Stability of β-carotene during baking of orange-fleshed sweetpotato-wheat composite bread and estimated contribution to vitamin A requirements

Madjaliwa Nzamwita
Amanda Minnaar &
Gyebi Duodu

1 March, 2017

Introduction

- Vitamin A deficiency is a public health problem
- The main strategy used to fight against VAD has been the distribution of high dose capsules of vitamin A
- Need for alternative source of vitamin A
- Orange-fleshed sweet potato (OFSP) is recognised as a rich and cheap source of vitamin A as it contains high amounts of β-carotene.
- However, the baking process may adversely affect β-carotene in OFSP-wheat composite breads as well as their vitamin A activity.

Materials and Methods

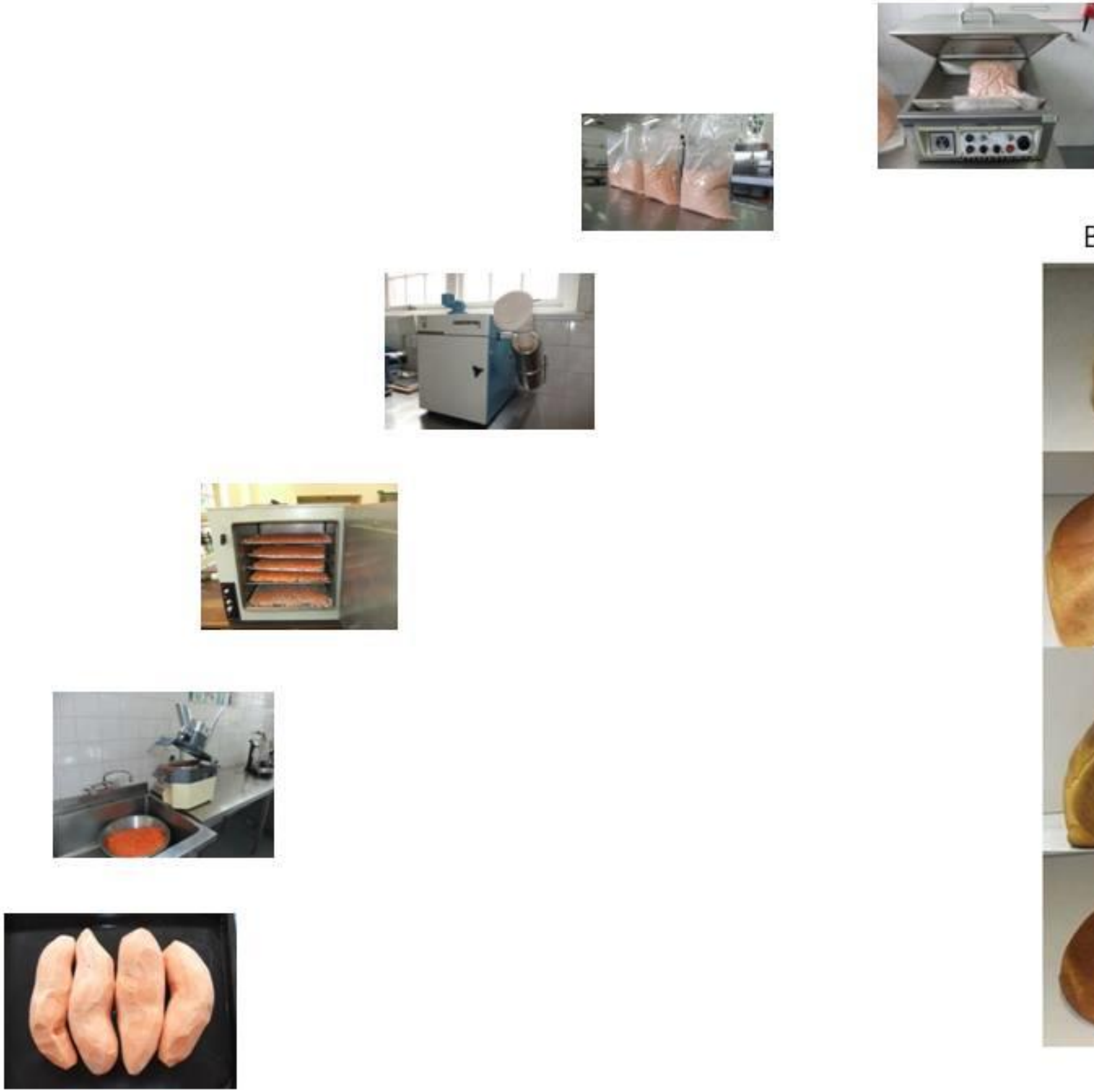


Fig 1. OFSP flour production

+ Wheat flour

Baking (190ºC for 30 min)

