Hemina Skin Rebuilding and Reconditioning Therapy: Treating Ichthyosis & Xerosis

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Purpose

- To design a moisturizing package that treats ichthyosis skin disorder and xerosis (dry skin)

- May target other skin disorders
Agenda

- Anatomy
- The Skin Disorder
- Treatment
- Our Original Product
- Substitutes and Modeling Consumer Attitudes
- Demand Model
- Manufacturing
- Economic Analysis
Anatomy
The Human Skin

- Self-contained organ that exists as a semipermeable barrier layer
- Two components with interdependent functions: epidermis and dermis

Source: www.healthzone.co.uk
Epidermis

- ~40 µm thick
- Four (or five) layers
  1. Stratum corneum
  2. (Stratum lucidium)
  3. Stratum granulosum
  4. Stratum spinosum
  5. Stratum basale
- Basal membrane (6)

Source: www.eucerim.co.uk
Stratum Corneum

- Generally ~10-15 µm thick
- Tough but pliable quality given by keratin
- 10–20 layers of corneocytes embedded in a matrix of lamellar lipids
Stratum Corneum

- “Brick and mortar” structure
  - Corneocytes (bricks)
    - Anucleated, non-viable, keratin-rich cells
    - Hydrophilic
  - Lipid lamellae (mortar)
    - Tight lateral packing
    - Hydrophobic

Source: www.pg.com

- Ceramides (40-50%)
- Cholesterol (25%)
- Fatty acids (10-15%)
- Other lipids, such as cholesterol sulfate (≤5%)
Stratum Corneum Cohesion

- Desmosomes - main cohesive forces
  - Protein bridges
  - Attach to cell envelopes and lock into position

- Covalent bonding of lipids in matrix
- van der Waals forces hold the lipid lamellae and the corn

Source: www.netwellness.org
Desquamation

- Corneocytes break apart and are lost
- Enzymatic process – dissolves desmosomes
- These proteolytic enzymes are present in well-hydrated SC
- Defective desquamation - corneocytes build up
Natural Moisturizing Factor

- High concentration inside the corneocytes
- Some in the intercellular lipid matrix
- Humectants - absorb water
- Allow for the outermost layers of the SC to remain hydrated
Stratum Corneum

- Desmosomes
- Lipid Matrix
- Corneocytes

NMF Components
- Lactic acid
- Urea
- Urocanic acid
- PCA
- Citrates
- Sugars
Types of diffusion through skin

- Percutaneous diffusion:
  Rate and extent that a chemical is absorbed into and through the skin
- Transepidermal water loss (TEWL)
  Passage of water from the body through the skin into the outside environment
Percutaneous Diffusion

SC is rate-limiting step

Intercellular diffusion through the lipid lamellae
*rate determining component of the SC barrier

Transcellular diffusion through both the corneocytes and lipid lamellae

Diffusion through appendages (hair follicles and sweat ducts)

Corneocytes
Lipid lamellae

*rate determining component of the SC barrier
The Skin Disorder
Xerosis

- Dry skin of a ‘normal’ or non-pathological state
- Low water content in SC
- Dry and itchy skin
- Occurs when natural moisture is drawn out
- Can be due to cold weather or exposure to too much water
Ichthyosis

What is it?

- A family of disorders in the production and/or desquamation of epidermal cells
- Generically characterized by dry, thickening, scaly skin

Figure 1: Ichthyosis Vulgaris

Figure 2: Ichthyosis Vulgaris

Source: Geneva Foundation for Medical Education and Research, www.gfmer.ch
Ichthyosis
Incidence

- Several ichthyoses exist – most affect only one person out of tens of thousands
- Most common forms – Ichthyosis Vulgaris
  - Incidence: 1 in 250

Source: www.ichthyosis.com
Ichthyosis Vulgaris

- Reduced water content affects the enzymatic reactions governing desquamation
- Genetic defects – inherited
- Rare cases are acquired – AIDS and cancer
- Currently, there is no cure
- Symptomatic treatment
Treatment
Treatment

- To better treat the disorder, it is necessary to improve skin function by
  - Promoting desquamation
  - Replacing components such as NMF
  - Restoring the lipid barrier
- Current treatments focus on only one step of the cascade of dehydration
- No current product that is offered as a package to treat different causes of poor hydration
Current Treatment

- Many topically applied moisturizers work to trap water - occlusives
  - Can be very greasy – unpleasant to consumer
- Some ingredients promote desquamation
  - Keratolytic agents such as lactic acid
- Current treatment has disadvantages
  - Very temporary
  - Focuses on one symptom
Moisturizers

