CENTRO DE INVESTIGACIÓN Y DE ESTUDIOS AVANZADOS
DEL INSTITUTO POLITÉCNICO NACIONAL

UNIDAD QUERÉTARO

APPLICATION OF SECOND FICK´S LAW TO STUDY THE MECHANISM OF OIL UPTAKE AND LOSS WATER DURING DEEP-FAT FRYING OF TORTILLA CHIPS

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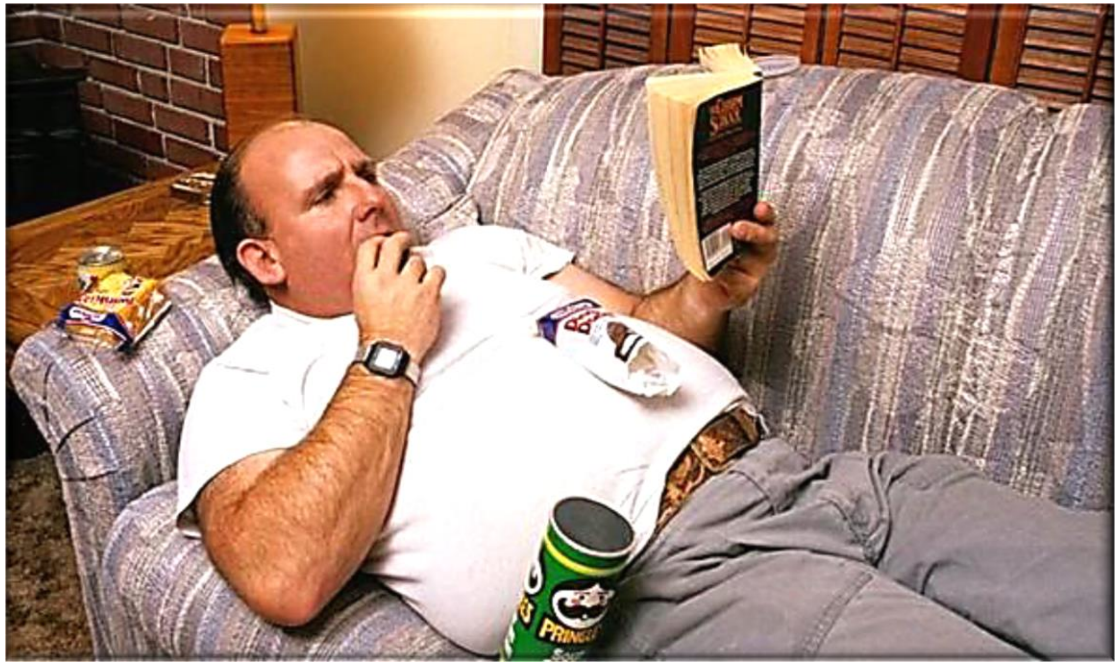
12 March, 2018

Outline

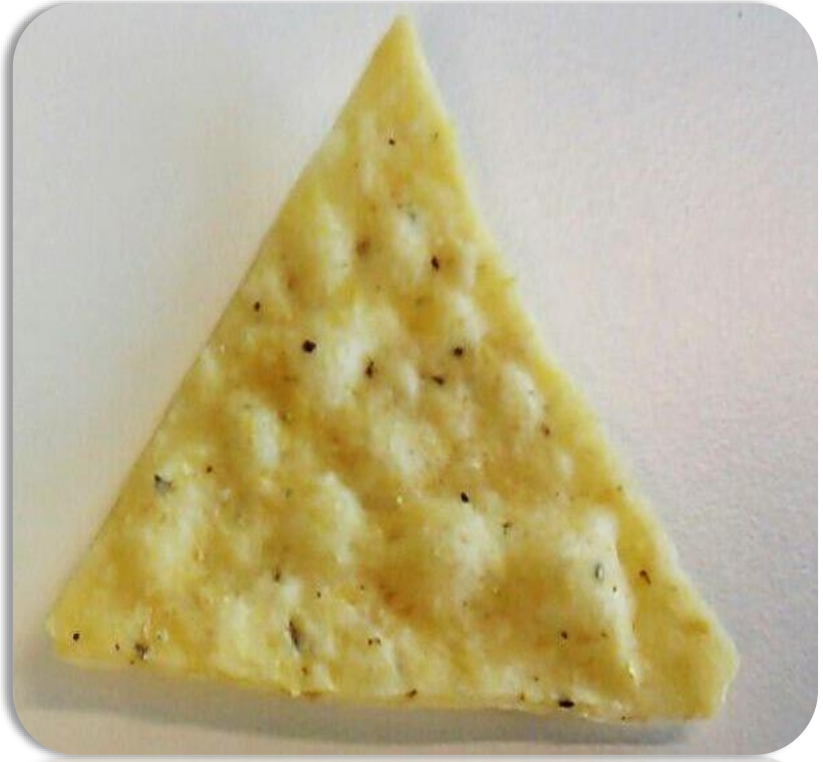
- Overweight and Obesity
- Evaluation processes with second Fick´s law
- Materials and Methods
- Results
- Conclusions

Overweight and Obesity



The overweight and obesity in Mexico is now a global epidemic

Reduction fat content in tortilla chips



The elaboration of tortilla chips is principally using the traditional nixtamalization,

Fraying the oil absorption is a multifactorial problem system

- The genotype
- Initial Moisture from tortilla chips
- Frying temperature
- Frying time
- **Particle size**
- **Nixtamalization process**

Materials

Commercial Maize

Calcium hidroxide (Alquimia Mexicana S.A)

Process to make tortilla chip


Spaghetti Squash Nachos

Traditional 1% Lime

Cooking corn only water

Commercial corn → Nixtamalization → Grinding **(masa)**

Chips and Baked (260 C° with IR 15 s)

Frying **(at 185 °C)**

Time (s)
S/N
5
10
15
30
60

% **Oil** absorption

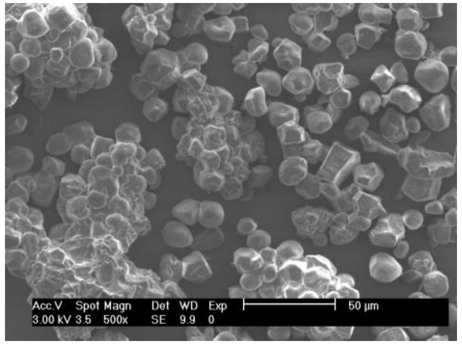
% **Moisture** content

Process to make tortilla chip with different particle sizes

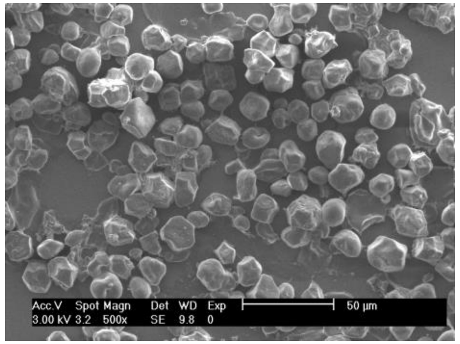
Commercial *Maize* → Traditional Nixtamalization 1 % Lime → Grinding (masa) → Molding tortilla chips and Baked **(260 C° with 15-15-10 each side)** → Frying (at 185 °c) → Times (s) S/N frying 5 10 15 30 60 → % Oil absorption; % Moisture content

Grinding (masa) → Drying sample masa at room temperatura → **Fine particle size (500 µm)**; **Coarse particle size (600 µm)**

