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Liquid-Form Iron Innovation: A Dual-Engine Iron System Combining Lytox™ Nano-Micellar Iron and Iron Hydroxide Adipate Tartrate

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Abstract: Iron supplementation is critical for women with increased iron needs due to menstruation, pregnancy, dietary patterns, and busy modern lifestyles, but conventional iron supplements often suffer from slow perceived response, gastrointestinal discomfort, constipation, poor palatability, and low long-term compliance. To address these limitations, Eternal Grace R&D Center developed a Dual-Engine Iron System combining Lytox™ nano-micellar ferric pyrophosphate with IHAT (Iron Hydroxide Adipate Tartrate), supported by a cofactor matrix containing vitamin C, copper, vitamin B_{12}, L-5-methyltetrahydrofolate, lactoferrin, sialic acid, and 2'-fucosyllactose, delivered in a chewable, sweet-tasting vegetarian softgel for daily use. An internal comparative absorption assessment showed that the Lytox™ nano-micellar iron system achieved 12-times higher absorption efficiency than ordinary ferrous sulfate. A 12-week human trial conducted in Kuala Lumpur, Malaysia by Eternal Grace R&D Center further evaluated iron nutrition markers, iron reserve, complexion-related parameters, fatigue score, daily endurance score, menstrual-burden perception, and gastrointestinal tolerance. The observed results suggest that this Dual-Engine Iron System offers a differentiated iron supplementation approach by combining rapid iron nutritional response, steady iron reserve support, cofactor-assisted iron utilization, and a more consumer-friendly dosage form.

1. Introduction

Iron is an essential mineral involved in oxygen transport, muscle metabolism, energy-related biological processes, and red blood cell function. The NIH Office of Dietary Supplements describes iron as a key component of hemoglobin and myoglobin, both of which are central to oxygen transport and utilization [1].

Women of reproductive age are particularly relevant consumers for iron supplementation because menstruation increases iron loss and contributes to higher iron requirements. The World Health Organization recognizes daily iron supplementation as an intervention that can improve hemoglobin and iron stores in menstruating women in relevant public-health settings [2].

Despite wide availability, many iron supplements still face unresolved consumer barriers (Table 1).

Table 1. Key Market Challenges and Consumer Concerns of Conventional Iron Supplements

Market Challenge	Consumer-Relevant Concern
Conventional iron salts	Often perceived as harsh or difficult to tolerate
Slow perceived response	Users may not feel a clear change quickly
Single-source iron logic	Many products focus only on elemental iron dose
Gastrointestinal burden	Constipation, nausea, stomach discomfort, and dark stools may affect compliance
Poor palatability	Metallic taste and large tablets reduce user acceptance
Weak female wellness connection	Few products connect iron nutrition with complexion, tiredness, endurance, and post-period recovery

This creates an opportunity for an iron supplement that is not only iron-containing, but also designed around **iron response, iron reserve, nutritional cofactors, user experience, and women's daily wellness needs**.

2. Product Concept: Dual-Engine Iron System

The formula is built around two complementary iron forms:
Lytox™ Nano-Micellar Iron + IHAT Iron
This creates a dual-positioning strategy:
Fast Iron Replenishment + Steady Iron Reserve Support

2.1 Engine 1: Lytox™ Nano-Micellar Ferric Pyrophosphate

The first iron source is **liquid nano-micellar ferric pyrophosphate** processed using Lytox™ technology.

In Eternal Grace R&D Center's internal comparative assessment, Lytox™ nano-micellar iron showed:

12× higher absorption efficiency compared with ordinary ferrous sulfate

This internal result supports its positioning as the **fast-response iron engine** of the formula.

The Lytox™ nano-micellar format is designed to support:

- faster iron nutritional response;
- improved dispersion in a liquid-form softgel system;
- a modern alternative to conventional iron tablets;
- better consumer experience when combined with a chewable softgel dosage form.

For publication-level wording, this should be expressed as:

In an internal comparative absorption model, Lytox™ nano-micellar ferric pyrophosphate demonstrated 12-fold higher absorption efficiency than ordinary ferrous sulfate. Further controlled human studies would be required to confirm the magnitude of this effect in broader populations.

This wording is much more rigorous than directly saying "clinically proven 12× absorption."

2.2 Engine 2: IHAT Iron as a Reserve-Oriented Iron Source

The second iron source is **IHAT, Iron Hydroxide Adipate Tartrate**.

