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Influence of Processing on Quality of Carrot Juice

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Abstract

This study was conducted to determine the organoleptic and physical properties and carotenoid of commercial canned, frozen and freshly-made carrot jucice. Samples were evaluated by sensory panel and measured for viscosity and acidity. For carotene analysis, HPLC of alpha- and beta-carotene, and spectrophotometry of total carotenoid content were used. Sensory evaluation indicated that the canned sample was less acceptable, especially for flavor and texture, than other juices, while forzen juice was considered as acceptable as freshly-made carrot juice. The canned product showed about 10 times higher viscosity and lower acidity than others. Between two kinds of frozen samples, one sample was the same as freshly-made sample for all parameters while the other showed less alpha-carotene content which was 2 times higher than that of canned one. Canned sample contained 70-77% of freshly-made or frozen samples in total carotenoid and beta-carotene content and 24% of freshly-made one in alpha-carotene. These results suggest that freezing process is a good preservation method for carrot juice with respect to sensory evaluation, physical property and carotenoid content.

Key words: sensory evaluation, physical property, carotenoid, carrot juice, High Pressure Liquid Chromatography(HPLC)

Introduction

The carrot is a low acid food of about pH 6.0 and requires severe heat treatment(240-250°F) for protection from food spoilage agents[1]. Thermal processing required in the canning of carrots has been reported to result in undesirable changes in color, texture, and flavor and loss of nutritive values including carotenoid content[2]. Interestingly, other studies have suggested that the carotenoid content of carrots may increase after canning[3,4]. The freezing process has been reported as less destructive of nutrients than canning, with carotenoid content unaltered[1].

Food composition tables are used to list the nutrient composition of the foods consumed, and to estimate the adequacy of a person's diet and assess nutritional status such as vitamin A status. Several workers have pointed out the tendency of the food composition table to overestimate the vitamin A content in some furits and vegetables[5,6,7]. The analysis of carotenoid for the food composition table uses the AOAC method[8] which assumes that all carotenes have the activity of β-carotene or that β-carotene is the only carotene present. If the carotenes other than β-carotene, such as α-carotene or lycopene, are present in the foods, the overestimation could be much higher.

The purposes of this study were (1) to determine the organoleptic properties(flavor, texture, appearance), acidity, viscosity and carotene contents in carrot juices which were made by different processing, (2) to analyze individual carotenes in carrot juices qualitutively and quantitatively by a sensitive HPLC mehtod and (3) to compare the total vitamin A activity of samples with the values in food composition table.

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Materials and Methods

Preparation of samples

Two brands of frozen carrot juice and one brand of canned carrot juice were purchased in local stores in the Rhode Island and Massachusetts areas. For freshly-made carrot juice, fresh carrots were obtained locally and extracted by the Oster automatic pulp ejector and juice extractor (Model 323-06, Milwaukee, WI), extracting approximately 50% of the weight of the fresh carrots as juice.

Sensory Panel

The thirteen judges were staff members and graduate students of the Department of Food Science and Nutrition. To evaluate the reliability of judges, samples were duplicated and the differences between the scores of duplicate samples were analyzed by Student'st test[9]. There were no significant differences between the scores given to duplicate samples for all panel judges; therefore all scores were included in the study. All judges were free from colds, mouth or sinus infections, or allergies to a large number of food stuffs, nor were they heavy smokers nor have smoked within two hours before the tests.

Sensory evaluation score

Samples were evaluated for flavor, texture, and appearance. Each category had between 4 and 9 criticism factors which would indicate that the samples were disagreeable, foreign, or poor in flavor, texture or appearance[10,11]. Total frequency was obtained by checking of criticism factors by sensory panels, and statistical analysis was performed to evaluate the differences among samples for flavor, texture and appearance. For overall sensory score, selecting a criticism factor resulted in a deduction from the perfect score. The perfect scores for flavor, texture, and appearance were 45, 25, and 20, respectively. Temperature and package were assumed to be perfect in the test and allowed a perfect score of 5 for each. The sum of the perfect scores for all categories was therefore 100. The total of the scores for each category resulted in an assessment of either excellent (90-100), good (83-90), fair (76-83), poor (54-76) or bad (10-54) for each of the juices.

