Citrus counts amongst one of the oldest fruit types and most commercialised horticultural crops worldwide, and is utilised freshly as well as for processing purposes. By Jon Roberts

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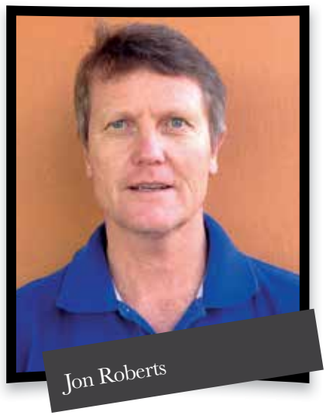
1. CGA CC Juice comparison with Lane Late 2. CGA CC Juice comparisons - Cara, Lina and Valentine 3. CGA CC Juice comparison - Cara and Lina

Properties of citrus fruit



Jon Roberts

Oranges (*Citrus sinensis*) are an important source of bioactive compounds and phytonutrients such as vitamins A, C and E; and folic acid, minerals, flavonoids, phenolic compounds, limonoids, carotenoids, pectin's and fibre, among others[1, 2, 3].

The consumption of these bioactive compounds through the consumption of fruit or juice has been linked to health-related benefits that include[1, 2, 3, 4, 5, 6]:

- antioxidants
- anti-inflammatory properties
- reduction of the risk of certain cancers and cardiovascular diseases
- hepatoprotectors
- obesity control
- immune system enhancement.

Further benefits[3, 4, 5, 6, 7, 8, 9, 10]:

- "The moderate consumption provides potential health benefits."
- "Studies in humans show enhancement of cardiovascular markers, improved insulin sensitivity and body-fat reduction."
- "Oxidative stress plays an important role in the development of human diseases."

The citrus industry and consumers are constantly on the lookout for new varieties with new distinguishing features and added value, in relation to human nutrition and health.

The CGA Cultivar Company (CGA-CC) and its partners in the northern hemisphere, as well as other cultivar management companies, are introducing and releasing a range of new red fleshed citrus: oranges, grapefruit and pummelos.

But what are the main features of these varieties? Why is the pulp red? What properties do these varieties provide compared to traditional oranges? What is the degree of accumulation of lycopene in the pulp? And what are the anthocyanin qualities?

Lycopene is a carotenoid that provides the reddish and pink colour to several fruits, such as tomato and watermelon. The accumulation of lycopene in citrus is an unusual feature, restricted to only a few cultivars of grapefruit, pummelo and sweet orange.

Carotenoids are the pigments responsible for the colour of the peel and pulp of citrus fruit. The variability of carotenoids content and composition provides the specific colour of the different orange and mandarin varieties. Additionally, carotenoids have two key properties related to human health: antioxidants and vitamin A precursors.

The carotenoid content in the pulp of red oranges and grapefruit is much higher than that of traditional oranges. Moreover, they contain:

- lycopene, which is completely absent in ordinary oranges
- very high amounts of other carotenes, phytoene and phytofluene as per featured **Table 1**.

Carotenoid's content (µg/g FW)[11, 12]

Interestingly, phytoene and phytofluene are two unusual colourless carotenes that accumulate in very high concentrations in the pulp of the red oranges compared to the traditional oranges.

Recent studies indicate that these carotenes may have relevant beneficial properties for health and as nutricosmetics, suggesting benefits in the[25, 26, 27, 28, 29]:

- protection against oxidative stress
- enhancement of anti-inflammatory response
- reduction of cholesterol in plasma
- positive effects related to breast and prostate cancer
- protection against ultraviolet radiation (UV).

What features does lycopene have?

Due to its structure, lycopene has a high antioxidant capacity.

Numerous epidemiological studies – *in vivo* and *in vitro* – suggest that the regular intake of lycopene has beneficial effects for health, as the reduction of the risk of degenerative diseases.

