

Chemical Consumer Product Design

Pukyong National University
Department of Chemical Engineering
Prof. Gyeongbeom Yi

Physical Form		Product form/ Delivery System	Example		
			Cosmetic and Personal care	Health care and pharmaceuticals	Household and Office supplies
SOLID	SHAPED	Composites	Bar soap, Lipstick	Inhalant stick	Compact disk, Glue stick
		Capsules	–	Whale oil Capsule	Microencapsulated Carbonless paper
		Tables	–	Aspirin tablet	Moth balls
		Solid foam	–	–	Styrofoam
	BULK	Powders and Granules	Facial powder, Baby powder, Diaper absorbent	Powdered Herbal, Medicine	Powdered Detergent, dry toner
SEMI- SOLID	Pastes	Toothpaste	Pain relief Ointment	Silicone sealant, Metal adhesive	
	Creams	Cleansing cream, hair cream	Pharmaceutical Cream	Multipurpose Adhesive	
LIQUID	Liquid foams	Shaving foam	–	–	
	Macromolecular Solution	Mouthwash, Shampoo	–	Dishwashing Liquid	
	Microemulsions	Skin cleanser, Hair conditioner	Hydrocortisone, Cyclosporine	–	
	Dilute emulsions And suspensions	Suntan lotion, Nail polish	Penicillin	Correction fluid, Writing ink	
	Solutions	Perfume	Eye drop, Ginseng extract	Drain cleaning Solution	
GAS	Aerosols	Hair Spray	Sore throat spray	Aerosol paint, Antifreeze spray	

**Example of
chemical-based
Consumer
product of
different forms
and delivery
systems.**

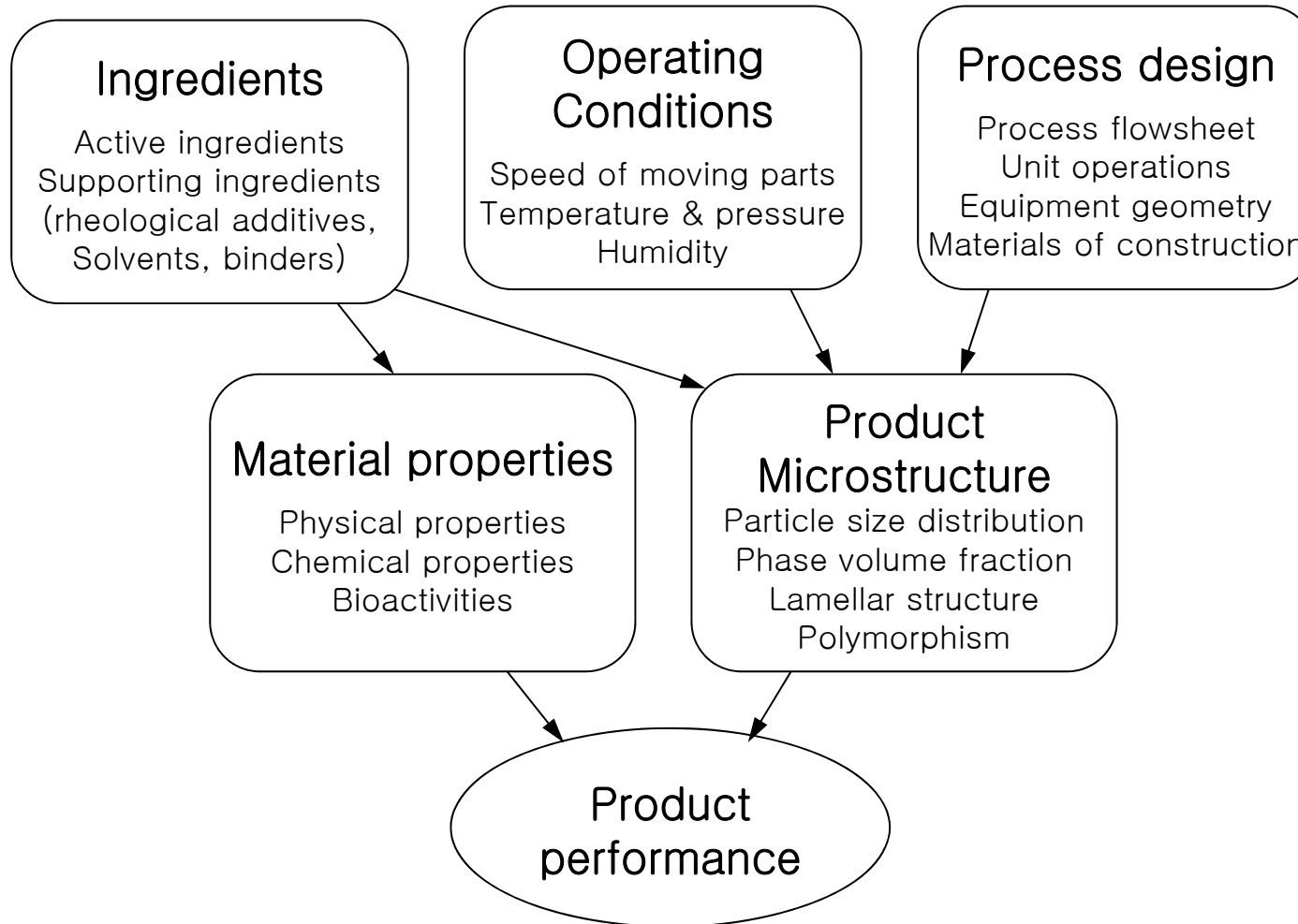
Procedure for the Synthesis and Development of Consumer Products

Step 1 (Define)	product conceptualization
Step 2 (Measure)	Identification of product quality factors
Step 3 (Analyze)	Product formulation <ul style="list-style-type: none">• Selection of ingredients• Selection of emulsion type (if applicable)• Selection of emulsifier (if necessary)• Determination of product microstructure
Step 4 (Design)	Design of manufacturing process <ul style="list-style-type: none">• Synthesis of flow sheet alternatives• Selection of equipment units• Selection of feed addition policy• Selection of equipment operating conditions
Step 5 (Verify)	Product and process evaluation <ul style="list-style-type: none">• Examination of the base case product• Determination of necessary modifications to meet the objectives• Evaluation of scale -up issues

Typical Packaging for Chemical-Based Consumer Products

Type of Packaging	Product Form / Delivery System						
	Composite	Tablet/ capsule	Powder/ Granule	Cream/ Paste	Viscous liquid	Dilute liquid	Aerosol
Wrapping							
Carton box	V	V	V				
Paper/Plastic wrap	V	V					
Aluminum foil	V	V					
Bag (Paper/plastic)							
Resealable bag		V	V				
Scaled bag / sachet		V	V	V	V		
Bottle (Glass/plastic)							
Screw cap		V	V	V	V	V	
Flip cap					V	V	
Slit orifice					V	V	
Pump top					V	V	
Tube (Metal/Plastic)							
Collapsible Tube				V	V		
Squeezable tube					V	V	
Can (Metal)							
Spray can							V

Factors determining product performance



Typical Market Trends to be Considered in Consumer Product Development

Consumer Wants and Needs

- The product should last longer and / or cost less
- Products performing complementary functions should be combined in one product
- The use of a personal care product should be a pleasurable experience
- The product should be smaller in size, easy to carry when traveling

Product Safety

- The product should not contain toxic solvent or allergenic materials
- The product should not contain dangerous chemical for little children
- The product should contain more natural ingredients

Legal and Environmental Issues

- It is preferable that the product is biodegradable
 - Refillable container should be used to reduce waste
-

Typical Quality Factors Expected from Chemical-Based Consumer Product

<i>Class of product</i>	<i>Quality Factor</i>
Cosmetic and personal care	Protection effect Cleaning power Ease of spread Odor Shelf life
Pharmaceutical and health care	Bioactivity Dissolution or disintegration time Active ingredient release time Ease of application
Household and office supplies	Cleaning power Hiding power Mechanical strength

Performance Indices for Typical Chemical-Based Consumer Product Quality Factors

Quality Factor	Product Form / Delivery System							Performance Index
	<i>Composite</i>	<i>Tablet/ capsule</i>	<i>Powder/ Granule</i>	<i>Cream/ Paste</i>	<i>Viscous liquid</i>	<i>Dilute liquid</i>	<i>Aerosol</i>	
<u>Sensorial</u>								
Visual appearance: transparent opaque, pearlescent, color	V	V	V	V	V	V	V	Arbitrary indices based on panelist evaluation
Smell: fragrant, odorless, stinky	V	V	V	V	V	V	V	
Taste: sweet, sour, bitter	V	V	V	V	V	V		
Sense upon application: smooth, oily, sticky				V	V	V		
<u>Physicochemical</u>								
Product stability(resistance against creaming)				V	V	V	V	Shelf life
Ability to change phase upon application	V	V	V	V	V			Melting point, glass transition temperature
Hygroscopicity	V	V	V	V	V	V		Moisture absorption rate
Ease of dispersion in a liquid								Wetting time
Ability to dissolve in a liquid	V	V	V					Dissolution time
Rate at which an active ingredient is released	V	V	V	V	V	V		Release time
<u>Mechanical</u>								
Resistance to failure	V	V	V					Tensile strength
Resistance to indentation (hardness)	V	V	V					Hardness numbers
Ease of failure by fracture (toughness)	V	V	V					Fracture energy
Elasticity	V	V	V					Young's modulus
Ease of flow			V					Flow number
<u>Rheological</u>								
Ease of spreading when rubbed onto a surface, applied by brush, or shaken				V	V			Viscosity at application shear rate
Ability to flow under gravity				V	V			Yield value
Ability applied on a surface when applied on a surface				V	V			Minimum thickness at which even coating is observed

