NOTESKARTS

COSMETIC SCIENCE

B.Pharmacy 8th Semester

UNIT 4 — Detailed Study Notes

As per AKTU / PCI Syllabus

Principles of Cosmetic Evaluation

Sebumeter | Corneometer | TEWL Measurement | Skin Colour Measurement
Hair Tensile Strength | Hair Combing Properties
Soaps and Syndet Bars — Evolution and Skin Benefits

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PRINCIPLES OF COSMETIC EVALUATION

Cosmetic evaluation is the scientific assessment of safety, efficacy, stability, and sensory properties of cosmetic products using validated, reproducible, and objective measurement techniques. It bridges formulation science with consumer satisfaction.

WHY COSMETIC EVALUATION IS IMPORTANT:

1. Objective proof of efficacy claims: 'moisturizes 24h', 'reduces oiliness by 40%'
2. Regulatory compliance — EU Cosmetics Regulation 1223/2009 requires claim substantiation
3. Product development optimization — guides formulation iteration
4. Quality control — ensures batch-to-batch consistency
5. Consumer trust — scientific data supports marketing claims

Method Category	Techniques	Parameters Measured
Biophysical Instrumental	Sebumeter, Corneometer, Tewameter, Mexameter, Cutometer	Sebum, hydration, TEWL, skin colour, elasticity
Mechanical Testing	Tensile strength tester, Combing rig, Dynamometer	Hair tensile strength, elongation, combing force
Optical / Imaging	VISIA, Cross-polarized photography, Confocal microscopy	Pores, wrinkles, pigmentation, texture, UV spots
Sensory / Panelist	Expert panel, consumer perception, QDA	Skin feel, texture, spreadability, fragrance
Chemical / Analytical	HPLC, GC-MS, ISE, ICP-OES, AAS	Active content, preservatives, heavy metals, fluoride
Microbial	PET, TAMC, TYMC, MLT	Microbial safety, preservative effectiveness

SEBUMETER — Measurement of Skin Sebum

Sebumeter: The Sebumeter (Courage + Khazaka, Germany — Model SM 815) is a non-invasive biophysical instrument that quantitatively measures the amount of sebum (skin surface lipids) on the skin surface by photometry of a special sebum-collecting tape.

Why Measure Sebum?

- Classify skin type: oily, normal, dry, combination skin
- Evaluate efficacy of sebum-controlling cosmetics — mattifiers, toners, anti-acne products
- Monitor skin changes during product use or environmental variation
- Research: correlate sebum levels with acne severity, dandruff, hair greasiness

Principle of Operation

> The Sebumeter works on photometry of a special polypropylene (PP) tape cassette. The tape is opaque when dry. Sebum (lipid) absorbed from skin renders the tape transparent. The degree of transparency, measured by transmitted light, is directly proportional to sebum content.

Detailed Mechanism:

> Step 1: Special polypropylene (PP) tape cassette inserted into instrument measurement head
> Step 2: Tape pressed against skin surface for exactly 30 seconds under standardized pressure
> Step 3: Sebum (skin surface lipids) transfers from skin onto and into the porous tape
> Step 4: Tape (now lipid-saturated) moved to photometric measurement unit
> Step 5: Halogen lamp shines transmitted light THROUGH the tape
> Step 6: Sebum-free tape = opaque = low light transmission; Sebum-saturated tape = transparent = high light transmission
> Step 7: Photodiode detector measures transmitted light intensity
> Step 8: Microprocessor converts light value to sebum content in micrograms per cm2
> Step 9: Result displayed as SU (Sebum Units) — 1 SU approximately equals 1 µg sebum/cm2

Physics Behind Measurement:

- **Fat transparency principle:** Lipids are transparent to visible light; polypropylene tape is opaque; when sebum fills tape pores it renders tape transparent — directly proportional relationship between sebum and transparency
- **Measurement range:** 0 to 350 µg/cm2; displayed as SU (Sebum Units)

Technical Specifications

Parameter	Specification
Instrument	Sebumeter SM 815 (Courage + Khazaka, Germany)
Measurement principle	Photometry of lipid-impregnated polypropylene tape (transmitted light)
Light source	Halogen lamp (visible light spectrum)
Detector	Photodiode measuring transmitted light intensity
Measurement tape	Special polypropylene tape cassette (3 cm x 6.4 cm)
Contact time with skin	30 seconds under standardized pressure
Measurement range	0 - 350 SU (Sebum Units / µg/cm2)
Measurement area	64 mm2 skin area per measurement
Standard skin sites	Forehead, cheeks, chin, T-zone, nose, scalp

Interpretation of Sebumeter Values

Sebum Level	SU Value (µg/cm2)	Skin Type / Condition

Dry	0 - 30 SU	Very dry skin; sebaceous hypoactivity; needs rich moisturizer
Normal	30 - 70 SU	Normal balanced skin type; maintain with regular moisturizer
Slightly oily	70 - 100 SU	Combination skin; T-zone oiliness; oil-free formulations recommended
Oily	100 - 175 SU	Oily seborrhoeic skin; mattifying products needed; acne-prone
Very oily	> 175 SU	Severe seborrhoea; significant acne association; medical referral may be needed

Standardization Conditions

- **Acclimatization:** Subject sits in room for 15-20 min at 20-22°C and 40-60% relative humidity before testing
- **No product use:** No washing, products, or touching of measurement area for at least 4 hours before measurement
- **No exercise:** No physical activity for at least 2 hours before (sweat alters sebum distribution)
- **Consistent time of day:** Sebum follows circadian rhythm — peak in morning; same time of day for comparative studies
- **Multiple measurements:** 3 consecutive measurements at same site; discard first; report mean of measurements 2 and 3

Applications of Sebumeter

Application	How Sebumeter is Used
Mattifying product efficacy	Measure SU before and 1h, 2h, 4h, 8h after product; calculate % sebum reduction
Skin type classification	Screen volunteers for clinical studies; categorize dry/normal/oily by SU values
Anti-acne formulation testing	Monitor sebum reduction over 4-12 weeks; correlate with acne grade improvement
Niacinamide efficacy	Niacinamide 5% reduces sebum production; Sebumeter quantifies reduction over 8 weeks
Seasonal and environmental studies	Track sebum changes in summer vs winter; hot-humid vs cold-dry climates

CORNEOMETER — Measurement of Skin Hydration

> **Corneometer:** The Corneometer (Courage + Khazaka, Germany — Model CM 825) is a non-invasive instrument that measures the hydration (water content) of the stratum corneum using electrical capacitance measurement. It is the gold standard for skin hydration assessment.

