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Identification and quantification of carotenoids in pumpkin cultivars (*Cucurbita maxima* L.) and their juices by liquid chromatography with ultraviolet-diode array detection

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Summary

The carotenoid pigments of different cultivars of *Cucurbita maxima* L. (pumpkin) were investigated in pulp, peel and genuine juice by means of HPLC. In dependence of the variety different concentrations and distributions of α-carotene, β-carotene, violaxanthin, neoxanthin, *all-trans*-lutein, zeaxanthin, lutheoxanthin and the isomers 9-*cis*-β-carotene and 13-*cis*-β-carotene were obtained. The total carotenoid content (expressed as dry weight) of the pumpkin peel depends on the variety with 12 mg/kg for „Butternut" up to 1751 mg/kg for „Rouge", whereas total carotenoid contents in the pulp differed from 17 mg/kg for „Baby Bear" to 683 mg/kg for „Rouge". The variety „Hokkaido" showed high total carotenoid contents in pulp (218 mg/kg) and peel (1048 mg/kg), whereas for „Butternut" minor concentrations in pulp (44 mg/kg) and peel (12 mg/kg) were detected. The red and orange coloured *Cucurbita maxima* L. varieties are valuable sources of carotenoids among vegetables or vegetable juices.

Introduction

Recent research is focused on the protective properties of fruits and vegetables against diseases, such as cancer or coronary heart disease. This is due to their high content of antioxidant vitamins, such as vitamins C and E, phenolic compounds, and not at least carotenoids (Burns et al., 2003). New products are being produced in this line with juice mixtures that provide increased quality (nutritive value, colour, etc.), such as high carotenoid content.

Carotenoids are known for a wide range of important and well-documented biological activities. They act as potent antioxidants, as well as free radical scavengers (Grassmann et al., 2002) modulate the pathogenesis of cancers (Van Poppel et al., 1995; Giuvannucci et al., 1999) as well as coronary heart disease (Krichevsky et al., 1999). Various carotenoids, including α-carotene, β-carotene, and β-cryptoxanthin, possess provitamin A activity by being transformed into retinal by mammals. Due to the ability of capturing free oxygen and blue light in the retina, the xanthophylls lutein and zeaxanthin are also known to provide protection against macular degeneration connected with aging (Landrum et al., 2001).

At present, there is no officially recommended dietary intake for carotenoids. The recommended dietary intake for vitamin A is about 1 mg/d retinal equivalent for German speaking countries and the dietary reference intake for vitamin A in North America is up to 3 mg/d (Food and Nutrition Board, 2001).

The red and orange coloured pumpkins *Cucurbita maxima* L. are valuable sources of carotenoids among vegetables or vegetable juices, especially those varieties with orange pulp. Hermann (1992) presented total carotenoid contents in *Cucurbita maxima* L. between 1.4 and 7.6 mg/100 g fresh weight. Murcovic et al. (2002) focused their research on the quantification of α-carotene, β-carotene and lutein on different varieties of the species *C. pepo* L.*, C. maxima* L., and *C. moschata* L.. The content of the carotenoids ranged from 0.06 to 7.4 mg/100 g for β-carotene, from 0 to 7.5 mg/100 g for α-carotene and from 0 to 17 mg/100 g for lutein. Hidaka et al. (1987) and Arima et al. (1988) found substantial differences in the carotenoid profile of several *Cucurbita* species as well.

The purpose of this study was to investigate differences of carotenoid content and composition in pulp and peel in seven different orange or red coloured varieties of *Cucurbita maxima* (var. „Muscat", „Bischofsmütze", „Baby Bear", „Butternut", „Rouge", „Neon", „Hokkaido") grown in Germany. Therefore, HPLC analysis was conducted in order to evaluate their carotenoid content. With regard to juice processing, tree varieties („Muscat", „Rouge", „Neon") were processed to genuine juices in a half technical scale. Carotenoid contents and distributions were analysed in the genuine juices and pomace extracts. Additionally chemical parameters like content of extract, sugar, minerals, total phenols as well as antioxidant capacity were investigated.

Materials and methods

Chemicals. Methanol, tert-butyl methyl ether (MTBE), calcium carbonate and anhydrous sodium sulfate were purchased from Sigma Aldrich GmbH (Taufkirchen, Germany). Acetone and hexane were purchased from Merck (Darmstadt, Germany). High-purity water was prepared using a Milli-Q 185 Plus water purification system (Millipore, Eschborn, Germany). *Trans*-β-*apo*-8´-carotenal, β-carotene, *all-trans*-lutein and lycopene were purchased from Fluka (Buchs, Germany) and zeaxanthin from Roth (Karlsruhe, Germany).