Viscosity

Viscosities were measured using a Brookfield viscometer(Model RVT, Brookfield Engineering Laboratories, Inc., Stoughton, MA) with a spindle No. 1 (54mm diameter and 13cm height). Triplicate measurements of 240ml of each sample were m ade at 50 rpm. The apparent viscosity(centipoise, mPa·s) at a given speed was computed using the equation; dial reading $\times$ correction factor= viscosity (mPa·s).

Acidity

The pH of four kinds of carrot juices were measured at room temperature, using an Ionalyzer (Specific Ion Meter, Model 401, Orion Research, Inc., Cambridge, MA) at room temperature. Triplicate measurements were made for each of the unified samples.

Determination of alpha- and beta-carotene and total carotenoids: Reagents

Crystalline alpha- and beta-carotene and lycopene standards were obtained from Sigma Chemical Co.(St. Louis, MO). Magnesium oxide, hyflosuper cel (chromatographic use), sodium sulfate (anhydrous granular form), and all solvents were purchased from Fisher Scienctific Co. (Boston, MA). Acetonitrile and methanol were HPLC grade. Acetone and petroleum ether (PE) were freshly distilled before use.

Method of extraction

The extraction of carotenoids was achieved by employing the modified method of Britton and Goodwin[12]. Duplicate 25ml aliquots of 5 samples of each kind of carrot juice were extracted with acetone. Final extraction was carried out with methanol. An equal volume of freshly distilled PE was added to the acetone-methanol extract which was washed with distilled water. The upper PE layer was reextracted, dried with anhydrous sodium sulfate and concentrated using a rotary evaporator at 30℃.

The saponification was carried out by adding methanolic KOH and then allowing the extract to stand in the dark at room temperature overnight in a nitrogen atmosphere. Afterwards, an equal volume of PE was added to the cold alkaline solution, followed by water. The aqueous phase was re-extracted with a fresh volume of PE, and the combined PE extract was washed with water until free from alkali. The PE extract was dried over anhydrous sodium sulfate and rotary evaporated. The evaporated samples were redissolved with PE for the determination of total carotenoids by using an extinction coefficient of 2500 at 450nm[12] or with acetonitrile/methanol/acetone(40:20:20) for the determination of alpha- and beta-carotene by HPLC.

Determination of alpha- and beta-cartotene by HPLC

The HPLC equipment was composed of a Waters solvent delivery system(Model 600A, Waters Asso., Milford, MA) and spectrophotometric detector (LC-85, Perkin-Elmer Co., Norwalk, CT). A reverse-phase C18(E. Merck, Darmstadt, F.R. Germany) stainless steel column (4.6×25cm) packed with C18 of 10μm particle size was used. Development of the chromatography was accomplished with a solvent system composed of acetonitrile/methanol/acetone(40:40:20) at 2ml/min. The visible detection was achieved at 450nm (0.01 Absorbance Units Full Scale). All solvents were filtered and degassed under vacuum prior to use.

Standards and standard curves

Alpha- and beta-carotene standards were purified by column chromatography[6] and recrystallized using a modification of the procedure of Davies[13] after being obtained from Sigma Chemical Co. The purity of the standard was determined spectrophotometrically. (Beckman DU 8B spectrophotometer, Fullerton, CA). The extinction coefficients used were: alpha-carotene, 2800 at 444nm in PE, beta-carotene, 2592 at 453nm in PE. For the determination of alpha- and beta-carotene, initial standard curves were generated comparing quantities of the compound vs. integrated peak areas. The standard lycopene was not used for quantitation, but for identification of the compound in the samples.

Statistical analysis

The data were analyzed by the analysis of variance method and Duncan's multiple rang test and processed by using Statistical Analysis System package (SAS)[9].