Why Measure Skin Hydration?

- Evaluate moisturizing efficacy of creams, lotions, serums, and skin care products
- Prove claims: '24-hour hydration', 'clinically proven moisturization'
- Classify skin as dry, normal, or well-hydrated before and after treatment
- Monitor treatment of dry skin conditions: xerosis, atopic dermatitis

Principle of Operation

> The Corneometer uses electrical capacitance to measure the dielectric constant of the stratum corneum. Water has an extremely high dielectric constant ($\varepsilon = 80$) compared to proteins ($\varepsilon = 2$-4) and lipids ($\varepsilon = 2$-7). Therefore, capacitance of the SC increases proportionally with its water content.

Physics of Capacitance Measurement:

- **Capacitor principle:** Capacitance $C = \varepsilon_0 \times \varepsilon_r \times A / d$; where ε_r = relative permittivity (dielectric constant) of material
- **Dielectric constants:** Water $\varepsilon_r = 80$ (very high); Keratin protein $\varepsilon_r = 2$-4; Lipids $\varepsilon_r = 2$-7; Air $\varepsilon_r = 1$
- **SC as dielectric:** Stratum corneum acts as dielectric between electrode plates; more water = higher ε_r = higher capacitance
- **Measurement depth:** Penetrates only 10-20 µm — outermost SC layers only; does NOT measure dermis water

Detailed Mechanism:

> Step 1: Corneometer probe (10.5 mm diameter circular gold electrode grid) placed gently on skin
> Step 2: Probe generates high-frequency electromagnetic field (1 MHz operating frequency)
> Step 3: Field penetrates outermost 10-20 µm of stratum corneum — the measurement zone
> Step 4: Water molecules in SC align with alternating electric field — dielectric polarization occurs
> Step 5: Capacitance of the SC dielectric layer measured by instrument electronics
> Step 6: Higher SC water content → higher dielectric constant → higher capacitance reading
> Step 7: Capacitance value converted to Corneometer Units (CU) via internal calibration algorithm
> Step 8: Result displayed digitally — higher CU = better hydrated stratum corneum

Technical Specifications

Parameter	Specification
Instrument	Corneometer CM 825 (Courage + Khazaka, Germany)
Measurement principle	Electrical capacitance of stratum corneum (dielectric measurement)
Operating frequency	1 MHz (high frequency alternating current)
Probe size	10.5 mm diameter circular gold electrode grid
Measurement depth	10-20 µm (outermost stratum corneum layers only)

Measurement range	0 - 120 Corneometer Units (CU)
Repeatability	CV (coefficient of variation) < 5%
Output	Corneometer Units (CU) — dimensionless relative unit

Interpretation of Corneometer Values

Hydration Level	CU Value	Skin Condition
Very dry	< 30 CU	Severely dehydrated SC; clinically dry skin; xerosis; atopic dermatitis flare
Dry	30 - 45 CU	Dry skin type; reduced NMF; increased TEWL; needs intensive moisturization
Normal	45 - 60 CU	Normal well-hydrated skin; good barrier function
Well hydrated	60 - 80 CU	Good hydration; healthy SC; effective moisturizer use
Very well hydrated	> 80 CU	Excellent hydration; seen after moisturizer application; occluded skin

Standardization Conditions

- **Temperature and humidity:** 20-22°C; 40-60% relative humidity; 15-20 minutes acclimatization
- **No product use:** No moisturizer or lotion for minimum 4 hours before baseline measurement
- **Gentle probe placement:** Do not press hard — pressure activates sweat glands → falsely elevated reading
- **Multiple measurements:** Minimum 3 consecutive measurements at same site; report mean with standard deviation

Applications in Cosmetic Studies

Study Design	How Corneometer is Used
Immediate moisturization test	Measure CU baseline → apply product → measure at 0.5h, 1h, 2h, 4h, 8h, 24h; plot hydration curve
4-8 week repeated use study	Daily CU measurements; compare baseline week 1 with week 4 and week 8; shows cumulative benefit
Comparison study	Product A vs product B vs placebo; same parameters; statistical analysis (ANOVA, t-test)
Dry skin monitoring	Track CU before and after emollient therapy in atopic dermatitis patients

MEASUREMENT OF TEWL (Transepidermal Water Loss)

TEWL: Transepidermal Water Loss (TEWL) is the passive diffusion of water vapour through the skin layers to the skin surface and into the environment. It indirectly measures skin barrier function — higher TEWL = compromised barrier; lower TEWL = intact healthy barrier.

Why Measure TEWL?

