Design of a Pizza Crust Process

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Objective:

- Understand the process of how pizza crust is made in an industrial size plant.
- Create a business plan to produce a successful product which has zero water discharge while keeping the energy usage at a minimum.

Problem Statement:

- About 22% of the worlds water supply is used in industrial settings, and this number is projected to double over the next 2 decades.
- To keep this percentage lower it is important for us as future engineers to help find ways of conserving the water used in the places we are employed.

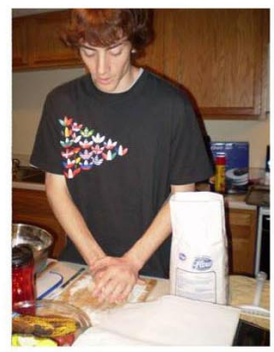
Summary of Production

850 crust/batch

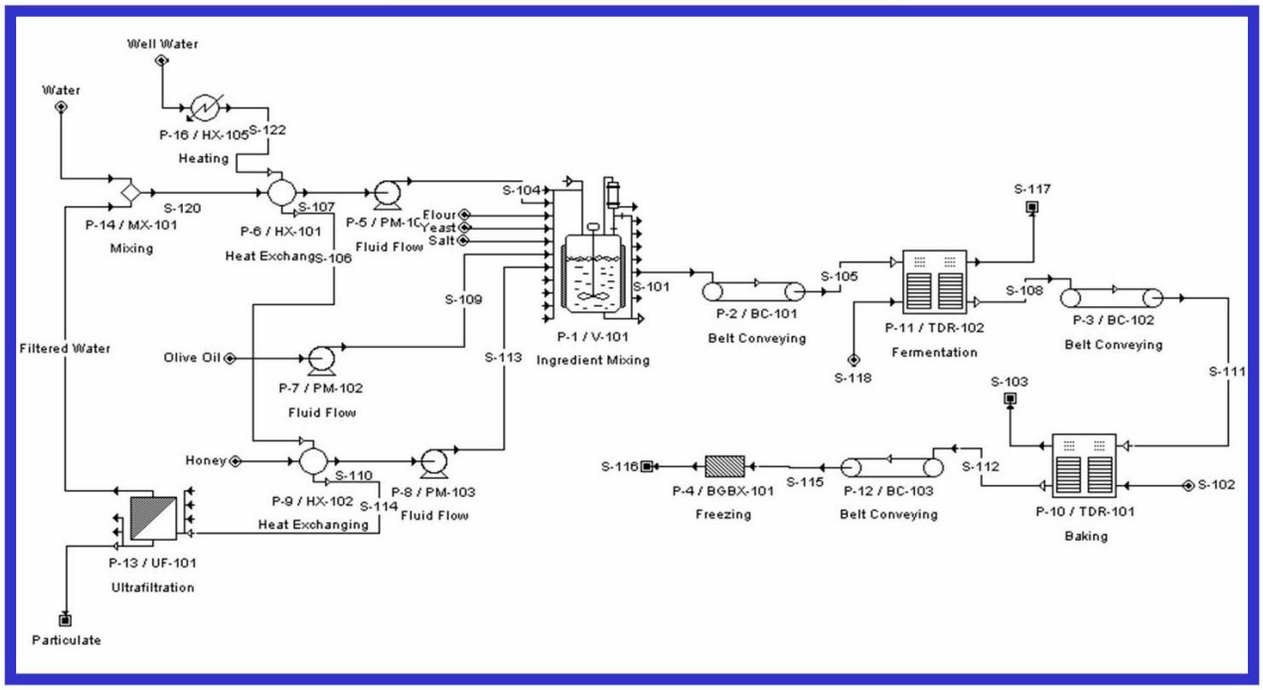
1973 batches/year

Price of pizza crust - $3.00

Annual Return on Investment 29.37%



Process Flow Diagram



Processing Steps:

Mixing – Make sure all the ingredients are evenly distributed though out the product. Also the amount of mixing changes the gluten formation in the dough which will effect the cell structure of the product.

