- **Literature shows that the bioavailability of vitamins added to foods is at least equivalent to that of vitamins indigenous to foods**
- **In many cases, bioavailabilty of added vitamins exceeds naturally occurring nutrients bound within cell walls or other complexes**
- **When vitamin formulations are properly developed, there is no loss in bioavailability of vitamins added to foods, beverages, or condiments.**



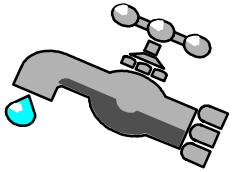
- 4 wk intervention study
  [$^{13}C_{11}$]-labelled serum folate
- 73µg/d food folate + capsules
  - □ 92µg folic acid/d
  - ○ 191µg folic acid/d
  - x 289µg folic acid/d
- Individual variability much greater for food folate than folic acid

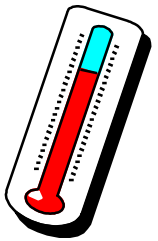
Winkels RM et al. 2007 AJCN 85:465

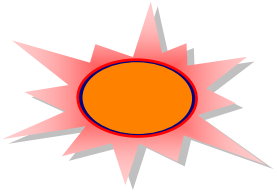
DSM
BRIGHT SCIENCE. BRIGHTER LIVING.

Factors Affecting Vitamin Stability

- Moisture
- Heat - time & temperature
- Air/Oxygen
- Light (uv)
- pH
- Metallic Impurities e.g.: copper, iron
- Oxidizing/Reducing Agents
- Processing Conditions e.g.: shear
- Headspace
- Packaging: plastic/glass, clear/opaque
- Shelf Life







Cu(III)

Fe(II)

DSM
BRIGHT SCIENCE. BRIGHTER LIVING.

Stability of Vitamins

	Vitamin	Heat	Oxygen	Light	pH - Value		
					acid	*neutral*	*basic*
Fat-soluble	A	U	U	U	U	S	S
	D	U	U	U	S	S	U
	E (Acetate)	S	U (S)	U (S)	S (U)	S	S
	K	S	S	U	U	S	U
Water-soluble	C	U	U	U	S	U	U
	B1	U	U	S	S	U	U
	B2	S	S	U	S	S	U
	B6	S	S	S	S	S	S
	B12	S	U	U	S	S	S
(B8)	Biotin	S	S	S	S	S	S
(B9)	Folic Acid	S	S	U	U	U	S
(B3)	Niacin	S	S	S	S	S	S
(B5)	Pantothenic Acid	U	S	S	U	S	U

S = stable / U = unstable

DSM
BRIGHT SCIENCE. BRIGHTER LIVING.

Effects of Milling on Vitamin Content of Maize Flour

Vitamins	Whole maize	Dehulled	% Loss	Degermed	% Loss
Thiamin (B1)	4.7	4.4	6%	1.3	72%
Riboflavin (B2)	0.9	0.7	22%	0.4	56%
Niacin	16.2	13.9	14%	9.8	40%
Pyridoxine (B6)	5.4	5.4	0%	1.9	65%
Folate	0.3	0.2	33%	0.1	67%
Biotin	0.073	0.055	25%	0.014	81%

Source: Dunn M et al. 2014 Annals NYAS 1312:15
Image: Win Tone Corn Processing Machinery Manufacturer

DSM
BRIGHT SCIENCE. BRIGHTER LIVING.

