RETROSPECTIVE STUDY OF STARCH DIGESTIBILITY IN CORN TORTILLA

Maize

Food crop

Nixtamalization

Nixtamalized corn increase the nutritional value

⇧ Bioavailability

Aminoacids and Calcium

Soluble fiber and Resistant starch

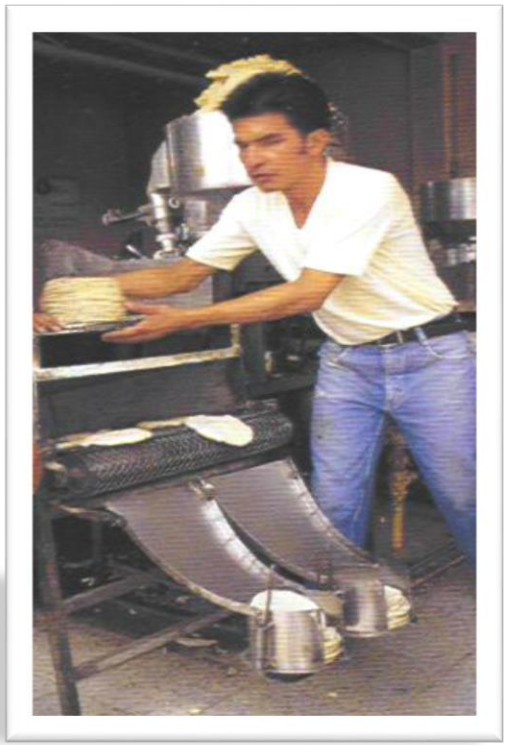
Tortillas consumed in Mexico

TRADITIONAL NIXTAMALIZATION METHOD

70% calories

37% calcium

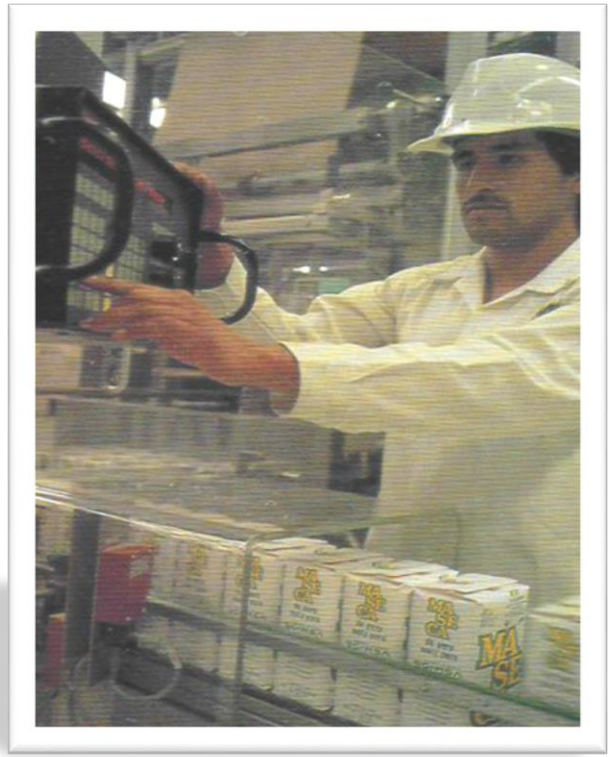
50% proteins



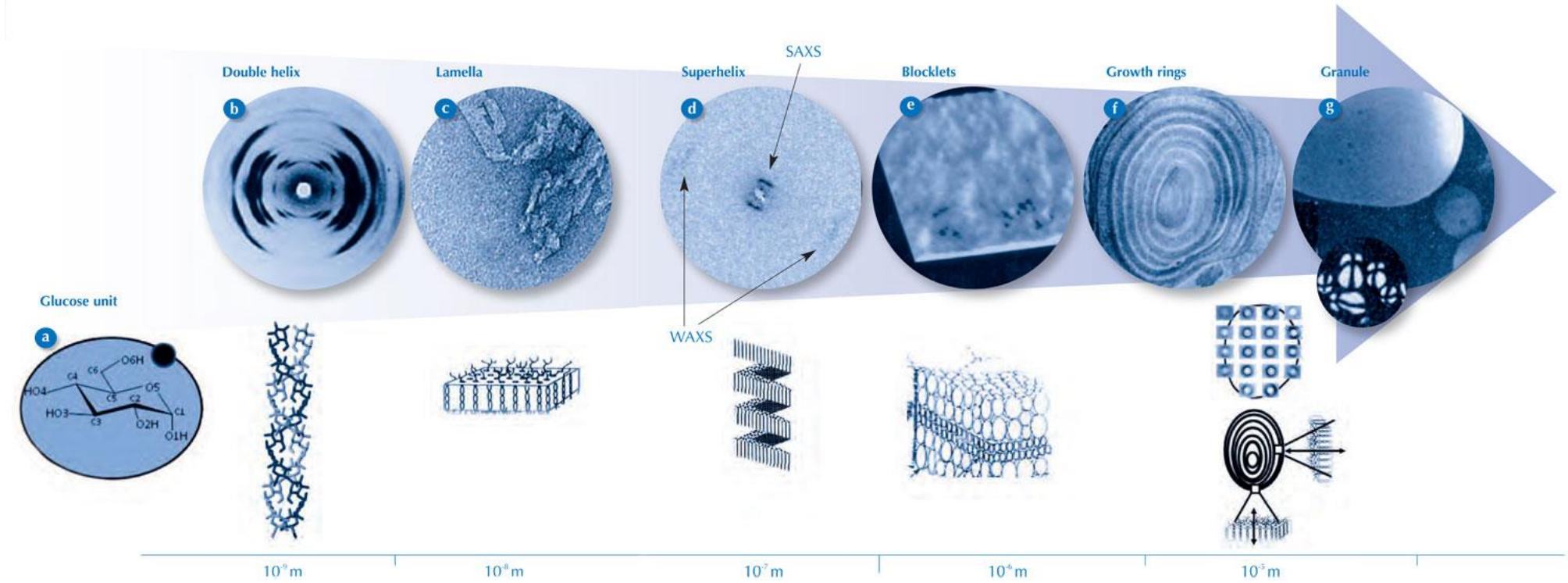
Processes

Flour **Masa**

Flavour **Texture**



Starch


Double helix
Lamella
Superhelix
SAXS
Blocklets
Growth rings
Granule
Glucose unit
WAXS
10^{-9} m
10^{-8} m
10^{-7} m
10^{-6} m
10^{-5} m