Preparation of samples. *Cucurbita maxima* L. cultivars (var. „Muscat", „Bischofsmütze", „Baby Bear", „Butternut", „Rouge", „Neon", „Hokkaido"), cultivated at the Department of Vegetable Crops of the Research Institute Geisenheim, were manually peeled. Peel and pulp were cut into small cubes and freeze dried (Model P20-B, Fa. Piatowski, München). Sample extraction was conducted according to Marx et al. (2000). In dependence of the expected concentration an aliquot of the freeze dried material was mixed with solid calcium carbonate, sodium sulfate and internal standard *trans*-β-*apo*-8´-carotenal (to guarantee that there where no losses of carotenoids during extraction procedure) and homogenized by an Ultra Turax (Model T50, Janke & Kunkel IKA Labortechnik) for 2 min. Aliquots were immediately extracted with acetone/hexane (1:1; v/v) until extracts were colourless (total volume: 100 mL). The organic layer was washed with water, dried with anhydrous sodium sulfate, filtered through a folded filter and evaporated to dryness in vacuo (200 mbar) at 25 °C. The dry residue was redissolved in tert-butyl methyl ether/methanol/water (90:6:4; v/v/v; 2 mL) and measured by means of HPLC. All procedures were done under dim light, respectively with bay-coloured glassware.

For juice and pomace extract preparation, 10 mL were extracted with acetone/hexane (1:1; v/v) until the water phases were colourless (total volume: 50 mL). Following preparation steps were analogous to the preparation of pulp and peel.

High-Performance Liquid Chromatography. The chromatographic system consisted of a Merck-Hitachi pump model L-6200 (intelligent pump) with a gradient former and a photodiode array detector (L-7450, La Chrom, Fa. Merck). Column was 250 x 4.6 mm i.d. YMC

C_{30}, 5 µm (YMC, Wilmington, USA). The eluent was 81% methanol, 15% tert-butyl methyl ether, 4% water (v/v) (eluent A) and 90% tert-butyl methyl ether, 6% methanol, 4% water (v/v) (eluent B). The linear gradient programme was 100% A to 44% A / 56% B in 50 min. The flow rate was 1.0 ml/min, column temperature was set at 20 °C.

Identification of peaks. Carotenoids were identified according to their chromatographic behaviour (retention time) on HPLC and UV-Vis absorption spectra. By comparing both, their retention times and absorption spectra with those of obtainable authentic carotenoids and published data, respectively, we were able to identify their property. Photodiode array measurements of spectral properties for the individual peaks (from 300 to 500 nm) were determined at the upslope, apex and downslope.

Quantification. The quantitative determination of the total carotenoid contents of pumpkin peel, pulp and juice was performed by UV-Vis (DAVIES et al.,1976). The chromatogrammes were evaluated quantitatively by relating the areas of the individual carotenoids and external calibrating curves of β-carotene and *all-trans*-lutein. To avoid *cis*/*trans* isomerization and epoxide-furanoid oxide rearrangement, great care was taken during the carotenoid isolation procedure. The individual carotenoid content and total carotenoid contents in pulp and peel were expressed on the basis of the vegetable dry weight. The values given in Tab. 1 and 2 represent means of three independent determinations.

Chemical analysis. The chemical analyses were done according to the international fruit juice union (IFU) and the official collection of examination methods §35 LMBG, respectively. The soluble dry substance of the individual juice (°Brix) was analysed via refraction. Glucose, fructose, sucrose and the organic acids (malic acid, lactic acid) were analysed enzymatically. The volatile acid was analysed after distillation with 0.01 mol/L NaOH, the pH-value and total acid content were done potentiometrically (TANNER, 1979). The minerals copper, iron, zinc, sodium, calcium, potassium and magnesium were analysed via AAS. Total phenols were analysed at a wavelength of 720 nm (Folin-Ciocalteau method, (TANNER, 1979)). The antioxidative capacity (TEAC) of the water soluble antioxidants was measured at 734 nm (UV-Vis) (MILLER et al., 1993).