- Maintain hydration and smoothness of the skin
- Putting water back into the skin is no longer the only method for hydrating the skin
- Active ingredients can improve abnormal skin function and structure
Moisturizer Components

- **Active Ingredients**
  - Occlusives: Retard water loss by forming a layer on the surface of skin
  - Emollients: Fill intercellular spaces with droplets of oil
  - Humectants: Draw water from the dermis and from air by hydrogen bonding into the epidermis
  - Exfoliants: Increase sloughing of dead cells on the surface of the skin
Moisturizer Components

- Complementary Ingredients
  - Emulsifying agents: Help the emulsion
  - Preservatives: Prevent microbiologic contamination
  - Thickeners: Help reach a specific viscosity
  - pH Adjustors: Adjust the pH of the moisturizer
  - Antioxidants: Prevent oxidative damage in the skin
Moisturizer Technology

- **Liposomes**
  - Cheap and simple to manufacture

- **Microemulsions**
  - Droplets are greater than 0.5 nm in size
  - High surface area allow effective transport of active to skin
    - W/O
    - O/W
  - Advantages
    - Low toxicity
    - Uptake by endocytosis (can fuse with cell wall)
    - Biodegradable and non-toxic in nature
    - Replace surfactants and emulsifiers
  - Disadvantages
    - Short circulation half-time

100-200 nm diameter
Manufacturing Delivery Technology

1. Inverted emulsion with aqueous solution to encapsulate active
2. Emulsified in an organic continuous phase PEG coating
3. Techniques to control size particle and encapsulation yield (sonication and extrusion)
   - Bath sonicator
Our Original Product
Skin Rebuilding and Reconditioning Therapy

- Package of 3 separate products:

1. Pre-Shower Lotion (16 oz)
   - Promotes desquamation

2. Shower Gel (20 oz)
   - Restores NMF and exfoliates

3. After-Shower Lotion (16 oz)
   - Rebuilds skin barrier and leaves skin smooth and hydrated
Target of Our Product

- Desmosomes
- Lipid Matrix
- Corneocytes
- NMF Components:
  - Lactic acid
  - Urea
  - Urocanic acid
  - PCA
  - Citrates
  - Sugars
- Water
Skin Rebuilding and Reconditioning Therapy

- Our package works as a system of treatment that will surpass current treatments because ours will rebuild skin function producing a longer period of relief.
  - Rather than replacing water lost by the SC, our products will give the skin the tools it needs to prevent future dehydration and scaling.
Original Formulation

- Active ingredients based on the intended function of each package product

**After-Shower Lotion**
- Ceramide
- γ-linoleic acid
- Cholesterol
- Dimethicone
- Lanolin

Intended to restore the lipid matrix

**Pre-Shower Lotion**
- Ammonium lactate
- Sodium PCA
- Dimethicone
- Urocanic acid
- Lanolin
- Citric Acid

Effective for treatment of ichthyotic disorders by helping to shed the built-up layers of corneocytes

These ingredients are found naturally in the skin as components of the NMF

Humectants that will absorb water into the skin
FDA Regulations

- FDA does not regulate cosmetics as it does to drugs. Manufacturers are not obligated to pre-register their products before they go into market. Cosmetics are defined as articles applied to the body in any manner...for cleansing, beautifying, promoting attractiveness, or altering the appearance.

But.....Cosmetic producers must keep ingredients below the regulated concentration given in the “Cosmetic Ingredients Review”
## Original Formulation: Pre-Shower Lotion

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Percent (%)</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>60</td>
<td>Solvent</td>
</tr>
<tr>
<td><strong>Ammonium Lactate</strong></td>
<td>10</td>
<td>Desquamation</td>
</tr>
<tr>
<td>Retinyl Palmitate</td>
<td>8</td>
<td>Antioxidant</td>
</tr>
<tr>
<td>Jojoba Oil</td>
<td>8</td>
<td>Emollient</td>
</tr>
<tr>
<td>PEG-4</td>
<td>8</td>
<td>Emollient/Liposome Formation</td>
</tr>
<tr>
<td>Cetyl Alcohol</td>
<td>2.9</td>
<td>Emulsifier</td>
</tr>
<tr>
<td>Octyldodecanol</td>
<td>2.9</td>
<td>Thickener</td>
</tr>
<tr>
<td>Phenoxyethanol</td>
<td>0.196</td>
<td>Preservative</td>
</tr>
<tr>
<td>Maleic Acid</td>
<td>0.004</td>
<td>pH Adjuster</td>
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</tbody>
</table>
# Original Formulation: Shower Gel

