Center for Research and Advanced Studies
(Cinvestav) Campus Querétaro, Mex.

Evolution of Nixtamalization Process: Advantages and Disadvantages

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4th ICC Latin American Cereals Conference
13th International Gluten Workshop

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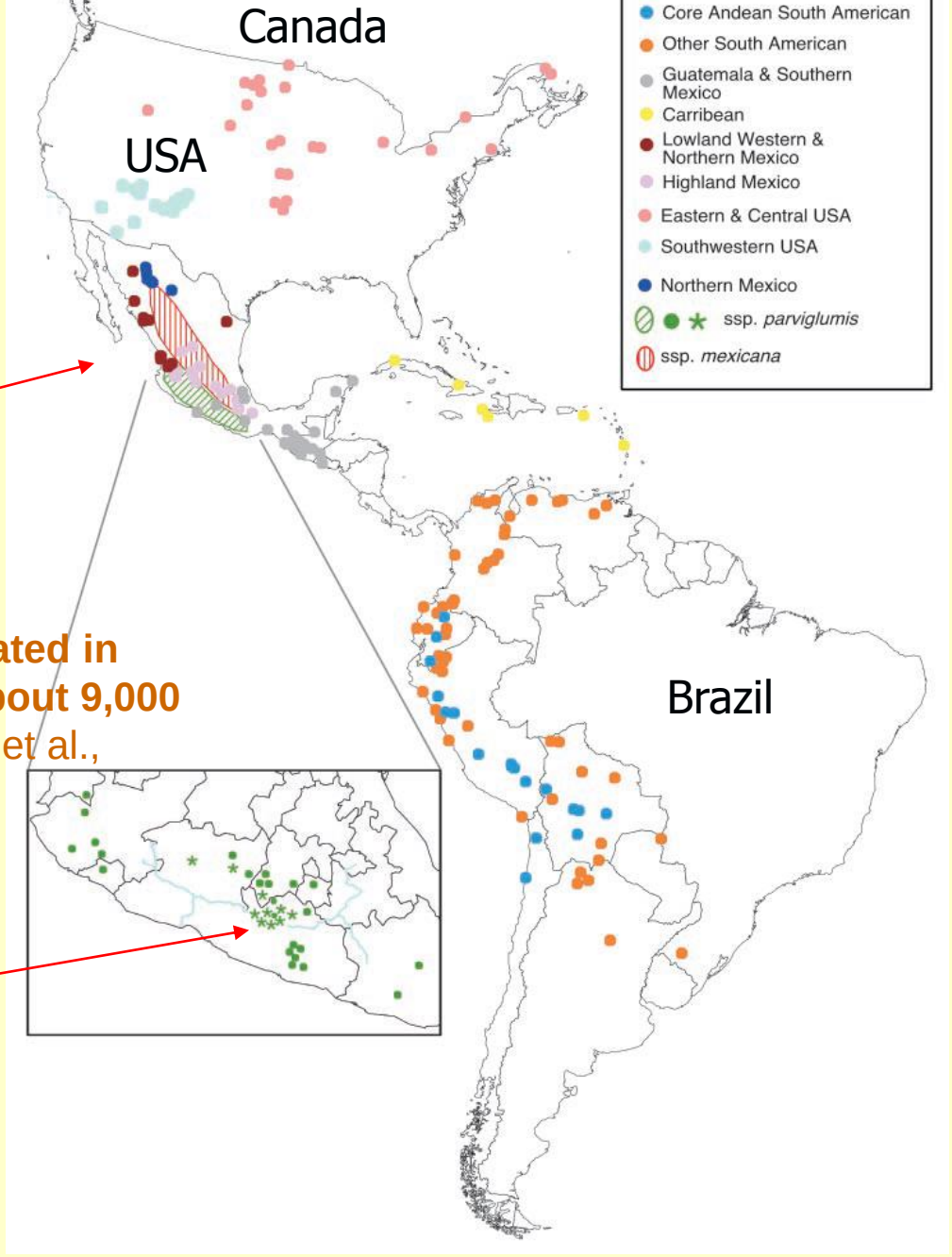
Mexico City, Mexico

LACC IGW

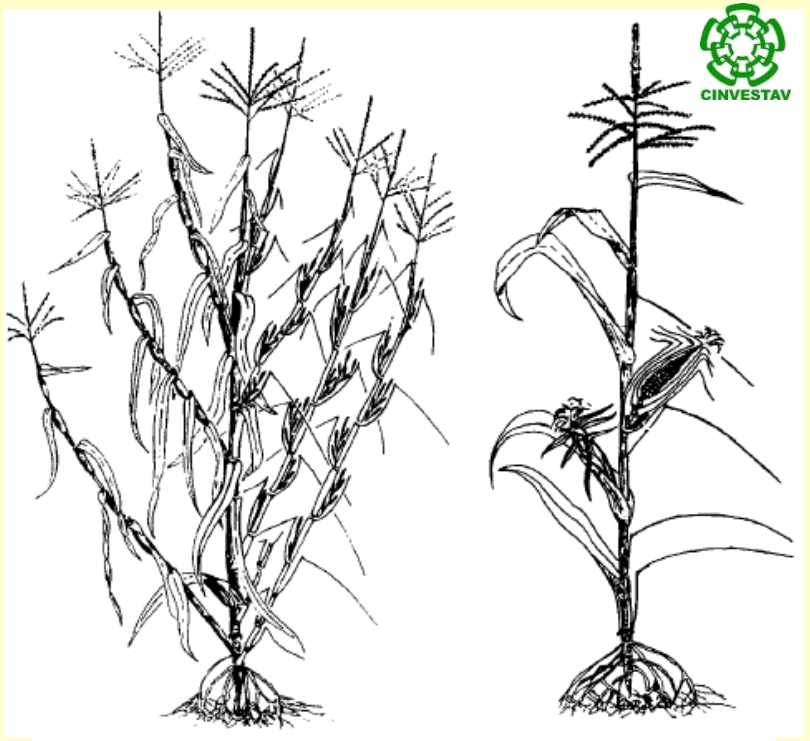
Mexico, City
March 12, 2018



Maize was domesticated in Mexico by women about 9,000 years ago (Matsuoka et al., 2002**)**

Matsuoka et al., 2002. Proceeding of National Academy of Science 99:6080-6084

Teosinte (Zea mays perennis)



TEOSINTE

MAIZE

Doebley et al., 1990.

(STEP 1) Minimal processing Technology

Technology ***Whole grain form***

Popping

Teosinte popcorn
Before 10,000 years ago????

Popping on cob or hot sand

Popcorn 9000 year after maize domestication

Roasting

Green corn
Elotes
Choclos

Infrared Cooking

More than 3,500 years ago??
Totopos

Comixcal.
González-Amaro et al., 2017.
Cereal Chem.

STEP 2 Classic Nixtamalization

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Ash nixtamalization and the Mayan women connection

After 5900 years later of the maize domestication

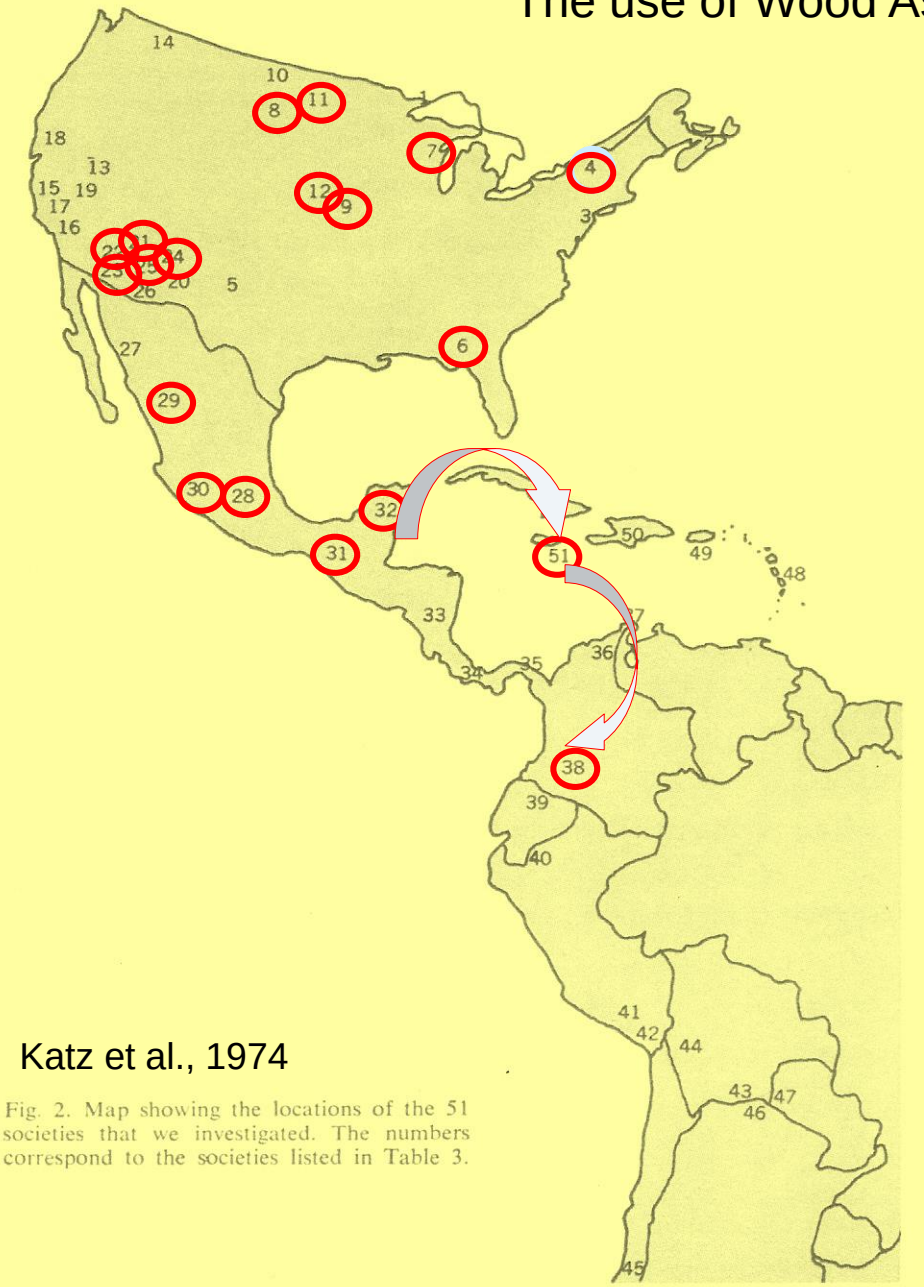
Mineral fortification high in Ca, Fe, Zn, Mg, and K

Boiling
+
ashes or salts

Fortified Products

- ✓ Cooked green corn
- ✓ Boiled Vegetables
- ✓ Tamales (corundas)
- ✓ Beans
- ✓ Tejate (beverage of chocolate and nixtamalized maize)
- ✓ Atoles
- ✓ Memelas, corn cakes into ash???
- ✓ Arepas in Colombia

The use of Wood Ashes in the nixtamalization



Katz et al., 1974

Fig. 2. Map showing the locations of the 51 societies that we investigated. The numbers correspond to the societies listed in Table 3.