Amylose

Amylopectin

Gelatinization

Water absorption

Gelatinization

20ºC

50ºC

100ºC

Partial

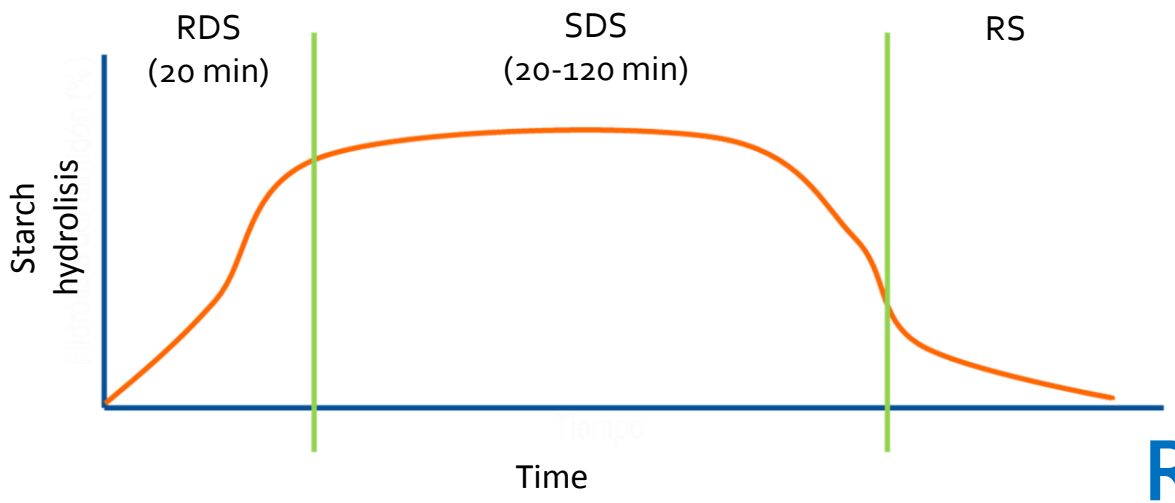
Total

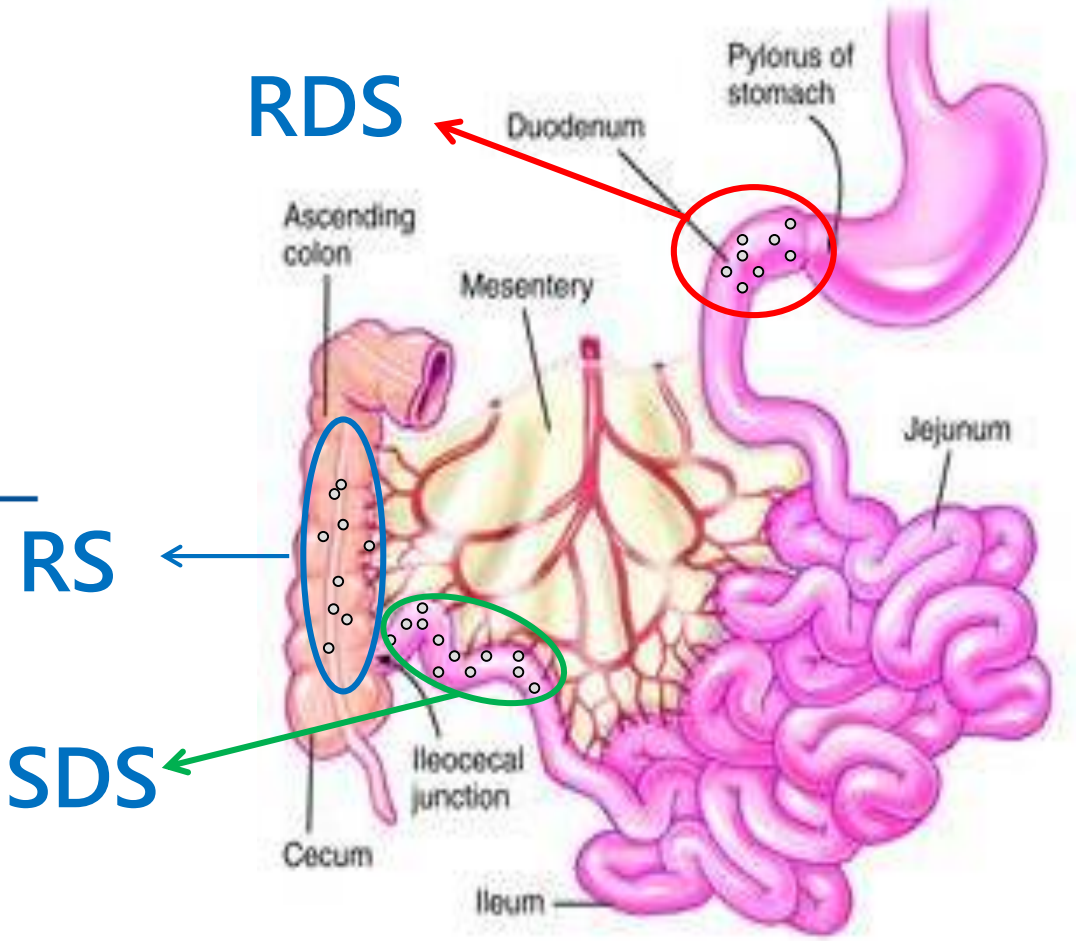
Retrogradation

Staling

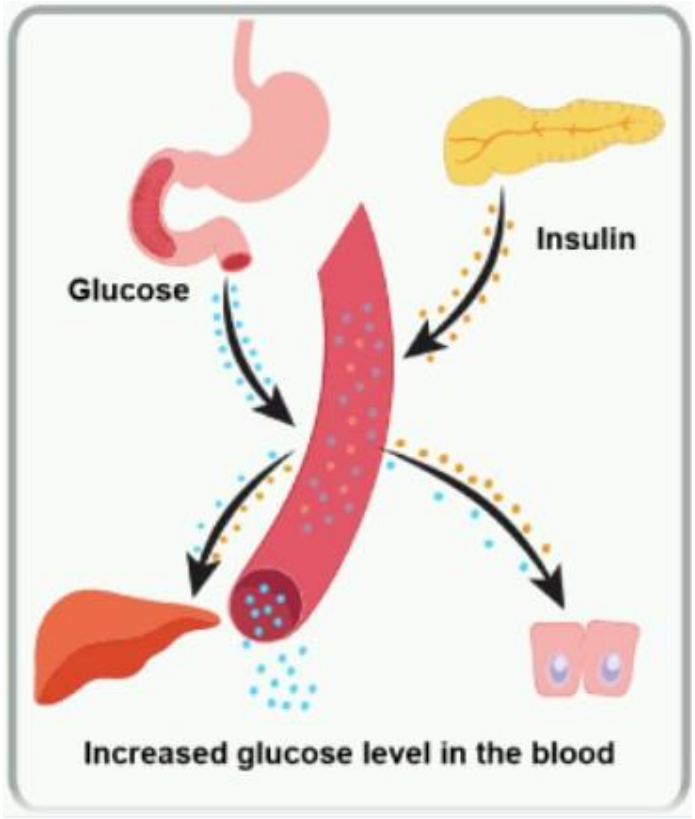
Starch Digestibility

Englyst et al.,1992





RDS



