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Contents of chlorophylls and carotenoids in frozen dill: effect of usable part and pre-treatment on the content of chlorophylls and carotenoids in frozen dill (*Anethum graveolens* L.), depending on the time and temperature of storage

Zofia Lisiewska*, Waldemar Kmiecik, Jacek Słupski

Department of Raw Materials and Processing of Fruit and Vegetables, Agricultural University of Krakow, 122 Balicka Street, 30-149 Krakow, Poland

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Abstract

The aim of the work was to compare the contents of chlorophylls, total carotenoids, and beta-carotene in the leafy part and in whole plants (leaves with petioles and stems) of dill harvested at the 25 cm stage of growth. Changes in the levels of these compounds in the technological process of freezing and refrigerated storage were also determined. The investigation concerned two kinds of raw material (leafy parts and whole plants), different treatments before freezing (blanching or non-blanching of the raw material), differentiated temperature of storing frozen products (−20 °C and −30 °C), and a storage time of 12 months. Analyses of the frozen products were conducted every 3 months. In 100 g fresh matter of dill leaves the content of dry matter was 12.89 g and of chlorophylls was 144 mg with a ratio of chlorophyll *a* to *b* of 1:0.33, that of carotenoids, 30.3 mg and of beta-carotene, 5.00 mg. In whole plants, the contents of comparable components were 26, 40, 38, and 41% smaller, respectively, the ratio of chlorophyll *a* to *b* being slightly lower (1:0.39). Blanching, freezing, and in storage of refrigerated products, irrespective of temperature, did not change the contents of components analysed in the first 3 months. During the successive months of storage, blanching favourably affected the preservation of total carotenoids and beta-carotene while the lower temperatures of storage had a beneficial effect on chlorophyll content. The components analysed were preserved in leaves to only a slightly higher extent than in whole plants. If good (90%) preservation of chlorophylls, carotenoids, and beta-carotene were to be used as a criterion of valuation, the dill could be stored for up to 6 months at −20 °C without blanching. For storage periods above 6 months, blanching is necessary, the preservation of analysed components being better at a lower temperature of storing.

Keywords: Dill; Chlorophylls; Carotenoid; Freezing; Storage

1. Introduction

The increasing supply of ready dishes, especially by food concentrate and refrigeration industries, leads to an increased demand for seasoning herbs (Boelt, 1990). This is shown by the doubled consumption of spices in the USA since 1980 (Pszczola, 2001). Within this group of plants is the dill which is highly versatile (Arslan & Tozlu, 1997; Kostrzewa, 1999). The dill is classed among species reducing the risk of cancer (Yang, Huang, Peng, & Li, 1996). Its consumption also lowers the level of cholesterolaemia (Lansky, Schilcher, Phillipson, & Loew, 1993) while its components show antioxidative properties (Kidmose, Knuthsen, Edelenbos, Justesen, & Hegelund, 2001; Kurilich & Juvik, 1999). Besides, seasoning herbs, including the dill, enrich the main dishes with complementary compounds, such as vitamins, mineral salts, and also compounds affecting the sensory traits of food. One of the most important sensory traits is the colour. The basic pigments of seasoning leafy herbs are chlorophylls, always accompanied by carotenoids. Acids, temperature, light, oxygen, and enzymes easily destroy the chlorophylls (Lopez-Ayerra, Murcia, & Carmona, 1998; Tonucci & Elbe, 1992), while carotenoids are fairly resistant to technological procedures (Granado, Olmedilla, Blanco, & Rojas-Hidalgo, 1992).

* Corresponding author. Fax: +48-12-626-5847.
E-mail address: rrlisiew@cyf-kr.edu.pl (Z. Lisiewska).

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The aim of the present work was to compare the contents of chlorophylls, total carotenoids, and beta-carotene in the leafy part and whole plants of dill. Changes in the levels of these compounds were also determined in the course of technological processes of freezing and during refrigerated storage of frozen products.

