Keeping Vitamin B12 Stable: Light, pH and Premix Protection

How cobalamin breaks down, how to predict shelf life, and how to design the studies that prove it

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Abstract

B12 is dosed in micrograms, so even a small loss changes what ends up on the label. The vitamin breaks down under light, at extreme pH, in the presence of vitamin C and when heated, and how fast it goes depends on which chemical form you are using. This summary walks through why the losses happen, how to estimate shelf life, what a protective barrier can and can't do, and how to set up a sound stability study. A caution before you read on: every number here comes from published work on **unencapsulated** B12. None of it is VitaSphere™B12 performance data.

Key Points

- **Four things hurt B12:** light, pH extremes, vitamin C and heat. Of the common forms, cyanocobalamin (CNCbl) holds up best and methylcobalamin (MeCbl) worst.
- **Keep B12 away from vitamin C.** Rate constants for hydroxocobalamin (OHCbl) can be as much as 100 times those for CNCbl.
- **Measure Q10 in your own matrix.** It shifts with the temperature range, so a borrowed value is risky.
- **Treat 40 °C/75% RH as a screen, not an answer.** Shelf life needs a humidity-corrected model backed by real-time data.
- **Run photostability to ICH Q1B** on the ingredient, the product and the pack, always with a dark control.
- **Work out overage from measured retention,** not from a rule-of-thumb percentage.

1. How B12 Degrades

All cobalamins share a corrin ring with a cobalt atom at its centre. What separates one form from another is the group attached to that cobalt: cyano (CNCbl), hydroxo (OHCbl), methyl (MeCbl) or adenosyl (AdoCbl). Because of this, any testing has to be done form by form.

Stress	What studies report	Mechanism	Control
Light	UVA turns MeCbl and AdoCbl into OHCbl within seconds. CNCbl also converts under visible light.	The bond between cobalt and its ligand is split by light. Riboflavin acts as a photosensitiser and speeds this up.	Opaque coat, light-proof pack
pH	CNCbl dropped by about 15% at pH 3 and at pH 9. Sorbitol prevented the loss.	Hydrolysis. Stability runs CNCbl > OHCbl > MeCbl.	Buffering, polyols
Vitamin C	Half-life of 13.7–137.5 h for CNCbl against 2.5–87.5 h for OHCbl, across pH 1–8.	Vitamin C reduces the cobalt. The two need moisture to make contact.	Physical separation, low moisture
Heat	In milk at 102–142 °C, loss was first-order with E_a of 130 ± 5 kJ/mol. Microwaving cost 30–40%.	Thermal breakdown. Some of the products have no vitamin activity.	Add B12 after heat steps

Interaction to keep in mind: light converts the other forms into OHCbl, and OHCbl is the form vitamin C attacks hardest. So light protection and vitamin C separation have to be planned together, not one after the other. **A note on assays:** inactive breakdown products can register as B12 in non-specific methods, which makes retention look better than it is.

2. Predicting Shelf Life

2.1 Kinetics and temperature dependence

B12 loss is usually first-order, and t_{90} is the time taken to reach 90% of the starting content. The Arrhenius equation ties the rate to temperature, and Q10 tells you how much faster the reaction runs for each 10 °C rise.

$$C(t) = C_0 \cdot e^{-kt} \quad | \quad t_{90} = 0.105/k \quad | \quad k = A \cdot e^{-Ea/RT} \quad | \quad Q10 = e^{(Ea/R)\cdot 10/(T(T+10))}$$

Q10 isn't a fixed number. With E_a = 130 kJ/mol it comes out near 2.6 at 130–140 °C but around 5.5 at 25–35 °C. If you assume a generic Q10 of 2–3, or apply an E_a measured at processing temperatures to storage conditions, you will get shelf life wrong.

2.2 Humidity-corrected model (ASAP)

For solids, the Accelerated Stability Assessment Program holds samples at several temperature and humidity pairings until each reaches the same degree of loss (isoconversion). The data are fitted to the model below, and Monte Carlo simulation puts a

number on the uncertainty. The B term shows how sensitive the barrier is to moisture, which helps in choosing the pack and desiccant.

$$\ln k = \ln A - E_a/(RT) + B \cdot RH$$

2.3 Where accelerated testing falls short

- Lipid barriers can soften close to 40 °C, and 75% RH may push past a deliquescence point that the real pack never reaches.
- Heat stress says nothing about photolysis, and results on the ingredient alone don't predict how it behaves in a premix.