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Percent %</th>
<th>Function</th>
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<tbody>
<tr>
<td>Water</td>
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<tr>
<td>Polysorbate-20</td>
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<td>Surfactant</td>
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<tr>
<td>Cocoamidopropyl Betaine</td>
<td>5</td>
<td>Surfactant</td>
</tr>
<tr>
<td><strong>Lactic Acid</strong></td>
<td>4</td>
<td>Exfollient/NMF</td>
</tr>
<tr>
<td>Urea</td>
<td>4</td>
<td>NMF</td>
</tr>
<tr>
<td>Sodium PCA</td>
<td>3</td>
<td>NMF</td>
</tr>
<tr>
<td><strong>Urocanic Acid</strong></td>
<td>3</td>
<td>NMF</td>
</tr>
<tr>
<td><strong>Citric Acid</strong></td>
<td>3</td>
<td>NMF</td>
</tr>
<tr>
<td>Oleic Acid</td>
<td>3</td>
<td>Emollient/Thickener</td>
</tr>
<tr>
<td>Cetyl Alcohol</td>
<td>2.796</td>
<td>Emulsifier</td>
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<tr>
<td>Phenolxyethanol</td>
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<td>Preservative</td>
</tr>
<tr>
<td>Maleic Acid</td>
<td>0.004</td>
<td>pH Adjustor</td>
</tr>
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</table>
# Original Formulation: After-Shower Lotion

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Percent %</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>60</td>
<td>Solvent</td>
</tr>
<tr>
<td><strong>Dimethicone</strong></td>
<td>10</td>
<td>Humectant</td>
</tr>
<tr>
<td><strong>Lanolin</strong></td>
<td>8</td>
<td>Humectant</td>
</tr>
<tr>
<td>PEG-4</td>
<td>6.996</td>
<td><strong>Emollient/Liposome Formation</strong></td>
</tr>
<tr>
<td>Cetyl Alcohol</td>
<td>5</td>
<td>Emulsifier</td>
</tr>
<tr>
<td><strong>Ceramide</strong></td>
<td>3</td>
<td>SC Lipid/Humectant</td>
</tr>
<tr>
<td>Isostearic Acid</td>
<td>2.8</td>
<td>Thickener</td>
</tr>
<tr>
<td>Palm Oil</td>
<td>2</td>
<td>Emollient</td>
</tr>
<tr>
<td><strong>γ-Linoleic Acid</strong></td>
<td>1</td>
<td>SC Lipid</td>
</tr>
<tr>
<td><strong>Cholesterol</strong></td>
<td>1</td>
<td>SC Lipid</td>
</tr>
<tr>
<td>Phenoxyethanol</td>
<td>0.2</td>
<td>Preservative</td>
</tr>
<tr>
<td>Maleic Acid</td>
<td>0.004</td>
<td>pH Adjustor</td>
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</table>
Cost for the Package

<table>
<thead>
<tr>
<th></th>
<th>Cost (million $)</th>
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</thead>
<tbody>
<tr>
<td>Raw Material Cost/yr</td>
<td>51.62</td>
</tr>
<tr>
<td>Total Product Cost/yr</td>
<td>58</td>
</tr>
<tr>
<td>Annual Product Revenue/yr</td>
<td>16.2</td>
</tr>
<tr>
<td><strong>NPW</strong></td>
<td><strong>-125.54</strong></td>
</tr>
</tbody>
</table>
Substitutes and Modeling Consumer Attitudes
Substitute Ingredients

- Ingredients costing more than $10^5 / year were considered for replacement with less expensive chemicals serving the same purpose.

- Active ingredients were not substituted.

