Skin Remedies, Inc.

Engineering Lotion

by
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Purpose

- Develop a moisturizing lotion to treat ichthyosis and xerosis
- Design the manufacturing procedure for the lotion

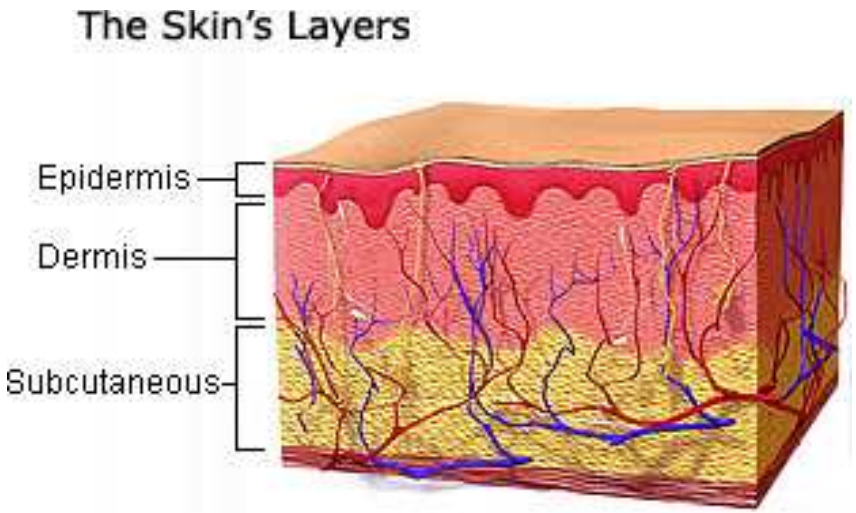
Agenda

- The Skin
- Skin Disorders
- Treatment
- Consumer Satisfaction Model
- Demand Model
- Manufacturing Process
- Economic Analysis
- Future

The Skin

The Skin

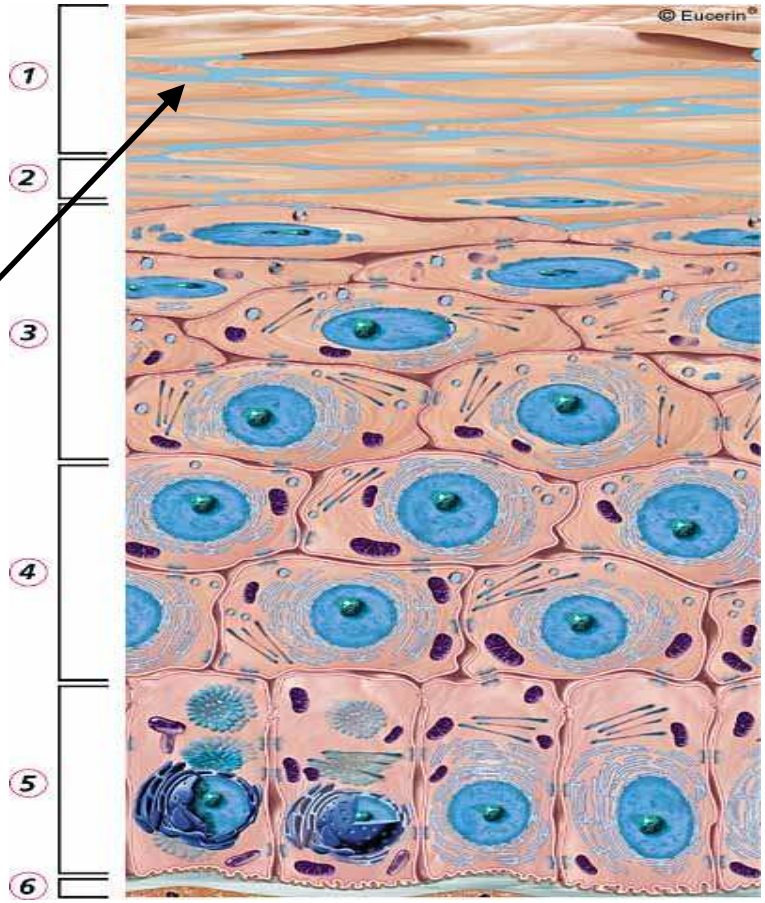
- Functions as a barrier to provide immunity from disease
- Repairs itself daily by replacing the outer layer
- Contains three layers: epidermis, dermis and subcutaneous



Source: http://cancer.healthcentersonline.com/skincancer/basalcellcarcinoma.cfm

Epidermis

- The outermost layer of skin
- Composed of several layers
  - Stratum Corneum (1) is outermost layer of the epidermis



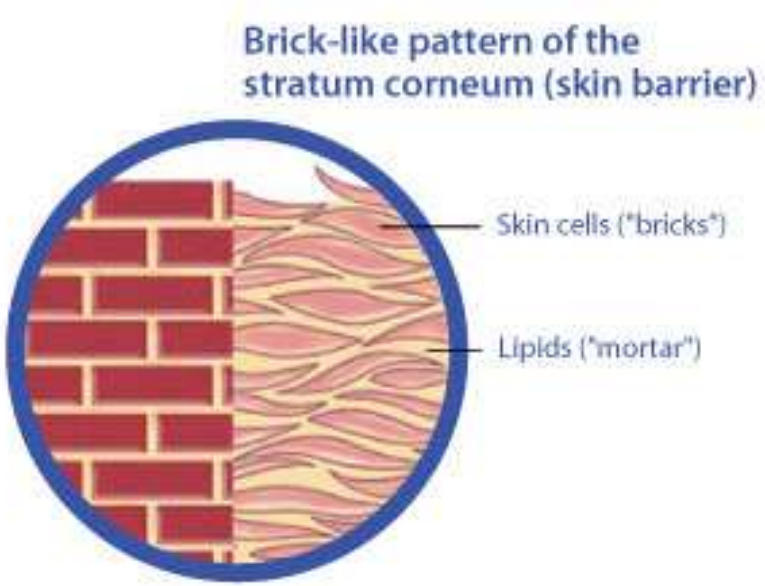
Source: www.eucerim.co.uk

Stratum Corneum

- Interacts directly with environment
- Approximately 20 cell layers thick
- Location in which desquamation occurs
  - Desquamation is the shedding of the top layer of cells in the stratum corneum
  - Approximately 1 layer per day is released

Stratum Corneum (cont.)

- Contains hydrophilic cells surrounded by a hydrophobic lipid bilayer
  - The lipid bilayer prevents water removal from the skin to the atmosphere
- Contains natural moisturizing factors (NMF) responsible for the absorption and retention of water
  - Water content is about 30%



www.cerave.com/barrier.htm

Skin Disorders

Xerosis (Dry Skin)

- Reduced water content in Stratum Corneum
- Occurs when natural moisturizers on the skin's surface are removed
- Caused by overexposure to water, sun, or cold weather
- Symptoms include dry, itchy skin

Ichthyosis

- Genetic disorders in the production and/or desquamation of cells
  - Rapid production of skin cells
  - Desquamation is slowed or inhibited
- Results in dry and thickened, scaly skin
- Incurable disorders

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

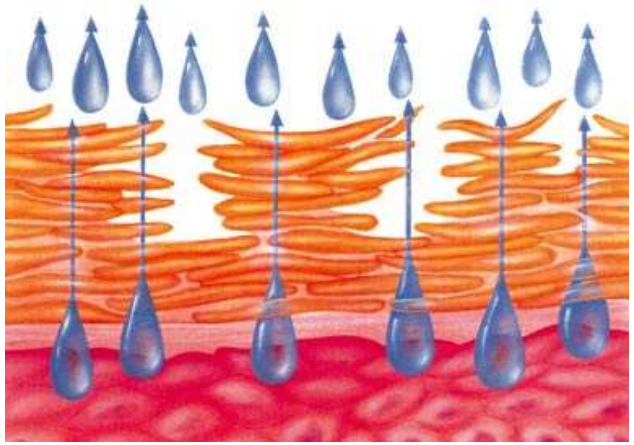
Ichthyosis Vulgaris

- Accounts for 95% of all ichthyosis cases
- Affects 1 in 250 people
- Caused by low water content in Stratum Corneum
  - The enzymatic reactions controlling desquamation are inhibited

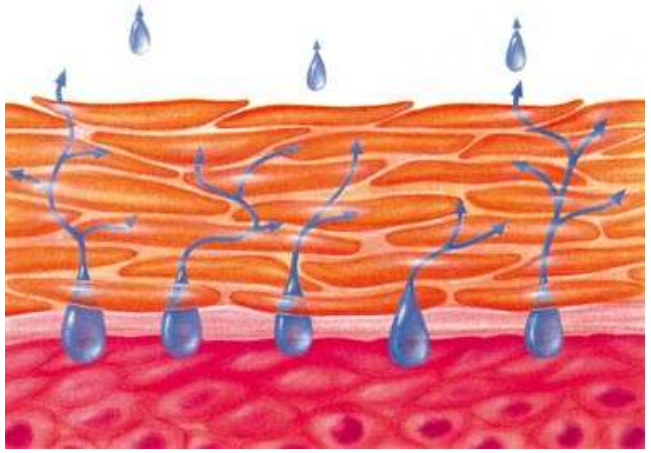
Source: www.ichthyosis.com

Effects on Skin Barrier

- Reduced or low water content in the Stratum Corneum results in a compromised barrier
- This compromised barrier must be restored in order to prevent excessive water loss



Compromised Barrier



Intact Barrier

Source: http://www.cetaphil.com.au/importance_of_your_skin_more.asp

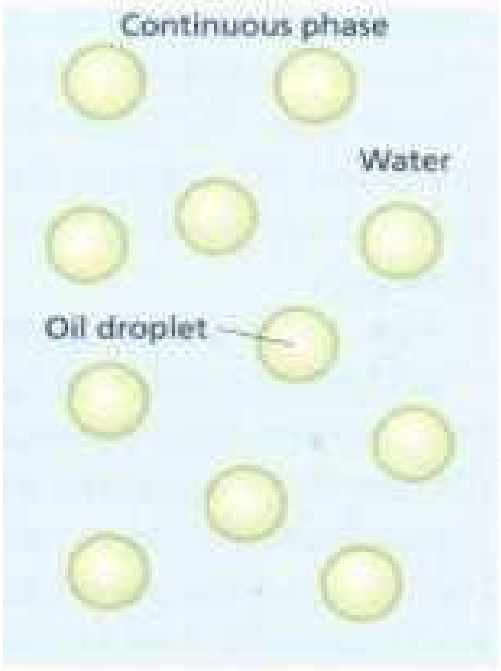
Treatment

Current Treatment

- Temporary and symptomatic
- Primarily focus on supplying ingredients that replenish and retain water content
- However, there are three key steps to effectively treat the disorders:
  1) Promote desquamation
  2) Deliver moisturizing agents to underlying skin
  3) Restore the skin's lipid bilayer

Moisturizer Formulation

- The simplest vehicle for skin moisturizers are emulsions
- For lotions, oil-in-water emulsions are used
  - Water is the continuous phase
  - Oil is the dispersed phase



Source: http://www.pg.com/science/skincare/Skin_tws_101.htm

Moisturizer Formulation (cont.)

