



Nutrients in 100% fruit juice are bioavailable, but bottled has edge over fresh for bioactives

In accordance with EU regulations, 100% fruit juice (100% FJ) has nothing added or taken away, which is why it reflects the nutrient content of the fruit from which it is made.¹

The nutrient composition of 100% orange juice (100% OJ) is shown below per 100 g. Values in red represent official 'source' claims that can be made on pack.

Energy	41 kcal
Calcium	11 mg
Iron	0.2 mg
Magnesium	9.5 mg
Phosphorus	15.3 mg
Potassium	152 mg
Zinc	0.06 mg
Vitamin C	36.4 mg
Thiamin	0.08 mg
Riboflavin	0.02 mg
Niacin	0.29 mg
Folate	21.5 µg
Vitamin B6	0.07 mg
Vitamin B12	0.02 mg
Provitamin A	4.1 µg
Vitamin D	0.0 µg
Vitamin E	0.18 mg
Vitamin K	0.08 µg

As well as these nutrients, 100% FJ contains bioactive substances such as carotenoids (e.g. betacarotene, lutein and cryptoxanthin), polyphenols (hesperidin and narirutin which are within the flavanone group) and fibre (pectin). In clinical trials, hesperidin has been found to have a beneficial impact on neurological disorders, psychiatric disorders and cardiovascular disease.² The actions on brain health may be due to

citrus flavanones traversing the blood-brain barrier, thus increasing their usefulness as candidates to help lower the risk of neurodegeneration.³ Other effects attributed to hesperidin include antioxidant and anti-allergic effects, immuno-modulatory activity, alleviation of hormonal disorders, antiulcer activity and potential wound healing.⁴

What is bioavailability?

Bioavailability is the degree to which food nutrients are available for absorption and utilisation in the body. For example, spinach is rich in iron but, due to other natural compounds, such as oxalic acid, less than 10% of the contained iron is absorbed.⁵ However, certain foods and nutrients can optimise bioavailability. In the case of spinach, iron absorption may be improved by including a glass of 100% FJ. The term 'bioaccessible' is also used in studies and refers to the fraction of a compound that was potentially absorbable and bioavailable in comparison with the fraction that was actually absorbed.

Are nutrients in 100% fj bioavailable?

The bioavailability of 100% OJ polyphenols was measured in 12 adults who ate a low-polyphenol diet for two days before being given 250 ml pulp-enriched 100% OJ or a placebo drink, following a two-week washout.⁶ The 100% OJ contained 584 mmol of polyphenols, mostly as flavanones. 24-hour urine sampling showed that metabolites of flavanone were appearing two to ten hours after consumption, which is consistent with the accepted view that flavanones are absorbed in both the small and large intestines.

Flavanone catabolites (produced during breakdown) were seen in large quantities, equivalent to 88% of what had been consumed. These findings suggest that polyphenols in 100% OJ appear to be more bioavailable than previously believed.

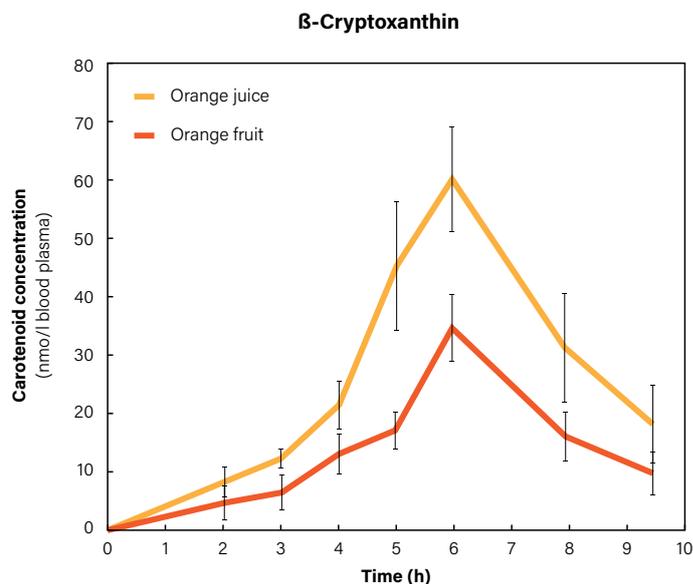
A longer term study⁷ examined the bioavailability of nutrients and bioactive substances in 100% OJ. For three weeks, 13 healthy, normal weight adults drank 236 ml juice three times daily, which provided 256 mg vitamin C, 229 mg hesperidin, 6 mg carotenoids and 160 µg folate.

Compared with the baseline, blood sampling revealed a significant increase in nutrient levels i.e. vitamin C and folate levels increased by around 50%, while flavanone levels rose by eight times. Carotenoid levels increased by 22%. Urine results confirmed a nine times higher excretion of flavanones, which returned to baseline levels within two weeks of stopping the juice consumption. Interestingly, subjects' weight did not change during the study and the participants reported a lower intake of snacks and smaller portion sizes of meals.

How do juices compare with whole fruit?

Aschoff et al. (2015)⁸ compared the bioavailability of β-cryptoxanthin, lutein, zeaxanthin and zeinoxanthin from fresh oranges (400 g) versus pasteurised 100% OJ (719 g). Using a randomised cross-over design with 12 participants, an identical amount of β-cryptoxanthin was provided in both test conditions. Blood samples were taken hourly for the next ten hours.

The results showed that β-cryptoxanthin was 1.8 times more bioavailable in 100% OJ than in whole oranges. Based on a separate *in vitro* method, β-cryptoxanthin was five times more bioaccessible in 100% OJ versus whole oranges (see chart below for β-cryptoxanthin; there was also a similar although non-statistically significant trend for lutein):



The differences may be due to high pectin levels in the whole fruit inhibiting absorption, or the disruption of cell walls in 100% OJ leading to a greater release of β-cryptoxanthin. Other work⁹ has found that more of the carotenoids in 100% OJ are present in droplet form which may explain why absorption from juice is greater than from whole fruits.