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Mayans in Classic period
3100 years ago

Mineral fortification high in **Ca,** Fe, Zn, Mg, and K in food products

Cooked green corn
Tamales (corundas)
Beans
Tejate (chocolate and nixtamalized maize)
Atoles

Mayan technology from 3100 years ago

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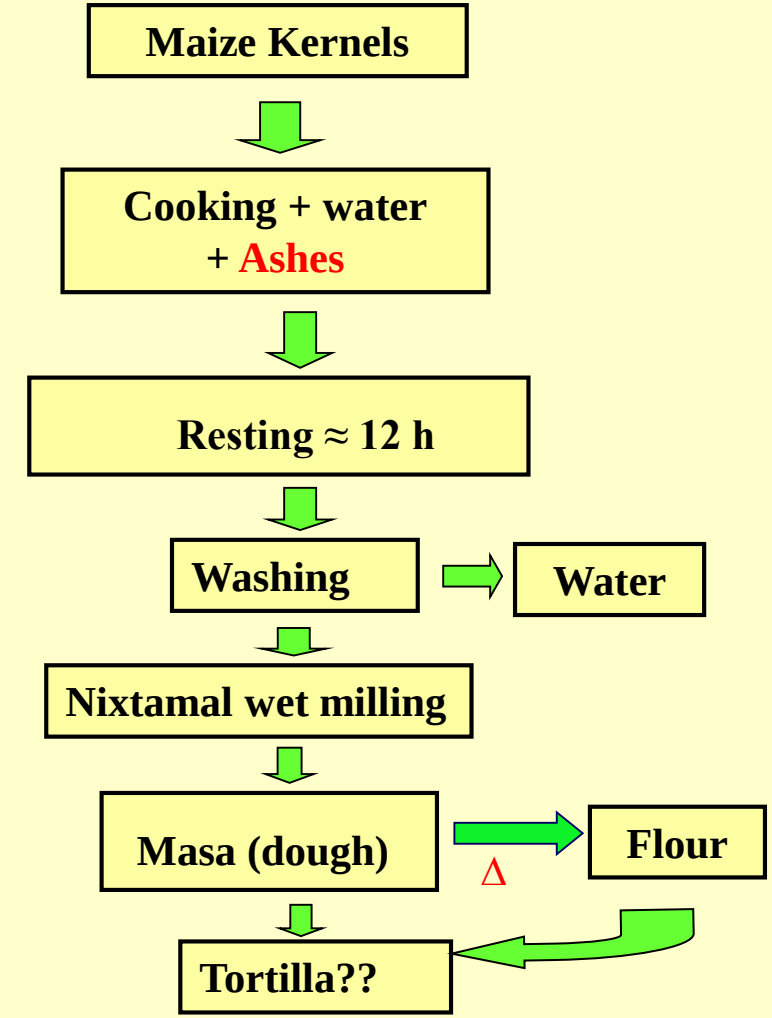
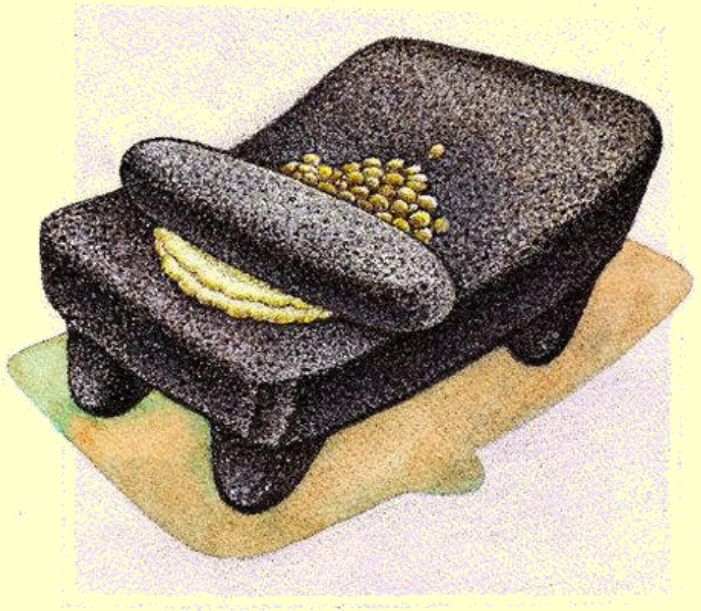
CLASSIC NIXTAMALIZATION (whole grain products)





STEP 3

REFINED PRODUCTS

Traditional Nixtamalization (with lime)
Aztec women invented about 1325 years ago

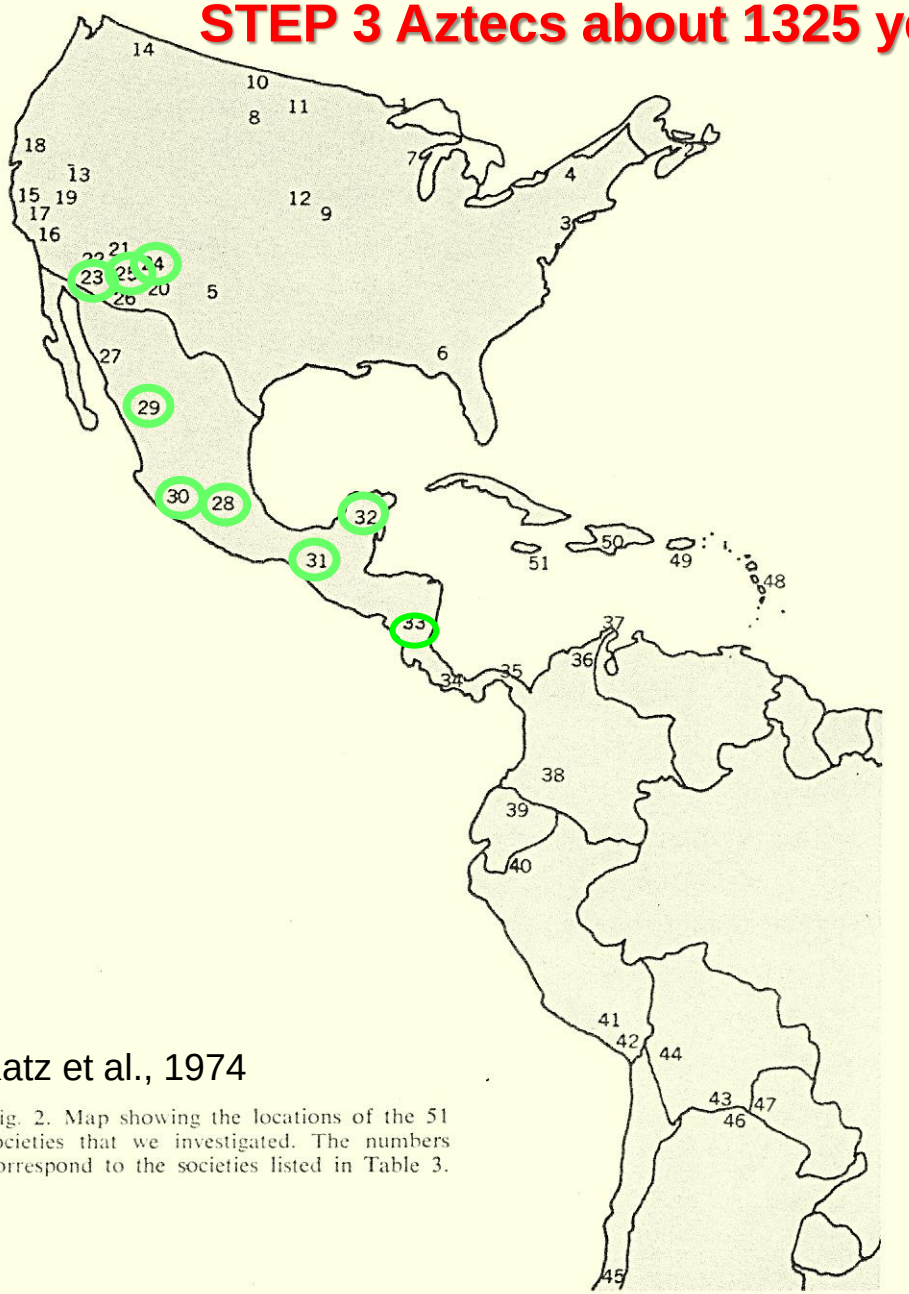
- **Tortillas**
- Pozole
- Tamales
- Totopos
- Atoles

Mexicolor

STEP 3 Aztecs about 1325 years ago

Alkali cooking Techniques

Traditional Nixtamalziation Process



Katz et al., 1974

Fig. 2. Map showing the locations of the 51 societies that we investigated. The numbers correspond to the societies listed in Table 3.

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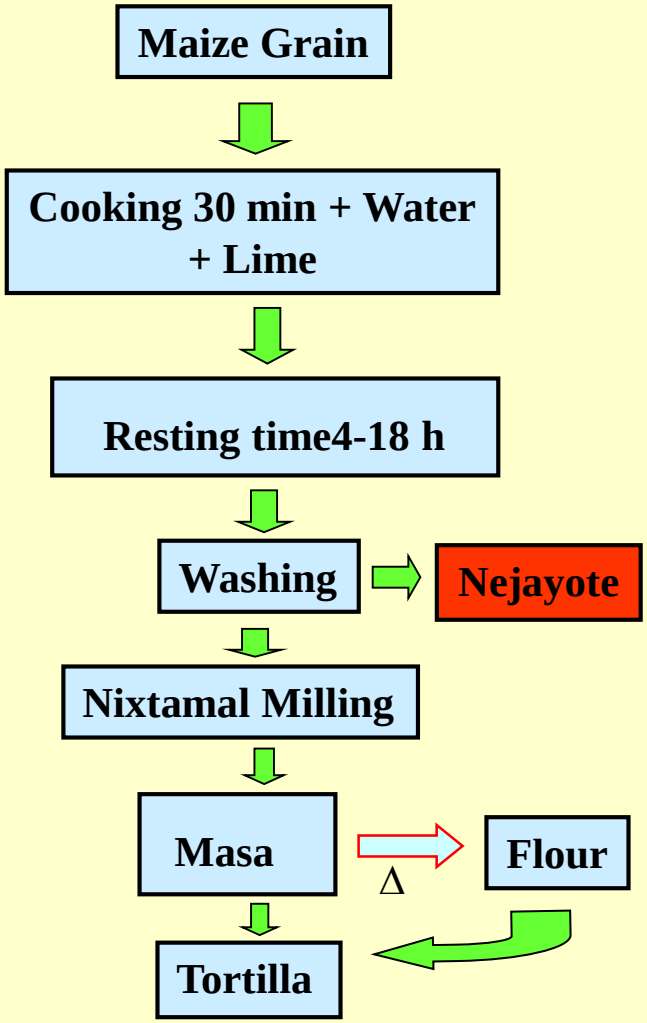
Aztec woman blowing on maize (corn) before putting it into the cooking pot. Florentine Codex 16th century.

