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Effect of storage period and temperature on the chemical composition and organoleptic quality of frozen tomato cubes

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Abstract

Micra RS tomatoes, frozen in the form of cubes, were stored during 12 months at −20 and −30°C, analyses being conducted after freezing and after 3-, 6-, 9- and 12-months' storage. The storage did not affect the level of dry matter, soluble solids, sugars, dietary fibre, total nitrogen, nitrates, nitrites, pH, ash or its alkalinity. However, differences in the contents of protopectins, pectins, total acidity, vitamin C, carotenoids, beta-carotene and lycopene and also in the activity of peroxidase, catalase and lipase were statistically significant. In frozen products at a temperature of −30°C in comparison with those at −20°C the contents of the following were: protopectins 33%, pectins 68%, vitamin C 90%, carotenoids 30%, beta-carotene 39% and lycopene 43%, while the activities of catalase and of lipase were 52% and 45% lower, respectively. Organoleptic ecaluation showed good conservation quality in tomato cubes stored at −20°C during 9 months and, in the case of −30°C, throughout the entire investigated period.

1. Introduction

Tomato is consumed fresh but also in the form of processed products; however, freezing gives poor results, especially when frozen tomatoes are used for direct consumption.

New tomato cultivars appearing on the vegetable market yield fruits with a hard, compact flesh and breeders of these cultivars claim that their sensory properties are well preserved in frozen products.

The aim of the work was therefore to characterize Micra RS tomatoes produced by the firm Seminis Vegetable Seeds, by freezing in the form of cubes, at two storage temperatures. Criteria were the results of sensory evaluation and the conservation of physico-chemical indices important for both, dietetics and freezing technology.

2. Materials and methods

2.1. Raw material

The investigated materials were Micra RS tomatoes bred by the firm Seminis Vegetable Seeds. The cultivar was selected out of six products of this firm, recommended for freezing in the form of slices or cubes. The following criteria of selection were taken into consideration: the low price of seeds (standard cultivar), comparable yields with the remaining cultivars, favourable morphological traits, a proper sugars to acids ratio, the high content of protopectins and pectins, and the concentrations of vitamin C, beta-carotene and lycopenes, similar to those in the remaining cultivars, accompanied by a medium to high activity of peroxidase, catalase, and lipase (Kmiecik & Lisiewska, 1999).

2.2. Conditions of tomato growth

The tomatoes were grown in southeastern Poland on an experimental plantation of the firm's agency, on loess-podsolic soil. No organic fertilizers were used, but the intensive mineral fertilization, adapted to soil fertility, was determined by the breeder. The harvest for technological processing was carried out in the second week of the fruiting period, on 30 August 1997. Fruits were harvested at the stage of commercial maturity, corresponding with almost full technological ripeness. Up to the time of full technological and processing usability the fruits were kept in a bright room at about 18°C and a relative humidity of 80%.

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2.3. Method of freezing

The technological process of freezing the tomatoes included sorting, washing, drying, cutting into 12×12×12 mm cubes, filling into plastic boxes of 500 g capacity and freezing in a type 3101-01 Feutron blast freezer at −40°C. The products frozen to −20 and −30°C were stored for a period of 12 months.

2.4. Analyses

The cut raw tomatoes and frozen product after freezing and after 3, 6, 9 and 12 months of storage were subjected to sensory and physico-chemical analyses.

