Masa Verde: Zero Discharge Plant

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Objective:

Design a zero discharge 20MM Kg masa facility that minimizes waste water generation without compromising the quality of the final product

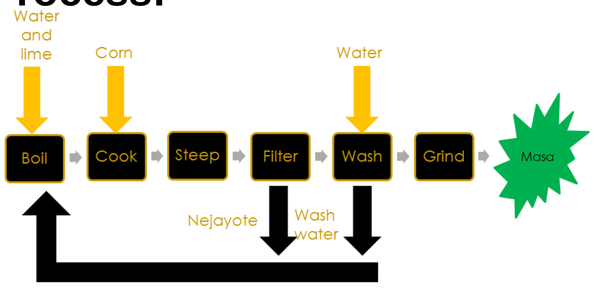
Background:

- Staple of Latin American diet
- Used in tortillas, tamales, soups, corn chips
- Corn tortillas make of 60% of US tortilla industry
- Process facilities use 2 billion gallons per year

Terminology:

- Nixtamalization: alkaline cooking and steeping process
- Nixtamal: alkaline-cooked corn
- Nejayote: steep liquor rich in lime and pericarp

Process:



Process Parameters:

- Cooked at 103ºC for 30 minutes
- Steeped at 75ºC for 10 hours
- Rinsed with de ionized water
- Rinse water reused in process

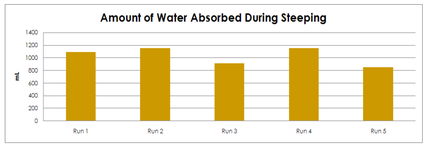
Experimental Design:

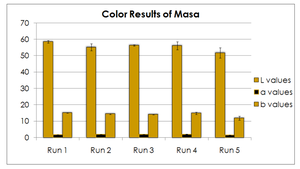
- Tested 4 reuses of nejayote to determine the effect on masa quality
- Measured mass and value of corn, water, and solids
- Analyzed masa physical parameters
- Centrifuged nejayote to determine solids
- Saved nejayote and masa samples for future testing

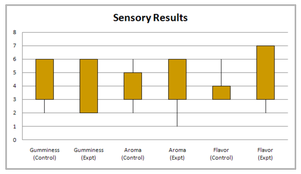
Results:

Total Overall Mass Balance

Mass (g)	Inputs			Outputs		Balance
Components	Corn	$Ca(OH)_2$	Water	Nejayote	Masa	Out-In
Bound Water	100	0	0	0	1790	1690
$Ca(OH)_2$	0	10	0	0	10	0
Corn Fiber	108	0	0	82	27	0
Corn Germ	36	0	0	10	25	0
Corn Gluten	80	0	0	24	56	0
Corn Starch	676	0	0	12	30	-633
Gel. Starch	0	0	0	190	443	633
Water	0	0	3184	1494	0	-1690
Total	1000	10	3184	1812	2381	0

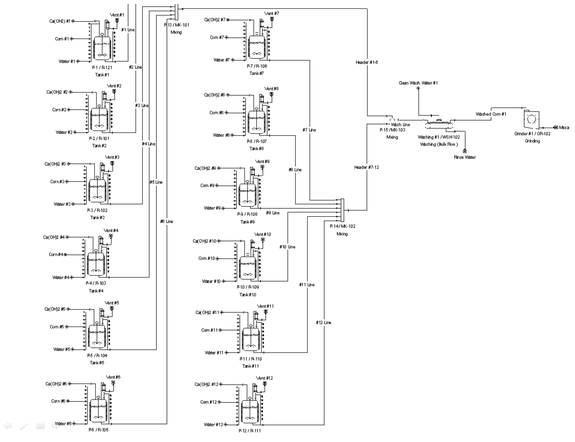






Value	Meaning
1	Like extremely
2	Like very much
3	Like moderately
4	Like slightly
5	Neither like nor dislike
6	Dislike slightly
7	Dislike moderately
8	Dislike very much
9	Dislike extremely

Plant Layout:



Scheduling:

Schedule of Semi-Continuous Nixtamalization Batch Reactors

Time (hrs)	Reactor #1	Reactor #2	Reactor #3	Reactor #4	Reactor #5	Reactor #6	Reactor #7	Reactor #8	Reactor #9	Reactor #10	Reactor #11	Reactor #12
0	Fill,Heat,Cook	Grind	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep
1	Steep	Fill,Heat,Cook	Grind	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep
2	Steep	Steep	Fill,Heat,Cook	Grind	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep
3	Steep	Steep	Steep	Fill,Heat,Cook	Grind	Steep	Steep	Steep	Steep	Steep	Steep	Steep
4	Steep	Steep	Steep	Steep	Fill,Heat,Cook	Grind	Steep	Steep	Steep	Steep	Steep	Steep
5	Steep	Steep	Steep	Steep	Steep	Fill,Heat,Cook	Grind	Steep	Steep	Steep	Steep	Steep
6	Steep	Steep	Steep	Steep	Steep	Steep	Fill,Heat,Cook	Grind	Steep	Steep	Steep	Steep
7	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Fill,Heat,Cook	Grind	Steep	Steep	Steep
8	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Fill,Heat,Cook	Grind	Steep	Steep
9	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Fill,Heat,Cook	Grind	Steep
10	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Fill,Heat,Cook	Grind
11	Grind	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Fill,Heat,Cook
12	Fill,Heat,Cook	Grind	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep
13	Steep	Fill,Heat,Cook	Grind	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep
14	Steep	Steep	Fill,Heat,Cook	Grind	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep
15	Steep	Steep	Steep	Fill,Heat,Cook	Grind	Steep	Steep	Steep	Steep	Steep	Steep	Steep
16	Steep	Steep	Steep	Steep	Fill,Heat,Cook	Grind	Steep	Steep	Steep	Steep	Steep	Steep
17	Steep	Steep	Steep	Steep	Steep	Fill,Heat,Cook	Grind	Steep	Steep	Steep	Steep	Steep
18	Steep	Steep	Steep	Steep	Steep	Steep	Fill,Heat,Cook	Grind	Steep	Steep	Steep	Steep
19	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Fill,Heat,Cook	Grind	Steep	Steep	Steep
20	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Fill,Heat,Cook	Grind	Steep	Steep
21	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Fill,Heat,Cook	Grind	Steep
22	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Fill,Heat,Cook	Grind
23	Grind	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Fill,Heat,Cook
24	Fill,Heat,Cook	Grind	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep	Steep

Plant Scale-up:

- Semi-continuous process with 12 4,000L steep tanks and 3 4,000L cookers
- Washing and grinding continuous process

Added Improvements:

- Reuse the rinse and steeping water in steeping process
- Filter solids from nejayote

Possible Uses for Nejayote Solids:

- Return to product stream to reestablish whole grain content
- Sell loose as animal feed or process into pellets
- Sell as compost material

Benefits:

- Reduce water waste by approximately 1.1 billion gallons per year
- Almost 2000 Olympic swimming pools!!
- Reduce waste water treatment load

Estimation of Capital Investment:

Direct Costs	% of Delivered-Equipment Cost	Cost
Purchased equipment delivered	100	775186.1
Purchased equipment installation	39	302322.6
Instrumentation and controls	26	201548.4
Piping	31	240307.7
Electrical Systems	10	77518.61
Buildings	29	224804
Yard Improvements	12	93022.33
Service facilities	55	426352.3
Total direct plant cost	302	2341062
Indirect costs		
Engineering and supervision	32	248059.5
Construction expenses	34	263563.3
Legal expenses	4	31007.44
Contractor's fee	19	147285.4
Contingency	37	286818.8
Total indirect plan cost	126	976734.5
Fixed capital investment	428	3317796
Working capital (15% of fci)	75	581389.6
Total capital investment	503	3899186

Economics Summary:

Total Investment ($)	15,525,230.00
Total Revenues ($/yr)	41,581,658.00
Operating Cost ($/yr)	21,376,678.00
Annual Production (kg/yr)	19,895,530.37
Product Cost ($/kg)	1.07
Selling Price ($/kg)	2.09
Return On Investment (%)	85.50
Payback Time (Yrs)	1.17
IRR After Taxes (%)	44.77
NPV at 7.0% interest ($)	71,378,904.00