Coarse. Average particle size (600 µm)



Fine. Average particle size (500 µm)



Methods

Particle size, Moreira et al., 1997

Moisture, 14-19.01 AACCI, 2010

Oil content, Acid method, 30-10.01 AACCI, 2010

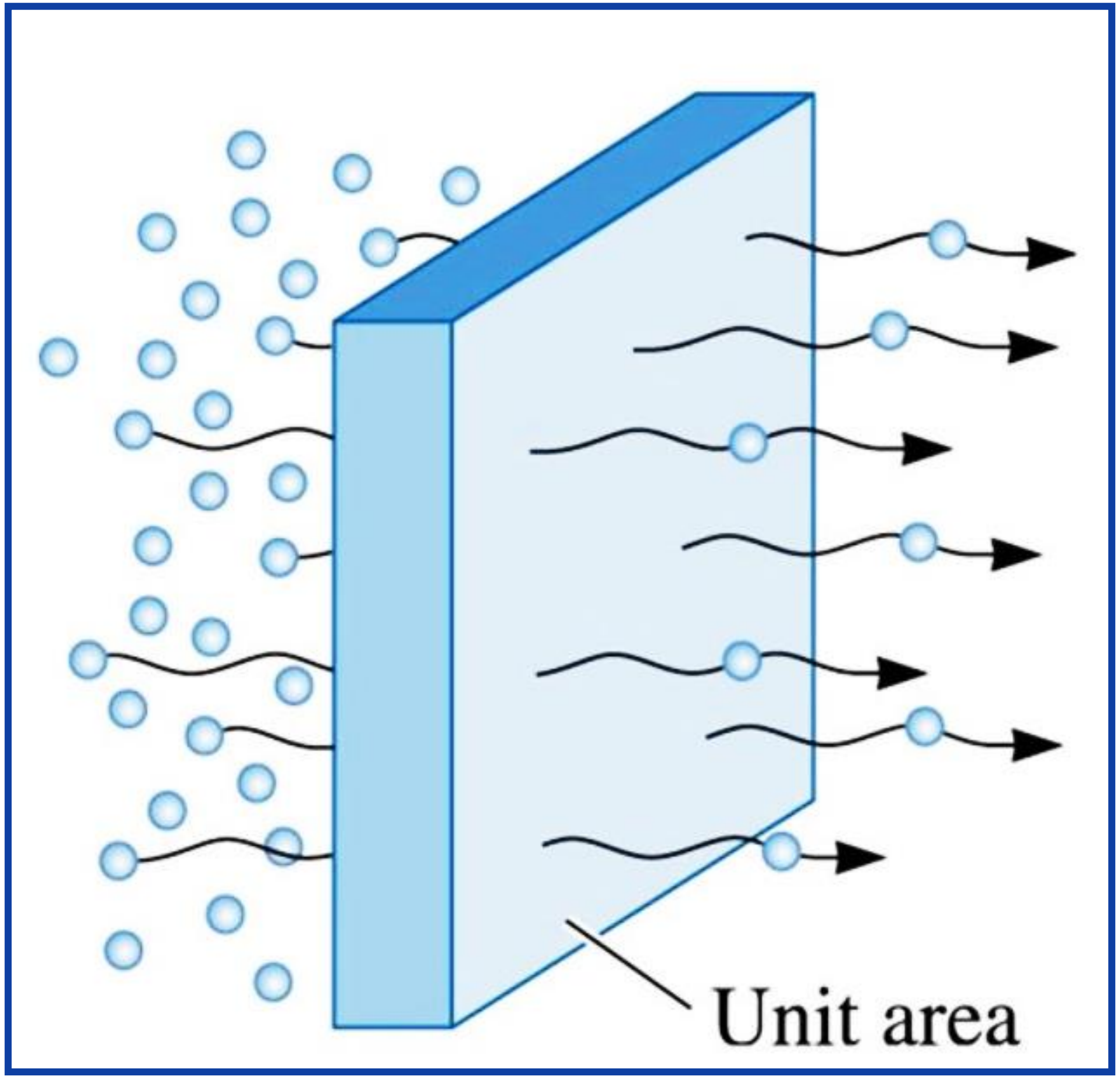
SECOND FICK´S LAW

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2}$$

- Nixtamalization
- Particle sizes

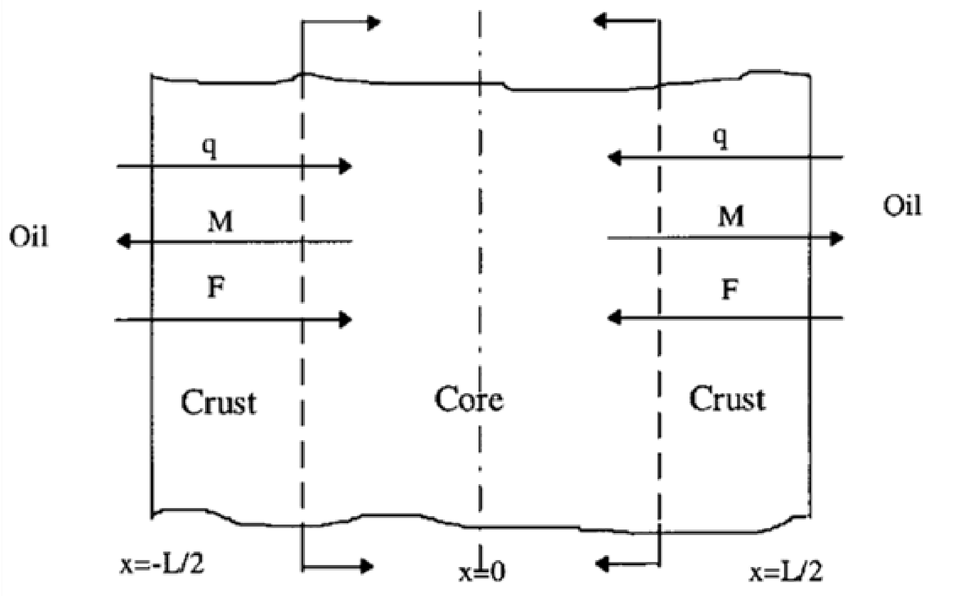
D

- Loss water
- Oil absorption



Equation from second Fick´s law

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2} \qquad (1)$$



l= Thickness

Chen and Moreira, 1997

Initial conditions:

t =0	$-l/2 < X < l/2$	$C = C_0$
t > 0	$X = \pm l/2$	$C = C_1$

The solution to second Fick´s law in the form of a trigonometric series under the above specified condition is (Crank, 1975):

