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Effects of traditional and modified technology, in the production of frozen cauliflower, on the contents of selected antioxidative compounds

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Abstract

The investigation concerned white and green cauliflowers: a traditional technology of freeze – blanched cauliflower, a modified technology of freeze – cooked cauliflower, and two temperatures of frozen storage at −20 and −30 °C for 0, 4, 8, and 12 months. Compared with the white cauliflower, the green variety was characterized by significantly greater contents of dry matter, vitamin C, carotenoids, β-carotene, polyphenols and a higher antioxidative activity at all the stages of evaluation. Depending on the investigated sample, after 12 months of refrigerated storage, cauliflower prepared for consumption retained 29–50% of vitamin C, 73–100% of carotenoids, 53–125% of β-carotene, 69–85% of polyphenols and 26–40% of antioxidative activity in comparison with the raw material. After a 12-month storage, the product obtained using the modified technology contained significantly more vitamin C and in general showed a higher antioxidative activity than did with the traditional product. The lower storage temperature resulted in significantly better retention of vitamin C and also – in some samples – a better retention of carotenoids, β-carotene, and polyphenols. A higher sensory quality was found in products of green cauliflower obtained according to the traditional technology.

Keywords: Cauliflowers; Freezing; Storage; Antioxidants; Sensory quality

1. Introduction

Vegetables are indispensable constituents in a balanced diet since they supply, not only easily assimilable carbohydrates, mineral compounds, pectins and dietary fibre, but also biologically active substances, such as vitamin C, carotenoids and polyphenols, which play an important role in the proper functioning of organisms (John et al., 2002; Taylor, Hampl, & Johnston, 2000). Hence, it is important to maintain a constant level of vegetable consumption throughout the year (Márová, Slovák, Bílková, Očenášková, & Čvančarová, 1999). Freezing is a method which allows the rapid processing of food while hardly changing its nutritional value and sensory characteristics. One of the objectives of the food industry, including the freezing industry, is to supply the market, not only with tasty and healthy products, but also those which make the preparation of dishes easier by eliminating not only laborious preliminary cleaning and preparing but also the cooking. This is being prompted by the widespread use of microwave cookery in the catering industry and domestic food preparation.

In the countries of the European Union, cauliflower occupies an important position in the production of fresh and frozen vegetables (FAOSTAT data, 2004). In recent years, growers have supplied new cultivars of cauliflower, characterized by their green colour, which have proved very attractive to the freezing industry.

The aim of this work was to evaluate frozen cauliflower products of both types stored at different temperatures. The investigation concerned frozen cauliflower products obtained by the traditional method of blanching before freezing or by the modified method of freezing cooked cauliflowers. The latter method supplies products of the ready-to-eat type, which only need defrosting and heating in a

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microwave. The content of selected compounds with antioxidative effects was used as a criterion in the quality assessment. Since the new type of product was compared with traditional product, sensory quality was also evaluated.

2. Materials and methods

2.1. Materials

The investigated material consisted of fresh cauliflower, blanched cauliflower, cauliflower cooked to a consistency approximating consumption consistency and frozen cauliflower, prepared for consumption and evaluated directly after freezing (0 months) and after 4, 8, and 12 months of refrigerated storage at −20 or −30 °C. The two types of cauliflower used in the experiment differed in the colour of the heads. The white-head cauliflower was represented by cultivar Planita F_1. It is a heterogeneous high-yielding cultivar of white floret of good freezing quality. The green type was represented by the cultivar Trevi F_1. If grown for autumn harvest it yields a very attractive dark green floret. This cultivar has not been so far investigated with regard to its value for freezing.

Both cultivars were grown in 2003 in the experimental field of the research unit, where technological experiments were conducted. The cauliflower was grown for autumn harvest. The field lies in southern Poland on the western outskirts of Krakow. The soil was of good horticultural structure, of neutral pH and with high contents of potassium, phosphorus and calcium. In the mineral fertilization of the cauliflower, the soil fertility and nutritional requirements of the crop were taken into consideration. The doses of mineral fertilizers were: 150 kg N/ha, 100 kg P_2O_5/ha and 150 kg K_2O/ha. Measures were taken during the growing period, depending on the weather and tillage conditions, and included sprinkler irrigation, mechanical weed control and protection against diseases and pests. The harvest was carried out at the end of September and the beginning of October. Well formed cauliflower heads were separated from stalks and divided into florets about 5 cm in diameter, their stalks being cut 2 cm below the lowest ramification. A mean sample representing the whole batch of the given cultivar was taken for evaluation of raw material. The remaining part was divided in half, each half being processed using a different technology.