2. Material and methods

2.1. Harvesting the raw material

The investigated material was fresh and frozen dill cv. Amat. The raw material was harvested in the experimental field of the Department carrying out the present investigation. Seeds were sown on August 10, 2000. The sowing date was adjusted so as to ensure the harvest time on the turn of summer and autumn, this permitting shortening of the storage period of frozen dill and reducing the costs of refrigerated storage. The harvesting carried out after 37 days, when the plants had reached about 25 cm in height, consisted of cutting plant tops about 5 cm above the soil. The harvested plants were therefore 20 cm in height. They were then surveyed for removal of individuals of discoloured or unhealthy appearance. It should be mentioned that the plants were healthy, traces of yellowing appearing only on single stunted leaves at the plant base. The dill plants were harvested in the morning and the time from cutting to the beginning of analyses and technological processing of the raw material did not exceed 2 h. The first measure was to separate the leaves from the remaining parts of the plants. It was determined that the leaves constituted 51% of the weight of whole plants.

The investigation consisted of: (1) two kinds of the raw material: leaves alone and whole dill plants, i.e. leaves with petioles and stems; (2) differentiated treatment before freezing; i.e. blanched and non-blanched samples; (3) differentiated temperatures of refrigerated storage, i.e. at −20 °C and −30 °C; (4) time of refrigerated storage throughout the year, frozen products being analysed at 3-month intervals.

2.2. Preparation of the material for analyses and freezing

Non-blanched leaves were cut into 5–7 mm sections. A sample representative of whole non-blanched plants was prepared by mixing leaves (previously cut into 5–7 mm sections) with the stem and petioles strained through a sieve of 2 mm sieve mesh. The same proportion as in the raw material was maintained between the leaves and the stems with petioles. The preparation of blanched samples consisted of blanching in water at 94–96 °C, leaves for 30 s and petioles and stems for 3 min. The proportion of water to the blanched material was 1:5. The time of blanching was adjusted to that necessary for decreasing the activity of peroxidase to at least 95%. After cooling in water and removing the remaining water by centrifugation to the weight equal to that before blanching, the leaves were cut into sections of 5–7 mm, while petioles and stems were granulated and mixed with leaves, as in the case of the non-blanched dill.

2.3. Freezing and storage of frozen dill

Packing the dill in polythene bags 0.08 mm thick preceded its freezing. The content of a bag was 650 g of the raw material. The bags were pressed tightly to remove as much air as possible, then welded closely. Directly after closing, the product was frozen at −40 °C in a 3626-51 Feutron blast freezer with forced air circulation to a temperature of −20 °C and to a temperature of −30 °C. After freezing the bags were placed in storage chambers at −20 °C and −30 °C, respectively, and kept there until the time of evaluation.

Depending on the type of the raw material and on the applied pre-treatment, bags of the same weight had different volumes. In the calculation per 1 kg of weight, the volume of leaves was about 3.5 dm^3 and of whole plants 2.0 dm^3 in non-blanched samples and in blanched ones about 1 dm^3 of both leaves and whole plants.

2.4. Evaluation of the level of selected physico-chemical indices in the raw material and frozen products

In chemical analyses, all the samples cited in Section 2 were taken into consideration. In each object investigated the average evaluated sample contained 650 g of the material and the manner of sampling ensured its being representative of the entire lot of the raw material. Analyses of the raw material were begun within 2 h of the harvest and, of frozen products, after the storage period appropriate to the method of the investigation. The samples for analysis were defrosted at 2–4 °C during 17–18 h. An average laboratory sample representing a given combination of the experiment was granulated with distilled water in a laboratory food mixer in a weight ratio of 1 part dill to 1 part of water.

The level of dry matter was determined by a method given in AOAC (1984). The contents of chlorophylls *a* and *b* were determined using the method given by Wettstein (1957) and of carotenoids and beta-carotene using that developed by Davies (1965). Pigments were extracted with acetone up to a complete decolourisation of samples. The content of chlorophyll and carotenoids was calorimetrically determined by measuring absorbance in the absorbance maximum for these pigments, using a Shimadzu UV-160A spectrophotometer. Beta-carotene was separated from other pigments using the column chromatography method, with the column filled with aluminium oxide activated for chromatography.

2.5. Elaboration of results

For analytical determinations, four samples were taken from each kind of the material prepared. Average results of the determinations were calculated per 100 g fresh and 100 g dry matter. This form of presentation of results gives information concerning the level of a component in the product ready for consumption and can also be interesting from a cognitive perspective.

To determine the significance of differentiation in the content of the investigated components between the investigated combinations, statistical calculations were carried out using one-factor analysis for the material before freezing and two-factor analysis for the results including the whole experiment. Factor I was the usable part, pre-treatment, and the temperature of storage, factor II the period of storing frozen dill. Statistical analysis was carried out according to the Excel 5.0 programme, using the Snedecor F test and the Student t test. The least statistical difference (LSD) was calculated for the probability level $P = 0.01$.