3. Barrier Protection

A barrier coat around a B12 core can do four jobs: cut down light reaching the core, slow moisture uptake, keep B12 apart from reactive partners such as vitamin C, and shield the core from the pH of the surrounding bulk. Related systems back this up, including spray-dried B12 microcapsules, liposomal CNCbl tested against vitamin C, and extruded feed vitamins (processed at 100–180 °C) that kept more activity when microencapsulated. **Test for the ways a coat can fail:** cracking, pinholes, melting of a lipid coat, and dissolving of water-soluble walls.

Product type	What to consider
Heat-processed foods	There is little heat-kinetic data on B12 and no verifiable baking data, so run baking trials in your own matrix.
Beverages	Light, pH and vitamin C all act at once. Test the reconstituted drink across the whole time it would be consumed.
Premixes	Test the ingredient alone, binary blends with vitamin C and with riboflavin, and the full premix, each against an uncoated control.

4. Designing the Stability Study

ICH Q1A(R2) is the reference framework here, and WHO 2018 defines climate zones IVa and IVb. A consolidated ICH Q1 draft came out in 2025, but the existing texts remain in force until it is adopted.

Study	Condition	Duration	Use
Long-term, zones I/II	25 °C / 60% RH	12 months	Temperate
Long-term, zone IVa	30 °C / 65% RH	12 months	Hot, humid
Long-term, zone IVb	30 °C / 75% RH	12 months	India, SE Asia
Accelerated	40 °C / 75% RH	6 months	Screening only
Photostability (Q1B)	≥1.2 M lux·h; ≥200 W·h/m²	One exposure	Ingredient, product, pack

- **Q1B:** wrap dark controls in foil, and compare coated against uncoated B12 of the same form.
- **Q1E:** shelf life is the point where the one-sided 95% confidence limit of the mean regression line crosses the lower specification. Pool batches only if the slope and intercept tests allow it.
- **Water activity (a_w):** it governs molecular mobility more than total moisture does. Ask for a_w at release, the sorption isotherm and the finished-product a_w.
- **Packaging:** specify light transmission, MVTR, headspace and desiccant capacity, then confirm with real-time data in the target zone.

5. Analysis and Overage

A stability-indicating method has to measure intact B12 and its breakdown products side by side. The usual approach is reversed-phase HPLC that separates the declared form from OHCbl, paired with a microbiological or intrinsic-factor assay to confirm bioactivity. Validation should show precision at the microgram level, protection from light during the analysis, and full extraction of B12 from the barrier.

$$\text{Overage (\%)} = [(1 + u)/R - 1] \times 100$$

Here R is the fraction left at the end of shelf life (from Q1E) and u is the allowance for process and analytical variation. Taking u = 0, an R of 0.85 gives roughly 17.6% overage and an R of 0.97 gives about 3%. Check the label-tolerance rules for each market.

6. Where Things Stand, and a Buyer Checklist

Data still needed from Umang: composition, opacity and melting range of the LC coat; Q1B results; real-time and accelerated data at 25/60, 30/65, 30/75 and 40/75; retention with vitamin C, riboflavin and a model premix; a_w, isotherm and a recommended pack; a validated HPLC method with recovery data; the CoA specification; and overage for each grade.

What buyers should ask for: (1) multi-batch Q1A/Q1E stability for the target zone; (2) a Q1B report with dark controls and an uncoated reference; (3) an ASAP-type study; (4) premix compatibility data; (5) an in-matrix process simulation; (6) validated HPLC plus a bioactivity assay on aged samples; (7) a CoA covering assay, form identity and a_w.

Conclusion

How much B12 you lose comes down to its form, the matrix and the stress involved. Predict shelf life from kinetics measured in your own matrix, use humidity-corrected models to steer design, and set claims from real-time data under ICH Q1E. Barrier technology is meant to shield B12 from light, moisture and reactive ingredients, but each VitaSphere™B12 grade still has to be proven with Umang's own data, in the buyer's matrix, pack and climate zone.

Abbreviations: CNCbl, OHCbl, MeCbl, AdoCbl = cyano-, hydroxo-, methyl-, adenosylcobalamin; E_a = activation energy; ASAP = Accelerated Stability Assessment Program; a_w = water activity; MVTR = moisture vapour transmission rate; RH = relative humidity.