- Assess skin barrier integrity — impaired barrier shows elevated TEWL
- Evaluate barrier-repairing efficacy of cosmetics: ceramides, fatty acids, emollients
- Diagnose and monitor barrier disorders: atopic dermatitis, psoriasis, ichthyosis
- Test mild irritancy — irritant exposure raises TEWL as first sign of barrier disruption
- Assess sunscreen, after-sun, and repair cream efficacy

Physics of TEWL — Fick's First Law

- **Fick's First Law of Diffusion:** $\text{TEWL} = D \times A \times (C_1 - C_2) / d$
  - D = diffusion coefficient of water through stratum corneum
  - A = skin surface area (cm2)
  - C_1 = water vapour concentration at inner SC (high)
  - C_2 = water vapour concentration at outer SC surface (low; equilibrium with atmosphere)
  - d = effective thickness of SC diffusion barrier
- **Normal TEWL:** Healthy skin 5-10 g/m2/h; Exposed dermis (no SC): >50 g/m2/h

Instrument — Tewameter TM 300

INSTRUMENT: Tewameter TM 300 (Courage + Khazaka, Germany) — Open Chamber Evaporimetry

Principle: Measures water vapour density gradient at the skin surface in an open cylindrical probe

Two pairs of sensors (temperature + relative humidity) positioned at two heights (h_1 and h_2) inside hollow probe

Temperature sensors: thermistors; Humidity sensors: capacitive RH sensors

Both sensor pairs measure T and RH simultaneously at their respective heights above skin surface

From T and RH values: absolute water vapour density (g/m3) calculated using Magnus formula at each sensor level

$\text{TEWL} = -D \times (C_2 - C_1)/(x_2 - x_1)$ applied across the known sensor gap distance

Measurement time: 90-120 seconds per site to allow signal equilibration and stabilization

Output: g/m2/h (grams of water lost per square meter of skin per hour)

Open Chamber vs Closed Chamber:

Parameter	Open Chamber (Tewameter)	Closed Chamber (Vapometer)
Principle	Water vapour gradient in open cylinder above skin	Sealed chamber; measures RH rise over time
Air sensitivity	Sensitive to air movement — must be draft-free	Not sensitive to air movement
Speed	Slow — 1-3 minutes equilibration	Fast — 20-30 seconds
Gold standard	YES — open chamber is the established gold standard	Good correlation but different absolute values

Technical Specifications — Tewameter

Parameter	Specification
Instrument	Tewameter TM 300 (Courage + Khazaka)
Measurement principle	Open-chamber evaporimetry — water vapour density gradient
Sensors	Two pairs of temperature (thermistor) + humidity (capacitive) sensors
Sensor positions	Fixed at h_1 and h_2 inside probe (approx. 3 mm apart)
Measurement range	0 - 200 g/m2/h (up to 500 g/m2/h in advanced models)
Measurement time	90-120 seconds per site (signal stabilization required)
Output	g/m2/h — grams of water per square meter per hour

Interpretation of TEWL Values

TEWL Value	g/m2/h	Skin Condition
Very low — excellent barrier	< 5 g/m2/h	Excellent SC barrier; very well-protected; after emollient application
Normal	5 - 10 g/m2/h	Healthy skin with intact SC barrier; normal physiological range
Mildly elevated	10 - 15 g/m2/h	Slightly compromised barrier; mild dryness; borderline sensitive skin
Moderately elevated	15 - 25 g/m2/h	Significantly impaired barrier; dry skin disorder; early atopic dermatitis
Severely elevated	25 - 50 g/m2/h	Severely compromised SC; active atopic dermatitis; post-procedure skin
Barrier absent	> 50 g/m2/h	No functional SC; wound; burned or tape-stripped skin

Standardization and Sources of Error

- **Draft-free room:** Air movement causes falsely elevated TEWL — must avoid fans, A/C vents, and open windows
- **Temperature:** Constant 20-22°C; thermoregulatory sweating falsely elevates TEWL reading
- **Humidity:** 40-60% RH; very low RH (<30%) increases evaporation gradient artificially
- **Acclimatization:** Subject sits in room for 20-30 minutes before measurement; emotional sweating must subside
- **Probe placement:** Hold probe vertically above horizontal skin; do NOT press down — pressure impairs local blood flow and affects TEWL

Applications of TEWL in Cosmetics

Application	Details
Barrier repair cream testing	Measure TEWL before and after 4-8 weeks of ceramide/fatty acid cream; TEWL reduction confirms improved barrier
Irritancy patch test	Apply potential irritant under occlusive patch 24-48h; elevated TEWL at site = barrier damage
Sun protection evaluation	Measure TEWL at UV-exposed vs UV-protected sites; sunscreen reduces UV-induced TEWL rise
Tape-stripping model	Remove SC by repeated tape stripping; plot TEWL rise per strip; creates barrier damage model for testing repair creams

MEASUREMENT OF SKIN COLOUR

> Skin colour measurement is the objective, quantitative assessment of skin pigmentation and erythema using spectrophotometric or colorimetric instruments, enabling scientific proof of claims for brightening, anti-pigmentation, anti-redness, and anti-aging products.

Why Measure Skin Colour?

- Evaluate skin lightening/brightening creams — kojic acid, niacinamide, arbutin
- Assess anti-redness and soothing products — measure erythema reduction
- Monitor sunscreen efficacy — measure UV-induced tanning and erythema prevention
- Clinical studies for pigmentation disorders: melasma, vitiligo, PIH

CIE L*a*b* Colour Space — Gold Standard

Axis	Range	Meaning for Skin Measurement
L*	0 (black) to 100 (white)	Lightness/Luminance — measures skin brightness; higher L* = lighter skin; L* increases with whitening treatment; parameter for anti-pigmentation claims
a*	-60 (green) to +60 (red)	Red-Green axis — measures erythema (redness); positive a* = red/inflamed; anti-redness products reduce a*; also indicates sunburn response
b*	-60 (blue) to +60 (yellow)	Yellow-Blue axis — measures yellowness/tanning; positive b* = yellow/tan; sunscreen prevents b* increase after UV exposure; anti-aging reduces yellow b* from AGEs