2.5. Physico-chemical analyses

Physico-chemical analyses were conducted in four determinations. A mean sample of about 1000 g was used for determinations, the frozen tomatoes being thawed at temperatures from +2 to +4°C. The AOAC (1984) methods were used in determining the analysed indices: the level of dry matter (32.019), soluble solids (32.023), simple sugars (32.040), total sugars (32.041), total nitrogen (2.058), total ash (32.027), alkalinity of ash (32.028), total acids (32.043), and active acidity (32.016). The content of vitamin C was determined using the ISO/6557/2 (1984) method, of nitrates and nitrites ISO/6635 (1984). Published methods were used for carotenoids, beta-carotene and lycopene (Davies, 1965), pectin and protopectin (Lopez-Andreu, Esteban, Molla & Carpena, 1988), and dietary fibre (Hellendoorn, Noordhoff & Slagman, 1975). The activities of enzymes are expressed as: peroxidase units, $-\Delta$ OD$\times$min^{-1}/g (Cano, Hernandez & De Ancos, 1997), catalase (units mg) $H_2O_2\times$min^{-1}/g (Ciszewska, Przeszlakowska, Sykut & Szynal, 1997), lipase (units cm^3) 0.1 M KOH$\times 10^{-2}$/g (Brzeski & Kaniuga, 1957).

2.6. Sensory analyses

In the sensory evaluation, the discriminants most significant from the standpoint of the consumer and the planned use of the product were taken into consideration. Organoleptic analyses were carried out by a team of five tasters, always the same persons. The team used the method of Tilgner's direct evaluation based on a 5-score scale of grading.

2.7. Statistical analyses

Results were statistically verified using the Snedecor F and the Student t tests. In the case of physico-chemical evaluation, the results are presented in tables and diagrams, the latter being used for the indices whose statistically significant changes, depending upon the temperature or period of storage, were demonstrated.

3. Results and discussion

The values of physico-chemical indices in fresh Micra RS tomatoes were comparable with values given for fruit of this species by Collins, Abdalla and Schoenemann (1994), Elkner (1994), Lopez-Andreu, Lamela, Esteban and Collado (1986), and Wills, Lim and Greenfield (1987). It should be stressed that the number of analysed discriminants was distinctly smaller in the works mentioned above.

The freezing and storage of frozen cubes at −20 and −30°C for 12 months did not significantly change the level of dry matter, soluble solids, sugars, dietary fibre, total nitrogen, nitrates, nitrites, pH, ash and its alkalinity (Table 1). Statistically significant changes were observed in the contents of protopectins, pectins, total acidity, vitamin C, carotenoids, beta-carotene and lycopene (Fig. 1) and also in the activities of peroxidase, catalase and lipase (Fig. 2).

The levels of protepectins and pectins were signifcantly reduced by the freezing process itself. Further gradual losses were induced during frozen storage. These results were reflected in the evaluation of sensory traits, such as the leaching of juice and, especially, consistency. This should be regarded as obvious, since Gradziel (1988) reported that freezing and frozen storage caused deterioration of the texture of tomatoes while Fuchigami, Miyazaki and Hyakumoto (1995) observed their worsened texture accompanied by a decrease in the content of pectic compounds.

In the course of storage a tendency to an increasing content of total acids was observed in frozen tomatoes, though a significant increase was found only after 9 months of storage at −20°C. This factor might to a certain degree have affected organoleptic quality, especially since, after the 12-months' storage, the acids to sugars ratio changed from 1:8.0 in the raw material to 1:6.2 and 1:6.4 in frozen tomatoes. In contrast to these results, Zackel and Schillinger (1979) reported a decrease in the content of acids even to 32% of the initial value.

The freezing itself induced slight losses in the content of vitamin C while an even higher level of this vitamin was determined by Jurics (1970) in tomatoes directly after freezing. In the present experiment, long-term storage brought about gradual pronounced losses in vitamin C content. They fell to 71% of the initial value after 12-months' storage at −20°C and 45% at −30°C. In the case of a 9-month storage of frozen tomatoes, similar losses were reported by Brovchenko and Golbert (1973), while Zackel and Schillinger (1979) reported a distinctly greater degradation of this vitamin.