IHAT has been described in scientific and regulatory literature as a novel nano-iron supplement and a dietary ferritin analogue. The IHAT-GUT trial described IHAT as a dietary ferritin analogue, and EFSA identified iron hydroxide adipate tartrate as an engineered analogue of the ferritin core and

considered it a bioavailable source of iron under proposed conditions of use [3-4].

In this formula, IHAT is positioned as the **reserve-oriented iron engine**, supporting the long-term iron reserve narrative through ferritin-related endpoints.

The formula logic can therefore be summarized in Table 2:

Table 2. Technical Roles and Consumer Interpretation of the Dual-Engine Iron System

Iron Form	Technical Role	Consumer Translation
Lytox™ nano-micellar ferric pyrophosphate	Fast-response iron	Helps iron nutrition respond faster
IHAT, Iron Hydroxide Adipate Tartrate	Reserve-oriented iron	Helps support steady iron reserve
Dual-Engine Iron System	Fast + reserve strategy	Replenish fast, reserve steadily

3. Cofactor Matrix: Supporting Iron Utilization

Iron nutrition does not depend on iron alone. This formula includes a cofactor matrix designed to support absorption, metabolism, and red blood cell-related nutrition. Table 3 lists the cofactor matrix ingredients and their rationale in the formula.

Vitamin C is widely recognized as an enhancer of non-heme iron absorption [5]. Classical human nutrition research describes ascorbic acid as a strong enhancer of non-heme iron absorption, and HSA's health supplement guideline also lists "increases iron absorption" as an accepted claim for vitamin C.

Table 3. Cofactor Matrix Ingredients and Their Rationale in Formula

Ingredient	Rationale in Formula
Vitamin C	Supports non-heme iron absorption
Copper	Supports normal iron metabolism and red blood cell-related nutrition
Vitamin B_{12}	Supports normal red blood cell formation
L-5-Methyltetrahydrofolate	Active folate form for daily nutritional support
Lactoferrin Complex	Supports an iron-binding and iron-carrying nutrition concept
Sialic Acid	Premium women's wellness positioning ingredient
2'-Fucosyllactose HMO	Modern nutritional support ingredient

Folate, vitamin B_{12}, and iron play important roles in erythropoiesis, while copper is necessary for normal iron metabolism and red blood cell production and function [6-7]. Lactoferrin has also been studied in relation to iron supplementation and gastrointestinal tolerability, including randomized trials and systematic reviews comparing bovine lactoferrin with iron salts in pregnancy-related iron deficiency settings [8]. Together, the system is positioned as: **Iron Replenishment + Iron Reserve + Cofactor Support + Women's Daily Wellness**

4. Dosage Form: Chewable Sweet Vegetarian Softgel

Conventional iron products often have a metallic taste or are presented as tablets that some users find difficult to swallow. This product is designed as a Chewable, Sweet-Tasting Vegetarian Softgel (Table 4).

The dosage form was developed to improve daily compliance and consumer acceptance.

Table 4. Dosage-Form Features and Consumer Benefits

Dosage-Form Feature	Consumer-Relevant Benefit
Chewable format	Easier than swallowing large tablets
Sweet taste	Helps reduce unpleasant iron taste
Vegetarian softgel	Modern, female-friendly format
Once-daily serving	Simple daily routine
Prenatal-friendly positioning	For pregnant women under healthcare professional advice

The intended benefit is not only iron delivery, but also a better daily supplementation experience.

5. Human-Use Experiment Overview

A 12-week human-use experiment was conducted in **Kuala Lumpur, Malaysia** by **Eternal Grace R&D Center**.

This internal human experiment was designed to evaluate both objective iron nutrition markers and consumer-perceivable wellness outcomes.

5.1 Objective

The experiment assessed the effects of the Lytox™ Nano-Micellar Iron + IHAT Dual-Engine Iron System on:

1) fast iron nutritional response;
2) iron reserve status;
3) red blood cell-related nutritional indicators;
4) facial complexion parameters;
5) fatigue score;
6) daily endurance score;
7) menstrual-burden perception;
8) gastrointestinal tolerance;
9) product compliance.

5.2 Study Description

The summary of the human experiment design is shown in Table 5.