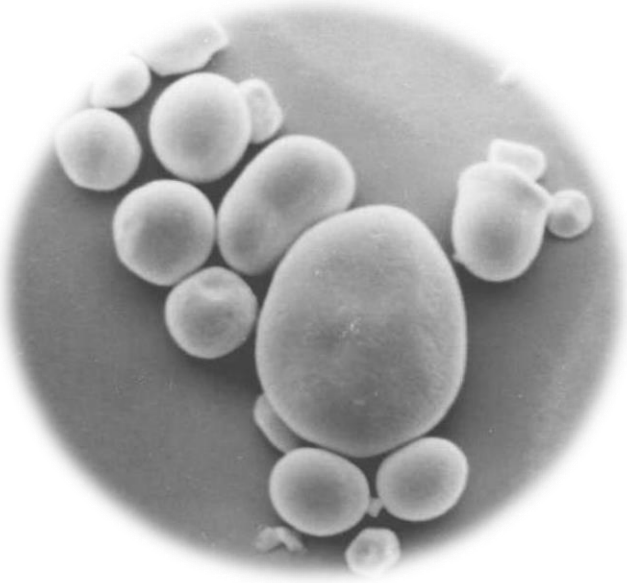
Health complications

Cardiovascular Diseases

Diabetes

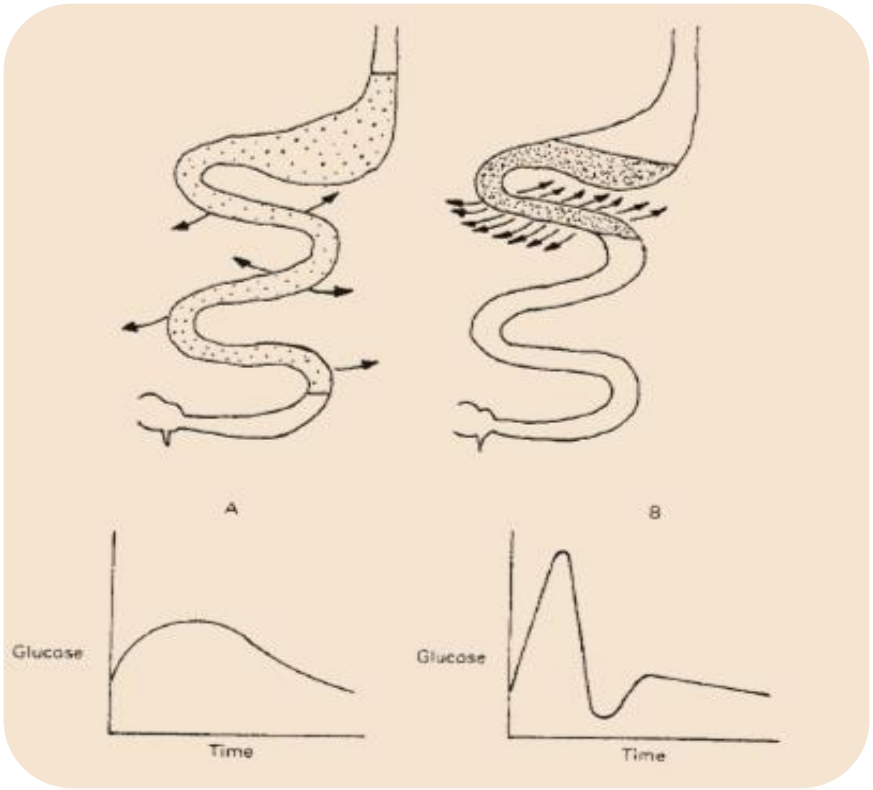
SDS

Cereals



Slow digestion

Postprandrial glucose response



Grandfeldt et al., 1995

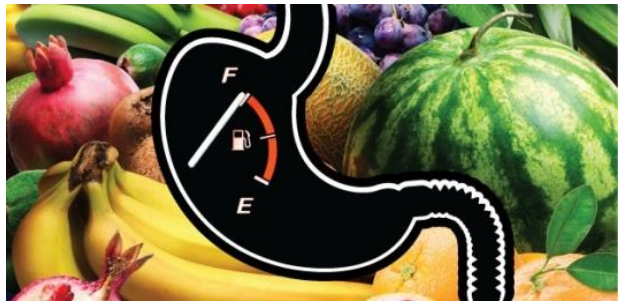
SDS

Sustainable glucose supply

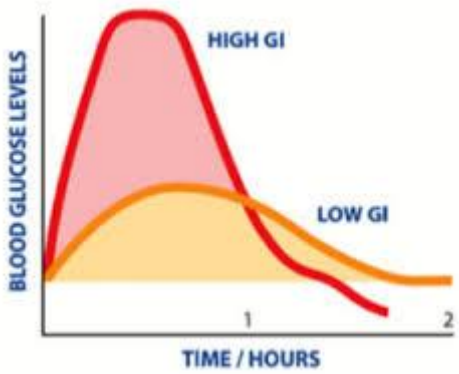
