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COMPARISON OF THE QUALITY OF CANNED SPINACH *(SPINACIA OLERACEA* L.) AND NEW ZEALAND SPINACH (*TETRAGONIA EXPANSA* MURR.)

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ABSTRACT

The technological process of producing canned products brought about a decrease in the level of analysed discriminants by 1-63%, nitrites in New Zealand spinach being excepted. The greatest losses were recorded in the content of total acids and vitamin C and in the case of New Zealand spinach also of chlorophylls. During one-year storage of the two products an increase in the content of nitrites of 44-66% and a fall in the level of nitrates of 8-11% were noted. In spinach the content of chlorophylls was reduced 51% and in New Zealand

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spinach that of total acids and vitamin C 12-37%. After one-year storage the preserves of New Zealand spinach compared with those of spinach contained 35% less dry weight, 4-6% less nitrates and nitrites, 20-50% less starch, dietary fibre, total nitrogen, ash and total acids, 55% less chlorophylls, and 69% vitamin C. Both products showed good organoleptic quality.

Key words: spinach, New Zealand spinach, canning, nutritive value, sensory analysis

INTRODUCTION

In recent years all over the world, including Poland, the consumption of processed fruit and vegetables has been constantly increasing [14, 15, 19]. Spinach is one of vegetable species highly important for the food processing industry. In cut or chopped form it is subjected to freezing or sterilization. Similar methods can be used in processing New Zealand spinach [10, 12]. Canned preserves constitute a large group of products. It is estimated that in the countries of the European Union their share in the total consumption of vegetables reaches about 20% [15]. In Poland the consumption of processed vegetables is distinctly smaller, only 10-11% of harvested vegetables being processed by the food industry. Of this quantity 11-12% is prepared in the form of canned products [14, 19].

The common opinion is that the nutritive value of canned preserves is distinctly poorer than that of fresh and frozen material. It is obvious that this value is to a great degree determined by the pattern of technological processes and, to a slightly smaller degree, by the conditions and length of storage [3, 4, 13, 18, 24]. The quality of the products is affected by the preliminary procedures such as the removal of inedible parts, time and temperature of blanching, the amount of added brine, and if necessary of additives introduced with the brine. However, the components of food products, particularly vitamins and pigments, are affected by the conditions of heat conservation to the greatest degree, including the duration and temperatures of the treatment [5, 6, 16, 17, 18, 22]. Canned products are also characterized by numerous positive traits. They are regarded as a group of convenience food easily prepared for consumption, wholesome, and preserving their consumption value for a fairly long time, even 24 months. The costs of their storage are fairly low [4, 13, 18].

The aim of this work was to compare the quality of canned spinach and New Zealand spinach with respect to the level of selected discriminants of their chemical composition and sensorial traits. In selecting the evaluated parameters their significance in the aspect of dietetics and technology of conservation was considered.

MATERIALS AND METHODS

The investigation was conducted on leaves of spinach cv. Markiza F_1 of Plantico Golebiew breeding and shoots with leaves of New Zealand spinach, the reproduction of the Dutch firm Topstar. The two species were grown on the experimental field of the Department of Raw Materials and Processing of Fruit and Vegetable, located in the vicinity of Krakow. Sterilized products were prepared of material harvested in September. The dates of cultivation of the two species ensured the nearest possible dates of their harvest. The spinach was harvested on 23rd September and the New Zealand spinach two days later. In the case of spinach leaves with petioles 4-5 cm in length and of New Zealand spinach leaves with petioles up to 15 cm in length were used for processing. The conditions of cultivation and harvest of the two species were given by Jaworska and Kmiecik [11]. Directly after harvest the raw material was sorted, yellowish, damaged, stunted, overgrown or infected with diseases leaves being discarded. The material fully suitable for technological processing was washed in running water and blanched at 96-98°C for 2 min. During the treatment the proportion of water to the raw material was 5:1. After blanching the spinach was rapidly cooled and dripped on a sieve for 10 min, the excess water being gently shaken off. After blanching and cooling changes in the weight of the two species was determined in relation to the fresh material. For sterilization whole leaves of spinach and shoots cut in half of New Zealand species were used. The material was placed in Twist-off jars 0.45 dm^3 in volume. The content of a jar was composed of 400 g of blanched material and 50 g of hot water. No salt was added since it affects certain parameters such as the level of dry matter and ash. The parameters of sterilization were determined on the basis of preliminary technological experiments. The following values were accepted: temperature rising to 100°C – 10 min, to 120°C – 15 min, maintaining the temperature of 120°C – 50 min, temperature decreasing to 100 – 15 min, to 30°C – 10 min. Sterilization was conducted in an experimental high-pressure boiler. After the preservation the jars were transferred to a store at 4 – 6°C and kept there until the time of analyses.