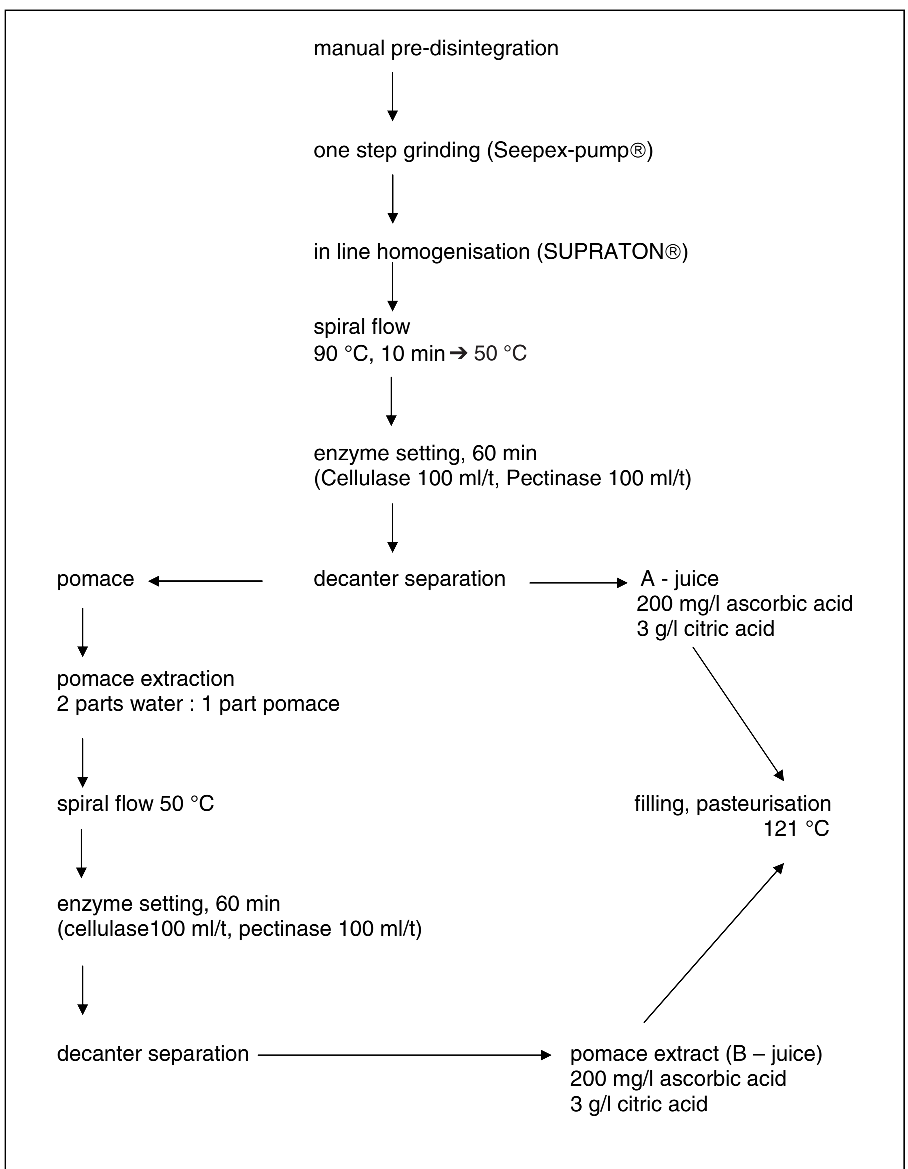

Fig. 1: Processing technology of pumpkin juice in a half technical scale.

Juice processing. Genuine pumpkin juices were produced in half technical scale with lots of 150 kg of three pumpkin varieties separately („Rouge“, „Neon“, „Muscat“) (Fig. 1). The processing consisted of washing, manual pre-disintegration, one step grinding with a seepex-pump®, in line homogenisation (SUPRATON®) for a fine dispersion of the pumpkin mash, mash heating for enzyme deactivating over a spiral flow (90 °C), cooling over a spiral flow to 50 °C and immediate enzyme setting with 100 g/t Cellulase and Pectinase (Erbslöh, Geisenheim) for 60 minutes. Subsequently juice and pomace were separated with a decanter (Flottweg Z23), after adding 3 g/L citric acid and 200 mg ascorbic acid, juices were bottled and pasteurised. Besides juice production (A-juice) a pomace extraction was made. Therefore, water (2:1) and enzymes (100 g/t Pectinase and Cellulase, Fa. Erbslöh, Geisenheim) were added at 50 °C for 60 minutes, followed by decanter separation. Then, 3 g/L citric acid and 200 mg/L ascorbic acid were added, the pomace extracts were filled and pasteurised in bottles.