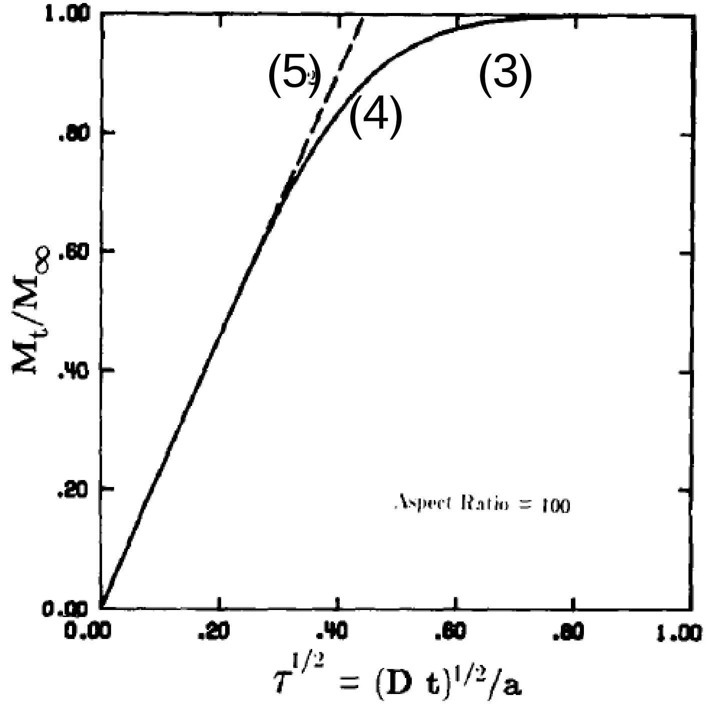
$$\frac{M_t}{M_\infty} = 1 - \sum_{n=0}^{\infty} \frac{8}{(2n+1)^2\pi^2} exp\left(\frac{-D\,(2n+1)^2\pi^2}{4l^2}\,t\right) \qquad (2)$$

An alternative solution to Eq. (2) is given in the form of an error fuction series:

$$\frac{M_t}{M_\infty} = \left[\frac{Dt}{l^2}\right]^{\frac{1}{2}} \left[\frac{1}{\pi^2} + 2\sum_{n=1}^{\infty}(-1)^n \ ierfc\ \frac{nl}{2\sqrt{Dt}}\right] \quad (3)$$

For short time, Eq. (3) can be approximated by:

$$\frac{M_t}{M_\infty} = 4\left[\frac{Dt}{\pi l^2}\right]^{\frac{1}{2}} \quad (4)$$



Eq. (4) can be interpreter as **Power Law**

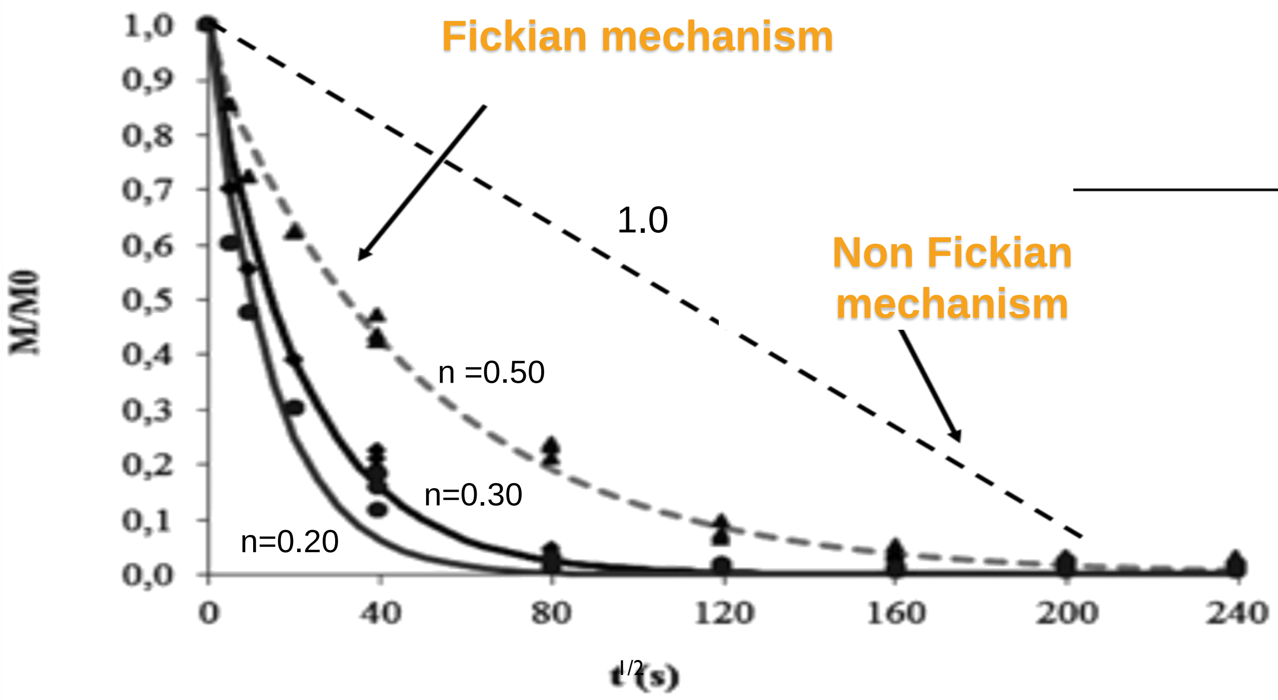
$$\frac{M_t}{M_\infty} = Kt^n \quad \text{or} \quad \frac{M_t}{M_\infty} = K_1 + K_2t^n \quad (5)$$

(Peppas and Ritger, 1985)

Exponent diffusion

$$\frac{M_t}{M_\infty} = K_1 + K_2 t^n$$

Loss Water



Difussional exponent and mechanism of diffusional

Diffusional exponent, n	Release mechanism
Thin slab	
0.5	Fickian diffusion
0.5<n<1.0	Non-Fickian transport
1	Zero orden release

Ortega, A., 2014

Software

WolframAlpha

$$\frac{M_t}{M_\infty} = 1 - \sum_{n=0}^{\infty} \frac{8}{(2n+1)^2\pi^2} exp\left(\frac{-D\,(2n+1)^2\pi^2}{4l^2}\, t\right)$$

