Quality assessment of baby food made of different pre-processed organic raw materials under industrial processing conditions

Kathrin Seidel · Johannes Kahl · Flavio Paoletti · Ines Birlouez · Nicolaas Busscher ·
Ursula Kretzschmar · Marjo Särkkä-Tirkkonen · Randi Seljåsen ·
Fiorella Sinesio · Torfinn Torp · Irene Baiamonte

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Abstract The market for processed food is rapidly growing. The industry needs methods for “processing with care” leading to high quality products in order to meet consumers’ expectations. Processing influences the quality of the finished product through various factors. In carrot baby food, these are the raw material, the pre-processing and storage treatments as well as the processing conditions. In this study, a quality assessment was performed on baby food made from

different pre-processed raw materials. The experiments were carried out under industrial conditions using fresh, frozen and stored organic carrots as raw material. Statistically significant differences were found for sensory attributes among the three autoclaved puree samples (e.g. overall odour $F=90.72$, $p<0.001$). Samples processed from frozen carrots show increased moisture content and decrease of several chemical constituents. Biocrystallization identified changes between replications of the cooking. Pre-treatment of raw material has a significant influence on the final quality of the baby food.

K. Seidel · U. Kretzschmar
Department of Food Quality, Safety and Processing, FiBL Research
Institute of Organic Agriculture, Ackerstrasse, Frick, Switzerland

J. Kahl (✉) · N. Busscher
Department of Organic Food Quality and Food Culture, Faculty of
Organic Agricultural Sciences, University of Kassel,
Nordbahnhofstr. 1a, 37213 Witzenhausen, Germany
e-mail: kahl@uni-kassel.de

F. Paoletti · F. Sinesio · I. Baiamonte
Scienze Applicate alla Alimentazione, Istituto Nazionale di Ricerca
per gli Alimenti e Nutrizione (INRAN), via Ardeatina,
546, Rome, Italy

I. Birlouez
Spectralys Innovation, Parc Biocitech, 102 avenue Gaston Roussel,
93230 Romainville, France

M. Särkkä-Tirkkonen
Ruralia Institute, University of Helsinki, Lönnrotinkatu 7,
50100 Mikkeli, Finland

R. Seljåsen
Arable Crops Division, Seljåsen, BIOFORSK, Norwegian Institute
for Agricultural and Environmental Research, Reddalsveien 215,
4886 Grimstad, Norway

T. Torp
Plant Health and Plant Protection Division, BIOFORSK,
Norwegian Institute for Agricultural and Environmental Research,
Høgskoleveien 7, 1432 Ås, Norway

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Introduction

After the first period of human life an adequate supply with complementary feeding to breast milk should be ensured (Majchrzak et al. 2000). Vegetable based foods are easy to digest and offer high nutrient density (Cizkova et al. 2009). Therefore baby puree made out of carrots, parsnips or potatoes plays a major role in early nutrition. Carrots are considered to have high nutritional value and are mostly the first vegetable the babies receive after breast feeding. Therefore, carrots were chosen as the model vegetable for this study. The nutritional quality, sensory and food safety of baby puree, e.g. from carrots, is influenced by many factors within the production chain. They are, for example, the quality of raw material, the pre-processing as well as the processing conditions.

As Cizkova et al. (2009) showed the nutritional quality determined as ascorbic acid and total polyphenols content and nutrient density differs strongly within commercial baby

food. The ingredient composition and quality of raw material (organic and non-organic food) influence the carotenoid content and bioavailability of the baby meals (Jiwan et al. 2010). The differences in the amount of carotenoids and retinol of purchased carrot baby products that were reported by Majchrzak et al. (2000) were caused by the different size, age and variety of the carrots. It is known that processing vegetables by mechanical homogenization has the potential to increase the bioavailability of carotenoids (Van het Hof et al. 2000). At the same time heat treatments such as sterilization decrease the content of carotenoids and water-soluble vitamins (Yim and Sohn 2004). The outsourcing of pre-processing steps, for example peeling, cutting, blanching, freezing, and the acquisition of semi-finished frozen vegetables with standardised parameters available during the whole year is common in industrial baby food production (QACCP 2012).

In the production of frozen carrot cubes, blanching is performed to reduce microbial load, stabilize quality and inactivate enzymes which can cause discoloration and oxidation of e.g. phenolic compounds. However, blanching may also cause undesirable changes in physico-chemical properties, such as a darker colour and softer texture (Gonçalves et al. 2010), and decrease nutrient content on account of heat-induced as well as diffusion or leaching losses (Kidmose and Martens 1999). Freezing conditions (cryogenic or blast) should not influence nutritional quality significantly, but the period of storage increases the sugar content and drip loss. The freezing temperature is the most critical factor affecting the cell structure of the carrots, because large ice crystals damage the cell structure and texture irreversibly (Préstamo et al. 1998). By contrast, blanching may improve final product safety regarding heat-induced neoformed contaminants such as the carcinogenic compound furan, due to leakage of the precursors, vitamin C, sugars and carotenoids (Crews and Castle 2007).