Hyperglycemia control and prevention

Foods containing SDS

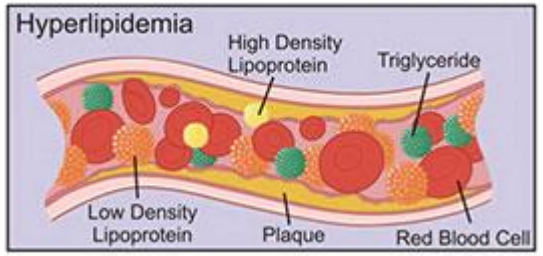
Satiety

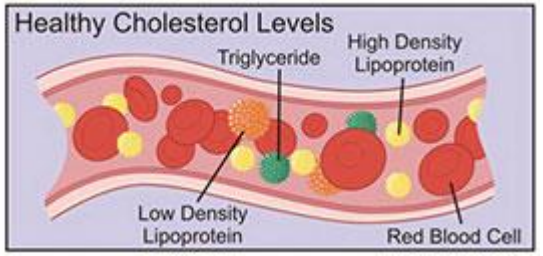


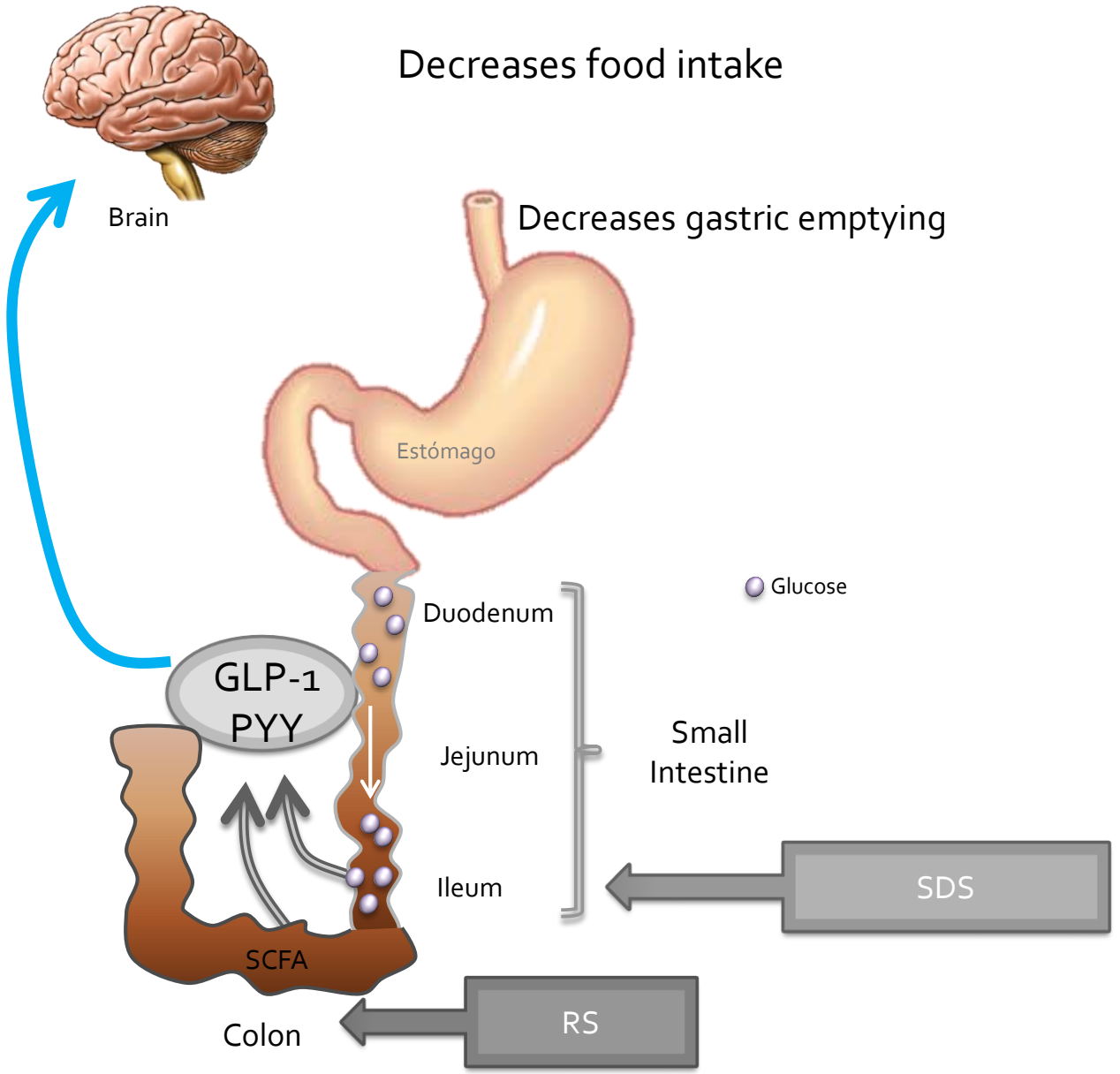
Glycemic Response



Controlled glucose levels



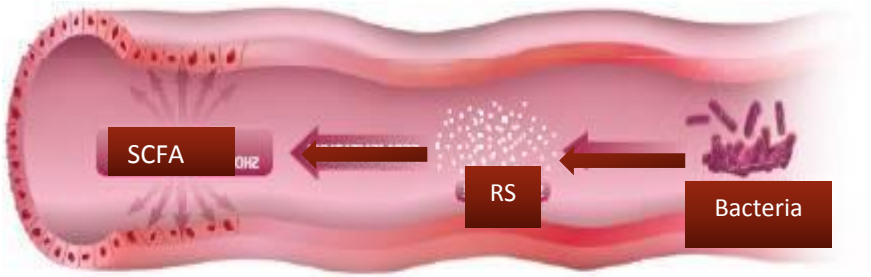




Lee et al., 2013