Fermentation – This allows the yeast to be activated and begin growing of the yeast and releasing the CO2 gas and ethanol that gives the pizza dough flavor. During the release of the CO2 and ethanol the pizza dough begins to rise and creates the desired cell structure of the pizza dough.

Baking – The baking cooks the pizza dough to give it the end desired texture, flavor, and mouth feel. The baking actually dries out the dough and releases water in to the atmosphere that we would want to recover and be able to reuse.

Freezing – The freezing of the pizza dough is to keep the product fresh longer. Also our product will be used in further steps to create an entire pizza with toppings that could be cooked again.

Conveying – The conveyers are used as resting times for the dough. After the dough has been manipulated it needs some recovery time so that it still has the desired structure.

Aaron – Batch Mixer Hydraulic Tilt

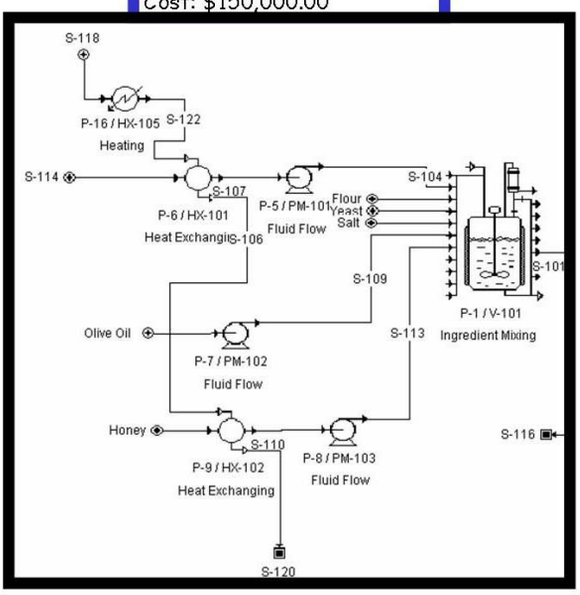
Batch Size: 780.15 kg/batch
850 pizza crusts/batch

Ingredients:

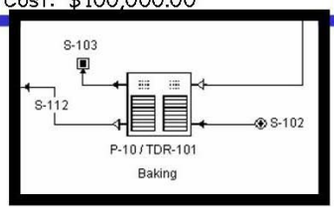
Flour	413.0 kg/batch
Water	236.0 kg/batch
Olive Oil	55.6 kg/batch
Honey	45.4 kg/batch
Yeast	27.2 kg/batch
Salt	2.95 kg/batch

Despatch – PC Series Continuous Production Oven

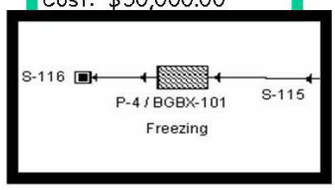
Mixer
Mixing Capacity: 600 gal
Power: 15HP
Blade Speed: 16 to 28 RPM
Time: 15 min.
Cost: $150,000.00



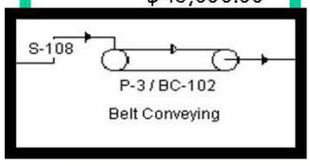
Baking
Temperature: 500 F
Interior Width: 28 in.
Conveyor Belt Width: 24 in.
Air Flow: Vertical Up
CFM: 3000
Energy Usage: 250,000 BTU/hr
Motor Size: 3 HP
Time: 12 min
Max Loading: 4 lbs/sq ft.
Cost: $100,000.00



Freezing
Length: 18 ft.
Width: 12 ft.
Height: 10 ft.
Belt Width: 24 in.
Belt Length: 400 ft.
Power supply: 15 kW
Time: 60 min.
Cost: $50,000.00