Aztec women about 1325 years ago invented the traditional nixtamalization for elaborating Tortillas and Pozole

TRADITIONAL NIXTAMALIZATION



The use of lime in Traditional Nixtamalization Process

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Lime
$Ca(OH)_2$

- ✓ ***Helps in removing pericarp***
- ✓ ***Inhibits the microbial activity***
- ✓ ***Improves the color, flavor and shelf life of tortilla***
- ✓ ***Increases the Ca, Fe in the diet***
- ✓ ***Gives functional properties to the masa***
- ✓ **Releases niacin and prevents pelagra.**
- ✓ **Increases the solubility of glutenins and availability of escential aminoacids.**
- ✓ **Reduces aflatoxinas, DON** (Deoxynivalenol from *Fusarium*)
- ✓ **Reduces acrylamide in deep-frying products**

Technological Problems with the use of lime in Traditional Commercial Nixtamalization Process

Problems

- ✓ ***Produces a liquid waste (nejayote) that is a pollution problem,***
- ✓ ***High losses of nutrients*, such as vitamins, proteins, minerals and dietary fiber.**
- ✓ ***Requires too much water for processing*, requires about 3 to 9 liters of water/kg of corn.**
- ✓ ***Large processing times for obtaining high quality products.***
- ✓ **Short shelf life of the products, due to losses of natural antioxidants.**

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Nixtamalization

Classic Process

- Mayas about 3500 years ago.
- Ashes.
- Mineral fortification Ca, Fe, Zn, K, Mg.
- Tamales.
- Whole grain products

Traditional Process

- Aztecs about 1325 years ago
- Lime
- Tortillas,
- Minerals Ca, Fe
- Pozole
- Pollution effluents

Ecological Process

- Patented by Figueroa et al. (2011)
- Ca salts and weak acids.
- Green techology.
- Whole grain products
- Minerals Ca, Fe,

Ecological Nixtamalization Process

Figueroa J.D.C., Rodríguez-Chong A., Véles Medina J.J. 2011. Proceso ecológico de nixtamalización para la producción de harinas, masa y tortillas integrales. Mexican Patent núm. 289339. (Whole grain products)

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Advantages

Enviromental frienly (ecological).
Clean effluents.
Better quality and extended shelf life of products

Ecological Process (with salts)

Some Theoretical and practical aspects of the Nixtamalization

Changes in some properties of the system due to ionic specificities (Hofmeister effect):

Pericarp components hydrolysis
Protein solubillity,
Gelatinization
Starch annealing
Retrogradation
Protein annealing
Viscoelasticity
Structure Properties,
pH,
Saponification

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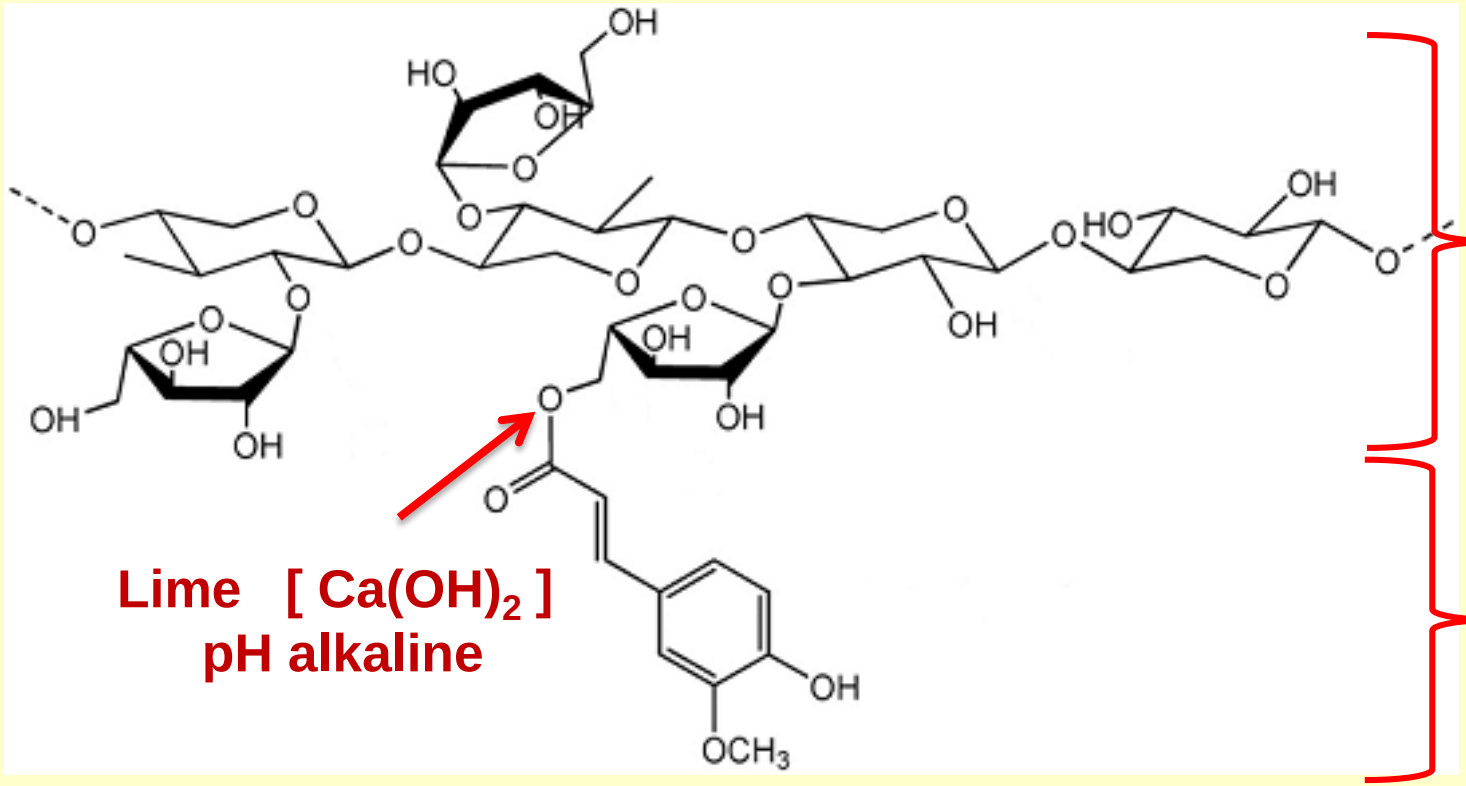
NEJAYOTE (EFFLUENTS) FORM NIXTAMALIZATION PROCESSES

Effects of lime $Ca(OH)_2$ in the Maize Pericarp during the Traditional Nixtamalization



Ferulic acid linked to arabinoxylans

Figueroa J.D.C., Rodríguez-Chong A., Véles Medina J.J. 2011. Mexican Patent 289339.

SEPARATION OF NEJAYOTE BY-PRODUCTS FROM TRADITIONAL NIXTAMALIZATION

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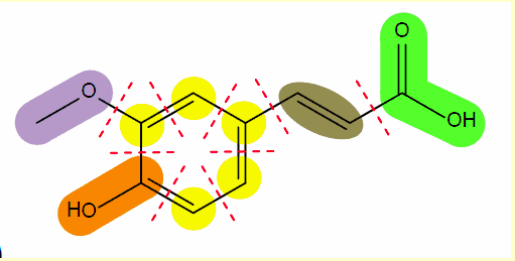
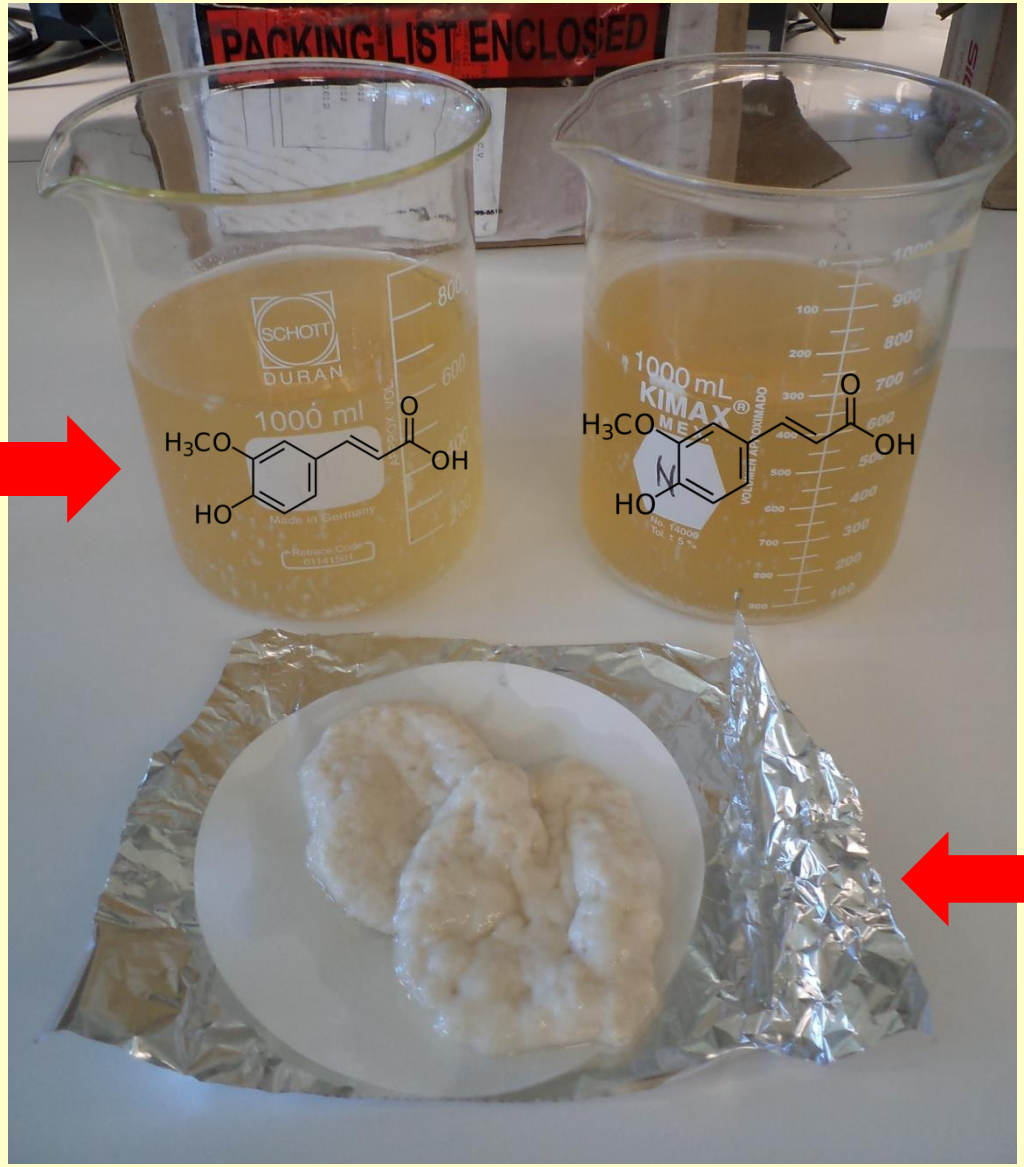


FERULIC ACID



GUMS

Foto:María Fernanda Terrazas Pira
Universidad de San Carlos Guatemala

The soluble solids (gums) and ferulic acid are dietary fiber and antioxidants present in mayor amount in the tortillas from Ecological process than in Traditional tortilla and products and improve the quality.