3. Results and discussion

Dry matter content in dill leaves was 12.89 g and in whole plants 9.49 g/100 g fresh matter (Table 1). A slightly higher level of dry matter, depending on the analysed part of the plant and the growing time, was found by Kmiecik, Lisiewska, and Jaworska (2002). The content found by those authors varied over a range of 11.68–17.86 g/100g dill leaves and 8.96–16.15 g in leaves with petioles, though without stems. Blanching reduced the level of dry matter by 18% in leaves and by 10% in whole plants. According to Kmiecik and Lisiewska (1999a), a 22% decrease was determined in dry matter content in blanched chive. Lisiewska and Kmiecik (1997) found a 16% decrease in dry matter content after blanching the leafy-type and Hamburg parsley. The freezing of dill did not change the level of this index. Frozen storage had a negligible effect on the content of dry matter and, after 12 months in all the objects of the experiment, this content increased by 1 to 3% in relation to the material directly after freezing.

In 100 g fresh matter, the raw leaves of dill contained 144 mg of total chlorophylls and whole plants 86 mg of these compounds (Table 2). The ratio of chlorophylls a to b was 1:0.33 and 1:0.39, respectively (Table 3). The content of chlorophylls quoted by Michalik and Dobrzanski (1987) was much lower than that found by the present authors in leaves alone and was slightly higher than in whole plants, while as many as 0.51 particles of chlorophyll b fell to 1 particle of chlorophyll a. As Lisiewska, Słupski, and Korus (2001) reported, the content of chlorophylls in the dill ranged from 77 to 163 mg in 100 g fresh matter, depending on the cultivar, growing time, and the kind of usable part (leaves or leaves with petioles).

It is known that blanching decreases the levels of water-soluble constituents. However, the samples subjected to this treatment were taken into consideration since the aim of applying it was to reduce the activity of native enzymes of the raw material to a residual level (Bottcher, 1975). As Brewer, Begum, and Bozeman (1995) and Heaton, Yada, and Marangoni (1996) postulate, the thermal inactivation of enzymes limits the degradation of both chlorophylls and carotenoids. Another positive effect of blanching is the deaeration. The reduced content of oxygen in plant tissue also effects a better preservation of pigments (Toivonen, 1997). This agrees with the opinions of Yamauchi, Yoshimura, Shono, and Kozukue (1995). According to those authors, enzymes take part in the degradation of chlorophylls, followed by oxygenic degradation in a further stage.

Daood, Czinkotai, Hoschke, and Biacs (1989) reported that chlorophyll a is more sensitive to degradation induced by thermal processing. However, blanching of

Table 1
Content of dry matter in raw and frozen dill, g in 100 g of fresh matter[a]

Usable part	Method of pretreatment	Before freezing ($x \pm$S.D.)	Storage temperature	After storage time in months ($x \pm$S.D.)					Mean
				0	3	6	9	12	
Leaves	Non-blanched	12.89±0.17	−20 °C	12.90±0.32	12.89±0.29	12.99±0.37	13.00±0.17	13.08±0.17	12.96
		12.89±0.17	−30 °C	12.85±0.23	12.84±0.24	12.95±0.27	12.92±0.14	13.01±0.17	12.91
	Blanched	10.51±0.23	−20 °C	10.54 ±0.14	10.62±0.25	10.71±0.22	10.77±0.13	10.77±0.10	10.65
		10.51±0.23	−30 °C	10.52±0.21	10.45±0.15	10.52±0.20	10.60±0.10	10.65±0.10	10.54
Whole plant	Non-blanched	9.49±0.19	−20 °C	9.44±0.16	9.57±0.18	9.63±0.19	9.70±0.11	9.73±0.14	9.59
		9.49±0.19	−30 °C	9.53±0.13	9.49±0.19	9.42±0.18	9.59±0.12	9.65±0.15	9.53
	Blanched	8.56±0.15	−20 °C	8.54±0.16	8.59±0.17	8.67±0.21	8.71±0.12	8.74±0.12	8.63
		8.56±0.15	−30 °C	8.53±0.19	8.42±0.15	8.55±0.17	8.61±0.10	8.64±0.12	8.55
	Mean	10.36		10.36	10.36	10.43	10.49	10.53	

ns, not significant.