Table 5. Summary of Human Experiment Design

Item	Description
Location	Kuala Lumpur, Malaysia
Research center	Eternal Grace R&D Center
Design	Internal human-use experiment
Duration	12 weeks
Product	Chewable vegetarian softgel containing Lytox™ nano-micellar ferric pyrophosphate and IHAT iron
Serving	One softgel daily according to product direction
Population	Adult women with daily tiredness, low-normal iron status, or increased iron nutritional needs
Assessment timepoints	Baseline, Day 14, Day 20, Week 4, Week 8, Week 12
Evaluation type	Biomarkers, facial color measurement, scoring systems, tolerance records

6. Assessment Methods

6.1 Fast Iron Response

Fast iron response was evaluated using short-window iron-related indicators which is shown in Table 6.

Table 6. Fast Iron Response Assessment Indicators and Their Meanings

Indicator	Meaning
Serum Iron $AUC_{0–8h}$	Overall serum iron response over 8 hours
Serum Iron C_{max}	Peak serum iron response
TSAT $AUC_{0–8h}$	Iron transport response
T_{max}	Time to peak serum iron response
Ret-He / CHr	Early red blood cell iron supply signal

6.2 Iron Reserve

Ferritin was used as the primary iron reserve indicator. WHO recognizes serum ferritin as a useful marker for assessing iron status, while also noting that inflammation can affect interpretation, which is why inflammatory markers such as CRP or AGP may be needed for adjustment in research settings. The iron reserve assessment indicators and their meanings are shown in Table 7.

Table 7. Iron Reserve Assessment Indicators and Their Meanings

Indicator	Meaning
Ferritin	Iron reserve
TSAT	Iron transport status
sTfR	Tissue-level iron demand
Hemoglobin	Red blood cell-related oxygen-carrying marker
Ret-He / CHr	Early red blood cell iron supply marker

6.3 Facial Complexion Parameters

Facial complexion was assessed using L*, a*, and b* values. In CIELAB color measurement, L* reflects lightness, a* reflects the red-green axis, and b* reflects the yellow-blue axis [9]. These parameters are widely used in objective skin color measurement. Facial complexion assessment parameters and their meanings are shown in Table 8.

Table 8. Facial Complexion Assessment Parameters and Their Meanings

Parameter	Interpretation
L* value	Facial brightness
a* value	Rosiness / red tone
b* value	Yellow tone / dullness tendency
Subjective complexion score	Self-rated complexion improvement
Dullness score	Self-rated dull or yellowish appearance

6.4 Fatigue Scoring System

Fatigue was assessed using a participant-reported scoring system, including:

- Daily Fatigue Score;
- Afternoon Slump Score;
- Morning Energy Score;
- Overall Vitality Score.

This endpoint is biologically relevant because iron supplementation has been studied in non-anemic women with fatigue and low ferritin. Randomized studies have reported fatigue improvement after oral iron supplementation in women with low or borderline ferritin [10-11].

6.5 Daily Endurance Scoring System

Daily endurance was evaluated using consumer-relevant routine activity scores, including:

- walking or commuting stamina;
- stair-climbing tolerance;
- post-activity recovery feeling;
- physical activity comfort;
- willingness to stay active during the day.

This scoring system was designed to reflect perceived daily endurance, not athletic performance enhancement [12].

6.6 Menstrual-Burden Perception

Because menstruation contributes to iron loss and higher iron needs in women, menstrual-burden perception was recorded as a supportive wellness endpoint. Iron requirements in menstruating women have been studied in relation to menstrual blood losses, and WHO provides guidance on iron supplementation for menstruating adult women and adolescent girls in relevant public-health contexts [2].

This assessment was not intended to claim reduction of menstrual bleeding or treatment of menstrual disorders. It was used to evaluate participant-perceived menstrual burden, post-period tiredness, and post-period recovery during daily iron supplementation.

6.7 Gastrointestinal Tolerance

Tolerance was assessed through participant-reported records, including constipation, stomach discomfort, nausea or reflux, stool-form abnormality, compliance rate, and discontinuation rate. This is important because daily iron supplementation is known to increase gastrointestinal side effects in some contexts.

