Low Clump Reconstitution of Powdered Infant Formula

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Why is low clump reconstitution important in the production of powdered infant formula?

Powdered formula is difficult to mix at the correct temperature and get the right amount of powder into the bottle while an infant is crying for food. The last thing a parent wants to deal with is formula that will not come out of the bottle because it hasn't dissolved properly.

Objective:

The purpose of this project is to design a highly efficient process to produce a powdered infant formula with excellent reconstitution properties.

Production:

Operating time – 8000 hr/yr

320 g/can

6hr cycle time

453,000 cans/yr

$7.17/can

Processing Steps:

Mixing: Distribute product uniformly.

Pasteurization: Destroy pathogens and enzymes.

Homogenization: Reduce diameter and size distribution of fat globules.

Evaporation: Decrease energy demand.

Spray Drying: Remove moisture.

Agglomeration: Improve rehydration properties.

Process Flow Diagram:

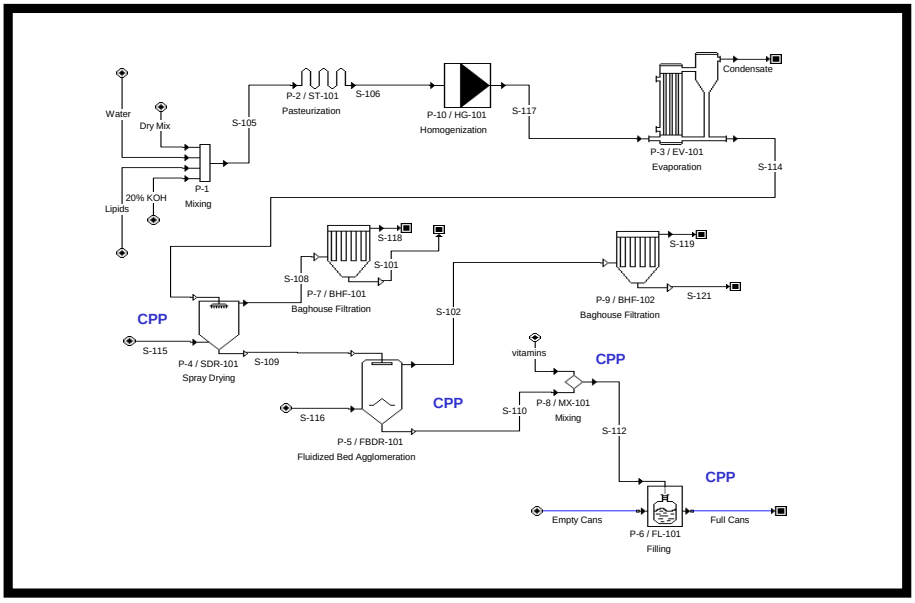


Plate and Frame Heat Exchanger/Pasteurizer

Sterilization T needed= 82.2 °C

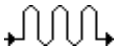
Preheat Outlet T = 38 °C

Final Exit T = 80 °C

Steam Rate = 2849 kcal/h

Area = 60 ft^2

Price = $11,000.00



P-2 / ST-101

Pasteurization

Energy Balance Information:

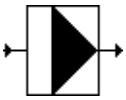
Cp = 3.85 kJ/kg ºC

T_{out} = 80 ºC

T_{in} = 25 ºC

Feed Stream: h= 212 kJ/kg

Homogenizer



P-10 / HG-101

Homogenization

Exit T = 62 °C

Chilled Water Inlet T = 5 °C

Chilled Water Outlet = 10 °C

Cooling rate = 1017.2 kcal/h

Pressure Drop = 206.8 bar

Price = $ 200,000

Double Effect Evaporator

Steam T (first effect) = 140 °C

Solution T (last effect) = 35 °C

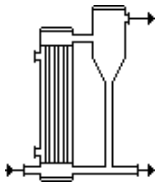
Steam Rate = 8054.7 kcal/h

Evaporator Economy
1.035 kg H_2O/kg Steam

Evaporator Capacity
13.932 kg H_2O/h

Area = 74 ft^2 , 20 ft^2

Price = $ 140,000 and 40,000



P-3 / EV-101

Evaporation

Energy Balance Information:

Cp = 4.50 kJ/kg ºC

Tout = 35 ºC

Tin = 80 ºC

Feed Stream: h= 589 , 344 kJ/kg

Spray Dryer

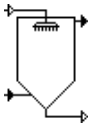
Initial Moisture % = 50.5

Final Moisture % = 3.3

Final Solids T = 70 °C

Steam Rate = 31.84 kcal/h

Price = $ 100,000



P-4 / SDR-101

Spray Drying

Energy Balance Information:

Cp = 1.71 kJ/kg oC

Tout = 70 oC

Tin = 35 oC

Feed Stream: h= 59.92 kJ/kg

Shear Mix Agglomerator

Initial Moisture % = 6.2

Final Moisture % = 3.3

Final Solids T = 70 °C

Evaporation Rate= 100 kg evap./ m^3h

Feed Composition During Processing

Ingredients	Concentration Initial (Mass Percent)	Concentration after Evaporator	Concentration after Spray Dryer	Concentration Final, after Agglomeration
Calcium Phosphate	0.17	0.24	0.45	0.45
Chorine Chloride	0.02	0.02	0.04	0.04
Fat	10.73	15.17	28.76	29.68
Potassium Chloride	0.05	0.07	0.13	0.13
L-carnitine	0.00	0.01	0.01	0.01
Lactose	11.28	15.95	30.23	31.20
Magnesium Phosphate	0.03	0.04	0.08	0.08
NFDM	6.25	8.83	16.73	17.27
Potassium Citrate	0.04	0.06	0.11	0.11
Potassium Hydroxide	0.00	0.01	0.01	0.01
Water	65.00	50.53	6.23	3.21
Whey	6.43	9.08	17.22	17.77
Total	100.01	100.01	100.00	99.96

DIRECT COSTS

Equipment:	2002
Bag Filter (10^3 scfm)	20,000
Bag Filter	20,000
Condenser(500 gpm)	10,400
Compressor(10 hp)	72,000
Agglomerator (Fluidized Bed)(10 ft/sec)	180,000
Spray Dryer(500 lb/hr)	400,000
Evaporator(74 ft^2)	140,000
Evaporator(20 ft^2)	40,000
Filler(55 cans/hr)	400,000
Heat Exchanger(60 ft^2)	11,000
Homogenizer	200,000
Mixer(5 hp)	4,800
Mixer	4,800
Pump(125 hp)	6,000
Pump	6,000
Pump	6,000
Pump	6,000
Pump	6,000
Pump	6,000
Storage Tank(200m^3)	20,000
Storage Tank	20,000
Storage Tank	20,000
Storage Tank	20,000
Storage Tank	20,000

EQUIPMENT TOTAL: $1,639,000

Cost Analysis

Installation (40% of Equipment)	655,600
Instrumentation and Controls (25% of Equipment)	409,750
Piping (31% of Equipment)	508,090
Electrical System (20% of Equipment)	327,800
Building (New) (47% of Equipment)	770,330
Yard Improvements (15% of Equipment)	245,850
Service Facilities (55% of Equipment)	901,450
Land (6% of Equipment)	98,340
TOTAL DIRECT COSTS:	**$5,556,210**
INDIRECT COSTS:	
Engineering and Supervision (30% of Equipment)	491,700
Construction Expenses (35% of Equipment)	573,650
Legal Expenses (4% of Equipment)	65,560
Contractor's Fee (20% of Equipment)	327,800
Contingency (40% of Equipment)	655,600
TOTAL INDIRECT COSTS:	**$2,114,310**
FIXED CAPITOL INVESTMENT:	**$7,670,520**
Working Capitol (75% of Equipment)	1,229,250
TOTAL CAPITOL INVESTMENT:	**$8,899,770**

Manufacturing Costs:	**$3,311,900**
Direct Production Costs	2,351,327
Raw Materials (30% of Total Product Cost)	1,170,000
Operating Labor (10% of Total Production Cost)	390,000
Direct Supervision & Clerical Labor (10% of Labor)	39,000
Utilities (10% of Total Product Costs)	390,000
Maintenance & Repairs (3% of FCI)	230,116
Operating supplies (10% of Maintenance)	23,012
Laboratory Charges (8% of Labor)	31,200
Patents & Royalties (2% of Total Product Cost)	78,000
Fixed Charges:	**$631,015**
Local Taxes (2% of Fixed Capitol Investment)	153,410
Insurance (3% of Fixed Capitol Investment)	230,116
Rent (8% of Land and Buildings)	69,494
Financing (interest) (2% of Total Capitol)	202,865
Plant Overhead (50% of Labor, Main., & Super.)	345,634
General Expenses:	**$605,867**
Administrative (15% of Labor, Main., & Super.)	98,867
Distribution & Marketing Costs (8% of TPC)	312,000
Research & Development (5% of TPC)	195,000
TOTAL PRODUCT COSTS:	**$3,900,000**

Selling Price = $18/can

Total Sales = $6,795,000

ROI = 41%

Gross Profit = $5,656,888

ANNUAL NET PROFIT: $3,676,977

Marketing Data

27 billion ounces/yr in United States
$2.9 billion in sales
Powdered Formula = 62% of market

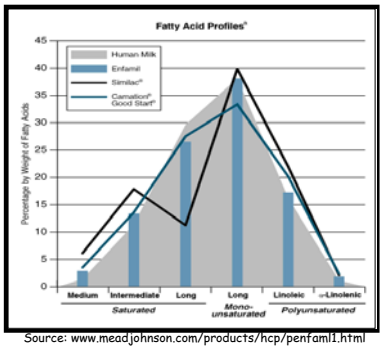
Powdered: $7.00 - $20.00 / 340g
Reconstituted: $ 1.40 - $ 3.15
67% less then Ready-to-Feed
82% less then Liquid Concentrate

Microbial Issues

Because of its low water activity, powdered infant formula has traditionally been a microbially safe product. It has been only recently that infections and even baby deaths have been linked to powdered infant formula and *Enterobacter sakazakii*. *E. sakazakii* is a problem in wet-processing environments where the bacteria can grow in standing water. The organism usually contaminates the formula after it has been made into powder, whether through exposure in the spray dryer or during agglomeration. There is no heat or sterilizing step once the liquid has been dried. It remains dormant through storage, but begins growth again when the powdered formula is reconstituted.