Fig 2. Wheat-OFSP composite bread

Colour analysis

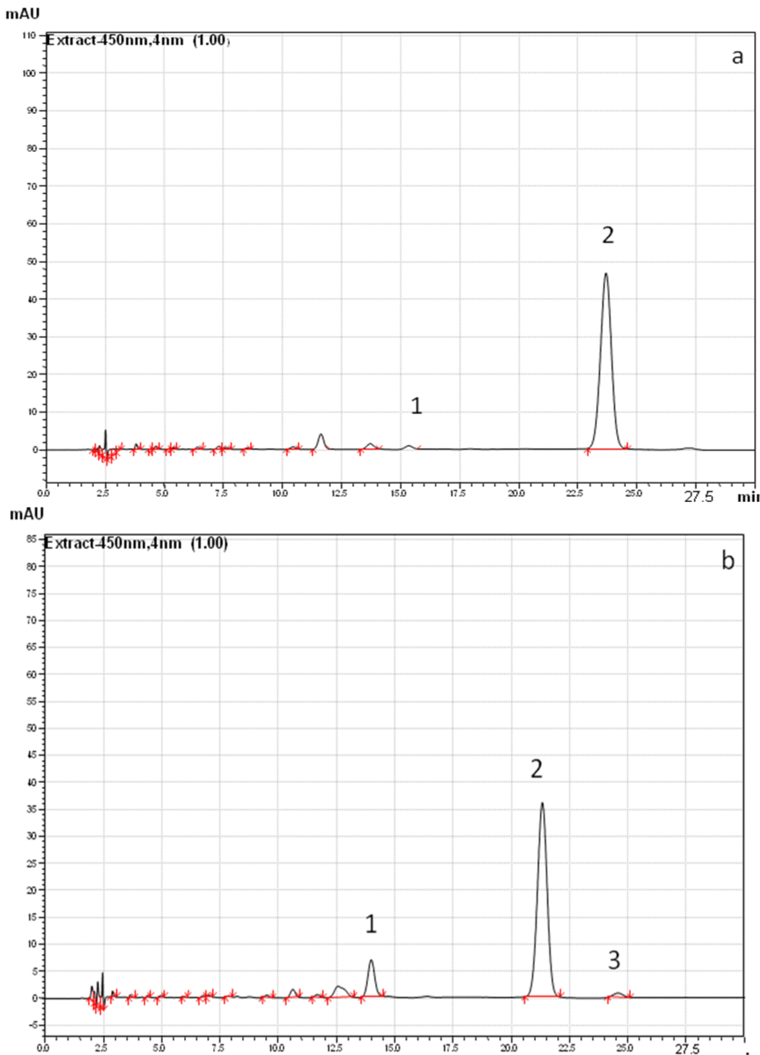
Colour analysis was done based on L*a*b* value:

L* (measure of lightness ranging from 0-100 indicating black to light),
a* (+a, redness and –a, greenness) and
b* (+b, yellowness and –b, blueness) values (Shalini & Laxmi, 2007).
Chroma and hue angle according to the method of Little (1975) as follows:

Chroma= $\sqrt{a^2+b^2}$
Hue angle= $\tan^{-1}(b/a)$

Analysis of the carotenoids

Figure 3. Chromatographic analysis of the carotenoids



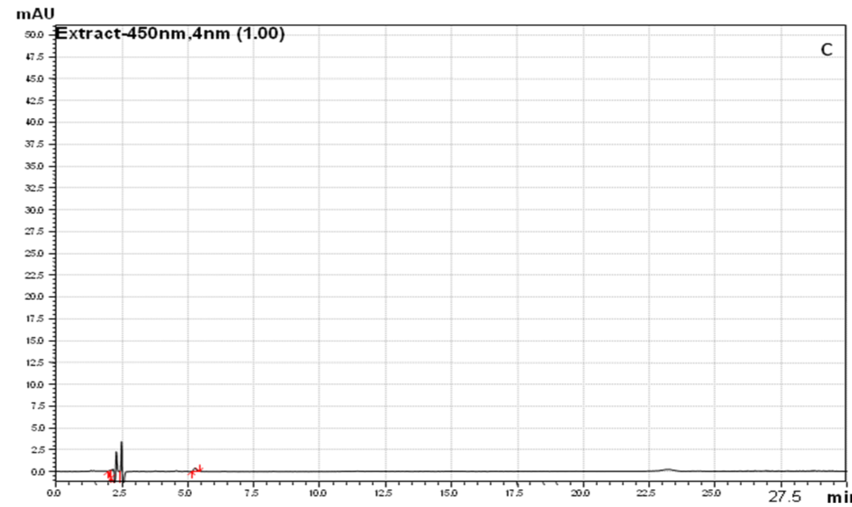


Figure 4. Chromatograms of the carotenoids of (a) dough containing 30% OFSP flour (b) bread containing 30% OFSP flour and (c) bread containing 100% wheat flour

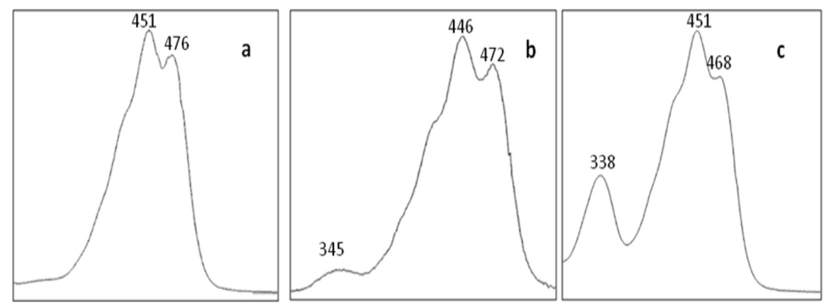


Figure 5 Photodiode array spectra of (a) all-*trans*-β-carotene, (b) *cis*-9- β-carotene and (c) *cis*-13-β-carotene

NB: The separation of carotenoids was performed at 25^{o}C on a C30 YMC carotenoid column

Results and discussion

Table 1. Effect of substituting wheat flour with OFSP flour and baking on β-carotene (db) content in OFSP-wheat composite breads [a]

	Dough		Bread				
OFSPF:WF (w/w)	All-*trans*-β-carotene (µg/100g of dough)	13-*cis*-β-carotene (µg/100g of dough)	All-*trans*-β-carotene (µg/100g of bread)	9-*cis*-β-carotene (µg/100g of bread)	13-*cis*-β-carotene (µg/100g of bread)	Retention of All-*trans*-β-carotene (%)[b]	Vitamin A activity (µg RAE /100g of bread [a])
0:100	ND	ND	ND	ND	ND	ND	0.0
10:90	3100.0 ± 57.0[a]	39.6 ± 1.0[a]	2037.4 ± 46.0[a]	47.6 ± 1.2[a]	349.6 ± 8.8[a]	65.7 ± 1.5[a]	186.3
20:80	5956.0 ± 120.0[b]	82.3 ± 1.2[b]	4251.7 ± 85.0[b]	120.3 ± 2.3[b]	703.5 ± 13.0[b]	71.4 ± 1.4[b]	388.6
30:70	8020.0 ± 167.0[c]	114.7 ± 3.0[c]	6657.1 ± 101.0[c]	148.4 ± 4.1[c]	862.6 ± 14.0[c]	83.0 ± 1.2[c]	596.9

[a] The standard deviations were not provided because the vitamin A activity (µg RAE /100g of bread [a]) of each type of bread was determined based on different forms of provitamin A carotenoids

[b] The retention was determined based on the remaining amount of all-*trans*-β-carotene after baking because other carotenoids were formed at its expense.

Different subscripts in the same column indicate that means were significantly different ($p < 0.05$)

OFSPF: Orange-fleshed sweet potato flour, WF: wheat flour. RAE: Retinol activity equivalent.

