Tropical fruits from Solanaceae family as source of functional foods

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Universidad Nacional de Colombia was founded in 1867 as the first and biggest public university in Colombia.

Faculty of Engineering Building, 1978

It is the most important university of the country and has the largest offering of academic programs.

As the main university of the nation, its aim is to promote equitable access to higher education studies for Colombians.

León de Greiff Auditorium, 2012

Bogotá, 1940

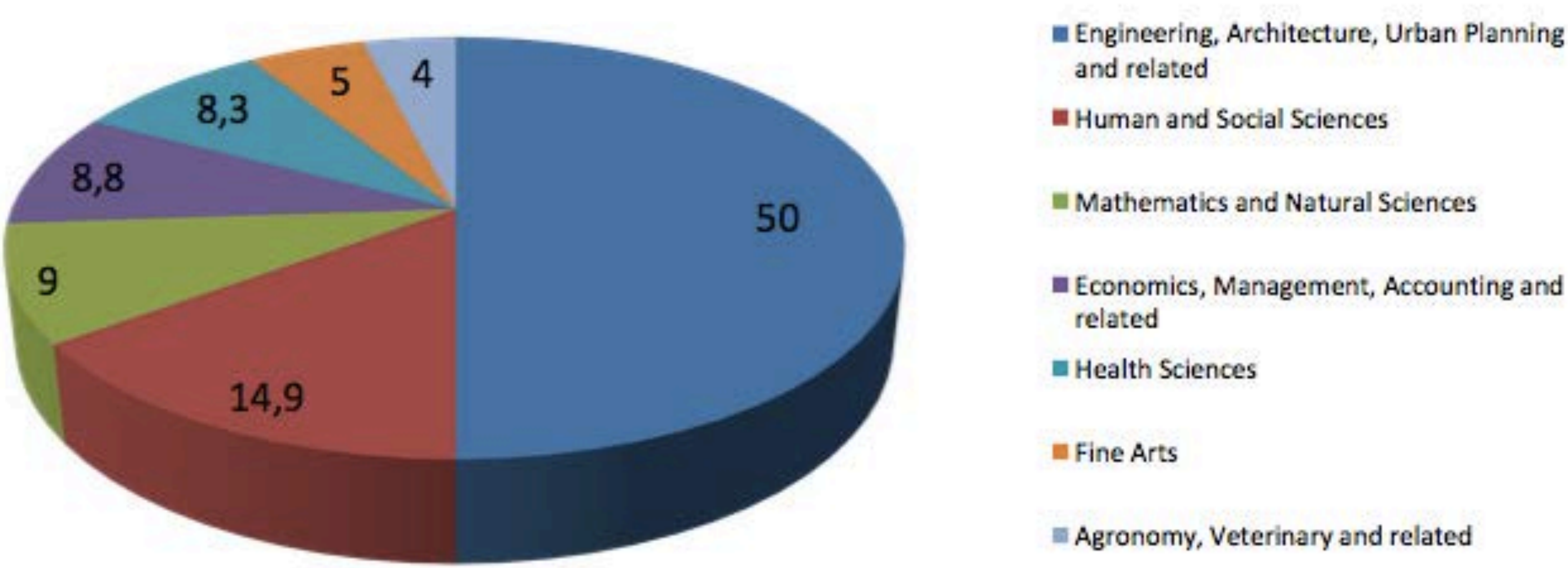
Campuses

Responding to their national character, the University has eight campuses.

Bogotá	
Medellín	Leticia
Manizales	San Andrés
Palmira	Arauca
	Tumaco

Undergraduate students enrolled

% students per Knowledge area (2015)



Total undergraduate students (2015): 43.184

“Increasing fruit and vegetable consumption is a major public health challenge at the moment”

COLOMBIA has a huge biodiversity

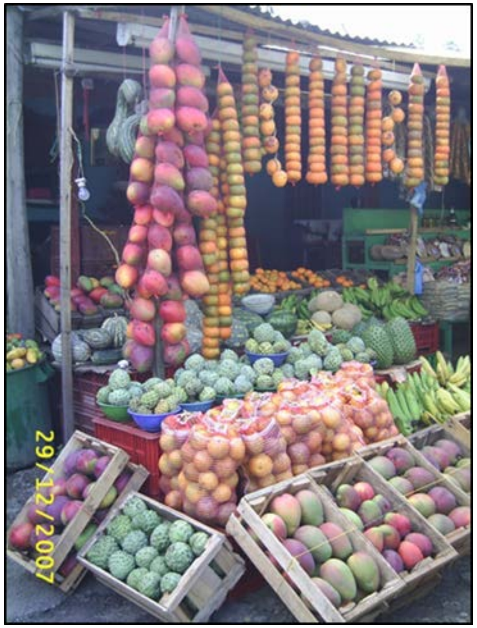
* Source of vitamins and minerals: need for many metabolic processses.
* Pleasant sensory properties: hedonic value
* High dietary fiber content: helps to eliminate waste materials from the bddy
* Source of antioxidants: cell protection

FAO’s Food and Nutrition Division (http://www.fao.org/english/newsroom/focus/2003/fruitveg1.htm, november 2017)

RIFRUTBIO-Red Nacional para la Bioprospección de Frutas Tropicales (2013-2017)

Pleasant sensory properties
Biofunctional properties
Highly perishable

Value-added food products with original characteristics and longer shelf-life



BIOPROSPECTION OF COLOMBIAN TROPICAL FRUITS

KNOWLEDGE

TRANSFORMATION

PROCESSING

Colombia is one of the ten major tropical fruit producers worldwide with ca. 450.000 families are involved in agriculture (330.000 Has)