GraphPad PRISM

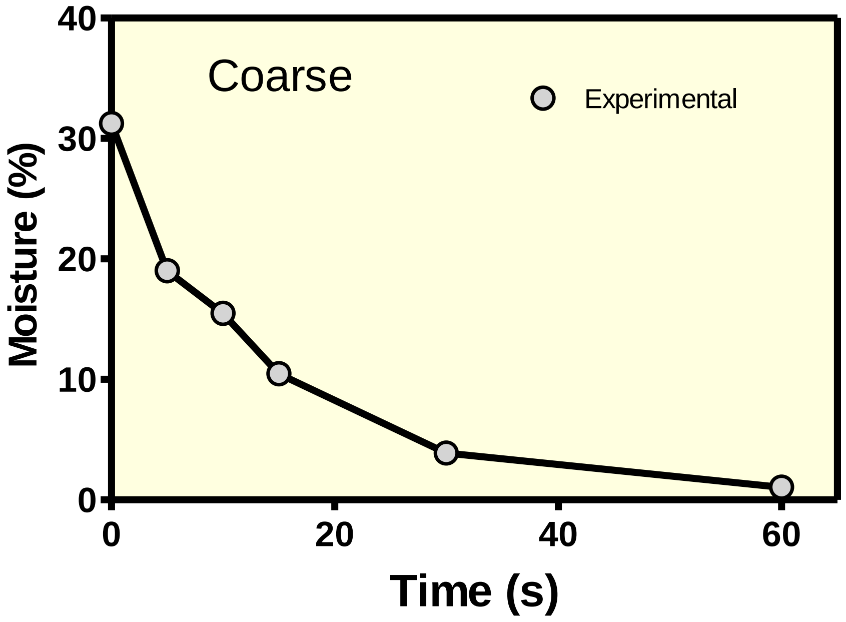
VERSIONE 6

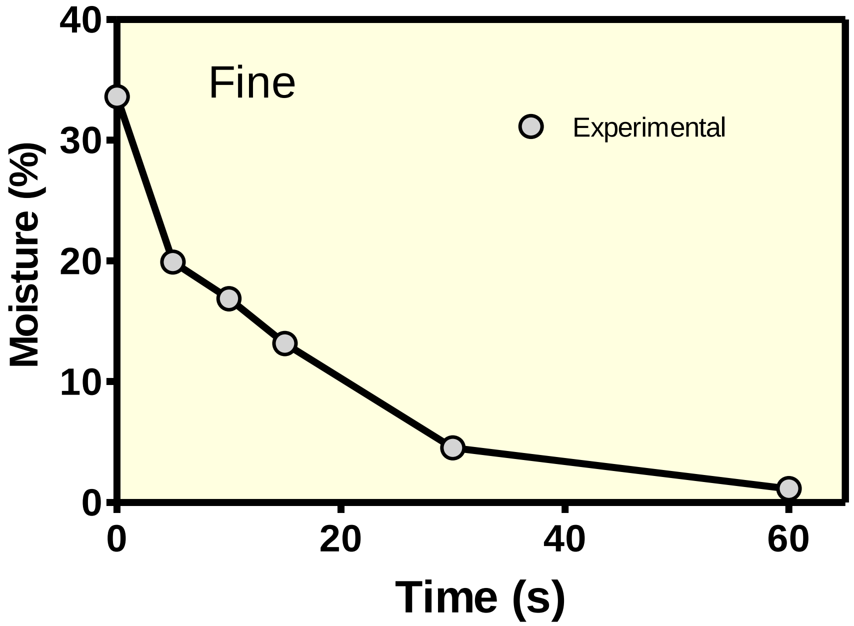
$$\frac{M_t}{M_\infty} = Kt^n$$

$$\frac{M_t}{M_\infty} = K_1 + K_2t^n$$

RESULTS

Loss water during frying chip with different particle sizes





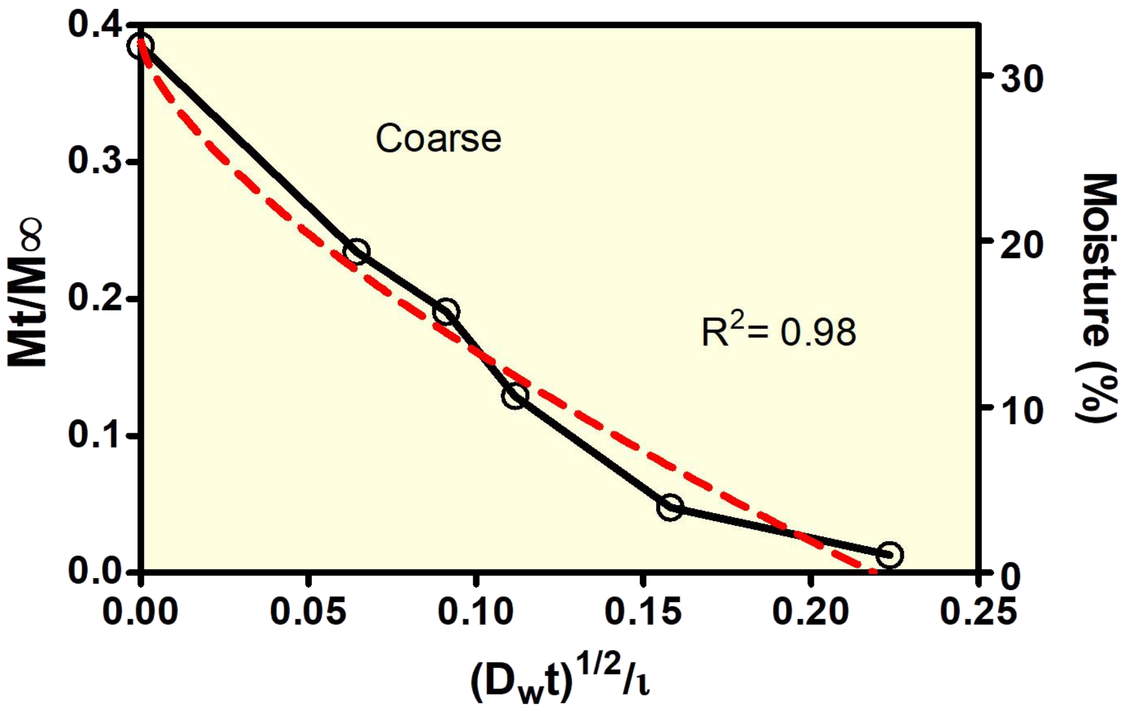
Use power law in the loss water during deep frying chip

$$\frac{M_t}{M_\infty} = 1 - \sum_{n=0}^{\infty} \frac{8}{(2n+1)^2\pi^2} exp\left(\frac{-D\,(2n+1)^2\pi^2}{4l^2}\,t\right)$$

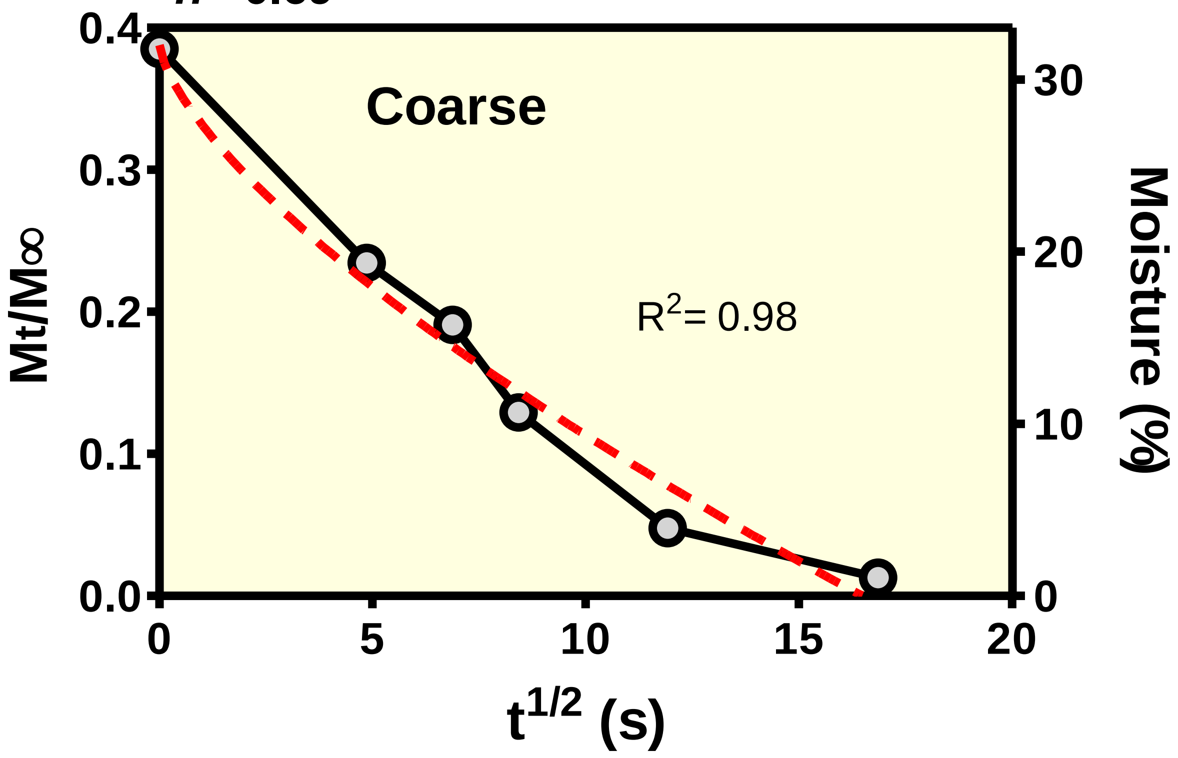
$$\frac{M_t}{M_\infty} = K_1 + K_2 t^n$$