Table 1. Active Ingredients of Lotions

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

Table 2. Typical Active Ingredients

Humectants	Occlusives	Emollients	Exfoliants
Glycerin (glycerol)	Mineral Oil	Sunflower Oil	Urea
Allantoin	Petrolatum	Almond Sweet Oil	Lactic Acid
PEG	Ceramide	Macadamia Nut Oil	Malic acid
Sodium-2-pyrrolidone carboxylate (PCA)	Beeswax NF	Hazelnut, Oil	
Propylene glycol	Dimethicone	Coconut Oil (76%)	
Urea	Cholesterol	Aloe Vera Oil	
Lactic Acid	Lanolin	Grapeseed Oil	
		Acrylates/c10-30 Alkyl Acrylate Crosspolymer	
		Isopropyl Palmitate	
		Decyl Oleate	
		Palm Oil	
		Castor Oil	

Table 3. Inactive Ingredients of Lotions

Class	Function
Solvent	Contains and Disperses Ingredients
Thickeners	Increase viscosity
Preservatives	Prevent contamination by microbial organisms
Buffers	Adjust pH of moisturizer
Emulsifiers	Helps Mix Aqueous and Oil Phases
SC Lipids	Lipids naturally found in stratum corneum, help barrier recovery
Color	Usually white
Fragrance	Provide desirable scent

Table 5. Concentration Bounds

Type of Ingredient	Min Concentration	Max Concentration
Solvent	65.00%	75.00%
SC-Lipid	0.00%	35.00%
Emulsifiers	1.00%	20.00%
Humectants	0.05%	15.00%
Emollients	0.05%	15.00%
Preservatives	0.10%	10.00%
Fragrance	0.00%	0.25%
Occlusive	0.10%	10.00%
Thickener	0.10%	2.00%
Buffer	0.00%	2.00%
Exfoliants	0.10%	1.00%

Table 13. Composition of Original and Optimized Formulation of Our Lotion

Ingredient	Function	Reference Formulation	Optimized Formulation
Deionized Water	Solvent	74.50%	65.00%
glycerin (glycerol)	Humectant	5.00%	0.00%
Sodium PCA (50%)	Humectant	3.00%	5.00%
Mineral Oil	Occlusive	3.00%	3.04%
Isopropyl Myristate	Emollient	2.00%	0.00%
Hydrogenated Polyisobutene (polysynlane)	Emollient	4.00%	6.65%
Xanthan Gum	Thickner	0.50%	2.00%
Cetyl Alcohol	Emulsifier	2.00%	6.90%
Sorbitan Palmitate	Emulsifier	1.20%	0.00%
Polysorbate 40	Emulsifier	3.80%	10.53%
Titanium Dioxide	Cosmetic Pigment	0.00%	0.88%
Citric Acid	pH adjuster	q.s	q.s
Other components	Preservative/dye/fragrance	q.s.	q.s
Total Sum	–	99.00%	100.00%
Consumer Preference	–	78.7%	80.3%

Examples of Typical Quality Factors for Creams and Pastes

Functional Quality Factors

- Protect parts of the body
 - Cleans parts of the body
 - Provides a protective or decorative coating
 - Causes adhesion to a surface
 - Delivers an active pharmaceutical ingredient (API)
-

Rheological Quality Factors

- Can be poured easily
 - Spreads easily when rubbed on the skin
 - Does not flow readily under gravity but easy to stir
 - Should give a uniform coating when applied to a surface
 - Should not flow by itself, but can be squeezed out of the container
-

Physical Quality Factors

- Must be stable for a certain period of skin
 - Melts at a certain temperature
 - Must release an ingredient at a controlled rate
-

Sensorial Quality Factors

- Feel smooth
 - Does not feel oily
 - Appears transparent, opaque, or pearlescent
-

감각적 품질요인을 결정하는 규칙

- 얇게 제공되는 높은 점성의 제품은 thixotropic (문지르면 점성이 감소하다가 멈추면 원래대로 서서히 되돌아가는 성질) 특성을 가지는 것이 좋다.
- 제품이 정지상태에서는 두껍고, 문지르면 쉽게 퍼져야 한다면 pseudoplastic(문지르는 속도가 증가할수록 점도가 감소) 특성을 가지는 것이 좋다.
- 상분리를 막고 제품의 안정성을 증가시키기 위해서는 고점도 제품이나 semi-solid 가 좋다.
- 제품이 중력에 의해 흘러내리지 않으려면, 적어도 20 Pa 까지 견디도록 한다.
- 로션(액체같은 크림)은 최대점도 120-500 Pa.s, 고체같은 크림은 최대점도 1350-3500 Pa.s 로 조정하는 것이 인지도를 높인다.
- 피부에 적용되는 제품에 대해서는 적용되는 문지르는 속도에서 점도가 0.025 Pa.s 되도록 조정하는 것이 인지도를 높인다.

Typical shear rates of creams and pastes

Action	Shear rate (s^{-1})
Suspending pigment or Active ingredients	0.001–0.1
Pouring from a bottle	50–100
Extrusion from a bottle or tube	10–1000
Topical applications of lotions/creams	100–10000
Application of lipstick	2000–10000
Application of brush	5000–10000
Roller mill	1000–10000
Forcing through homogenizing valve	1000–100000
Colloid mill	100000–1000000

Examples of Typical Ingredients used in Creams and Pastes

Desired Function	Ingredients	Typical Raw Materials	Typical Amount
Control of product humidity	Humectant	Glycerol , Propylene glycerol Sorbitol	Up to 20%
Emulsion stabilization	Emulsifier	Sodium lauryl sulfate , Parabens Formaldehyde	0.1 -3%
Occlusivity / protection effect	Opacifier	Titanium dioxide, Styrene / acrylate copolymers	Up to 10%
Film formation / ease of spread	Thickener	Beeswax , Xanthan gum GMS (glycerol monostearate)	0.1 -2%
Formation of cohesive structure	Binder	Precipitated silica Carboxymethyl cellulose , Starch	Up to 15%
Dissolution of ingredients	Solvent	Purified water , Mineral oil	20 -85%
Regulation of Hp	Buffer	citric acid , sodium hydroxide Amino acid	q.s.
Stability against microorganisms	Preservative	Sorbic acid , Methyl paraben Phenoxy ethanol	q.s.
Color	pigment	Titanium dioxide (white) B -carotene (yellow) , Iron oxides	q.s.
Odor	Perfume	Essential oils Synthetic aromatics	q.s.
Taste	Flavor	Salt , Aspartame (sweetener) Cocoa powder	q.s.

성분의 선택 규칙

- 가능한한 다기능 성분을 선택한다.
- 가능한한 부패하지 않는 성분을 선택한다.
- 품질이 색깔에 의해 영향을 받는 제품에는 산화나 환원제를 피한다.
- 에멀전 제품에 대해서 thixotropic 특성이 요구되면 약한 네트워크 구조를 가진 hydrocolloid 농축제 (gum 또는 carboxymethyl cellulose)를 추가한다.
- Pseudoplastic 특성이 요구되면 W/O 유탁액에 왁스나 지방 알콜 같은 유동학적 첨가제를 추가한다.

제품 공급시스템의 선택규칙

- 피부에 적용될 때 스늘한(따뜻한) 느낌을 주기 위하여 O/W (W/O) 유탁액을 선택한다.
- 제품에 느낌이 없거나 기름기 있는 맛이 나지 않아야 하면 O/W 유탁액을 사용한다.
- 제품이 땀이나 세탁에 저항성을 가져야 하면 W/O 유탁액을 사용한다.
- 바람직한 내부 상 부피 비가 정해진 유동학적 성질을 내지 못하면 이중 유탁액의 사용을 고려한다.
- 약처럼 주성분이 장시간 공급되어야 하면 이중 유탁액의 사용을 고려한다.
- 둘다 친수성 (소수성) 인 서로 잘 적응하지 못하는 물질을 포함하는 제품에 대해서는 W/O/W (O/W/O) 유탁액의 사용을 고려한다.

미세구조의 결정규칙

- 연속상과 분산상은 Newtonian 성질을 보이고 제품은 viscoelastic 성질을 가지려면 분산상의 부피분율이 매우 높은 에멀전을 만든다.
- 부드러운 질감의 고체같은 제품을 원하면 연속상 크리스탈이나 분산상 고체의 입자 크기를 $1\ \mu m$ 이하로 작게 만든다.
- 묽은(농축된) 유탁액과 현탁액의 점도는 연속상의 점도에 의해 주로 조절되고(상관이 없고), 입자의 크기나 상 부피 분율에는 상관이 없다(에 의해 조절된다).
- 쌍봉분포를 가지면 크림같은 경향이 강한 제품이 된다.

유화제를 선택하는 기준

- 유화제 또는 유화제의 조합은 원하는 형태의 유탁액을 형성해야 한다.
- 형성된 에멀전은 처리, 저장 및 응용중에 격을 여러가지 조건하에서 장시간 동안 안정적이어야 한다.
- 유화제는 혼합물에서 부차적인 반응이 일어나지 않도록 다른 성분들과 잘 어울려야 한다.
- 유화제는 고객의 건강이나 환경에 독성을 끼치지 않아야 한다.
- 유화제의 비용은 가능한 적어야 한다.