The nutritive value of the raw material before sterilization and of sterilized whole products (plant material plus brine) after 1- and 12-month storage was determined. Chemical analyses included the level of dry weight [2], total sugars [2], starch using the Lintner method based on the decomposition of polysaccharides in the medium of hydrochloric acid and then on the chemical determination of sugars [20], dietary fibre [7], total nitrogen [2], ash [2], total and active acidity [2], vitamin C [8], chlorophylls [2], and nitrates and nitrites [9].

At each step of the investigation the determination of physico-chemical indices for spinach and New Zealand spinach were compared using the F-Snedecor and Student t tests. Besides, the effect of the conservation process and storage on the level of selected components was evaluated using analysis of variance for one variable. The least significant difference was calculated for the level of probability of error at p=0.01.

The sterilized products were subjected to sensory analysis after 1- and 12-months storage. Evaluation was carried out after preparing the preserves in two ways: (a) after heating the whole products to about 40°C and adding 1% salt, and (b) after the culinary treatment consisting of boiling for about 5-min whole products with salt (1%), butter (5%), and light natural yoghurt (5%). The evaluation was based on a 5-score scale, every discriminant being given a specific ponderability factor. The significance of differences in the results of the final score was determined on the basis of analysis of variance for one variable. The least significant difference was calculated for the level of probability of error at p=0.05.

RESULTS

Before the conservation in airtight containers spinach and New Zealand spinach were blanched in order to soften their tissue before filling the jars with the raw material. The treatment brought about a decrease in the level of ash, total acidity, vitamin C, and nitrates reaching 11-57% in spinach and 10-33% in New Zealand spinach as compared with the raw material (Table 1). Significant decreases were also noted with respect to nitrate content in spinach. The decreases in the level of the above components were due to their dilution in water used for blanching. The level of losses was similar or even smaller than that noted by Jaworska and Budnik [10] for sugars, acids, ash, and vitamin C in New Zealand spinach, by Ajyai et al. [1] for vitamin C in some leafy vegetables, and by Sistrunk [24] for vitamin C and nitrates in kale. In blanched New Zealand spinach a statistically significant increase in the level of dry weight, dietary fibre, and total nitrogen and in pH value reached 12-18%. In the case of spinach a slight increase was recorded in the content of dry weight and total nitrogen. The recorded increases were due to the dripping of the material on the sieve and then shaking off the excess water. After the blanching and the dripping of water the weight of New Zealand spinach was reduced by 21-24% (n=12) depending on the sample, and of spinach by 17-21% (n=12). A similar decrease in weight of spinach after blanching was noted by Scheffeldt et al. [21].