RIFRUTBIO Members

AGRO

Asociación de Productores de Aguacate del Carmen de Bolívar-ASPROATEMON

Asociación de Productores de Frutos del Sumapaz-Frutipaz

ACADEMIA

Universidad Nacional de Colombia-Sede Bogotá

Universidad de Cundinamarca

Universidad de Cartagena

Universidad de Nariño

INDUSTRY

Laboratorio QFA Ltda. (Palmira-Valle) (Phytoterapeuticals and cosmetics)

Alimentos Naranja Verde Ltda. (Bogotá) (Food industry)

Laboratorio de Farmacología Vegetal, Labfarve (Pharmaceuticals)-Universidad Corpas

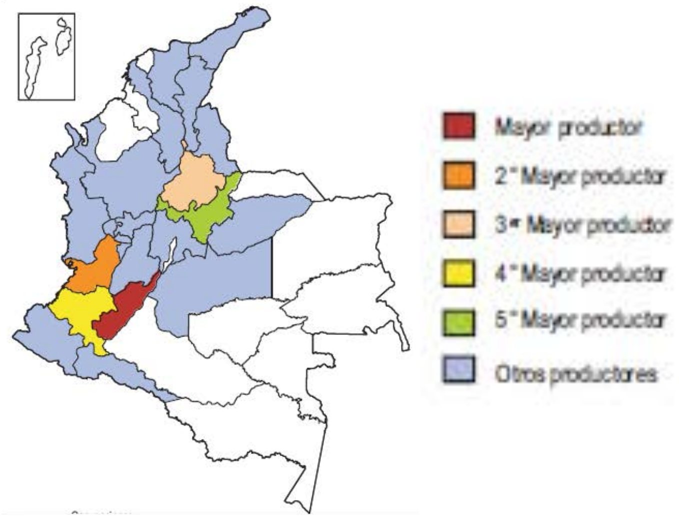
AREAS DE DESARROLLO RURAL (ADR)

Interdisciplinary Colombian network

Lulo (*Solanum quitoense* Lam.)

http://www.k-listo.com/categoria-producto/menu-cali/

Lulo, Naranjilla or Little Orange
(*Solanum quitoense* Lamarck, Solanaceae)



- Its production has been increased from 30.590 tons in 2014 up to the amount of 47.983 tons during 2015.
- 6810 Hectares planted in several states of Colombia between 1600 and 2450 m above sea level in humid Andean forests (15 – 20 °C)

http://www.agronet.gov.co/www/docs_agronet/20101715620_AnuarioEstadisticodefrutasyhortalizas2014-2015.pdf

Isolation of taste-active compounds

Fresh fruit

•Freeze drying

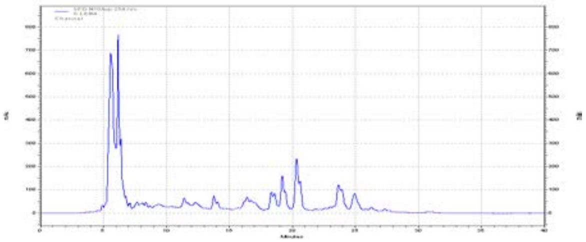
Ethanolic extraction

1. Extraction of taste-active compounds

•Filtration
•Solvent evaporation
•Freeze drying

2. Clean up (SPE-C_{18})

•Solvent evaporation
•Freeze drying



3. HPLC - 1D (Restek C-18, λ = 254 nm)

•Fractionation
• Taste analysis
Bitter fractions

Purification and Identification of bitter-active compounds

4. HPLC - 2D (Zorbax bonus RP)

5. LC-MS, LC-MS/MS, ^{1}H and ^{13}C NMR

2. Clean-up of the extract

SPE
(C_{18}-cartridges)