Selected Unit Operations for Mixing and Structure Formation Step in Chemical-Based Consumer Product

<i>Processing Step/Criterion</i>	<i>Unit operation</i>	<i>Examples of Equipment</i>
<i>Mixing</i>		
<i>Ingredients to be Mixed</i>		
Soluble liquids	Mixing	Agitated vessel, in-line mixer
Liquid and soluble solids	Dissolution	Agitated vessel
Liquid and insoluble solid	Dispersion	Agitated vessel, planetary mixer, mixer-kneader
Two immiscible liquids	Emulsification	Agitated vessel
Two solid phases	Melt mixing	Agitated vessel, high-speed mixer
	Solids	V-shaped mixer, ribbon blender
	Powder coating	Coating machine
<i>Structure Formation</i>		
<i>Product delivery system</i>		
Composite	Molding	Extruder
Tablets	Tableting	Tableting machine
Capsules	Filling	Encapsulation machine
Powders/granules	Size enlargement	Pan granulator, roller compactor
	Size reduction	Jaw crusher, roller crusher, cutter, fluid jet mill Fluid jet mill
	Spray drying	Spray drier
Creams, emulsions	Homogenization	Pressure homogenizer, ultrasonic homogenizer
Pastes, suspensions	Wet milling	Ball mill, roller mill, pebble mill

혼합장치를 선택하는 규칙

- 혼합되어지는 고체중의 하나가 상대적으로 낮은 용융점과 유리전이온도 (Glass Transition Temperature) (50-80 'C)를 가지면 용융 혼합을 선택한다.
- 적절한 크기를 가진 미립자 고체를 혼합하기 위하여 고체배합을 선택한다.
- 큰입자의 표면에 아주작은 입자를 바르려면 분말피복(powder coating)을 선택한다.
- 혼합물이 고농도의 계면활성제를 포함하면, 진공 또는 저교반속도의 장치를 선택한다.

구조형성 단위조작 선택규칙

- 만약 원하는 제품입자크기가 혼합후 입자크기 보다 크다면(작다면) 크기확대(크기축소)를 선택한다.
- 혼합후보다 작은 입자성분을 가진 Tablet(Capsule) 을 생산하려면 크기축소후 Tableting(Capsule 삽입)을 한다.
- 만약 원하는 제품의 형태가 (알갱이)분말이고 혼합단계의 출력이 액체이면 분무건조 다음에 크기확대를 한다.

Selected Equipment for Emulsification in Manufacturing Creams and Pastes

Equipment	Breakup Mechanism	Batch/Cont.	Design and Operating Variables
<i><u>Pre-emulsification</u></i>			
Pipeline mixer	Turbulent shear	B,C	Pumping velocity
Agitated vessel	Turbulent shear	B	Agitation speed Vessel geometry
Ribbon mixer	Turbulent shear	C	Agitation speed Impeller geometry
Planetary mixer	Turbulent shear	C	Agitation speed Impeller geometry
<i><u>Homogenization</u></i>			
Colloid mill	Laminar/turbulent shear	B,C	Rotational speed Gap width
Tooth disc disperser	Turbulent shear	B,C	Rotational speed Gap width
Pressure homogenizer	Turbulent shear/cavitation	B,C	Homogenizing pressure
Ultrasonic homogenizer	Cavitation	C	Ultrasonic wave frequency And intensity

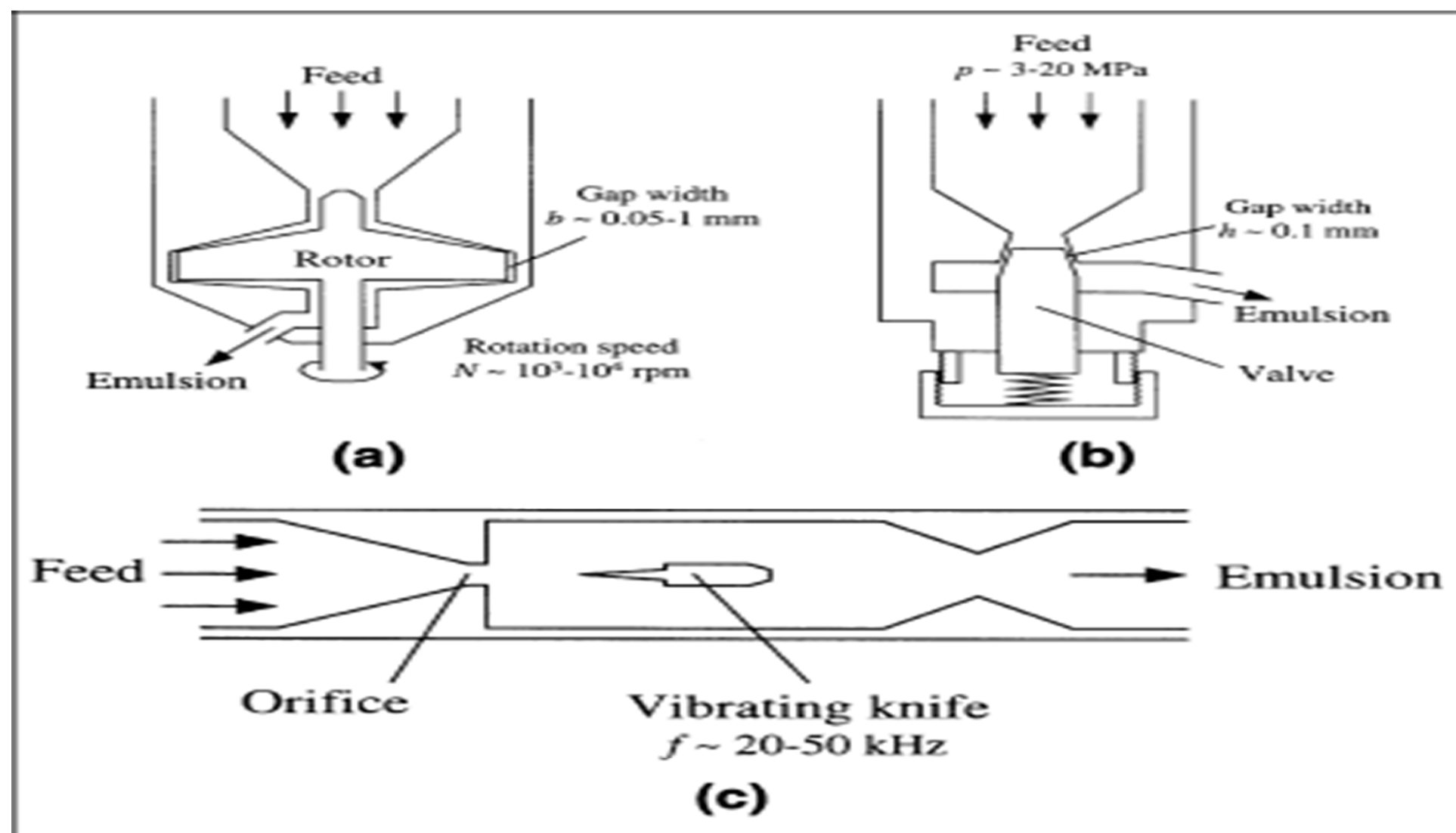


Figure 3. Selected equipment for homogenization in the manufacture of creams and pastes:

(a) Colloid mill; (b) pressure homogenizer; (c) ultrasonic homogenizer.