- Lotions are composed of both active and inactive ingredients
- Active and Inactive ingredients result in a combination of properties (i.e. effectiveness, smoothness, creaminess, etc.)

Moisturizer Formulation (cont.)

- Active Ingredients and their function

Actives	Function
Humectants	Attract and bind to water
Occlusives	Prevent water loss from skin
Exfoliants	Promote dead skin removal
Emollients	Fill intercellular spaces of skin

Moisturizer Formulation (cont.)

- Inactive Ingredients and their function

Inactives	Function
Solvents	Contain and disperse ingredients
Emulsifying Agents	Stabilize the emulsion
Preservatives	Antimicrobials and antioxidants
Thickeners	Increase viscosity
pH adjustors	Adjust pH
Color Additives	Provide desirable color
Fragrant Components	Provide desirable scent

FDA Regulations

- The FDA defines cosmetic products as

  "…articles intended to be applied to the human body for cleansing, beautifying, promoting attractiveness"
- Skin moisturizers are considered cosmetic products and do not have to undergo FDA process
- However, cosmetics are subject to ingredient restrictions set forth by the "Cosmetic Ingredient Review"

Source: http: www.cfsan.fda.gov/~dms/cos-206.html

Consumer Satisfaction Model

Consumer Satisfaction Model

- A model was developed to assess the consumer needs
- The model measures how satisfied the consumer is with the properties of the lotion

Consumer Satisfaction Function

- Determine the relationship between the consumer and physical properties
- Weight the properties according to importance to consumer

$$S_i = \sum w_i y_i$$

$$S_i = satisfaction\ (0-100)$$

$$w_i = weight\ of\ \ property\ (0-100)$$

$$y_i = normalized\ \ scores\ of$$

$$consumer\ \ attributes\ (0-1)$$

Source: http://www.ou.edu/class/che-design/a-design/Pricing%20of%20Consumer%20Products.pdf

Consumer Tests

- Consumer tests are used to determine the satisfaction of the consumer for each property
- The consumers rates the properties based upon extremes (i.e. very thin to very thick)
- Consumer ratings are then correlated to the physical properties to find consumer satisfaction

Related Properties

Consumer

- Effectiveness
- Spreadability
- Thickness
- Smoothness
- Creaminess
- Absorption Rate
- Greasiness

Physical

- Diffusion (C/C^{ideal})
- Surface Tension
- Viscosity
- Coefficient of Friction
- Viscosity & Insolubles
- Diffusion S.S. Time
- Insolubles

Effectiveness

- Based on diffusion of ingredients and their healing ability
- Concentrations weighted upon function
- Concentration as a function of time and location

Effectiveness (cont.)

$$\frac{C_w}{C_w^{ideal}} = 1 - \frac{x}{L_{sc}} - \frac{2}{\pi}\sum_{x-1}^{\infty}\frac{1}{n}\sin\frac{n\pi x}{L_{sc}}e^{\frac{-D_{sc}n^2\pi^2 t}{R_{sc}L_{sc}^2}}$$

$C_w = concentration\ of\ ingredient\ at\ desired\ depth$

$C_w^{ideal} = ideal\ concentration\ of\ ingredient\ at\ desired\ depth$

$D_{sc} = effective\ diffusion\ coefficient\ of\ 3-phase\ stratum\ corneum\ continuum$

$R_{sc} = retardation\ factor\ of\ the\ 3-phase\ stratum\ corneum\ continuum$

$L_{sc} = distance\ into\ stratum\ corneum\ from\ the\ surface$

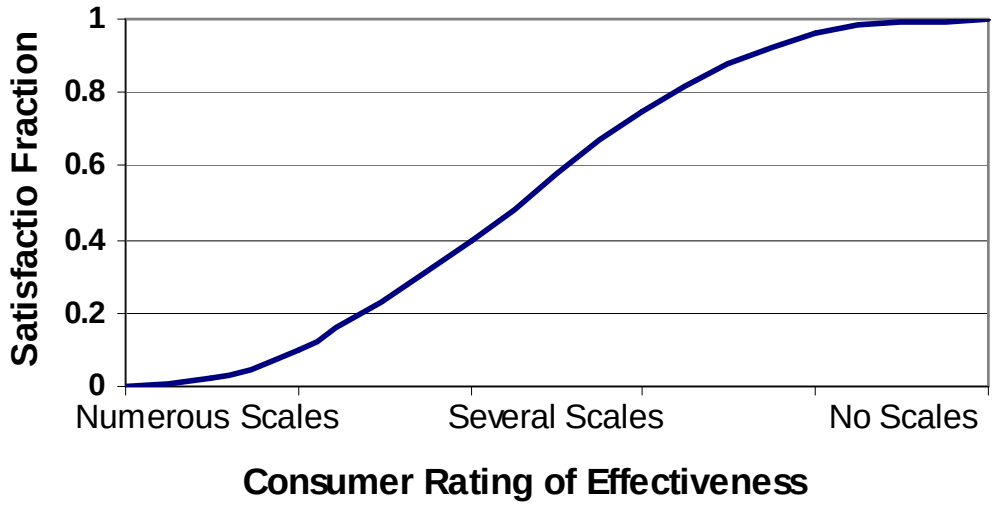
$x = desired\ depth$

$n = integer\ from\ 1-\infty$

Source: A Geoscience Approach to Modeling Chemical Transport through Skin

Effectiveness (cont.)

- Effectiveness Test:
  1. Count the scales per square inch of skin.
  2. Apply given amount of lotion to one of the designated areas while using other area as control.
  3. Consumer rates lotion based upon number of scales remaining after a specified amount of time.



Effectiveness (cont.)

- Assumptions:
  - Scaling rate is proportional to diffusion

Spreadability

- Based on surface tension
- Surface tension of each ingredient is found using:
- Surface tension of the lotion is found using:

$$\gamma = [P(\rho_l - \rho_v)]^4$$

$P = parachor\ value\ (dependent\ \ upon\ structure)$

$\rho_l = density\ of\ \ liquid$

$\rho_v = density\ of\ \ vapor\ (neglected\ \ at\ low\ \ pressure)$

$$\gamma_{ow} = \frac{(\gamma_{oe} - \gamma_{we})}{\cos\theta}$$

$\gamma_{ow} = surface\ tension\ between\ oil - water$

$\gamma_{oe} = surface\ tension\ between\ oil - emulsifier$

$\gamma_{we} = surface\ tension\ between\ water - emulsifier$

$\theta = contact\ angle$

Source: Surface Tension Prediction for Pure Fluids & http://www.tu-chemnitz.de/chemie/physchem/files/praktika/pcf/gcii6.pdf

Spreadability (cont.)

- Surface tension between the skin and the lotion is found using:

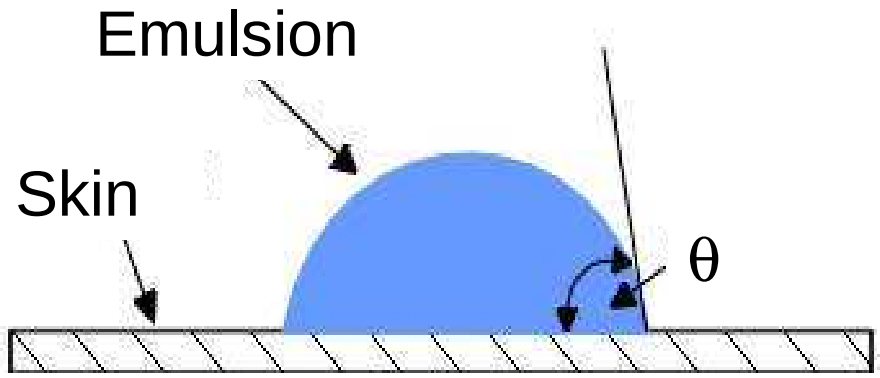
$$\gamma_{se} = \gamma_s - \gamma_e \cos\theta$$

$\gamma_{se} = surface\ tension\ of\ \ skin - emulsion$

$\gamma_s = surface\ tension\ of\ \ skin$

$\gamma_e = surface\ tension\ of\ \ emulsion$

$\theta = contact\ angle$



Source: http://www.pcn.org/Technical%20Notes%20-%20Corona.html &
Comparison of surface free energy between reconstructed epidermis and in situ human skin

Spreadability (cont.)