Results and discussion

Carotenoids in pumpkin peel and pulp

The quantitative results of all cultivars investigated for pumpkin peel are presented in Tab. 1, the results for pumpkin pulp in Tab. 2.

The values given represent means of three independent determinations. Thus, the standard deviation reflects the native variation of the carotenoid content of the samples. The wide variation observed in some cases, especially if considering very low carotenoid concentrations, may be the result of the small number of samples, the stage of ripeness and the weather conditions during growth.

Tab. 1 and 2 reveal the complexity of the carotenoid composition in *Cucurbita maxima* L. cultivars. Distinct differences could be observed in the different *Cucurbita* varieties as well as pulp and peel of the same variety. The *C. maxima* L. var. „Rouge“ was the richest in carotenoids in peel (mean 1751 mg/kg dry weight) and pulp (mean 683 mg/kg dry weight). Also in the peel of „Baby bear“ (mean 1070 mg/kg) and „Hokkaido“ (mean 1048 mg/kg) high carotenoid concentrations were detectable. „Bischofsmütze“ (mean 518 mg/kg), „Muscat“ (mean 570 mg/kg) and „Hokkaido“ (218 mg/kg) showed remarkable concentrations in pulp. „Muscat“ and „Butternut“ had means of only 135 and 12 mg/kg dry weight in the peel, respectively. For „Butternut“ and „Baby Bear“ only 44 mg/kg and 17 mg/kg total carotenoids in the pulp could be detected. The structures of the identified carotenoids are given in Fig. 2.

Only one carotenoid was found in all pulp and peel samples analysed, namely β-carotene. In the pumpkin peel β-carotene was the principle carotenoid in „Muscat“ (61 mg/kg), „Baby Bear“ (403 mg/kg), „Butternut“ (8 mg/kg) and „Neon“ (185 mg/kg). In the pulp of „Muscat“ (263 mg/kg), „Baby Bear“ (17 mg/kg) and „Butternut“ (22 mg/kg) it was the principle carotenoid as well, but not in „Neon“. Lutein was the major carotenoid in the pulp of „Neon“ and „Rouge“ with 115 mg/kg and 146 mg/kg respectively and the second major carotenoid in the peel of „Bischofsmütze“ (69 mg/kg), „Baby Bear“ (376 mg/kg), „Rouge“ (253 mg/kg) and „Neon“ (76 mg/kg). Lutein was not detected in the peel of „Butternut“ and in the pulp of „Muscat“, „Baby Bear“ and „Butternut“.

α-Carotene appeared to be the second major carotenoid in the peel and pulp of „Butternut“ (4 mg/kg; 22 mg/kg), but was neither detected in the peel of „Muscat“, „Bischofsmütze“, „Rouge“, „Neon“, „Hokkaido“, nor in the pulp of „Muscat“, „Baby Bear“, „Rouge“, „Neon“ and „Hokkaido“.

The xanthophyll α-cryptoxanthin was found in major concentrations in the peel of „Bischofsmütze“ (173 mg/kg), „Rouge“ (542 mg/kg) and „Hokkaido“ (489 mg/kg) and in the pulp of „Bischofsmütze“ (178 mg/kg), „Rouge“ (98 mg/kg) and „Hokkaido“ (99 mg/kg), but was not detected in the other varieties. Exclusively in the pulp and peel of the varieties „Bischofsmütze“, „Rouge“ and „Hokkaido“ also β-cryptoxanthin could be detected. High concentrations were found in the peel of „Hokkaido“ (445 mg/kg) and „Rouge“ (289 mg/kg).

Tab. 1: Carotenoid content [mg/kg dry weight] of *Cucurbita maxima* peel of different varieties. The given values represent means ± standard deviations (SD) of three independent determinations.
*: unidentified carotenoid, λ max in eluent B
ND: not detected