- **ITA (Individual Typology Angle):** $\text{ITA}° = \arctan[(L^* - 50) / b^*] \times 180/\pi$; ranges from <28° (very dark skin) to >55° (very light skin); used for skin phototype classification
- **Delta E (Total colour change):** $\Delta E = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$; $\Delta E > 1.0$ is visually perceptible; $\Delta E > 3.0$ is clearly visible to naked eye

Instruments for Skin Colour Measurement

A. Mexameter MX 18 — Erythema and Melanin:

INSTRUMENT: Mexameter MX 18 (Courage + Khazaka)

Principle: Narrowband spectrophotometry at three specific wavelengths targeting oxyhaemoglobin and melanin

Light source: LED emitting at THREE wavelengths: 568 nm, 660 nm, and 880 nm

568 nm (green light): absorbed by oxyhaemoglobin in blood — measures ERYTHEMA (redness/inflammation)

660 nm (red light): absorbed by melanin (pigmentation) — measures MELANIN content

880 nm (near-infrared): reference wavelength — NOT absorbed by Hb or melanin; corrects for skin surface factors

Erythema Index (EI) = differential absorption at 568 nm vs 880 nm reference

Melanin Index (MI) = differential absorption at 660 nm vs 880 nm reference

Output: EI (0-999 Arbitrary Units) and MI (0-999 Arbitrary Units)

Higher EI = more erythema (redness); Higher MI = more melanin (darker pigmentation)

B. Colorimeter CR-400 (Konica Minolta):

INSTRUMENT: Colorimeter CR-400 (Konica Minolta)

Principle: Measures total reflected light from skin surface in CIE L*a*b* coordinates directly

Light source: Xenon pulse lamp providing diffuse illumination over entire measurement area

Detector: Silicon photodiodes behind X, Y, Z tristimulus filters matching CIE standard observer

Measurement geometry: d/0 degree (diffuse illumination / 0 degree observation)

Output: Direct CIE L*, a*, b* values; also ITA, Delta-E, chroma (C*), hue (h*)

Measurement area: 8 mm diameter aperture

Advantage: Directly gives CIE values without calculation; highly reproducible; widely accepted

C. VISIA Complexion Analysis System:

INSTRUMENT: VISIA Complexion Analysis System (Canfield Scientific)

Multi-spectrum imaging: standard white light, UV fluorescence, cross-polarized light, parallel-polarized light

Standard white light: visible pores, wrinkles, surface texture, spots

UV fluorescence: UV spots (sub-surface pigmentation); porphyrins from C. acnes bacteria

Cross-polarized light: eliminates surface glare → reveals deep pigmentation, veins, hemoglobin

Parallel-polarized light: surface texture, skin smoothness, fine lines

Software automatically quantifies: wrinkles, pores, pigmentation, UV spots, porphyrins, redness

Comparison feature: before vs after treatment photography with percentile database ranking

Standardization for Skin Colour Measurement

- **White standard calibration:** Calibrate instruments against standard white ceramic tile before each session
- **Acclimatization:** 15-20 minutes in controlled room (22°C, 50% RH) — flushing from heat affects a* erythema readings
- **Site marking:** Mark measurement sites with semi-permanent marker for reproducible positioning in repeat visits
- **No makeup:** Remove all makeup; no product use on measurement area for 4 hours minimum
- **Multiple measurements:** 3-5 measurements per site; calculate mean; report standard deviation

Applications in Cosmetics

Application	Parameters and Interpretation
Anti-pigmentation cream	MI and L* before and after 8-12 weeks; MI reduction + L* increase = brightening efficacy confirmed
Anti-redness soothing cream	EI and a* before and after product use; reduction confirms anti-inflammatory, anti-redness efficacy

Sunscreen evaluation	b* and MI before and after UV exposure with/without sunscreen; sunscreen prevents b* and MI increase
Anti-aging yellowing	b* measures skin yellowing from AGEs; anti-glycation products reduce b*
Vitiligo treatment	Track L* and MI at vitiligo patches over treatment; re-pigmentation shown by MI increase

MEASUREMENT OF HAIR TENSILE STRENGTH

> **Hair Tensile Strength:** Hair tensile strength refers to the mechanical properties of the hair fiber — its resistance to stretching (extension) and breakage (tensile strength). These reflect the structural integrity of the cortex, particularly the disulfide (S-S) bonds and keratin protein network.

Measure Hair Tensile Strength?

- Evaluate damage caused by chemical treatments: bleaching (H2O2), perming, relaxing, heat styling
- Assess protective efficacy of hair conditioners, protein treatments, and oils
- Compare untreated vs chemically damaged hair before and after conditioning
- Support claims: 'strengthens hair', 'reduces breakage by 30%', '10x stronger hair'

Mechanical Parameters

Parameter	Unit	Definition and Significance
Maximum (Breaking) Force	mN or cN	Force at which hair breaks; directly measures fiber strength; normal hair: 80-200 mN
Maximum Stress	N/mm2 (MPa)	Breaking force / cross-sectional area; corrects for fiber diameter variation
Elongation at Break	% extension	% hair extends before breaking; normal 30-40% dry; 60-80% wet; reflects elasticity
Young's Modulus	GPa	Stiffness in initial elastic region; slope of initial linear stress-strain curve region
Work to Break	mJ	Area under force-extension curve; total energy to fracture; fracture toughness
Yield Point	N/mm2	Point where permanent deformation begins — hair cannot return to original length beyond this

Stress-Strain Curve of Hair

When hair is extended in a tensile tester, the force-extension curve passes through distinct regions:

Region	Strain Range	Molecular Mechanism
Hookean (Elastic)	0 - 2% extension	Alpha-helix coils in cortical keratin begin straightening; fully reversible elastic deformation; Young's modulus constant here
Yield Plateau	2 - 30% extension	Alpha-helices unfold into beta-sheets (alpha-to-beta transition); disulfide bonds begin to be stressed; IRREVERSIBLE deformation begins
Post-yield region	30 - 50% extension	Disulfide bonds (S-S) bear most load; matrix protein deformation; further irreversible extension
Hard Region	50 - 80% wet	Hydrogen bonds and S-S bonds resist extension; slope increases; requires higher force per unit extension
Breaking Point	At maximum extension	Complete rupture of disulfide bonds and protein backbone; catastrophic failure; hair breaks

Instrument

INSTRUMENT: Hair Tensile Strength Tester (Diastron MTT 175 / Instron / TA.XT Texture Analyzer)

Type: Universal miniaturized tensile testing machine for single fiber measurement

Two precision miniature clamps: upper fixed jaw and lower moving jaw (or vice versa)

Gauge length: Standard 20 mm between clamps (known length of hair mounted between jaws)

Extension rate: Constant crosshead speed 5-10 mm/min (standardized)

Force transducer: High-sensitivity load cell (1 N or 10 N range); records force in mN resolution

Environment: Controlled at 55-65% RH and 20-22°C — humidity dramatically affects hair mechanical properties

Fiber preparation: Individual fiber 20-25 mm long; attached to jaws with adhesive tabs

Sample size: Minimum 30 fibers per treatment group for statistical validity

Effect of Chemical Damage on Tensile Properties

Treatment	Breaking Force Effect	Elongation Effect
Virgin (untreated) hair	Baseline ~150 mN	30-35% dry; 60-70% wet
Bleached (H2O2 6%)	Decreases 15-30%; disulfide bond oxidation	Increases (more plastic deformation before break)
Permanently waved (thioglycolate)	Decreases 10-20%; disulfide restructuring	Altered; depends on processing

Relaxed (NaOH)	Significant decrease; irreversible cortex damage	Dramatically altered; reduced elasticity
Heat styled repeatedly	Decreases 10-15%; thermal protein denaturation	Reduces; brittle hair
After conditioner treatment	Improved vs damaged control; silicone lubrication	Improved or maintained

MEASUREMENT OF HAIR COMBING PROPERTIES

> **Hair Combing Properties:** Hair combing properties quantify the ease of passing a comb through hair without snagging or tangling, measured as combing force (grams-force or Newtons) by a standardized motorized combing rig drawing a comb through a standardized hair tress.

Measure Combing Properties?

- Evaluate conditioning efficacy — good conditioner significantly reduces combing force
- Compare conditioner, 2-in-1 shampoo, and leave-in conditioner performance
- Substantiate claims: 'detangles instantly', 'reduces combing force by 50%'
- Study effect of chemical damage on fiber-fiber friction and entanglement

Science of Hair Tangling

- **Cuticle scale interlocking:** Cuticle scales point root-to-tip; adjacent fiber scales interlock → tangles and resistance to combing
- **Damaged cuticle:** Chemical/mechanical damage lifts and breaks cuticle scales → irregular surface → more friction → harder to comb
- **Electrostatic charge:** Hair is negatively charged; static build-up in low humidity → fly-away; increases combing difficulty
- **Conditioner mechanism:** Cationic conditioners (BTAC) adsorb on negative hair surface → smooth cuticle → reduce fiber-fiber friction → lower combing force
- **Silicone role:** Dimethicone deposits on hair → slippery lubricating film → dramatically reduces combing force

Measurement Method — Combing Rig

> **INSTRUMENT: Combing Rig / Hair Combing Tribometer (Instron, Diastron, or custom-built)**

Apparatus: Motor-driven combing rig mounted on tensile tester or dedicated tribometer

Hair tress: Standardized tress of 3-5 grams of hair at defined length (15-20 cm); bound at one end

Comb: Standard testing comb (defined tooth spacing, shape, and material — usually metal or acetate)

Comb attachment: Comb arm attached to load cell/force transducer of tensile tester

Comb motion: Motorized arm draws comb through tress at constant speed 5-10 cm/min; root-to-tip direction

Force recording: Load cell measures force in grams-force (gf) or Newtons during each complete comb stroke

Output: Force-displacement trace per stroke; peak force = max detangling force; area = work of combing

Protocol: 5-10 strokes per tress; mean peak force reported; first stroke usually highest

Parameters Measured:

Parameter	Definition and Significance
Peak combing force (gf or N)	Maximum force to pass comb through tress; first stroke highest; indicates maximum detangling resistance
Mean combing force (gf or N)	Average force over all strokes; reflects overall combing ease during routine grooming
Work of combing (mJ)	Area under force-displacement curve; total energy to comb tress; integrates force over full stroke
Number of snags	Count of sharp force peaks (>30% above baseline) per stroke; each snag = tangle/knot
Combing force reduction (%)	[(Control force - Treated force) / Control force] x 100; quantifies % conditioning benefit

Wet vs Dry Combing:

Parameter	Wet Combing	Dry Combing
Hair state	Soaked in water or product for defined time	Air-dried; conditioned at standard RH
Combing force	Higher — swollen hair; more entanglement	Lower; dependent on conditioning
Relevance	Post-shampoo detangling; rinse-off conditioner	Daily styling; leave-in product efficacy

Standardization

- **Tress preparation:** Use standardized tresses from certified suppliers; same weight (3g), length (15cm), ethnic origin for all groups
- **Damage protocol:** Pre-damage with bleach (H_2O_2 6%, 30 min) or heat to simulate real-world condition before conditioning test
- **Treatment protocol:** Apply shampoo → rinse → apply conditioner 30s → rinse → comb; mimic consumer use pattern exactly
- **Speed:** Constant motor-driven speed (5-10 cm/min); manual combing not standardized enough for science