The prevailing opinion is that freezing does not prevent the degradation of carotenoids. According to Biacs and Wissgott (1997) the losses are above-all due to the activity of enzymes, particularly in an oxygen

Table 1
Changes in the levels of physicochemical indices in frozen tomato cubes depending on the time and temperature of storage

Item[a]	Raw material before freezing	Storage period in months: 0, −20°C	0, −30°C	12, −20°C	12, −30°C	LSD $P=0.05$	$P=0.01$
Dry matter (g/100 g)	5.75	5.79	5.81	5.86	5.84	n.s.[b]	n.s.
Soluble solids (g/100 g)	4.88	4.93	4.94	4.98	4.97	n.s.	n.s.
Simple sugars (g/100 g)	2.70	2.73	2.67	2.69	2.59	n.s.	n.s.
Total sugars (g/100 g)	2.81	2.84	2.82	2.74	2.69	n.s.	n.s.
Dietary fibre (g/100 g)	0.62	0.63	0.64	0.65	0.64	n.s.	n.s.
Protopectin (g/100 g)	0.117	0.085	0.086	0.040	0.053	0.0075	0.0101
Pectin (g/100 g)	0.216	0.146	0.145	0.037	0.061	0.0104	0.0139
Total nitrogen (g/100 g)	0.16	0.15	0.16	0.16	0.16	n.s.	n.s.
N-NO_3 (mg/l000 g)	32	33	34	40	38	n.s.	n.s.
N-NO_2 (mg/1000 g)	0.0	0.0	0.0	0.0	0.0	–	–
Total acidity (g/100 g)	0.35	0.34	0.35	0.44	0.37	0.031	0.041
Active acidity (pH)	4.18	4.26	4.28	4.35	4.34	n.s.	n.s.
Ash (g/100 g)	0.48	0.48	0.47	0.47	0.47	n.s.	n.s.
Alkanility of ash (cm^3/1 M) HCl/100 g	4.48	4.49	4.46	4.46	4.45	n.s.	n.s.
Vitamin C (mg/100 g)	23.6	22.9	22.7	6.8	12.9	0.76	1.02
Carotenoids (mg/100 g)	4.97	4.91	4.93	3.16	4.12	0.195	0.262
Beta-carotene (mg/100 g)	1.42	1.37	1.37	0.69	0.96	0.116	0.156
Lycopene (mg/100 g)	3.28	2.99	2.99	1.69	2.42	0.170	0.228
Peroxidase (units)	4.57	1.61	1.80	0.00	0.00	0.174	0.234
Catalase (units)	2.40	2.38	2.35	2.22	1.06	0.176	0.236
Lipase (units)	1.95	1.79	1.66	0.69	0.38	0.099	0.133

[a] From four determinations.
[b] n.s., not significant.

environment. In the present work, a fairly pronounced stability of total carotenoids, beta-carotene, and lycopene was recorded up to the third month of storage, irrespective of the applied temperature. After this period, slow losses occurred, their rates being significantly faster at the higher storage temperature. In some tomato cultivars, Urbanyi and Horti (1989) observed a significant increase in the contents of carotenoids, beta-carotene, and lycopene in relation to the raw material after 1-months' storage of frozen tomatoes, although, after a further 3 and 6 months, the preservation of these compounds was much poorer than that found in the present experiment. On the other hand, after 9-months' storage of frozen tomatoes, Brovchenko and Golbert (1973) observed preservation of beta-carotene at a level of 90% compared with 66 and 79% in this work. After 12-months' storage at −20°C, the losses of carotenoids reached 36%, of beta-carotene 51%, and of lycopene 48%. After the same period, in samples stored at −30°C, in comparison with those stored at −20°C, the contents