n= 0.70

Dw= 1.14X10^{-5} m^2/s



n= 0.69



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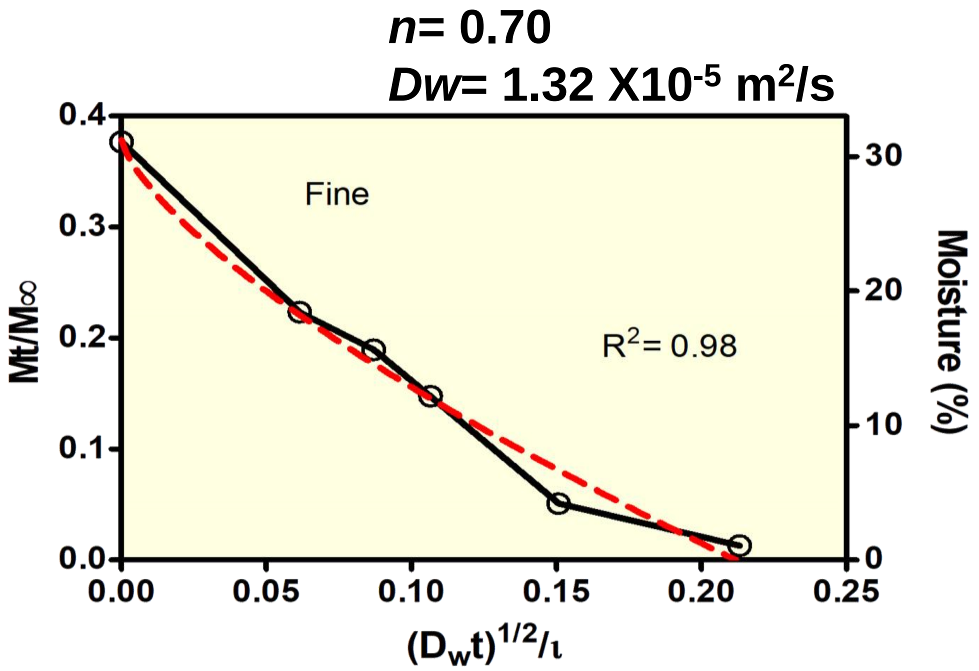
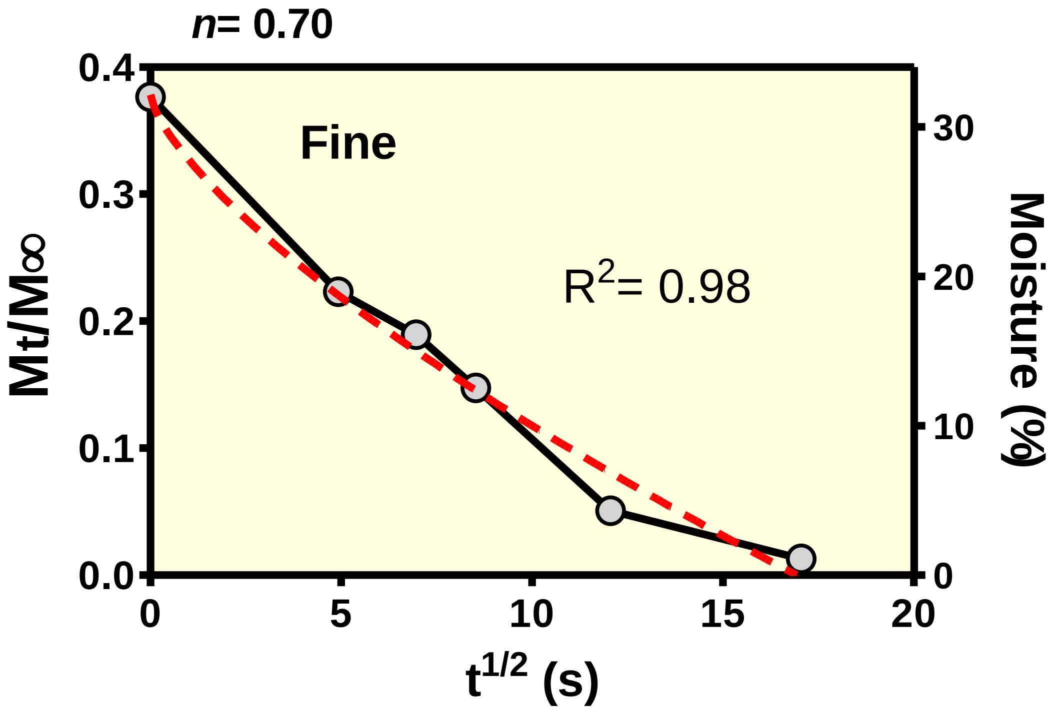
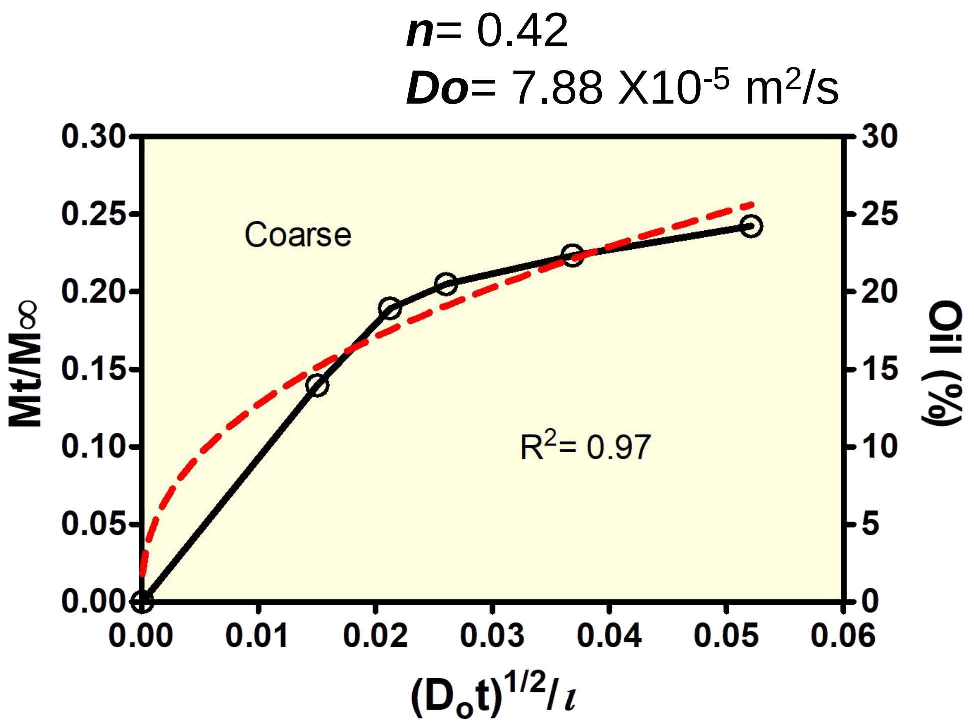
$$\frac{M_t}{M_\infty} = K_1 + K_2 t^n$$