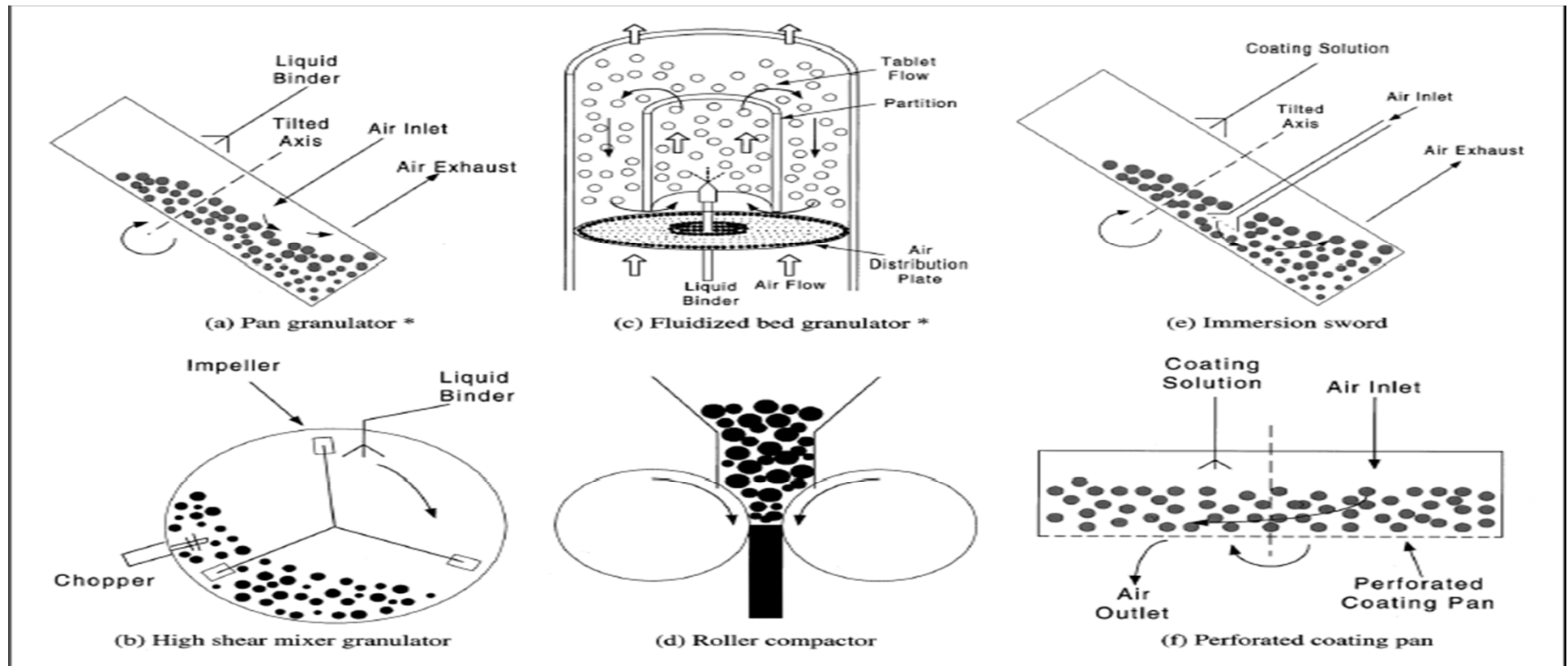
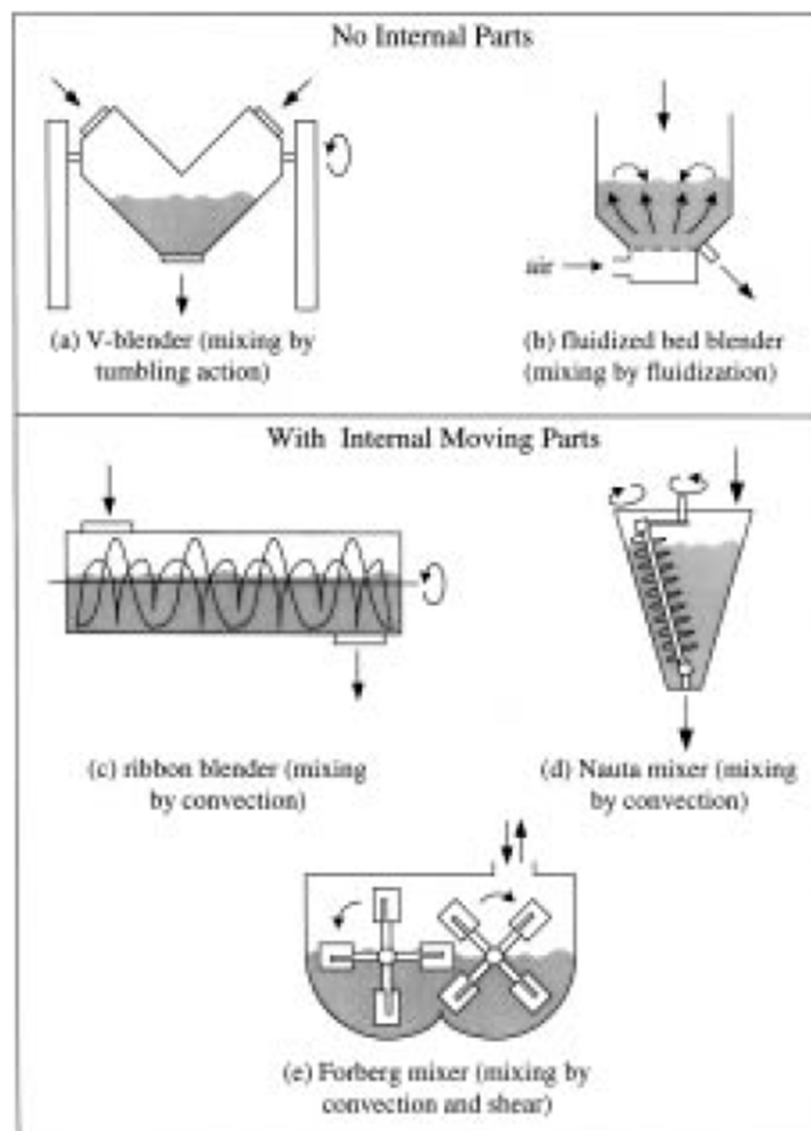
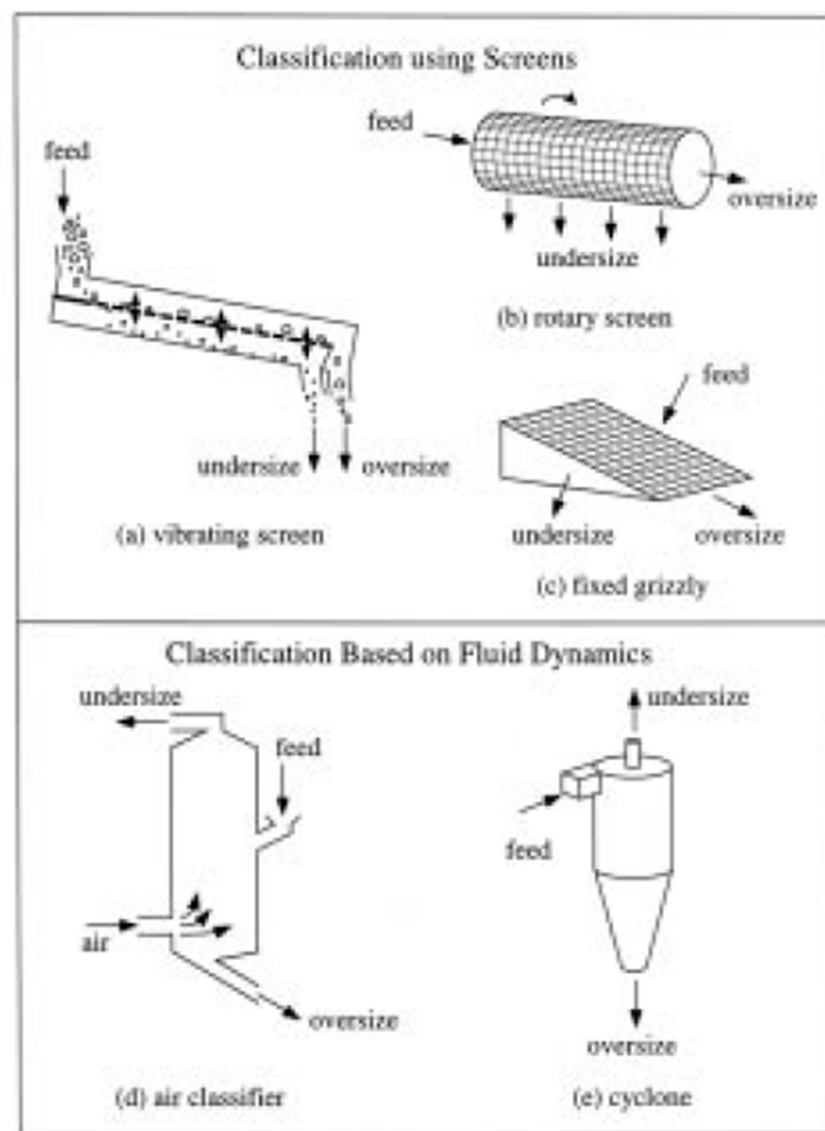


Figure 3. Granulation (a–d), and coating (e,f) equipment.

Pan granulator and fluidized-bed granulator can be used for coating with the liquid binder replaced by coating solution.

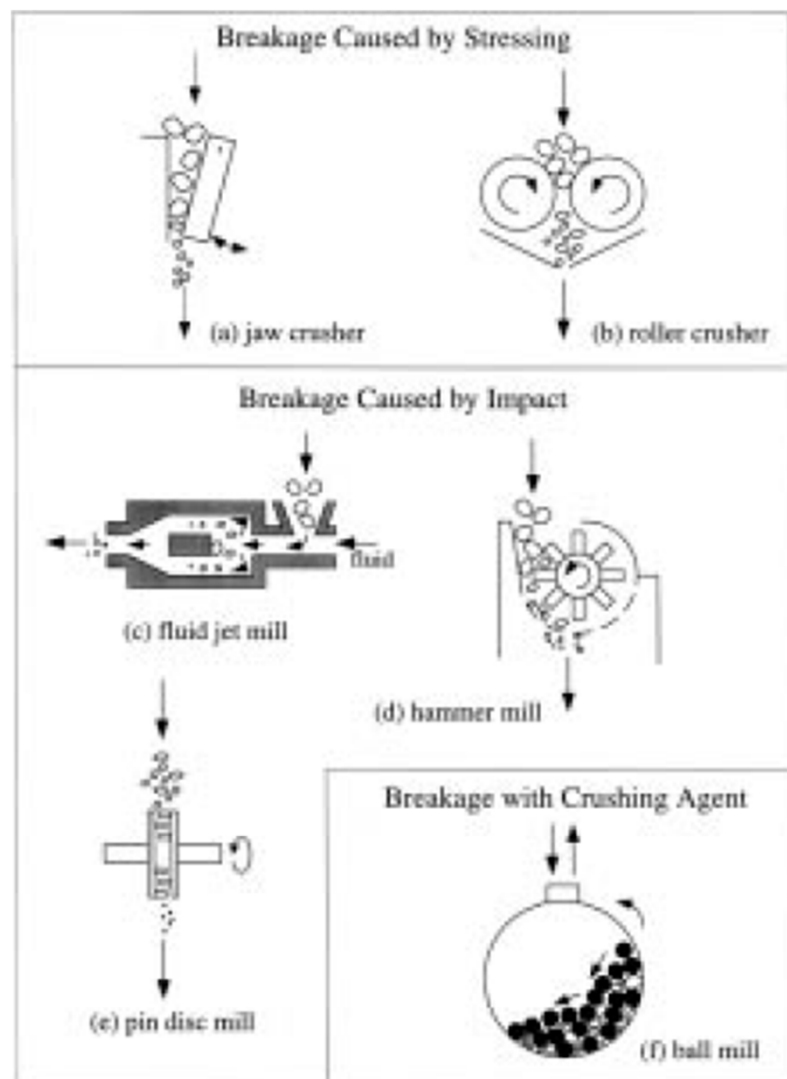


(a)