***In vitro* antioxidant capacity is higher than in ordinary oranges against "singlet oxygen" radicals. The studies suggest reduction of these as potential biological effects[7,18,19,22,23,24]:**

- oxidative stress
- risk of cardiovascular diseases
- hypertension
- risk of lung, prostate and stomach cancer
- cholesterol LDL
- lipidic oxidation and atherosclerosis.

In vivo, epidemiological studies have demonstrated that the intake of red-fleshed oranges provide relevant beneficial effects for health.

Adults – regular or overweight – who consumed 750 mℓ of orange juice/day along with their normal diet, for eight weeks, showed (Silveira et al., 2015):

- reduction in total cholesterol
- reduction of LDL-C
- enhancement of antioxidant capacity
- reduction of C-reactive protein (anti-inflammatory processes)

Internal quality and other features

There are no significant differences in other quality parameters such as ºBrix, acidity or vitamin C. However, the studies performed by the research group of IATA CSIC that are reflected in the featured table, show that total carotenoids content in red-fleshed oranges is at least five times higher than that of traditional orange varieties. Therefore, red-fleshed oranges providing an additional contribution of antioxidant carotenoids over traditional varieties and their consumption, may have an added health value.

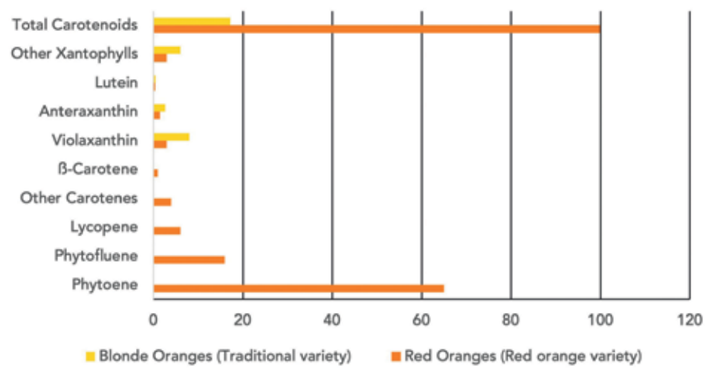


Table 1: Carotenoids, (content µ g/g/FW)

REFERENCES:

1. Vilaplana, A., D.A. Moreno, and C. García-Viguera. 2014 "Phytochemistry and biological activity of Spanish Citrus fruits." *Food and Function* 5:764-772.
2. Lv, X., S. Zhao, Z. Ning, H. Zeng, Y. Shu, O. Tao, C. Xiao, C. Lu, and Y. Liu. 2015. "Citrus fruits as a treasure trove of active natural metabolites that potentially provide benefits for human health." *Chemistry Central Journal* 9:68.
3. Zou, Z., W. Xi, Y. Hu, C. Nie, and Z. Zhiquin. 2016. "Antioxidant activity of Citrus fruits." *Food Chemistry* 196: 885-896.
4. Ma, G., L. Zhang, M. M. Sugiura, and Kato. 2020. Citrus and health. In:TalónM, Caruso M and Fred Gmitter FG (eds) The Genus Citrus. Cambridge: Woodhead Publishing, pp, 495-508.
5. Turner, T., and B.J. Burri. 2013. "Potential Nutritional benefits of current citrus consumption." *Agriculture* 3: 170-187.
6. Cirmi, S., A. Maugeri, N. Ferlazzo, S. Gangemi, G. Calapai, U. Schumacher, and M. Navarra. 2017. "Anticancer potential of citrus juices and their extracts: asystematic review of both preclinical and clinical studies." *Frontiers* 8:420.
7. Silveira, J.Q., K.Z.S. Grace, D. Cesar, and T.B. Cesar. 2015. "Red-fleshed sweet orange juice improves the risk factors for metabolic syndrome." *International Journal of Food Sciences and Nutrition* 66 (7): 830-836.
8. Rampersaud, G.C., and M.F. Valim. 2017. "100% citrus juice: Nutritional contribution, dietary benefits, and association with anthropometric measures." *Critical Reviews in Food Science and Nutrition* 57(1): 129-140.
9. Rajendran, P., N. Nandakumar, T. Rengarajan, R. Palaniswami, E.N. Gnanadhas, and U. Lakshminarasaiah. 2014. "Antioxidants and human diseases." *Clinica Chimica Acta*, 436: 332–347.
10. Tan. B., M.E. Land Norhaizan. 2019. "Carotenoids: How effective are they to preventage-related diseases." *Molecules* 24: 1801.
11. Alquezar, B., M.J. Rodrigo and L. Zacarías. 2008. "Regulation of carotenoid biosynthesis during fruit maturation in the red-flesh edorange mutant Cara Cara." *Phytochemistry* 69: 1997-2007.
12. Zacarias, J. 2017. "Caracterización fisiológicay molecular delmetabolismode carotenoid esendos varied adesde naranja (Citrussinensis) epulparoja." Máster Universitarioen Calidady Seguridad Alimentaria, 8ªEdición. Departamentode Medicina Preventivai Salut Pública, Ciènciesdel' Alimentació, Toxicologiai Medicina Legal, Universidadde Valencia, España.
13. Alquézar, B., M.J. Rodrigo, and L. Zacarías. (2008b). "Carotenoid biosynthesis and their regulation in citrus fruits." *Tree for Science Biotechnology* 2:23-35.
14. Rodrigo, M.J., B. Alquézar, E. Alós, J. Lado and L. Zacarias. (2013a). "Biochemical bases and molecular regulation of pigmentation in the peel of Citrus fruit." *Scientia Horticulturae* 163:46-62.
15. Amengual, J. 2019. "Bioactive Properties of Carotenoids in Human Health." *Nutrients* 11: 2388.
16. Berman, J., U. Zorrilla-López, G. Farré, C. Zhu, G. Sandmann, R.M. Twyman, T. Teresa Capell, and P. Christou. 2014. "Nutritionally important carotenoids as consumer products." *Phytochemistry Reviews* in press (doi:10.1007/s11101-014-9373-1).
17. Eggersdorfer, M. and A. Wyss. 2018. "Carotenoids in human nutrition and health." *Archives of Biochemistry and Biophysics* 652:18-26.
18. Rao, A. and L.G. Rao. 2007. "Carotenoids and human health." *Pharmacological Research*55: 207-216.
19. Bailey, J.R. 2015. "Lycopene: Food sources potential role in human health and antioxidant effects." *New York: Nova Publishers.*
20. Chen, J., Y. Song and L. Zhang. 2013. "Effect of lycopene supplementation on oxidative stress: an exploratory systematic review and meta-analysis of randomized controlled trials." *Journal of Medicinal Food* 16(5):361-374.
21. Basu, A., and V. Imrhan. 2007. "Tomatoes versus lycopenein oxidative stress and carcinogenesis: conclusions from clinical trials." *European Journal of Clinical Nutrition* 61: 295-303.
22. Chen, W., L. Mao, H. Xing, L. Xu, X. Fu, L. Huang, D. Huang, Z. Pu, and Q. Li. 2008. "Lycopene attenuates Aβ1-42 secretion and its toxicity in human cell and Caenorhabditis elegans models of Alzheimer disease." *Neuroscience Letters* 608:28-33.
23. De Oliveira, R., C. Orlando Muñoz, L. Carmona, L. Peña and R de Paula Oliveira. 2019. "Pasteurized orange juice rich in carotenoids protects *Caenorhabditis elegans* against oxidative stress and β-Amyloid toxicity through direct and indirect mechanisms." *Oxidative Medicine and Cellular Longevity* 5046280.
24. Mein, J.R., F. Lian, and X.D. Wang. 2008. "Biological activity of lycopene metabolites: implications for cancer prevention." *Nutrition Reviews* 66(12): 667-683.
25. Wang, X.D. 2012. "Lycopene metabolism and its biological significance." *American Journal of Clinical Nutrition* 96: 1214S-1122S.
26. Engelmann, N.J., S.K. Clinton, and J.W. Erdman Jr. 2011. "Nutritional aspects of phytoene and phytofluene, carotenoid precursors tolycopene." *American Society for Nutrition*2: 51-61.
27. Meléndez-Martínez, A.J., P. Mapelli-Brahm, and C.M. Stinco. 2018. "The colourless carotenoids phytoene and phytofluene: from dietary sources to their usefulness for the functional foods and nutri cosmetics industries." *Journal of Food Composition and Analysis* 68: 91-103.
28. Meléndez-Martínez, A.J., P. Mapelli-Brahm, A. Benítez-González, and C.M. Stinco. 2015. "A comprehensive review on the colorless carotenoids phytoene and phytofluene." *Archives of Biochemistry and Biophysics* 572: 188-200.
29. Meléndez-Martínez, A.J., C.M. Stinco, and P. Mapelli-Brahm. 2019. "Skin carotenoids in public health and nutricosmetics: the emerging roles and applications of the UV radiation-absorbing colourless carotenoids phytoene and phytofluene." *Nutrients* 11: 1093.
30. Aust, O., W. Stahl, H. Sies, U. Tronnier Hand Heinrich. 2005. "Supplementation with tomato-based products increasesly copene, phytofluene, and phytoene levels in human serum and protects against UV-light-inducederythema." *International Journal for Vitamin and Nutrition Research* 75: 54-60.