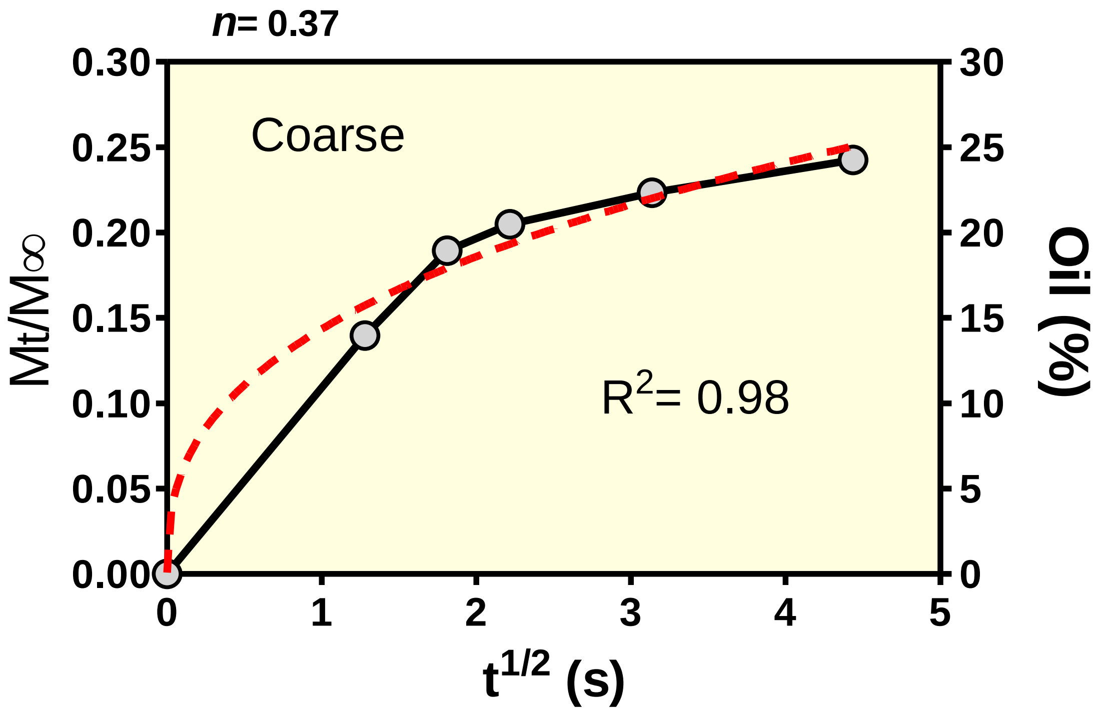




Oil absorption during deep frying chip with different masa particle sizes

$$\frac{M_t}{M_\infty} = Kt^n$$





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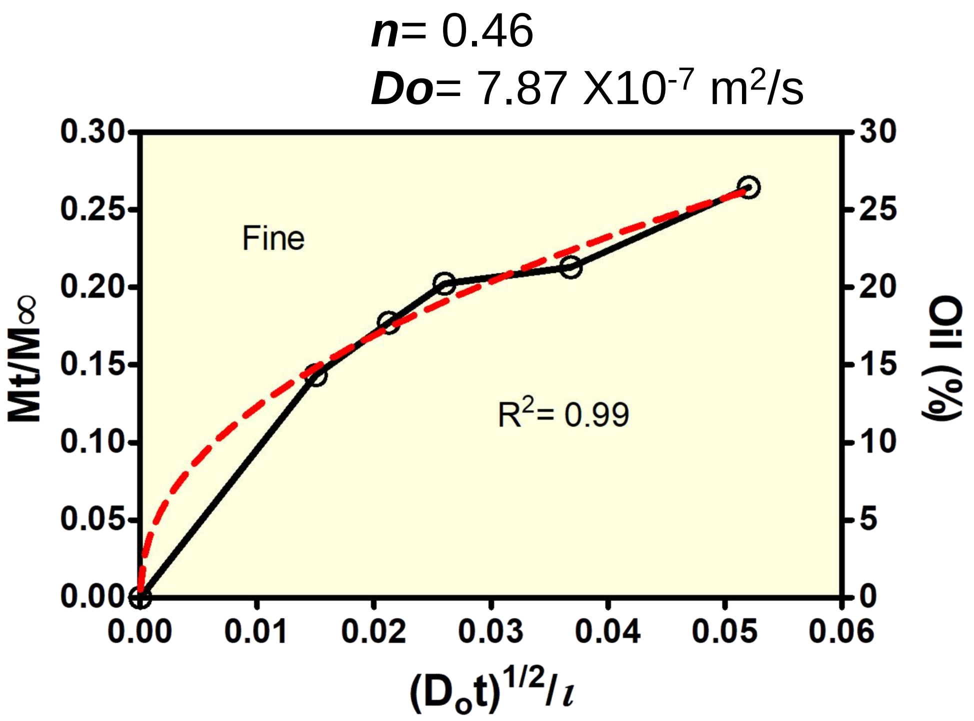
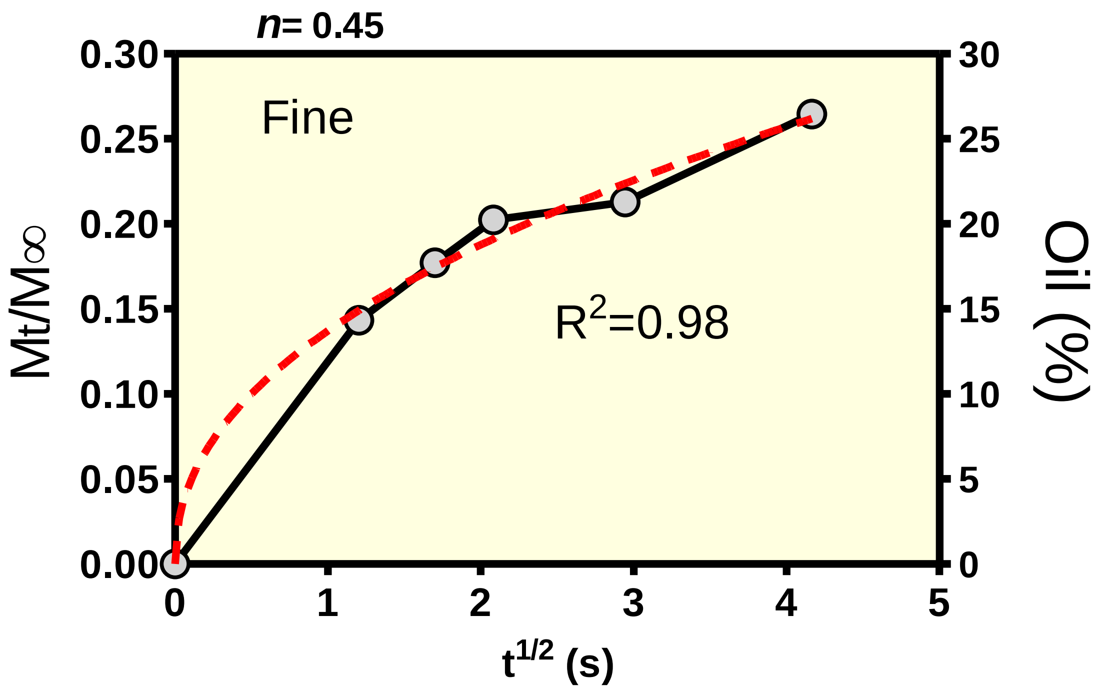
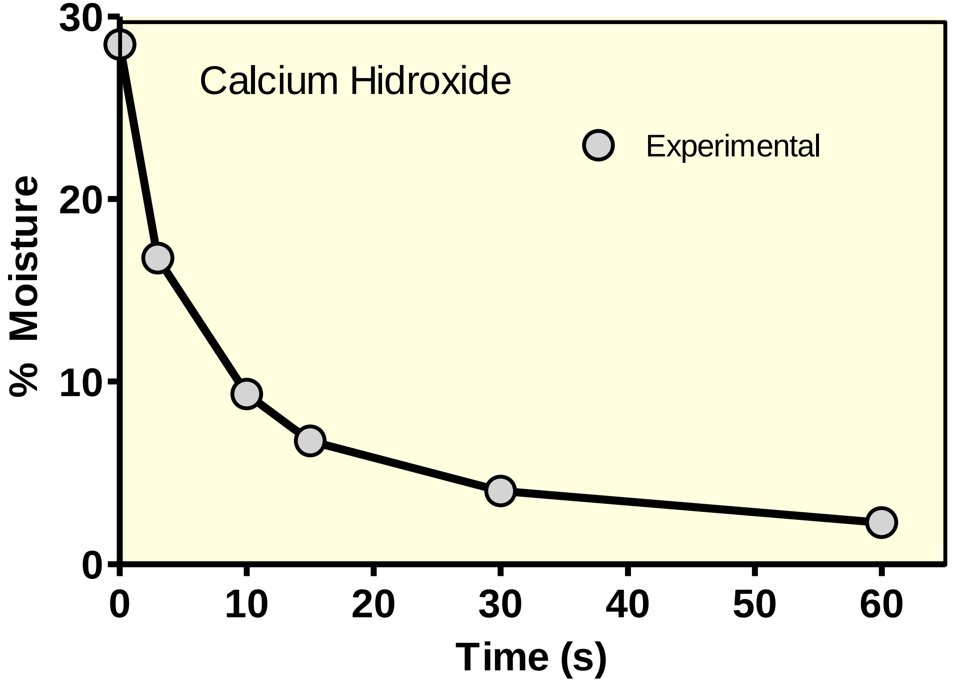
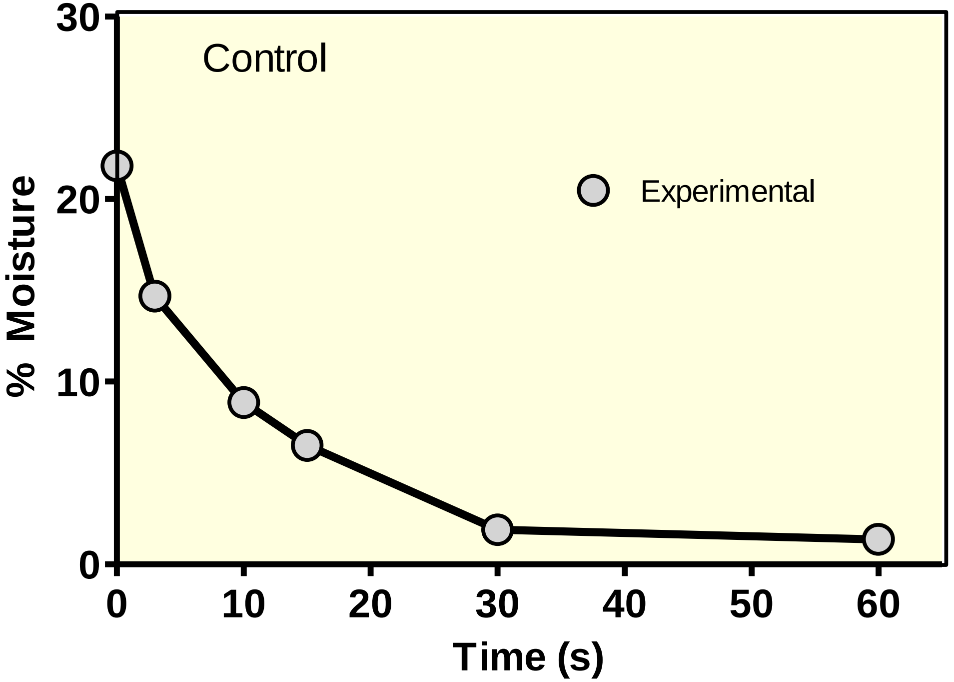




