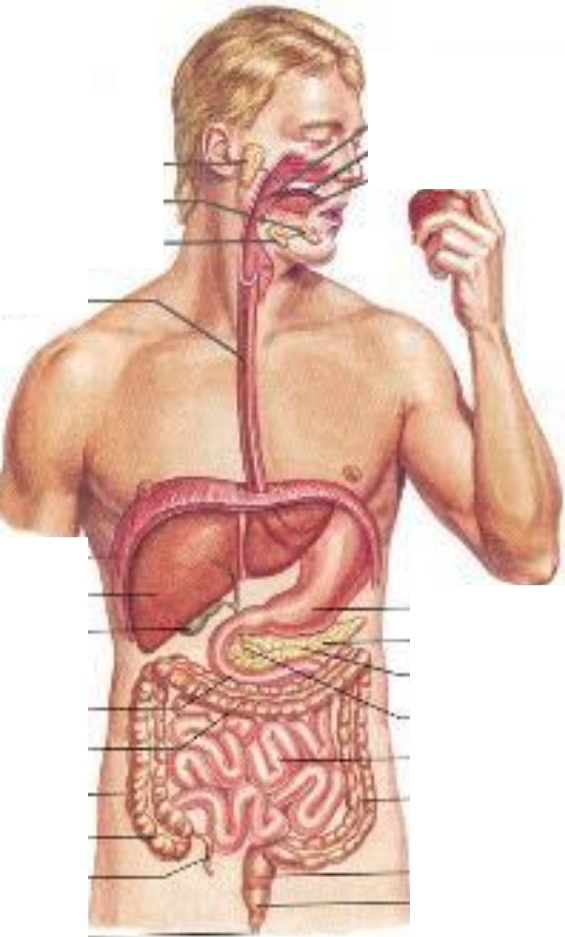


Maximization of Vitamin A, Folic Acid, and Other Essential Micronutrient Utilization in the Body

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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

What is the Purpose of the Assessment?

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

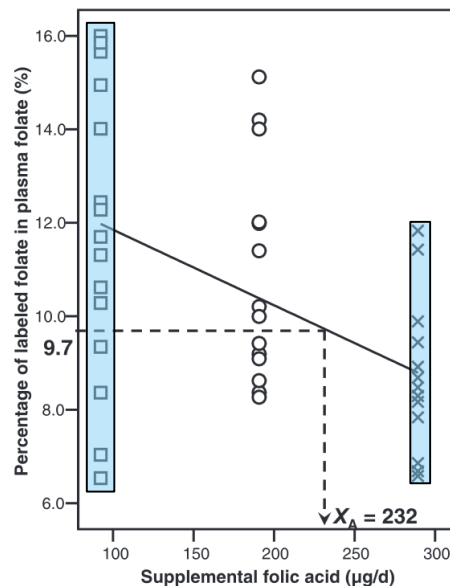


Two girls aged seven, one showing the dramatic effects of stunting.

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

Vitamin Bioavailability

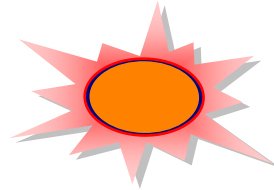
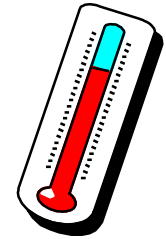
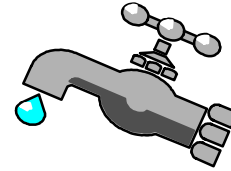
- Literature shows that the bioavailability of vitamins added to foods is at least equivalent to that of vitamins indigenous to foods
- In many cases, bioavailability of added vitamins exceeds naturally occurring nutrients bound within cell walls or other complexes
- When vitamin formulations are properly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



- 4 wk intervention study
[¹³C₁₁]-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

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)



Stability of Vitamins

| | <u>Vitamin</u> | <u>Heat</u> | <u>Oxygen</u> | <u>Light</u> | <u>pH - Value</u> | | |
|-----------------------|-----------------|-------------|---------------|--------------|-------------------|----------------|--------------|
| | | | | | <i>acid</i> | <i>neutral</i> | <i>basic</i> |
| 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 | S | U | S | U |