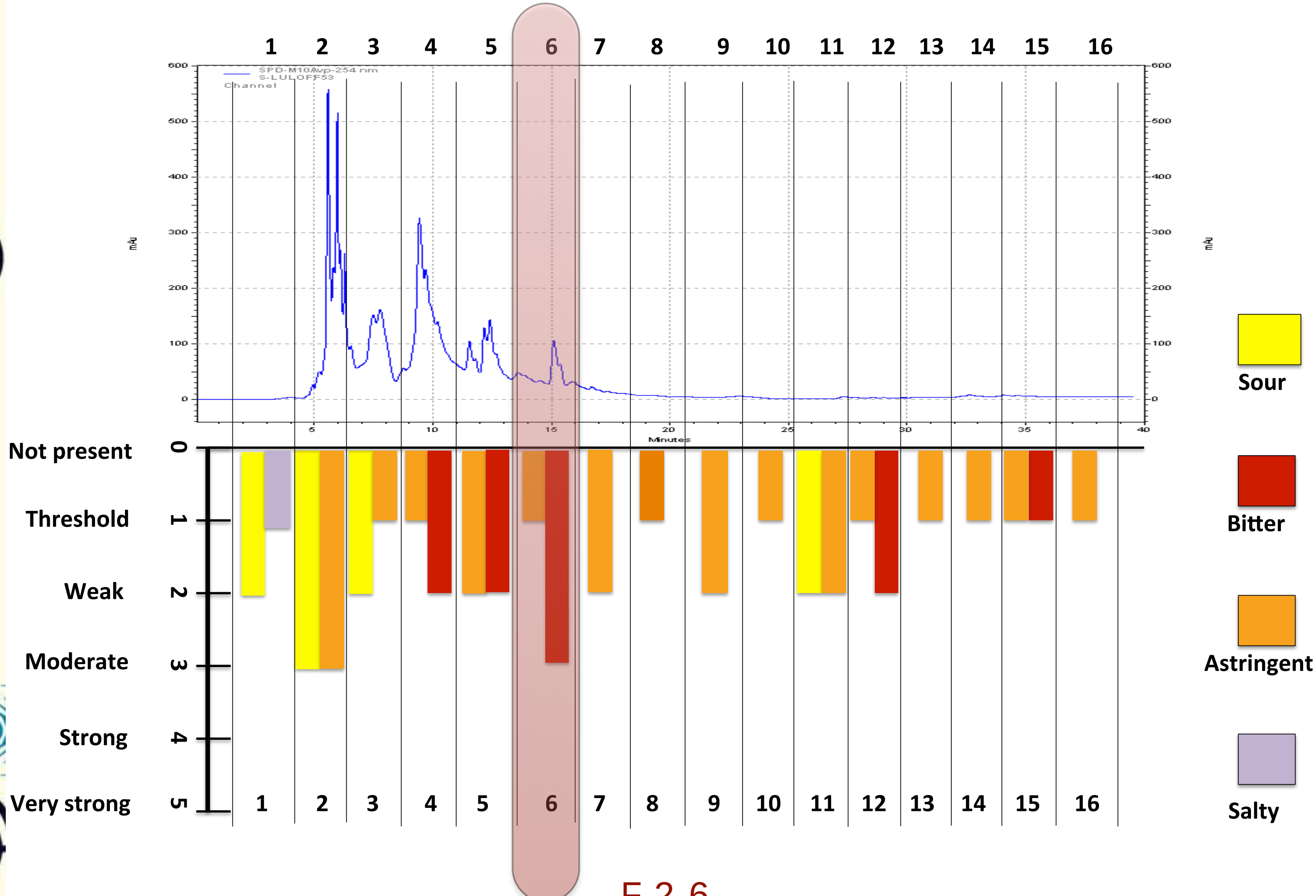
50 g

F1: Water (43 g) → Sour

F2: EtOH (2.1 g) → Bitter/astringent

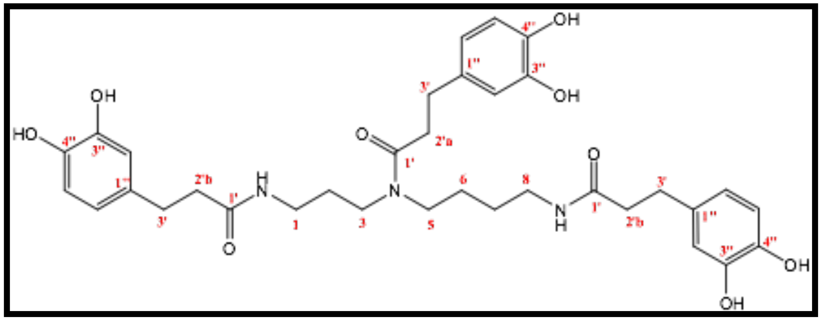
F3: hexane (4.0 g)