		carotenoids in pumpkin peel [mg/kg dry weight]						
ret. time	pigment	Muskat	Bischofsmütze	Baby Bear	Butternut	Rouge	Neon	Hokkaido
11.6	neoxanthin	ND	5 ± 3	ND	ND	108 ± 13	ND	ND
12.1	violaxanthin	ND	5 ± 2	ND	ND	108 ± 2	ND	ND
15.0	lutheoxanthin	19 ± 1	55 ± 5	218 ± 15	ND	199 ± 10	ND	ND
15.4	lutein	12 ± 1	69 ± 9	376 ± 37	ND	253 ± 2	76 ± 7	89 ± 5
17.4	* λmax: 462 Nm	ND	ND	ND	ND	54 ± 1	ND	ND
17.8	zeaxanthin	ND	ND	ND	ND	72 ± 8	ND	ND
32.6	13-*cis*-β-carotene	ND	ND	33 ± 8	ND	ND	ND	ND
34.9	α-carotene	ND	ND	40 ± 7	4 ± 1	ND	ND	ND
35.1	* λmax: 447 Nm	38 ± 2	ND	ND	ND	ND	ND	ND
38.7	α-crypthoxanthin	ND	173 ± 3	ND	ND	542 ± 7	ND	489 ± 4
39.5	β-carotene	61 ± 2	10 ± 1	403 ± 23	8 ± 2	36 ± 13	184 ± 12	25 ± 3
40.4	9-*cis*-β-carotene	5 ± 2	ND	ND	ND	54 ± 6	325 ± 5	ND
44.1	β-crypthoxanthin	ND	30 ± 1	ND	ND	289 ± 4	ND	445 ± 6
46.1	* λmax: 450 nm	ND	ND	0	ND	36 ± 18	ND	ND
total carotenoid [mg/kg dry weight]		135	347	1070	12	1751	293	1048
total carotenoid [mg/kg fresh weight]		20	46	206	2	195	36	148

Tab. 2: Carotenoid content [mg/kg dry weight] of *Cucurbita maxima* pulp of different varieties. The given values represent means ± standard deviations (SD) of three independent determinations.
*: unidentified carotenoid, λ max in eluent B
ND: not detected

		carotenoids in pumpkin pulp [mg/kg dry weight]						
ret. time	pigment	Muskat	Bischofsmütze	Baby Bear	Butternut	Rouge	Neon	Hokkaido
11.6	neoxanthin	ND	ND	ND	ND	49 ± 1	ND	ND
12.1	violaxanthin	ND	ND	ND	ND	49 ± 4	ND	ND
15.0	lutheoxanthin	ND	50 ± 03	ND	ND	118 ± 2	ND	ND
15.4	lutein	ND	50 ± 6	ND	ND	146 ± 6	115 ± 8	20 ± 3
17.4	* λmax: 462 Nm	ND	39 ± 1	ND	ND	7 ± 3	ND	ND
17.8	zeaxanthin	ND	ND	ND	ND	7 ± 2	ND	ND
32.6	13-*cis*-β-carotene	53 ± 2	ND	ND	ND	ND	ND	ND
34.9	α-carotene	ND	6 ± 1	ND	22 ± 1	ND	ND	ND
35.1	* λmax: 447 Nm	254 ± 18	ND	ND	ND	ND	ND	ND
38.7	α-crypthoxanthin	ND	178 ± 3	ND	ND	98 ± 2	ND	99 ± 2
39.5	β-carotene	263 ± 16	89 ± 4	17 ± 1	22 ± 2	132 ± 5	71 ± 6	59 ± 3
40.4	9-*cis*-β-carotene	ND	56 ± 1	ND	ND	ND	ND	ND
44.1	β-crypthoxanthin	ND	28 ± 3	ND	ND	63 ± 3	ND	40 ± 3
46.1	* λmax: 450 nm	ND	22 ± 1	ND	ND	14 ± 1	ND	ND
total carotenoid [mg/kg dry weight]		570	518	17	44	683	186	218
total carotenoid [mg/kg fresh weight]		47	38	2	6	36	13	70

Several epoxycarotenoids were also encountered, namely neoxanthin, violaxanthin and lutheoxanthin in the peel and pulp of „Rouge“ and in the peel of „Bischofsmütze“. Additionally lutheoxanthin was detected in the peel of „Muscat“ (19 mg/kg) and „Baby Bear“ (218 mg/kg). In the varieties „Rouge“ and „Bischofsmütze“ two unidentified carotenoids were also detected, presenting absorption spectra in tert-butyl methyl ether with a single broad peak at 462 nm and 447 nm, respectively.
However, the extend of variation demonstrated by the *Cucurbita maxima* L. varieties analysed in this study is very capacious. The discrepancy could be due to the long period of pumpkin harvest. In contrast to other vegetables, pumpkins could be kept for weeks, but biochemical processes continue during storage (Arima et al., 1988). Initial products of biodegradation, such as *cis*- and epoxycarotenoids were thus present in fluctuating, low concentrations.

