Experiment 2 — Structured R&D ELN Record (Parallel DoE Study)

Focus: Surfactant System Optimization / Mildness vs Foam Balance
Project: CLEARSCALP Sulfate-Free Shampoo Initiative
Experiment ID: CS-221-A08 (DoE Set 2)
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Objective

Evaluate the effect of **primary surfactant ratio adjustment** on:

- Foam quality (creaminess vs volume)
- Mildness proxy (zein reduction screening)
- Viscosity stability
- Fragrance clarity retention (held constant system-wide)

Experimental Design (True Parallel DoE, Same Process Conditions)

Three prototypes were manufactured **in parallel using identical processing steps, identical shear profile, identical temperature profile, and identical addition sequence**.

Only formulation variables were changed.

Prototype	Sarcosinate (%)	CAPB (%)	Total Active Matter	Design Intent
A	14.0	7.0	21.0	Baseline control
B	12.0	9.0	21.0	Foam boost / mildness shift
C	15.5	5.5	21.0	High cleansing / high structure

All other ingredients (PEG-40 HCO, fragrance, HEC, pH system) held constant.

Base Formula (Constant Across All Prototypes)

Ingredient	Function	Target %
DI Water	Carrier	q.s.
Sodium Lauroyl Sarcosinate	Primary Surfactant	variable
Cocamidopropyl Betaine	Secondary Surfactant	variable
PEG-40 Hydrogenated Castor Oil	Solubilizer	2.5
Eucalyptus Oil Blend	Fragrance	0.8
Hydroxyethylcellulose	Rheology Modifier	0.7
Citric Acid (20%)	pH Adjuster	q.s.

Equipment (Identical Parallel Setup)

Equipment	IDs
Silverson Homogenizer	MIX-01 / MIX-02 / MIX-03
Overhead Stirrer	STR-21 / STR-22 / STR-23
Brookfield DV2T	VIS-08
pH Meter	PH-03

Procedure (Identical Process Across All Prototypes)

Phase 1 — Hydration (Parallel)

08:05–08:35

- DI water charged into three identical 2 L vessels
- Hydroxyethylcellulose dispersed at 250 rpm
- Hydrated at 68°C for 20 min

Observation:

- Uniform gel formation across all vessels
- No dispersion variance detected

Phase 2 — Surfactant Addition (Parallel)

08:40–09:20

- Surfactants added in identical sequence:
    1. Sodium Lauroyl Sarcosinate
    2. Cocamidopropyl Betaine

Observations (all systems):

- Foam formation at addition onset
- Controlled vortex instability above 280 rpm
- All systems stabilized at 180–200 rpm range

Notable differentiation:

- B exhibited visibly lower foam collapse rate
- C exhibited higher initial viscosity rise during surfactant build

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Phase 3 — Fragrance Solubilization (Parallel)

09:25–09:45

- PEG-40 HCO + eucalyptus fragrance premix prepared identically per prototype mass balance
- Premix homogenized at 4000 rpm for 90 sec

Observation:

- All premixes fully transparent prior to addition

Phase 4 — Incorporation (Parallel, Identical Shear)

09:50–10:10

- Premix added dropwise under 250 rpm
- High shear applied: 3500 rpm for 3 min (identical across all vessels)

Observations:

- A: transient haze (30–40 sec)
- B: near-instant clarity retention

- C: slight opalescence during addition phase only

All systems cleared under high shear within 3–4 min.

Phase 5 — Cooldown & pH Adjustment (Parallel)

10:20–11:00

- Cooled to 34°C
- pH adjusted to 5.5 ± 0.1 using citric acid

Results Summary

Parameter	A (Control)	B (High CAPB)	C (High Sarcosinate)
Appearance	Clear	Clear (highest clarity)	Slightly opalescent (cleared post-shear)
Foam Volume	Medium	High	High but dense
Foam Quality	Standard	Creamy, stable	Fast-rise, less creamy
Viscosity (cP)	5,650	5,900	6,150
Fragrance Stability	Pass	Pass (best retention)	Pass
Processing Stability	Good	Very stable	Slight thickening during addition

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Interpretation

1. **CAPB increase (Prototype B)** improves foam structure and stabilizes fragrance microemulsion behavior, likely due to improved micellar flexibility.
2. **Sarcosinate increase (Prototype C)** drives higher viscosity and stronger cleansing profile but increases transient instability during incorporation.
3. Baseline (A) remains balanced but suboptimal in foam aesthetics compared to optimized systems.

Conclusion

- The system shows strong sensitivity to **secondary surfactant ratio (CAPB)** for sensory and stability performance.
- Primary surfactant increase improves viscosity but introduces **process sensitivity during fragrance incorporation**.
- No changes required to solubilizer level for this design space (held stable across all conditions).

Next Study Direction

- Explore **CAPB-rich system (≥10%) with reduced primary surfactant for foam texture optimization**
- Introduce **polymeric foam stabilizer screening (low-dose associative thickeners)**
- Evaluate sensory panel correlation with foam density metrics