S = stable / U = unstable



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

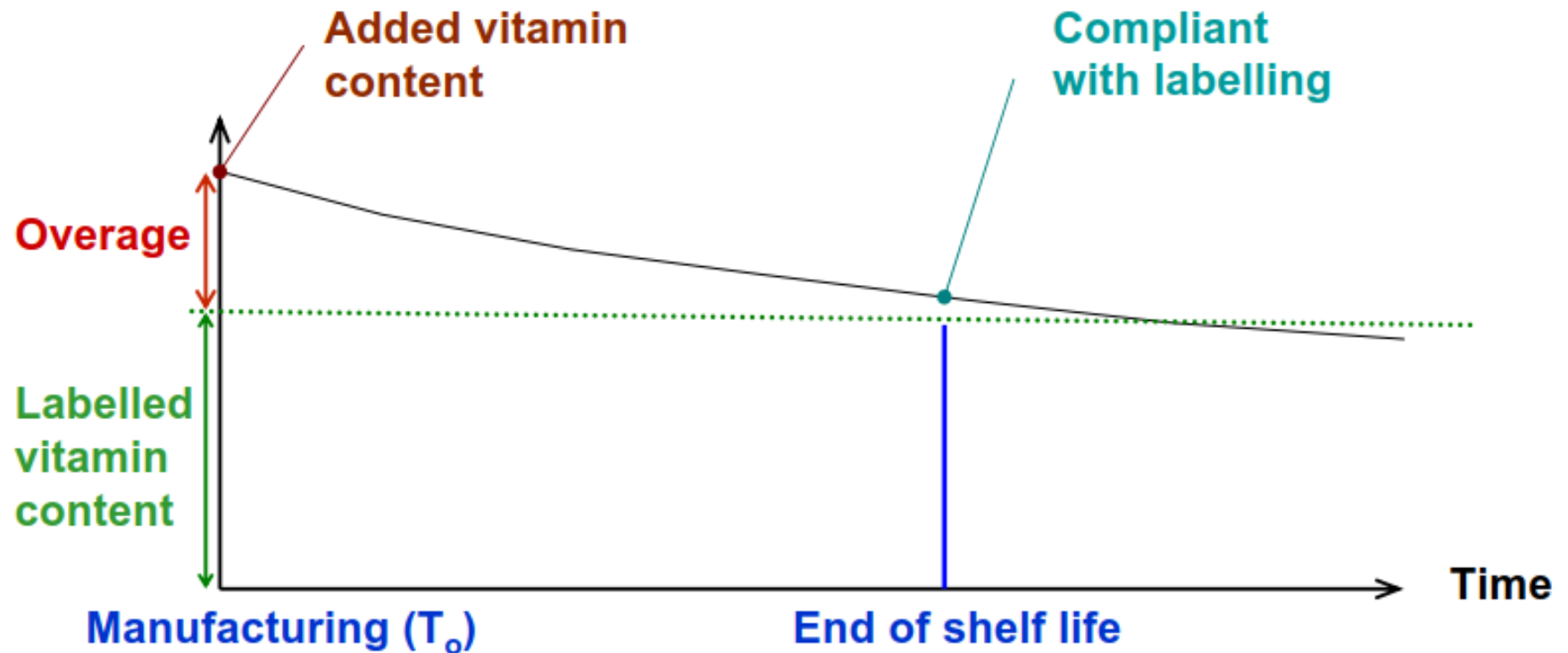


Extrusion Conditions and Vitamin Retention

| 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

Stability and Labelling Requirements



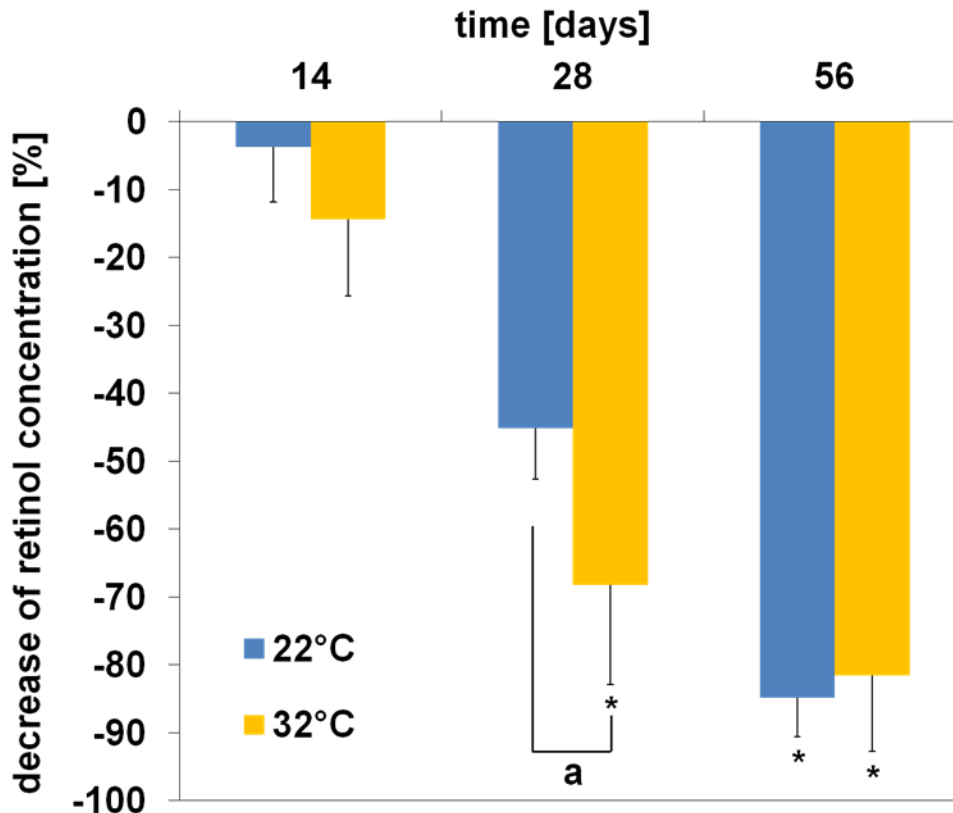
Terms of Stability

Retention and Overage (Overdosage)