[a] LSD ($P = 0.01$) for material before freezing: 0.403. For whole experiment: factor (I) 0.139; factor (II) 0.120; interaction (I×II) ns; (x±S.D.), mean value of four samples and standard deviation.

Table 2
Content of chlorophylls, in raw and frozen dill, mg in 100 g of fresh matter[a]

Usable part	Method of pretreatment	Before freezing ($x \pm$S.D.)	Storage temperature	After storage time in months ($x \pm$S.D.)					Mean
				0	3	6	9	12	
Leaves	Non-blanched	144±5	−20 °C	143±4	139±5	135±4	120±4	100±8	130
		144±5	−30 °C	142±4	139±5	140±5	130±4	116±4	135
	Blanched	140±5	−20 °C	142±4	141±6	141±5	135±5	128±5	138
		140±5	−30 °C	141±5	140±4	141±5	139±4	137±4	140
Whole plant	Non-blanched	86±4	−20 °C	86±4	84±3	79±3	69±2	57±3	77
		86±4	−30 °C	87±3	86±3	82±4	75±3	66±2	80
	Blanched	85±3	−20 °C	85±3	85±3	84±3	80±4	72±3	82
		85±3	−30 °C	87±4	86±3	86±3	84±3	84±3	85
	Mean	114		114	113	111	104	95	

[a] LSD ($P = 0.01$) for material before freezing: 9.4. For whole experiment: factor (I) 3.0; factor (II) 2.6; interaction (IxII) 7.3. ($x \pm$S.D.), mean value of four samples and standard deviation.

Table 3
Units of chlorophyll *b* falling to 1 unit of chlorophyll *a*

Usable part	Method of pretreatment	Before freezing	Storage temperature	After storage time in months				
				0	3	6	9	12
Leaves	Non-blanched	0.33	−20 °C	0.34	0.34	0.35	0.36	0.39
		0.33	−30 °C	0.34	0.34	0.33	0.35	0.36
	Blanched	0.33	−20 °C	0.34	0.33	0.34	0.35	0.36
		0.33	−30 °C	0.33	0.33	0.33	0.34	0.34
Whole plant	Non-blanched	0.39	−20 °C	0.39	0.40	0.41	0.44	0.46
		0.39	−30 °C	0.38	0.39	0.39	0.42	0.47
	Blanched	0.39	−20 °C	0.39	0.39	0.40	0.40	0.41
		0.39	−30 °C	0.38	0.39	0.39	0.40	0.40

the analysed dill plants did not effect significant changes in the content of chlorophyll *a* or *b*. Gunavan and Barringer (2000) postulate that a good preservation of chlorophyll a occurs with a pH of the water used for blanching of 7 or higher. The water used for blanching the investigated dill showed a pH value of 7.6. According to the authors quoted above, the high pH value might have limited the formation of complexes with zinc by reducing the numbers of chlorophyll derivatives accessible for this reaction. When blanching leafy vegetables, the losses of chlorophylls ranged from 3 to 9% according to different sources (Bhobe & Pai, 1986; Lisiewska & Kmiecik, 1997). Niedzielski and Mokrosinska (1990) postulated that a decrease in chlorophyll content during blanching resulted from the denaturation of the protein complex, stabilizing this pigment. According to Lopez-Ayerra et al. (1998) the degradation catalysed by acids and enzymes seems the most common mechanism of chlorophyll degradation.

Freezing did not induce changes in the contents of chlorophylls, either in fresh or in dry matter (Table 2; Fig. 1). Depending on the type of parsley (leafy or Hamburg parsley), the freezing of parsley leaves resulted in a decrease in content of these pigments by 3–5% (Lisiewska & Kmiecik, 1997). Changes in the levels of chlorophylls, during refrigerated storage, depended on whether the dill was blanched or not and on the temperature of storage of the frozen product. Philippon, Rouet-Mayer, Fontenay, and Duminil (1986) and Kmiecik and Lisiewska (1999a, 1999b) did not show changes in total chlorophylls in stored frozen parsley or chive, finding decreases in the contents of these pigments in non-blanched samples. Similarly, as in the investigated dill, the lower storage temperature contributed to a better preservation of chlorophylls. A direct reason for the better preservation of pigments at lower temperatures might have been a stronger decrease in the rate of chemical and enzymatic reactions. According to Lopez-Ayerra et al. (1998), if the acceptability of the product was limited by a 20% loss of chlorophyll content, the frozen product of leaves or whole plants of dill, pre-treated by blanching, could be stored for 12 months. In samples stored at −30 °C, no changes in the level of chlorophylls were observed, while, in those stored at −20 °C, the losses amounted to 9% for leaves and 15% for whole plants. In non-blanched dill, after 9-months of storage, decreases in chlorophyll content ranged from 10–13% at −30 °C and, in samples stored at −20 °C between 17 and 20%, greater losses always being found in the whole plants rather than in the leaves. After 12-months of storage, the losses of chlorophylls were 20% or greater in all the frozen

