

Article

Micronutrient Stability and Energy-Related Functional Context of a Multivitamin–Mineral Single-Layer Tablet

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Abstract: We studied a segmented-premixing, single-layer multivitamin–mineral tablet as a delivery system for micronutrients involved in energy metabolism and fatigue-related physiology. The representative tablet combined vitamins B1, B2, B6, B12, niacin, pantothenate, biotin, folate and vitamin C with an iron source. Total-blend RSD was 3.9% for folate and 4.6% for B12. After three months of accelerated storage, retention was 85.1% for folic acid, 83.7% for vitamin C and 85.4% for vitamin B1. Randomized placebo-controlled studies in healthy adults have reported changes in selected measures of fatigue, vigour, physical stamina and performance during demanding tasks after multivitamin/mineral or B-vitamin-rich supplementation. Responses were not uniform across populations, baseline nutritional states or formulations. The formulation data justify tablet-specific studies of perceived energy, fatigue and functional performance under defined nutritional conditions.

Keywords: B Vitamins, Vitamin C, Iron, Energy Metabolism, Fatigue, Stamina, Multivitamin–Mineral, BCLC

Introduction

Cellular energy production is distributed across pathways rather than controlled by a single nutrient. Thiamine, riboflavin, niacin and pantothenate contribute coenzyme forms used in carbohydrate oxidation and mitochondrial metabolism; vitamin B6, folate and vitamin B12 are involved in amino-acid and one-carbon reactions, and biotin supports carboxylation. Vitamin C participates in redox and biosynthetic chemistry, while iron is required for oxygen transport and electron-transfer proteins. The practical consequence is that fatigue or reduced performance can arise in settings where one or more micronutrients are marginal, but the same symptoms can also occur in people whose nutritional status is adequate. A review of the biochemical and clinical literature on vitamins and minerals therefore treats energy, fatigue and cognition as related but distinct outcomes rather than as interchangeable markers [1].

Human supplementation studies illustrate that distinction. In a 9-week randomized study of women performing extended multitasking, a multivitamin-mineral preparation attenuated deterioration in mood and fatigue and improved task accuracy [2]. A 33-day trial in employed men

using a high-dose B-complex with vitamin C and minerals reported changes in vigour, stress-related ratings, mental tiredness and selected cognitive measures [3]. A separate 28-day study used repeated mobile assessments and found higher self-rated physical and mental stamina during supplementation [4]. When randomized nonclinical studies were pooled, fatigue and perceived stress were reduced on average, although the magnitude and consistency of response varied among formulations and populations [5]. Taken together, these findings support measuring specific functional outcomes rather than assuming that a multivitamin will produce a uniform sensation of increased energy.

Starting nutritional status is an important part of that interpretation. Daily multivitamin supplementation has been shown to change circulating vitamin concentrations in older adults [6]. Studies of iron, folate and vitamin B12 in populations at risk of deficiency or anaemia likewise demonstrate that biochemical response depends on the nutrient combination and the population studied [7]-[10]. Those trials were not designed as fatigue studies, and their hematological or vitamin-status endpoints should not be used as substitutes for perceived energy. They do, however, show why the same labeled dose can have different physiological meaning in a person with low stores than in someone whose intake is already sufficient. For an energy-related trial, baseline ferritin, folate and B-vitamin status can therefore be as informative as the assigned supplement.

The wider micronutrient literature gives a similar warning about endpoint choice. Long-term supplementation in institutionalized older adults has been associated with fewer infectious events in settings where deficiencies were common [11], whereas a shorter multivitamin-mineral trial in healthier older adults improved vitamin C and zinc status without changing every measured immune-function endpoint [12]. Reviews of micronutrients and immune biology, together with intervention evidence for vitamin D and vitamin C, also show that effects differ with baseline status, exposure and the outcome selected [13]-[15]. These studies address immune rather than energy outcomes, but the methodological lesson is relevant here: biochemical repletion, symptom change and functional performance should be measured separately, and evidence from one formulation should not automatically be assigned to another.