- The main factor for spreadability is wettability
- Due to trade secrets, correct values for this were not obtained.
- Approximated spreadability using only surface tension between skin and emulsion

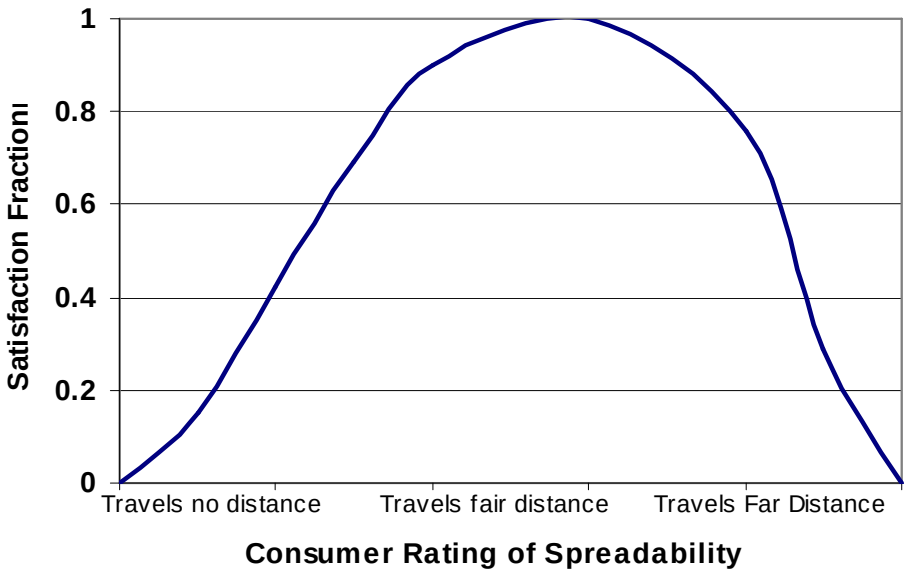
$$S_{e/s} = \gamma_s - (\gamma_{se} + \gamma_e)$$

$$S_{e/s} = Spreadability\ Coefficient$$

Source: Surfactants and Interfacial Phenomena

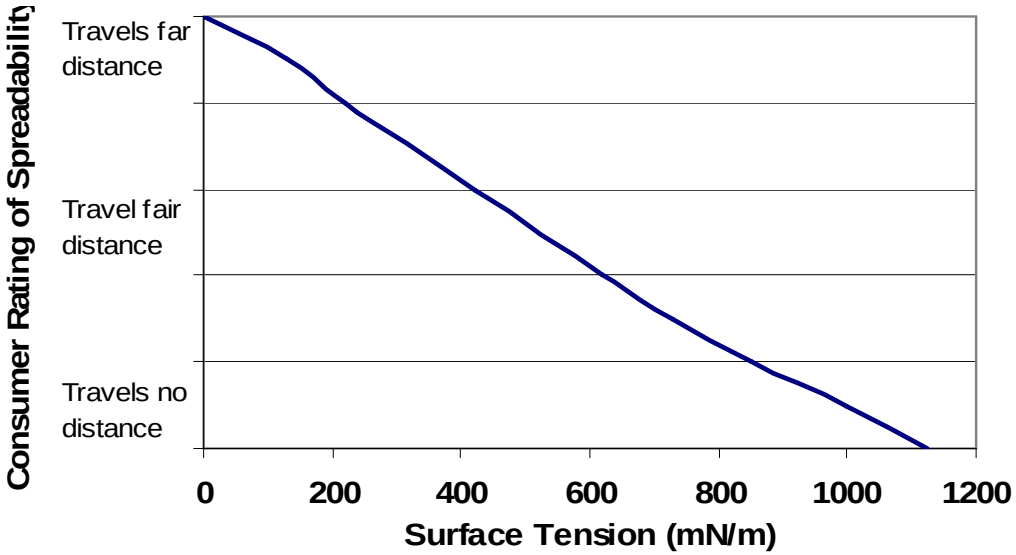
Spreadability (cont.)

- Spreadability Test:
  1. Pour given amount of lotion on hand
  2. Measure distance lotion travels in designated amount of time
  3. Consumer rates spreadability of lotion



Source: http://en.wikipedia.org/wiki/Surface_tension

Spreadability (cont.)



- Assumptions:
  - The spreadability is inversely proportional to surface tension between the skin and lotion

Thickness

- Based on viscosity, η:

$$thickness = \eta^{0.5}$$

- Viscosity found for each ingredient
- Viscosity of an emulsion was found using:

$$\eta = 1 + \frac{5.5\left[4\lambda^7 + 10 - \left(\frac{84}{11}\right)\lambda^2 + \left(\frac{4}{\kappa}\right)\left(1-\lambda^7\right)\right]\phi}{10\left(1-\lambda^{10}\right) - 25\lambda^3\left(1-\lambda^4\right) + \left(\frac{10}{\kappa}\right)\left(1-\lambda^3\right)\left(1-\lambda^7\right)}$$

$$\kappa = vis\cos ity\ of\ \ dispersed\ \ \ phase\ /\ vis\cos ity\ of\ \ continuous\ \ \ phase$$

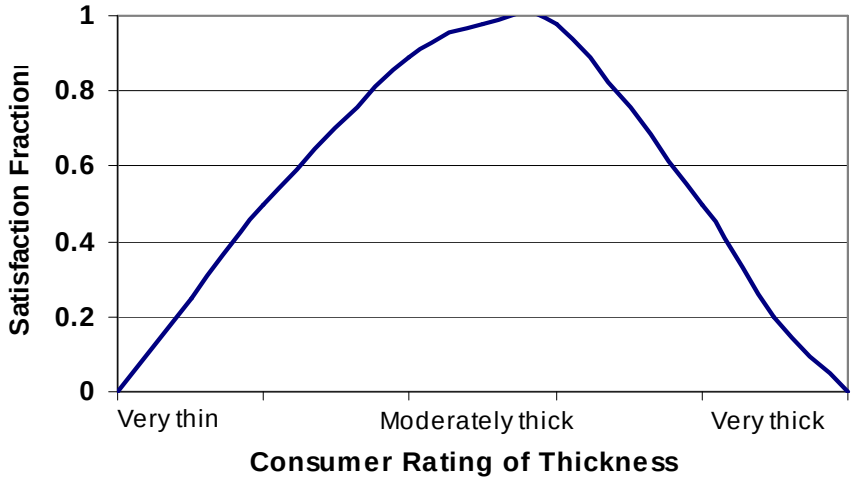
$$\phi = volume\ \ \ fraction\ \ of\ \ the\ \ dispersed\ \ \ phase$$

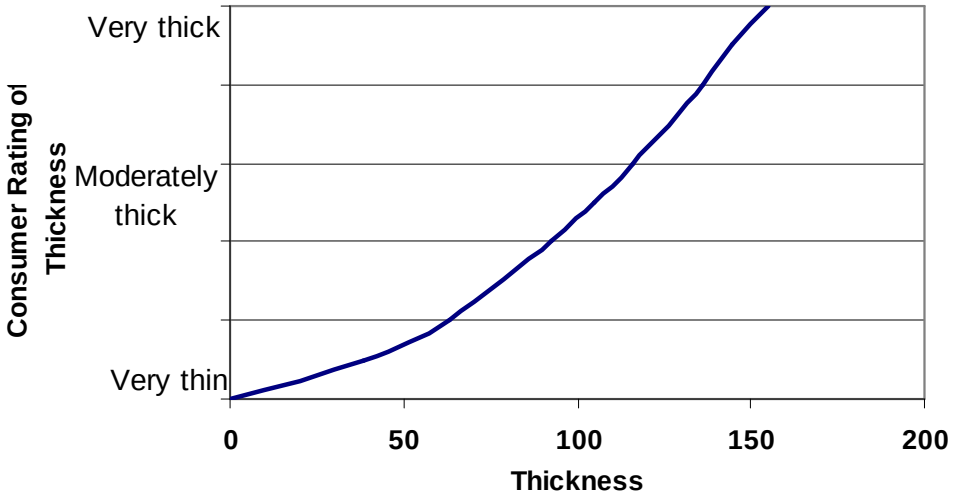
$$\lambda = (\phi)^{1/3}$$

Sources: 1.Evaluation of theoretical viscosity models for concentrated emulsions at low capillary numbers; 2. Chemical Product Design

Thickness (cont.)

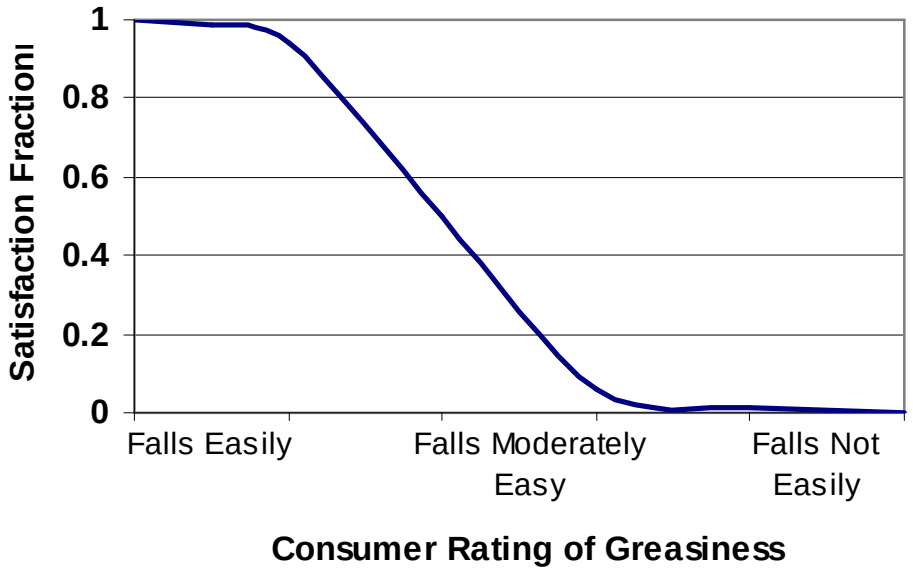
- Thickness Test:
  1. Place given amount of lotion on pad of thumb.
  2. Consumer rubs lotion between thumb and index finger in lateral motion.
  3. Consumer rates thickness of lotion.