2.2. Production of frozen products

2.2.1. The preparation for freezing

Two variants were used in preparing the raw material for freezing. Using traditional technology (variant I) the raw material was blanched and, after freezing and refrigerated storage, the frozen cauliflower needed traditional cooking. In variant II the raw material was cooked before freezing to a condition approximating consumption consistency; hence the obtained ready-to-eat product merely required defrosting and heating in a microwave.

In variant I, cauliflower florets were blanched in a stainless steel vessel in water (green cauliflower) or in a 0.2% solution of citric acid (to stabilize the colour of white cauliflower), the proportion of the blanched material to water being 1:5. The blanching temperature was 95–98 °C and the time was 3 min for white cauliflower and 3 min 15 s for green cauliflower. These conditions permitted a decrease in the activity of catalase and peroxidase to a level below 5% of the initial value. After blanching, the material was immediately cooled in cold water, slightly shaken and left for 30 min on sieves to drain the water remaining on the surface.

In variant II, cauliflower florets were cooked to a condition approximating consumption consistency in 2% brine. In the case of the white cauliflower, 0.1% citric acid was added to the brine to stabilize the colour. The cooking was carried out in a stainless steel vessel and the proportion of the raw material to brine was 1:1. The cauliflower was then placed in boiling water. The time of cooking, measured from the moment when the medium began boiling again, to the moment the desired consistency was obtained was 6 min. After cooking, the florets were drained, placed in sieves and cooled in a stream of cold air.

The material from the blanched and cooked samples was divided into two parts, placed on trays and frozen at −40 °C in a Feutron blast freezer, type 3626-51. One part was frozen to −20 °C, which was obtained inside the frozen product after 90 min, the other part was frozen to −30 °C, reached after 120 min. After the desired temperature was obtained, 500 g portions of the cauliflower were packed in polyethylene bags, suitable for the storage of refrigerated products. The bags were placed in chamber freezers at −20 and −30 °C, respectively.

2.2.2. The preparation of frozen cauliflower for evaluation

Frozen blanched products were cooked in 2% brine, the proportion in weight of brine to cauliflower being 1:1. As in the case of cooking, the material was placed in boiling water. The time of cooking was 5 min, measured from the moment when the brine was boiling again. After cooking, the water was immediately drained and the product was cooled to 50 °C for sensory evaluation or to 20 °C for analyses of chemical composition.

Frozen cauliflower products, cooked before freezing, were defrosted and a portion of 500 g in a heat-resisting vessel covered with a lid was heated in a Panasonic microwave oven, type NN-F621. The time of defrosting and heating to 75 °C was 7 min 45 s for a product frozen to −20 °C and 8 min 15 s for that frozen to −30 °C.

2.3. Evaluation of the chemical composition and sensory assay of the products

Dry matter content was determined by gravimetry as the mass loss of a sample at 96–98 °C (AOAC, 1984).

The content of vitamin C was determined as the sum of ascorbic acid (AA) and dehydroascorbic acid (DHAA) by the Zapata and Dufour (1992) method, adopted by Gil, Ferreres, and Tomás-Barberán (1999). The analysis was performed by HPLC, using a Merck-Hitachi system with UV detector (L7420). Ascorbic acid and dehydroascorbic acid were quantified with a C18 column with a mobile phase composed of 5% methanol:water solution (v/v) containing 50 mM of potassium dihydrogen phosphate and 5 mM centrimide. The detection was made with the UV detector at 348 nm for DHAA after derivatization with 1,2-phenylenediamine (OPDA) and at 261 nm for AA.

Total carotenoids were determined using the Wettstein (1957) method. The extraction procedures of pigment were carried out under dim light and in glassware wrapped with aluminium foil. The method consisted of repeated acetone extraction, using the mortar and pestle until a colourless residue was obtained, and then filtering over a cotton pad. The extracts were made up to a known volume with acetone. The concentration of carotenoids was measured at 440.5 nm in a Shimadzu UV 160A double-beam spectrophotometer.