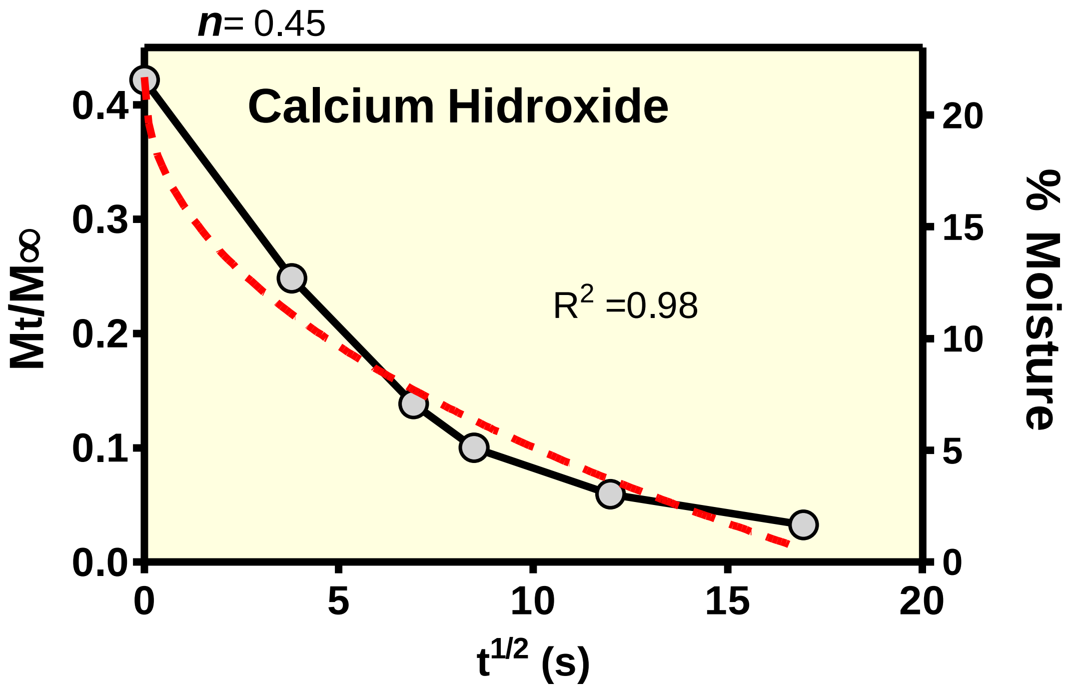
Loss water during deep frying tortilla chip from different nixtamalization