Results

Sensory evaluation

Table 1 shows the distribution of criticism factors and the summary of the mean sensory scores for flavor, texture, and appearance for the four kinds of carrot juice. The canned product was highly criticized in the areas of flavor and texture, cited frequently as lacking freshness and having an unnatural and bitter flavor, as well as grainy, lumpy and coarse. Frozen and canned products were frequently reported to lack uniformity of appearance.

Mean sensory scores, calculated from the evaluations of the 13 judges, for freshly-made, forzen 1, forzen 2, and canned samples were 88, 89, 90 and 71, respectively, with only the canned product significantly different from all the others ($p < 0.05$). Comparing these values to the standard scoring system used by the judges leads us to conclude that while the freshly-made and frozen carrot juices were considered to be good, the canned carrot juice was considered to be poor.

Table 1. Frequency distribution and overall sensory score for carrot juice samples

Frequency distribution		Fresh	Frozen 1	Frozen 2	Can
Flavor :	Bitter	5	2	0	9
	Lacks fine flavor	5	2	1	9
	Lacks flavoring	5	0	3	3
	Lacks freshness	4	3	3	11
	Lacks sweetness	6	0	2	7
	Too sweet	1	6	7	1
	Too high flavoring	0	1	1	5
	Unnatural flavoring	0	1	2	21
	Unclean	0	2	0	7
	Total frequency	26^a	17^a	19^a	73^b
Texture :	Grainy	2	5	4	14
	Lumpy	0	3	0	25
	Weak	9	4	6	2
	Coarse	5	4	4	11
	Total frequency	16^a	16^a	14^a	52^b
Appearance :	Unnatural color	5	4	4	6
	Color leaching	5	5	0	0
	Lacks uniformity	6	14	9	18
	Translucent	2	1	6	0
	Total frequency	18^a	24^a	19^a	24^a
Overall sensory score		88 ± 7^a	88 ± 7^a	90 ± 8^a	71 ± 15^b

Values with different superscripts are significantly different at $p < 0.05$.
Overall sensory scores are presented as mean$\pm$S.D

Viscosity and acidity

The apparent viscosity and pH of the carrot juices are shown in Table 2. The viscosities of freshly-made, frozen 1, forzen 2, and canned product were 10.4, 9.4, 9.4 and 106.5 mPa·s,respectively. Only the canned product had a viscosity different from the other products. The pH of freshly-made and frozen samples ranged from 6.4-6.6 and the canned sample had a pH of 5.5.

Table 2. Viscosity and acidity of carrot juices

	Fresh	Frozen 1	Frozen 2	Can
Apparent viscosity	10.4^a	9.4^a	9.4^a	106.5^b
Acidity (pH)	6.4^a	6.6^a	6.6^a	5.5^b

Values with different superscripts are significantly different at $p < 0.05$.
The apparent viscosity was measured at 50 rpm and computed using an equation; Dial reading $\times$ Factor= Viscosity in centipoise(mPa·s)

Alpha- and beta-carotene and total carotenoid contents

Alpha- and beta-carotene and total carotenoid contents of the carrot juices are shown in Table 3 and 4. For total carotenoid content there were no significant differences between freshly-made and either of the two frozen products. However, the freshly-made and frozen products were all significanlty different from the canned product($p < 0.05$). For alpha- and beta-carotene contents, there were no significant differences between the freshly-made and the forzen samples, but the canned sample was significantly different from the others. Most of the carotenoid content in carrot juice was contributed by alpha- and beta-carotene while only a small amount of lycopene was detected (Fig. 1). Individual carotene has different absorption maxima and different extinction coefficient which varies with the solvent dissolved. For example, alpha-carotene in PE has an extinction coefficient of 2800 at 444*nm* and 2592 at 453*nm* for beta-carotene. AOAC method, which was used for total carotenoid content in this study, assumes that