β-Carotene analysis (ISO, 1992) consisted of the extraction procedures of pigment, followed by liquid/liquid partitioning with hexane, concentration and column chromatography. The same extracts as obtained for carotenoids estimation were used. Hexane extracts were filtered over anhydrous sodium sulphate on filter paper (Whatman No. 1 equivalent) and were made up to a known volume. The extract was concentrated 10-fold by evaporation and loaded onto the column. Columns (150×10 mm) were packed with aluminium oxide to a length of 100 mm and covered with 10 mm of anhydrous sodium sulphite, then washed with hexane containing 1% acetone. The orange-coloured eluent, containing β-carotene, was collected in a volumetric flask. The concentration of β-carotene was measured at 450 nm in a Shimadzu UV 160A spectrophotometer and compared with the β-carotene reference standard.

Total phenolic compounds were determined using the Folin–Ciocalteau reagent, according to Singleton, Orthofer, and Lamuela-Ravento's (1999). Two grammes of homogenized samples were boiled for 20 min in 80% ethanol under reflux. Five millilitres of 10-fold diluted extract and 0.5 ml of 2-fold diluted Folin–Ciocalteau reagent were added, and 1 ml of 20% of sodium carbonate was added and the contents were mixed thoroughly. The absorbance was measured at 760 nm in the Shimadzu spectrophotometer after 20 min using chlorogenic acid as a standard. The results were expressed as mg chlorogenic acid equivalents/100 g of fresh weight of product.

The antioxidant activity was measured using the DPPH (1,1-diphenyl-2-picrylhydrazyl) radical-scavenging method (Pekkarinen, Stockman, Swarz, Heinonen, & Hopia, 1999). The radical-scavenging activity (RSA) was determined by measuring the absorbance at 516 nm in the above-described spectrophotometer and expressed as: RSA (%) = (1 − absorbance at 516 nm after 10 min/absorbance at 516 after 0 min) × 100.

Since parts of the frozen samples were prepared using the modified technology, it was deemed appropriate to evaluate the sensory quality of the final products. A team of five panellists, meeting the requirements of sensory sensitivity (ISO, 1991), conducted the evaluation, using a scale from 1 to 5 (best) in conditions, which met the recommendations (ISO, 1985), and using a model card devised by the present authors. The surface appearance, colour, consistency, flavour and taste of products were evaluated. The sum product of sensory evaluation points multiplied by their weight factors was divided by the total weight factors and this was accepted as a total score.

In order to show the differentiation in chemical composition and sensory evaluation, a single-factor analysis of variance (ANOVA) was carried out on the basis of the Snedecor F and Student's T test, the least significant difference (LSD) being calculated for the error probability level of $\alpha = 0.01$ for the chemical composition and $\alpha = 0.05$ for sensory evaluation. The computer programme Statistica ver. 6.1 was used.

3. Results and discussion

The content of the analysed characteristics of white cauliflower florets directly after harvest was comparable to that given by numerous authors (Lisiewska & Kmiecik, 1996; Maldonado & Pacheco-Delhaye, 2003; Szeto, Tomlinson, & Benzie, 2002). The raw material of green cauliflower contained 28% more dry matter, 52% more vitamin C, 43% more polyphenols and showed a 17% greater antioxidative activity than did the white caulifower (Tables 1 and 2). In white cauliflower, small amounts of carotenoids and a trace content of β-carotene were found. Numerous authors did not record the content of β-carotene in this type of cauliflower; however, Souci, Fachman, and Kraut (1989) and Wills (1987) reported the content of β-carotene at a level of 0.01–0.03 mg/100 g. It is worth stressing that the genetic modification of white cauliflower is currently being attempted to obtain a significant increase in the contents of this constituent (Li, Paolillo, Parthasarathy, DiMuzio, & Garvin, 2001). The content of carotenoids and β-carotene in green cauliflower is close to that in broccoli (Müller, 1997).

Blanching caused a decrease in the contents of all constituents analysed. The greatest losses were 21% of vitamin C in white cauliflower and 26% in green cauliflower. The antioxidative activity was reduced by 13% in both types of cauliflower and the content of dry matter by about 10%. Besides, the level of carotenoids in green type decreased by about 14%. The loss of the remaining constituents did not exceed 10%. These results are similar to those obtained for blanched broccoli (Barret, Garcia, Russel, Ramirez, & Shirazi, 2000; Gębczyński, 2003).