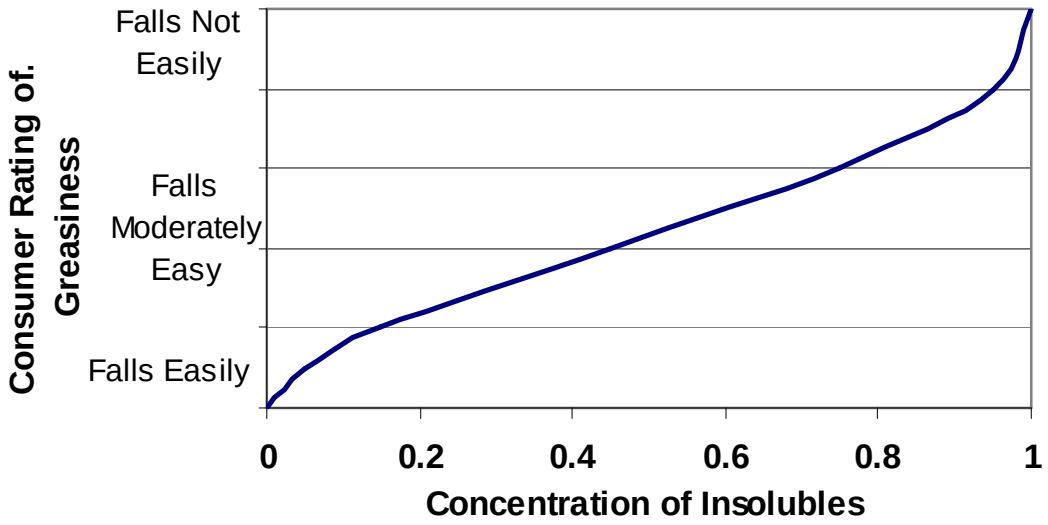


Greasiness

- Based on the concentration of insoluble ingredients
- Greasiness Test:
  1. Apply given amount of lotion to designated region on skin.
  2. Place a piece of paper on lotion and rotate arm slowly 90 degrees.
  3. Consumer rates lotion based on how easily paper slides off skin.



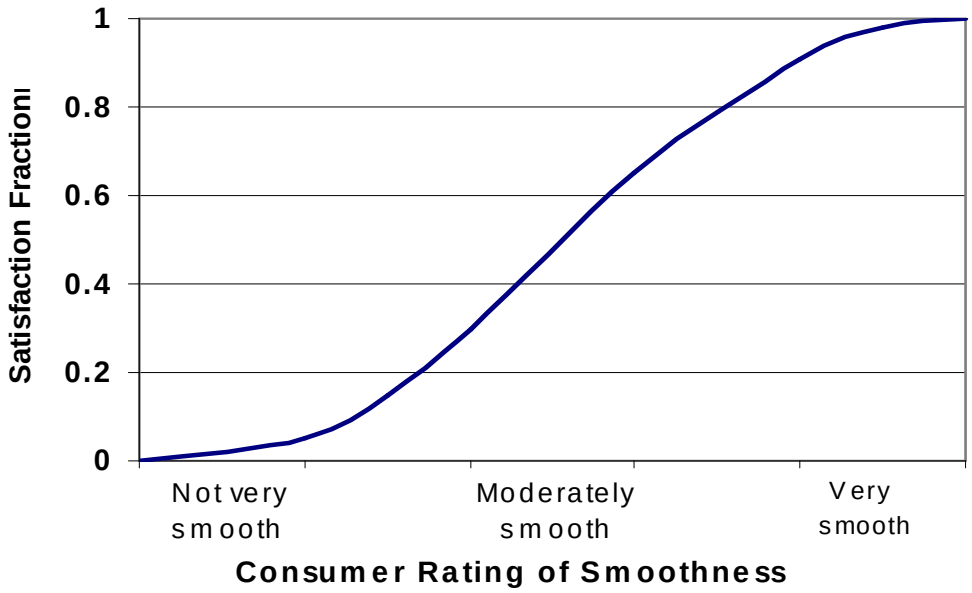
Greasiness (cont.)



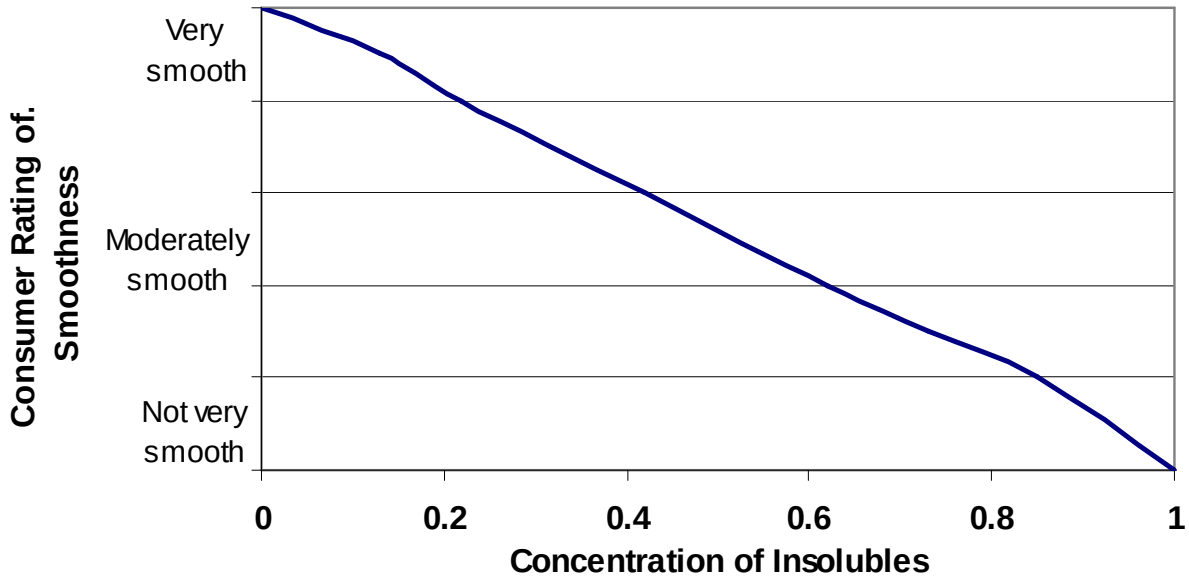
- Assumptions:
  - Ease at which paper falls is approximately linear to the oil content in the lotion
  - As the oil content starts to exceeds the water content, the lotion becomes a water-in-oil emulsion resulting in a sharp increase in greasiness

Smoothness

- A function of the coefficient of friction, μ and greasiness
- Smoothness Test:
  1. Apply lotion to skin in lateral motion
  2. Consumer then rates smoothness



Smoothness (cont.)



- Assumptions:
  - Smoothness is proportional to greasiness and inversely proportional to the coefficient of friction

Creaminess

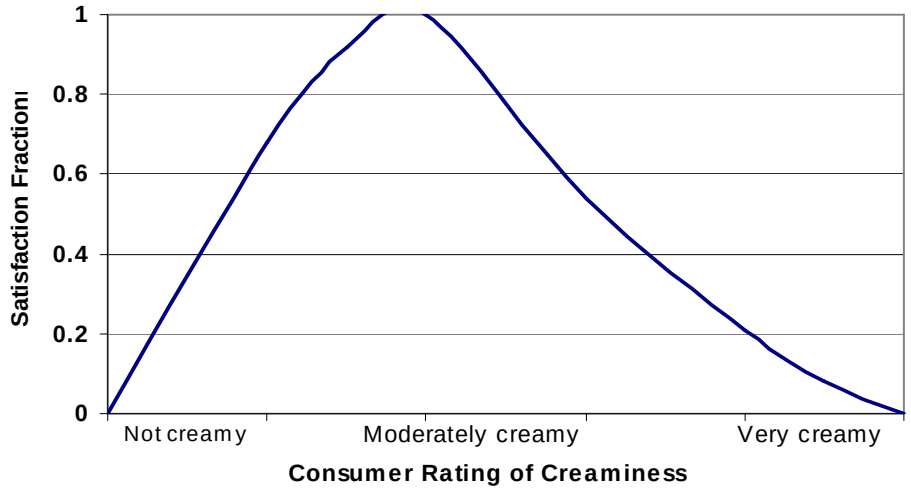
- Based on the thickness and smoothness
- Creaminess is found using:

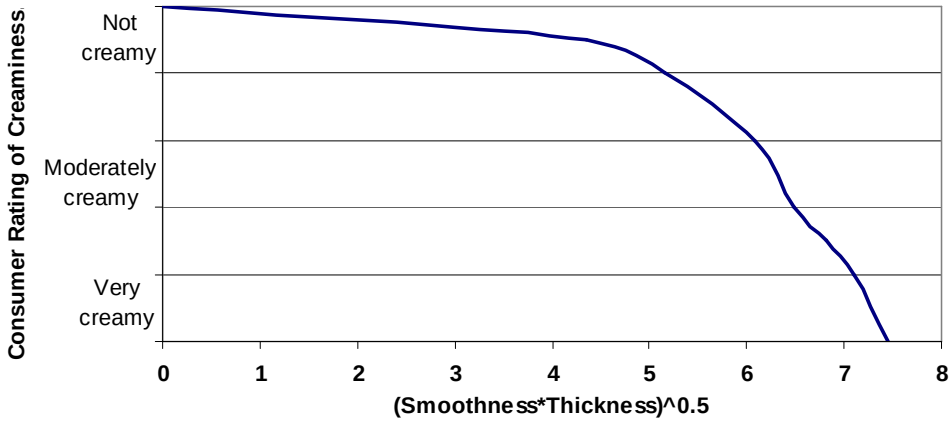
$$Creaminess = [(thickness)(smoothness)]^{0.5}$$

Source: Chemical Product Design

Creaminess (cont.)