Consumer information on processing is low, but nevertheless they expect gentle processing methods for organic foods. Ideas about the special processing techniques of organic baby purees turn out to be rather fuzzy (QACCP 2012). This is probably due to a generalised lack of consumer knowledge about processing techniques (Sylvander and Francois 2006). Not only consumer expectations but also Codex Alimentarius ask for processing with care of organic products (Codex 1999).

The aim of this study was to evaluate to what degree the quality of raw material, here the intensity of pre-processing (fresh, frozen, stored) influence the end product quality. For quality evaluation we followed a multi-parameter approach (Kahl et al. 2012), where several parameters were measured in parallel. In this study the effects of blanching and freezing compared to processing fresh or stored quality followed by sterilization and standardised processing of pureed baby food at industry level were compared and assessed.

Materials and method

Sample treatments

Three industrial tests were performed together with two SMEs for pre-processing and processing in Switzerland in January 2009 with fresh raw material, in March 2009 with frozen raw material and in April 2009 with 3 month stored raw material.

For the industrial tests 10 t Swiss Demeter carrots (*Daucus carota*) of the Bolero variety were grown in the same field (Basadingen, Switzerland), harvested at the same time (October 2008) and stored under standardised circumstances (1–2 °C, 90 % RH). Washing, peeling and cutting into carrot cubes are pre-processing steps, which were done in a standardised manner. Carrots ($\varnothing > 35$ mm) were washed for around 5 min with tap water, without adding any washing additives. For peeling, the carrots were steamed batchwise (140 kg) in a rotating steam peeling pot for 60 s under a pressure of 8.5–9 bar. During leaving the steam peeling pot the sudden pressure loss makes the skin of the carrots burst open. The carrots fall down into a rotation barrel where the skin can be removed with mechanical movement.

Faulty raw material was removed and green stems were mechanically cut. The peeled and clean carrots fell into the cutter with a 3D knife (round, cross and high) and were cut in 6,4*6,4*6,4 mm cubes. Small pieces as well as brown or green carrot cubes were taken out in a colour separation machine.

Carrot cubes for freezing were steam-blanching at 92 °C for 3 min and directly afterwards cooled down to 11 °C by using cold tap water. Before the carrots were frozen a last visual inspection was done by workers. The freezing process took place in two steps and lasted a total of 9 min. During the first step (3 min) the cubes were quick frozen (IQF) individually at –31 °C, jiggled all the time not to freeze together, and afterwards iced for 6 min. at temperatures of –25 °C.

Each kind of raw material (fresh, stored and frozen) was processed by adding 10 % water to the baby puree. Two batches of each kind of raw material were processed according to the standard protocol of the industrial partner and passed through the processing steps of cooking, milling, filtering, bottling into 190 g glasses and sterilising. One batch of cooked carrot puree produced 10.500 glasses. In one of the cooking replications of the stored carrots, the circulation process within the cooking device did not work as expected and the carrot mass was heated up to 105 °C for about 8,400 s compared to the normal average of 4,600 s. Double samples were taken as shown in the flow chart (Table 1) and sent to all participating laboratories in France, Germany and Italy. The coded samples were analysed after April 2009 for quality and safety parameters including biocrystallization and sensory analysis. Raw material samples were taken as pooled samples before pre-processing in January.

Table 1 Outline of the industrial baby food processing from three differently processed raw materials. Each processing was done with one replication, followed by two samplings per each replication

Date	Fresh	Stored	Frozen+stored
23.01.2009	Processing fresh cubes	In storage	Pre-processing and freezing
10.03.2009		In storage	Processing frozen cubes
03.04.2009		Pre-processing and processing stored cubes	

Dry matter, color and soluble solids

Carrot puree samples were analyzed for their moisture content under standard conditions (at 70 °C for 12 h followed by 70 °C under vacuum for 12 h), soluble solids content by a digital refractometer and titratable acidity by titration with KOH 0.1 N. Color characteristics were determined by a sphere spectrophotometer X-Rite SP60 (X-Rite, Incorporated, Grandville, Michigan).