Db: Dry basis

ND: Not detected

Table 2 Effect of baking on the retention of colour in OFSP-wheat composite bread

OFSPF:WF (%)	Colour of the dough					Bread colour [a]				
	L*	a*	b*	Chroma	Hue angle	L*	a*	b*	Chroma	Hue angle
0:100	66.0±2.3[a]	-0.2±0.1[a]	11.7±0.7[a]	11.7±0.7[a]	-0.8±0.3[a]	59.6±0.8[a]	1.4±0.4[a]	11.8±0.5[a]	11.8±0.5[a]	83.3±1.8[a]
10:90	57.5±2.4[b]	10.2±0.6[b]	25±1.6[b]	27±1.7[b]	22.3±0.7[b]	50.7±0.8[b]	6.3±0.2[b]	25.4±0.6[b]	26.2±0.6[b]	76.1±0.2[b]
20:80	50.2±1[c]	15.2±0.4[c]	22.3±0.5[c]	27±0.6[b]	34.2±0.5[c]	48.6±0.6[c]	10.7±0.1[c]	25.6±0.8[b]	27.8±0.8[c]	67.2±0.4[c]
30:70	48.8±0.8[c]	18.4±0.5[d]	22.7±1[c]	29.2±1 [c]	39±0.4[d]	44±1.3[d]	13.1±0.2[d]	23±1.5[c]	26.4±1.4[bc]	60.1±1.4[d]

[a] Crust and crumb blended together

Different subscripts in the same column indicate that means were significantly different ($p < 0.05$); n=3

0:100, 10:90, 20:80 and 30:70 represent wheat breads containing 0, 10, 20 and 30% OFSP flour respectively.

OFSPF: Orange-fleshed sweet potato flour; WF: wheat flour

Table 3 Relationship between the stability of all-*trans* β-carotene during baking and colour parameters of OFSP-wheat composite bread[a]

Parameters	L*	a*	b*	Chroma	Hue angle	Amount of all-*trans*-β-carotene retained	Amount of all-*trans*-β carotene lost
L*	1						
a*	-0.985*	1					
b*	-0.553**	0.575**	1				
Chroma	-0.710*	0.729*	0.978*	1			
Hue angle	0.981*	-0.987*	-0.444	-0.617**	1		
Amount of all-*trans*-β-carotene retained	-0.892*	0.889*	0.858*	0.941*	-0.822*	1	
Amount of all-*trans*-β carotene lost	-0.237	0.268	0.929*	0.842*	-0.123	0.633**	1

[a] Crust and crumb blended together
OFSP: Orange-fleshed sweet potato
Significance level: *=p < 0.001 and **= p < 0.01

Table 4. Contribution (%) of OFSP-wheat composite breads (100 g portion, wb) to the RDA of vitamin A in different groups [a]

OFSPF:WF (w/w)	3-10 years children (RDA=400[b])	Adolescents 10-18 years (RDA=600[c])	Adult female 19-65 years (RDA=500[c])	Adult male 19-65 years (RDA=600[c])	Pregnant women (RDA=800[c])	Lactating women (RDA=850[c])
0:100	0.0	0.0	0.0	0.0	0.0	0.0
10:90	29.0	19.2	23.1	19.3	14.5	13.6
20:80	61.0	40.7	48.8	40.7	30.5	28.7
30:70	89.2	59.5	71.4	59.5	44.6	42.0

[a] The standard deviations were not provided because the contribution of each type of bread was determined based on different forms of provitamin A carotenoids.
[b] RDA adapted from FAO (1988), reviewed by Woolfe (1992).
[c] RDA adapted from FAO/WHO (2005).