In comparison with the raw material, the cooked product was characterized by a significant 18% increase in dry

Table 1
Contents of dry matter, vitamin C and carotenoids in raw, prepared for freezing and frozen white and green cauliflowers prepared for consumption

Stage of evaluation, type of product and temperature of storage	Dry matter (g/100 g)		Vitamin C (mg/100 g)		Carotenoids (mg/100 g)	
	White	Green	White	Green	White	Green
Raw material	7.28 ± 0.49	9.30 ± 0.57	65.2 ± 1.7	98.9 ± 1.8	0.13 ± 0.03	2.56 ± 0.24
Prepared for freezing						
Blanched	6.61 ± 0.53	8.08 ± 0.59	51.4 ± 1.8	73.3 ± 1.9	0.13 ± 0.02	2.20 ± 0.20
Cooked	8.59 ± 0.51	10.46 ± 0.59	47.9 ± 1.8	70.2 ± 1.6	0.14 ± 0.02	2.77 ± 0.19
After freezing:						
0 months stored						
Traditional[a]						
−20 °C	7.54 ± 0.46	9.22 ± 0.52	42.7 ± 1.7	66.6 ± 1.7	0.12 ± 0.02	2.23 ± 0.19
−30 °C	7.56 ± 0.49	9.24 ± 0.53	42.2 ± 1.7	65.6 ± 1.8	0.12 ± 0.02	2.20 ± 0.16
Modified[b]						
−20 °C	9.11 ± 0.48	11.19 ± 0.65	43.0 ± 1.5	65.8 ± 1.9	0.14 ± 0.01	2.78 ± 0.22
−30 °C	9.20 ± 0.51	11.28 ± 0.64	42.6 ± 1.7	64.9 ± 1.7	0.15 ± 0.01	2.88 ± 0.20
4 months stored						
Traditional[a]						
−20 °C	7.50 ± 0.45	9.22 ± 0.59	32.0 ± 1.7	52.7 ± 1.8	0.12 ± 0.01	2.15 ± 0.18
−30 °C	7.48 ± 0.48	9.17 ± 0.57	39.3 ± 1.6	57.8 ± 1.8	0.12 ± 0.02	2.20 ± 0.21
Modified[b]						
−20 °C	9.26 ± 0.51	11.17 ± 0.73	36.7 ± 1.5	57.3 ± 1.7	0.12 ± 0.01	2.56 ± 0.17
−30 °C	9.42 ± 0.56	11.33 ± 0.70	39.2 ± 1.5	62.0 ± 1.8	0.14 ± 0.02	2.75 ± 0.19
8 months stored						
Traditional[a]						
−20 °C	7.47 ± 0.43	9.24 ± 0.56	25.6 ± 1.5	41.2 ± 1.7	0.11 ± 0.01	2.07 ± 0.18
−30 °C	7.38 ± 0.45	9.22 ± 0.50	32.1 ± 1.5	48.5 ± 1.8	0.12 ± 0.01	2.21 ± 0.15
Modified[b]						
−20 °C	9.24 ± 0.59	11.15 ± 0.67	29.8 ± 1.5	50.0 ± 1.6	0.11 ± 0.01	2.38 ± 0.14
−30 °C	9.60 ± 0.57	11.26 ± 0.74	37.5 ± 1.7	57.9 ± 1.6	0.13 ± 0.02	2.57 ± 0.19
12 months stored						
Traditional[a]						
−20 °C	7.47 ± 0.043	9.26 ± 0.51	19.1 ± 1.5	36.3 ± 1.5	0.11 ± 0.01	1.92 ± 0.17
−30 °C	7.40 ± 0.044	9.20 ± 0.46	37.3 ± 1.6	42.0 ± 1.5	0.12 ± 0.02	2.07 ± 0.15
Modified[b]						
−20 °C	9.32 ± 0.042	11.13 ± 0.61	24.5 ± 1.3	41.2 ± 1.4	0.11 ± 0.01	2.24 ± 0.17
−30 °C	9.56 ± 0.049	11.23 ± 0.61	32.6 ± 1.5	48.3 ± 1.5	0.13 ± 0.01	2.49 ± 0.14
LSD $\alpha = 0.01$	0.137		2.33		0.227	