Tech Evolution of the Whole Grain Foods to Refined Foods

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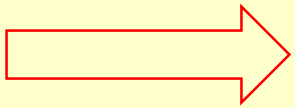

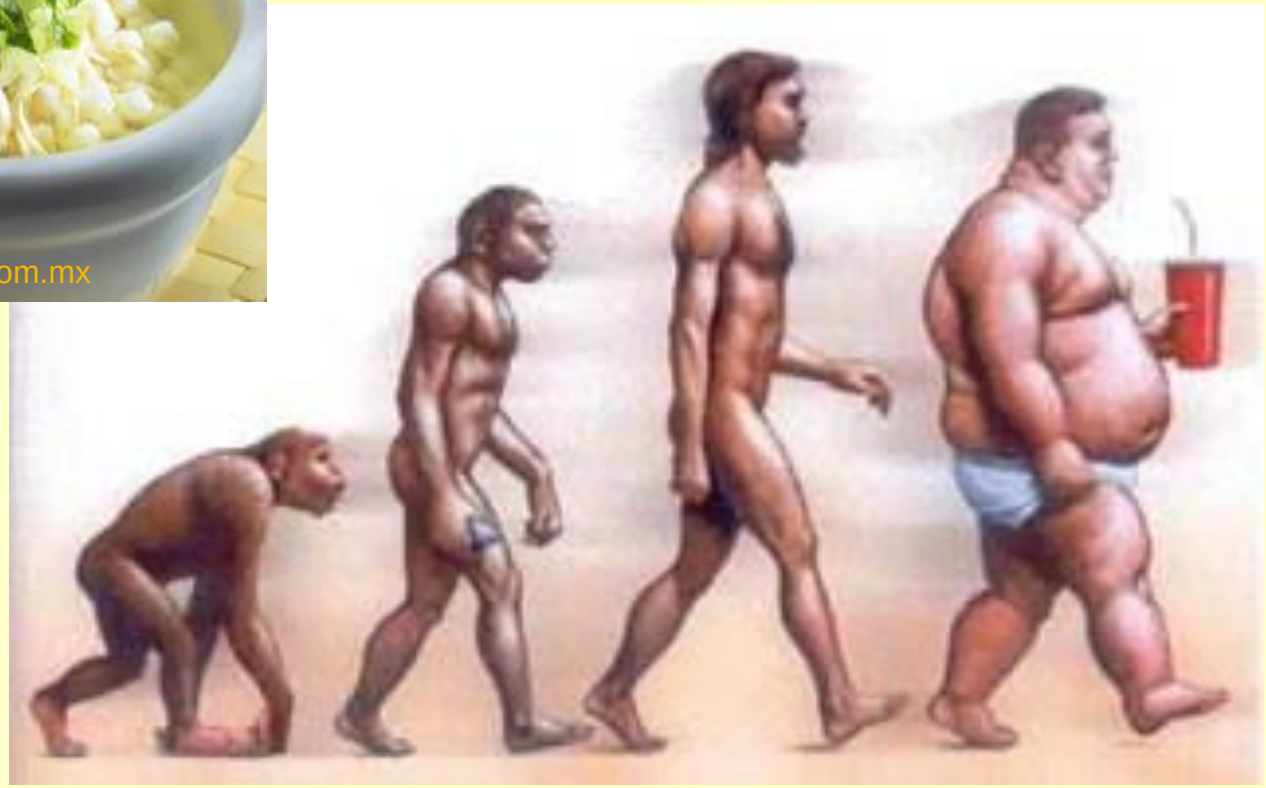

Anonimussonoara ferero 8, 2013

Aztec Tech from 1350 years ago

Mayan Tech 3,500 years ago and Ecological Tech

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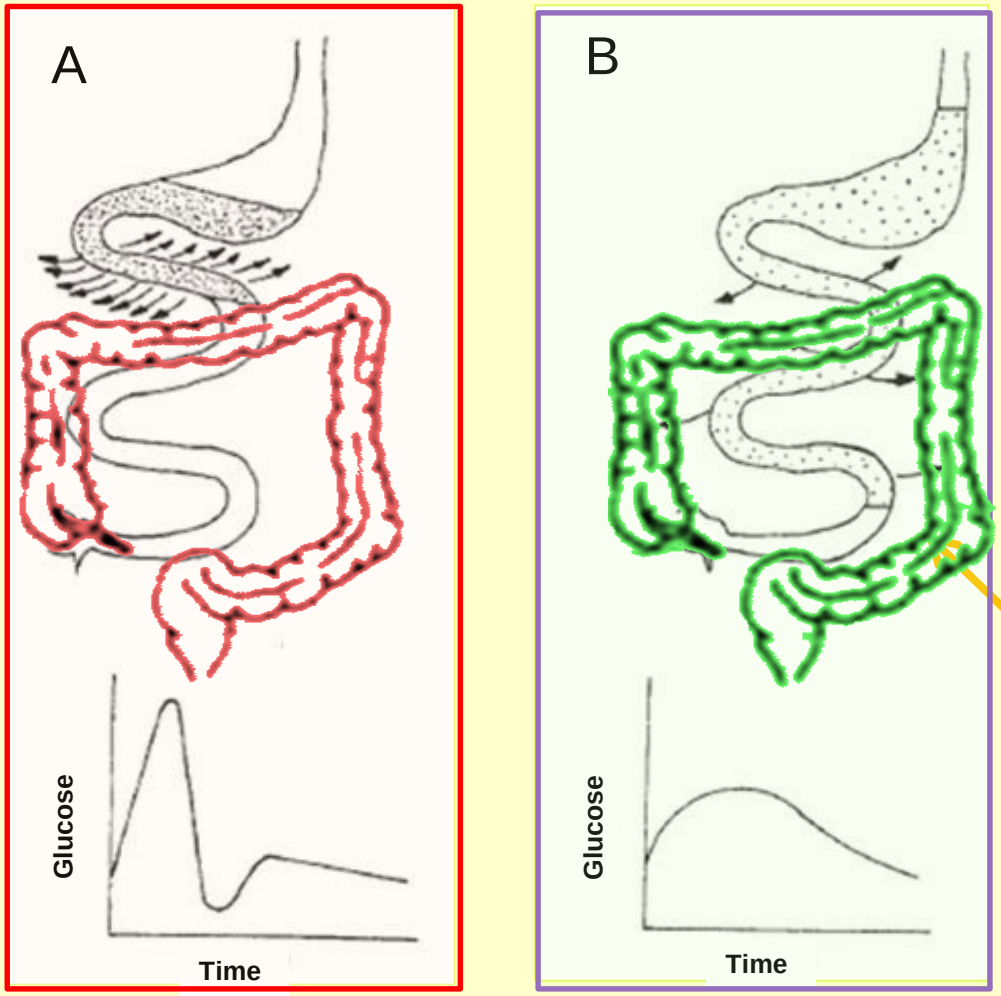
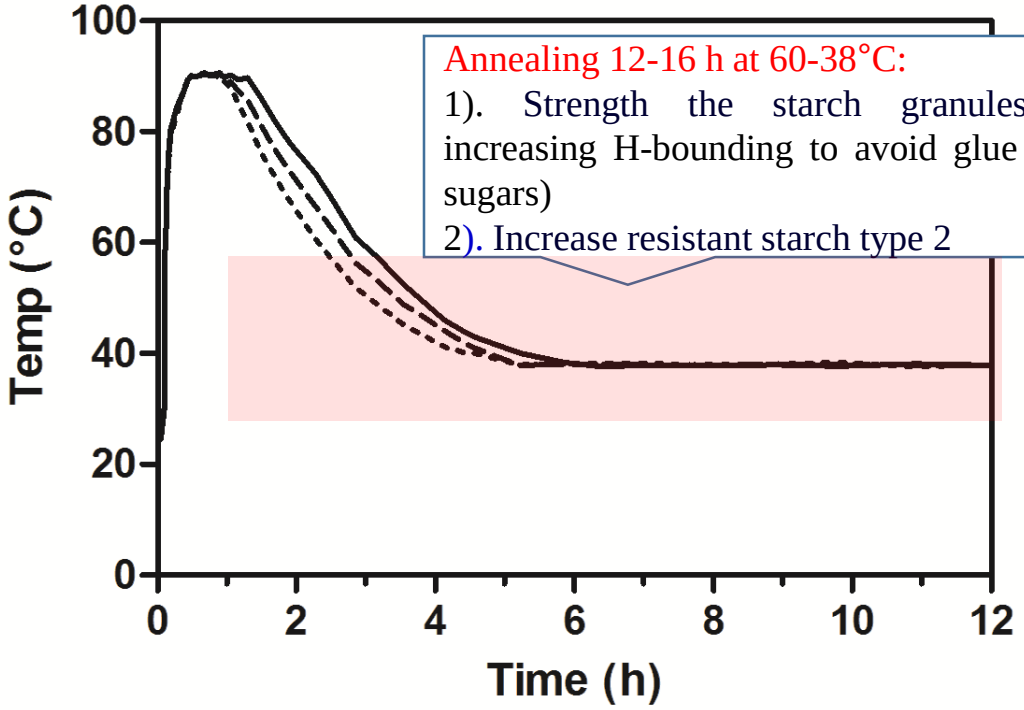


Hypotetic effect of Nixtamalization technology to produce products with (A) High Glycemic Index (Traditional with lime) and (B) Low Gycemic Index (Ash technology and Ecological with Salts) in the pospandrial glucose absorption in blood

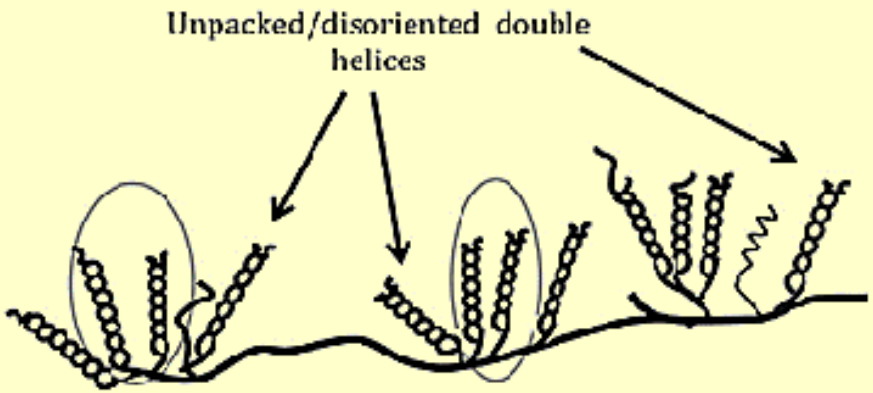
Typical steeping nixtamalization profile