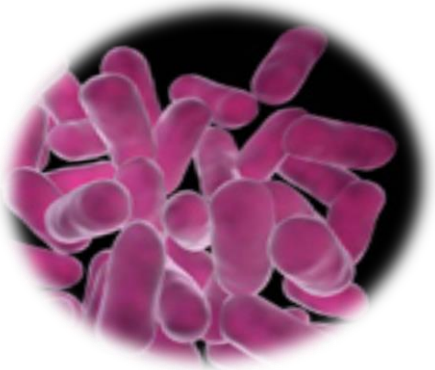
RS

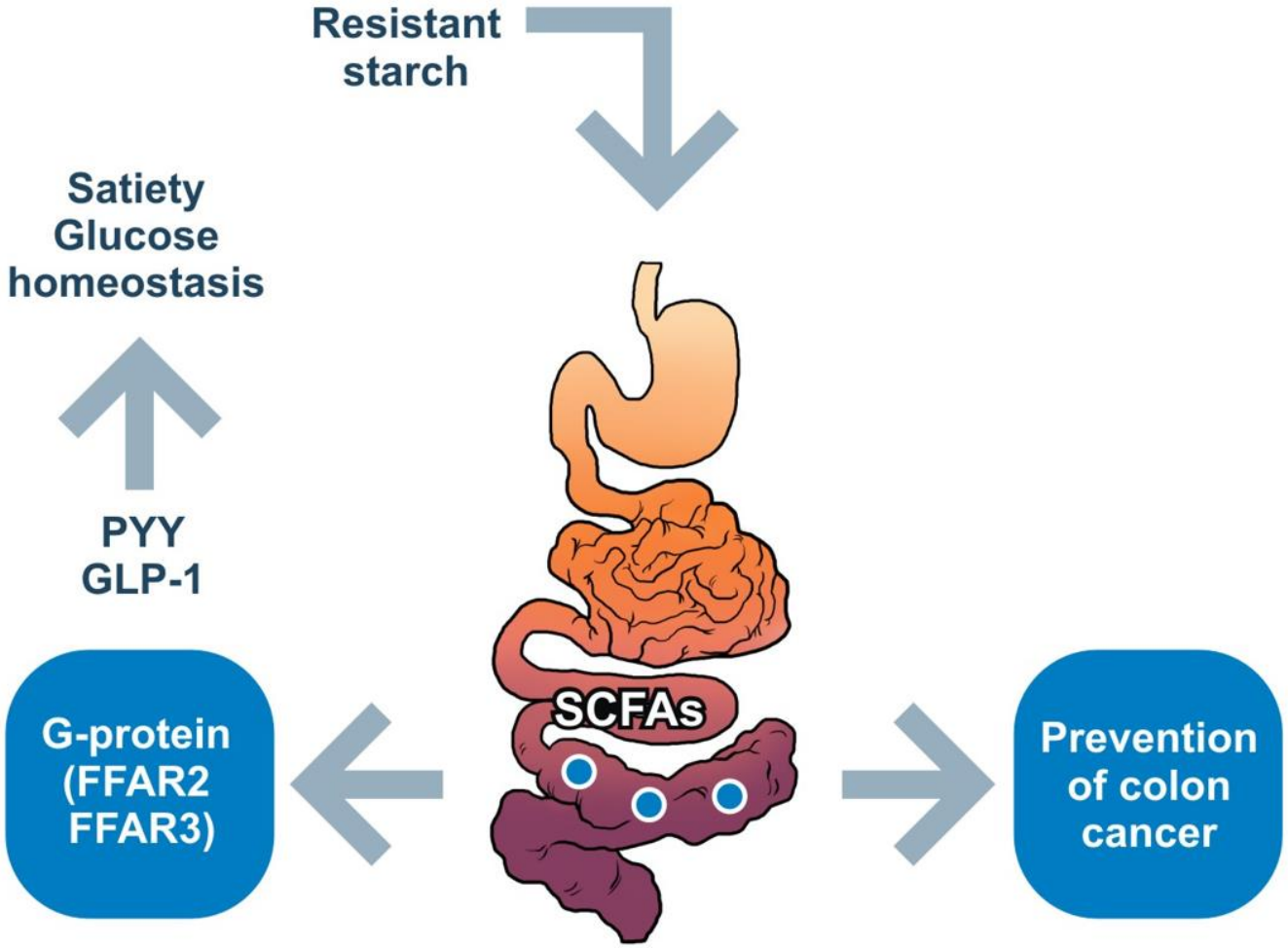
Fermentation



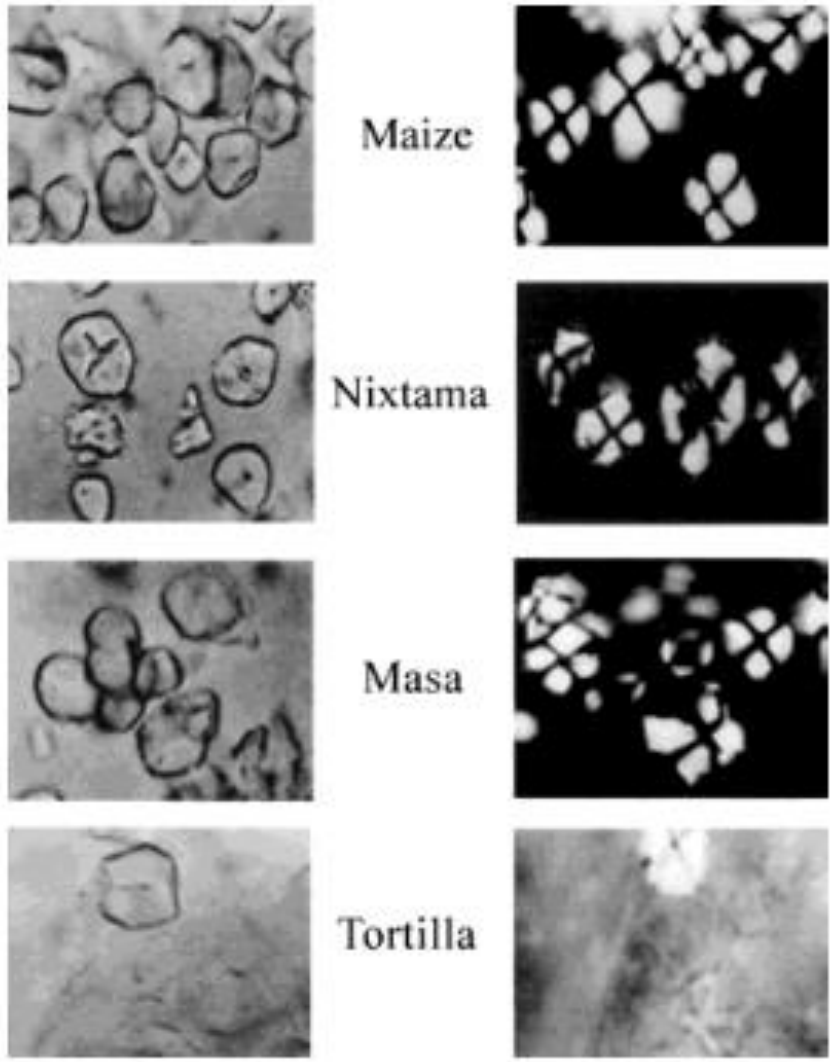
Selective bacterial growth

Prebiotic



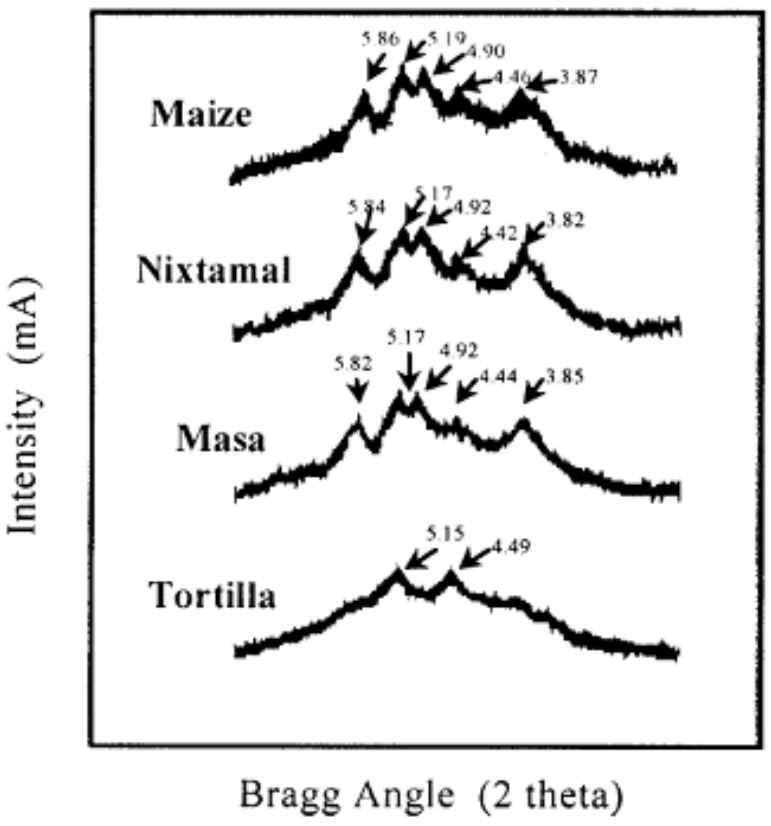

Resistant starch
Satiety
Glucose homeostasis
PYY
GLP-1
G-protein (FFAR2 FFAR3)
SCFAs
Prevention of colon cancer