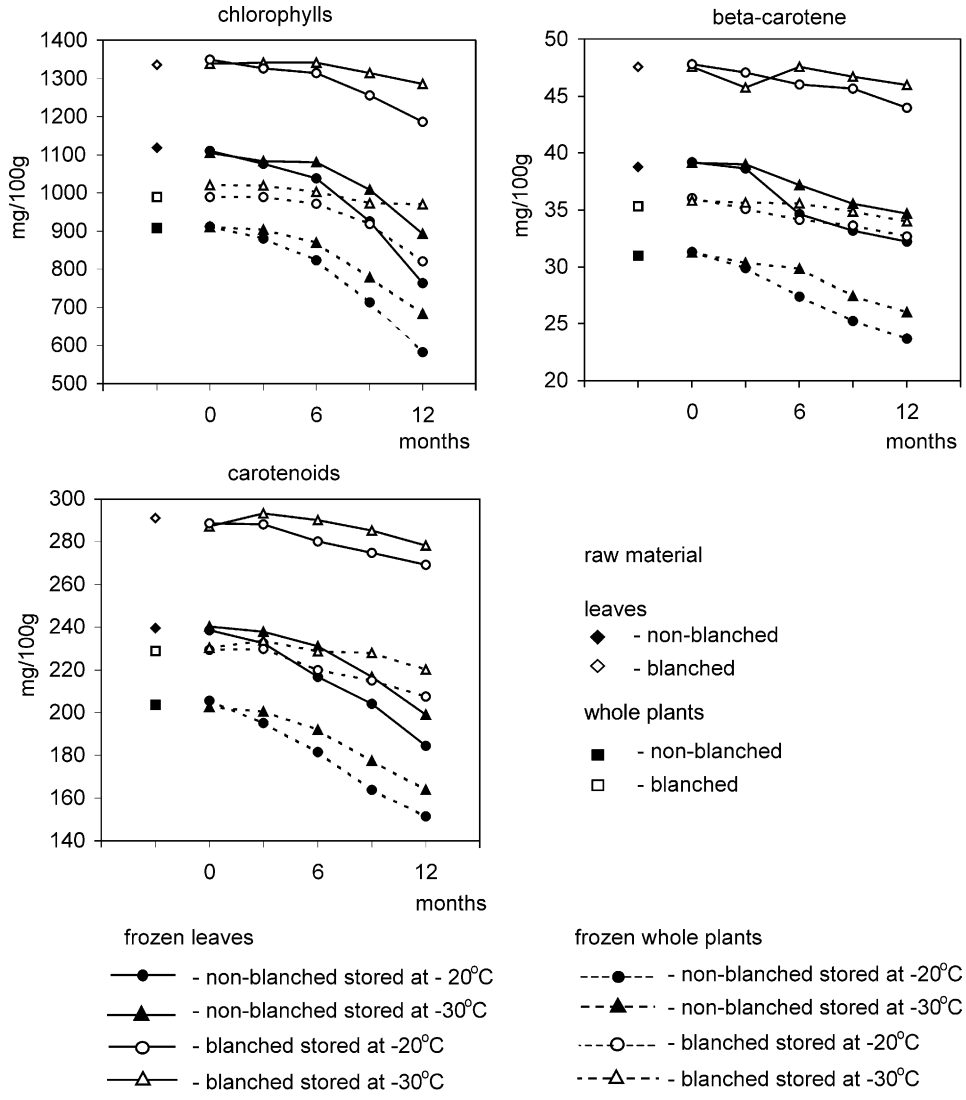

Fig. 1. Changes in the level of chlorophylls, beta carotene and carotenoids during freezing and storage of frozen dill, in dry matter.

products of non-blanched dill. The pattern of changes in chlorophyll content, calculated on dry matter, was fairly similar. The decomposition of chlorophyll a occurred faster than that of chlorophyll b. It was also faster in non-blanched than in blanched samples (Table 3).