Table 1. Level of selected physico-chemical indices in blanched spinach and New Zealand spinach (in 100 g fresh matter)

Component	Spinach		New Zealand spinach		LSD
	x∀ SD	% Rm	x∀ SD	% Rm	p=0.01
Dry matter [g]	8.99 ∀ 0.136	102	5.99^{A} ∀ 0.121	113	0.338
Total sugars [g]	0.15 ∀ 0.014	79	0.13 ∀ 0.037	81	ns
Starch [g]	0.92 ∀ 0.067	97	0.68 ∀ 0.109	92	ns
Dietary fibre [g]	1.35 ∀ 0.039	95	1.12^{A} ∀ 0.087	118	0.176
Total nitrogen [g]	0.56 ∀ 0.008	102	0.32^{A} ∀ 0.015	114	0.032
Ash [g]	1.45^{A} ∀ 0.034	77	1.04^{A} ∀ 0.021	90	0.074
Total acids [mg as oxalic acid]	36^{A} ∀ 1.7	43	28^{A} ∀ 0.8	72	3.5
pH	6.74^{A} ∀ 0.013	110	6.63^{A} ∀ 0.030	112	0.060
Vitamin C [mg]	41^{A} ∀ 2.8	84	10^{A} ∀ 1.4	67	5.7
Chlorophyll [mg]	89 ∀ 3.7	97	47 ∀ 2.6	96	8.5
Nitrates [mg N-NO_3/1kg]	1473^{A} ∀ 47.1	89	1401^{A} ∀ 21.0	80	ns
Nitrites [mg N-NO_2/1kg]	0.41^{A} ∀ 0.079	75	0.31 ∀ 0.041	82	ns

x ∀ SD – mean value for four samples each from two independent replications and standard deviation
% Rm - % retention regarding raw material, A – significant differences regarding to raw material (p=0.01)

Directly after harvest New Zealand spinach was characterized by a content of dry weight smaller than spinach. Therefore in 100 g of this vegetable the content of analysed components was smaller by 40%, except for nitrates. The blanching, cooling, and dripping water caused a distinctly higher increase in dry matter content in New Zealand spinach than in spinach, this reducing the differences in most components. However, the differences between the two spinach species were statistically non-significant only with respect to sugars, starch, nitrates, and nitrites. After the blanching differences in favour of spinach decreased from 40% to 33% for dry weight, from 16% to 13% for total sugars, from 33% to 17% for dietary fibre, from 49% to 43% for total nitrogen, from 39% to 28% for ash, from 53% to 22% for total acids, from 3% to 2% for pH, and from 31% to 24% for nitrites. On the other hand, the differentiation increased with respect to starch from 22% to 26% and to vitamin C from 69% to 76%.

The principle of the work was that the entire product including the brine would be consumed. The results concerning final products were expressed in 100 g or 1 kg of the whole commercial product, since its nutritive value is important from the point of view of the consumer. Because of added brine in each 100 g of product there was 88.9 g of blanched material.

The addition of water in the form of brine and the sterilization induced the dilution of components of the raw material on the one hand and on the other the destruction of some of them by increased temperatures. As compared with the material after blanching in 100 g of the two kinds of preserves the content of dry matter, dietary fibre, total nitrogen, ash, and nitrates was significantly smaller, and that of total acids greater. The lowering of the level of most components analysed varied from 4 to 20%, a distinctly greater one being noted in the case of vitamin C (56%) in spinach and of chlorophylls (57%) in New Zealand spinach (Table 2).