- Creaminess Test:
  1. Consumer swirls finger in container of lotion
  2. Consumer rates creaminess





Absorption Rate

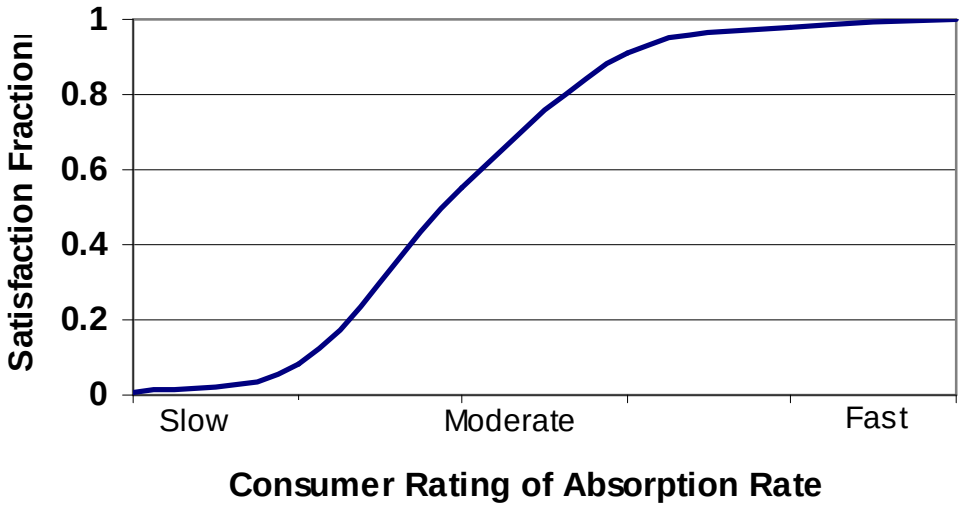
- Based on the diffusion rate of each ingredient
- Found using the time to steady-state value

$$t_{ss} = \frac{0.45 x R_{sc}}{D_{sc}}$$

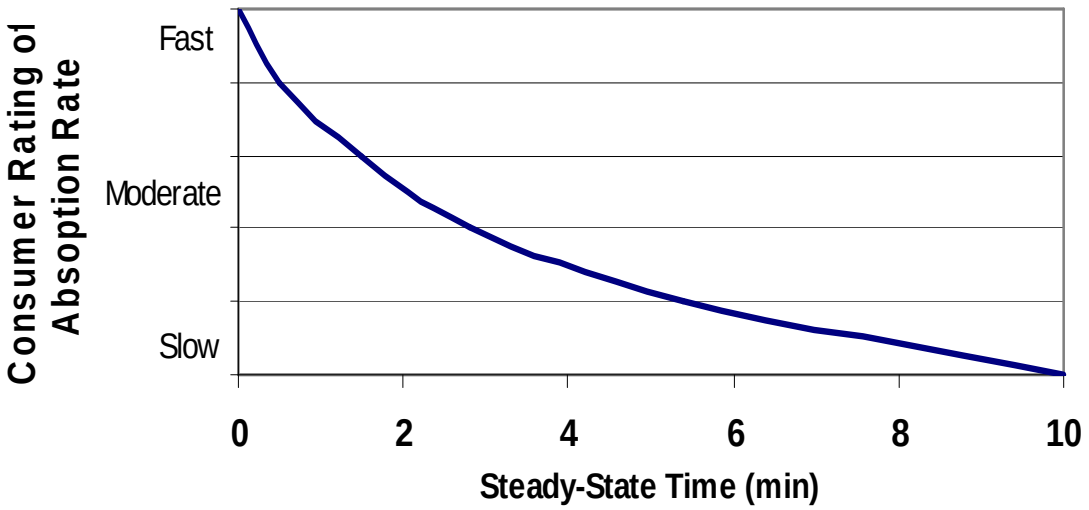
Source: A Geoscience Approach to Modeling Chemical Transport through Skin

Absorption Rate (cont.)

- Absorption Rate Test:
  1. Apply a known amount of lotion
  2. Measure time for lotion to completely absorb into skin
  3. Consumer scores absorption rate



Absorption Rate (cont.)



- Assumptions:
  - Based on informal surveys

Consumer Satisfaction Model

				Creaminess	*Effectiveness*
Ingredient	**Fraction**	**formulation min %**	**formulation max %**	**(Smoothness*Thickness)^0.5**	**C_w/C_w^o**
Solvent					
Deionized Water	70.0000%	50.00%	70.00%		0.50
Occlusives					
petrolatum	0.0000%	0.000%	5.00%		0.35
Ceramide*	3.0002%	0.00%	5.00%		0.32
Dimethicone	0.0141%	0.00%	10.00%		0.35
Cholesterol*	1.0001%	0.00%	5.00%		0.35
Total Mixture Value	100.0000%			0.748513656	0.47
Consumer Score				9.76307994	3.13
Happiness percentage				0.777602044	0.45
Weight of variable				0.05	0.450000682
Relative happiness (%)=	**68.12**				

Maximum Satisfaction Product

- Satisfaction is 68%

Ingredient	Composition	Function
Deionized Water	70.0000%	Solvent
Sorbitol	0.0500%	Humectant
Ceramide	3.0002%	Occlusive
Dimethicone	0.0141%	Occlusive
Cholesterol	1.0001%	Occlusive
Castor Oil	0.0500%	Emollient
Carbomer	5.0000%	Thickener
Phenoxyethanol	5.0000%	Preservative
EDTA	5.0000%	Preservative
γ-linoleic acid	1.0000%	SC lipid
Maleic Acid	0.0040%	pH adjustor
Cetyl Alcohol	8.8316%	Emulsifier
Lactic Acid	1.0000%	Exfoliant
Titanium Dioxide	0.0500%	Color Additive

Competitor Satisfaction-51%

Ingredient	Composition	Function
Deionized Water	70.840%	Solvent
C10-30 Alkyl Acrylate	0.600%	Thickener
Titanium Dioxide	3.000%	Colorant
Allantoin	0.200%	Occlusive
PEG	3.000%	Humectant
Methylparaben	0.150%	Preservative
Dilaureth-4 Phosphate	3.000%	Emulsifier
Cetyl Alcohol	2.000%	Emulsifier
Mineral Oil	10.300%	Emollient
Decyl Oleate	6.200%	Emollient
Propylparaben	0.050%	Preservative
TEA	0.360%	pH adjustor
Phenoxyehtanol	0.200%	Preservative
Fragrance	0.100%	Fragrance

Source: Cosmetic and Toiletry Formulations, Volume 4 (2nd ed.)

Demand Model

Demand Model

$$\beta p_1 d_1 = \alpha p_2 d_2 \left(\frac{d_1^{\alpha}}{d_2^{\beta}} \right)$$

$$\beta = \frac{S_2}{S_1}$$

$$\alpha = awareness\ \ of\ \ product$$

$$p_1 = our\ \ price$$

$$p_2 = competitor's\ \ price$$

$$d_1 = our\ \ demand$$

$$d_2 = competitor's\ demand$$

Demand Model (cont.)

- Budget Model
  - Consumer has a budget in which the product price is the main determining factor
- Fixed Demand Model
  - The total demand is constant and product price is not as significant
- We initially applied the budget model, but used the fixed demand model when this failed (i.e. individual demands exceed total demand)

Demand Model (cont.)

- Budget Model

$$Y = p_1 d_1 + p_2 d_2$$

$$\Rightarrow d_2 = \frac{Y - p_1 d_1}{p_2}$$

$$\therefore d_1 = \left(\frac{\alpha p_2}{\beta p_1}\right)\left(\frac{Y - p_1 d_1}{p_2}\right)^{1-\beta} \cdot d_1^{\alpha}$$

- Fixed Demand Model

$$D = d_1 + d_2$$

$$\Rightarrow d_2 = D - d_1$$

and maximizing $U = d_1^{\alpha} + d_2^{\beta}$

$$\therefore d_1 = \left(\frac{\alpha}{\beta}\right)^{1/1-\alpha} \left(D - d_1\right)^{1-\beta/1-\alpha}$$

Market Research

- Ichthyosis Vulgaris
  - Hereditary, genetic disease that cannot be cured: market demand should not decrease
  - The symptoms of the disorders worsen in colder, drier climates

Incidence of Some Prominent Forms of Ichthyosis

There is little reliable data on the incidence of the ichthyoses. Most figures are informed estimates. Below is a table of commonly accepted figures; however, most of these figures are broad estimates and the margin of error is large.