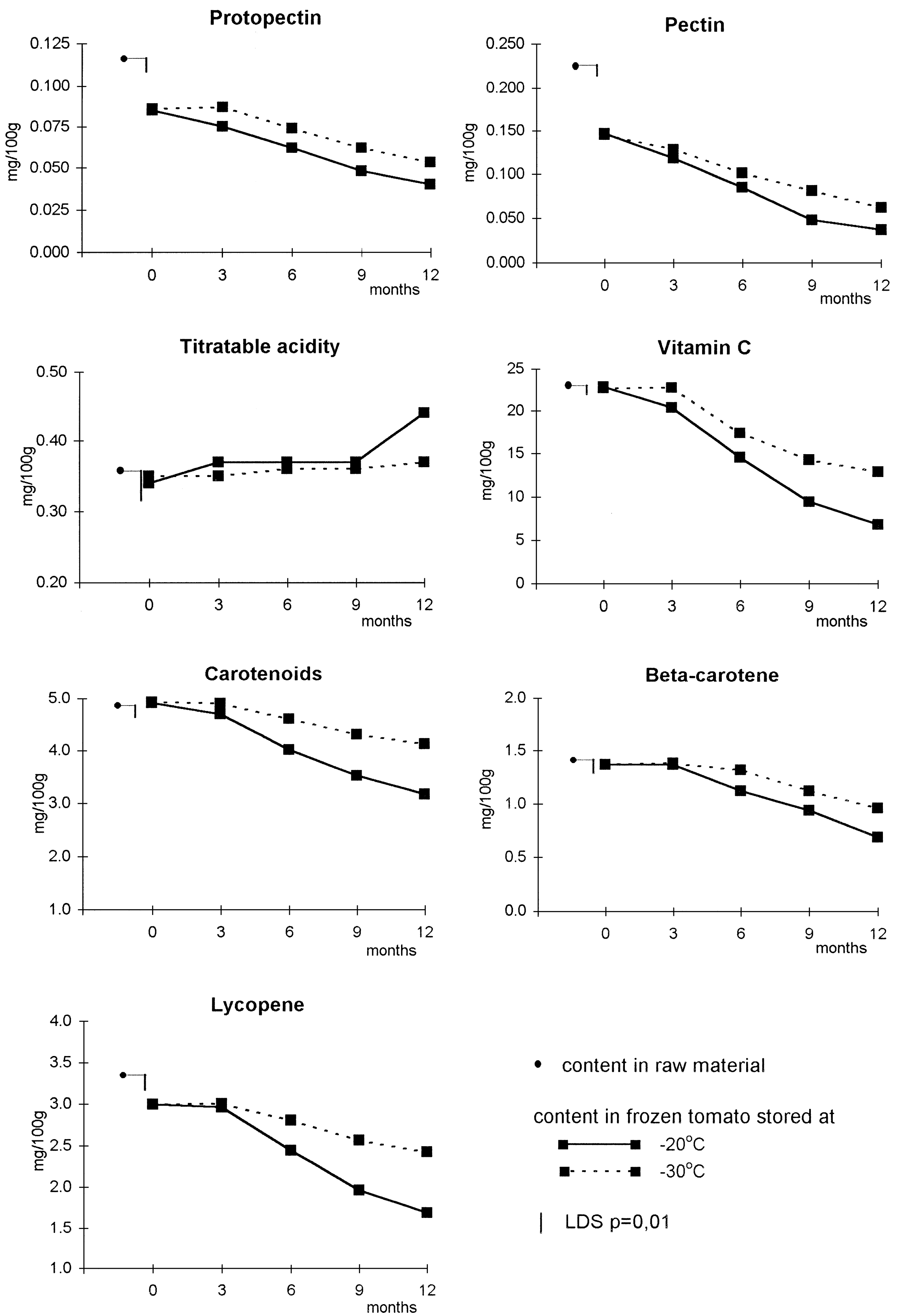

Fig. 1. Changes in the levels of chemical components in frozen tomato cubes depending on the time and temperature of storage.