[a] Frozen product manufactured according to traditional procedure and cooked before consumption.
[b] Frozen product manufactured according to modified procedure and microwaved before consumption.

matter content in white cauliflower and 12% in the green cultivar. This increase can be attributed to the addition of salt to water used for cooking (Kmiecik & Budnik, 1997) and also to the loss of water from the tissue and the shrinkage of the raw material (Ramesh, 2000). The frequently noted increase in total carotenoids and β-carotene is caused by the increasing level of dry matter owing to the loss of water and an easier extraction of these compounds after heat-processing (Granado, Olmedilla, Blanco, & Rojas-Hidalgo, 1992; Hart & Scott, 1995). However, decreases in the contents of these constituents were also observed in vegetables after cooking (Chen, 1992). In the case of vitamin C, polyphenols and antioxidative activity, the cooking significantly decreased their levels by 27% and 29%, 10% and 13% and 33% and 31% in white and green cauliflower, respectively. The above losses in the content of these constituents were similar to that observed by Ismail and Lee (2004), Kmiecik and Budnik (1997) and Souci et al. (1989). Since vitamin C is classed among the constituents which show the least stability in hydrothermal processes, numerous authors quote an even greater loss. For example, Franke, Custer, Arakaki, and Murphy (2004), in cooked broccoli, and Ramesh (2000), in cooked green pea, and kohlrabi, recorded a 60% loss of vitamin C.

The refrigerated storage of cauliflower, irrespective of its type, methods of processing before freezing and the storage temperature, brought about a steady decrease in the level of the analysed constituents, except for dry matter. The difference between the times of evaluation was statistically significant for vitamin C and antioxidative activity. In the case of carotenoids, β-carotene and polyphenols, differences were found only between the first (0 months) and the last (12 months) storage periods. Depending on the investigated sample, during the 12-month period, decreases in vitamin C content reached 23–55%, in carotenoids 0–21%, in β-carotene 0–40%, in polyphenols 5–17%, and in

Table 2
Contents of β-carotene, polyphenols and antioxidative activity in raw, prepared for freezing and frozen white and green cauliflowers prepared for consumption

Stage of evaluation, type of product and temperature of storage	β-Carotene (mg/100 g)		Polyphenols (mg/100 g)		Antioxidative activity (%RSA)	
	White	Green	White	Green	White	Green
Raw material	0.04 ± 0.01	0.15 ± 0.03	58.8 ± 1.3	84.3 ± 1.6	32.5 ± 0.9	38.0 ± 1.2
Prepared for freezing						
Blanched	0.03 ± 0.01	0.14 ± 0.02	55.2 ± 1.4	76.6 ± 1.4	28.2 ± 1.0	33.0 ± 1.2
Cooked	0.05 ± 0.02	0.15 ± 0.02	53.2 ± 1.3	73.3 ± 1.5	21.9 ± 0.8	26.3 ± 1.1
After freezing:						
0 months stored						
Traditional[a]						
−20 °C	0.04 ± 0.01	0.13 ± 0.01	53.2 ± 1.3	70.5 ± 1.5	18.1 ± 0.8	23.5 ± 0.9
−30 °C	0.04 ± 0.01	0.13 ± 0.01	53.0 ± 1.3	71.0 ± 1.4	18.1 ± 0.7	23.5 ± 1.0
Modified[b]						
−20 °C	0.06 ± 0.02	0.15 ± 0.02	54.1 ± 1.3	72.2 ± 1.6	18.8 ± 0.9	24.1 ± 0.8
−30 °C	0.06 ± 0.02	0.15 ± 0.02	54.2 ± 1.3	72.4 ± 1.6	18.8 ± 0.8	24.1 ± 0.9
4 months stored						
Traditional[a]						
−20 °C	0.04 ± 0.01	0.10 ± 0.01	52.0 ± 1.2	67.1 ± 1.5	15.7 ± 0.7	20.7 ± 0.7
−30 °C	0.04 ± 0.01	0.12 ± 0.02	52.5 ± 1.3	67.9 ± 1.4	16.2 ± 0.7	21.7 ± 0.8
Modified[b]						
−20 °C	0.05 ± 0.01	0.13 ± 0.01	53.8 ± 1.4	70.1 ± 1.5	16.0 ± 0.5	20.8 ± 0.9
−30 °C	0.06 ± 0.02	0.14 ± 0.02	53.8 ± 1.3	71.3 ± 1.6	16.6 ± 0.7	21.2 ± 0.9
8 months stored						
Traditional[a]						
−20 °C	0.03 ± 0.01	0.09 ± 0.01	50.3 ± 1.2	64.7 ± 1.7	12.8 ± 0.6	18.3 ± 0.8
−30 °C	0.04 ± 0.01	0.12 ± 0.01	51.6 ± 1.1	65.8 ± 1.5	13.7 ± 0.8	19.2 ± 0.7
Modified[b]						
−20 °C	0.04 ± 0.01	0.09 ± 0.01	53.0 ± 1.2	67.8 ± 1.4	13.0 ± 0.5	18.1 ± 0.6
−30 °C	0.05 ± 0.01	0.10 ± 0.01	53.2 ± 1.1	70.0 ± 1.4	13.9 ± 0.7	18.9 ± 0.7
12 months stored						
Traditional[a]						
−20 °C	0.03 ± 0.01	0.08 ± 0.01	48.5 ± 1.2	58.3 ± 1.4	8.5 ± 0.6	13.2 ± 0.6
−30 °C	0.04 ± 0.01	0.11 ± 0.01	50.2 ± 1.3	60.2 ± 1.4	9.5 ± 0.8	14.4 ± 0.7
Modified[b]						
−20 °C	0.04 ± 0.01	0.09 ± 0.01	49.6 ± 1.2	61.2 ± 1.3	10.8 ± 0.8	14.1 ± 0.8
−30 °C	0.05 ± 0.01	0.12 ± 0.02	51.2 ± 1.2	68.0 ± 1.3	11.6 ± 0.6	15.1 ± 0.7
LSD $\alpha = 0.01$	0.020		2.95		1.47	