7. Results

7.1 Fast Iron Response

Table 9. Observed Results of Fast Iron Response Indicators

Indicator	**Observed Result**
Serum Iron AUC0–8h	+42%
Serum Iron Cmax	+38%
TSAT AUC0–8h	+32%
Tmax	2–4 hours
Ret-He / CHr at Day 14	+4.5%

The short-window response data indicate that the Lytox™ nano-micellar iron component was

associated with a faster iron nutritional response. The increase in Serum Iron AUC0–8h and TSAT AUC0–8h supports the positioning of Lytox™ iron as the **fast-response engine** of the formula.

As shown in Table 9, the Lytox™ nano-micellar iron component demonstrated a rapid iron-response profile, with Serum Iron AUC0–8h increasing by 42% and TSAT AUC0–8h increasing by 32% in this internal human-use experiment.

7.2 Iron Reserve Support

Table 10. Changes in Iron Reserve-Related Indicators Over Time

Indicator	Week 4	Week 8	Week 12
Ferritin	1.86 × baseline	2.15 × baseline	2.35 × baseline
TSAT	+19%	+23%	+28%
sTfR	-7%	-10%	-12%

As shown in Table 10, ferritin increased progressively over 12 weeks, reaching 2.35 × baseline at Week 12. This supports the positioning of IHAT as the **reserve-oriented engine** of the formula. Ferritin levels showed a progressive increase throughout the 12-week experiment, suggesting improved iron reserve status during continuous use of the Dual-Engine Iron System.

7.3 Red Blood Cell-Related Nutritional Indicators

Table 11. Observed Results of Red Blood Cell-Related Nutritional Indicators

Indicator	Observed Result
Hemoglobin at Day 20	+12.8%
Hemoglobin at Week 12	+12–18 g/L
Ret-He / CHr at Day 14	+4.5%

As shown in Table 11, the changes in hemoglobin and Ret-He / CHr suggest improvement in red blood cell-related nutritional status during the supplementation period. Red blood cell-related nutritional indicators improved over the 12-week period, supporting the role of the formula in iron nutrition and normal red blood cell-related nutritional processes.

7.4 Facial Complexion Results

Table 12. Changes in Facial Complexion Parameters Over Time

Parameter	Week 4	Week 8	Week 12
L* value, facial brightness	+1.2	+1.8	+2.2
a* value, rosiness	+0.7	+1.0	+1.3
b* value, yellow tone	-0.8	-1.2	-1.6
Subjective complexion score	+22%	+31%	+38%
Dullness score	-18%	-28%	-35%

As shown in Table 12, after 12 weeks, participants showed increased facial brightness, increased rosiness, and reduced yellow-tone appearance. By Week 12, L* value increased by 2.2, a* value increased by 1.3, and b* value decreased by 1.6, suggesting improvements in facial brightness, rosiness, and yellow-tone appearance.

7.5 Fatigue Score Results

As shown in Table 13, participants reported lower daily tiredness, reduced afternoon slump,

improved morning energy, and higher overall vitality scores. Daily Fatigue Score decreased by 38% at Week 12, while Morning Energy Score increased by 33% and Overall Vitality Score increased by 36%, suggesting improved daily energy perception.

Table 13. Changes in Fatigue and Vitality Scores Over Time

Indicator	Week 4	Week 8	Week 12
Daily Fatigue Score	-22%	-31%	-38%
Afternoon Slump Score	-20%	-28%	-35%
Morning Energy Score	+18%	+26%	+33%
Overall Vitality Score	+19%	+29%	+36%

As shown in Table 13, participants reported lower daily tiredness, reduced afternoon slump, improved morning energy, and higher overall vitality scores. Daily Fatigue Score decreased by 38% at Week 12, while Morning Energy Score increased by 33% and Overall Vitality Score increased by 36%, suggesting improved daily energy perception.

7.6 Daily Endurance Score Results

Table 14. Changes in Daily Endurance Scores Over Time

Indicator	Week 4	Week 8	Week 12
Daily Endurance Score	+18%	+28%	+36%
Stair-Climbing Tolerance Score	+16%	+25%	+34%
Post-Activity Recovery Score	+15%	+24%	+32%
Physical Activity Comfort Score	+17%	+27%	+35%

As shown in Table 14, participants reported better perceived stamina during walking, commuting, stair climbing, and daily movement. By Week 12, Daily Endurance Score increased by 36%, indicating improved perceived stamina during routine daily activities.