Extrusion Conditions and Vitamin Retention

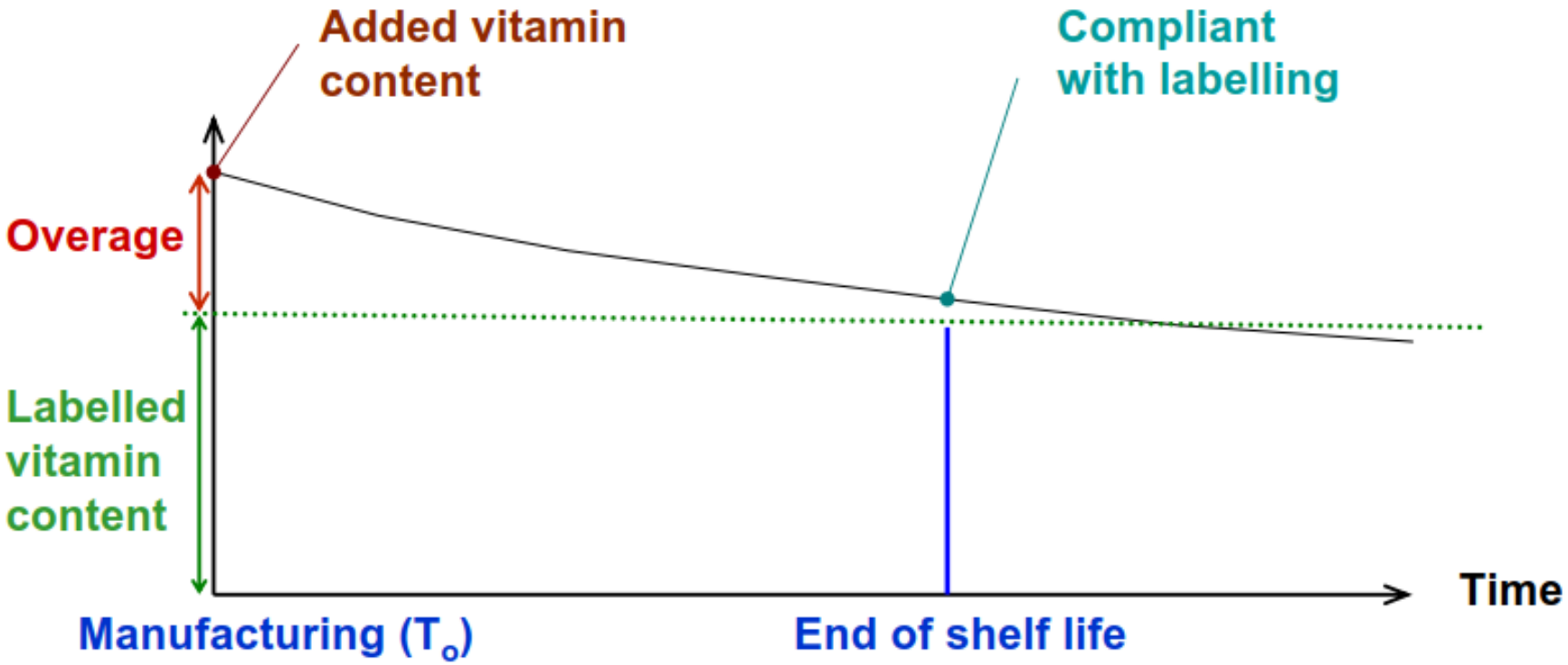
Extrusion cooking Variables (Increased)	Vitamin Retention			
	Thiamin	Riboflavin	Ascorbic Acid	Vitamin A
Temperature	−,0	+, 0	−	0
Moisture	+	−, 0	− ***	
Screw Speed	−, 0	−	−	+
Screw compression ratio	0		−	
Dams in screw				
Die diameter	+, 0	0	+	
Torque and pressure				
Pressure			0	
Energy Input				

* += Increase, − = Decrease, 0 = no effect; **Modified from Bjorck and Asp (1983); *** At high temperature, more is retained at low moisture

Source: Riaz MN et al. 2009 Crit Rev Food Sci Nutr 49:361

DSM
BRIGHT SCIENCE. BRIGHTER LIVING.