Organic acid and carotenoid composition

The chromatographic analyses were performed on a Hewlett Packard (Palo Alto, CA) HPLC system with 1,100 Series quaternary pump, a diode array detector and a refractive index detector. The analytical procedure used for organic acid determination has been described in detail in (Raffo et al. 2007). All solvents were of HPLC grade and were purchased from Carlo Erba. All reagents and standards were obtained from Sigma Chemicals, except for β -apo-8'-carotenal, α -carotene (from Fluka), β -carotene and lutein (from Carote Nature GmbH, Lupsingen, Switzerland). For the organic acid composition, 10 g of puree sample were added to 10 mL of 2 % metaphosphoric acid and extracted by UltraTurrax homogenizer (8,000 rpm) for 3 min. The obtained mixture was then centrifuged at 15,000 rpm for 10 min (at 4 °C), and the supernatant was collected and filtered with a syringe filter. For the chromatographic analysis of the obtained aqueous extract, a ReproSil-Pur C18-AQ column (5 μ m, 4.6×250 mm), thermostated to 35 °C, was used. The organic acids were eluted isocratically with aqueous H₃PO₄ 0.5 %, at a flow rate of 0.7 mL/min and the eluate was monitored at 214 nm for malic, citric and fumaric acids, and at 240 for ascorbic acid.

For carotenoids extraction the procedure described by Hart and Scott (1995) was followed, with few modifications. Five grams of puree sample were added with 0.5 g of CaCO₃, 200 μ L of β -apo-8'-carotenal 800 mg/L in THF and 20 mL of a mixture THF:methanol 1:1 (containing 0.1 % butylated hydroxytoluene, BHT), and then extracted four times by UltraTurrax for 3 min at 0 °C (at 8,000 rpm). The combined liquid fractions were filtered under vacuum with Whatman filter paper n. 1. The THF/MeOH/aqueous phase was partially evaporated at 35 °C in a rotary evaporator, to near 10 mL.

Twenty milliliter of petroleum ether (containing 0.1 % BHT), 20 mL of aqueous NaCl 10 % were then added and mixed by shaking. The mixture was centrifuged at 1,000 rpm for 2 min and the petroleum ether phase collected. The aqueous phase was washed 3 times with 20 mL petroleum ether, and the ether fractions collected. The combined petroleum ether fractions were evaporated at 35 °C in a rotary evaporator to near dryness. The residue was re-dissolved to a final volume of 10 mL in acetone (containing 0.1 % BHT). The extract was then filtered by a syringe filter and injected for chromatographic analysis. HPLC separation was achieved on a YMC C30 column (5 μ m, 4.6×250 mm), with a YMC basic VS guard column (3 μ m, 4.0×10 mm), thermostated to 35 °C, using the following linear gradient: 0 min 40 % A and 60 % B; 3 min 70 % A; 15 min 90 % A; 25 min 95 % A; 30–65 min 100 % A; 70 min 40 % A, where “A” was methanol/acetone 60:40 and “B” acetone/water 60:40. The flow rate was 0.5 mL/min and the volume injected 20 μ L. Peak responses were detected at 450 nm. Identification of α -carotene, β -carotene and lutein was performed on the base of comparison of retention times and UV–vis spectra with those obtained on authentic standards. Quantification was carried out by using calibration curves obtained from standard solutions of pure compounds.

Volatile compounds

Fifty grams of sample and 100 mL of deionized water were mixed and stirred for 2 min. The obtained mixture was filtered under vacuum with Whatman filter paper n.113 and glass wool, and then 100 mL of the obtained juice were infused with 100 μ L of the methanol solution containing two internal standards (1.5 μ L/mL methylcyclopentadiene dimer and 1.5 μ L/mL (–)- α -copaene, both purchased from Sigma-Aldrich (Sigma-Aldrich, Milwaukee, WI).

Isolation of volatile compounds from this working solution was performed by the Stir Bar Sorptive Extraction (SBSE) technique (Baltussen et al. 1999) according to the conditions described in detail elsewhere [19]. Also the conditions of the GC-MS analysis were as described in that paper, except for the analytical capillary GC column, that was a DB-1 (Agilent Technologies Inc.) column (30 m×0.25 mm i.d., 0.25 μ m film thickness), the split injection (solvent vent mode, and purge flow to split vent at 50 mL min^{–1} after 0.01 min) and the

temperature program (from 40 °C (2 min) to 150 °C at 4 °C min⁻¹ and then to 290 °C (5 min) at 15 °C min⁻¹). All analyses were performed in triplicate. For peak identification the following authentic standards were used: α -pinene, γ -terpinene, terpinolene, bornyl acetate, β -caryophyllene, β -pinene, 1-octanal, p-cymene, limonene, α -humulene, β -ionone, myristicin (all purchased from Sigma-Aldrich, Milwaukee, WI). Quantification was performed on the basis of chromatograms obtained in the scan mode. Response factors were determined referring to methylcyclopentadiene dimer, as internal standard, for all monoterpenes and 1-octanal, and referring to (-)- α -copaene as internal standard, for all sesquiterpenes, β -ionone, myristicin and elemicin. Whenever an authentic standard was not available, the response factor of the most similar compound, for which an authentic standard was available, was used for calculation. Levels of volatile compounds were expressed as mg per kilogram of carrot fresh weight.