Taste Fingerprint Profile of Lulo Fruit



ACE-I inhibition of lulo (*S. quitoense*) fruit

in silico

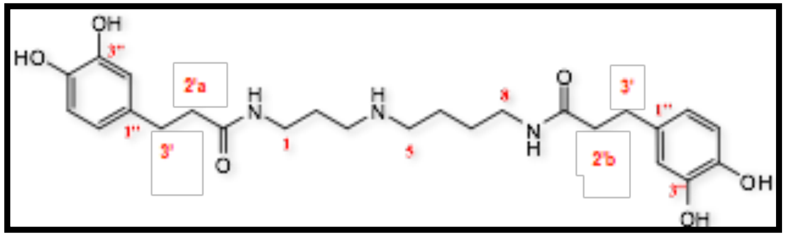


N^1,N^4,N^8-tris(dihydrocaffeoyl)spermidine

Amount: 1.6 mg/g fruit pulp
IC_{50}: 9.55 ± 1.20 ppm

Lisinopril
IC_{50}: 709.36 ± 54.90 ppm

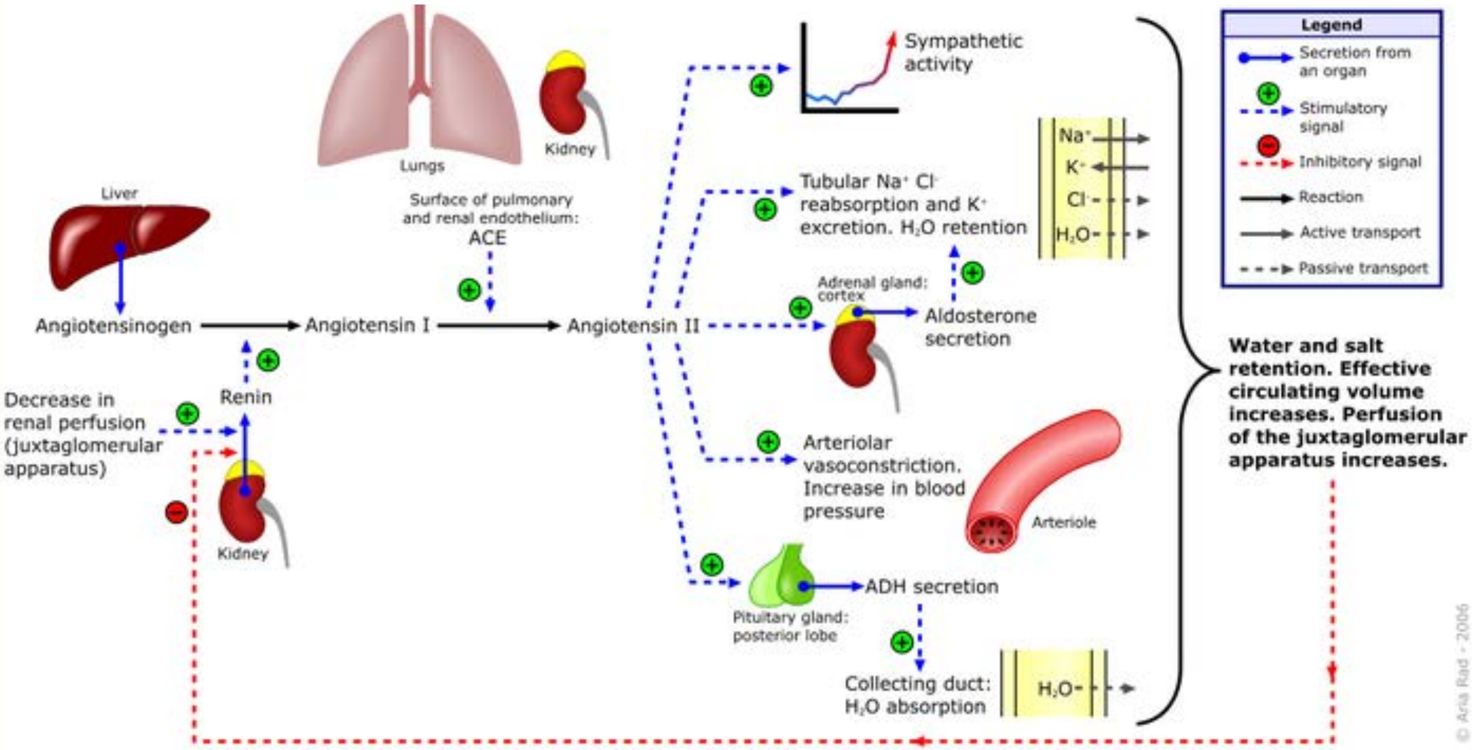
in vitro



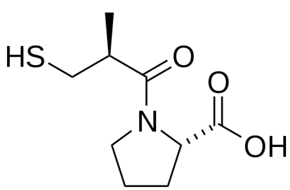
N^1,N^8-bis(dihydrocaffeoyl)spermidine

Forero, D. P., Masatani, C., Fujimoto, Y., Coy-Barrera, E., Peterson, D. G., Osorio, C. (2016). Spermidine derivatives in lulo (*Solanum quitoense* Lam.) fruit: sensory (taste) versus biofunctional (ACE-Inhibition) properties. *Journal of Agricultural and Food Chemistry*, *64*, 5375–5383.

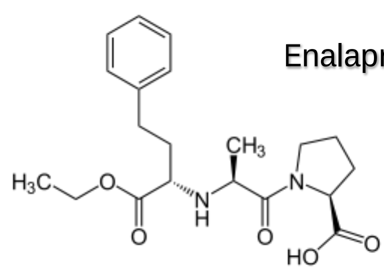
Renin–Angiotensin–Aldosterone System (RAAS)



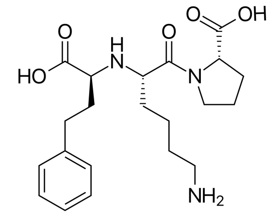
Captopril



Enalapril



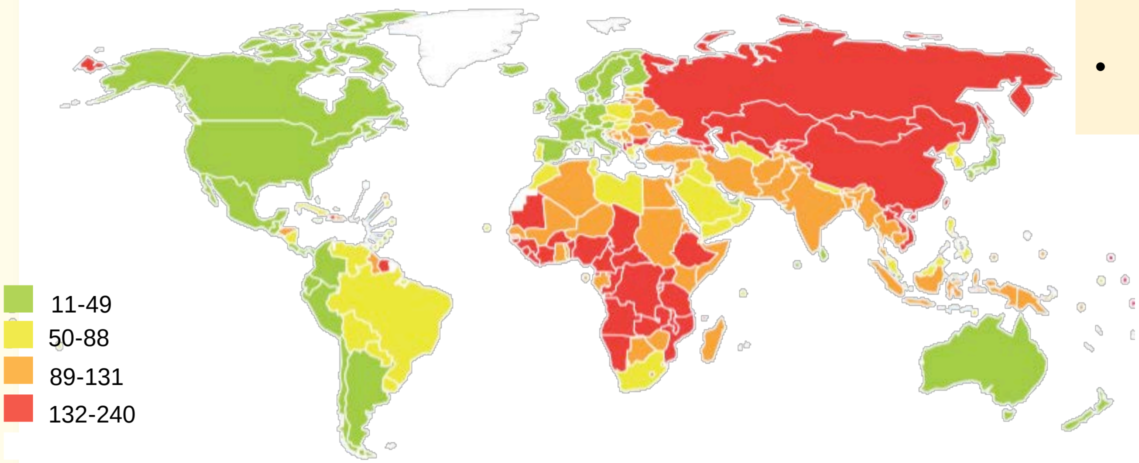
Lisinopril



https://www.slideshare.net/hhnoel/drugs-acting-on-renin-angiotensin-aldosterone-system