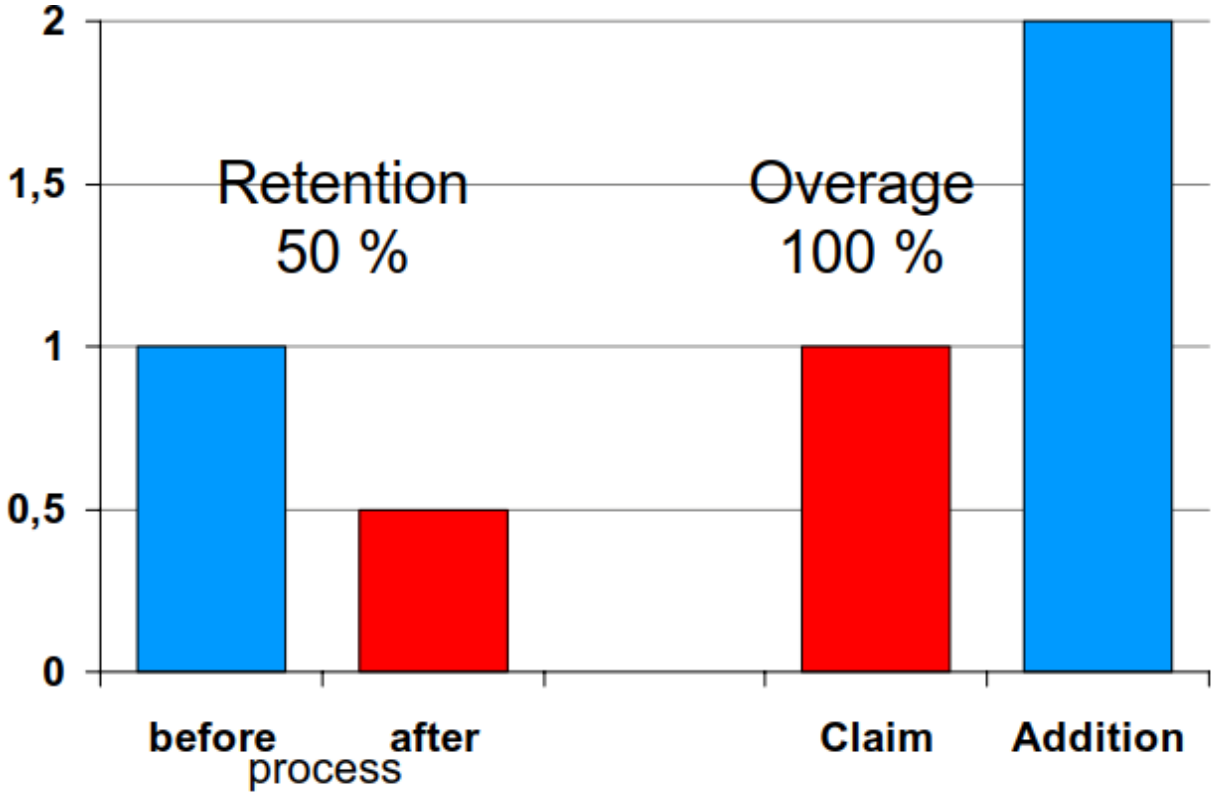
Stability and Labelling Requirements



DSM
BRIGHT SCIENCE. BRIGHTER LIVING.

Terms of Stability

Retention and Overage (Overdosage)