Vitamin A value

A comparison of the vitamin A values of pumpkin peels and pulps and additionally in the whole vegetables are given in Tab. 3. The values are calculated from the concentrations of vitamin A-active carotenoids in RE (retinal equivalent) per 100 g fresh weight according to Arima et al. (1988). The vitamin A value of pumpkin varieties depend mainly on the content of β-carotene (100% activity; 0.6 µg β-carotene is equivalent to 0.1 RE), α-carotene (50% activity) and β-cryptoxanthin (50% activity). „Hokkaido“ appeared to be the best source of provitamin A with average concentrations of 425 RE/100g in the pulp, 580 RE/100g in the peel and 331 RE/100g relating to the whole vegetable. For the variety „Muscat“ also high RE values can be calculated with 359 RE/100 g in pulp, 152 RE/100g in peel and 315 RE/100g calculated for the whole vegetable. The varieties „Bischofsmütze“, „Butternut“ and „Neon“ were low in vitamin A value, presenting averages of 93, 65 and 88 RE per 100 g, respectively. Conspicuous is the high vitamin A value in the peel of „Baby Bear“ (1356 RE/100g) which depends on a high β-carotene concentration. In contrast to the values in the peel, only RE values of 32 RE/100g in the pulp and, therefore 159 RE/100g can be determined for the whole vegetable.

Pumpkin juice

With regard to pumpkin juice processing, three varieties („Muscat“, „Rouge“, „Neon“) were processed in a half technical scale to genuine juices. Especially high amounts of carotenes in juice are preferable. It is well known that during juice processing a big part of secondary plant metabolites get lost in the pomace. Therefore the pumpkin pomace was extracted after enzyme setting and addition of water (1:2, w/w) additionally. This extract leads to a pomace extract rich in carotenes, which can be used as natural supplement for food industry. The results of the carotenoid content and carotenoid distributions of the genuine juices and pomace extracts are given in Tab. 4. The juice and pomace extract of the variety „Muscat“ were rich in total carotenoid content in juice (19.7 mg/L) and in pomace extract (34.0 mg/L). For the varieties „Rouge“ and „Neon“ only minor carotenoid contents were investigated in the juices (3.7 mg/L and 3.8 mg/L). Therefore considerable concentrations could be transferred from the pomace into the pomace extract (11.0 mg/L „Rouge“ and 14.1 mg/L „Neon“). In all juices and pomace extracts β-carotene appeared to be the main carotenoid. In the variety „Rouge“ α- and β-cryptoxanthin were detectable additionally in juice and particularly in pomace extract as a result of high concentrations in the peel. Lutein appeared to be detectable in the juice and pomace extracts of „Rouge“ and „Neon“, but not in the juice of „Muscat“. This confirms the results of the carotenoid analyses in pulp and peel, due to the fact that there were no or only minor concentrations of lutein detectable.
Additionally to the carotenoid analyses, basic juice parameters were investigated in the genuine juices and pomace extracts. Results of the juice and pomace extract analyses are given in Tab. 5. Sugar contents varied in dependence of the variety between 8.4-10.3 g/L