Hypertension: Public health problem

Mortality rate per CVD (normalized per100.000)

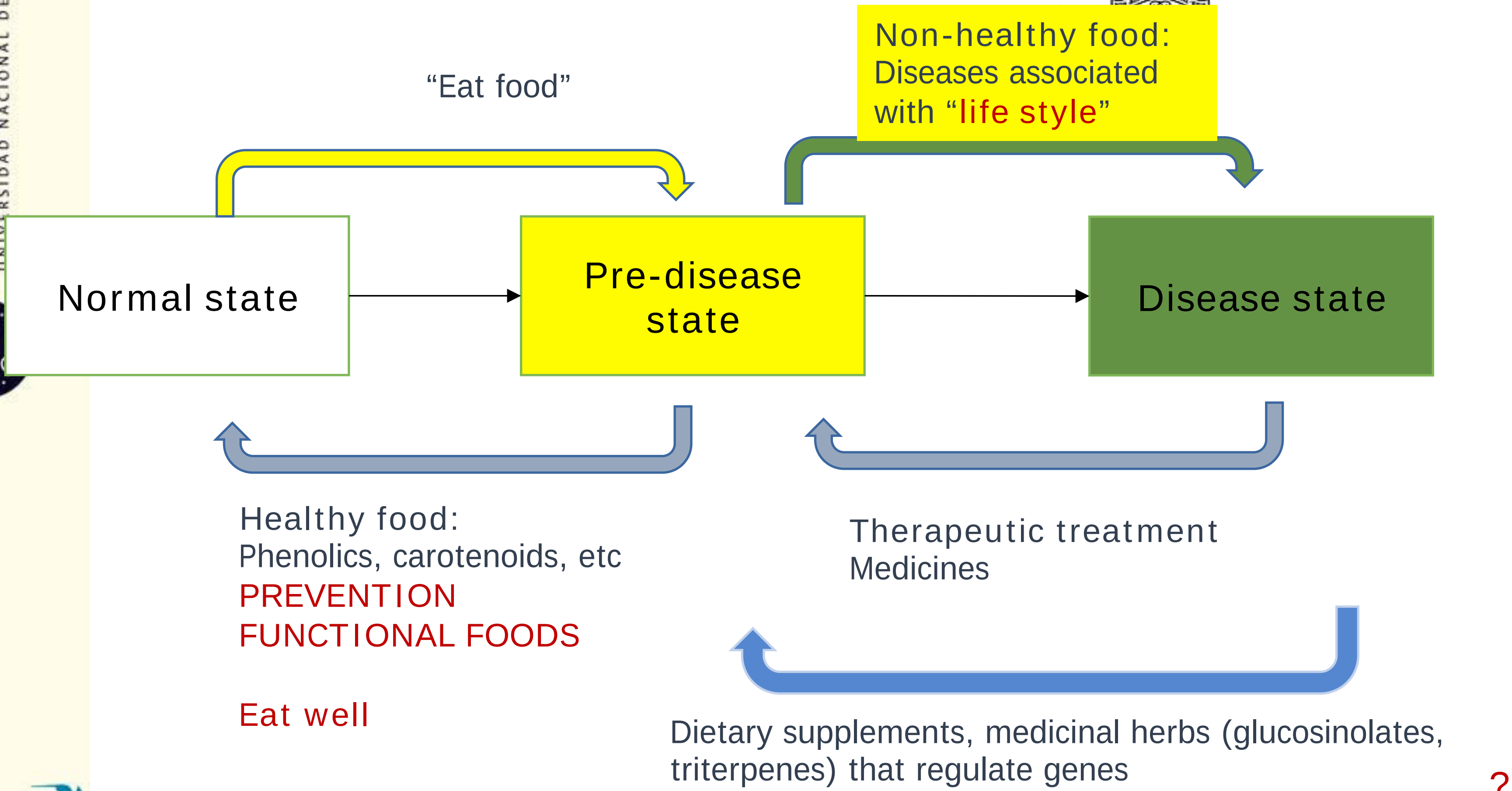


- World average rate of disease = 17. 5 millions of people
- In Colombia 54 thousands people died by CVD per year

http://www.colombiacorazon.com/Sobrenosotros.html

Consequences of hypertension:

Heart attack
Cerebrovascular accident
Heart failure
Nephropathy



C. Osorio, M. E. Schreckinger, P. Bhargava, W. Y. Bang, D. A. Jacobo-Velazquez, L. Cisneros-Zevallos. Golden berry and selected tropical (Açai, Acerola, and Maqui) juices. *In: Handbook of Functional Beverages and Human Health.* Shahidi, F., and Alasalvar, C. Eds. CRC Press Taylor & Francis Group. Boca Raton, FL, USA, 2016, pp. 251-269, chapter 21.

Biofunctional properties

- Antioxidant activity
- Antihypertensive activity (inhibition of ACE-1)

Forero, D. P., Masatani, C., Fujimoto, Y., Coy-Barrera, E., Peterson, D. G., Osorio, C. (2016). Spermidine derivatives in lulo (*Solanum quitoense* Lam.) fruit: sensory (taste) versus biofunctional (ACE-Inhibition) properties. *Journal of Agricultural and Food Chemistry*, *64*, 5375–5383.

http://www.k-listo.com/categoria-producto/menu-cali/

Excellent sensory properties (refreshing sour and citric, flavor)

Forero, D. P., Orrego, C. E., Peterson, D. G., Osorio, C. 2015. Chemical and sensory comparison of fresh and dried lulo (*Solanum quitoense* Lam.) fruit aroma. *Food Chemistry*.169, 85-91.

