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Bioavailability of all-*trans*- and 9-*cis*-β-carotene from raw and boiled carrots (*Daucus carota* L.)

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Vitamin A must be obtained from the diet, either as preformed retinol or as provitamin A carotenoid precursors[1]. The bioavailability of β-carotene (BC) is of particular interest owing to its provitamin A activity. All-*trans* BC is the predominant isomer found in unprocessed carotene-rich plant foods such as carrots; however, several different geometric isomers of BC exist in foods[1]. Therefore, it is important to consider influential factors such as food matrix, cooking and isomerisation when determining the bioavailability and vitamin A value of BC-rich foods.

Carrots, which originated from The Netherlands, were purchased from Dennigans fruit and vegetable wholesalers (Lenaghmore, Cork, Ireland). All manipulations with the vegetables were performed under yellow light to minimise carotenoid photodegradation. For boiling, one peeled and sliced carrot was added to 500 ml boiling water and cooked for 6 min. For the puree method, carrots were boiled for 20 min, and then mashed. Each sample was weighed (2 g), homogenised, and subjected to an *in vitro* digestion procedure[2], which simulated human digestion. Micelle fractions were isolated from digested samples by ultracentrifugation. Differentiated human intestinal Caco-2 cells were incubated with micelles obtained from digested raw and cooked carrots. The apical side of the transwell plate received micelle-enriched media and the basolateral side received serum-free media. Following 4 h incubation, the micelle-enriched media was removed from the apical side and replaced with media containing chylomicron-stimulating compounds for 16 h. Carotenoid transport refers to the amount of BC isomers detected in the cells (uptake) plus basolateral media (secretion).

	Carrots					
	Raw		Boiled		Pureed	
	Mean	SE	Mean	SE	Mean	SE
	Micelle content (μg/100 g)					
All-*trans*-β-carotene (BC)	23.3^{p}	4.0	72.2^{p}	2.1	$203.3^{r,b}$	24.6
13-*cis*-BC	29.0^{p}	1.4	64.6^{p}	6.8	$165.7^{r,b}$	14.3
	Transport (ng/well)					
All-*trans*-BC	$3.9^{b,p}$	0.5	$21.1^{r,p}$	2.9	$37.9^{r,b}$	4.5
13-*cis*-BC	$3.1^{b,p}$	0.3	14.5^{r}	1.9	22.1^{r}	2.0

Values are means for four independent experiments. ^{r,b,p}Means with unlike superscript letters denote a significant difference between the carrot samples; one-way ANOVA, followed by Tukey's multiple comparison test; $P<0.05$.

Cooking carrots not only enhanced the amount of 13-*cis*-BC in micelles but also all-*trans*-BC isomers. Micelles from pureed carrots had significantly greater ($P<0.05$) amounts of all-*trans*- and 13-*cis*-BC compared with those derived from raw and boiled carrots. In terms of cellular transport, both all-*trans*- and 9-*cis*-BC isomers were transported to similar levels. Carotenoids obtained from cooked carrots were transported to a greater extent by Caco-2 cells than those derived from raw carrots. Again, pureed carrots provide the most bioavailable BC isomers. Our findings show that *cis*-BC isomers are present in micelle fractions derived from raw and cooked carrots. Furthermore, cooking enhances the bioaccessibility and bioavailability of both all-*trans*- and 13-*cis*-BC isomers.

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2. Garrett DA, Failla ML & Sarama RJ (1999) *J Agric Food Chem* **47**, 4301–4309.