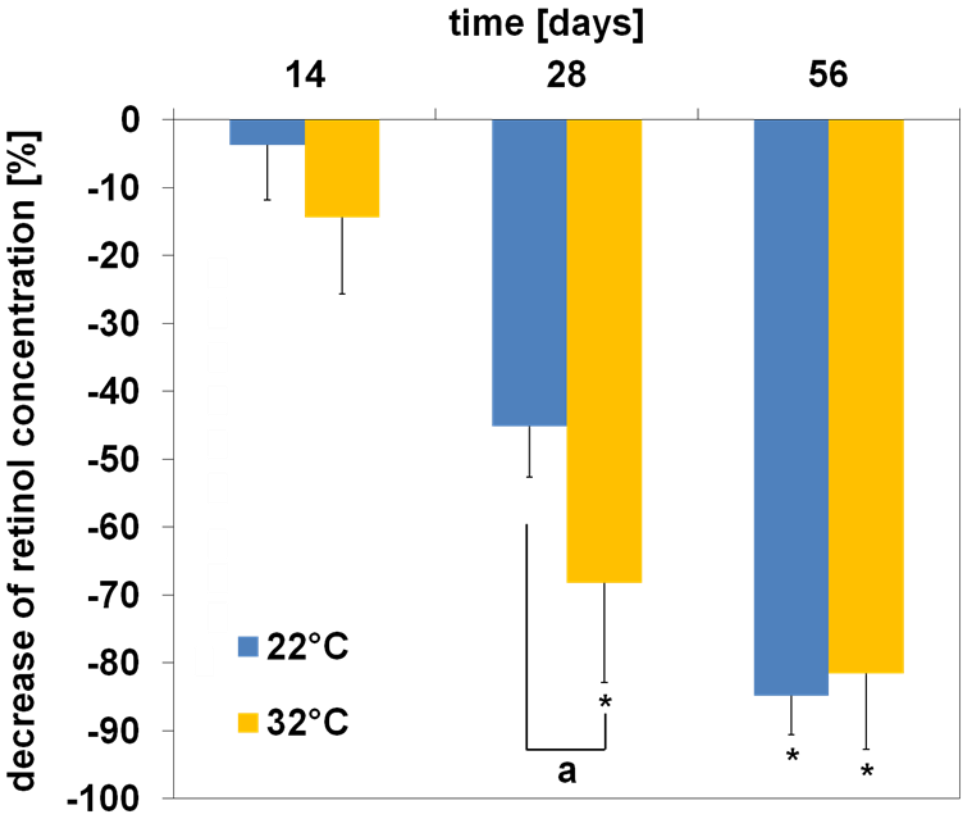


For calculation of necessary overage from retention:

Overage % = (100 / Retention % - 1) 100

DSM
BRIGHT SCIENCE. BRIGHTER LIVING.