Highly perishable → Drying

Physicochemical characterization of dried lulo fruit pulp

Property	Drying method			
	HD	HUD	FD	SD
Aw	0.37 ± 0.02	0.55 ± 0.02	0.24 ± 0.02	0.26 ± 0.02
Moisture content (%)	3.3 ± 0.1	3.8 ± 0.1	2.7 ± 0.1	3.8 ± 0.1
IC_{50} (ppm) ACE-I inhibition			83.49 ± 4.10	43.17 ± 3.80
N^1, N^4, N^8-tris(dihydrocaffeoyl)spermidine (mg/g fruit pulp)	nd	nd	25.1 ± 0.8	25.0 ± 0.7

IC_{50} fruit pulp: 1.08 ± 0.30 ppm

HD = hot air-drying; and HUD = hot air-drying assisted with ultrasound; FD = freeze-drying; SD = spray-drying.
nd =not determined


HD


HUD


FD


SD

Forero, D. P., Carriazo, J. G., Osorio, C. (2016). Effect of different drying methods on morphological, thermal, and biofunctional properties of lulo (*Solanum quitoense* Lam.) fruit powders. *Drying Technology*,34,1085-1094.

Development of spray-dried microencapsulates of lulo mixtures with vegetables

1. ACE-I inhibition dried *S. quitoense* fruit pulp
2. To increase the antioxidant and antihypertensive activity
3. Mix with vegetables (antihypertensive activity reported)
4. Evaluation

Trend in the food market!

Development of spray-dried microencapsulates of lulo mixtures with vegetables

Mixtures with vegetables

Lulo: vegetable (w/w)
2:1
5:1
10:1

Factorial design 3x3

Spray drying

Labplant SD-06

Processing conditions

Inlet temp.:120 ± 2ºC
Outlet temp.: 65 ± 5ºC
Inlet flux: 485 mL/h
Air flux: 100 m^3/h ç
Maltodextrin as encapsulating agent

Microencapsulate

C. A. Muñoz, C. Osorio. Desarrollo de microencapsulados biofuncionales a partir de lulo (*Solanum quitoense* Lam.) y vegetales mediante spray drying. Agronomía Colombiana, 34, Suplemento 1, S906-S910, 2016

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Physicochemical characterization of lulo mixtures microencapsulates

Sample	Aw	Total phenolic content (mg GAE/g)	Total carotenoid content (ug **β**-carotene/g)
L	0.35 ± 0.001[a]	1.38 ± 0.04[a]	2.09 ± 0.02[a]
LT 2:1	0.34 ± 0.004[b]	0.87 ± 0.06[b]	3.19 ± 0.03[b]
LT 5:1	0.33 ± 0.001[c]	1.02 ± 0.06[c]	2.15 ± 0.02[c]
LT 10:1	0.32 ± 0.002[d]	1.06 ± 0.02[c]	1.76 ± 0.12[d]
LB 2:1	0.37 ± 0.001[e]	1.01 ± 0.06[c]	3.25 ± 0.09[b]
LB 5:1	0.27 ± 0.003[f]	1.03 ± 0.09[c]	3.09 ± 0.08[b]
LB 10:1	0.30 ± 0.001[g]	1.16 ± 0.09[c,d]	2.69 ± 0.09[d]
LS 2:1	0.34 ± 0.001[b]	1.07 ± 0.06[c]	5.68 ± 0.01[e]
LS 5:1	0.34 ± 0.009[b]	1.23 ± 0.08[d]	3.91 ± 0.04[f]
LS 10:1	0.27 ± 0.001[e]	1.24 ± 0.04[d]	2.73 ± 0.03[d]

Mean ± SD, n=3. Different letters in the same column indicate significant differences among data ($p \leq 0.05$).
L = lulo; LT = lulo-tomato; LB = lulo-broccoli; LE = lulo-spinach (w/w).

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Biofunctional properties of lulo mixtures microencapsulates

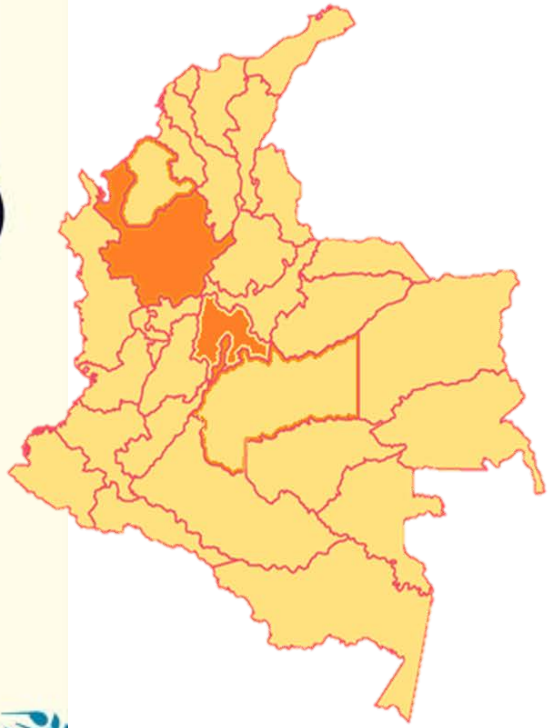
Sample	Antioxidant activity (mmolTrolox/100 g)	ACE-I inhibition (%)
L	1.3 ± 0.004[a]	57.96 ± 0.18[a]
LT 2:1	0.6 ± 0.002[b]	-
LT 5:1	0.7 ± 0.003[c]	-
LT 10:1	0.7 ± 0.002[c]	26.49 ± 026[b]
LB 2:1	0.4 ± 0.002[d]	-
LB 5:1	0.5 ± 0.001 [e]	-
LB 10:1	0.7 ± 0.009[c]	59.18 ± 0.23[c]
LS 2:1	0.6 ± 0.002[b]	-
LS 5:1	0.6 ± 0.003[b]	-
LS 10:1	0.6 ± 0.008[b]	9.39 ± 0.01[d]