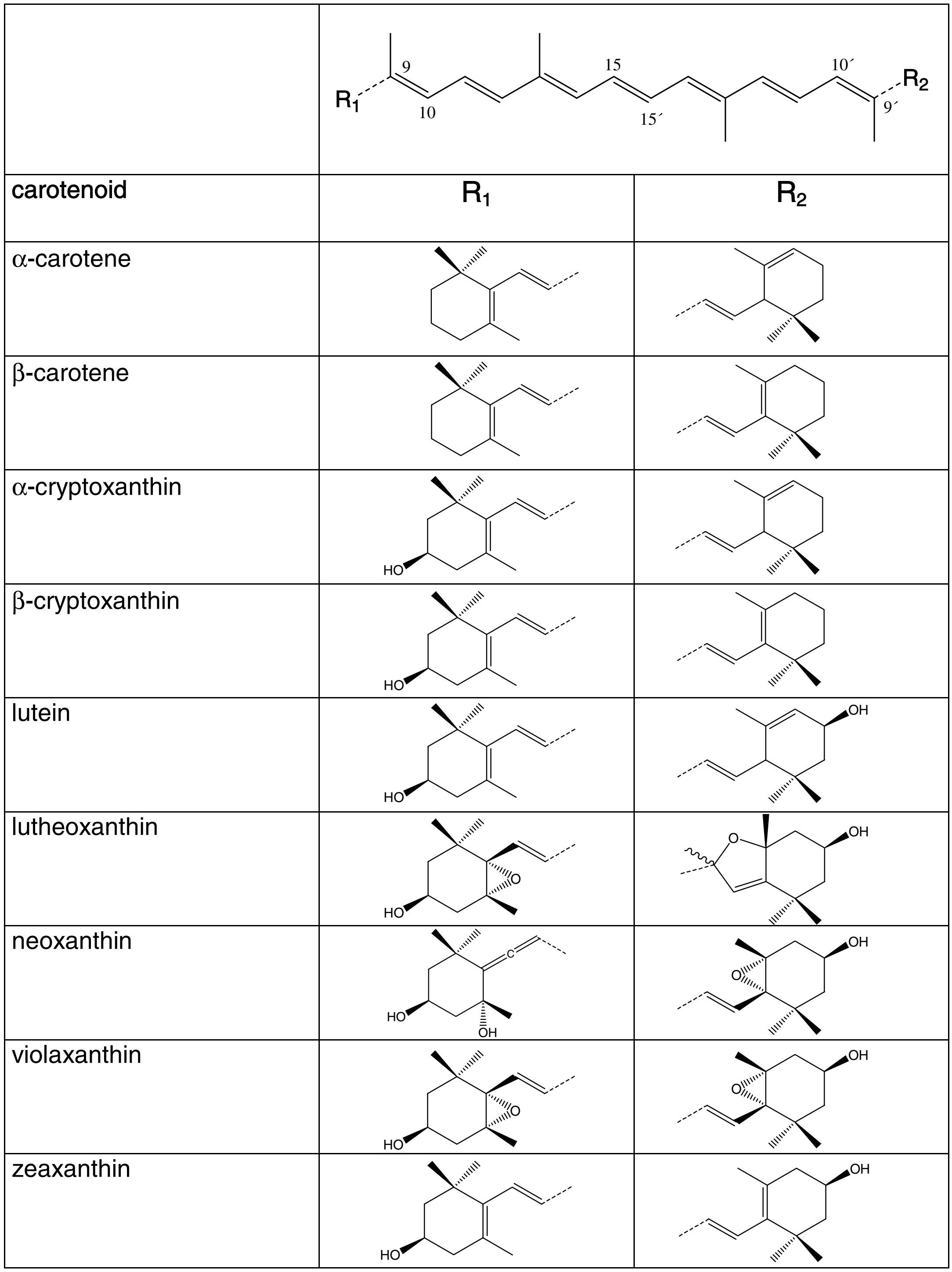

Fig. 2: Structures of carotenoids detected in *Cucurbita maxima L.* varieties; α-carotene; β-carotene; α-cryptoxanthin; β-cryptoxanthin; lutein; lutheoxanthin; neoxanthin; violaxanthin; zeaxanthin.

glucose, 9.5-15.9 g/L fructose and 2.3-17.6 g/L saccharose in the juices and 3.0-4.4 g/L glucose, 3.4-5.9 g/L fructose and 0.9-3.7 g/L saccharose in pomace extracts. The microbiological parameters volatile acid and lactic acid were inconspicuous in all juices and pomace extracts. Ash contents were comparable in all juices (6.54 g/l-6.88 g/L) and pomace extracts (2.28 mg/L-3.26 mg/L). The mineral contents in the pumpkin juices were assimilably high. Potassium concentration ranged between 3682 mg/L („Muscat") and 4121 mg/L („Rouge"), calcium contents laid between 156 mg/L („Muscat") and 293 mg/L („Rouge") and magnesium underlay variations between 127 mg/L („Rouge") and 186 mg/L („Neon"). The total phenol contents, analysed according to the Folin-Method with catechin as standard, varied between 258 mg/L („Muscat") and 323 mg/L („Neon") (total phenol contents were not corrected in respect of ascorbic acid). The water soluble antioxidative capacity was determined from 2.1 mmol/L Trolox („Muscat") up to 2.7 mmol/L Trolox („Neon"). It has to be stressed that the values are comparable to the antioxidative capacity of carrot juice.