7.7 Menstrual-Burden Perception Results

Table 15. Changes in Menstrual-Burden Perception Scores Over Time

Indicator	Cycle 1	Cycle 2	Cycle 3
Menstrual-Volume Burden Score	-11%	-18%	-24%
Post-Period Tiredness Score	-16%	-26%	-34%
Post-Period Recovery Score	+18%	+28%	+37%
Menstrual Energy Support Score	+15%	+25%	+33%

As shown in Table 15, participants reported reduced menstrual-burden perception, reduced post-period tiredness, improved post-period recovery, and higher menstrual energy support scores. This assessment does not indicate reduction of abnormal menstrual bleeding or treatment of menstrual disorders. It reflects participant-perceived menstrual burden and post-period recovery in the context of daily iron nutrition support.

7.8 Gastrointestinal Tolerance and Compliance

As shown in Table 16, the formula was well tolerated during the experiment, with low reported rates of constipation, stomach discomfort, and nausea. The compliance rate remained high, supporting the suitability of the chewable vegetarian softgel format for daily use.

Table 16. Observed Results of Gastrointestinal Tolerance and Compliance

Indicator	Observed Result
Constipation incidence	≤6%
Stomach discomfort incidence	≤8%
Nausea / reflux incidence	≤5%
Abnormal stool-form score	≤8%
Compliance rate	≥95%
Discontinuation rate	≤3%

8. Discussion

This human-use experiment suggests that the Dual-Engine Iron System may provide a more complete approach to women's iron supplementation compared with conventional single-source iron products.

As shown in Table 17, the main differentiation is the two-engine design.

Table 17. Technical Division and Positioning of the Dual-Engine System

Engine	Ingredient	Positioning
Fast-response engine	Lytox™ nano-micellar ferric pyrophosphate	Faster iron nutritional response
Reserve-oriented engine	IHAT, Iron Hydroxide Adipate Tartrate	Steady iron reserve support

Traditional iron supplements often focus primarily on elemental iron dose. Some newer products emphasize microencapsulation to improve tolerability. In contrast, this formula is designed around a broader framework: **Fast Response + Reserve Support + Cofactor Utilization + Female Daily Wellness**

The 0–8 hour iron-response data support the fast-response positioning of Lytox™ nano-micellar iron. The 12-week ferritin data support the reserve-oriented positioning of IHAT. The cofactor matrix further supports iron absorption, iron metabolism, and red blood cell-related nutrition.

Importantly, this experiment expanded evaluation beyond laboratory biomarkers. By including facial L*/a*/b* values, fatigue scoring, daily endurance scoring, menstrual-burden perception, and gastrointestinal tolerance, the assessment better reflected real consumer concerns.

For female consumers, iron supplementation is not only about laboratory values. It is also about whether they feel less tired, look less dull, recover better after menstruation, tolerate the product well, and are willing to take it every day.

9. Conclusion

The 12-week human-use experiment conducted by Eternal Grace R&D Center in Kuala Lumpur, Malaysia showed that the Lytox™ Nano-Micellar Iron + IHAT Dual-Engine Iron System was associated with improvements in iron nutritional response, iron reserve, red blood cell-related nutritional indicators, facial complexion parameters, fatigue score, daily endurance score, menstrual-burden perception, and gastrointestinal tolerance.

Key observed findings was shown in Table 18.

Overall, the product may be positioned as a modern women's iron supplement designed around: **Fast Iron Replenishment, Steady Iron Reserve, Cofactor Support, Daily Vitality, Complexion Support, Menstrual-Period Nutritional Support, and Gentle Everyday Use.**

Table 18. Summary of Key Observed Results of the Dual-Engine Iron System

Area	Key Result
Internal absorption assessment	12 × higher absorption efficiency than ordinary ferrous sulfate
Fast iron response	Serum Iron AUC0–8h +42%
Iron transport response	TSAT AUC0–8h +32%
Iron reserve	Ferritin 2.35 × baseline by Week 12
Hemoglobin	+12–18 g/L by Week 12
Facial brightness	L* value +2.2 by Week 12
Rosiness	a* value +1.3 by Week 12
Yellow-tone appearance	b* value -1.6 by Week 12
Fatigue	Daily Fatigue Score -38% by Week 12
Daily endurance	Daily Endurance Score +36% by Week 12
Post-period recovery	Post-Period Recovery Score +37% by Cycle 3
Tolerance	Constipation incidence ≤6%
Compliance	≥95%

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