- PEG was also not substituted - liposome formation.
# Pre-Shower Lotion Substitutes

<table>
<thead>
<tr>
<th>Material</th>
<th>Function</th>
<th>Substitutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deionized Water</td>
<td>Solvent</td>
<td></td>
</tr>
<tr>
<td>Ammonium Lactate*</td>
<td>Desquamation</td>
<td></td>
</tr>
<tr>
<td>Jojoba Oil</td>
<td>Emollient</td>
<td>Castor Oil</td>
</tr>
<tr>
<td>PEG</td>
<td>Emulsifier/Liposome Formation</td>
<td></td>
</tr>
<tr>
<td>Octyldodecanol</td>
<td>Thickener</td>
<td>Paraffin Oil</td>
</tr>
<tr>
<td>Retinyl Palmitate (Vitamin A Palmitate)</td>
<td>Antioxidant</td>
<td>Ascorbic Acid</td>
</tr>
<tr>
<td>Cetyl Alcohol</td>
<td>Emulsifier</td>
<td>Polysorbate 20</td>
</tr>
<tr>
<td>Phenoxyethanol</td>
<td>Preservative</td>
<td></td>
</tr>
<tr>
<td>Maleic Acid</td>
<td>pH Adjuster</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fragrance</td>
<td>Peppermint Oil</td>
</tr>
</tbody>
</table>
# Shower Gel Substitutes

<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Deionized Water</td>
<td>Solvent</td>
<td></td>
</tr>
<tr>
<td>Polysorbate-20</td>
<td>Surfactant</td>
<td></td>
</tr>
<tr>
<td>Cocoamidopropyl Betaine</td>
<td>Surfactant</td>
<td></td>
</tr>
<tr>
<td><strong>Lactic Acid</strong></td>
<td>NMF</td>
<td></td>
</tr>
<tr>
<td><strong>Urea</strong></td>
<td>NMF</td>
<td></td>
</tr>
<tr>
<td>Sodium PCA</td>
<td>NMF</td>
<td></td>
</tr>
<tr>
<td><strong>Urocanic Acid</strong></td>
<td>NMF</td>
<td></td>
</tr>
<tr>
<td><strong>Citric Acid</strong></td>
<td>NMF</td>
<td></td>
</tr>
<tr>
<td>Oleic Acid</td>
<td>Emollient/Thickener</td>
<td></td>
</tr>
<tr>
<td>Cetyl Alcohol</td>
<td>Emulsifier</td>
<td>Polysorbate 20</td>
</tr>
<tr>
<td>Phenoxyethanol</td>
<td>Preservative</td>
<td></td>
</tr>
<tr>
<td>Maleic Acid</td>
<td>pH Adjuster</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fragrance</td>
<td>Peppermint Oil</td>
</tr>
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</table>
# After-Shower Lotion

<table>
<thead>
<tr>
<th>Material</th>
<th>Function</th>
<th>Substitutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deionized Water</td>
<td>Solvent</td>
<td>---</td>
</tr>
<tr>
<td><strong>Dimethicone</strong></td>
<td>Humectant</td>
<td>Sorbitol</td>
</tr>
<tr>
<td><strong>Lanolin</strong></td>
<td>Humectant/Emollient</td>
<td>Isopropyl Palmitate</td>
</tr>
<tr>
<td>PEG</td>
<td>Emollient/Liposome Formation</td>
<td>---</td>
</tr>
<tr>
<td>Cetyl Alcohol</td>
<td>Emulsifier</td>
<td>Polysorbate 20</td>
</tr>
<tr>
<td>Isostearic Acid</td>
<td>Thickener</td>
<td>---</td>
</tr>
<tr>
<td>Palm Oil</td>
<td>Thickener</td>
<td>Paraffin Oil</td>
</tr>
<tr>
<td><strong>Ceramide</strong></td>
<td>SC Lipid/Emollient</td>
<td>---</td>
</tr>
<tr>
<td>γ-linoleic acid</td>
<td>SC Lipid</td>
<td>---</td>
</tr>
<tr>
<td><strong>Cholesterol</strong></td>
<td>SC Lipid</td>
<td>---</td>
</tr>
<tr>
<td>Phenoxyethanol</td>
<td>Preservative</td>
<td>---</td>
</tr>
<tr>
<td>Maleic Acid</td>
<td>pH Adjustor</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Fragrance</td>
<td>Peppermint Oil</td>
</tr>
</tbody>
</table>
Consumer Preferences Based on Physical Properties
Happiness Model

- Optimizes relative happiness by determining formulation based on 4 factors:

1. Thickness
   - Thickness = (Viscosity)\(^{0.5}\)
   - Viscosity found or estimated for all ingredients
   - Ideal values from viscosity experiment and general recommendations

2. Creaminess
   - Creaminess = (Smoothness \(\times\) Thickness)\(^{0.5}\)
   - Smoothness = (Coefficient of Friction)\(^{0.5}\)
   - Smoothness is weighted based on function

3. Spreadability
   - Based on surface tension of active ingredients and PEG
   - Surface tension is estimated for all ingredients
   - Gusing ability determined from:

4. Effectiveness
   - Related to curing ability of active ingredients and PEG
   - These concentrations are weighted based on function
   - Curing ability determined from:
   - \[\frac{C_{w}^{0}}{C_{w}^{0}} \times (C_{w})_{HM} \]
   - \[\frac{DM}{C_{w}} \]
   - \(C_{w}\) neglected at low pressure
## Happiness Model Pre-Shower

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Ideal values</th>
<th>CIR allowed maximum</th>
<th>Viscosity μ (cP)</th>
<th>Thick ness μ^.5 (cP^.5)</th>
<th>Grease</th>
<th>Coefficient of friction</th>
<th>Sense upon Application</th>
<th>Ideal Value</th>
<th>Curing ability C_w^0 (g/L)</th>
<th>Spreading ability</th>
<th>Surface tension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deionized Water</td>
<td>55%</td>
<td>178.10</td>
<td>13.345</td>
<td>4</td>
<td>0.472</td>
<td>2.51</td>
<td></td>
<td>.125</td>
<td>31.246</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium Lactate*</td>
<td>10%</td>
<td>10</td>
<td>27.93</td>
<td>5.2845</td>
<td>S</td>
<td></td>
<td></td>
<td>0.87</td>
<td>40.521</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jojoba Oil</td>
<td>5%</td>
<td>25</td>
<td>43.50</td>
<td>6.5955</td>
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<td></td>
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<td>0</td>
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<tr>
<td>Total Mixture Value</td>
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<td>326.118</td>
<td>8.372</td>
<td>0.15</td>
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<td></td>
<td>0.125</td>
<td>46.674</td>
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<tr>
<td>Happiness percentage</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>0.6273</td>
<td>0.966</td>
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<td>Weight of variable</td>
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<td></td>
<td>0.7032</td>
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<td>Relative happiness</td>
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<td></td>
<td></td>
<td></td>
<td>0.6273</td>
<td>0.966</td>
</tr>
</tbody>
</table>

**Happiness Model Pre-Shower**

<table>
<thead>
<tr>
<th>Pre-Shower</th>
<th>Smoothness</th>
<th>Creaminess</th>
<th>Effectiveness</th>
<th>Spreading ability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.783</td>
<td>0.2</td>
<td>0.3</td>
<td>0.2</td>
</tr>
</tbody>
</table>
Diffusion Model

- Accounts for mass transport through:
  - Oil Phase
  - Water Phase
  - Protein Phase

- Disregards:
  - Diffusion through the appendages since it accounts for 0.1% of the total surface area of the skin
  - TEWL since it is constant and represents a very small portion of the water contained by the body

\[
\left( \frac{C_w}{C^0_w} \right)_{DM} \ast \left( C^0_w \right)_{HM} \frac{C_{Ideal}}{C_w}
\]
Diffusion Model of the SC

This equation was derived using a diffusion model based on Fick’s Law

\[ \frac{C_w}{C^o_w} = 1 - \frac{x}{L_{sc}} - \frac{2}{\pi} \sum_{n=1}^{\infty} \frac{1}{n} \sin \frac{n \pi x}{L_{sc}} e^{-\frac{D_{sc} n^2 \pi^2 t}{R_{sc} L_{sc}^2}} \]

This model is a function of time and location in the skin

- 10 minutes- Pre-shower Lotion
- 3 minutes- Shower Gel
- 12 minutes- Post-Shower Lotion
- 5 μm- Pre-shower Lotion
- 15 μm- Shower Gel
- 15 μm- After-Shower
Demand Model
Market Trends

- Patients will always need a product to treat the disorder
  - No cure

- Demand should never decrease
  - No cure
  - Approximate constant number of people affected by the disorder
Demand Model

\[ \beta \ p_1 \ d_1 = \alpha \ p_2 \ d_2 \]

\[ \beta = \frac{H_2}{H_1} \]

\[ d_1 = D - d_2 \]

\[ d_1 = \alpha \ D \ p_2 \]

\[ \alpha \ p_2 + \beta \ p_1 \]

Demand Constants

Time (year)

Constants

[Graph showing the demand model with variables and constants plotted over time]
Distribution and Advertising

- Promoting our package to the Ichthyosis community by:
  - Free samples to:
    - General practitioners and dermatologists
    - Patients registered on Ichthyosis registries
  - Advertisements in:
    - Ichthyosis organization websites
    - Posting in medical offices
Manufacturing
Process Design
# Equipment