- **Replication:** 5-10 tresses per treatment group; multiple strokes per tress; statistical analysis required

Typical Results

Hair Treatment	Typical Combing Force (gf)	Interpretation
Untreated virgin hair (dry)	20-50 gf	Baseline; smooth cuticle; low resistance
Damaged hair (bleached, dry)	100-200 gf	Lifted rough cuticle; high friction; difficult
Damaged hair after shampoo (wet)	150-250 gf	Swollen, rough; no conditioning benefit from shampoo alone
After standard rinse-off conditioner	50-100 gf reduction vs control	40-60% combing force reduction; significant conditioning
After 2-in-1 conditioning shampoo	Moderate reduction	20-40% reduction; less than dedicated conditioner
After leave-in conditioner	Low dry combing force	Excellent smoothing; best for daily styling ease

SOAPS AND SYNDET BARS — EVOLUTION AND SKIN BENEFITS

> Cleansing bars have evolved from simple animal fat + ash preparations (soap) to sophisticated synthetic detergent (syndet) formulations engineered to cleanse at skin-compatible pH without disrupting the natural protective barrier.

Parameter	Traditional Soap	Syndet Bar
Full Name	Saponified fatty acid salt bar	Synthetic Detergent Bar (Combar)
Chemical Basis	Sodium/potassium fatty acid salts	Synthetic surfactant blend (mild anionic + amphoteric)
pH	9.0 - 11.0 (alkaline)	5.5 - 7.0 (skin-compatible near-neutral)
Skin Compatibility	Disrupts acid mantle; causes dryness and irritation	Maintains acid mantle; minimal barrier disruption
Examples	Lifebuoy, Dettol soap, Glycerin soap	Dove Beauty Bar, Cetaphil Bar, CeraVe Bar

SOAPS — CHEMISTRY, EVOLUTION AND SKIN EFFECTS

Historical Evolution of Soap

Era	Development	Facts
Babylonia (2800 BC)	First written soap recipe on clay tablet	Water + animal fat + wood ash (alkali); used for cleaning textiles
Ancient Egypt (1550 BC)	Ebers Papyrus mentions soap-like substance	Animal/vegetable oils + alkaline salts; skin and hair use
Ancient Rome (1st Century AD)	Pliny the Elder describes soap from Gaul	Goat tallow + beech ash; hair coloring and skin use
Middle Ages (8th-12th C)	Trade established; Castile and Aleppo soaps	Olive oil soap (Castile, Spain); laurel oil soap (Aleppo, Syria); luxury soaps
1791 — LeBlanc Process	Industrial soda ash production begins	Cheap NaOH from NaCl; soap becomes affordable for masses; large-scale industry
1916 — World War I	Germany: First synthetic surfactant (Nekal)	Fat shortage → synthesis from petroleum; proof of concept for soap-free cleansing
1955	Dove Beauty Bar launched (Unilever)	First commercial syndet bar; revolutionized mild cleansing; changed the personal care industry
21st Century	Advanced syndet bars with ceramides, HA, prebiotics	Cleansing bars as active skin treatment; cosmeceutical cleansing bars

Chemistry of Soap — Saponification

Saponification Reaction:

> **Triglyceride (Fat/Oil) + NaOH (or KOH) → Sodium Soap (Fatty Acid Salt) + Glycerol**
> Example: $(C_{17}H_{35}COO)_3C_3H_5 + 3NaOH \rightarrow 3\ C_{17}H_{35}COONa$ (Sodium Stearate) + $C_3H_5(OH)_3$ (Glycerol)
> (Glyceryl Tristearate + Sodium Hydroxide → Sodium Stearate Soap + Glycerol)

Types of Soap:

Soap Type	Alkali	Oil/Fat	Properties and Uses
Hard Soap (Sodium Soap)	NaOH	Tallow, palm, coconut oil	Solid bar; traditional; pH 9-11; good lather

Soft Soap (Potassium Soap)	KOH	Cottonseed, linseed, soybean	Semi-liquid/paste; liquid soaps; softer texture
Castile Soap	NaOH	Olive oil (min. 72%)	Mild; high oleic acid; gentle; from Castile, Spain
Glycerin (Transparent) Soap	NaOH	Vegetable oils + retained glycerin	Translucent; humectant; gentler; cosmetic quality
Superfatted Soap	NaOH (reduced)	Excess unsaponified oils 5-20%	Milder; free oils = emollient; for sensitive/dry skin
Medicated Soap	NaOH	Tallow/vegetable + active	Contains triclosan 0.3% or ZPT; antibacterial

Fatty Acid Contribution to Soap Properties:

Fatty Acid	Chain	Saturation	Contribution to Soap
Lauric Acid	C12	Saturated	Excellent foaming; fast-lathering; from coconut and palm kernel oil
Myristic Acid	C14	Saturated	Excellent lather; pleasant skin feel; from coconut/palm kernel
Palmitic Acid	C16	Saturated	Bar hardness; stability; long-lasting bar; from palm oil and tallow
Stearic Acid	C18	Saturated	Bar hardness; stability; from tallow and shea butter
Oleic Acid	C18:1	Monounsaturated	Mild; conditioning; non-drying; from olive, sunflower; makes softer soap

Manufacturing Process of Soap

Hot Process (Industrial):

- **Step 1 — Saponification:** Oils/fats at 80-100°C + NaOH solution → saponification → soap paste + glycerol
- **Step 2 — Salting out (Graining):** Add brine (NaCl) → soap separates from glycerol + lye → neat soap remains
- **Step 3 — Glycerol recovery:** Glycerol recovered by evaporation/distillation of spent lye → valuable cosmetic co-product
- **Step 4 — Finishing:** Adjust TFM (Total Fatty Matter) to 72-80% by brine control
- **Step 5 — Drying:** Spray-dry or vacuum-dry to 10-15% moisture → soap chips/noodles
- **Step 6 — Amalgamation:** Add colorants, fragrance, actives, glycerin to soap noodles
- **Step 7 — Milling:** Triple roller mill → homogeneous, smooth, consistent chips
- **Step 8 — Plodding + Stamping:** Extruder shapes → log cut into bars → stamped/embossed → final product