Tab. 3: Comparison of vitamin A values of different pumpkin varieties in pulp, peel and in the whole vegetable.

variety	Provitamin	Vitamin A value RE per 100 g fresh weight		
		pulp	peel	whole vegetable
Cucurbita maxima var. Muscat	β-carotene	359	152	315
Cucurbita maxima var. Bischofsmütze	α-carotene, β-carotene, β-cryptoxanthin	130	56	93
Cucurbita maxima var. Baby Bear	α-carotene, β-carotene	32	1356	159
Cucurbita maxima var. Butternut	α-carotene, β-carotene	74	28	65
Cucurbita maxima var. Rouge	α-carotene, β-carotene, β-cryptoxanthin	144	334	130
Cucurbita maxima var. Neon	β-carotene	84	379	88
Cucurbita maxima var. Hokkaido	β-carotene, β-cryptoxanthin	425	580	331

Tab. 4: Carotenoid content mg/L of *Cucurbita maxima* L. juice and pomace extract of different varieties. The given values represent means ± standard deviations (SD) of three independent determinations.

		carotenoids in pumpkin juice and pomace extract [mg/L] 8° Brix					
ret. time	pigment	Muscat juice	Muscat pomace extract	Rouge juice	Rouge pomace extract	Neon juice	Neon pomace extract
15.4	lutein	ND	ND	0.6 ± 0.2	1.3 ± 0.2	0.7 ± 0.1	5.8 ± 0.2
35.1	* λmax: 447 nm	9.1 ± 0.5	16.4 ± 0.7	ND	ND	ND	ND
38.7	α-crypthoxanthin	ND	ND	0.6 ± 0.1	2.6 ± 0.2	ND	ND
39.5	β-carotene	10.6 ± 0.8	17.6 ± 0.2	1.9 ± 0.3	5.2 ± 0.4	3.1 ± 0.3	8.3 ± 0.6
44.1	β-crypthoxanthin	ND	ND	0.6 ± 0.2	1.9 ± 0.3	ND	ND
	total carotenoids	19.7	34.0	3.7	11.0	3.8	14.1

*: unidentified carotenoid, λ max in eluent B
ND: not detected

Conclusion

The study was focused on carotenoids in peel, pulp and juices of different pumpkin cultivars grown in Germany. Pumpkin is not a very common food but its consumption increased during the last years. This study shows that pumpkin can contribute significantly to the uptake of provitamin A and carotenoids with special physiological functions, especially lutein. With regard to a rapidly growing market of functional foods worldwide, pumpkin may be considered as an interesting and valuable source of carotenoids.

Further studies will be focused on pumpkin juice processing with special regard to pumpkins rich in carotenoid content and high vitamin A values, respectively.

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Tab. 5: Quality parameters of pumpkin juices and pumpkin pomace extracts of the varieties *Cucurbita maxima* „Muscat“, „Rouge“ and „Neon“.

		pumpkin juice			pumpkin pomace extract		
		Muscat	Rouge	Neon	Muscat	Rouge	Neon
density	[20/20]	1.0317	1.0225	1.0211	1.0131	1.011	1.0087
brix	[°]	7.22	5.05	4.68	3.07	2.47	1.94
conductance	[µS/cm]	6010	7170	7000	2680	3880	3200
extract	[g/L]	81.2	58.2	54.6	33.9	28.4	22.4
sugar free extract	[g/L]	37.4	35.8	33.7	19.9	18.1	15.0
glucose	[g/L]	10.3	9.7	8.4	4.4	4.4	3.0
fructose	[g/L]	15.9	10.4	9.5	5.9	5.0	3.4
saccharose	[g/L]	17.6	2.3	3.0	3.7	0.9	1.0
pH-value		4.41	3.97	4.31	3.79	4.33	3.77
total acid (pH 8.1, citric acid)	[g/L]	3.66	3.76	3.63	2.82	2.99	3.02
ascorbic acid	[mg/L]	184	104	92	164	325	88
lactic acid	[g/L]	< 0,05	< 0,05	< 0,05	< 0,05	0.12	0.05
malic acid	[g/L]	3.75	3.19	1.34	1.12	1.26	0.44
volatile acid	[g/L]	0.08	0.09	0.1	0.11	0.11	0.1
copper	[mg/L]	0.5	0.3	0.5	0.2	0.3	0.3
iron	[mg/L]	1.5	1.0	1.0	0.3	0.3	0.2
zinc	[mg/L]	0.9	0.8	1.2	0.5	0.4	0.5
sodium	[mg/L]	3	3	8	5	5	7
calcium	[mg/L]	156	293	176	71	142	71
potassium	[mg/L]	3682	4121	3955	1027	1434	1141
magnesium	[mg/L]	130	127	186	51	61	76
ash	[g/L]	6.54	6.6	6.88	2.28	3.26	2.63
total phenol	[mg/L]	258	318	323	156	171	169
TEAC	[mmol/L Trolox]	2.1	2.3	2.7	1.1	1.5	1.5

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