That distinction is particularly important for a single-layer multivitamin-mineral tablet. The active ingredients span from microgram quantities of vitamin B12 to milligram quantities of vitamin C and iron-containing material, so a nominal formula can still give uneven exposure if low-dose ingredients are poorly distributed. Moisture and prolonged contact during processing can also reduce the amount of labile vitamin that remains available at the end of storage. The BCLC® tablet therefore uses separate folate, water-soluble-vitamin and iron-source premixes before a brief final blend. In the present study, we first measured distribution and accelerated-storage retention of energy-related micronutrients, then placed those formulation results beside randomized human evidence on fatigue, stamina, mood and performance. The aim was not to infer a clinical effect from tablet stability alone, but to establish whether the formulation provides a sufficiently controlled nutrient exposure for a later tablet-specific human study.

Table 1. Selected active components of the representative BCLC® single-layer tablet (800 mg core).

Component	Amount per tablet
Vitamin C	55 mg
Vitamin E acetate powder	20 mg
Vitamin A acetate microcapsule powder	4 mg
Vitamin D3 microcapsule powder	6 mg
Vitamin B1 / B2 / B6	1.1 / 1.1 / 1.3 mg
Vitamin B12	2 µg
Nicotinamide	12 mg
D-calcium pantothenate	5 mg
Biotin	30 µg
Folic acid	0.4 mg
Ferric pyrophosphate	24 mg

Zinc citrate	20 mg
Selenium yeast	20 mg

Materials and Methods

Energy-related nutrient matrix

Each 800 mg tablet core provided vitamin B1 1.1 mg, B2 1.1 mg, B6 1.3 mg, vitamin B12 2 µg, nicotinamide 12 mg, D-calcium pantothenate 5 mg, biotin 30 µg, folic acid 0.4 mg, vitamin C 55 mg and ferric pyrophosphate 24 mg. Before the brief final blend, the ingredients were distributed among dedicated folate, water-soluble-vitamin and iron-source premixes.

Stability and uniformity endpoints

Folate and vitamin B12 distribution was measured as total-blend and inter-tablet RSD. Tablets were stored for three months at 40°C ±2°C and 75% ±5% relative humidity, after which folic acid, vitamin C and vitamin B1 retention was measured. Direct blending and processing at high humidity served as contrasting conditions.

Human evidence synthesis

We selected randomized controlled trials and a meta-analysis that assessed fatigue, stamina, vigour, stress-related mood or performance during demanding cognitive work after multivitamin/mineral or B-vitamin-rich supplementation. Because their formulations were different from the tablet tested here, the studies were used to describe physiological and clinical context rather than formulation-specific effects.

Table 2. Selected randomized and pooled human evidence on multivitamin/mineral supplementation, energy and fatigue-related outcomes.

Study	Population / duration	Intervention context	Energy/fatigue-related observation
Haskell et al. 2010	216 women aged 25-50; 9 weeks; double-blind randomized placebo-controlled	Multivitamin/mineral	Attenuated task-related mood/fatigue deterioration and improved multitasking accuracy.
Kennedy et al. 2010	215 employed men aged 30-55; 33 days; double-blind randomized placebo-controlled	High-dose B-complex + vitamin C + minerals	Improved vigour, stress-related ratings, selected cognitive performance and mental tiredness.
Kennedy et al. 2011	198 employed men; 28 days; double-blind randomized placebo-controlled	Multivitamin/mineral	Greater self-rated physical stamina and mental stamina during repeated real-world mobile assessments.
Long & Benton 2013	Meta-analysis of randomized placebo-controlled micronutrient studies	Multivitamin/mineral, often B-vitamin rich	Pooled evidence showed reductions in fatigue and perceived stress with heterogeneity across formulations and populations.

Results

Distribution and storage performance

Total-blend RSD was 3.9% for folate and 4.6% for vitamin B12; inter-tablet RSD was 4.8% and 5.3%, respectively. After accelerated storage, retention was 85.1% for folic acid, 83.7% for vitamin C and 85.4% for vitamin B1. Direct one-step blending reduced retention to 76.5%, 74.8% and 78.1%. At 60% relative humidity, the corresponding values were 78.9%, 76.2% and 80.0%.

Randomized human evidence

In a 9-week randomized placebo-controlled study of 216 women, Haskell et al. found less deterioration in mood and fatigue during extended cognitive work and higher multitasking accuracy with a multivitamin/mineral [2]. Kennedy et al. studied 215 employed men for 33 days; the B-complex/vitamin C/mineral group reported greater vigour and changes in stress ratings, selected cognitive outcomes and mental tiredness [3]. In a related 28-day mobile-assessment trial, supplemented participants

reported greater physical and mental stamina [4]. A meta-analysis of randomized nonclinical samples found reductions in fatigue and perceived stress, with differences among formulations [5].