Annealing 12-16 h at 60-38°C:

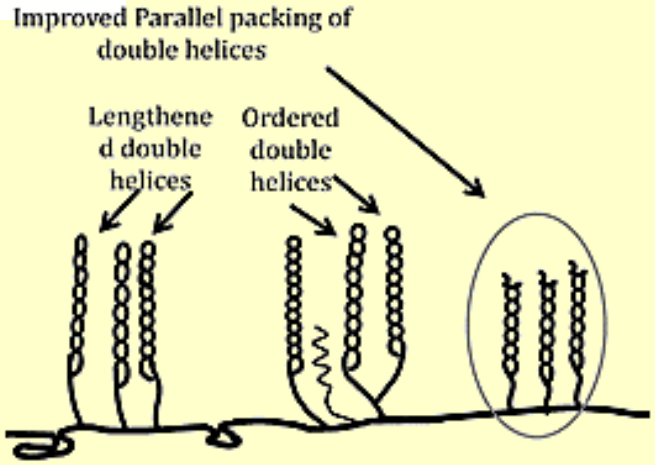
1). Strength the starch granules by increasing H-bounding to avoid glue (free sugars)

2). Increase resistant starch type 2

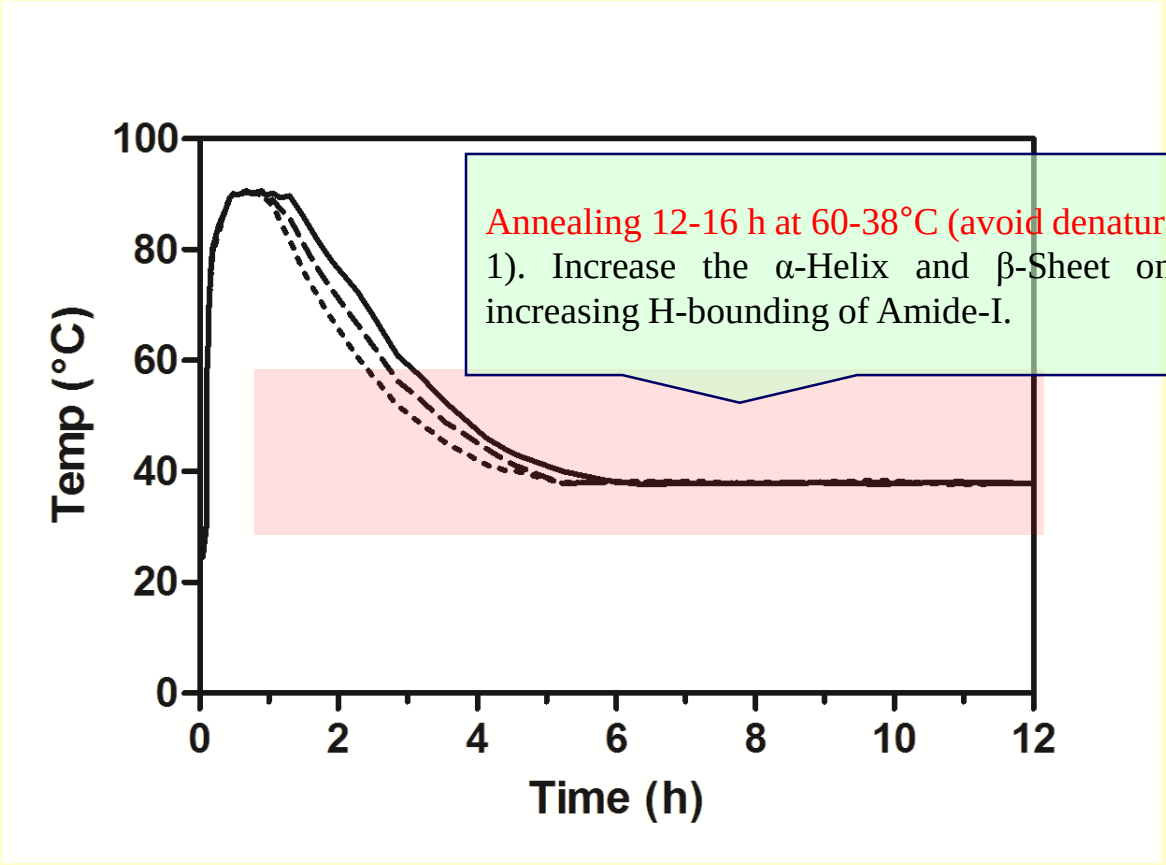


Before annealing

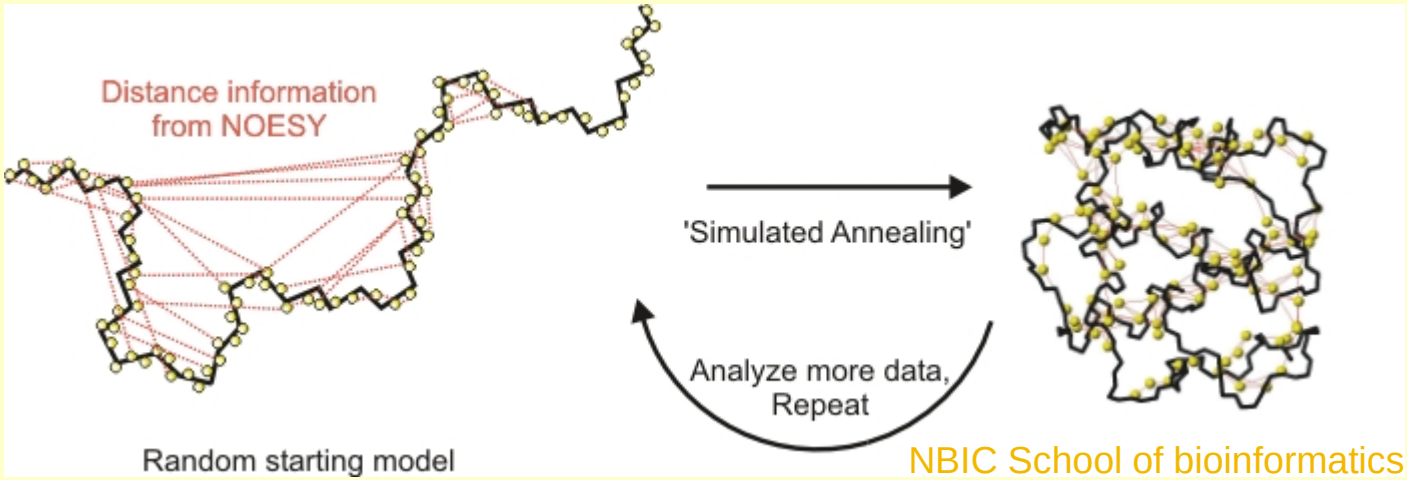
Time



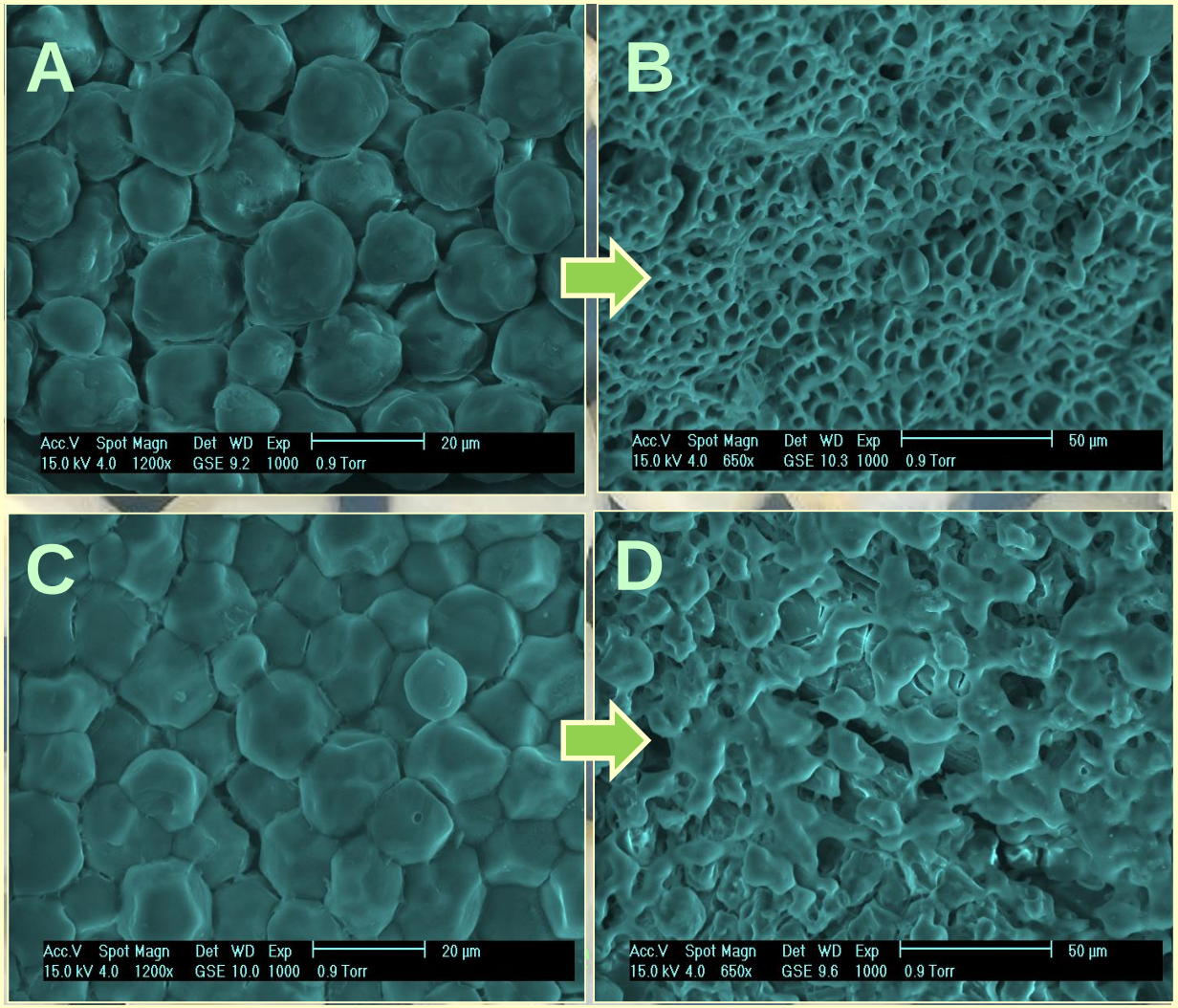
After annealing



Annealing 12-16 h at 60-38°C (avoid denaturation Temp):
1). Increase the α-Helix and β-Sheet on Proteins by increasing H-bounding of Amide-I.