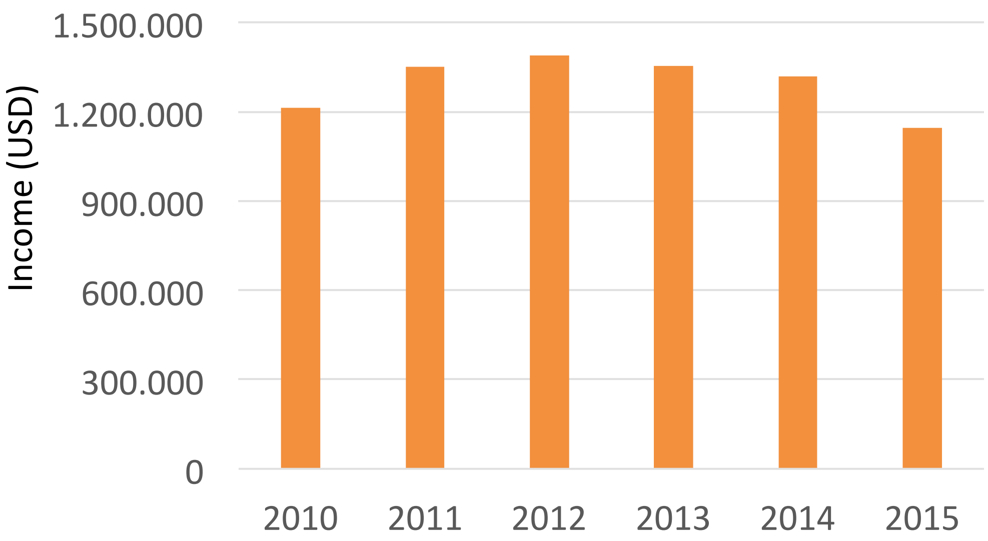
Mean ± SD, *n*=3. Different letters in the same column indicate significant differences among data ($p \leq 0.05$). L = lulo; LT = lulo-tomato; LB = lulo-broccoli; LS = lulo-spinach (w/w). - = not determined.

Tamarillo (*Solanum betaceum* Lam.)

Medina, C. I.; I Reunión sobre Investigación y Producción de Frutales Menores
Ponencia Caracterización morfológica de tomate de àrbol. *Corpoica* **2004**, 82.

Production and exportation of tamarillo in Colombia





The exportations of tamarillo has been constant since 2010-2015 towards European markets (Germany, The Netherlands, France and United Kingdom)

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Commercial varieties of tamarillo (*Solanum betaceum*)

*Native to the Andes, Peru, Ecuador and Colombia

*Source of vitamins A, B_6, C, and E; and calcium, iron, and phosphorus.

*Rich in carotenoids, and anthocyanins, as well as phenolic compounds.

Residual bitter flavor is undesirable for some consumers!

Parameter	Value
Total soluble content (°Brix)	10.05 ± 0.23
Tritratable acidity (% as citric acid)	0.864% ± 0.021
pH	3.87 ± 0.03
% Humidity	86.83 ± 1.62

Sensomics approach of yellow tamarillo (*Solanum betaceum*) fruit

Fruit pulp (*ca.* 5 Kg)

→ Physicochemical characterization

SAFE distillation dichloromethane (DCM)

Freeze-drying (676 g) and acetone-H_2O (7:3) extraction

AROMA -ACTIVE VOLATILES

TASTE ACTIVE COMPOUNDS

Liquid-liquid partition (5 fractions) Et_2O, DCM, EtOAc, BuOH, H_2O

F.AcOEt (1.1 g)

Toyopearl HW-40S ($MeOH$-acetone-H_2O) F1-F4

F2: Bitter compound 1 (23 mg)