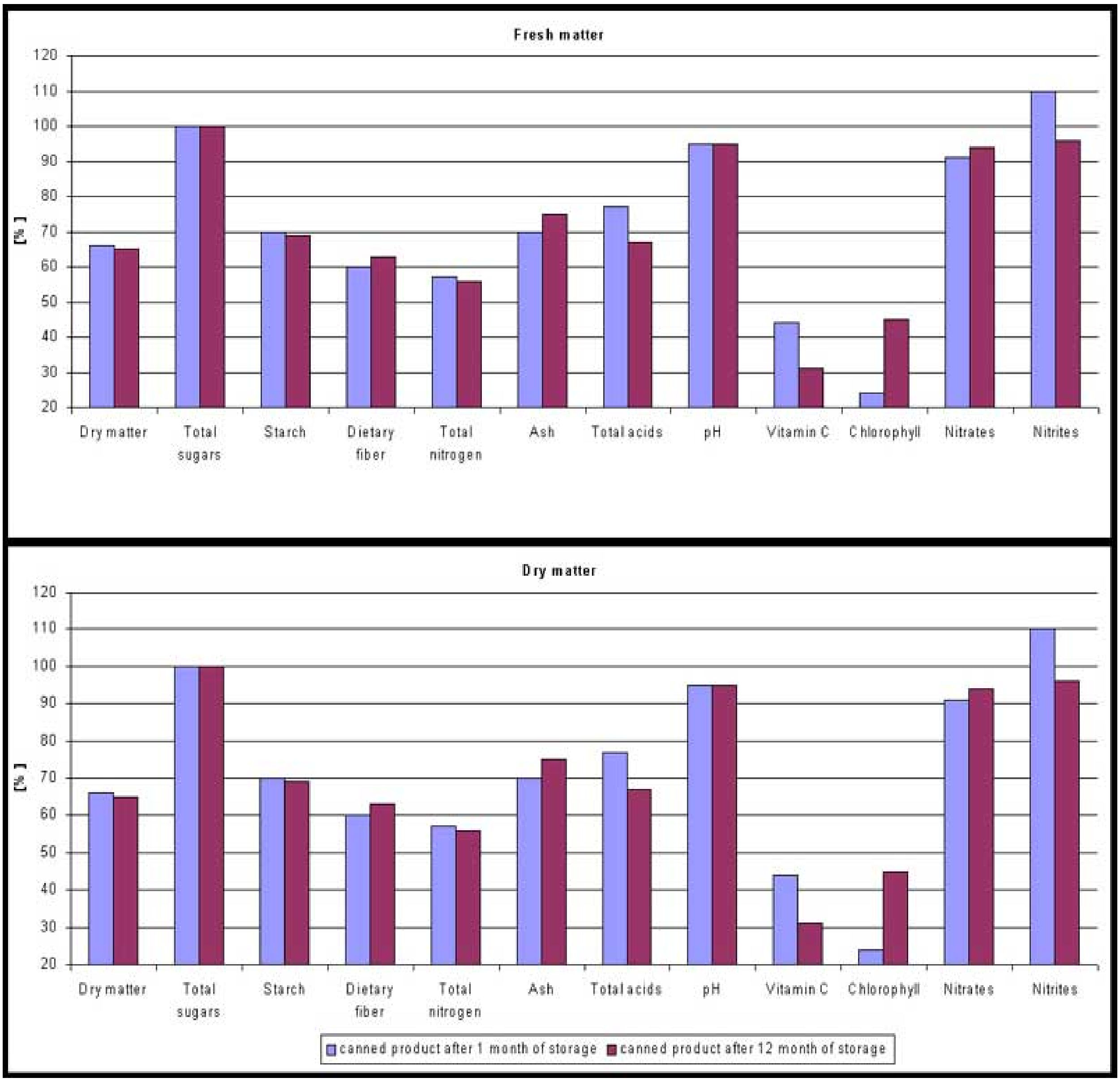
Table 2. Level of selected physico-chemical indices in canned spinach and New Zealand spinach after 1 month of storage (in 100 g fresh matter)

Component	Spinach		New Zealand spinach		LSD
	x∀ SD	% BLA	x∀ SD	% BLA	p=0.01
Dry matter [g]	8.03^{AB} ∀ 0.038	89	5.27^{AB} ∀ 0.018	88	0.078
Total sugars [g]	0.12^{A} ∀ 0.014	80	0.12 ∀ 0.024	92	ns
Starch [g]	0.80^{AB} ∀ 0.058	87	0.56^{A} ∀ 0.047	82	0.138
Dietary fibre [g]	1.13^{AB} ∀ 0.087	84	0.68^{AB} ∀ 0.089	61	0.230
Total nitrogen [g]	0.46^{AB} ∀ 0.006	82	0.26^{AB} ∀ 0.012	81	0.024
Ash [g]	1.31^{AB} ∀ 0.054	90	0.92^{AB} ∀ 0.008	88	0.100
Total acids [mg as oxalic acid]	44^{AB} ∀ 1.8	122	34^{AB} ∀ 0.8	121	3.7
pH	6.00^{AB} ∀ 0.036	89	5.69^{AB} ∀ 0.021	86	0.077
Vitamin C [mg]	18^{AB} ∀ 1.3	44	8^{A} ∀ 1.0	80	2.9
Chlorophyll [mg]	85^{A} ∀ 4.3	96	20^{AB} ∀ 0.5	43	8.1
Nitrates [mg/1kg]	1295^{AB} ∀ 23.8	88	1180^{AB} ∀ 45.2	84	94.7
Nitrites [mg/1kg]	0.41^{A} ∀ 0.077	100	0.45^{B} ∀ 0.082	145	ns