For calculation of necessary overage from retention:
Overage % = (100 / Retention % - 1) 100

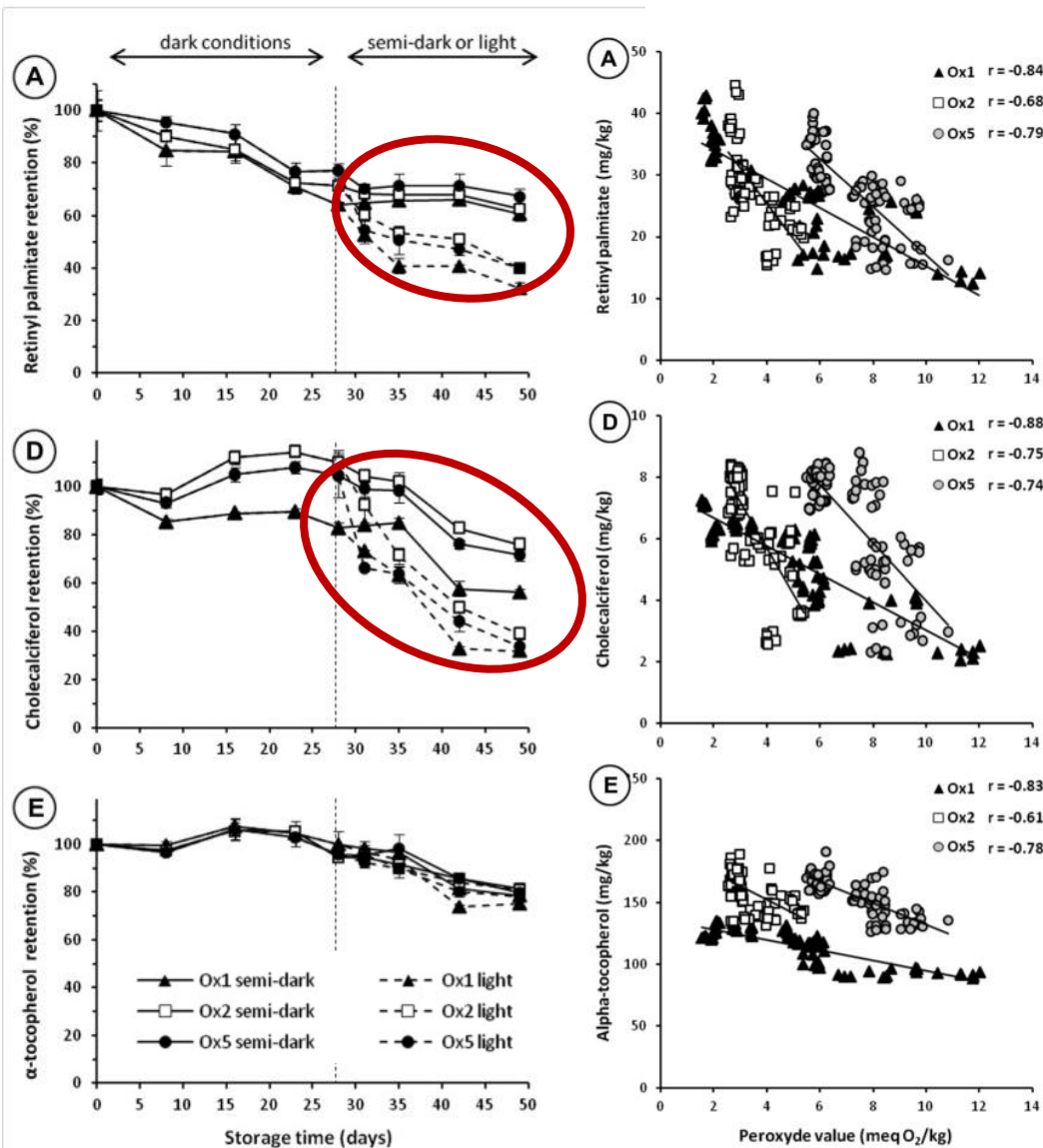
Temperature Affects Vitamin A Stability in Fortified Soybean Oil



- 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

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



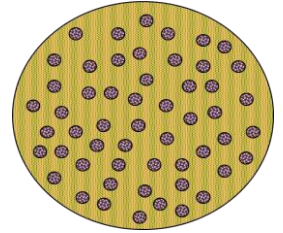
2x greater decrease in vitamin A & D content of oils exposed to natural light

- Drivers of A & D Losses
1. Storage time
 2. Light exposure
 3. Oxidative status of oil

Vitamin E was protective

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





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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, β -carotene | Retinyl esters hydrolyzed to retinol in gut, β -carotene |
| Vitamin D | Cholecalciferol (D ₃), ergocalciferol (D ₂) | Cholecalciferol, Ergocalciferol, 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