VITAMIN C AND BEYOND

The health benefits of a plant-rich diet are well established. And nutritionally, citrus offers a lot more than just vitamin C. By **Paula Bester**

The Nutrient Rich Foods (NRF) Index is a formal scoring system ranking foods on their nutrient content. This index was previously paired with a food price database and identified citrus fruits and juices as both nutritious and affordable, giving consumers the highest nutrients per unit cost.[2,3] In light of the challenging times we live in and the universal desire to pursue healthier lifestyles and immune boosting diets, this article aims at providing some insight on the potential health benefits related to citrus consumption.

If we imagine a single citrus fruit as a pie chart, its proximate composition in descending order would be water (85-88%), sugars (9-11%), fibre (0.3-1.7%), protein (0.7-1.5%), essential oils (0,5 -5 % of the peel), vitamins, minerals, and non-nutritive phytochemicals in trace amounts.[1,2] There are many intriguing compounds within the phytochemical group, including the flavonoids, and their significance may very well outweigh their concentration.

Flavonoids

The subclasses of flavonoids found in citrus are the flavanones (generally the most abundant in citrus), flavones, flavonols, chalcones, anthocyanins and flavanonols.[3,4] Flavonoids give flowers and fruits their colour and aroma, which attract pollinators, and they protect plants against extreme environmental conditions such as frost and drought.[3] Flavonoids have been the topic of many research studies due to their miscellaneous health promoting effects, including anti-oxidants, and being anti-inflammatory, anti-carcinogenic, anti-microbial and anti-diabetic, amongst many others.[3,5,6,7] These are some bold claims, but here things start to get interesting. Although there is still much to learn in this avenue on how exactly phytochemicals work inside our bodies, there is already a substantial amount of research to showcase this.

If you consider the chemical structure of flavonoids, they all share the same basic skeleton, rich in double carbon-hydrogen bonds and hydroxyl (–OH) groups, enabling them to donate electrons (H·) to highly reactive free radicals.[5] In essence, these phytochemicals protect our cells this way, by neutralising free radicals so that structures within our own cells do not get oxidised, hence the term anti-oxidants. What a noble sacrifice!

Flavanones are introduced in our diet almost exclusively through citrus fruits and juices, besides through some herbs such as mint.[7,8] Taking this into account,

> Previously paired with a food price database, the NRF Index identified citrus fruits and juices as both nutritious and affordable, giving consumers the highest nutrients per unit cost.