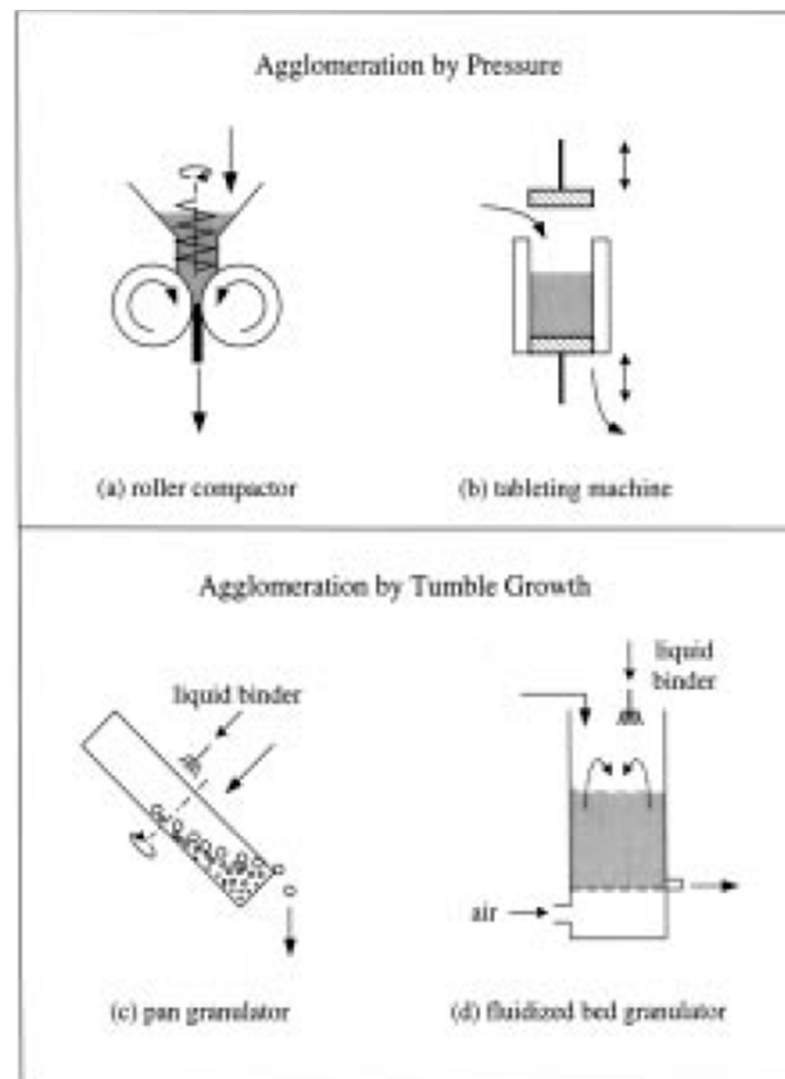


(b)

Figure 2. Selected types of (a) blenders and (b) size classification equipment (*continued*).



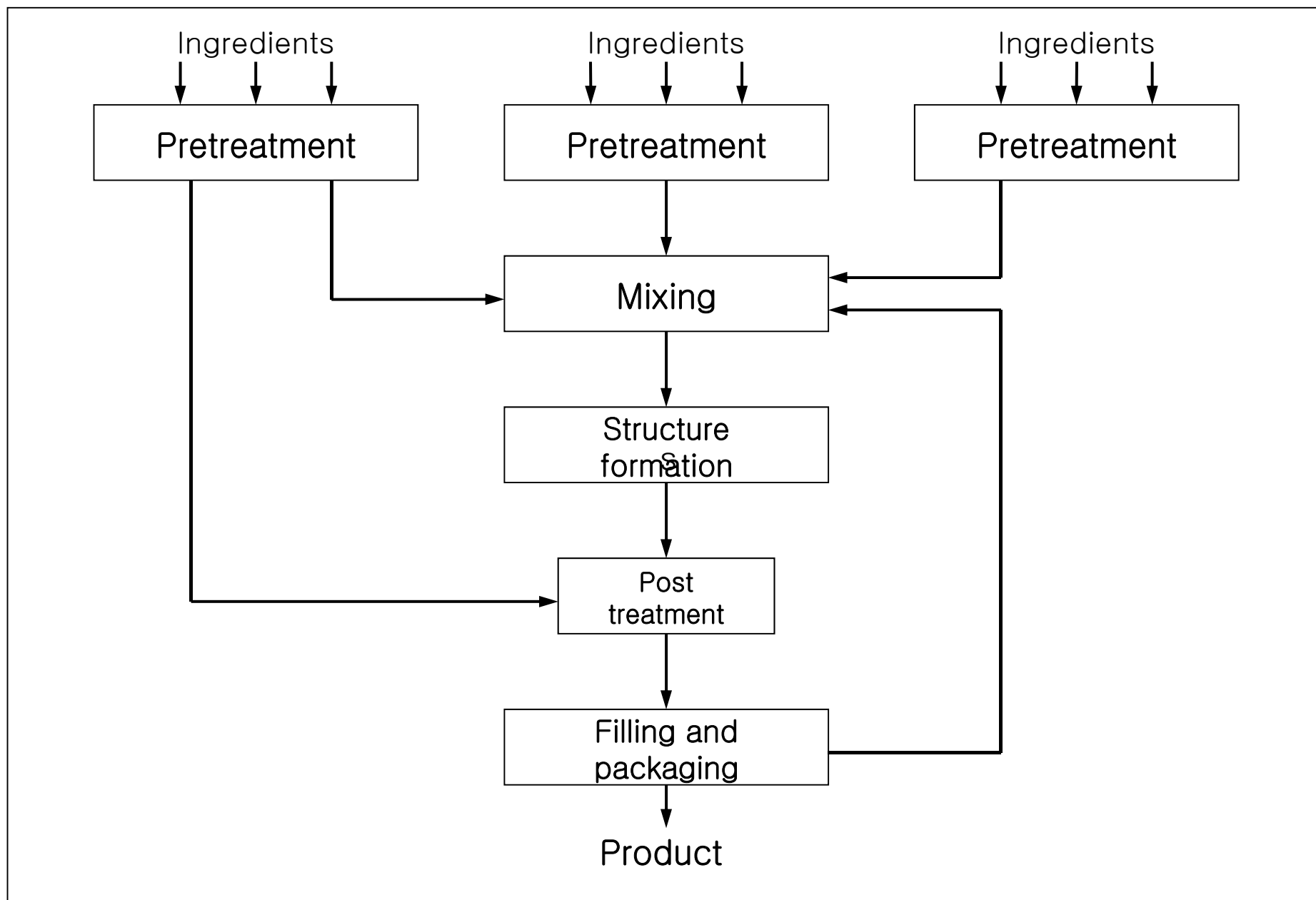
(c)



(d)

Figure 2. Selected types of (c) size reduction equipment and (d) size enlargement equipment.

Generic flowsheet of chemical-based consumer product manufacturing processes



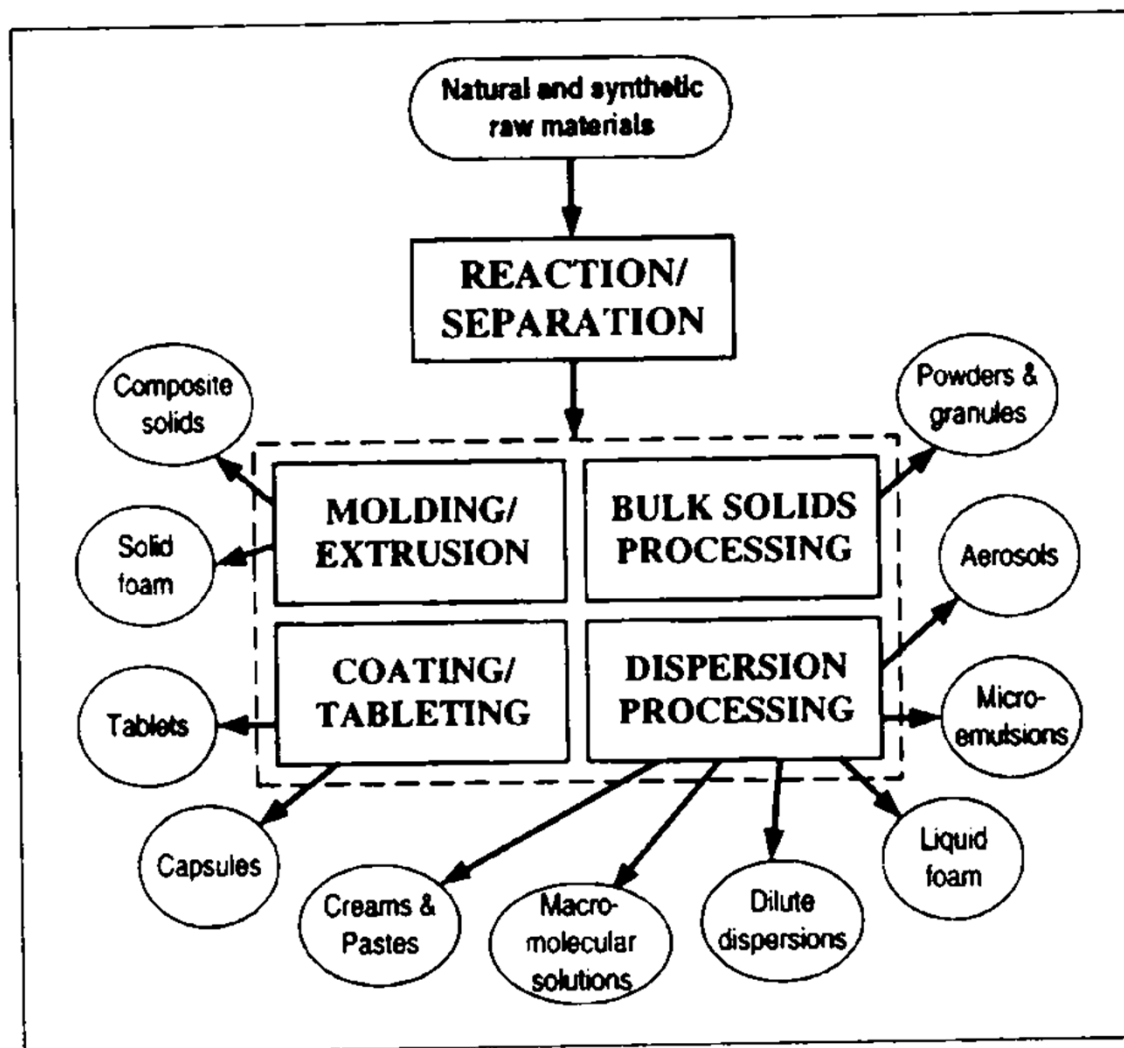


Figure 3. Unit operations in chemical-based consumer product manufacture.