Furosine, carboxymethyl lysine (CML) and furan

100 mg of lyophilized carrot puree samples were hydrolyzed at 110 °C for 18 h in 1 ml of 7.8 M hydrochloric acid containing the internal standard cycloleucine (10 μ g/ml). During this step FL was converted into furosine but CML remained stable. The modified amino-acids furosine and CML were analyzed by GC-MS-MS after methylation of the carbonyl groups and acylation of the amine residues according to the method of Charissou et al. (2007). After drying 500 μ L of the hydrolysate, the precipitate was diluted in 500 μ L ultra-pure water, filtrated through a 0.45 μ m pore nylon filter (Cluzeau, France) and dried again. The dried samples were derivatized with 1 ml of thionyl chloride/methanol solution (1.46 ml of thionyl chloride in 100 ml of methanol), heated in an oven for 30 min at 110 °C and dried under a nitrogen stream. Two ml dichloromethane and 400 μ L of trifluoroacetic acid anhydride were then added to allow amine acylation at ambient temperature for 1 h. The derivatized sample was dried under nitrogen and 1 ml dichloromethane was added. The dried extract was dissolved in 100 μ L dichloromethane and injected into the GC. Quantification was done on a TRACE GC ULTRA GC coupled to an ion Trap Mass Spectrometer ITQ 900 (Thermo Electron Corporation) using a DB5-MS capillary column (30 m $\times$ 0.25 mm, 0.25 μ m) and split injection mode with selected ion monitoring after electron ionization at 70 eV. The temperature programme was 2 min at 70 °C, then increasing by 5 °C/min to 260 °C, 15 °C/min to 290 °C and finally 290 °C for 5 min. The carrier gas was helium with a flow rate of 1.5 ml/min. Selected ions (m/z) formed by electron ionization used for quantification were as follows: 240, 180, 67 for cycloleucine, 305, 275, 192, 180, 164 for FUR and 392, 374, 360, 332, 206 for CML. External calibration for furosine and CML was performed in the 0.25–20 μ g/ml range.

Furane was determined by GC-MS-MS in headspace mode and isotopic dilution using a HP-Plot Q (15 m, 0.32 mm, 0.20 μ m) column, a Varian 3,800 chromatograph and a Saturn 2,000 mass spectrometer. D4-furane and 250 μ L of water were added to 250 mg of solid matrix in an injection vial. The vials were heated at 80 °C for 30 min. The calibration curve used d4-furane as internal standard.

Sensory analysis

Descriptive sensory profiling analyses were performed according to international (ISO) standards (ISO 2003, 1994) in a sensory laboratory equipped with facilities for individual work. The environment for tasting was controlled as required by ISO 2007. Eight members of a panel selected and trained according to guidelines in the International Standards (ISO 2008, 1993) and with long experience (12–20 years) in sensory evaluations, took part in the experiment. In the week prior to the test sessions, the panellists participated in specific training sessions on the products (four sessions of 60 min each). During the training sessions panellists reached consensus on the attributes.

The tests were run in 2 days. Each day the assessors participated to two 1-h sessions with a 20-min break. During the test sessions, every panellist evaluated the complete set of samples presented twice. Samples were allocated at random to the session, and replicates were served in sessions on different days. Within a session each participant received the samples in a unique order according to a Latin Square Design in order to balance serving order and carryover effects (MacFie et al. 1989). Portions of the samples (30 g) were served at 22 $\pm$ 2 °C temperature in plastic covered caps, coded with three digit random numbers for anonymity purposes. Still mineral water and unsalted crackers were available for palate cleaning.

For all evaluations a computerized score collection (FIZZ software v.2.3c, Biosystemes, France) was used. Definition of terms were available during the session, and the intensity or strength of the descriptive terms was marked on a horizontal 150 mm unstructured line scale, anchored at the extremes 'zero' (0) and 'strong' (9).

Biocrystallization

The basic principles of biocrystallization are described in (Busscher et al. 2010a, Kahl et al. 2010), the application for carrots is described in (Busscher et al. 2010b). The biocrystallization can be applied on many different food samples, from which a watery extract or juice can be made such as milk and milk products (Kahl et al. 2009), carrots (Busscher et al. 2010a, b) or wheat (Szulc et al. 2010).