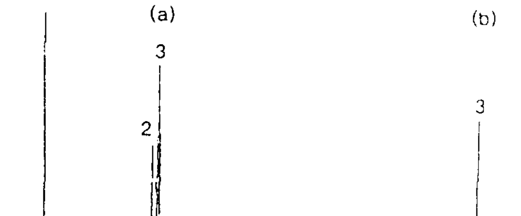

Fig. 1. HPLC chromatogram of carotenoids in carrot juices;(a) fresh or frozen sample and (b) canned sample. Chromatographic condition; column, Merck RP-C 18, 10μm; eluent, acetonitrile/methanol/acetone (40:40:20); flow rate, 2ml/min; temperature, ambient; detection, 450nm; sensitivity, 0.01 A.U.F.S. 1; lycopene, 2; α-carotene and 3; β-carotene.

all carotenes have the activity of beta-carotene and uses extinction coefficient of 2500 at 450nm for total carotenoid analysis. This is the reason for the difference between total carotenoid and sum of alpha- and beta-carotene in this study(Table 3 and 4). In this study, alpha- and beta-carotene were separated and quantitated by a sensitive HPLC method.

Discussion

The volatile products in the carrot root are terpenes and their derivatives [14] and the major contributors are 2-methoxy-3-sec-butyl-pyrazine, aldehyde, sabinene, myrcene, and terpinolene[15]. In our study, only the flavor of the canned product was cited as bitter, unnatural, and lacking freshness. Thermal processing(canning) probably resulted in a large increase in the amount of methanol, acetaldehyde, propanol and acetone, as well as ethanethiol and dimethyl sulphide, which were not present in the raw carrot. The presence of sulphur compounds in the canned carrot is probably due to the thermal degradation of s-methyl methionone sulphonium salt[16].

Bibeau et al.[17] have suggested that conversion of glutamine to acidic products during processing may be a good indication of the harshness of the processing. Glutamine has been reported to be converted by cyclization into acidic products by canning and retort packing of carrots[18]. The results of our study would support this observation as the canned carrot juice was acidic as compared with the frozen or fresh juice products.

Carotenoids and their precursors identified in raw carrots are phytonene, phytofluene, alpha-,

Table 3. Total carotenoid contents and vitamin A activities of the carrot juices

	Fresh	Frozen 1	Frozen 2	Can
Total carotenoid(μg/ml)	95.2±4.3^{a,b}	99.4±2.1^{a}	87.3±10.0^{b}	67.3±10.1^{c}
Vitamin A activity from total carotenoid (RE/ml)	15.9±0.7	16.6±0.2	14.5±1.6	11.2±1.7

Data are presented as mean±S.D.
Values with the different superscripts are significantly different at $p < 0.05$
RE represents retinol equivalent.

Table 4. α-and β-carotene contents and vitamin A activities of the carrot juices by HPLC

	Fresh	Frozen 1	Frozen 2	Can
α-carotene (μg/ml)	43.5±1.4[a]	42.6±2.3[a]	29.5±1.6[b]	15.8±1.8[c]
(RE/ml)	3.6±0.1	3.6±0.2	2.5±0.1	1.3±0.1
β-carotene (μg/ml)	67.9±7.7[a]	72.9±8.0[a]	68.1±2.0[a]	52.8±6.0[b]
(RE/ml)	11.3±1.3	12.2±1.4	11.4±0.3	8.8±1.0
Vitamin A activity from α-and β-carotene				
(RE/ml)	15.0±1.2[a]	15.7±1.3[a]	13.8±0.4[b]	10.1±1.1[c]

Data are presented as mean±S.D.
Values with the different superscripts are significantly different at $p < 0.05$
RE represents retinol equivalent.

beta-, and gamma-carotene, beta-zeacarotene, neurosporene, lycopene, and lutein[19,20,21]. The composition and the quantity of carotenoids present differ according to the variety of the carrot[22]. Recent HPLC determination of carotenoids in 22 fruits and vegetables demonstrated that there was no significance of either sampling location or season of analysis and that beta-carotene comprised 85% of total provitamin A activity of these vegetables with the exception of carrots[5]. The carrot contained 80% of total provitamin A activity as beta-carotene and 20% as alpha-carotene. The vitamin A activity reported for carrots in their study was 15,475 IU/100g, which was lower than the USDA Handbook No. 8-11 value[23] of 25.751 IU/100g. In our study, carrot juice samples contained 76-82% of total provitamin A activity as beta-carotene and 18-23% as alpha-carotene except for the canned product which had 87% activity from beta-carotene and 13% from alpha-carotene. All of our samples had vitamin A activities lower than the USDA handbook No. 8-11 value[23].