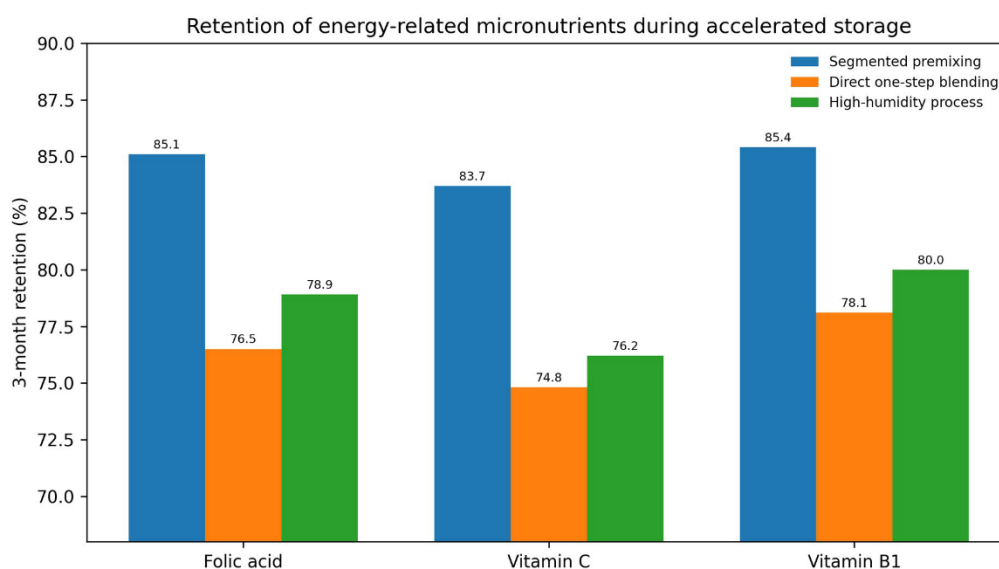


Figure 1. Accelerated-storage retention of selected energy-related micronutrients under optimized, direct-blend and high-humidity process conditions.

Discussion

The formulation results matter because B vitamins and vitamin C occur at low mass fractions and may be affected by moisture, long processing times or local contact within the tablet. The scale difference is substantial: B12 is present at the microgram level and folate below one milligram, alongside components supplied in tens or hundreds of milligrams. Separate premixing distributes these small quantities before they enter the final blend.

Low-humidity processing and a short final residence time also improved storage performance. Retention of B1, folate and vitamin C was higher in the optimized condition, leaving a more stable nutrient matrix for physiological exposure. The human trials were less uniform. Several reported changes in fatigue during demanding tasks, vigour or stamina [2]-[5], but not every fatigue or cognitive measure responded. Baseline diet and nutritional adequacy, occupational stress and the precise supplement composition differed among studies.

A controlled delivery platform makes it possible to test whether those responses extend to this formulation. Such work could relate measured nutrient status to perceived energy, fatigue and performance instead of assuming that the same response will occur under every baseline condition.

Current Scope and Future Directions

The experiments measured nutrient uniformity and stability, not long-duration human performance. A trial could use validated fatigue scales, ecological momentary assessment of energy, work-performance tasks and exercise tolerance, together with homocysteine, ferritin and B-vitamin status. Stratification by dietary quality would help identify responsive baseline states and exposure patterns.

Conclusion

Segmented premixing produced low variability for trace folate and vitamin B12 and improved retention of three labile, energy-related micronutrients during accelerated storage: total-blend RSD was 3.9% for folate and 4.6% for vitamin B12, while folic acid, vitamin C and vitamin B1 retained 85.1%, 83.7% and 85.4%, respectively, after three months. These formulation results provide a better-controlled basis for studying energy- and fatigue-related outcomes because the administered tablet is less affected by low-dose distribution error and processing-related loss. The study remains limited to formulation performance and comparison with published human trials; it did not test long-term fatigue, stamina or work performance with the complete BCLC® tablet, and the cited trials used different formulations and baseline populations. A formulation-specific randomized study should therefore pair validated fatigue and energy measures with functional tasks and markers such as ferritin, homocysteine and B-vitamin status, while stratifying participants by baseline dietary and nutritional adequacy. That design would show whether the controlled micronutrient exposure demonstrated here translates into measurable functional benefit under defined conditions.