BIS Specifications for Toilet Soap (IS 2090)

Parameter	BIS Specification (IS 2090)	Test Method
Total Fatty Matter (TFM)	Grade 1: min 76%; Grade 2: min 70%; Grade 3: min 60%	Petroleum ether extraction; gravimetric; IS 2888
Free Alkali (as NaOH)	Maximum 0.1%	Titration with HCl; phenolphthalein indicator
Free Fatty Acid (as oleic acid)	Maximum 0.5%	Acid-base titration; IS 2889
Moisture Content	Maximum 15%	Loss on drying at 105°C; gravimetric; IS 2890
Matter insoluble in alcohol	Maximum 0.3%	Alcohol extraction; gravimetric (excess filler/binders)
Chlorides (as NaCl)	Maximum 0.5%	Mohr's titration with $AgNO_3$

pH Problem — Skin Effects of Soap

Effect of Alkaline pH (9-11)	Mechanism and Consequence
Acid Mantle Disruption	Normal skin pH 4.5-5.5; alkaline soap raises SC pH to 8-9 temporarily after washing; acid mantle takes 1-2 hours to recover; disrupts protective environment
Serine Protease Activation	SC serine proteases (kallikreins KLK5, KLK7) are pH-sensitive; optimally active at alkaline pH 7-9; elevated activity → premature corneodesmosomes breakdown → increased SC desquamation → visible flaking and dryness
Ceramide and NMF Loss	High pH disrupts SC lipid bilayer organization; alkaline conditions increase lipid solubility → ceramides and fatty acids washed away → impaired barrier function
Skin Irritation	Repeated alkaline exposure → barrier disruption → pro-inflammatory cytokines (IL-1alpha, TNF-alpha) from keratinocytes → redness, tightness, irritation; risk of ICD
Microbiome Disruption	Skin microbiome (C. acnes, S. epidermidis) prefers acidic pH; alkaline soap disrupts microbiome balance → opportunistic pathogens may colonize

SYNDET BARS — SYNTHETIC DETERGENT BARS

> **Syndet Bar:** A Syndet bar (Synthetic Detergent bar, also called Combar) is a cleansing bar formulated with synthetic surfactants instead of soap (fatty acid salts), engineered to cleanse effectively at pH 5.5-7.0 — compatible with the skin's natural acid mantle.

Historical Development of Syndet Bars

Year	Development	Significance
1916	First synthetic surfactant (Nekal) — Germany, WW I	Proof of concept for non-soap cleansing during fat shortage
1930s	Fatty alcohol sulfates and alkyl sulfates developed	First mild synthetic detergents suitable for skin application
1955	Dove Beauty Bar launched (Unilever) — first commercial syndet	Landmark product; mild cleansing with cream formula; changed the industry permanently
1970s-80s	Amphoteric and amino acid surfactants improved; betaines developed	Gentler syndet formulations; suitable for sensitive and baby products
1990s	pH 5.5 acidic syndet bars established in dermatology	Recommended for atopic dermatitis, acne, sensitive skin — dermatologist-endorsed
2000s-present	Advanced bars with ceramides, hyaluronic acid, prebiotics	Cleansing bars as active skin treatment; cosmeceutical cleansing bars era

Surfactants Used in Syndet Bars

Surfactant	Type	Properties and Role
Sodium Cocoyl Isethionate (SCI)	Anionic	PRIMARY syndet surfactant; coconut oil + isethionic acid; excellent skin feel; creamy lather; pH 5-7; major component of Dove Bar; biodegradable
Sodium Lauroyl Methyl Isethionate (SLMI)	Anionic	Very mild; lauric acid derived; low irritation; excellent lather; premium syndet bars
Sodium Lauroyl Sarcosinate	Anionic	Amino acid-derived; very mild; good lather; low irritation; conditioning effect

Cocamidopropyl Betaine (CAPB)	Amphoteric	Co-surfactant; reduces irritation; conditioning; improves foam; baby products
Decyl Glucoside / Coco Glucoside	Nonionic	Sugar-based; very mild; naturally derived; gentle foam; biodegradable; natural syndet bars
Sodium Cocoyl Glutamate	Anionic (amino acid)	Glutamic acid derivative; pH close to skin; very gentle; conditioning; premium natural bars

Formulation Building Blocks of Syndet Bar

Ingredient	Conc.	Examples	Function
Primary surfactant	30-60%	Sodium Cocoyl Isethionate (SCI)	Cleansing; lather; mild; forms bar matrix
Secondary co-surfactant	5-15%	CAPB, Decyl glucoside	Reduce irritation; improve foam quality; conditioning
Solid binder/structurant	5-20%	Stearic acid, Behenic acid, Fatty alcohols	Create solid bar format; bar cohesion and hardness
Humectant	2-10%	Glycerin, Sorbitol, Propylene glycol	Moisturize skin; prevent post-wash dryness
Moisturizing oil/butter	1-10%	Shea butter, Coconut oil, Dimethicone	Emollient; skin conditioning during wash; 'beauty cream' effect
Active ingredient	Variable	Ceramides, HA, Niacinamide, Salicylic acid	Skin benefit actives for anti-aging, acne control, barrier repair
Preservative	0.1-0.5%	DMDM Hydantoin, Tetrasodium EDTA	Microbial stability of water-containing formulation
pH adjuster	q.s.	Citric acid, Lactic acid	Adjust to pH 5.5-7.0 for skin compatibility
Fragrance	0.5-2%	Floral, fresh, woody fragrances	Consumer appeal; brand identity