Cupric chloride solution is obtained from $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ (Merck, Nr. 1.02733) dissolved in milli-Q water (Millipore) to the final concentration of 0.59 mol l^{-1} .

To 40 g carrot baby food (per jar) Milli-Q water was added up to 400 g and moved at 200 rpm for 30 min (Heidolph Unimax 2010). The solution was sieved with a $110 \mu\text{m}$ nylon sieve and left to stand for 20 min at room temperature. 33.5 mL Milli-Q water and 9 mL 10 % CuCl_2 solution were mixed and 17.5 mL of the supernatant was added. This mixing ratio was determined in pre-experiments. Construction and function of the crystallization chamber used here are documented in Kahl et al. 2009. Crystallization took place in a vibration-free apparatus located in the inner chamber, including 43 dishes per course, positioned on an inner and outer ring. In the outer chamber, the climate parameters, temperature and humidity, were kept constant. The climate conditions were continually measured at various points and monitored online. Experiments were performed at a medium evaporation time of 13–14 h, 26°C and 53 % humidity in the outside chamber and 30°C , 53 % humidity over the dishes.

The dishes were taken out of the chamber directly after crystallization, the acrylic ring was removed and each plate was then appropriately labeled on the outside edge under the crystallization center. After 3 days of storage in the outer chamber the plates were scanned with a PowerLook III, UMAX Scanner in a transmitted light process and collected per chamber course and day and stored in the outer chamber.

Three to six dishes of each sample preparation (chamber solution) per chamber were crystallized in parallel. Crystallization took place in two chambers in parallel. For the evaluation of the trials all crystallization pictures per treatment were grouped together.

To evaluate the patterns the texture analysis developed in (Andersen et al. 1999) was used. Only variables of a second order (because of histogram matching) on Scale 1 are considered. The variables are described in (Carstensen 1992). Only those variables which showed a monotonous course with ROI were considered. The image analysis results are presented using different ROIs (20–100 %), but they have also been calculated for interim stages (Meelursarn 2007).

Statistical analysis

One-way ANOVA plus a post-hoc test at 95 % confidence level was run to examine the difference between the different pre-processing conditions. For biocrystallization a linear mixed effects model ANOVA was applied (Meelursarn 2007). Principal component analysis (PCA) was performed using Minitab 16 (Minitab Inc, State College, PA, USA) on all morphological, chemical and sensory variables from different laboratories available on the samples. Variables with a coefficient of variation less than 1% (0.01 in absolute value) were left out of the PCA. Data files from different laboratories were

checked for consistency and plausibility before they were merged (QACCP 2012).

Results and discussion

Moisture, color, organic acid and carotenoid composition

All the processed samples showed a higher moisture content than the fresh carrots, due to the water adding for processing. However, the moisture content of the processed samples from “frozen” carrot cubes showed a percentage of increase doubling that of the other samples (Table 2). It was observed by Howard et al. (1999) that changes of the moisture content did not occur either during refrigerated storage or frozen storage of carrots.

Blanching and freezing significantly damage carrot tissue, severely affecting the firmness and texture (Roy et al. 2001). Therefore, cell content can be easily released through the damaged cell membranes, thus resulting in a higher moisture content of the puree samples from frozen carrot cubes.

In comparison to the raw material, a slight decrease of malic acid and an increase of fumaric acid concentrations were observed in the processed samples, apart from the sample “frozen”, which showed a dramatic decrease of the content of both these acids (Table 2). According to Koka and Karadeniz (2008), cold storage causes a decrease of the soluble solids content and an increase of the titratable acidity in carrots. A significant reduction of carotenoid content compared to the raw carrots was shown in the processed samples. In particular, the reduction amounted to about 45 % for the content of lutein and about 35 % for alpha-carotene and beta-carotene. Compared to the fresh carrots, the heat processing caused a decrease in the total carotenoid concentration of the processed samples. Lutein seemed to be more affected than the other carotenoids, showing a concentration decrease higher than that of alpha and beta-carotene. The storage of the puree jars did not affect the carotenoid concentration, while the use of stored carrots and, more clearly, of frozen stored carrots resulted in a higher decrease of the carotene content (Table 2). The literature shows controversial outcomes about the effect of storage and processing on carotenoids content in carrot. According to Kidmose et al. (2004), carrot carotenoids are rather stable compounds during refrigerated and frozen storage. However, Howard et al. (1999) noted a slight decrease of the beta-carotene content in frozen carrots. Koka and Karadeniz (2008) registered retention of alpha- and beta-carotene content in cold stored carrots, but a decrease by 38 % of the lutein content. Finally, Van den Berg et al. (2000) observed a significant reduction (up to 60 %) in carotene concentration during frozen storage. Mild heat treatments, such as steam blanching, can cause an increase of alpha- and beta-