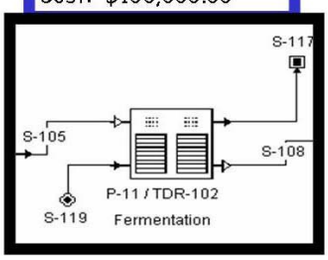


Conveying
Length: 50 ft./30 ft.
Width: 24 in.
Cost: $53,000.00/
$43,000.00



Dantech – Mini Spirial Freezer

Fermentation
Humidity: 75%
Temperature: 110 F
Time: 40 min.
Cost: $100,000.00



Experimental Data

Plackett- Burman Experimental Design

Variable	Low Value (-)	High Value (+)
Temperature	400	425
Time	12	15

Variable	1	2	3	4
Temperature	+	-	-	+
Time	-	+	-	+
Dummy Variable	+	-	+	-

Results

Test	Flavor	Texture	Color	Average of all Scores
1	8	7	7	7.33
2	7	6	8	7
3	9	7	9	8.33
4	7	8	9	8

Flavor – opinion of how well the crust is liked
Texture – base more on the doneness of the bread and the cell structure quality
Color – the color of the outside of the bread and how close to a real pizza crust it looked

The sensory test was based on a 1-9 hedonic scale
1 – the lowest value
9 – the highest value
Our results are shown as an average of a number of test subjects

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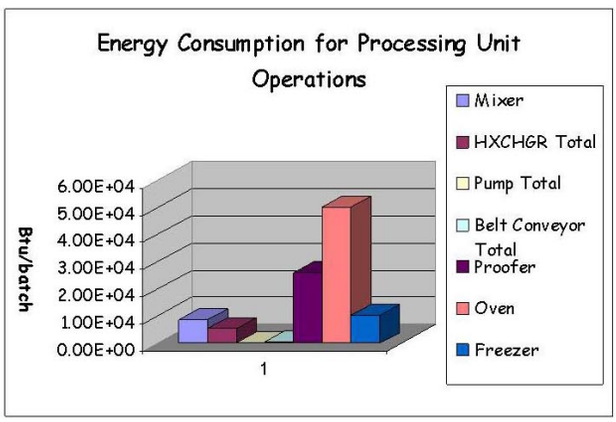
Economic Evaluation

Total Capital Investment

Unit Operation	Cost
Mixer	$150,000.00
50 ft. Conveyer Belt (1)	$53,000.00
30 ft. Conveyer Belt (2)	$86,000.00
Oven (2)	$200,000.00
Freezer	$50,000.00
Pump (3)	$22,500.00
Heat Exchanger (2)	$1,400.00
Boiler	$120,000.00
Blower	$50,000.00
Holding Tanks (3)	$45,000.00
Total Purchase Cost	$777,900.00
Direct Costs	
Purchased Equipment Cost	$777,900.00
Installation (50% of purchase equip. cost)	$388,950.00
Controls (25% of purchase equip. cost)	$194,475.00
Piping (25% of purchase equip. cost)	$194,475.00
Electrical (25% of purchase equip. cost)	$194,475.00
Buildings (50% purchase equip. cost)	$388,950.00
Service Facilities (70% of purchase equip. cost)	$544,530.00
Land (6% of purchase equip. cost)	$46,674.00
Total Direct Costs	$2,730,429.00
Indirect Costs	
Engineering and Supervision (15% of direct costs)	$409,564.35
Legal Costs (2% of fixed capital investment)	$72,811.00
Construction Costs (15% of fixed capital investment)	$546,086.00
Contingency (10% of fixed capital investment)	$364,057.00
Total Indirect Costs	$1,392,518.35
Fixed Capital Investment	$4,122,947.35
Working Capital (15% of total capital investment)	$727,579.00
Total Capital Investment	$4,850,526.35

