Corn Quality for Alkaline Cooking: Analytical Challenges

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Alkaline Cooking

- Ancient *Nixtamalization* process for producing tortillas, corn chips, tortilla chips and taco shells
- US Tortilla Market:
  - $2.1 Billion/yr with 4% annual growth
  - 35% Corn
## Snack Sales

<table>
<thead>
<tr>
<th>Product</th>
<th>Sales (USD)</th>
<th>Annual % Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tortilla Chips</td>
<td>4 Billion</td>
<td>+5.5%</td>
</tr>
<tr>
<td>Corn Snacks</td>
<td>1 Billion</td>
<td>+8.0%</td>
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</tbody>
</table>

Snack Food Association
Process Flow

Corn → Nixtamalization Tank (Cooking and Steeping) → Nixtamal Water-Washing → Nixtamal Stone Grinding for Mass Production

Mass Grinding → Continuous Tortilla Baking Oven → Tortilla Cooling Conveyers → Tortilla Collection
Nixtamalized Products

Whole Kernel Corn (Processing) → Instant Masa Flour

Nixtamalization → Masa

Shape Forming and Cutting

Baking → Tortillas

Frying → Baked Chips

Fold & Fry → Taco Shells

Frying → Corn Chips

Frying → Tortilla Chips
Masa Flour

“Instant Masa”

- End-Processors can produce alkaline cooked products without need for corn cleaning, cooking or steeping equipment.
- Very large production facilities.
- Rehydrated masa very different from conventional masa - products similar but often considered inferior.
Typical Masa Flour Production Scheme

Whole Kernel Corn

Cleaning

Continuous Cooking

Partial Grinding

Flash Drying (400°C)

Grinding/Sieving

Reblending

Packaging

Masa Flour

Additives (Antimicrobial Agents & Texture Modifiers)
Typical Plant Sizes

Red Oak
24,000 metric tons/yr
Muleshoe
86,400 metric tons/yr
Mexican Plants
143,000 - 300,000 mt/yr
Typical: 160,000 mt/yr

Employees
Usually about 1 per metric ton

1 mt = 1.102 US Short Ton
= 2,205 pounds
Corn Quality

- General Market Considerations
- Free (or very low) Mycotoxins
  - Aflatoxin
  - Fumonisin
- Clean and Consistent
- Good Shipping-Handling Quality
- Low Stress Cracks
- Meets end-use characteristics
- Not High Temperature Dried
Desired Traits

• Best corn and best processing conditions that will:
  — Maximize product yields
  — Minimize waste streams and reduce undesirable components
  — Provide a product consumers desire
Impacts on End-Use Properties

- Grain Quality
- Processing Conditions
  - Lime Concentration
  - Cook Temperature
  - Cook Time
  - Steep Time and Temperature Profile
  - Grinding Conditions and Water Addition
- Interaction between grain characteristics and process conditions
What is Quality for Nixtamalization?

- Cook/Steep Properties
  - Obtaining an appropriate cook with minimum waste generation that allows for the production of good quality masa.
  - Low loss of dry matter (DML)
  - Effective Pericarp Softening and Removal
Critical Process Steps: Cooking and Steeping

Terms: Cooked Corn - *Nixtamal*
Cook/Steep Water: *Nejáyote*
Cooking Conditions

- Depends on cooking method, finished product required and corn hardness
  - 10-60 minutes
    - 30 min average
- Near boiling temperatures
  - (75 - 95°C: ~ 90°C Average)
- Lime Addition
  - 0 - 1.5% (0.8 -1% Typical)
Vat Cooking

Corn, Lime, Water

Hot Water or Steam

Discharge
Corn: Nixtamal
Cook Water: Nejayote
Cooking

- Continuous Cooker

Corn, Lime, Water

Steam

10-30 min cook

Discharge
Partial corn cook
- ~ 30% gelatinized starch
- Annealed Starch
- Nixtamal moistures around 45%
- Pericarp Softening/Loosening
- Flavor Development
- Calcium Uptake

Cooking and Steeping Must Achieve...
Nixtamalization

Quality

- Masa Texture and Color
  - Bright white or yellow
  - Avoid black specs when possible
  - Cohesive but not sticky
Nixtamalization Quality

- Processing/Sheeting Characteristics
  - Pericarp does not stick to the sheeting wires.
  - Masa is not too sticky such that it fails to sheet.
How do you determine corn quality requirements?

- Good quality masa can be obtained using different combinations of cooking/steeping parameters
- Processors use VERY different combinations to get to similar endpoints
  - “Infinite” number of processing conditions
- Corn characteristics interact with process conditions
Corn Quality Testing

- Compositional Factors
  - Protein, fiber, ash, calcium, moisture
- Physical Properties
  - WBT, TADD, Stenvert, Floaters, Hardness Index, Test Weight, 1000 Kernel Wt.
Experiments

• 5 Corn Samples

• Each cooked on a pilot-scale using 10 different processing combinations
  • Centered on a range around 89°C cook temperature, 35 min. cook with 1% lime

• Tortillas could be produced from all treatments

• Multiple regression equations developed
## Impact of Process Conditions and Corn Qualities

<table>
<thead>
<tr>
<th>Nixtamal Moisture</th>
<th>Dry Matter Loss</th>
<th>Masa Texture</th>
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<tbody>
<tr>
<td>$r^2 = 0.78$</td>
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<tr>
<td>cook temperature</td>
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<td>cook time</td>
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<tr>
<td>steep time</td>
<td>steep time</td>
<td>WBT</td>
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<tr>
<td>thousand krnl wt.</td>
<td>WBT</td>
<td>floaters</td>
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<td>floaters</td>
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Corn Quality Traits

• Color
  — Bright white or bright yellow
  — Sometimes mixed

• Texture
  — Harder texture is usually preferred
  — Takes longer but is more forgiving
  — More flexibility in cook/steep times and temperatures
  — CAN be too hard!
  — Soft corn cooks OK, but must be more careful

• Pericarp Removal
  — Pericarp interferes with sheeting (builds up on wire)
  — Want little or no pericarp for chips - some for tortillas
  — Many food grade hybrids selected for easier pericarp removal
Need to find a better way of screening hybrids

- Must actually cook the corn - typical corn quality tests not fully predictive
- Most small sample screening uses multiple bags inside a large cook vessel
  - Difficult to assess pericarp removal
  - Difficult to assess dry matter loss (must weigh kernels)
- Realistically, a good small-scale process is needed to more carefully screen for corn quality measure’s predictability
Exploring a solution...

• Validate carefully thermally controlled laboratory (beaker) method with pilot plant process

• Will use a full range of cooking parameters and generate response surfaces for important response variables

• Will statistically determine if response surfaces are the same between pilot-plant and laboratory procedures