Table 2 Moisture, organic acid composition, carotenoid composition and color characteristics

	From fresh	From frozen	From stored	Raw material
Moisture (%)	91.68 (0.13) ^c	94.61 (0.16) ^a	91.91 (0.07) ^b	88.97 (0.06)
Malic acid (mg/g f.w.)	2.37 (0.22) ^a	1.29 (0.08) ^b	2.35 (0.19) ^a	2.93 (0.04)
Fumaric acid (mg/g f.w.)	0.070 (0.005) ^a	0.016 (0.001) ^b	0.068 (0.003) ^a	0.046 (0.003)
Lutein (μg/g f.w.)	1.99 (0.07) ^a	1.83 (0.07) ^b	1.66 (0.08) ^c	3.16 (0.04)
α-carotene (μg/g f.w.)	23.53 (0.75) ^a	19.98 (0.64) ^b	22.99 (2.13) ^a	31.17 (0.49)
β-carotene (μg/g f.w.)	75.04 (2.58) ^a	63.92 (1.25) ^b	65.69 (1.78) ^b	104.82 (2.59)
Color parameters				
L*	43.50 (0.09) ^b	44.26 (0.71) ^a	43.09 (0.15) ^c	47.67 (2.85)
a*	14.81 (0.20) ^a	13.73 (0.88) ^b	14.80 (0.31) ^a	22.56 (2.33)
b*	23.99 (0.17) ^a	23.48 (0.91) ^b	23.47 (0.29) ^b	29.49 (3.10)
c*	28.20 (0.18) ^a	27.20 (1.22) ^b	27.75 (0.29) ^a	37.15 (3.74)
h*	58.31 80.40) ^b	59.72 (0.68) ^a	57.75 (0.65) ^c	52.56 (1.55)

Different letters in the raw indicate significant differences between the values of the processed carrots ($P < 0.05$)

carotene content, probably due to an enhanced chemical extractability because of cell wall disruption. Conversely, a more severe heat treatment may result in carotenoid degradation (Howard et al. 1999, Kidmose et al. 2004). A carotenoid decline was observed in processed carrot samples and during their storage due to the presence of oxygen, thus confirming that O₂ exclusion can be beneficial for carotenoid and color retention (Talcott and Howard 1999).

All the puree samples showed a decrease in color parameter values compared to the fresh carrots, apart from the hue angle values that were higher. Significant differences in the parameter values resulted between the puree samples (Table 2). Puree samples from fresh carrots showed a higher value of a* and b*, while the samples from frozen carrot cubes were characterized by a higher value of L*. A slight but gradual decrease of the color parameters was observed during the cold storage of carrots Koka and Karadeniz (2008), but heat treatment can be considered as mainly responsible for the color changes in processed carrots. Brown color formation in processed carrots is perceived as a quality defect and methods to preserve the fresh carrot color are important for improving consumer acceptance. Maillard browning reactions have been proposed but not conclusively proven to be responsible for color changes. Since Maillard reactions do not occur extensively below pH 6.0 (retail carrot puree pH 5.0–5.5) or at commercial storage temperature, other sources of browning may be significant. Phenolic polymerization reactions due to autooxidation can result in brown-colored pigments that are detrimental to processed food quality. Since no enzyme activity remains in thermally processed products, oxidation of phenols via autooxidation reactions can be the main cause of color changes in processed carrots. Oxygen exclusion coupled with pH (low-medium acid food) is an important way for controlling phenolic polymerization reactions (Talcott and

Howard 1999). The reduction of the color parameters and the increase of the hue angle values are all indicators of a darker color of the processed carrots than that of the raw carrots.

Volatile compounds

Thirty-eight volatile compounds were detected and quantified in the fresh and/or processed carrots. Monoterpenes, sesquiterpenes and phenylpropanoid were the main fractions present in the analysed samples. Terpinolene was the main compound of the monoterpene fraction, while beta-caryophyllene and gamma-bisabolene were those in the sesquiterpene fraction. In the processed samples level of both monoterpenes and sesquiterpenes was observed that was substantially lower than in fresh carrot samples, with reductions of 80–90 %, probably due to losses mainly produced by the heat treatment. The differences in volatile composition between processed carrots and raw carrots were found to be mainly quantitative rather than qualitative, as observed also in a previous study on canned carrots (Heatherbell and Wrolstad 1971). Some compounds, which were not present in fresh samples, were formed as a result of thermal processing, such as styrene, a dimethyl substituted styrene compound and β-cyclocitral. Beta-damascenone and beta-ionone are known to be formed by carotenoid degradation and were found in higher levels in processed samples than in raw carrots. Moreover the presence of these two compounds might be relevant to the aroma properties of the puree due to their markedly low odour threshold (0.002 ppb for β-damascenone and 0.007 ppb for β-ionone). Compared to the others, a higher level of these compounds was found in the samples from frozen carrots.