The effects of processing on the carotenoid content of some fruits and vegetables including carrots have been reported[2,4,24]. In some investigations, canning resulted in a decrease of vitamin A activity of about 20%. In contrast, other reports have indicated that the carotenoid content of some vegetables such as the carrot and the green pea increased after canning[3,4,19,25,26]. A possible explanation suggested by Panalaks and Murray[3] is that during canning, water soluble solids leach into the brine, resulting in a decrease of the solid content in the processed vegetables. Calculations of the carotenoid content based on the dry weight would show an apparent increase after the canning process, but if the loss of soluble solids from the carrots is taken into consideration a decrease of carotenoids after canning would be found[27]. The results in our study demonstrated that the canned product contained significantly less total carotenoid than the freshly-made or frozen products and the freezing process appears to be a good preservation method for carrot juice with respect to organoleptic and physical properties and carotenoid content.

References

1. Desrosier, N.W. : *Technology of Food Preservation*, 4th ed., Avi Publishing Co., Westport, CT. p.110 (1976)
2. Khan, N.A., Khalil, J.K. and Khan, I. : Changes in the carotene content of carrots during maturity, processing, and storage under different temperature conditions. *Pakistan J. Sci. Res.*, **23**, 112(1975)
3. Ogunlesi, A.T. and Lee, C.Y. : Effect of thermal

processing on the stereo-isomerization of major carotenoids and vitamin A value of carrots. *Food Chem.*, **4**, 311(1979)