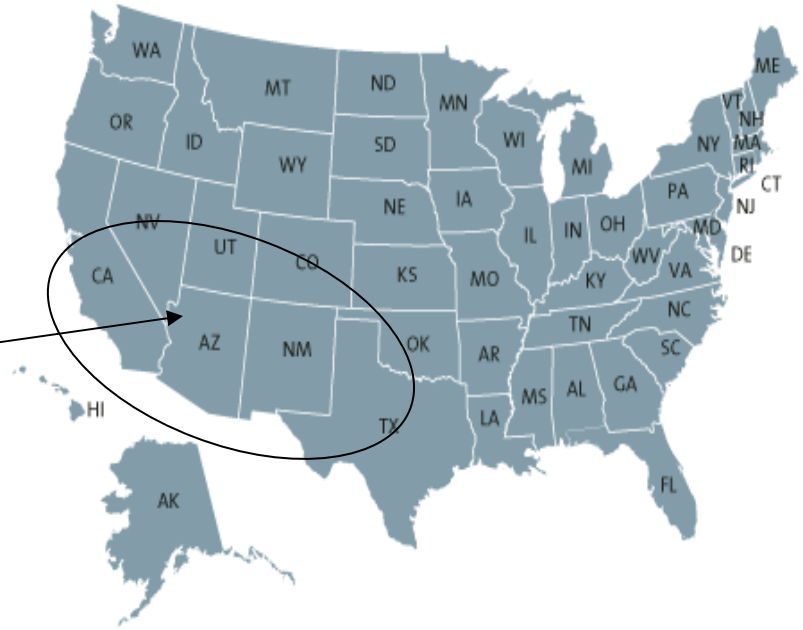
TYPE	INCIDENCE	PER MILLION	YEARLY BIRTHS
Lamellar (recessive)	1 : 200,000	5	19
CIE	1 : 200,000	5	19
EHK	1 : 100,000	10	38
Recessive X-Linked	1 : 6,000	167	635
Darier's Disease	1 : 100,000	10	38
Harlequin Ichthyosis	1 : 200,000	5	19
Ichthyosis Vulgaris	1 : 250	4,000	15,200

By these estimates, more than one million Americans are affected by ichthyosis, and more than 16,000 babies are born each year with one of this family of genetic skin diseases.

Source: www.ichthyosis.com

Target Market

- Based on Satisfaction Model
- Target audience chosen by determined weights of model
- Based on current model, main target audience is the southwest
- However, lotion can enter other markets over time



Manufacturing Process

Plant Location

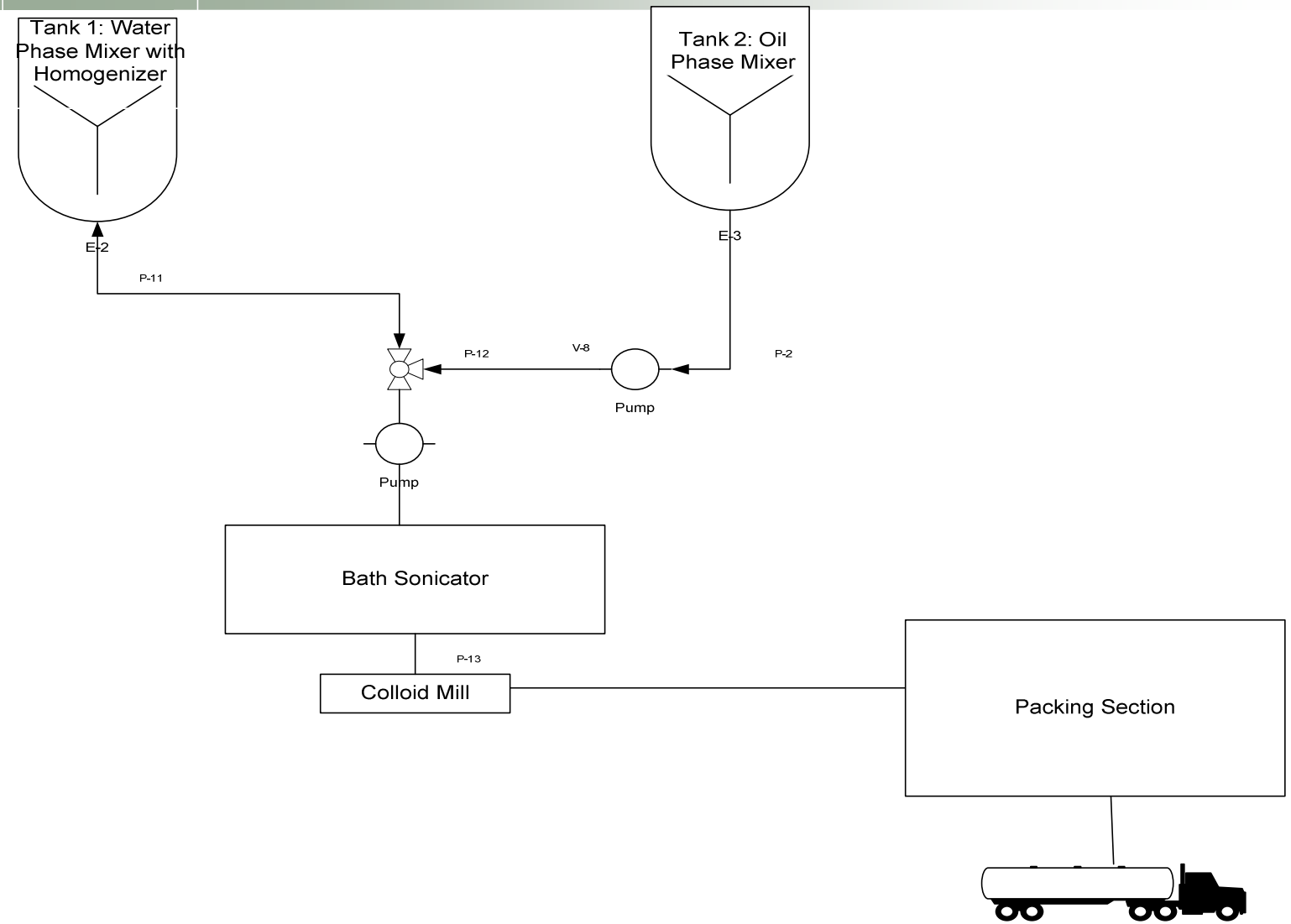
- Phoenix, AZ
  - Based on our target market
  - Centrally located within market
  - Inexpensive property value
  - High Productivity
  - Low Labor costs

Source: http://www.rlmartin.com/photos/scenic/arizona/default.htm

Manufacturing Procedure

- Two separate phases make up lotion: aqueous and oil phases
- Must completely combine two phases
- Steps in lotion formation:
  1) Heat and mix aqueous and oil phases separately
  2) Combine both phases into one batch
  3) Perform post treatment modifications (i.e. decrease particle size)

Process Flow Diagram



Equipment Costs

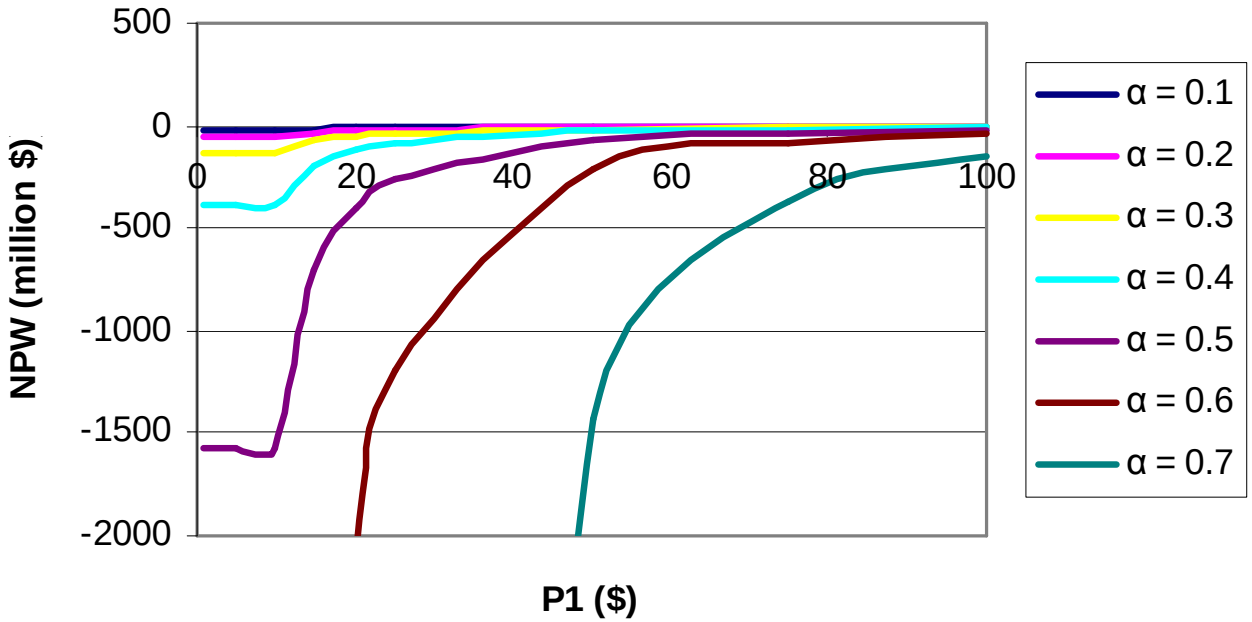
Equipment	Cost ($)
Storage Tanks	80,200
Water Phase Mixing Tank	20,100
Oil Phase Mixing Tank	13,500
Bath Sonicator	4,100
Homogenizer	21,000
2 Pumps	5,000
Colloid Mill	15,000
Total	**158,900**

Source: www.mhhe.com/peters-timmerhaus & www. heilscher.com/

Economic Analysis

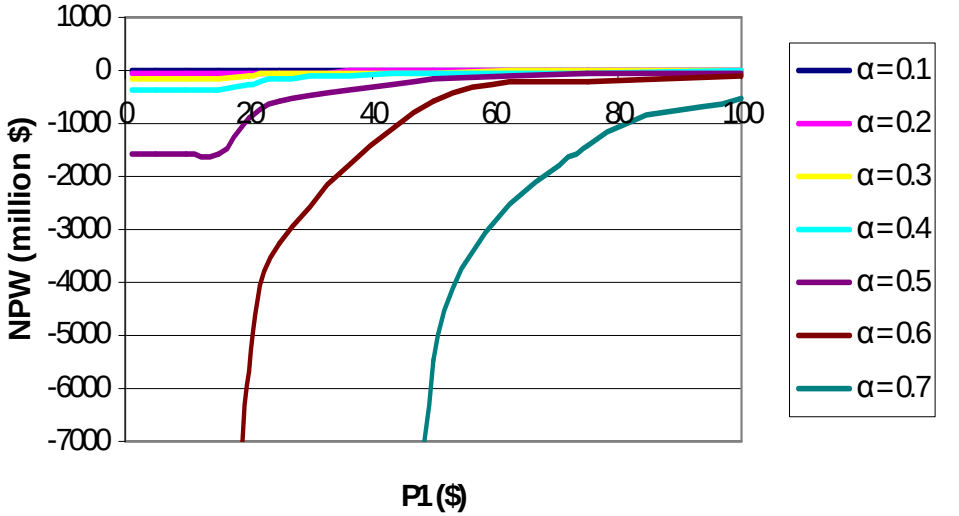
Maximum Satisfaction Product

- NPW is always negative for varying α values and our product price (p_2=\$10)