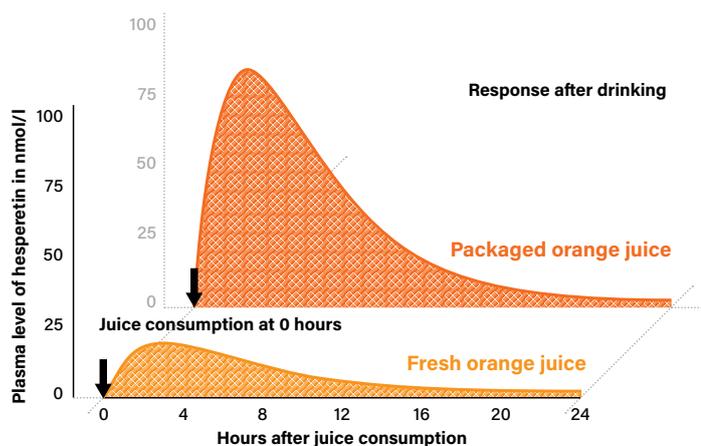
A second similar study¹⁰ examined how much of the flavanones, hesperidin and narirutin would be re-sorbed from 100% OJ versus whole oranges. This was done by tracking the excretion of a known amount of administered flavanones in urine. Despite the hesperidin content of whole oranges being 2.3 times higher than that of 100% OJ, 24-hour urine excretion of hesperidin (the main metabolite) was similar.

This could mean that absorption and metabolism of dietary flavanones becomes saturated when intake exceeds a certain limit, perhaps due to poor solubility or limitations of transport mechanisms in the gut. Or, it could mean that flavanones in the whole fruit are less bioavailable due to the fibre content compared with the juice. Dietary fibre in oranges is 16 times higher than in 100% OJ.

Fresh juice versus packaged juice

As packaged juice often contains slightly reduced levels of vitamins, due to the impact of shelf life, there is an assumption that it is less useful nutritionally than freshly squeezed fruit juice.

This was investigated for 100% OJ in a randomised cross-over trial in 24 adults¹¹ where the two types of juice were given for two days each separated by a 30-day washout. Blood and urine sampling revealed no statistical differences in the kinetics of the metabolism of the flavanones, hesperidin and narirutin coming from packaged or fresh 100% OJ. However, due to differences in the flavanone content (58 mg packaged vs. 16 mg fresh), gut absorption and urinary excretion were significantly higher following consumption of the packaged 100% OJ. Overall, this means that a glass of packaged 100% OJ provided the participants with 2.8-fold more hesperetin than an identical glass of fresh 100% OJ.



A glass of packaged orange juice (POJ) contains around three times more hesperidin (a flavanone) than a glass of fresh orange juice (FOJ). Consequently, around 2.8-fold more of hesperidin's main metabolite, hesperetin, reached the plasma when consuming POJ as compared to when consuming FOJ.

Silveira JQ et al. (2014) Pharmacokinetics of flavanone glycosides after ingestion of single doses of fresh-squeezed orange juice versus commercially processed orange juice in healthy humans. *J Agric Food Chem* 62: 12576-84.

Flavanones are soluble compounds in citrus fruits that are present in the juice cloud as well as the cell walls. The higher mechanical force applied during machine pressing of oranges 'pushes' more of the flavanones into the juice than when manually dejuicing. It has been proposed that the rich flavonoid content of 100% OJ may be responsible for some of the health effects seen in studies, i.e. anti-oxidative and anti-inflammatory responses, and improved vascular function.

In other work¹², the focus on vitamin C degradation in heat-treated foodstuffs may be rather narrow as health outcomes could be driven by complex mixtures of phytochemicals rather than a single antioxidant. As one example, vitamin C provides only 0.4% of the total antioxidant activity of apples with the remaining activity driven by phenolics, flavonoids and anthocyanins. Therefore, a broad spectrum of bioactive substances in food should be considered in future studies, as well as the water content, which can influence the concentration of nutrients.

Role of bioactives in the body

Various studies have confirmed the potential health impact of the bioactives found in 100% FJ. In a controlled trial in diabetic participants, hesperidin lowered oxidative DNA damage and lipid peroxidation.¹³ In another trial β -cryptoxanthin lowered total, LDL and HDL cholesterol and positively modified bone turnover markers.¹⁴ Lutein and zeaxanthin have been found to partially restore vision in people with age-related macular degeneration¹⁵, while citrus flavonoids may lower the risk of neurodegenerative diseases.¹⁶ No EU health claims have yet been authorised for citrus flavonoids, but claims exist for olive polyphenols (blood lipid oxidation) and cocoa flavanols (vascular health).

Conclusion

This collection of studies shows that:

- 100% FJ, especially 100% OJ, is a valuable source of nutrients and bioactives such as carotenoids and flavanones;
- these bioactives are bioavailable in 100% FJ;
- a glass of packaged 100% OJ provides 2.8-fold more hesperetin (the main metabolite of hesperidin) to the body than an identical glass of fresh 100% OJ;
- packaged 100% FJ has a similar bioavailability of flavanones to whole fruit but a higher carotenoids bioavailability;
- packaged 100% FJ compares well to freshly squeezed juice in terms of flavanones absorption and metabolism, suggesting that it has an equivalent nutritional value for bioactives;
- studies suggest that fruit bioactives may have a role in supporting normal health and lowering risk of some chronic conditions.

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