The puree samples from fresh carrots showed a higher level of both these compounds than the other processed samples. The reduction of the main monoterpene content

was significantly high in the sample from stored carrots, while the sample from frozen carrots showed a more marked decrease in the content of the main sesquiterpene, β -caryophyllene. The results are shown for terpinolene and β -caryophyllene in Fig. 1. Sesquiterpenes are generally characterized by a lower volatility than monoterpenes, which could explain the different effect of storage on the content of these two classes of volatile compounds (Niinemets et al. 2010).

Furosine, CML analysis and Furan

Neither CML, furosine nor furan are evidenced in the fresh carrots. But these neoformed compounds (NFC) appear in an increasing way during heat treatment as well as freezing, pasteurization and sterilising, and are both highly correlated.

Sterilising induces a strong increase in the NFC content of the carrot puree. No significant difference in the content of CML and Furosine was observed between the different raw materials: fresh, stored as fresh and deep frozen. The furan content of all baby food samples made of the three different raw materials corresponds to the average content of 25 $\mu\text{g/kg}$ reported in the monitoring of EFSA (2009) for commercial jarred baby food and is below the average furan content of

40 $\mu\text{g/kg}$ for baby food samples containing mainly vegetables shown by Zoller et al. (2007). A slight decrease of furan could be observed when the carrots were frozen before processing. A survey of furan contamination in 230 commercially-jarred ready-to-eat infant food products found significant high concentrations in pasta, meals containing meat or vegetables and signify a potential public health concern for this human carcinogen contaminant. Consumer advice could recommend including freshly prepared baby foods in the diet, as none of 20 home prepared baby foods contained furan.

Sensory analysis

Pre-processing the raw material influences the sensory quality of the final product. Deep frozen processed samples were characterised by lighter overall odour and flavour, a slightly higher intensity of boiled carrot odour and flavour and a substantially lower intensity of canned odour and flavour, sweet taste and texture attributes (Table 3). Scientific evidence regarding sensory quality of baby food is missing; merely Gambaro et al. (2006) showed that colour was highly correlated with consumers' rejection percentage and overall acceptability when purchasing apple baby food.

Biocrystallization

Based on replication of the process, the sampling, the sample preparation and the crystallization, baby food samples from different processing processes could be significantly differentiated. Baby food samples from fresh and frozen raw material can be differentiated with high significance ($p < 0.05$) after lme-models ANOVA. For baby food samples processed out of the stored raw material biocrystallization determined a difference between the processing replicates. The difference in the pictures reflects the difference in the cooking duration (8,400 s versus 4,600 s). We did not expect this result, because the final product is sterilized later on in the process.

PCA results

The application of PCA to the measured quality variables of baby food from fresh, stored and frozen raw materials yields a clear differentiation into three groups (results shown in Fig. 2a–d). Baby food made from frozen raw material could be characterized as being to the lowest extent associated with many negatively related response variables (bitter flavor, bitter after taste, sour taste, sour aftertaste, green flavor and orange brown color). However, these samples also were less associated with the positive characteristics fruity flavor, sweet taste and carotene content. These results are in accordance with the analysis of variance on the sensory results

Fig. 1 Terpinolene (above) and β -caryophyllene content of carrot baby food derived from fresh, stored and frozen raw material. Different letters in the raw indicate significant differences between the values of the processed carrots ($P < 0.05$)

Table 3 Sensory analysis results from carrot baby food samples processed from three different raw materials (freshly produced, from storage and frozen)

	From Fresh	From Frozen	From Stored	F-value
Overall odour	6.49 ^a	5.15 ^b	6.76 ^a	90.72 $P<0.001$
Boiled carrot odour	3.58 ^b	4.59 ^b	3.55 ^b	53.66 $P<0.001$
Canned food odour	5.88 ^a	3.13 ^b	6.21 ^a	151.01 $P<0.001$
Harsh odour	2.35 ^a	1.56 ^b	2.46 ^a	7.83 $P<0.01$
Sweet taste	5.10 ^a	3.17 ^b	4.92 ^a	125.32 $P<0.001$
Salty taste	1.38 ^a	0.80 ^b	1.38 ^a	39.49 $P<0.001$
Sour taste	1.75 ^a	1.07 ^b	1.96 ^a	26.40 $P<0.001$
Overall flavour	6.44 ^a	5.16 ^b	6.57 ^a	90.84 $P<0.001$
Boiled carrot flavour	3.70 ^b	4.43 ^a	3.51 ^b	43.30 $P<0.001$
Canned food flavour	5.67 ^a	2.53 ^b	5.94 ^a	280.79 $P<0.001$
Bitter aftertaste	1.23 ^a	0.63 ^b	1.40 ^a	21.74 $P<0.001$
Astringent mouthfeel	2.46 ^a	1.61 ^b	2.52 ^a	27.49 $P<0.001$
Heaviness (texture) ^a	6.27 ^a	1.87 ^b	6.51 ^a	265.15 $P<0.001$
Structure (texture) ^b	6.03 ^a	1.76 ^b	6.22 ^a	229.79 $P<0.001$