Within the last few years *E. sakazakii* can be blamed for millions of dollars in powdered infant formula recalls. *E. sakazakii* is a cause of neonatal meningitis, sepsis and necrotizing enterocolitis and can lead to death.

Other important organisms include: *Salmonella anatum* caused an infection in the UK in 1996. *S. bredeney* has been the source of two infections. One occurred in Australia in 1977 and the other in France in 1988. Another infection occurred in the UK in 1985 that was linked to *S. ealing*. *S. tennessee* and *S. virchow* were also sources of infections in 1993 and 1994. It was shown that none of these outbreaks occurred due to contamination during reconstitution, only from contaminated formula.



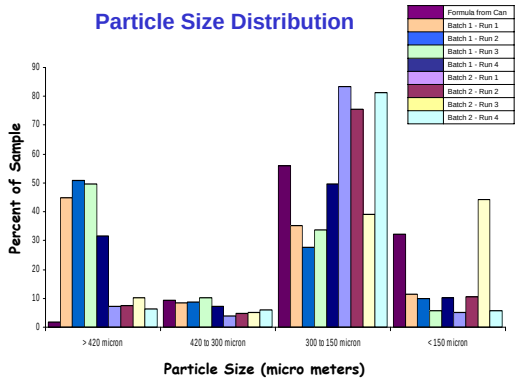
Source: www.meadjohnson.com/products/hcp/penfaml1.html

Wisconsin Center for Dairy Research Recipe:

According to the Wisconsin Center for Dairy Research in Madison, Wisconsin, basic powdered infant formula consists of 38.3% Lactose, 34% Nonfat Dry Milk, 27% Fat Blend, 0.5% Lecithin, and 0.2% Vitamins and minerals. Their recipe is as follows:

1) Calculate how much of each ingredient is necessary based on batch size.
2) Add the dry milk and lactose to water. The quantity of water should be enough to allow for a free flowing easily processed liquid.
3) Heat the solution to 140°F and mix in the remaining ingredients.
4) Heat the liquid to pasteurization temperature and homogenize in a two-stage process first at 2000 psi and secondly at 500 psi.
5) Spray dry, agglomerate, and package.

Particle Size Distribution



Plackett – Burman Experimental Design

N = 4 Model

2 batch sizes

Runs	A	B	C	(D)
1	+	-	-	+
2	+	+	-	+
3	+	+	+	-
4	-	+	+	-

Impeller Speed (rpm)		Agglomeration Time (sec)	
(+)	(-)	(+)	(-)
250	100	15	5
Mix Time (min)		Dummy	
(+)	(-)	(+)	(-)
3	1	---	---

Where:
A - Impeller Speed (rpm)
B - Agglomeration time (sec)
C - Mix Time (min)
(D) - Dummy Variable

Significant Variable were found to be:
Agglomeration Time
and
Batch Size

Experimental Data

Batch 1 = 100 gram samples

Runs	Sensory Test Rating 1 = no clumps 9 = extremely clumpy
1	7.4
2	6.9
3	6.2
4	6.1

Batch 2 = 200 gram samples

Runs	Sensory Test Rating 1 = no clumps 9 = extremely clumpy
1	5.6
2	3.4
3	1.8
4	4.0

Batch 2 had less clumping than Batch 1

Particle Size (micro meters)	Sensory Test Rating 1 = no clumps 9 = extremely clumpy
Range: 450 to < 150	1.8
420 to 300	1.1
300 to 150	1.7
< 150	2.3

Optimal Particle Size for Reconstitution: 420 to 300 µm

Sample ID	Moisture Content
Batch 1 - Run 1	5.98
Batch 1 - Run 2	6.42
Batch 1 - Run 3	5.36
Batch 1 - Run 4	3.99
Batch 2 - Run 1	3.18
Batch 2 - Run 2	2.99
Batch 2 - Run 3	2.76
Batch 2 - Run 4	2.09

Verification that binder was added in the correct concentrations

Future Work

Optimization -

- Run agglomeration trials using 200g and 300g batch sizes.
- Keeping variables constant during all future trial.
- Variable settings: Impeller Speed = 250 rpm, Mix Time = 3 minutes, and Agglomeration time = 15 seconds.
- Sieve all trials to obtain 420-150 µm particle sizes.
- Reconstitute trials using the set procedure.
- Run both qualitative and quantitative analysis for all trials.

Alternative Design Optimization -

- Run Plackett–Burman experimental design for the alternative design agglomerators.
- Determine the significant variable for each trial using both qualitative and quantitative analysis.