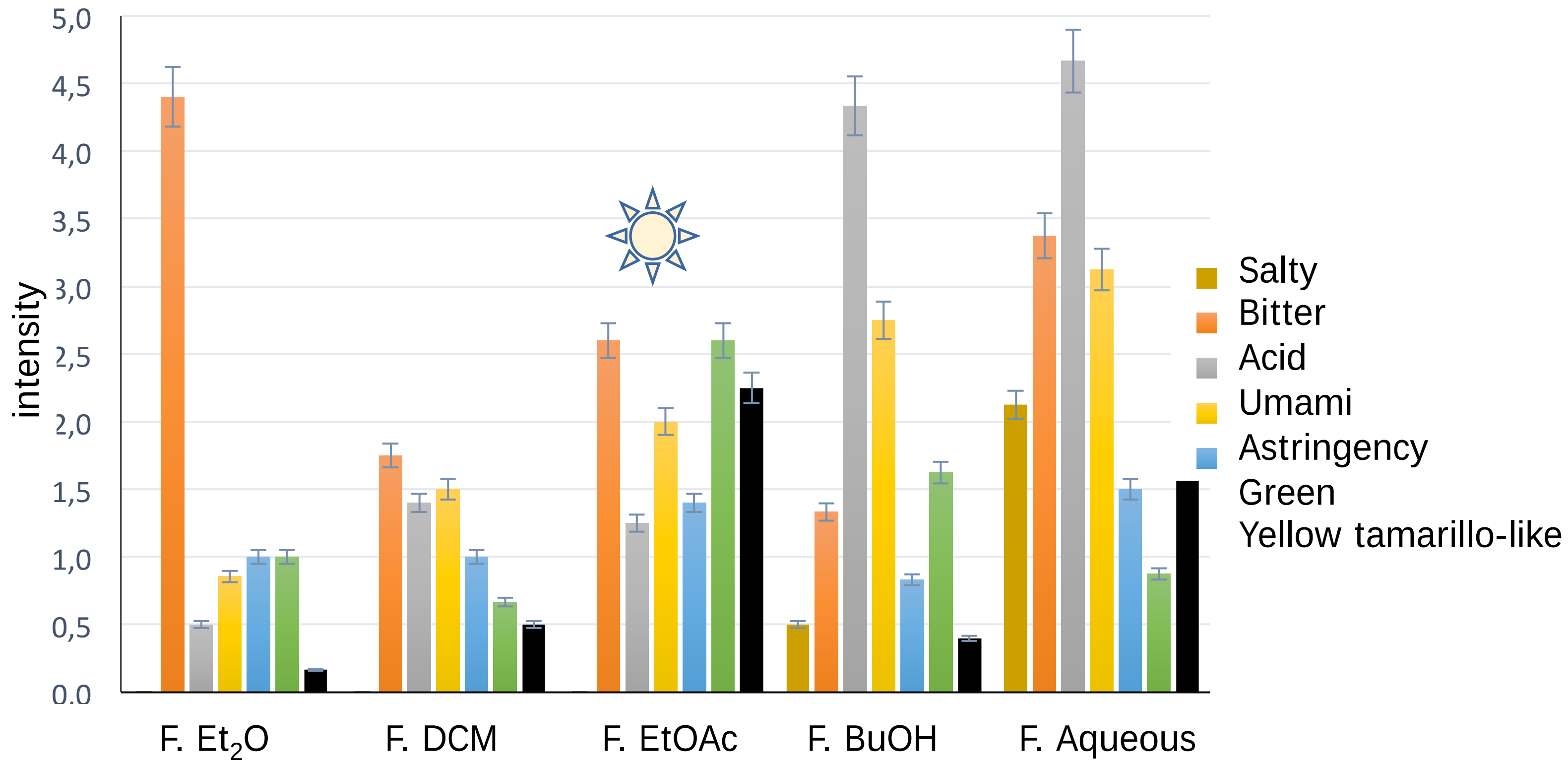
NMR, LC-ESI / MS, quantitation and taste threshold determination

SENSORY ANALYSES

Trained panellists,Disaromas S.A, Bogotá, Colombia

ACE-inhibitory assay (antihypertensive activity)

Taste intensity profile of the five yellow tamarillo fractions



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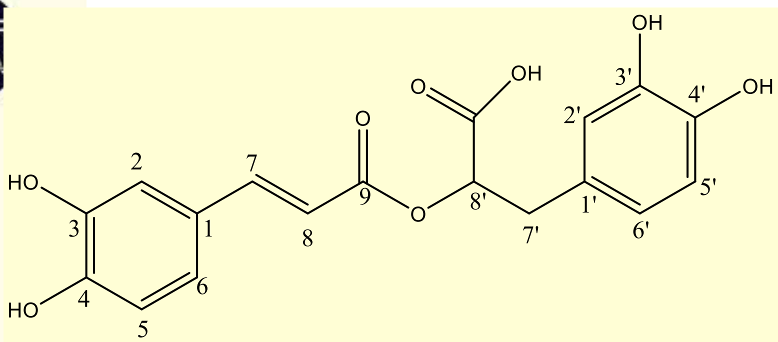
Rosmarinic acid bitter taste threshold determination: 3AFC (three-alternative forced-choice) *



Rosmarinic acid

Bitter taste threshold = 37.00 ± 1.25 mg/L

Quantitation by external standard method (7-400 ppm) by using UHPLC-PDA-ELSD

Amount in tamarillo = 46.17 ± 1.20 mg/L

J. M. García, L. J. Prieto, A. Guevara, D. Malagon, C. Osorio. Chemical studies of yellow tamarillo (*Solanum betaceum* Cav.) fruit flavor by using a molecular sensory approach. *Molecules,* 2016, 21, 1729.

Take home messages

✓ The amount of compound N^1,N^4,N^8-tris(dihydrocaffeoyl)spermidine is increased during the drying of the lulo fruit pulp, contributing for the ACE-I inhibitory activity increase, during this process.

✓The ACE-I inhibitory activity of lulo microencapsulates increased with the addition of broccoli. The presence of “off flavors” need to be studied.

✓These results suggest that *S. quitoense* as well as *S. betaceum* fruit pulps are promising functional ingredients for foods because they help in the hypertension control. *In vivo* experiments (bioavailability) need to be done.

Take home messages

P. Esquivel, A. Orjuela, M. Paes Barros, C. Osorio. **Potential opportunities and challenges for research collaboration with Latin America in agriculture and food science**. *J. Agric. Food Chem.* **2017**, *65*, 8096−8098.

Acknowledgments

Financial support: Fondo Nacional de Financiamiento para la Ciencia, la Tecnología y la Innovación, Francisco José de Caldas, Contract No. 0459 –2013 (Red Nacional para la Bioprospección de Frutas Tropicales-RIFRUTBIO).