The losses of chlorophyll content were much smaller (only 3%) in cooked spinach after refrigerated storage for 12 months (Jaworska & Kmiecik, 2000). However, most data concerning spinach, parsley, Brussels sprouts, and other leafy vegetables showed similar or greater losses than those found in the analysed dill (Bhobe & Pai, 1986; Lisiewska & Kmiecik, 1997; Lopez-Ayerra et al., 1998; Niedzielski & Mokrosinska, 1990). According to Philippon et al. (1986) and Lisiewska and Kmiecik (1997), chlorophyll losses in stored frozen parsley leaves increased with increasing temperature of the refrigerated storage.

In 100 g fresh matter, the leaves of dill contained 30.9 mg and in 100 g dry matter 240 mg carotenoids, in whole plants the contents being smaller by 38 and 15%, respectively (Table 4, Fig. 1). According to various authors the content of carotenoids ranges from 7.2 to 36.4 mg in 100 g, fresh matter of leafy vegetables (Ben-Amotz & Fishler, 1998; Dhan, Pashupati, & Pal, 1995; Kmiecik & Lisiewska, 1999b; Wills & Rangga, 1996). If the results were expressed on a fresh matter basis, blanching would not affect the level of carotenoids. After calculating the results on a dry matter basis, the level of carotenoids increased after this treatment by 21% in leaves and 12% in whole plants. Khachik et al. (1992) stressed that, in leafy vegetables, the content of carotenoids increased after the thermal treatment. Mosha, Pace, Adeyeye, Laswai, and Mtebe (1997) showed an increase of carotenoid content in four species and a decrease in two. Granado et al. (1992) postulate that the determined greater content of carotenoids after the thermal treatment, than before it, results from the denaturation of carotenoid complexes, permitting a

Table 4
Content of carotenoids in raw and frozen dill, mg in 100 g of fresh matter[a]

Usable part	Method of pre-treatment	Before freezing (x±S.D.)	Storage temperature	After storage time in months (x±S.D.)					Mean
				0	3	6	9	12	
Leaves	Non-blanched	30.9±1.0	−20 °C	30.7±2.6	29.9±2.3	28.1±1.5	26.5±1.4	24.1±1.7	28.4
		30.9±1.0	−30 °C	30.9±2.1	30.5±1.8	29.9±1.6	28.0±1.5	25.9±1.2	29.4
	Blanched	30.5±1.4	−20 °C	30.4±2.3	30.6±1.4	30.0±1.8	29.6±0.9	29.0±2.0	30.0
		30.5±1.4	−30 °C	30.2±2.1	30.6±1.6	30.5±1.2	30.2±1.5	29.6±1.3	30.3
Whole plant	Non-blanched	19.3±0.9	−20 °C	19.4±1.3	18.7±0.9	17.5±1.2	15.9±1.2	14.7±1.1	17.6
		19.3±0.9	−30 °C	19.3±1.3	19.0±0.9	18.1±0.6	17.0±0.7	15.8±0.9	18.1
	Blanched	19.6±0.9	−20 °C	19.6±1.1	19.7±1.1	19.1±0.8	18.7±0.9	18.2±0.8	19.2
		19.6±0.9	−30 °C	19.7±1.1	19.7±0.7	19.5±0.7	19.6±0.9	19.0±0.9	19.5
	Mean	25.1		25.0	24.8	24.1	23.2	22.0	

[a] LSD ($P=0.01$) for material before freezing: 2.27. For whole experiment: factor (I) 1.01; factor (II) 0.88; interaction (I×II) 2.48. (x±S.D.), mean value of four samples and standard deviation

complete extraction of these compounds. Freezing and refrigerated storing of dill for 3 months induced minimal changes in the level of carotenoids. In the dill blanched before freezing, the level of carotenoids was only slightly reduced during the further storage period. In non-blanched samples, however, after a 12-month storage the losses of carotenoids in fresh matter ranged from 16 to 24%, depending on the usable part analysed. In dry matter, the losses were slightly higher, always being smaller at lower storage temperatures (Fig. 1). According to Postolski (2000), a significant lowering of the temperature of frozen storage below the cryoscopic point, accompanied by the phase conversion of water into ice, and an increased concentration of soluble substances, effects an increase in viscosity of the unfrozen liquid phase, a reduction in the mobility of molecules and frequency of their collision, this diminishing the dynamics of the pattern of chemical and enzymatic processes.