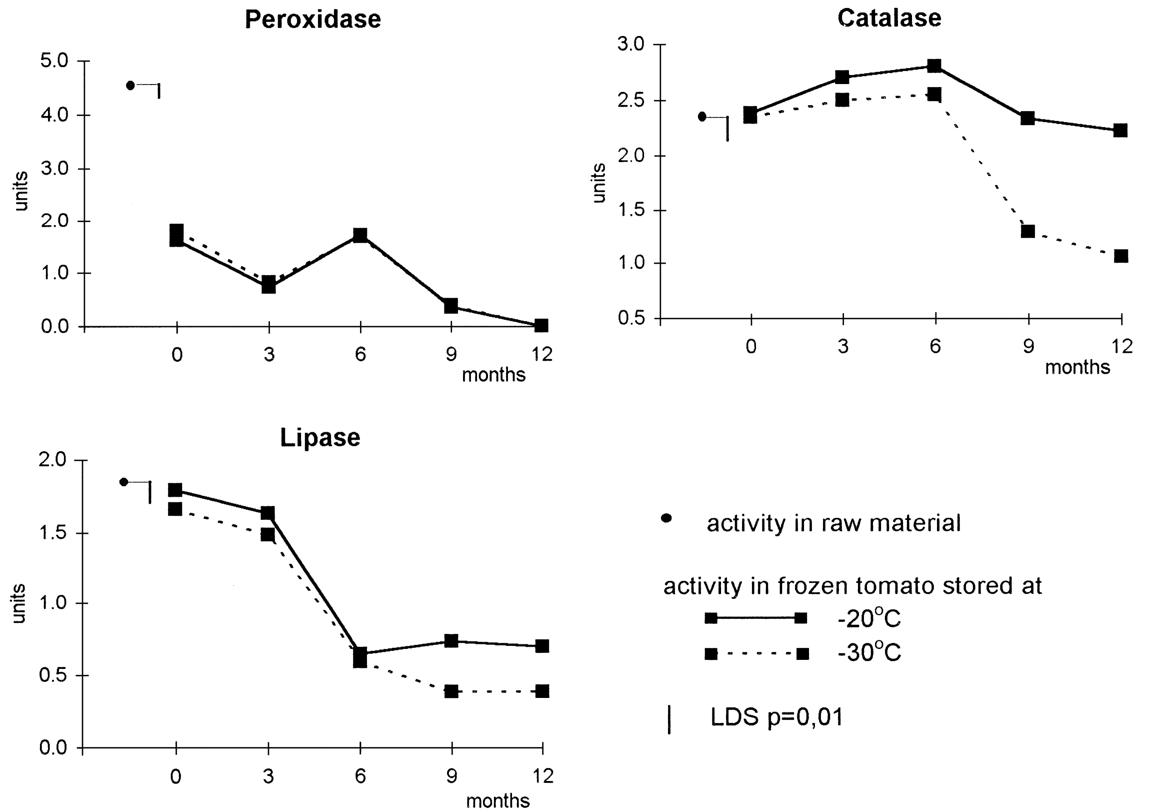

Fig. 2. Changes in the activity levels of selected enzymes in frozen tomato cubes depending on the time and temperature of storage.

of these compounds were larger by 30, 39 and 43%, respectively. Urbanyi and Horti (1989) observed that, during a 24-week frozen storage of tomatoes, the gradual reduction of carotenoids was accompanied by a change of colour from red to red with a yellow shade and therefore the colour of fruits seemed increasingly lighter. In the present work this was observed after 6 months of storing frozen tomatoes at −20°C while, at −30°C, organoleptically discernible changes were noted only after 12 months.

The occurrence of such enzymes as peroxidase, catalase, and lipase in the tomato contribute to a worsening of its organoleptic features and losses of nutrients (Begliomini, Montedoro, Servili, Petruccioli & Federici, 1995; Hemeda & Klein, 1990; Williams, Lim, Chen, Pangborn & Whitaker, 1986). Bizzarri, Andreotti and Massini (1981) classed peroxidase among the most important enzymes in tomato processing, although Postolski (1985) observed that the biochemical activities of enzymes rapidly declined in tomato fruits. Moreover, Prestamo and Manzano (1993) determined an inhibitory effect of ascorbic acid on peroxidase activity in the tomato. Irrespective of the storage temperature, the activity of peroxidase in frozen tomatoes declined to zero after 12 months. In frozen tomatoes, stored at −18°C, Hemeda and Klein (1991) observed a reduction of peroxidase to zero already after 4 weeks although, before freezing, they subjected these fruits to a mild pasteurization (75°C for 1.5 min).