공정합성 규칙

- 만약 물이나 기름에 녹는 성분이 포함되면 잘 어울리는 성분들을 결합하기 위하여 사전혼합 단계를 거친다.
- 물에 녹지 않는 성분의 입자크기를 원하는 정도로 줄이기 위하여 입도감소장치를 이용한다.
- 방울크기 100 μm 이하의 유탁액을 만들기 위해서는 균질화 장치를 이용한다.
- 점도를 줄여서 혼합이 더 잘되도록 하기 위하여 처리중에 혼합물을 가열한다.
- 상반전이 문제가 되면 상조합이나 계면활성제 위치의 순서 변환을 고려한다.
- 가능한 방울의 크기를 줄이는 것이 바람직하지만 최종제품은 여전히 점성을 가져야 한다면 냉각전에 균질화를 실행한다.
- 최종제품의 점성을 영원히 줄이고 싶으면 냉각후에 균질화를 실행한다.
- 만약 분산상의 부피분율이 30 % 보다 작으면, 저에너지 유화가술 (분산상을 연속상의 일부(C_1)에 혼합하고 유화한 뒤에 나머지 연속상(C_2)을 추가함) 사용을 고려한다.
- 만약 농축제가 포함되면 C_2 상에 분산되어야 한다.
- 결정화 전의 멸균장치 처럼 후처리 장치는 단지 액체에만 적용된다.

장치선택 규칙

- 에너지 소모가 증가하는 순서대로 장치를 선택한다.
- 사전 유탁액을 형성하기 위하여 분리된 상을 혼합하는 교반용기나 무동작 혼합기를 사용한다.
- 고체부피분율이 높은 현탁액을 형성하기 위하여는 Ribbon 혼합기나 Planetary 혼합기를 사용한다.
- 유탁액이 가열 또는 냉각에 민감하면, scraper 가 부착된 교반용기 같은 불감 또는 정체영역이 없는 장치를 선택한다.
- 분산상과 연속상의 점도비가 4 보다 크면, colloid mill 같은 전단흐름에서 유화파괴가 일어나는 유화장치의 사용을 금한다.
- 연속상의 점도가 0.02 Pa.s 이면 colloid mill 의 사용을 금한다.

원료 주입 규칙

- 분산상은 연속상에 천천히 추가되어야 한다.
- 혼합단계에서 간섭을 받거나 처리과정중 파괴되는 성분은 맨 나중에 추가된다.
- 만약 0.26 보다 낮은 분산상 부피분율과 작은 방울크기를 가진 유탁액을 만들려면 상반전의 사용을 고려한다.
- 만약 계면활성제가 한상에서 다른 상으로 이동하는것이 제품 점도에 바람직하지 못한 변화를 일으키면, 계면활성제를 상사이에 그들의 용해도에 따라서 분배하는 것을 고려한다.

장치운전조건의 선택규칙

- 유탁액의 점도가 높고 pseudoplastic 이면, 용기내의 좀더 균일한 전단속도 분포를 위하여 날개바퀴 대 용기지름의 비율이 높은 프로펠러를 선호한다.
- 제품점도의 비가역적인 감소를 초래한다면 장시간 교반해선 안된다.
- 공기가 제품속에 끼어드는 것을 최소화하기 위하여 날개바퀴가 완전히 잠기지 않은 채로 혼합작업을 하지 않는다.
- 연속상의 결정화에서 크고 균일한 결정을 얻기 위하여 서서히 냉각한다.
- 처리과정에서 제품이 오염되지 않아야 한다면, 장치는 미리 멸균되어야 하고 작업은 무균상태에서 수행되어야 한다.

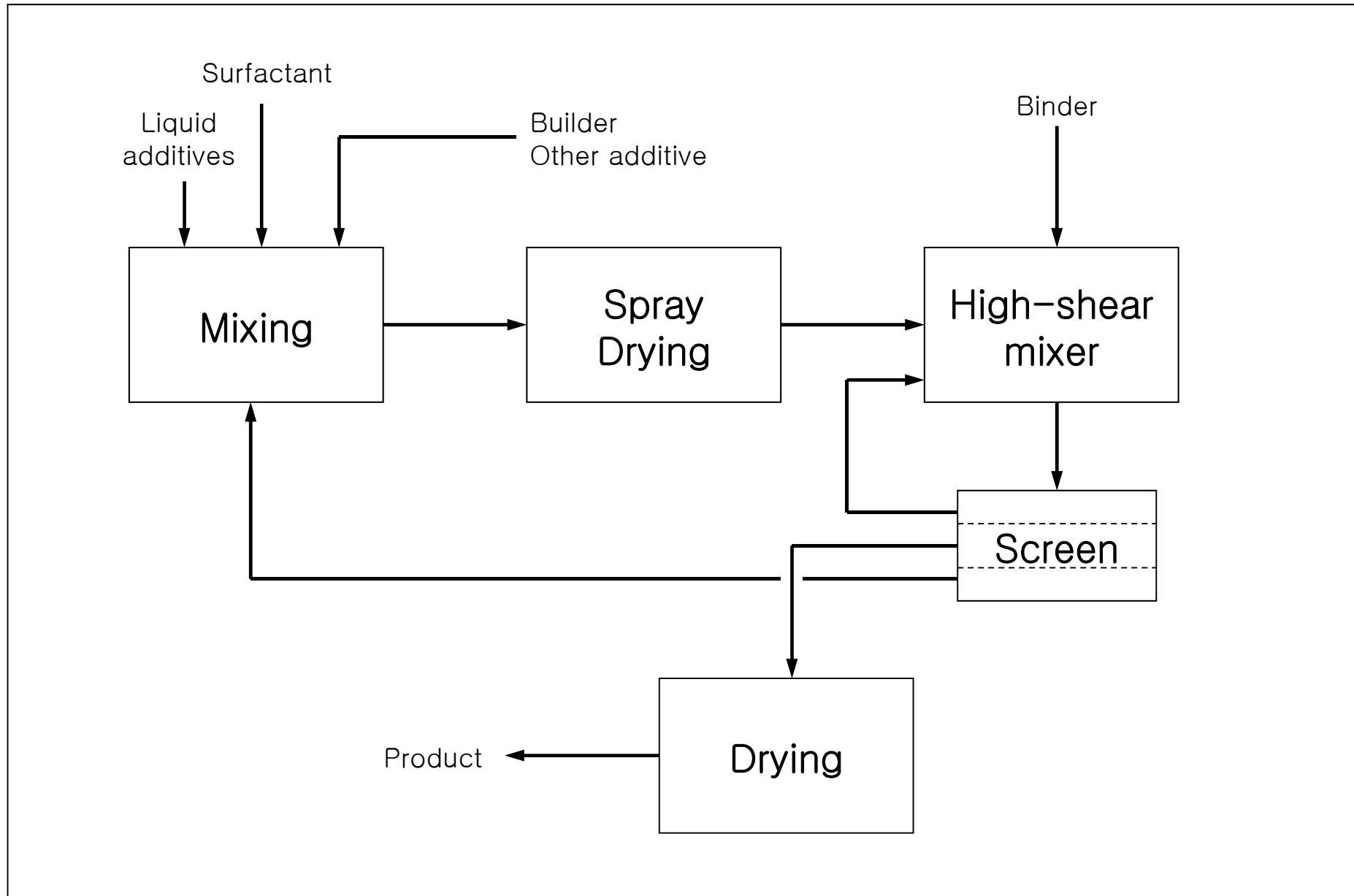
Customer Needs for Powdered Laundry Detergent

- Easier to carry
- Less space to store
- No agglomeration due to moisture
- Less water(Lower forming, Stronger soil suspension)
- Lower temperature(40C)
- Containing bleach
- Economical

Powdered Detergent Ingredients

<i>Desired Function</i>	<i>Ingredient Chosen</i>	<i>Examples</i>
Removing water-insoluble grease and soils	Biodegradable surfactant (Active ingredient)	
Bleaching	Inactivated bleach	Sodium perborate
Bleach activation	Bleach activator	Alkanoyloxybenzene sulfonate, N-acyl caprolactam
pH control(10)	Buffer	Sodium carbonate
Enhancement of washed fabric appearance	Whitening agent	Bistriazinyl derivatives of diaminostilbene disulfonic acid
Removal of unpleasant odors	Fragrance	Perfumes
Removal of protein, carbohydrate carbohydrate, and fat stains	Enzyme	Proteases, amylases, lipases, cellulases
Control of water hardness	Builder	Zeolite A, soda ash (Na ₂ CO ₃), Sodium polycarboxylate, δ-disilicate
Providing alkalinity		
Preventing redeposition		
Preventing corrosion		
Improving powder flow		
Filling	Filler	Sodium sulfate