Table 5. Contribution of individual provitamin A carotenoids to the RDA of vitamin A in different groups

OFSPF:WF (w/w)	Provitamin A carotenoids	Vitamin A (µg RAE/100g of bread)	3-10 years children (RDA=400 [a])	Adolescent 10-18 years (RDA=600 [b])	Adult Female (RDA=500 [b])	Adult male (RDA=600 [b])	Pregnant women (RDA=800 [b])	Lactating women (RDA=850 [b])
0:100	9-*cis*-β-carotene	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	13-*cis*-β-carotene	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
	All-*trans*-β-carotene	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
10:90	9-*cis*-β-carotene	1.2 ± 0.0^{a}	0.3 ± 0.0^{a}	0.2 ± 0.0^{a}	0.2 ± 0.0^{a}	0.2 ± 0.0^{a}	0.2 ± 0.0^{a}	0.1 ± 0.0^{a}
	13-*cis*-β-carotene	9.0 ± 0.2^{b}	2.3 ± 0.1^{b}	1.5 ± 0.0^{b}	1.8 ± 0.0^{b}	1.5 ± 0.0^{b}	1.1 ± 0.0^{b}	1.1 ± 0.0^{b}
	All-*trans*-β-carotene	105.4 ± 2.4^{c}	26.4 ± 0.6^{c}	17.6 ± 0.4^{c}	21.1 ± 0.5^{c}	17.6 ± 04^{c}	13.2 ± 0.3^{c}	12.4 ± 0.3^{c}
20:80	9-*cis*-β-carotene	3.1 ± 0.1^{a}	0.8 ± 0.0^{a}	0.5 ± 0.0^{a}	0.6 ± 0.0^{a}	0.5 ± 0.0^{a}	0.4 ± 0.0^{a}	0.4 ± 0.0^{a}
	13-*cis*-β-carotene	18.4 ± 0.3^{d}	4.6 ± 0.1^{d}	3.1 ± 0.1^{d}	3.7 ± 0.1^{d}	3.1 ± 0.1^{d}	2.3 ± 0.0^{d}	2.2 ± 0.0^{d}
	All-*trans*-β-carotene	222.5 ± 4.4^{e}	55.6 ± 1^{e}	37.1 ± 0.7^{e}	44.5 ± 1^{e}	37.1 ± 0.7^{e}	27.8 ± 0.6^{e}	26.2 ± 0.5^{e}
30:70	9-*cis*-β-carotene	3.7 ± 0.1^{a}	0.9 ± 0.0^{a}	0.6 ± 0.0^{a}	0.7 ± 0.0^{a}	0.6 ± 0.0^{a}	0.5 ± 0.0^{a}	0.4 ± 0.0^{a}
	13-*cis*-β-carotene	21.5 ± 0.3^{d}	5.4 ± 0.1^{d}	3.6 ± 0.1^{d}	4.3 ± 0.1^{d}	3.6 ± 0.1^{d}	2.7 ± 0.0^{d}	2.5 ± 0.0^{d}
	All-*trans*-β-carotene	331.7 ± 5^{f}	83 ± 1.3^{f}	55.3 ± 0.8^{f}	66.3 ± 1^{f}	55.3 ± 0.8^{f}	41.5 ± 0.6^{f}	39 ± 0.6^{f}

Different subscripts in the same column indicate that means were significantly different ($p < 0.05$)

[a] RDA adapted from FAO (1988) as reviewed by Woolfe (1992).

[b] RDA adapted from FAO/WHO (2005).

RDA: Recommended Dietary Allowance.

The retinol activity equivalency factors of 12:1 (FAO/WHO, 2005) and 24:1 (Haskell, *et al.*, 2004) were used for all-*trans*-β-carotene and *cis* isomers respectively.

0:100, 10:90, 20:80 and 30:70 represent wheat breads containing 0, 10, 20 and 30% OFSP flour respectively.

OFSPF: Orange-fleshed sweet potato flour.

WF: wheat flour

Conclusions

- Baking causes the degradation of all-*trans*-β-carotene which results into the formation of new forms of carotenoids in the *cis* configuration with low vitamin A activity.
- Nevertheless, breads (100 g portion) containing 20% and 30% OFSP flour can potentially be used for the eradication of vitamin A deficiency in children as they were found to contribute more vitamin A for children between the age of 3 and 10 years.
- As far as pregnant and lactating women are concerned, they may need more of OFSP bread (> 100 g) to fulfil both their vitamin A requirements and those of their children.
- These findings indicate that colour parameters such as a* value, hue angle and chroma may, in part, be used to predict the β-carotene content in breads or any other products containing OFSP flour if the OFSP cultivar used does not contain other natural colorants.

Obrigado!