x ∀ SD – mean value for four samples each from two independent replications and standard deviation,
% BLA - % retention regarding raw material after blanching, A – significant differences regarding to raw material (p=0.01), B – significant differences regarding to raw material after blanching (p=0.01)

In relation to the blanched material, sterilization did not change differences in the nutritive value of the compared vegetables as expressed by the level of dry weight. However, for dietary fibre, chlorophylls, and nitrates the percent differentiation was found to increase in favour of spinach while in the case of vitamin C the difference was distinctly smaller (Fig.1).

Fig. 1. Level of selected constituents in canned New Zealand spinach in comparison to canned spinach (level in canned spinach = 100%)



The one-year storage of canned products did not significantly change the level of dry weight, total sugars, starch, dietary fibre, total nitrogen, ash, or of pH. Changes in the above indices varied in the range of (-7%)-(+3%) (Table 3). During the storage of spinach preserves the content of chlorophylls and nitrates was significantly reduced (by 48% and 11%, respectively). In preserves of New Zealand spinach the reduction concerned total acidity (by 12%), vitamin C (by 37%), and nitrates (by 23%). In both preserves storage contributed to a significant increase in the content of nitrites by 44 – 66%.

Table 3. Level of selected physico-chemical indices in canned spinach and New Zealand spinach after 12 months of storage (in 100 g fresh matter)

Component	Spinach		New Zealand spinach		LSD
	x∀ SD	% STE	x∀ SD	% STE	p=0.01
Dry matter [g]	8.10^{AB} ∀ 0.057	101	5.27^{AB} ∀ 0.051	100	0.142
Total sugars [g]	0.12^{A} ∀ 0.022	100	0.12 ∀ 0.024	100	ns
Starch [g]	0.75^{AB} ∀ 0.033	94	0.52^{AB} ∀ 0.037	93	0.093
Dietary fibre [g]	1.12^{AB} ∀ 0.158	99	0.70^{AB} ∀ 0.108	103	0.354
Total nitrogen [g]	0.45^{AB} ∀ 0.008	98	0.25^{AB} ∀ 0.006	96	0.019
Ash [g]	1.23^{AB} ∀ 0.031	94	0.92^{AB} ∀ 0.017	100	0.066
Total acids [mg as oxalic acid]	45^{AB} ∀ 2.4	102	30^{ABC} ∀ 1.7	88	5.5
pH	5.96^{A} ∀ 0.032	99	5.69^{AB} ∀ 0.029	100	0.079
Vitamin C [mg]	16^{AB} ∀ 1.7	89	5^{ABC} ∀ 1.0	63	3.6
Chlorophyll [mg]	42^{ABC} ∀ 1.0	49	19^{AB} ∀ 0.8	95	2.4
Nitrates [mg/1kg]	1152^{ABC} ∀ 20.7	89	1084^{ABC} ∀ 17.4	92	50.1
Nitrites [mg/1kg]	0.68^{BC} ∀ 0.041	166	0.65$^{ABC∀}$ 0.056	144	ns

x ∀ SD – mean value for four samples each from two independent replications and standard deviation,
% STE- % retention regarding canned product after after 1 month of storage,
A – significant differences regarding to raw material (p=0.01), B – significant differences regarding to raw material after blanching (p=0.01), C – significant differences regarding to canned product after 1 month of storage (p=0.01)