Manufacturing powder detergent



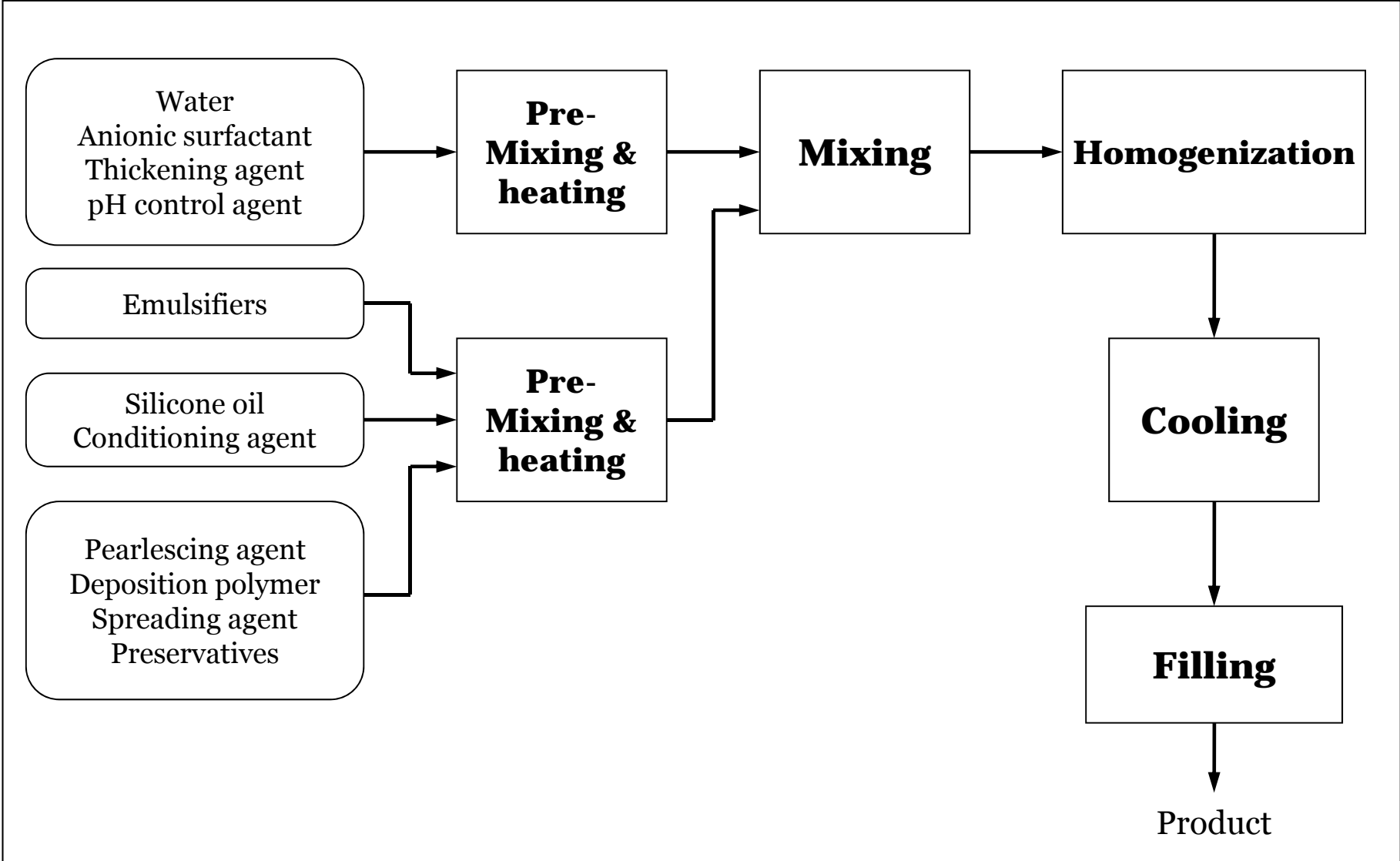
Customer Needs for Shampoo and Conditioner in One

- Clean the hair (anti-dandruff)
- Desirable combing or brushing(Conditioning)
- No buildup of any ingredient
- No splashing (High viscosity(500Pa.s) at low shear rate)
- Easy spreading (Low viscosity(2Pa.s) at high shear rate(10000/s))
- Stable while in storage

Shampoo and Conditioner Supporting Ingredients

<i>Desired Function</i>	<i>Ingredient Chosen</i>	<i>Examples</i>
Aiding the deposition of conditioning agent	Deposition polymer	Quaternary ammonium polymers
Improving spreadability of conditioning agent	Spreading agent	Quaternary ammonium compounds
Dissolving the conditioning agent	Organic solvent	Silicone oil
Shampoo base	Aqueous solvent	Water
Viscosity control	Thickening agent	Carboxyvinyl polymers, cellulose ethers, guar gum, starch
pH control	Acid of base	Sodium hydroxide, citric acid
Improving product appearance	Pearlescent agent	Ethylene glycol distearate
Enhance attractiveness	Perfume, pigment	Essential oils

Manufacturing Shampoo and Conditioner



Customer Needs for Toothpaste

- Remove stain → Abrasive (Solid) → Suspension
- Clean teeth → Surfactant
- Prevent dental caries → Fluoride component
- Retain moisture → Humectant
- Taste → Flavor
- Should not flow by itself (20Pa), squeezed easily out of tube, low viscosity when brushed → Shear-thinning product (Thickener)
- Soft and smooth texture → Small particle
- Color, Preservatives

Input Information for Toothpaste

Composition

Solid phase	
Silica (abrasive)	14 %
Carboxymethyl cellulose (thickener)	0.3%
Silica aerogel (thickener)	8.0%
Polyethylene glycol (thickener)	5.0%
Liquid/aqueous phase	
Sodium monofluorophosphate (active agent)	0.8%
Sorbitol (humectant)	32.7%
Glycerin (humectant)	20.1%
Sodium benzoate (preservative)	0.1%
Dye solution (color)	0.5%
Water (solvent)	14.8 %
Others	
Flavors	2.2%
Surfactant	1.5%

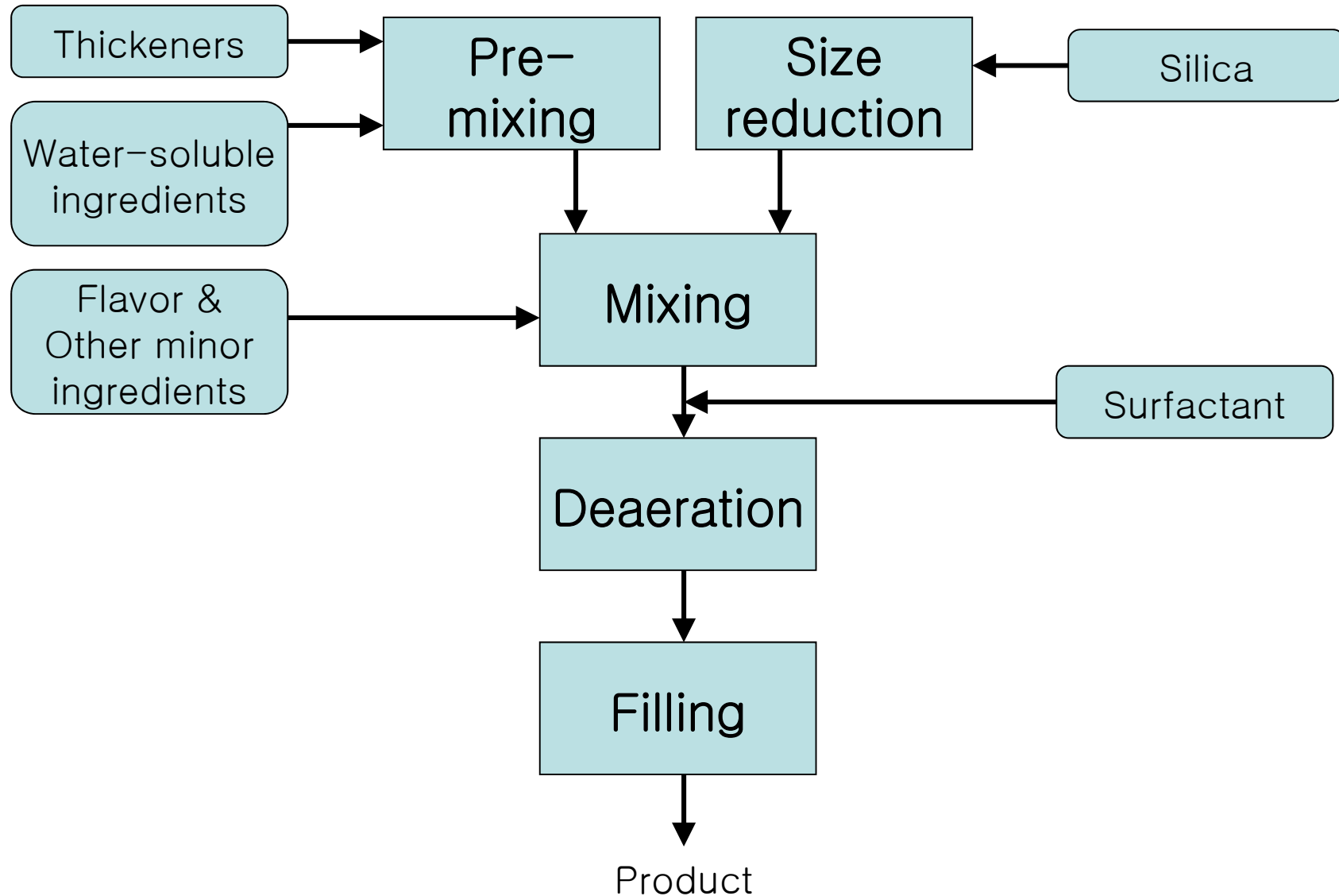
Aqueous Phase

Viscosity, μ_c	0.14 Pa · s
Density, ρ_c	1,100 kg/m ³

Solid Particles

Hamaker constant, A	$8.55 \times 10^{-20} \text{J}$
Dielectric constant, ϵ_r	48.65
Density, ρ_d	1,600 kg/m ³

Toothpaste Manufacture



Customer Needs for Hand Lotion

- Maintain the skin in a fully moisturized condition → Emollient
- Easily applicable and has to rub in quickly → Low viscosity when applied to the skin
- Flow when poured from the bottle but should not appear runny → High viscosity at low shear → Shear-thinning product (Thickener)
- Smooth and does not feel oily or greasy → O/W emulsion
- Maintain the humidity of the lotion → Humectant
- Attractive → Perfume, Preservatives

Input Information for Hand Lotion

Continuous Phase

Composition	
Purified water (solvent)	80–90%
Glycerol (humectant)	4–8%
Water-soluble polymers (thickener)	1.1%(variable) ← 0.025 Pa.s
Viscosity	
K	9.83xt ^{1.91} Pa.s
n	0.0598x ^{-0.97}
E _a	15,800J/mol
Density,	1,019 kg/m ³