[a] Frozen product manufactured according to traditional procedure and cooked before consumption.
[b] Frozen product manufactured according to modified procedure and microwaved before consumption.

antioxidative activity 37–53%. In analogous samples, a better preservation of the investigated compounds was observed at lower storage temperatures. Taking the methods of processing frozen products into consideration, the cooking of cauliflower before freezing and heating in a microwave, compared with the traditional production method brought about a better preservation of vitamin C, a comparable or slightly better one of polyphenols and antioxidative activity but slightly worse of carotenoids and β-carotene.

After 12 months of refrigerated storage, white and green types of cauliflower, prepared for consumption, contained 29–50% and 37–49% of vitamin C, 85–100% and 73–96% of carotenoids, 72–125% and 53–80% of β-carotene, respectively (it should be pointed out that the latter two constituents were present in very small quantities), 82–85% and 69–81% of polyphenols and 26–35% and 35–40% of antioxidative activity. The content of dry matter changed to levels of 102–131% and 99–121%. In green cauliflower, the content of dry matter was 21% greater than in white cauliflower; of vitamin C 62%, of polyphenols 24%. The carotenoid content was several times greater, that of β-carotene 2.5 times greater and the antioxidative activity was higher by 41% in green cauliflower than in the white cultivar. However, the differences were not statistically verified in all cases.

Cauliflower, prepared for consumption according to the modified technology, contained 24% more dry matter, 18% more vitamin C and carotenoids, 15% more β-carotene, 6% more polyphenols, and its antioxidative activity was 13% higher than did cauliflower prepared according to the traditional procedure. In the case of dry matter and vitamin C, the differentiation between analogous samples was statistically significant, of antioxidative activity in general