CARBOHYDRATE DIGESTIBILITY IN CORN TORTILLAS



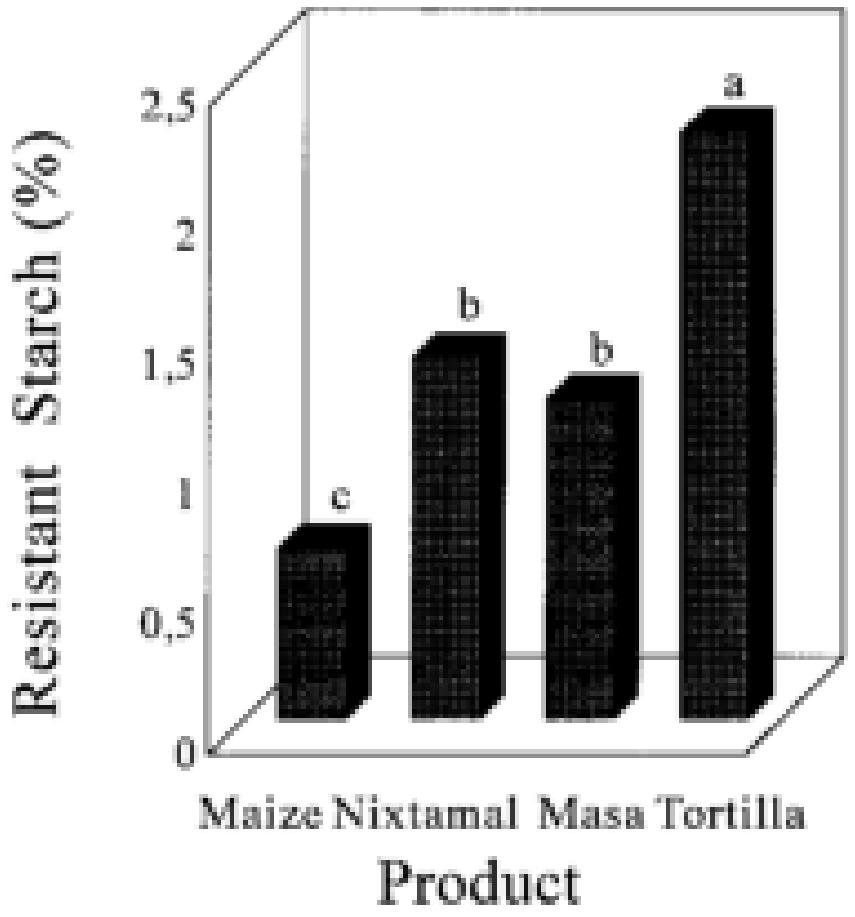
Starch granules in different steps of tortilla production

Campus-Baypoli et al. 1999



X-ray diffraction patterns in the different steps of tortilla production

Campus-Baypoli et al. 1999



Resistant starch in the different steps of tortilla production

Campus-Baypoli et al. 1999

Starch digestibility in the different steps of corn tortilla production

Sample	Available starch[a]	Resistant starch[b]	Retrograded resistant starch[c]	Reference
Maize	73.85	1.99	Nd	Rendón-Villalobos et al. (2002)
Nixtamal				
0	75.89	2.18	0.85	
24 h	71.31	2.47	0.82	
48 h	70.42	2.58	0.81	
72 h	70.2	2.6	0.72	
Masa				
0	79.64	2.05	0.65	
24 h	78.93	2.14	0.72	
48 h	76.99	2.25	0.85	
72 h	75.57	2.27	0.86	
Tortilla				
0	72.92	3.12	1.06	
24 h	72.83	3.27	1.79	
48 h	73.13	3.45	1.82	
72 h	70.97	3.87	1.84	

[a] Método de Holm et al. (1986).
[b] Método de Goñi et al. (1996).
[c] Método de Saura-Calixto et al. (1993).
Nd= no determinado

Digestible and resistant starch in the different steps of corn tortilla production (g/100g)

Sample	Digestible starch		Resistant starch	
	Costeño	Común	Costeño	Común
Maize	91.6±1.1	89.3±0.3	---	---
Masa	91.1±2.0	87.6±0.3	0.6±0.03	0.4±0.1
Tortilla	88.6±2.6	88.4±0.0	1.0±0.02	0.6±0.2
Stored Tortilla (5 days)	80.8±1.6	79.3±0.2	1.9±0.04	5.1±0.4
Stored Tortilla (10 days)	78.6±0.6	80.6±0.4	3.2±0.06	7.4±0.06

n=3 ± standard error

(Mora-Escobedo et al., 2004)

Starch digestibility in corn tortillas

Sample	Available starch[a]	Resistant starch[b]	Retrograded resistant starch[c]	pGI[d]	Reference
Commercial flour					Agama-Acevedo et al. (2004)
Comercial Mexicana®	76.5	1.38	Nd	Nd	
MASECA®	72.2	0.98	Nd	Nd	
MINSA®	75.0	1.29	Nd	Nd	
CICATA-IPN	75.0	1.80	Nd	Nd	
Control	73.0	3.10	1.10	108.5	Bello-Pérez et al. (2006)
Tortilla commercial masa	74.0	1.40	1.10	102.6	
Tortilla commercial flour	70.9	2.30	1.90	102.0	
Commercial tortilla	65.3	2.20	1.10	Nd	
Corn tortilla	65.2	2.14	1.05	75[e]	**Sáyago-Ayerdi et al. (2005)**
Tortilla mezcla de maíz/frijol 60/40 (Taco)	52.6	3.93	3.14	51	

pGI=predicted glycemic index; Nd = no determied
[a] Método de Holm et al. (1986)
[b] Método de Goñi et al. (1996)
[c] Método de Saura-Calixto et al. (1993)
[d] Glycemic index determined by Goñi et al. (1997)
[e] Glycemic index determined by Granfeldt et al. (1992)

Effect of endosperm type on texture and in vitro starch digestibility of maize tortillas

Table 3
Resistant starch (g/100 g tortilla) content of tortillas made with kernels of different endosperm[a].

Storage time (h)	Endosperm type		
	Floury	Intermediate	Vitreous
0	$4.4 \pm 0.1^{d,c,A}$	$3.2 \pm 0.0^{d,B}$	$4.0 \pm 0.4^{c,A}$
24	$4.5 \pm 0.1^{c,b,A}$	$3.6 \pm 0.2^{c,b,B}$	$5.2 \pm 0.3^{b,a,C}$
48	$4.6 \pm 0.1^{b,A}$	$3.8 \pm 0.1^{b,B}$	$5.5 \pm 0.3^{b,a,C}$
72	$4.7 \pm 0.2^{b,a,A}$	$3.8 \pm 0.1^{b,B}$	$5.6 \pm 0.2^{a,C}$
96	$4.9 \pm 0.3^{a,A}$	$4.4 \pm 0.3^{a,A}$	$5.6 \pm 0.1^{a,B}$

[a] Values with different lowercase letters in the same column and uppercase letters in the same row are statistically different ($p \leq 0.05$).