Total Product Cost

Manufacturing Costs (per year)	Cost
Raw Materials	$1,400,000.00
Operating Labor (25% of raw materials)	$350,000.00
Supervisory, Clerical Labor (15% of operating labor)	$52,500.00
Utilities (25% of raw materials)	$350,000.00
Maintenance and Repairs (6% of fixed capital investment)	$247,376.84
Operating Supplies (.7% of fixed capital investment)	$28,860.63
Laboratory Charges (15% of operating labor)	$52,500.00
Patents and Royalties (5% of raw material)	$70,000.00
Local Taxes (2% of fixed capital investment)	$82,458.95
Insurance (.7% of fixed capital investment)	$28,860.63
Rent (10% of rented building, land)	$43,562.40
Financing (5% of total capital investment)	$242,526.32
Plant Overhead Costs (17% of raw materials)	$238,000.00
Total Manufacturing Costs	$3,186,645.77
General Expenses	
Administrative Costs (5% of raw materials)	$70,000.00
Distribution and Marketing Costs (17% of raw materials)	$238,000.00
Research and Development Costs (8% of raw materials)	$112,000.00
Total General Expenses	$420,000.00
Total Product Cost	$3,606,645.77
Income	
Selling Price of Pizza Crust	$3.00
Number of Batches per Year	1973
Number of Pizzas per Batch	850
Total Sales	$5,031,150.00
Annual Net Profit	$1,424,504.23
Annual Return on Investment	29.37%



Water Conservation

Our main focus throughout the design of the process has been water conservation. Between water being heating and converted to steam for use in the heat exchanger and the water that will be used as an ingredient in our pizza crust we are consuming nearly 270 kg of water per batch. There are two ways that we will modify our process in order to conserve water. First, 30 kg of water is used per batch as a heat transfer medium in the heat exchangers to heat the incoming ingredients. This water will then be put through an ultrafiltration step and will be used as an ingredient in the next batch of pizza crusts. The second way that we thought to lessen the environmental impact of our plant is to condense the water that is lost in the baking step. According to our experiments approximately 40% of the water added to the pizza crust is lost during baking. If 50% of this evaporated water could be condensed, run through the ultrafiltration step and returned to the incoming water stream we would conserve 47 kg of water per batch. Between the two of these modifications we would conserve 77 kg of water per batch which equates to nearly 152,000 kg of water per year. This amounts to a reduction in water use of nearly 30%.

Picture of Each Test

Test 1 – Temp. 400 F
Time 15 min.

Test 2 – Temp. 400 F
Time 12 min.

Test 3 – Temp. 425 F
Time 12 min.

Test 4 – Temp. 425 F
Time 15 min.

As seen by the results test 3 was the favorite over all. The picture reinforces the quality of the pizza crust. Temperature of 425 F and in the oven for 12 minutes shown to be the best combination for the most excellent pizza crust.

Energy Conservation During Baking

As can be seen in the chart above, the baking step is by far the most energy intensive, so we are looking to reducing the energy lost during baking. In our experiments we determined that approximately 40% of the water added to the pizza crust as an ingredient is lost during baking. We can recover the heat from this water before it is recycled by using it to preheat the incoming water that is being used in the heat exchanger to heat the incoming ingredients. We only want to heat the heating water to 130 F, or 328 K.

Steam exiting the baking oven:

$Tout1 := 468.15\,K$

$Mout := 94\ \frac{kg}{batch}$ $Cpout := 4.404\ \frac{kJ}{kg \cdot K}$

Well water entering the plant:

$Tin1 := 298.15\,K$ $Tin2 := 328\,K$

$Min := 30\ \frac{kg}{batch}$ $Cpin := 4.181\ \frac{kJ}{kg \cdot KC}$

$$Tout2 := Tout1 - \frac{(Tin2 - Tin1) \cdot Min \cdot Cpin}{Mout \cdot Cpout}$$

$Tout2 = 459.106\,K$

Cost Analysis:

Electric heater duty:

$Cp := 4.181\ \frac{kJ}{kg \cdot K}$ $Min = 30\ \frac{kg}{batch}$

$Tin1 := 298.15K$ $Tin2 := 328K$

$Duty := (Tin2 - Tin1) \cdot Cp \cdot Min$

$Duty = 3.744 \times 10^{3}\ \frac{kJ}{batch}$

$EnergySaved := Duty \cdot 1973$ $EnergySaved = 7.387 \times 10^{6}\ kJ$

$$kWhsaved := \frac{(EnergySaved \cdot 1000)}{3600000}$$

$costkWh := 0.10$ $kWhsaved = 2.052 \times 10^{3}\ kWh$

$moneysaved := kWhsaved \cdot 0.10$ $moneysaved = 205.197\ dollars$

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