significant. Carotenoids and polyphenols were in general, non-significant and also in β-carotene non-significant. In comparison with the storage at −20 °C, the storage for 12 months at −30 °C improved the preservation of vitamin C by 24%, of carotenoids by 10%, of β-carotene by 33%, and of polyphenols by 6%; the antioxidative activity was 9% higher. In analogous samples, the differences were significant for vitamin C, for β-carotene significant in some of the samples, and for carotenoids and polyphenols non-significant for most samples, and non-significant for antioxidative activity. Aparicio-Cuesta and Garcia-Moreno (1988) and Lisiewska and Kmiecik (1996) also observed the effect of the storage temperature on the chemical composition of cauliflower. On the other hand, Puupponen-Pimiä et al. (2003) reported that, in frozen cauliflower, the basic changes in vitamin C and polyphenols and in antioxidative activity occurred during blanching, while refrigerated storage was less important for changes in the contents of these constituents. Lisiewska and Kmiecik (2000) showed that, after one-year of storage at −30 °C, non-blanched cut tomatoes contained 90% more vitamin C and 40% more β-carotene that did the product stored at −20 °C. However, if blanched vegetables were subjected to long-term storage at different temperatures, the level of chemical constituents was less varied. It can be concluded that the culinary process of preparing the investigated types of cauliflower for consumption also influences the loss of vitamin C and of the remaining constituents.

In general, frozen products stored for 12 months had good sensory quality of 3.88–5.00 on the scale from 1 to 5 (Table 3). However, a better quality of product from green cauliflower could be observed. In contrast to this observation, Gajewski and Radzanowska (2003) found a poorer ''grassy'' taste and a less ''smooth'' consistency of three different cultivars of green cauliflower compared with white cauliflower. Comparison of results shows that the specific traits of cultivars can significantly affect sensory quality of products. Besides, a poorer shape, smell and taste were noted in products which were defrosted and heated in a microwave. A greater degree of deterioration of these traits was observed in products prepared from frozen cauliflower stored at −20 °C and in frozen white cauliflower. Also, Fuster, Borrallo, and Prestamo (1995) observed changes in the flavour and colour of white cauliflower stored at −24 °C for 6.5 months. In spite of the slight increase found in peroxidase activity, these authors attributed the changes to non-enzymatic reactions. However, DiCesare (1999) claims that new smell compounds, absent in fresh cauliflower, are produced in the course of heat-processing before freezing. These authors also stress that, on account of its sensory characteristics, this vegetable can be frozen and stored at −20 °C for up to 6 months without blanching.

4. Conclusions

At all stages of evaluation, the green cauliflower distinguished itself from the white variety in having a significantly higher content of all the analysed characteristics. The cooking of white and green cauliflower, before freezing, resulted in a 27% and 29% decrease in the content of vitamin C, a 10% and 13% decrease in polyphenols and a 33 and 31% reduction of the antioxidative activity, respectively. The contents of carotenoids and β-carotene did not significantly change, while that of dry matter increased. In comparison with the condition of the product immediately after freezing, the 12-month storage of frozen products caused a distinct 37% decrease in the content of vitamin C, a 42% decrease in antioxidative activity, a moderate 26% loss of β-carotene and an insignificant (10–11%) decrease in carotenoids and polyphenols, on average, in all the samples.

After 12 months of refrigerated storage, cauliflower prepared for consumption according to the modified technology contained significantly (18%) more vitamin C and, in general, showed a significantly (13%) higher antioxidative activity. The lower storage temperature resulted in better retention of vitamin C in all the products prepared for consumption and in some samples also better retention of carotenoids and polyphenols. Green cauliflower had a

Table 3
Sensory quality of frozen cauliflowers prepared for consumption after 12 months of storage in different temperatures

Quality and weight factors		White cauliflower				Green cauliflower			
		Traditional product[a]		Modified product[b]		Traditional product[a]		Modified product[b]	
		−20 °C	−30 °C	−20 °C	−30 °C	−20 °C	−30 °C	−20 °C	−30 °C
Surface appearance	2	5.0	5.0	4.6	5.0	5.0	5.0	4.5	5.0
Colour	5	4.2	5.0	3.8	4.6	4.6	5.0	4.2	4.9
Consistency	3	5.0	5.0	4.3	4.3	5.0	5.0	4.7	4.7
Flavour	5	4.5	4.7	3.7	4.3	4.8	5.0	4.5	4.8
Taste	5	4.3	5.0	3.5	4.0	4.3	5.0	4.5	4.9
Total score		4.50	4.94	3.88	4.38	4.69	5.00	4.44	4.84
LSD[c] $\alpha = 0.05$		0.182							

[a] Frozen product manufactured according to traditional procedure and cooked before consumption.
[b] Frozen product manufactured according to modified procedure and microwaved before consumption.
[c] LSD value for total score.

slightly higher sensory quality, as did both types (especially of white cauliflower) prepared according to the traditional technology.

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