4. Panalaks, T. and Murray, Y.K. : Effect of processing on the content of carotene isomers in vegetables and peaches. *J. Ins. Can. Technol.*, **3**, 145(1970)
5. Bureau, J.L. and Bushway, R.J. : HPLC determination of carotenoids in fruits and vegetables in the United States. *J. Food Sci.*, **51**, 128(1986)
6. Simpson, K.L., Tsou, S.C.S. and Chichester, C.O. : *Biochemical Methodology for the Assessment of Carotenes*, IVACG., Nutrition Foundation, Washington, D.C. (1982)
7. Zakaria, M., Simpson, K., Brown, P.R. and Krstulovic, A. : Use of reversed phase HPLC analysis for the determination of provitamin A carotenes in tomatoes. *J. Chr.*, **176**, 109(1979)
8. A.O.A.C. : *Official Methods of Analysis*, 14th ed., Association of Official Analytical Chemists, Washington, D.C., p.835 (1980)
9. SAS : *SAS User's Gulde*, Heulwig, J.T. and Council, K.A. (ed), SAS Institute Inc., Cary, NC (1982)
10. Stone, H. and Sidel, J.L. : *Sensory Evaluation Practice*. Academic Press, New York, p.40 (1985)
11. Larmond, E. : *Methods for sensory Evaluation of Food*. Canada Dept. of Agriculture, Ottawa, Canada (1967)
12. Britton, G. and Goodwin, T.W. : Biosynthesis of carotenoids. *Methods in Enzymology*, 18C, 654(1971)
13. Davies, B.H. : Carotenoids. In *Chemistry and Biochemistry of Plant Pigments*. Goodwin, T.W. (ed), Academic Press, New York, Vol. 2, p.85 (1976)
14. Johnson, A.E., Nursten, H.E., and Williams, A.A. : Vegetable volatiles : a survey of components identified-Part 1. *Chem. and Ind.*, **43**, 556(1971)
15. Heatherbell, D.A., Wrolstad, R.E. and Libbey, L.M. : Carrot volatiles. 1. Characterization and effects of canning and freeze drying. *J. Food Sci.*, **36**, 219(1971)
16. Heatherbell, D.A. and Wrolstad, R.E. : Carrot volatiles. 2. Influence of variety, maturity, and storage. *J. Food Sci.*, **36**, 225(1971)
17. Bibeau, T.C., Clydesdale, F.M. and Sawyer, F.M. : Glutamine as a predictive measurement in the quality assessment of processed carrot puree. *J. Food Sci.*, **39**, 365(1974)
18. Luh, B.S., Autonakes, J. and Daoud, H.N. : Chemical and quality changes in strained carrots canned by the aseptic and retort processes. *Food Technol.*, **23**, 377(1969)
19. Baloch, A.K., Buche, K.A. and Edwards, R.A. : Separation of carrot carotenoids on hyflosuper cel-magnesium oxide-calcium sulfate thin layers. *J. Chr.*, **139**, 149(1977)
20. Bauernfeind, J.C. : Carotenoid vitamin A precursors and analogs in foods and feeds. *J. Agr. Food Chem.*, **29**, 456(1972)
21. Edwards, C.G. and Lee, C.Y. : Measurement of provitamin A carotenoids in fresh and canned carrots and green peas. *J. Food Sci.*, **51**, 534(1986)
22. Goodwin, T.W. : Distribution of carotenoids. In *Chemistry and Biochemistry of Plant Pigments*, Goodwin, T.W.(ed), Academic Press, New York, Vol. 1, p.65 (1976)
23. United States Department of Agriculture : *USDA Handbook No. 8-11*, United States Government, Washington, D.C.(1982)
24. Baloch, A.K., Buokle, K.A. and Edwards, R.A. : Effect of processing variables on the quality of dehydrated corrot. I. Leaching losses and carotenoid content. *J. Food Technol.*, **12**, 285(1977)
25. Lee, C.Y., Massey, Jr., L.H. and Van Bureau, J.P. : Effects of post-harvest handing processing on vitamin content of peas. *J. Food Sci.*, **47**, 961(1982)
26. Weckel, K.G., Santos, B., Herman, E., Laferriere, L. and Gabelman W.H. : Carotene components of frozen and processed carrots. *Food Technol.*, **16**, 91(1962)
27. Edwards, C.G. and Lee, C.Y. : Measurement of provitamin A carotenoids in fresh and canned carrots and green peas. *J. Food Sci.*, **51**, 534(1986)

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가공공정에 의한 당근쥬스의 품질변화에 관한 연구

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시중에서 판매되는 캔상태와 냉동상태의 당근쥬스와 신선하게 제조된 쥬스에 대한 관능적 평가 및 물리적 성질과 카로텐 함량을 연구하였다. 물리적 성질로서 점성과 산도를 측정하였고, HPLC와 spectrophotometry에 의해 알파와 베타 카로텐 및 총 카로테노이드 함량이 관찰되었다. 관능평가 결과, 캔쥬스는 냉동이나 신선한 시료에 비해 낮은 수응력을 보였으며, 특히 향기와 질감에서 낮은 적응성을 나타내었다. 또한 다른 시료에 비해 10배의 높은 점성과 낮은 산도를 나타내었다. 두 종류의 냉동시료중 한 시료는 신선한 상태의 쥬스와 모든 측정에서 같은 결과를 나타내었고, 다른 한 시료는 알파카로텐 함량이 유의적으로 낮았으나 캔보다는 2배의 함량이었다. 캔쥬스는 총 카로테노이드와 베타 카로텐 함량에서 신선한 상태나 냉동상태의 70-77%를 나타내었고, 특히 알파 카로텐은 신선한 경우의 24%를 함유하였다. 관능적 평가와 물리적 성질 및 카로텐 함량면에서 볼 때, 이와 같은 결과들은 냉동가공이 당근쥬스의 좋은 보존방법임을 시사해 주고 있다.