Annealing for increasing Dietary fiber (RS2 & RS5-I, RS5-II)



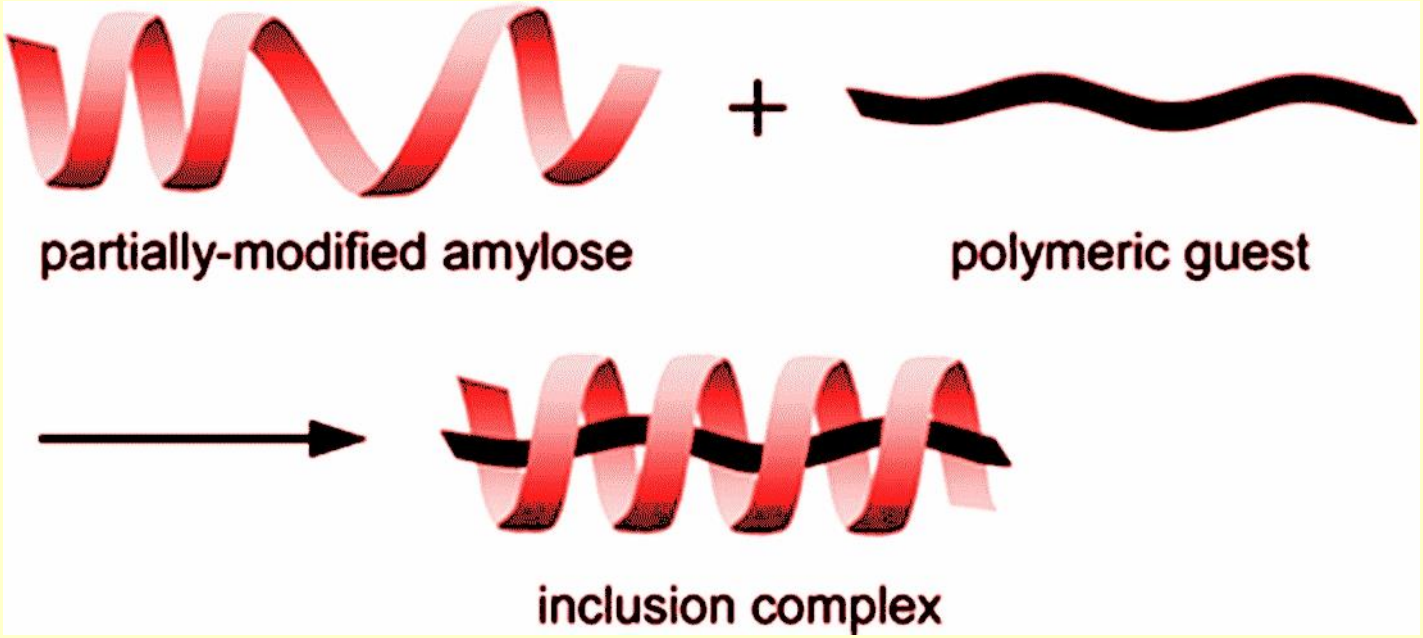
Low GI

High GI

Figueroa ., Véles ., Hernández., Aragón,. Gaytán, Chávez., Palacios, N., Willcox. M. 2013. J Cereal Sci
Figueroa ., Véles., Tolentino., Gaytán., Aragón., Palacios N., and Willcox M. 2013. J Food Eng.

Resistant Starch type 5 (AR5)

Formation by annealing of amylose-lipids at temperature >90°C



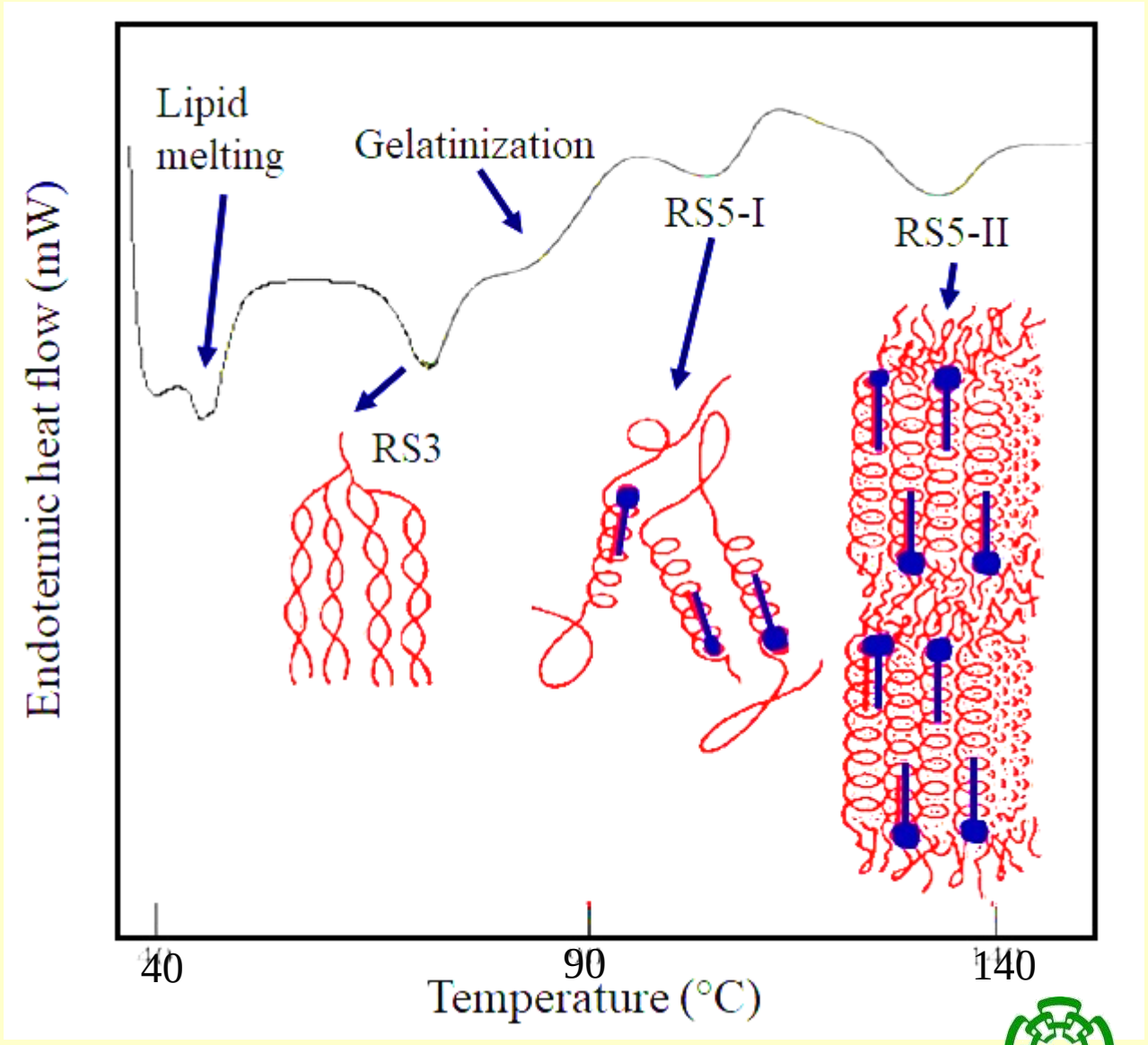
Hydrothermic treatment at >90°C

Effect of annealing on Resistant Starch Type 5-I and Type 5-II in Tamales

Tamal masa (dough)
mixed with shortening

Steam
2 hrs >90°C

Traditional tamales



Figueroa et al., 2016. Starch/Starke

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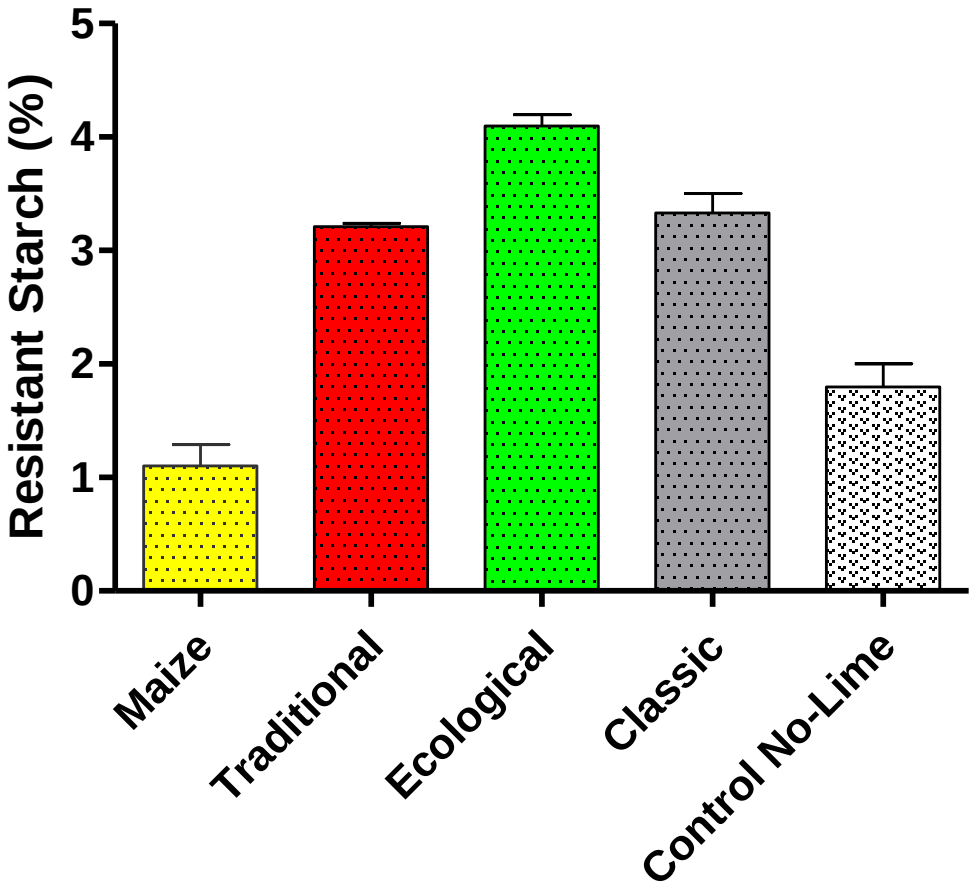
Formation of resistant starch in tamales*

Tamales emporio



*Analyzed using Megazyme, resistant starch kits.

Mariscal-Moreno et al., 2017. J Food Sci

Effect of nixtamalization process on RS and glycemic index

Table 4

Glycemic index for tortillas made from the different nixtamalisation processes[a].