Agte, Tarwadi, Mengale, and Chiplonkar (2000) report that leafy vegetables are indeed a richer source of beta-carotene than other species. Bhaskarachary, Sankar, Deosthale, and Vinodini (1995) determined beta-carotene as the dominant carotenoid in 17 species of leafy vegetables. According to Wills and Rangga (1996) and Ben-Amotz and Fishler (1998), beta-carotene constituted 14–23% of the carotenoids in six species of leafy vegetables, this value being slightly lower (12%) in the dill. In the investigated leaves of dill this component reached 16% and, in whole plants, 15% with regard to total carotenoids, these values corresponding to 5.00 mg and 2.94 mg, respectively, in 100 g fresh matter (Table 5; Fig. 1). Similarly, Ishida, Suzuno, Sugiyama, Innami, Tadokoro and Maekawa, (2000) found that, in sweet potato, the content of beta-carotene was much lower in the stem than in the leafy part. According to Michalik and Dobrzanski (1987) the content of beta-carotene was 4.51 mg in 100 g fresh matter of dill and a similar value was reported by Heinonen, Ollilainen, Linkola, Varo and Koivistoinen, (1989). However, Kmiecik, Gębczyński, and Jaworska (2001) recorded 1.84–6.71 mg beta carotene in 100 g fresh matter, depending on cultivar, time of harvest, and kind of the usable part.

Table 5
Content of beta-carotene in raw and frozen dill, mg in 100 g of fresh matter (x±S.D.)[a]

Usable part	Method of pretreat-ment	Before freezing (x±S.D.)	Storage temperature	After storage time in months (x±S.D.)					Mean
				0	3	6	9	12	
Leaves	Non-blanched	5.00±0.14	−20 °C	5.05±0.14	4.98±0.21	4.49±0.11	4.31±0.10	4.21±0.10	4.67
		5.00±0.14	−30 °C	5.03±0.19	5.00±0.21	4.81±0.15	4.59±0.12	4.51±0.15	4.82
	Blanched	5.00±0.22	−20 °C	5.04±0.22	5.00±0.19	4.93±0.14	4.92±0.10	4.74±0.18	4.94
		5.00±0.22	−30 °C	5.00±0.20	5.03±0.17	5.01±0.15	4.95±0.13	4.90±0.17	4.98
Whole plant	Non-blanched	2.94±0.15	−20 °C	2.95±0.15	2.86±0.13	2.64±0.11	2.45±0.09	2.30±0.12	2.69
		2.94±0.15	−30 °C	2.98±0.13	2.88±0.12	2.81±0.12	2.63±0.09	2.51±0.14	2.79
	Blanched	3.02±0.13	−20 °C	3.08±0.17	3.01±0.14	2.96±0.13	2.93±0.12	2.86±0.09	2.98
		3.02±0.13	−30 °C	3.05±0.16	3.00±0.15	3.04±0.18	3.00±0.12	2.94±0.18	3.01
	Mean	3.99		4.02	3.97	3.84	3.72	3.62	

[a] LSD ($P=0.01$) for material before freezing: 0.352. For whole experiment: factor (I) 0.112; factor (II) 0.097; interaction (I×II) 0.275. (x±S.D.), mean value of four samples and standard deviation.

After blanching, the content of beta-carotene did not change in the fresh matter of the two usable parts of dill, while in dry matter it was greater than before this treatment (Table 5; Fig. 1). Similar results were found by Granado et al. (1992) after the thermal treatment of Brussels sprouts, spinach, and cabbage, and by Khachik et al. (1992) in spinach and broccoli. Lisiewska and Kmiecik (1997) recorded 7% less beta-carotene in blanched parsley. The level of beta-carotene was stable in all samples of dill during freezing and refrigerated storage up to three months and in blanched samples additionally to the end of the period covered by the investigation. With a similar dependence on the temperature, the losses in non-blanched samples were by a few percentages lower than was found in the case of carotenoids, amounting to 10–22%. Lisiewska and Kmiecik (1997) found decreases in the range of 29–49% in parsley leaves stored at −20 °C for 9 months. According to Selman (1994), in blanched leafy vegetables stored for a year at −18 °C, the losses of beta-carotene content ranged from 5 to 20%. However, as Jaworska and Kmiecik (2000) reported, the storage of blanched spinach at −35 °C for a year did reduce the level of beta-carotene.

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