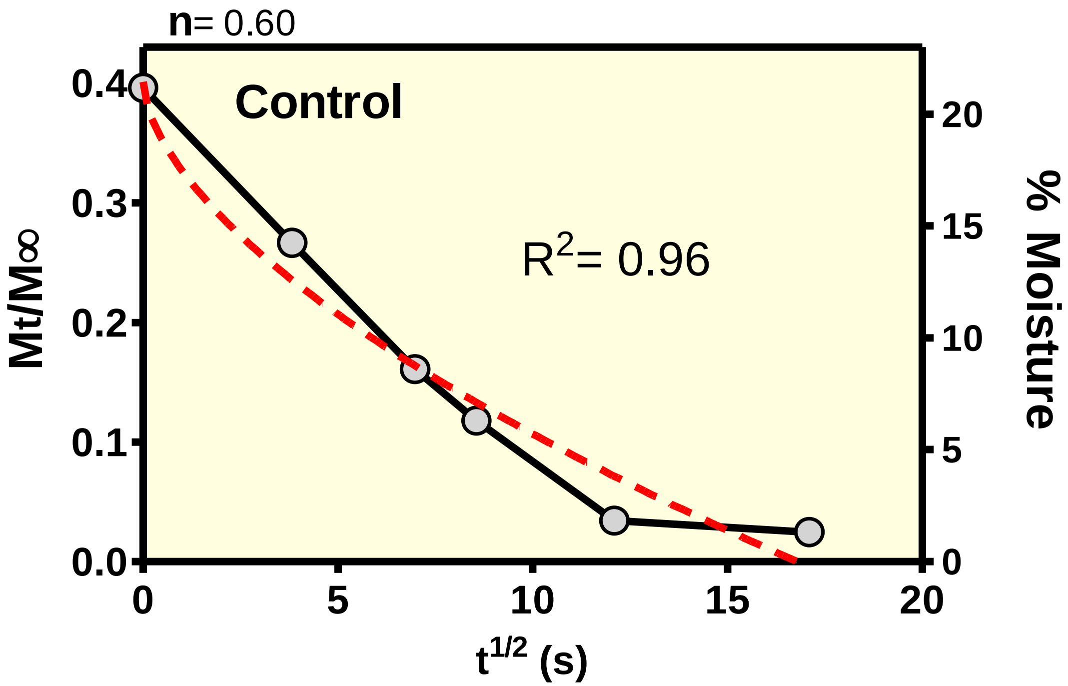




Application of power law model for losing water during the deep-frying

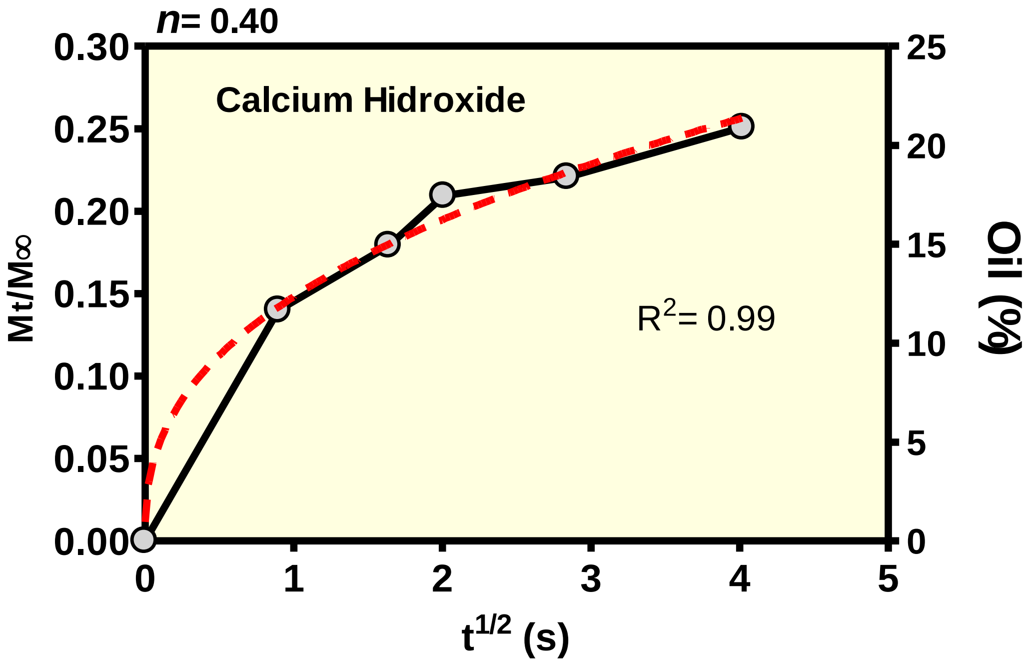
$$\frac{M_t}{M_\infty} = K_1 + Kt^n$$

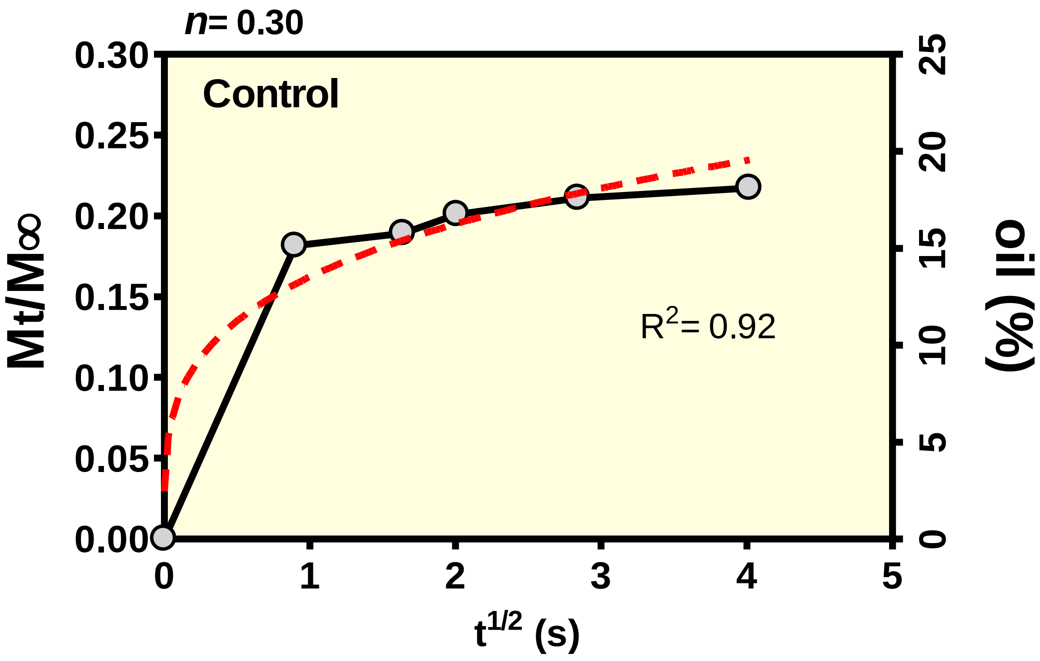




Use power law in oil absorption

$$\frac{M_t}{M_\infty} = Kt^n$$





Treatment	Water Losses (n)	Oil Absorption (n)
Control cooking	0.60 R^2 = 0.96	0.30 R^2 = 0.92
Traditional nixt.	0.45 R^2 = 0.98	0.40 R^2 = 0.99
Coarse particle	0.70 R^2 = 0.98	0.37 R^2 = 0.98
Fine particle	0.70 R^2 = 0.99	0.45 R^2 = 0.99

Difussional exponent and mechanism of diffusional

Diffusional exponent, n	Mechanism diffusion
Thin slab	
0.5	Fickian diffusion
0.5<n<1.0	Non-Fickian transport
1.0	Zero orden release

Closing remarks

1. Simple model to describe Fickian water loss and oil uptake in frying chips is proposed.
2. Exponent **n** of $M_t/M_\infty=kt^n$ indicates Fickian mechanism affected by physical and chemical factors.
3. Although oil is an important parameter, there is a lack of information on its diffusion mechanism.

Thank you

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4th ICC Latin American Cereals Conference

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