Dispersed Phase

Composition	
Mineral oil (Solvent)	30%
Stearic acid (Solvent)	12%
Cetyl alcohol (emollient)	12%
Isopropyl palmitate (emollient)	23%
Petrolatum (emollient)	23%
Viscosity,	
K at 25 °C	6.54*10 ⁻² Pa.s
n	1.0
E _a	17,200J/mol
Density, ρ _d	985kg/m ³

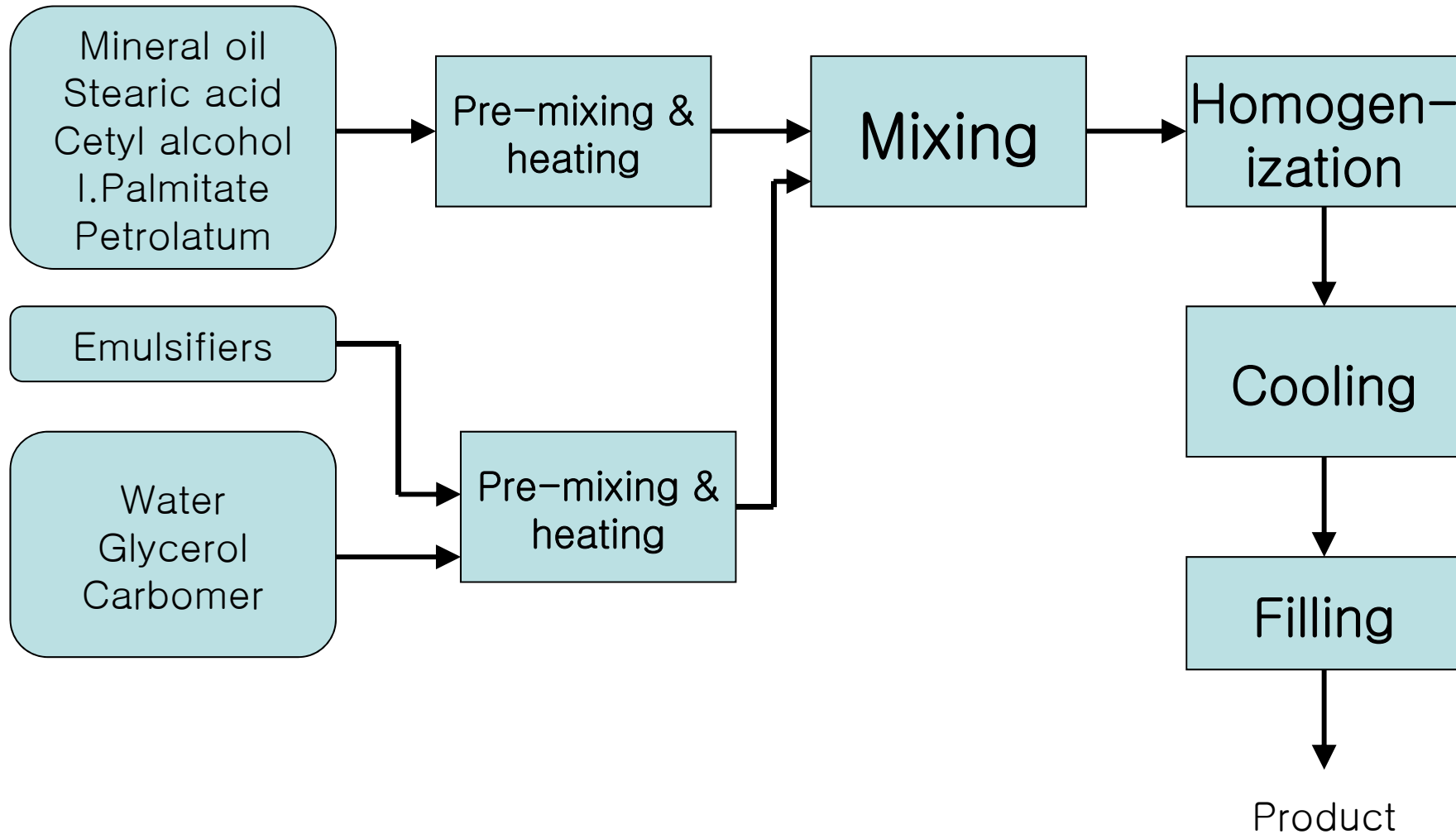
Emulsion

Surfactants	
Glyceryl monostearate	80%
PEG-40 stearate	20%
Interfacial tension, σ	2*10 ⁻² Pa.s
Excess surface concentration, Γ	1.0*10 ⁻⁶ kg/m ²
Surfactants critical micelle concentration (CMC)	30kg/m ³

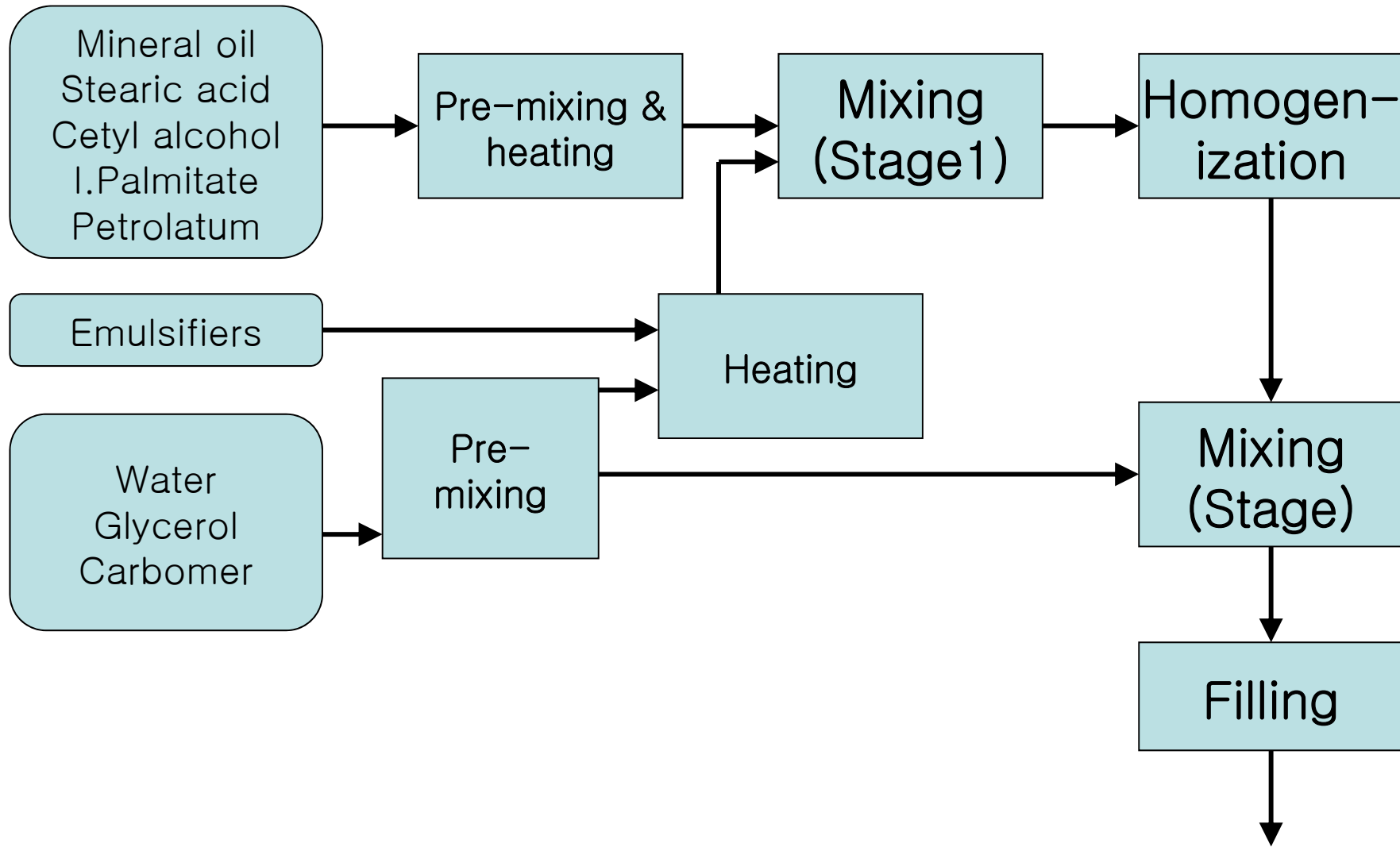
Equipment

Colloid mill rotor radius	5cm
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Process Design for Hand Lotion



(a) Standard



(b) Low Energy

Product

Design Factors for Preservative Free Lotion

- Pump-top bottle with hydrophobic filter to sterilize entering air → Low viscosity (0.1~0.5Pa.s) during pumping (10/s)
- Good feeling when applied to the skin → 0.025 Pa.s at high shear rate 500/s
- Reduce water activity < 0.8 by humectant
- Acidic condition (pH < 4.5)
- Natural anti-bacterial ingredients
- Chelating agent to bind metal ions
- High surfactant concentration

Preservative-Free Lotion Ingredients

<i>Desired Function</i>	<i>Ingredient Chosen</i>	<i>Examples</i>
Moisturize skin	Emollient (Active)	Stearic acid, cetul alcohol, petrolatum
Control of lotion humidity	Humectant	Glycerol
Emulsion stabilization	Surfactant	Glyceryl monostearate, quaternary ammonium salts
Increasing viscosity and obtaining shear-thinning behavior	Thickener	Carbomer, propylene glycol
Providing additional attractiveness	Aroma chemicals	Essential oils
Reducing water activity	Salts	Aluminum chlorohydrate, cationic surfactants
pH control	Organic acid	Citric acid
Preventing deterioration of fragrance and color	Chelating agent	EDTA, citric acid