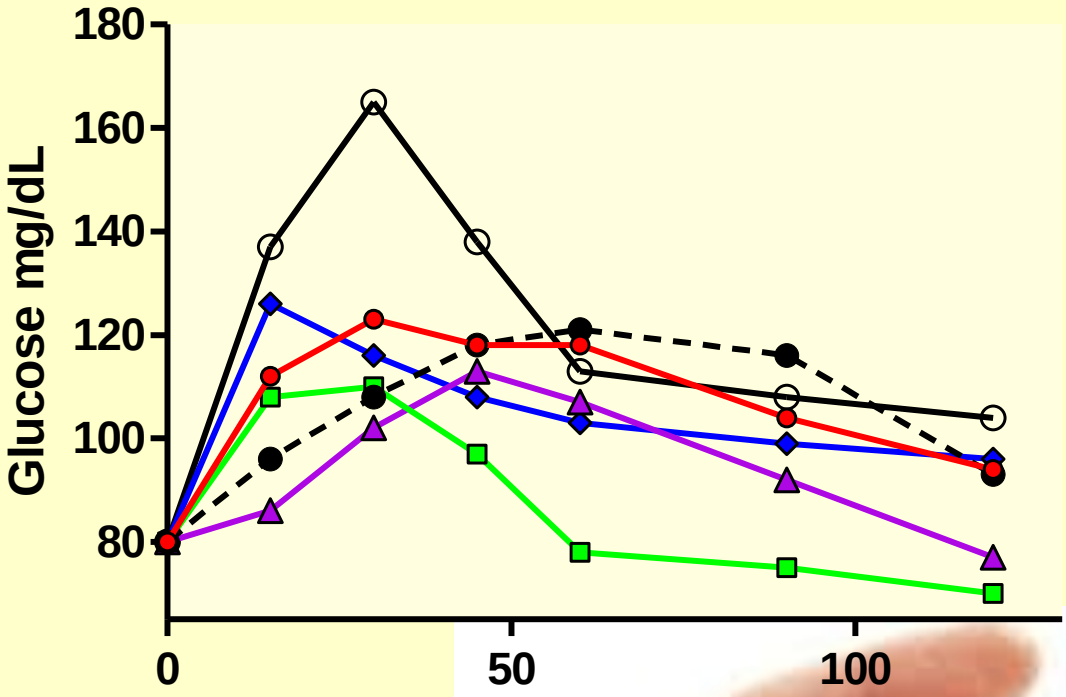
Process for tortilla preparation	Resistant starch (%)	Glycemic Index
Traditional $Ca(OH)_2$	2.99 ± 0.11a	70.0 ± 2.11b
Ecological $CaCO_3$	3.06 ± 0.19a	60.0 ± 1.45d
Ecological $Ca(C_2H_5COO)_2$	2.79 ± 0.12a	37.4 ± 0.87e
Classic 1% ash	2.96 ± 0.11a	29.2 ± 3.02f
Classic saturated ash	2.15 ± 0.09b	69.6 ± 0.93 c
Glucose	–	100.00a
Maize	0.86–0.93	

[a] Means ±SD followed by the same letter in the same column are not significantly different ($P < 0.05$). SD = standard deviation.

Total Resistant starch %. Analyzed using Megazyme, resistant starch kits.

Mariscal-Moreno et al., 2015. J Cereal Sci.

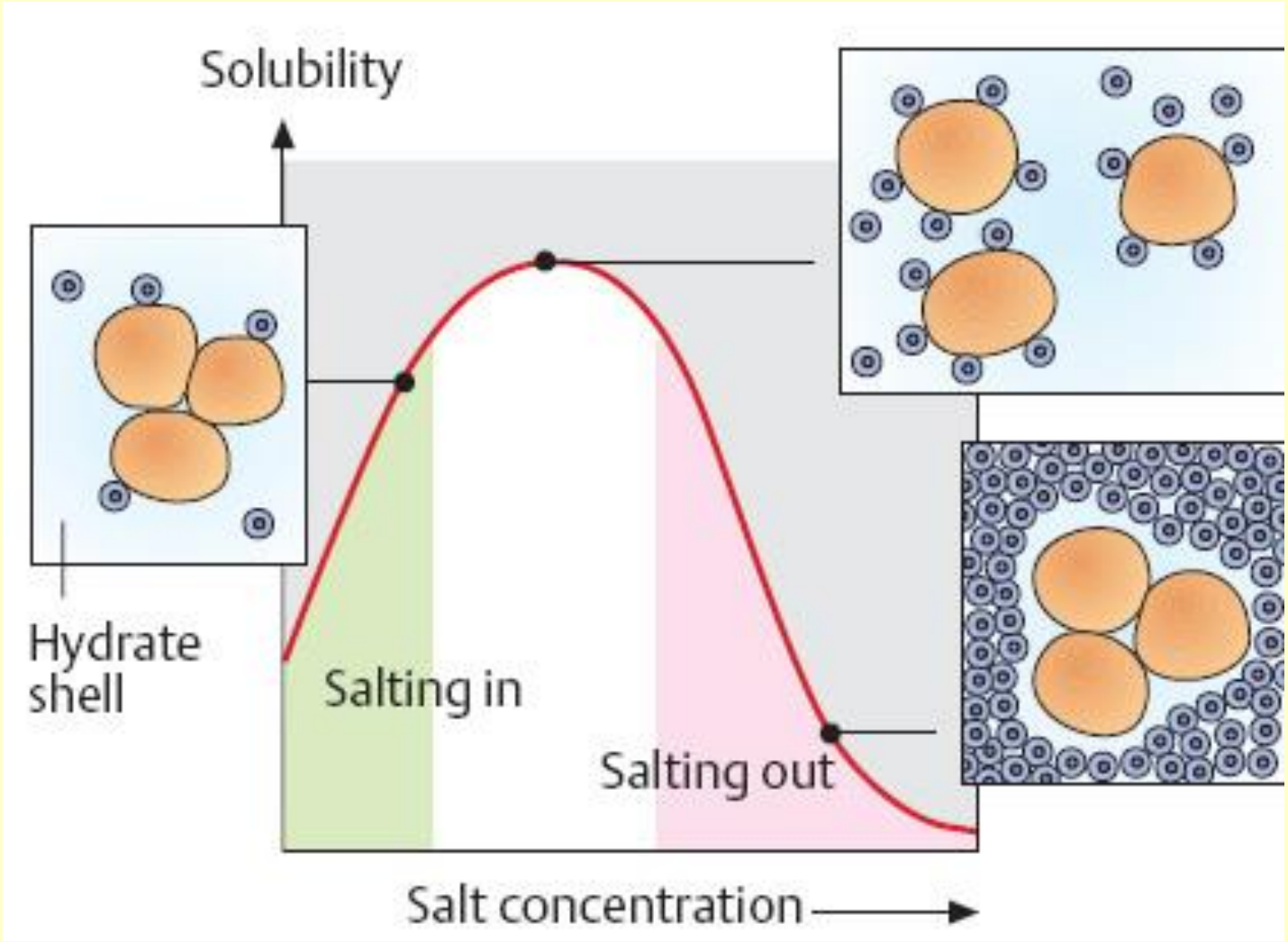
Glucemic Index



Mariscal-Moreno et al., 2015. J Cereal Sci.

Ecological Process (with salts)

Starch granules doping with salts (ions)



Luis Moreno Martínez 2012.

Producción of Resistant Starch Type 4?

Sarch Granule and Protein DOPING with Lime, Salts (Ions)

For reducing **Acrylamida** formation in Deep-frying products

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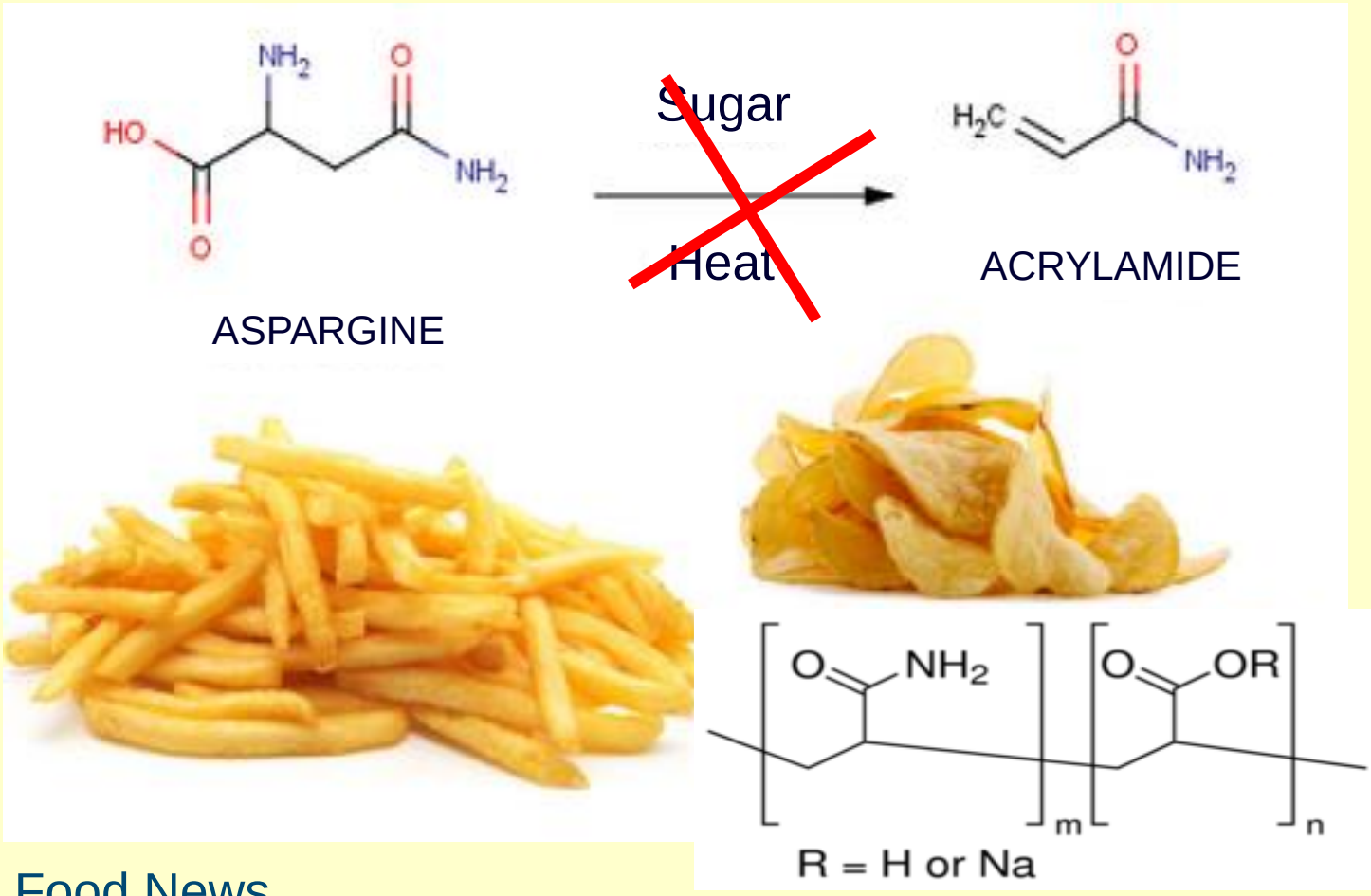
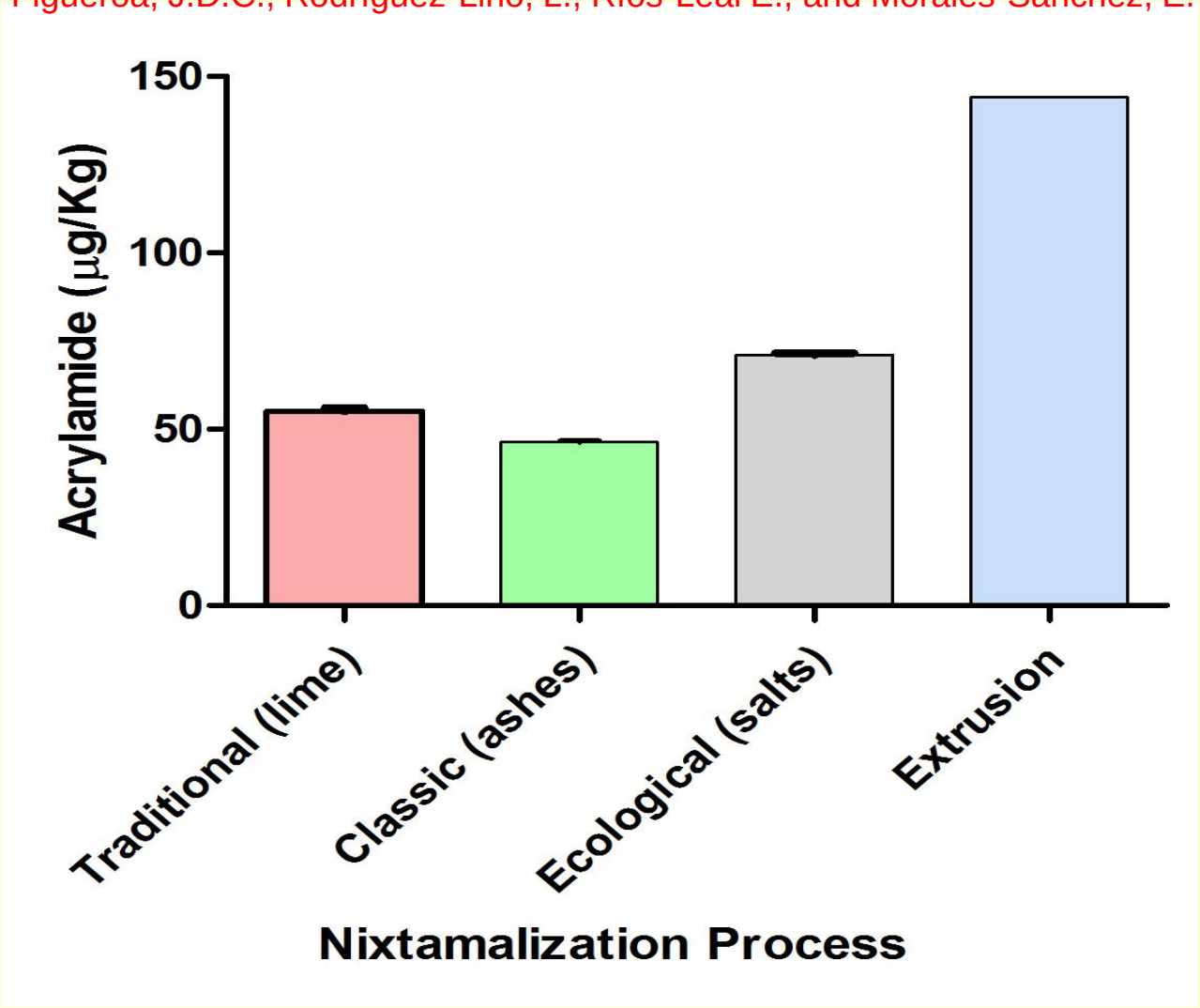