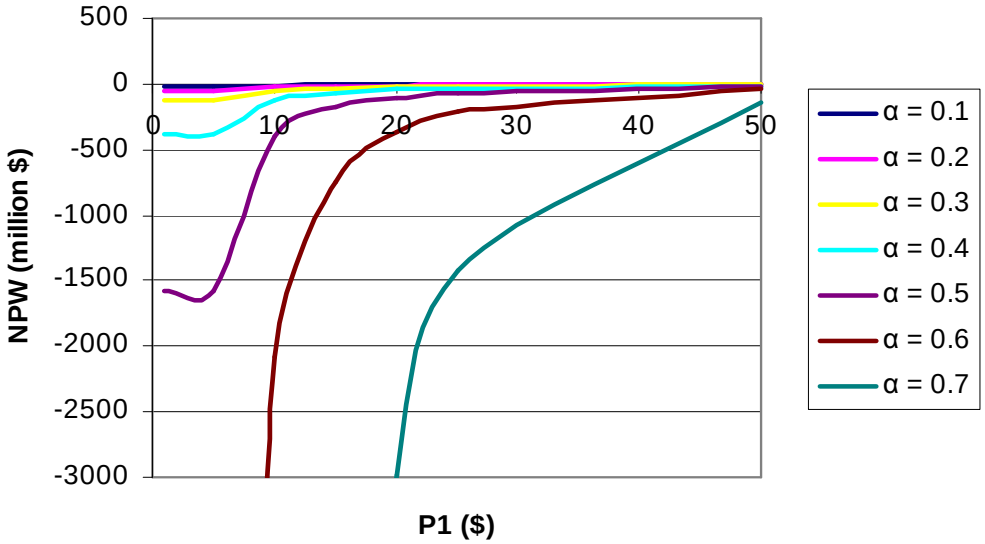


Maximum Satisfaction Product (cont.)

- Increasing competitor's price (i.e. p_2=\$15)



- Decreasing competitor's price (i.e. p_2=\$5)



Maximum Satisfaction Product

- Maximum Satisfaction Product provides a satisfaction of 68 %
- However, due to extreme raw material costs, it is not economically feasible to manufacture

Ingredient	Cost ($/kg)
Dimethicone	$ 120
Cholesterol	$ 330
Carbomer	$ 2,100
γ-Linoleic Acid	$ 5,900
Ceramide	$ 3,000,000

Maximum Profit Product

- Since Maximum Satisfaction Product cannot be economically produced, we had to develop a profitable product
- Profitable product includes:
  - Substituting Product Ingredients
  - Alternating Ingredient Concentrations

Maximum Profit Product (cont.)

- Solver was used to maximize the NPW with a constant α value at 0.8
- The ingredients and their concentrations were parameters that solver could manipulate to maximize NPW

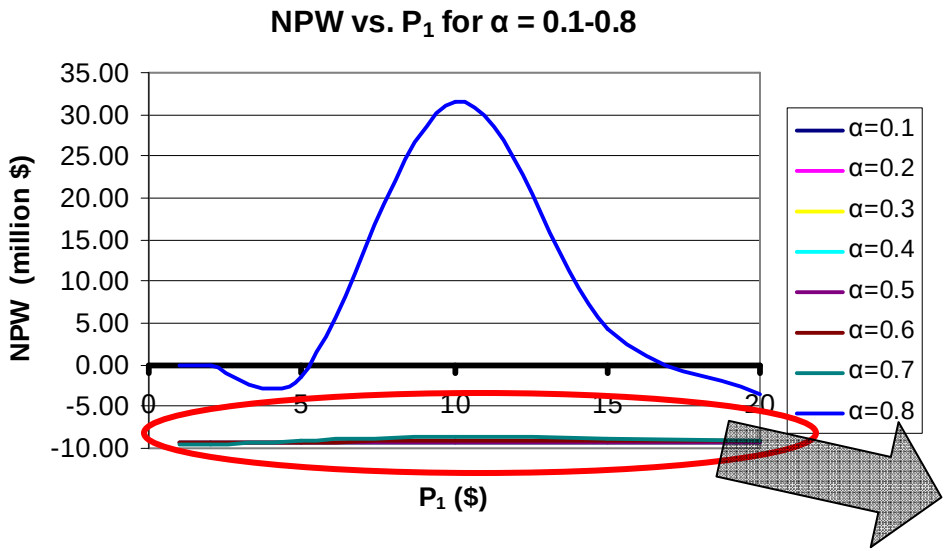
Maximum Profit Product (cont.)

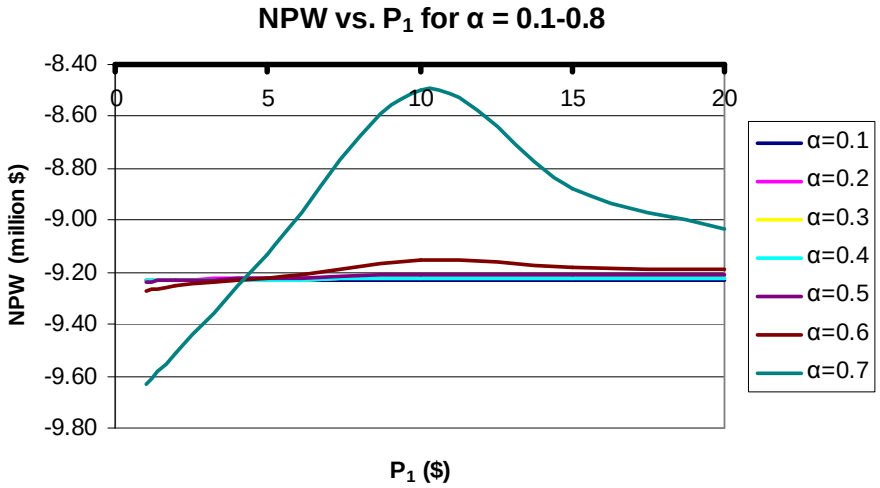
- Consumer Satisfaction is 62% while the maximum satisfaction product was at 68%

Ingredient	Composition	Function
Deionized Water	70.0000%	Solvent
Glycerin	10.0000%	Humectant
Petrolatum	1.0000%	Occlusive
Isopropyl Palmitate	1.0460%	Emollient
Isostearic Acid	2.0000%	Thickener
Phenoxyethanol	1.0000%	Preservative
Citric Acid	0.0040%	pH adjustor
Cetearyl Alcohol	13.9500%	Emulsifier
Malic Acid	1.0000%	Exfoliant

Maximum Profit Product

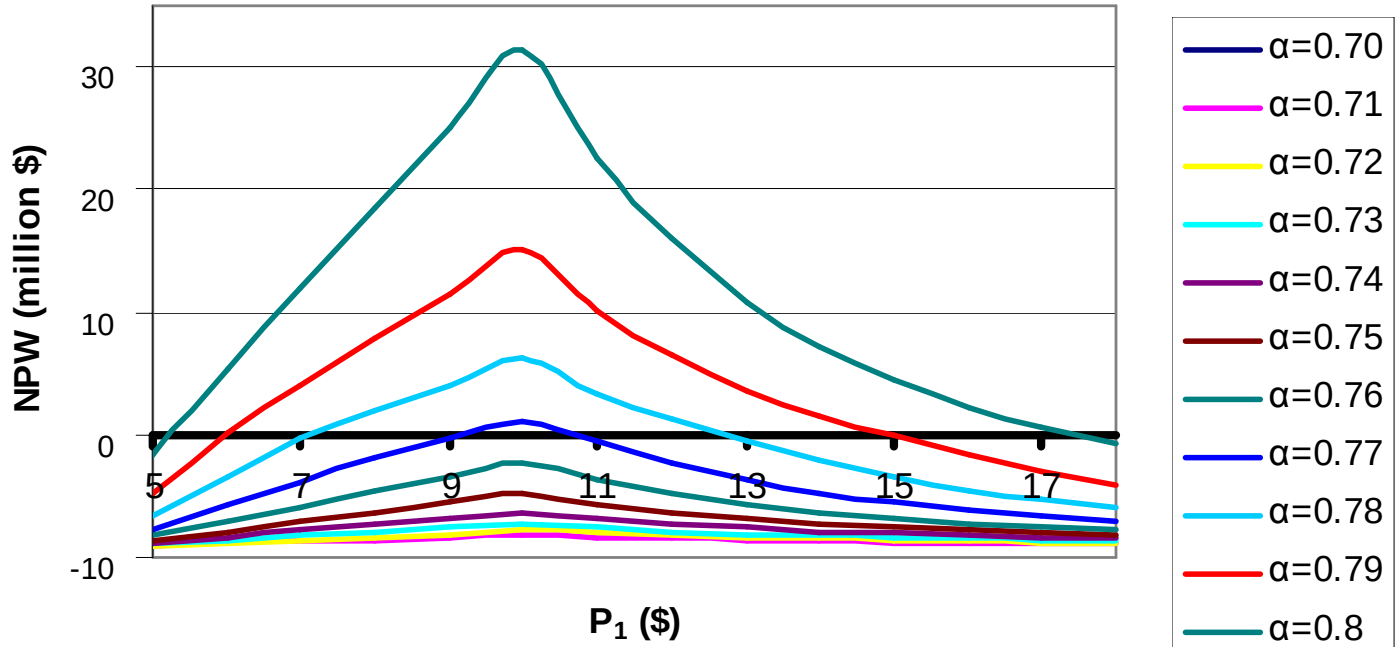
- NPW becomes positive when α ranges from 0.1 to 0.8