Temperature Affects Vitamin A Stability in Fortified Soybean Oil

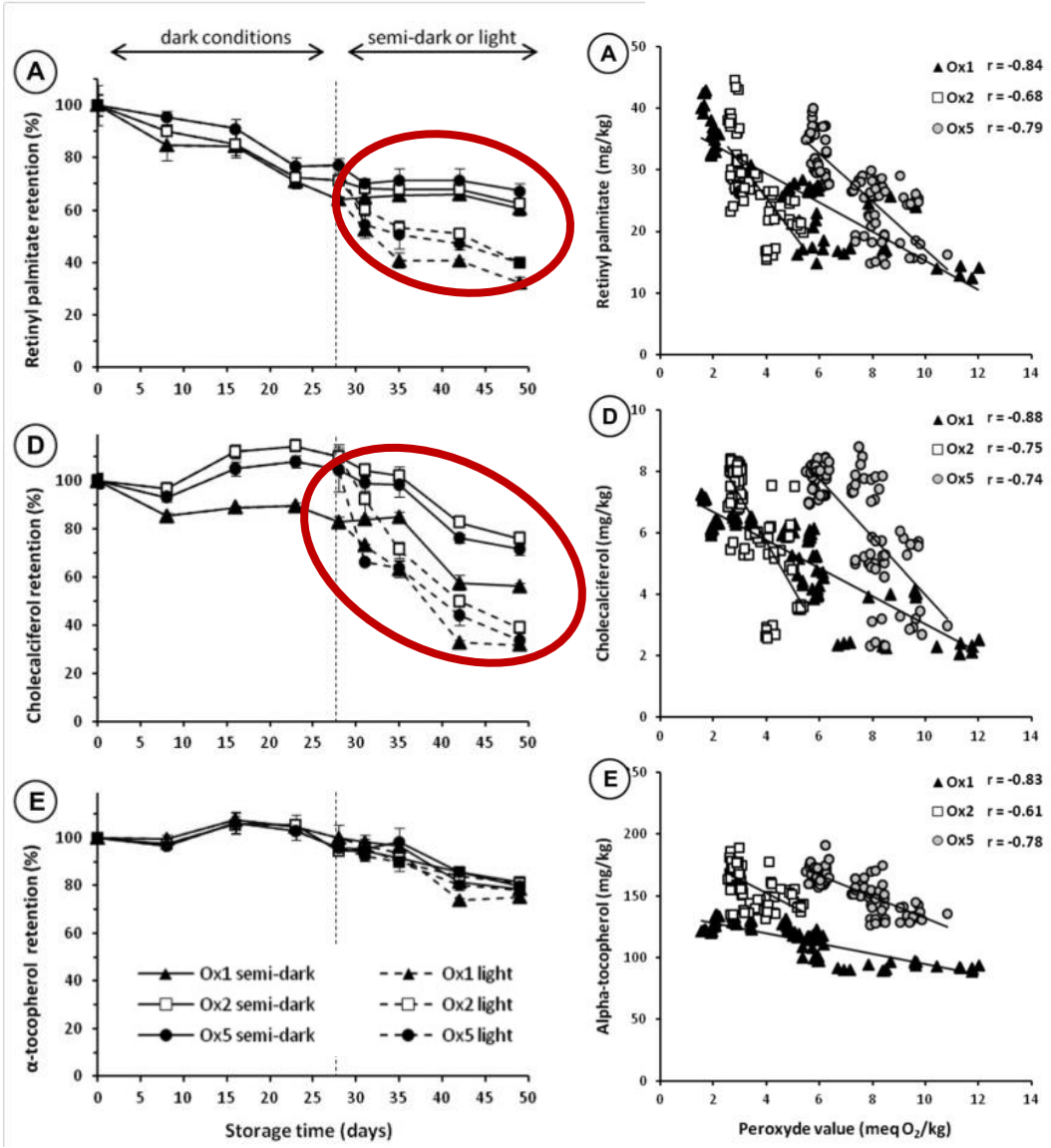


- Fortified soybean oil stored under household conditions resulted in a remarkable loss of vitamin A.
- After 56 days of storage, the concentration of retinyl palmitate in soybean oil decreased by approximately 80%, independent of temperature.

Pignitter M, Dumhart B, Gartner S, Jirsa F, Steiger G, Kraemer K, Somoza V. 2014 J Agric Food Chem doi: 10.1021/jf502109j

DSM
BRIGHT SCIENCE. BRIGHTER LIVING.

Light and Oxidative Status Affect Stability of Vitamins A, D & E in Fortified Soybean Oil



2x greater decrease in vitamin A & D content of oils exposed to natural light

Drivers of A & D Losses

1. Storage time
2. Light exposure
3. Oxidative status of oil

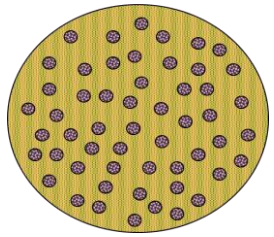
Vitamin E was protective

Source: Hemery YM et al. 2015 Food Chem 184:90

DSM
BRIGHT SCIENCE. BRIGHTER LIVING.

Considerations to Improve Stability

- Protect vitamins against humidity, oxygen, radicals, metal ions
  - Coating of vitamins to enhance stability
  - Improved handling properties for better dispersion
  - Addition of stabilizers



- Optimize Manufacturing Conditions
  - Heat, pH, shear, etc
  - Monitor/remove/neutralize damaging ingredients

- Optimize Packaging
  - Protect against moisture, light and oxygen
  - Headspace
  - Proper storage and handling

DSM
BRIGHT SCIENCE. BRIGHTER LIVING.

BRIGHT SCIENCE. BRIGHTER LIVING.™

Chemical Forms of Vitamins in Foods & Supplements

Vitamin	Added Forms	Endogenous Forms
Thiamin (B1)	Thiamin hydrochloride, thiamin mononitrate	Thiamin pyrophosphate (80%), thiamin monophosphate & triphosphate
Vitamin C	L-ascorbic acid, L-dehydroascorbic acid	L-ascorbate derivatives
Riboflavin (B2)	Riboflavin, Riboflavin-5-phosphate sodium	Non-covalently bound FMN and FAD and free riboflavin. Covalently bound forms unavailable
Niacin (B3)	Niacinamide, niacin	Niacytin, nicotinic acid, nicotinamide, tryptophan
Vitamin B6	Pyridoxine hydrochloride	Pyridoxine in alcohol, aldehyde, and amine forms. Glucoside forms only partly available.
Vitamin B12	Cyanocobalamin	Methyl, deoxyadenosyl and hydroxy forms requiring Intrinsic Factor in the gut
Folate (B9)	Folic acid	5,6,7,8-tetrahydrofolates with polyglutamate side chain requiring deconjugation in the gut
Biotin (B7)	Biotin	Biocytin requiring proteolytic and biotinidase activity in gut
Pantothenic acid	Calcium pantothenate, calcium chloride	Pantothenic acid CoA, phosphopantotheine requiring gut hydrolyzation
Vitamin A	Retinol palmitate, retinol acetate, ß-carotene	Retinyl esters hydrolyzed to retinol in gut, ß-carotene
Vitamin D	Cholecalciferol (D_3), ergocalciferol (D_2)	Cholecalciferol, Erogcalciferol, 25(OH)D
Vitamin E	Tocopherols, α-tocopherol acetate	Gamma-tocopherol (70%), tocopherols, tocotrienols

Adapted from 1997 EJCN 51:S1 with papers first-authored by Bates, Biesalski, Cohn, Gregory, Scott, van den Berg

DSM
BRIGHT SCIENCE. BRIGHTER LIVING.