Food News

Effect of Different Nixtamalization Processes on Acrylamide levels of Deep-frying Corn Tortilla Chips

Topete, A., Figueroa, J.D.C., Rodríguez-Lino, L., Ríos-Leal E., and Morales-Sánchez, E.



Paper submitted to Food Chem

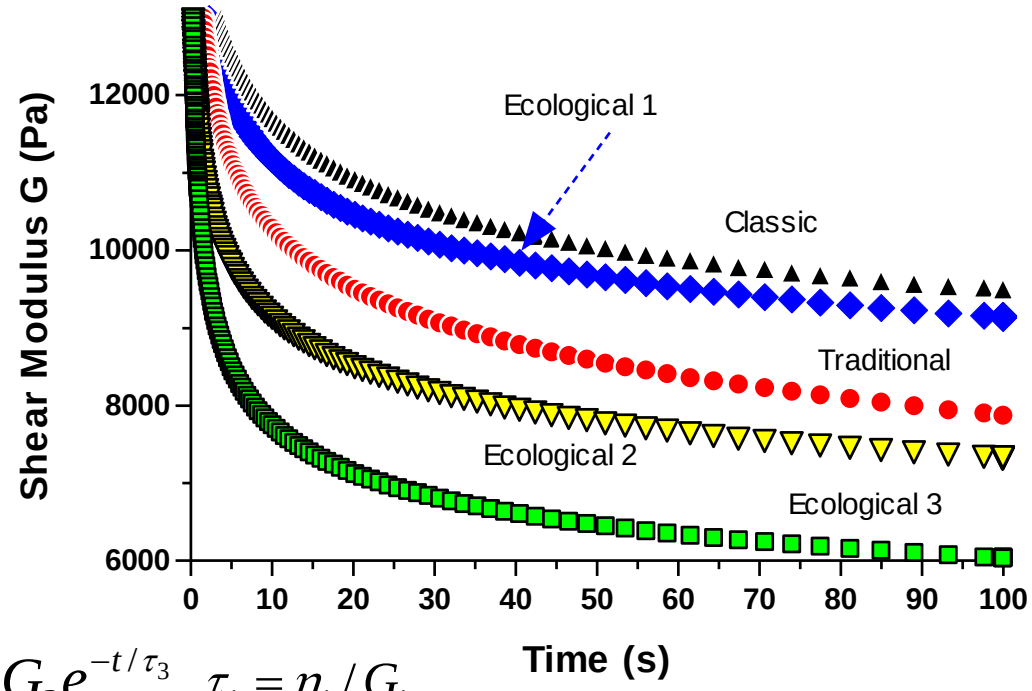
Nixtamalization Factors:

Processing temperature, time-genotype
Lime ($Ca(OH)_2$, (Ca^{2+}, OH^{1-})
Ca-Salts (ions Cl^{1-}, CO_3^{2-},SO_4^{2-}),
Ashes (Ca^{2+},CO_3^{2+}, K^{1+}, Na^{1+} ions)

Effects on:

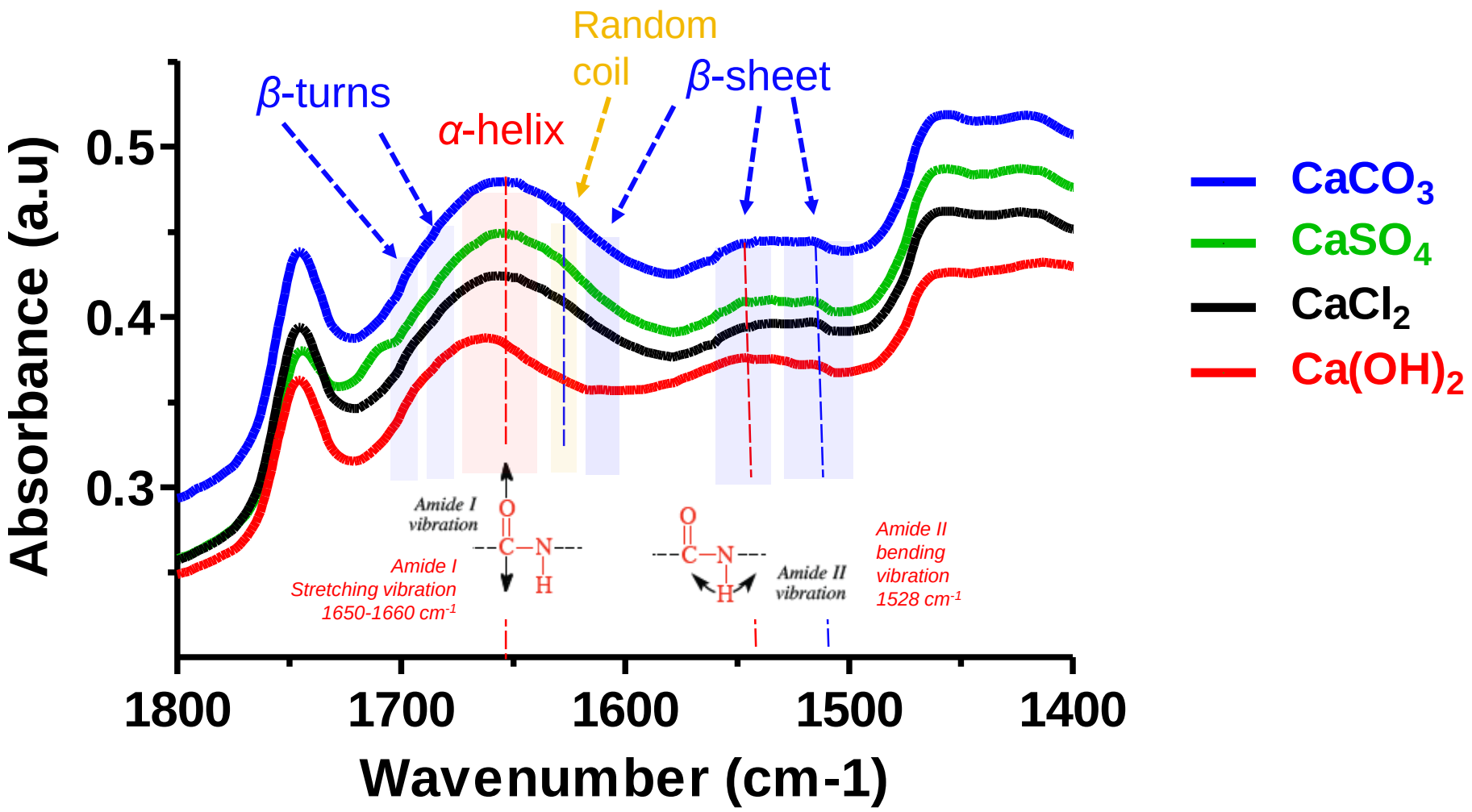
Gelatinization
Annealing
Protein structural changes
(α-hélix, β-sheet)
Saponification
Gums hydrolysis
Water absorption

Masa (dough) viscoelasticity



$$G(t) = G_0 + G_1 e^{-t/\tau_1} + G_2 e^{-t/\tau_2} + G_3 e^{-t/\tau_3} \quad \tau_i = \eta_i / G_i$$

Effect of Nixtamalization Ca Sources on Instant Dry Corn Flours ATR FT-IR spectra



Luo et al., 2016. Food Chem

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Final remarks

Maize domestication has important impact in the modern society.

Classic nixtamalization uses ashes as an inexpensive mineral fortification and prevents pelagra.

Traditional nixtamalization with lime to produce tortillas is using aronund the World has some pollution problems.

Ecological nixtamalization with salts produces whole grain products with good quality properties.