^a Denseness of a liquid or semisolid food that flows with some difficulty

^b Perception of the size, shape and amount of particles

(Table 3). The PCA results for the different groups based on measured quality variables are shown as Score Plots in Fig. 2. The 12 points correspond to the 12 samples (observations) in

the dataset, determined by their values on the first and second principal component. Based on these results three different answers can be identified:

Fig. 2 Score plots from PCA based on quality related attributes (variables) in baby food samples derived from three different pre-processing of the raw material (fresh, stored, frozen): terpenes in **a**, sensory

variables in **b**, color, dry matter, chemical compounds in **c**, and biocrystallization in **d**. The numbers 1 and 2 correspond to processing replicate

1. Monoterpenes show positive loadings both on the first and the second PC, whereas sesquiterpenes show positive loadings on the first, but negative loading on the second PC. Puree samples made from fresh raw material have higher values of both, monoterpenes and sesquiterpenes compared to those made from stored and frozen raw materials. This is in accordance with the stronger overall flavor and fruity flavor found in puree from this fresh raw material. The puree samples made from stored raw material have a smaller amount of monoterpenes and the samples made from the frozen raw material have a smaller amount of sesquiterpenes. This supports the results based on the analysis of variance for single variables.
2. Color, acids, carotenoids and dry matter, as well as sensory variables and biocrystallization indicate no difference between baby food samples from fresh and stored pre-processed raw material (Fig. 2b–d). On the other side, baby food derived from frozen raw material stands out from the other raw materials by having a more watery texture, stronger color hue and color intensity and being milder in taste (less bitter and harsh, but at the same time being less associated with sweet and fruity tastes).
3. The PCA results of the crystallization variables show a clear grouping of the puree from frozen raw material in the bottom left corner and the other samples more spread over the rest of the plot (data not shown). Interestingly, the PCA based on bio-crystallization may be able to reflect irregularities like the unexpected longer cooking time found for replicate nr 1 (Fig. 2d). However, new experiments are needed to confirm and explain this result.

Conclusions

The study was performed at industry level, in order to reflect the practical relevance. The influence of the thermal processes (cooking, sterilization) was common to all the samples measured by all of the different approaches. This was reported in the literature already. The different pre-processed raw material gave differences in the final baby food, which was not expected and not described before. The intensity of pre-processing may have both beneficial and detrimental effects on the end product quality of carrot baby puree. As the study shows the quality parameters determined for the sterilized end product differ depending on the raw material (fresh, stored or blanched and frozen). In conclusion, the common pre-processing (blanching and freezing) of carrot raw material caused significant changes in the measured parameters in comparison to fresh carrots as the raw material. Moreover, from the results it seems advisable to process fresh carrots as

fast as possible after harvest in order to avoid storage for a long time. This study demonstrates that stored raw material has detrimental and decreasing effects on the contents of carotenoids and volatile compounds. Among individual carotenoids, lutein was more resistant to blanching and freezing than to storage. Compared to fresh carrots, the heat processing caused a decrease in the total carotenoid concentration. Lutein concentration decrease was higher than that of alpha and beta-carotene. The use of stored carrots and, more clearly, of frozen carrots resulted in a higher decrease of the carotene content. The sensory evaluations showed similar results for samples from stored and fresh carrots, whereas puree processed from deep frozen raw material differed in the milder intensity of the variables global odour and flavour, canned odour and flavour, sweetness, saltiness and texture. Samples processed from frozen carrots showed increased moisture content as well as a dramatic decrease of fumaric and malic acid. Also, in the puree sample from frozen raw material a higher level of volatile compounds was found. This should be studied further. Our data confirm that fresh raw material, in spite of high thermal processing such as sterilizing, resulted in a sweeter, more fruity tasting puree that at the same time has a stronger taste in the bitter and harsh characteristics. The use of frozen raw material can contribute to a milder taste (less bitter taste, harsh taste and after-taste) and more watery texture besides reduced sweet and fruity taste. These findings have to be taken into account when defining “processing with care” in baby food production.

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