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Specifications</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank 1: Shower Gel</td>
<td>15.1 m³</td>
<td>43,750</td>
</tr>
<tr>
<td>Tank 2: Lotion</td>
<td>12.1 m³</td>
<td>38,700</td>
</tr>
<tr>
<td>Tank 3: Lotion</td>
<td>12.1 m³</td>
<td>38,700</td>
</tr>
<tr>
<td>Colloid Mill</td>
<td>7.5 hp</td>
<td>15,000</td>
</tr>
<tr>
<td>Bath Sonicator</td>
<td>115 V</td>
<td>800</td>
</tr>
<tr>
<td>Homogenizer</td>
<td>100 L/hr</td>
<td>11,500</td>
</tr>
<tr>
<td>2 Pumps</td>
<td>0.0145 m³/s</td>
<td>5,500</td>
</tr>
</tbody>
</table>

**Total Equipment Cost**

$154,000
Economic Analysis
Raw Material Cost

Original Raw Material Cost

Substitute Raw Material Cost
## Economic Evaluation

### Optimized Original Formulation

<table>
<thead>
<tr>
<th>Equipment Cost</th>
<th>0.153186</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Capital Investment</td>
<td>0.849263</td>
</tr>
<tr>
<td>Total Capital Investment</td>
<td>0.999233</td>
</tr>
<tr>
<td>Net Profit</td>
<td>-6986.15</td>
</tr>
<tr>
<td><strong>NPW</strong></td>
<td><strong>-4250.14</strong></td>
</tr>
</tbody>
</table>

### Optimized Substitute Formulation

<table>
<thead>
<tr>
<th>Equipment Cost</th>
<th>0.153186</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Capital Investment</td>
<td>0.849263</td>
</tr>
<tr>
<td>Total Capital Investment</td>
<td>0.999233</td>
</tr>
<tr>
<td>Net Profit</td>
<td>30.98</td>
</tr>
<tr>
<td><strong>NPW</strong></td>
<td><strong>28.55</strong></td>
</tr>
</tbody>
</table>
Net Present Worth vs Package Price

Optimal Formulation NPW vs Package Price

Substitutes NPW vs Package Price

Price per Package ($) vs NPW (million $)
## Final Formulation

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>%</th>
<th>Ingredient</th>
<th>%</th>
<th>Ingredient</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deionized Water</td>
<td>55</td>
<td>Deionized Water</td>
<td>50.7089</td>
<td>Deionized Water</td>
<td>50</td>
</tr>
<tr>
<td>Ammonium Lactate</td>
<td>10</td>
<td>Sodium PCA</td>
<td>3</td>
<td>Isopropyl palmitate</td>
<td>2</td>
</tr>
<tr>
<td>Ascorbic Acid</td>
<td>2.386</td>
<td>Lactic Acid</td>
<td>1</td>
<td>Sorbitol</td>
<td>2</td>
</tr>
<tr>
<td>Castor Oil</td>
<td>5.006</td>
<td>Urocanic Acid</td>
<td>1.5</td>
<td>Ceramide</td>
<td>0.003</td>
</tr>
<tr>
<td>Polysorbate 20</td>
<td>9.816</td>
<td>Citric Acid</td>
<td>2.73727</td>
<td>γ-linoleic acid</td>
<td>0.001</td>
</tr>
<tr>
<td>Paraffin Oil</td>
<td>3.015</td>
<td>Urea</td>
<td>9</td>
<td>Cholesterol</td>
<td>0.001</td>
</tr>
<tr>
<td>Maleic acid</td>
<td>0.004</td>
<td>Polysorbate-20</td>
<td>20</td>
<td>Polysorbate 20</td>
<td>15.99</td>
</tr>
<tr>
<td>Phenoxyethanol</td>
<td>0.221</td>
<td>Cocoamidopropyl Betaine</td>
<td>5</td>
<td>Paraffin Oil</td>
<td>10</td>
</tr>
<tr>
<td>PEG</td>
<td>14.551</td>
<td>Oleic Acid</td>
<td>6</td>
<td>Isostearic Acid</td>
<td>5</td>
</tr>
<tr>
<td>Peppermint Oil</td>
<td>0.001</td>
<td>Phenoxyethanol</td>
<td>1</td>
<td>Maleic acid</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maleic acid</td>
<td>0.00393</td>
<td>PEG</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peppermint Oil</td>
<td>0.04994</td>
<td>Peppermint Oil</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Phenoxyethanol</td>
<td>0.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Questions?