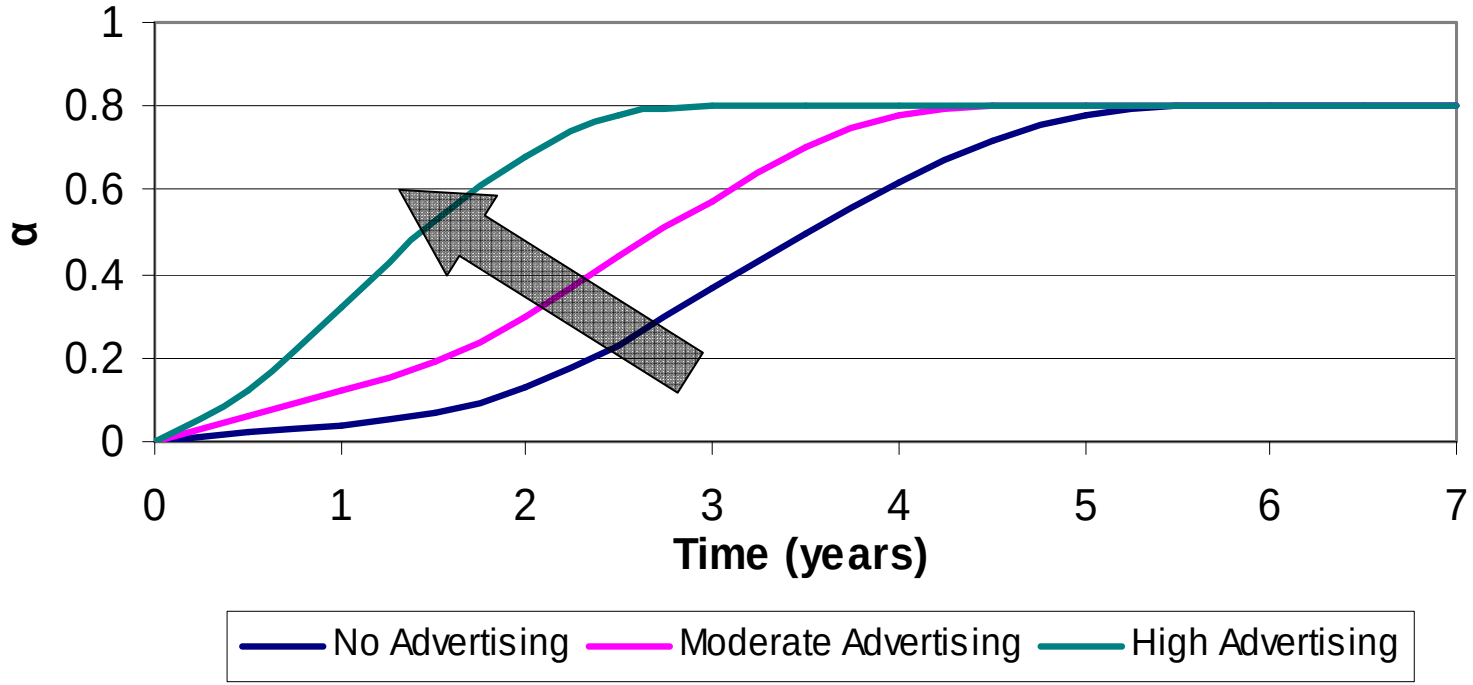
Maximum Profit Product (cont.)

- Plotting again for α values between 0.7 and 0.8, we see that the NPW peaks when p_1 is \$10



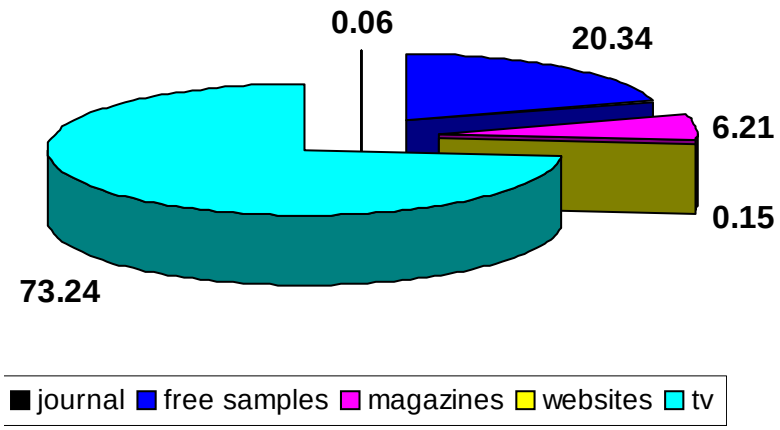
Advertising

- The maximum α occurs at 0.8
- As the amount of advertising increases, time to maximum α decreases

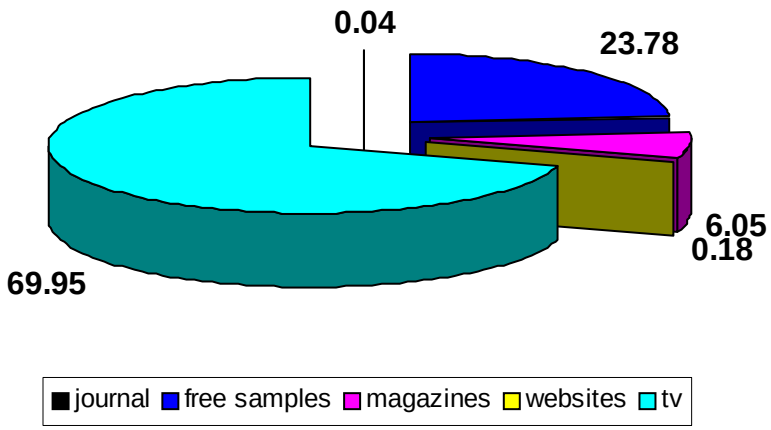


Advertising (cont.)

Moderate



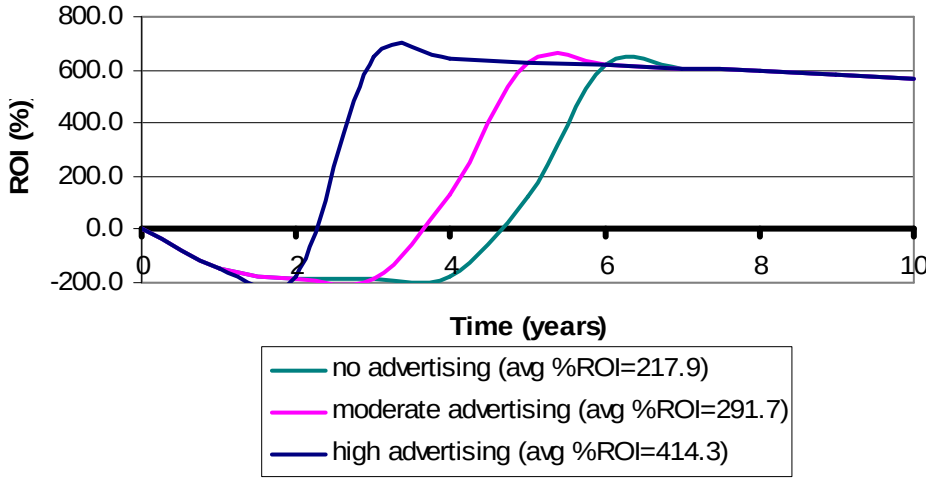
High

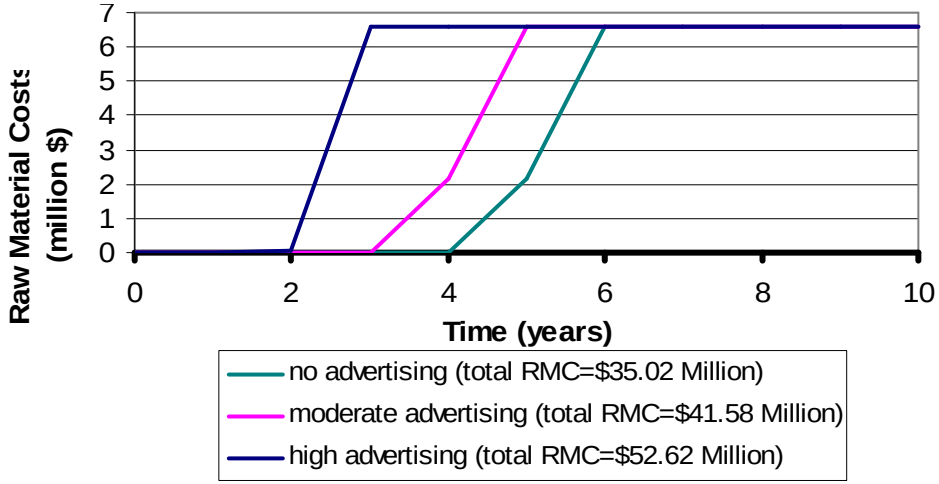


Total Advertising Costs (million $/year)	
Moderate	High
3.9	6.7

Advertising (cont.)

- High advertising also results in highest ROI
- Raw Material Costs rely significantly on α





Economic Analysis (cont.)

	Product	
	Maximum Satisfaction	**Maximum Profit**
Total Capital Investment ($10^{6})	0.994	1.06
Raw Material Cost ($10^{6})	49000	52.62
Return on Investment (%)	-5900000	414
Net Present Worth ($10^{6})	-280000	19.03

Future

- This model was a first approach
  - Perfected with further market analysis and consumer research
- More powerful software should be used in the future for the Demand and Consumer Satisfaction Models

Questions