Manufacturing of Syndet Bars

- **Step 1 — Melt phase:** Melt solid fatty acid structurants and oils at 70-80°C to form homogeneous liquid
- **Step 2 — Surfactant addition:** Add powdered SCI and other surfactants to hot melt; blend until fully incorporated
- **Step 3 — Active addition:** Add glycerin, humectants, preservatives, actives at appropriate temperature
- **Step 4 — pH adjustment:** Adjust to pH 5.5-7.0 using citric acid or lactic acid; verify with pH probe
- **Step 5 — Fragrance:** Add fragrance at 50-60°C to prevent volatilization loss
- **Step 6 — Molding:** Pour into bar molds or co-extrude; cut to size; cool and solidify
- **Step 7 — Conditioning/Curing:** Bars conditioned at controlled T and RH for 24-48 hours for final hardness and crystallization
- **Step 8 — QC and Packaging:** Check pH, hardness, surfactant content, microbial limits; wrap and package

Skin Benefits of Syndet vs Soap

Skin Property	Traditional Soap	Syndet Bar
Post-wash skin pH	Rises to 8-9; acid mantle recovery 1-2 hours	pH 5.5-7.0; acid mantle maintained or recovers rapidly
SC Hydration (Corneometer CU)	Decreases 10-15% post-wash; post-wash dryness	Maintained or improved with moisturizing syndet formulations
TEWL (Tewameter)	Increases post-wash — indicates barrier disruption	Minimal TEWL increase; barrier largely preserved
Skin Irritation	Higher risk; serine protease over-activation; ICD	Lower irritation; serine proteases not over-activated
Ceramide/Lipid Loss	Alkaline pH + surfactant removes SC lipids	Mild surfactants minimize SC lipid removal
Lather Quality	Rich, creamy, large bubbles; great consumer experience	Good to excellent (SCI gives creamy lather); improving formulations
Hard Water Performance	Forms soap scum with Ca2+/Mg2+ → less lather	No soap scum; works well in hard water conditions
Suitable for conditions	Normal skin; not recommended for sensitive/atopic/dry	All skin types; preferred for atopic, acne, rosacea, sensitive skin

Soap vs Syndet Comparison

Parameter	Traditional Soap	Syndet Bar
Chemistry	Fatty acid alkali salt (e.g., Sodium stearate)	Synthetic surfactant (e.g., Sodium Cocoyl Isethionate)
Saponification needed?	YES — triglyceride + NaOH → soap + glycerol	NO — surfactants pre-synthesized chemically
pH	9.0-11.0 (alkaline)	5.5-7.0 (skin-compatible near-neutral)
Skin pH impact	Disrupts acid mantle; elevation lasts 1-2 hours	Minimal disruption; acid mantle maintained
Lather	Rich, creamy; excellent foam volume	Good to excellent; SCI provides creamy lather
Skin dryness	Yes — removes NMF and SC lipids; post-wash tightness	Minimal; humectants compensate; smoother post-wash feel
Hard water performance	Forms soap scum with Ca2+ and Mg2+ ions	No soap scum; effective in hard water
Biodegradability	Excellent — fully biodegradable fatty acid salts	Variable; SCI and glucosides are biodegradable
Cost	Low — inexpensive raw materials	Higher — specialty surfactants are more expensive
TFM	Minimum 60-76% by BIS grade (IS 2090)	No TFM; active surfactant content specified instead
Dermatology suitability	Not recommended for sensitive, dry, atopic skin	Preferred for sensitive, dry, atopic, acne-prone skin types
Shelf life	Excellent stability; can last years	Good; requires preservative system for water-phase protection

★ EXAM IMPORTANT POINTS

Q: Sebumeter principle? Photometry of polypropylene tape — lipid makes tape transparent; more sebum = more transmitted light; output SU (μg/cm2)

Q: Corneometer principle? Electrical capacitance of SC; water dielectric constant epsilon = 80 (very high); more water = higher capacitance = higher CU value

Q: TEWL measured by? Tewameter TM 300 — open-chamber evaporimetry; two T+RH sensors; water vapour density gradient; Fick's Law; output g/m2/h

Q: Higher TEWL means? More impaired skin barrier — water passing through SC faster; atopic dermatitis has TEWL 15-30 g/m2/h

Q: CIE L*a*b* — each axis? L* = lightness (0-100); a* = erythema/redness (+) or green (-); b* = tanning/yellow (+) or blue (-)

Q: Mexameter measures? Erythema Index at 568nm and Melanin Index at 660nm (both vs 880nm reference)

Q: Hair tensile strength — stress-strain regions? Hookean (elastic/alpha-helix) → Yield (alpha-to-beta transition) → Post-yield (S-S bonds) → Hard region → Breaking point

Q: Combing force measured by? Motorized combing rig; force in grams-force (gf) or Newtons; 5-10 cm/min; standardized hair tress 3g/15cm

Q: Saponification equation? Triglyceride + NaOH → Sodium fatty acid salt (soap) + Glycerol

Q: Soap pH problem? Alkaline pH 9-11 → activates serine proteases (kallikreins KLK5/7) → SC desquamation → ceramide loss → barrier disruption → dryness and irritation

Q: TFM for soap? Total Fatty Matter; BIS IS 2090: Grade 1 min 76%, Grade 2 min 70%, Grade 3 min 60%

Q: Primary surfactant in syndet bar? Sodium Cocoyl Isethionate (SCI) — mild anionic; pH 5-7; creamy lather; from coconut oil + isethionic acid

Q: First commercial syndet bar? Dove Beauty Bar (1955) — Unilever; SCI + stearic acid + moisturizing cream; pH ~6.5