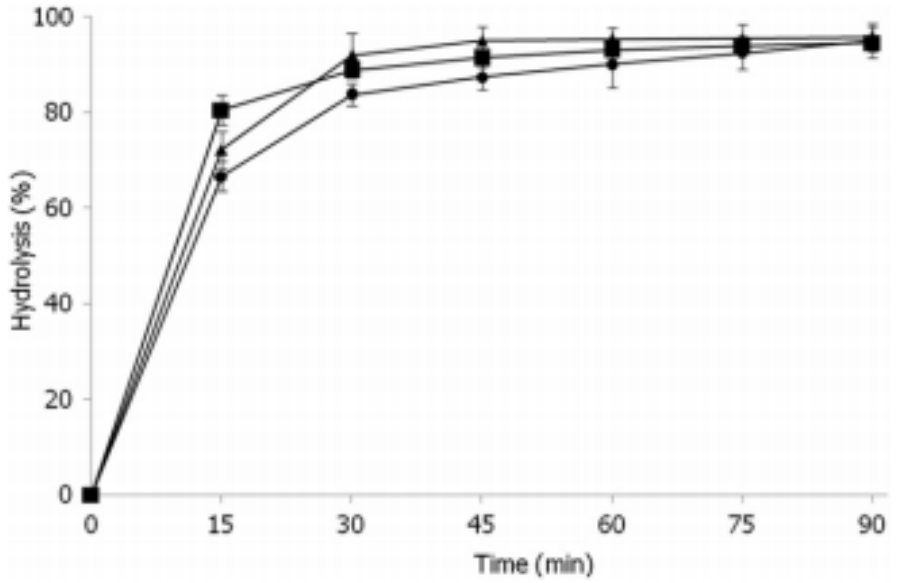


Fig. 1. *In vitro* enzymatic starch hydrolysis of fresh tortilla made with maize of different endosperm starch at 0 h, ■ floury, ▲ intermediate, ● vitreous.

Osorio-Díaz et al., 2011

Ecological nixtamalization process

Dietary fiber content in corn tortilla

Tortilla	Fiber	Insoluble	Soluble**
Traditional	12.93 ± 0.69	10.52 ± 0.76	2.41 ± 0.74
Ecological	16.90 ± 1.43	15.63 ± 1.58	1.27 ± 0.47
Commercial	12.60 ± 0.86	11.61 ± 1.44	0.99 ± 0.62

*Values are means ± estándar error r, n=3, dry basis.
**by difference

(Bello-Pérez et al., 2014)

STARCH DIGESTIBILITY OF CORN TORTILLA

Tortilla	Total Starch	Resistant Starch	Available Starch**
Traditional	63.99 ± 0.95	2.87 ± 0.15	61.11 ± 1.02
Ecological	63.16 ± 0.24	2.12 ± 0.09	61.04 ± 0.30
Commercial	66.50 ± 0.29	2.58 ± 0.17	63.92 ± 0.27

*Values are means ± estándar error r, n=3, dry basis.
**by difference

(Bello-Pérez et al., 2014)

Starch digestibility of corn tortilla (Englyst's test)

Tortilla	Total Starch	Rapidly digestible starch	Slowly digestible starch	Resistant starch**
Traditional	76.87 ± 0.94	52.60 ± 2.36	18.47 ± 1.77	5.79 ± 1.93
Ecological	79.88 ± 1.55	59.09 ± 2.77	12.41 ± 1.94	8.37 ± 1.57
Commercial	73.11 ± 3.61	57.78 ± 3.07	3.96 ± 3.31	11.36 ± 3.60
Stored for 96 h				
Traditional	76.87 ± 0.94	50.27 ± 1.61	41.62 ± 0.61	19.21 ± 1.63
Ecological	79.88 ± 1.55	49.58 ± 1.13	8.99 ± 1.66	21.29 ± 1.16
Commercial	73.11 ± 3.61	41.62 ± 0.61	13.86 ± 1.90	17.61 ± 3.69

*Values are means ± estándar error r, n=3, dry basis.
**by difference

(Bello-Pérez et al., 2014)

Predicted glycemic index (pGI) of corn tortilla

Tortilla	Hydrolysis index	pGI
White bread	100	94
Traditional	54.11 ± 2.37	55
Ecological	58.48 ± 3.92	59
Commercial	70.33 ± 2.97	69
96 h store		
Traditional	46.13 ± 3.15	48
Ecological	52.02 ± 2.92	53
Commercial	58.34 ± 3.18	59

(Bello-Pérez et al., 2014)

Resistant starch in tortillas with an ecological nixtamalization process

Chemical Composition of Samples from Selected Treatments[z]

Sample	Moisture	Lipids	Protein	Ash	IF	SF	TDF
Tortilla commercial flour	49.6a	4.0b	8.3ab	1.1ab	3.7d	1.7b	5.4d
Tortilla 0.8% $Ca(OH)_2$	46.1b	5.0a	7.9bc	1.3a	9.4c	2.7a	12.2c
Tortilla 0.4% $CaCO_3$	41.5c	5.1a	7.7c	0.8bc	15.3b	3.2a	18.7b
Tortilla 0.6% $CaSO_4$	45.3b	5.1a	8.6a	0.9bc	15.3b	2.8a	18.2b
Tortilla 0.6% $CaCl_2$	42.4c	5.3a	8.5a	0.7c	16.6a	3.1a	19.7a

[z] Means followed by the same letter in the same column are not significant different at $P < 0.05$. Data reported in %, dry basis. IF = insoluble fiber; SF = soluble fiber; and TDF = total dietary fiber.

Total, Resistant, and Available Starch of Samples from Selected Treatments[z]

Sample	TS	TRS	AS	RS3	Glycemic Index
Tortilla commercial flour	80.2a	3.4ab	76.8a	1.1ab	70.5b
Tortilla 0.8% $Ca(OH)_2$	77.9ab	3.1bc	74.8ab	1.3a	48.0c
Tortilla 0.4% $CaCO_3$	76.9b	3.0c	73.9ab	1.2a	66.0b
Tortilla 0.6% $CaSO_4$	75.0bc	2.8c	72.3b	1.0b	50.8c
Tortilla 0.6% $CaCl_2$	78.2c	3.8a	68.4c	1.0b	43.3c
Glucose solution	…	…	…	…	100.0a

[z] Means followed by the same letter in the same column are not significant different at $P < 0.05$. TS = total starch; TRS = total resistant starch; AS = available starch; and RS3 = resistant starch type 3.