According to Bizzarri et al. (1981), in spite of being very labile in tomato, catalase is capable of regeneration. In the present study, at the higher temperature of storage there appeared to be no significant differences in its activity that depended upon the length of storage while, at the lower temperature, the level of this enzyme did not change up to the sixth month, afterwards rapidly decreasing.

Vegetables whose blanching for freezing is not recommended, owing to their organoleptic qualities, should be characterized by a strong specific flavour so as to cover the possible changes brought about by oxidation of fats induced by lipase (Baardseth & Slinde, 1987; Gross & Ellis, 1969; Williams et al., 1986). However, according to Paulet, Mestres and Cronenberger (1974), a faster or slower hydrolysis of fats by lipase was not always accompanied by the appearance of an off-flavour. In the present study, a decreasing activity of lipase was observed in a period of 6 to 9 months of frozen storage, no significant differences being noted between the two applied temperatures up to the sixth month. Afterwards, at −20°C, the activity was on average 87% higher.

Already, after 6 months, statistical differentiation was manifested in the organoleptic quality of the frozen

Table 2
Results of sensory evaluation of thawed tomato cubes depending on the time and temperature of storage, on a 5-score scale

			Storage period in months									
			0		3		6		9		12	
Quality factor	Weight factor	Raw material before freezing	−20°C	−30°C	−20°C	−30°C	−20°C	−30°C	−20°C	−30°C	−20°C	−30°C
1. Appearance												
a. Exudation of sap	2	5.0	4.0	4.0	3.7	3.7	3.7	3.7	3.7	3.7	3.4	3.4
b. Preservation of shape	2	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
c. Colour	4	5.0	5.0	5.0	4.8	5.0	4.5	5.0	4.4	5.0	4.0	4.8
2. Consistency	3	5.0	4.5	4.5	4.3	4.3	4.0	4.3	3.8	4.2	3.0	4.0
3. Flavour	4	5.0	4.9	4.8	4.6	4.6	4.3	4.6	4.0	4.4	3.5	4.4
4. Taste	5	5.0	4.9	4.9	4.5	4.7	4.0	4.7	3.6	4.7	2.9	4.4
Total score	20	5.00	4.77	4.75	4.51	4.60	4.22	4.60	4.01	4.55	3.51	4.37
LSD $P=0.05$						0.236						

tomatoes, depending on the storage temperature (Table 2). In the case of the temperature of −20°C, their poorer quality was due to the poorer colour and consistency and particularly to poor flavour. The occurrence of enzymes in frozen tomato, especially of lipase, was certainly responsible for the deterioration of the latter two traits. This is confirmed by the results reported by Gradziel (1988) who stored frozen tomatoes at −10 and −40°C, and showed a poorer organoleptic quality, especially of flavour, in the case of storage at −10°C.

4. Conclusion

The results of organoleptic evaluation of colour, consistency, and flavour suggest the possibility of using frozen cubes of Micra RS tomato for pizzas and au-gratin dishes, even after 12 months' storage, with the reservation that, at −20°C, a good quality of frozen tomatoes was maintained during the period of 9 months. The use of frozen tomatoes in vegetable salads is possible after 6-months' storage at −20°C and after 12 months at −30°C. It should be stressed, however that, after 6 months of frozen storage, these tomatoes, in comparison with the raw material, contained 61 and 53% less pectin, 38 and 26% less vitamin C, 18 and 7% less carotenoids, 21 and 7% less beta-carotene and 26 and 15% less lycopene. After 12 months, the contents of the above components were respectively, 83 and 71%, 71 and 45%, 36 and 17%, 51 and 32% and 48 and 26% lower.

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