REFERENCES

- [1] Tardy AL, Pouteau E, Marquez D, Yilmaz C, Scholey A, "Vitamins and Minerals for Energy, Fatigue and Cognition: A Narrative Review of the Biochemical and Clinical Evidence," *Nutrients*. 2020;12(1):228. PMID:31963141.
- [2] Haskell CF, Robertson B, Jones E, et al, "Effects of a multi-vitamin/mineral supplement on cognitive function and fatigue during extended multi-tasking," *Hum Psychopharmacol*. 2010;25(6):448-461. doi:10.1002/hup.1144. PMID:20737518.
- [3] Kennedy DO, Veasey R, Watson A, et al, "Effects of high-dose B vitamin complex with vitamin C and minerals on subjective mood and performance in healthy males," *Psychopharmacology (Berl)*. 2010;211(1):55-68. PMID:20454891.
- [4] Kennedy DO, Veasey R, Watson A, et al, "Vitamins and psychological functioning: a mobile phone assessment of the effects of a B vitamin complex, vitamin C and minerals on cognitive performance and subjective mood and energy," *Hum Psychopharmacol*. 2011;26(4-5):338-347. PMID:21751253.
- [5] Long SJ, Benton D, "Effects of vitamin and mineral supplementation on stress, mild psychiatric symptoms, and mood in nonclinical samples: a meta-analysis," *Psychosom Med*. 2013;75(2):144-153. doi:10.1097/PSY.0b013e31827d5fbd. PMID:23362497.
- [6] B. A. Mann et al., "Daily multivitamin supplementation and vitamin blood levels in the elderly," *J. Am. Geriatr. Soc.*, vol. 35, no. 4, pp. 302–306, 1987, doi: 10.1111/j.1532-5415.1987.tb04635.x.
- [7] P. G. Bansal et al., "Impact of weekly iron folic acid supplementation with and without vitamin B12 on anaemic adolescent girls," *Eur. J. Clin. Nutr.*, vol. 70, no. 6, pp. 730–737, 2016.
- [8] A. Gupta et al., "Impact of daily-supervised administration of iron and folic acid and vitamin B12 on hemoglobin levels among adolescent girls," *Eur. J. Clin. Nutr.*, vol. 75, no. 11, pp. 1588–1597, 2021, doi: 10.1038/s41430-021-00878-6.
- [9] M. Zec et al., "Vitamin B12 supplementation in addition to folic acid and iron improves hematological and biochemical markers in pregnancy," *J. Med. Food*, vol. 23, no. 10, pp. 1054–1059, 2020, doi: 10.1089/jmf.2019.0233.
- [10] N. Haiden et al., "A randomized, controlled trial of the effects of adding vitamin B12 and folate to erythropoietin for anemia of prematurity," *Pediatrics*, vol. 118, no. 1, pp. 180–188, 2006, PMID: 16818564.
- [11] F. Girodon et al., "Effect of micronutrient supplementation on infection in institutionalized elderly subjects," *Ann. Nutr. Metab.*, vol. 41, no. 2, pp. 98–107, 1997, doi: 10.1159/000177984.

- [12] M. L. Fantacone et al., "The effect of a multivitamin and mineral supplement on immune function in healthy older adults," *Nutrients*, vol. 12, no. 8, Art. no. 2447, 2020, doi: 10.3390/nu12082447.
- [13] A. C. Gombart, A. Pierre, and S. Maggini, "A review of micronutrients and the immune system," *Nutrients*, vol. 12, no. 1, Art. no. 236, 2020, doi: 10.3390/nu12010236.
- [14] A. R. Martineau et al., "Vitamin D supplementation to prevent acute respiratory tract infections," *BMJ*, vol. 356, Art. no. i6583, 2017, doi: 10.1136/bmj.i6583.
- [15] H. Hemilä and E. Chalker, "Vitamin C for preventing and treating the common cold," *Cochrane Database Syst. Rev.*, no. 1, Art. no. CD000980, 2013.