Santiago-Ramos et al., 2015

Resistant starch in tortillas with an ecological nixtamalization process

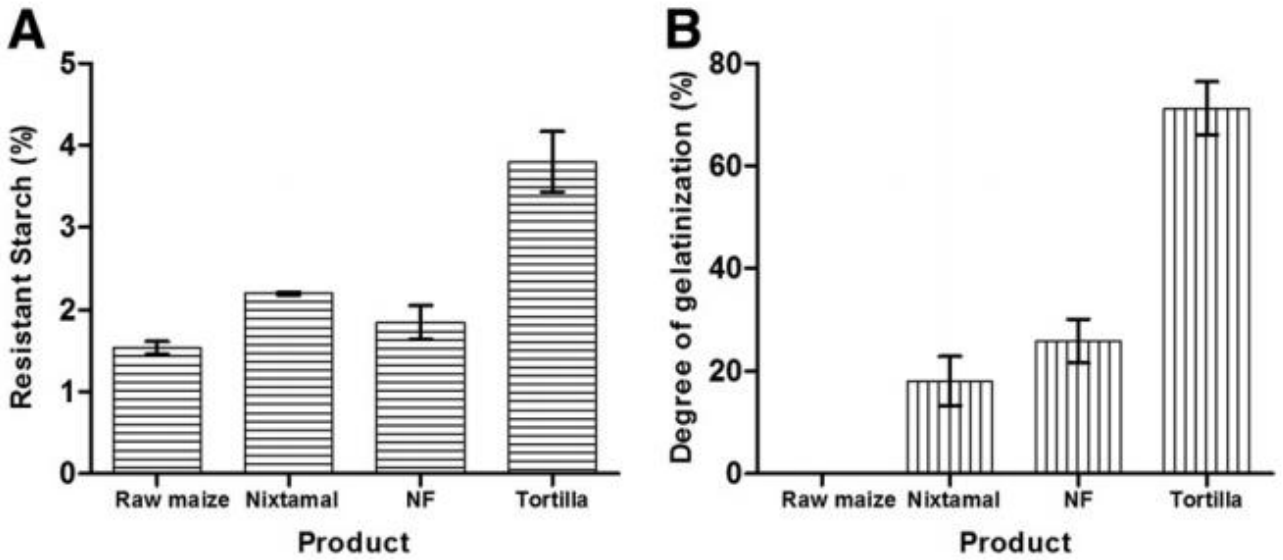


Fig. 1. A, Resistant starch content and **B,** degree of gelatinization in products from the ecological nixtamalization process with 0.6% $CaCl_2$. NF = nixtamalized flour.

Santiago-Ramos et al., 2015

Chemical composition and nutritional properties of maize, masa and totopo samples produced with different maize varieties

Sample	Protein (%)	Ash (%)	Lipids (%)	Crude Fiber (%)	CHO (%)	Energy (Kcal/100 g)	Energy (kJ/100 g)	RS (%)	TS (%)
Maize									
Zapalote Chico 1	7.0 ± 0.0ab	1.50 ± 0.00a	5.1 ± 0.1b	1.5 ± 0.0b	84.9 ± 0.1a	404 ± 1a	1,694 ± 3a	0.9 ± 0.0a	85.3 ± 1.9a
Zapalote Chico 2	7.4 ± 0.2a	1.40 ± 0.14ab	5.3 ± 0.0b	1.6 ± 0.0a	84.4 ± 0.0b	404 ± 0a	1,694 ± 1a	1.1 ± 0.3a	77.2 ± 0.6a
Tuxpeño	6.2 ± 0.4c	1.15 ± 0.07c	4.6 ± 0.1c	…	…	…	…	0.6 ± 0.4a	75.0 ± 2.9a
Chalqueño	6.7 ± 0.1b	1.30 ± 0.00abc	4.8 ± 0.1c	…	…	…	…	0.7 ± 0.0a	82.8 ± 8.4a
Hybrid	7.2 ± 0.0ab	1.25 ± 0.07bc	5.5 ± 0.1a	…	…	…	…	0.7 ± 0.0a	84.2 ± 0.6a
Masa									
Zapalote Chico 1	7.7 ± 0.0b	1.10 ± 0.00b	4.7 ± 0.0a	0.5 ± 0.1b	86.1 ± 0.1c	407 ± 0a	1,708 ± 1a	0.9 ± 0.1b	70.1 ± 0.1c
Zapalote Chico 2	8.5 ± 0.1a	1.20 ± 0.00ab	4.8 ± 0.2a	0.5 ± 0.1b	85.0 ± 0.0d	406 ± 1ab	1,702 ± 5ab	0.9 ± 0.0b	86.3 ± 0.9a
Tuxpeño	6.6 ± 0.2c	1.10 ± 0.014b	4.1 ± 0.1b	0.5 ± 0.1b	87.6 ± 0.6a	405 ± 1b	1,700 ± 3b	1.0 ± 0.1b	83.6 ± 0.8b
Chalqueño	7.7 ± 0.2b	1.15 ± 0.07ab	4.1 ± 0.2b	0.4 ± 0.0b	86.7 ± 0.0b	405 ± 1b	1,697 ± 4b	0.9 ± 0.0b	81.9 ± 1.4b
Hybrid	7.8 ± 0.0b	1.39 ± 0.13a	3.9 ± 0.1b	0.3 ± 0.1b	86.6 ± 0.0b	403 ± 1c	1,688 ± 3c	1.0 ± 0.0b	87.5 ± 1.5a
San Blas	6.7 ± 0.1c	1.10 ± 0.14b	3.5 ± 0.0c	1.3 ± 0.1a	87.5 ± 0.1a	400 ± 1d	1,677 ± 3d	1.5 ± 0.2a	82.2 ± 0.0b
Totopo									
Zapalote Chico 1	8.0 ± 0.0a	1.30 ± 0.00bc	3.4 ± 0.3abc	0.4 ± 0.1de	86.9 ± 0.1b	400 ± 2a	1,677 ± 8a	1.9 ± 0.0a	69.1 ± 1.5bc
Zapalote Chico 2	8.5 ± 0.4a	1.20 ± 0.00bc	3.4 ± 0.4abc	0.5 ± 0.1d	86.6 ± 0.3b	400 ± 2a	1,676 ± 7a	1.3 ± 0.0cd	90.2 ± 0.2a
Tuxpeño	7.6 ± 0.1ab	1.10 ± 0.14bc	2.7 ± 0.4c	0.4 ± 0.0e	88.2 ± 0.1a	398 ± 2a	1,672 ± 10a	1.2 ± 0.3de	65.6 ± 0.7bcd
Chalqueño	7.8 ± 0.2b	1.15 ± 0.21bc	3.5 ± 0.5abc	0.7 ± 0.0c	86.9 ± 0.4b	401 ± 3a	1,680 ± 11a	1.2 ± 0.1de	64.4 ± 4.4cd
Hybrid	7.2 ± 0.3c	1.05 ± 0.07c	4.1 ± 0.4a	…	…	…	…	1.0 ± 0.0e	65.0 ± 0.4bcd
San Blas	…	1.35 ± 0.08b	3.0 ± 0.2bc	0.8 ± 0.0b	…	…	…	1.7 ± 0.0ab	70.3 ± 0.9b
Tehuantepec	…	1.75 ± 0.07a	3.6 ± 0.1ab	0.9 ± 0.0a	…	…	…	1.6 ± 0.1bc	61.7 ± 3.1d

[z] Data reported in dry basis. CHO = carbohydrates; RS = resistant starch; and TS = total starch. Means ($n = 2$) ± standard deviations followed by the same letter in the same column within the same group are not significantly different at $P < 0.05$. San Blas and Tehuantepec were masa and totopos made by local women in the Isthmus of Tehuantepec region. RS and TS were measured by Megazyme TS and RS kits. RS was adjusted by the TS used.

Gonzalez-Amaro et al., 2017

Future trends……

Since maize tortillas are still a major staple in Mexican dietary pattern, there is a strong motivation for exploring tortillas with reduced glycemic index.

Future trends……

Pigmented maizes

Anthocyanins and polyphenols

Starch digestibility

Thank you