After processing and one-year storage of canned preserves the content of dry matter was smaller by 1-8%, of total sugars by 25-37%, of starch by 21-30%, dietary fibre by 21-26%, total nitrogen by 2-11%, ash by 20-35%, total acids by 23-46%, vitamin C by 67%, chlorophylls by 54-61%, and of nitrates by 30-38%. The content of nitrites increased by 24-71%, the raw material being the point of reference for all the values. The losses of such components as sugars, ash, total acids, and nitrates were above all induced by blanching, while the level of starch and dietary fibre was chiefly reduced in the course of sterilization. This was most probably due to the destruction of these compounds caused by acids at high temperatures. As shown by the above data the technological process of producing preserves and their storage affected vitamin C, chlorophylls, and nitrites to the greatest degree. The content of vitamin C gradually decreased at each stage of the investigation. The effect of blanching, sterilization, and storage of preserves have been analysed by numerous authors and the losses evidenced in the present work, though very high, were comparable with the data they reported Ajayi et al. [1], Esteve et al. [5], Lund [18], Selman [23], Sistrunk [24].

During the technological processes chlorophylls, the green pigments of plants, are degraded to pheophitin and pheophorbide, i.e. to compounds of olive-green and olive-yellow colour. They are particularly sensitive to the action of high temperatures, organic acids, and also of chlorophylase [6, 16, 17, 22]. In the present study about 40% of chlorophylls contained in the raw material remained after the sterilization and storage of preserves. According to Lopez-Ayera et al. [17] and Schwartz and Lorenzo [22], an almost complete conversion of chlorophylls to pheophitin occurs during the canning of spinach. It should be observed that the above authors evaluated products of chopped spinach. An interesting difference is observed in the kinetics of chlorophyll degradation between the two species of spinach. In the case of New Zealand spinach 90% of losses occurred during sterilization and the first month of storage while for the preserves of spinach 86% of losses were determined in the period from the 1st to the 12th month of storing. Heaton et al. [6] also suggest that the dynamics of chlorophyll degradation does not depend only on the pattern and parameters of the technological procedures and on the period and conditions of storage but also on the species of the raw material processed.

In the course of production and storage of canned products the content of nitrates decreased and that of nitrites increased. In relative numbers high increases were recorded in the level of the latter compounds although the preserves contained only 0.65-0.68 mg $N\text{-}NO_2$ in 1 kg fresh weight and 8.4-12.3 mg $N\text{-}NO_2$ in 1 kg dry weight. The observed changes in the content of the above compounds brought about by technological procedures were in agreement with the data reported by various authors [3, 4, 24].

Similarly as in the preceding stages of valuation, after storage the content of the determined constituents was significantly greater in the preserves of spinach than in those of New Zealand spinach, sugars and nitrites excepted. In 100 g of New Zealand spinach preserve the content of nitrates and nitrites was smaller by 4-6%, of dry matter, starch, dietary fibre, ash, and total acids by 20-40%, of total nitrogen by 44%, of chlorophylls by 55%, and of vitamin C by 69%. However, the differentiation of the two species was not so pronounced when the results were calculated per 100-g dry weight. The preserve of New Zealand spinach contained more sugars, nitrates, and nitrites and still smaller amounts of the remaining components, the differences being distinct only in the case of vitamin C and chlorophylls (Fig. 1).

In general, the compared products showed a good organoleptic quality (Table 4). The canned spinach products were usually given higher scores for the preservation of shape, colour, and firmness, and lower ones for aroma, the differences in the scores being fairly small, not exceeding 0.4 point. At all the stages of the investigation canned spinach obtained higher total scores than did New Zealand spinach, not all the differences being statistically verified. The greatest difference between the compared products was 0.15 point, this reaching 4% in relative numbers. After 1-month storage no statistically significant differentiation was found in the estimate of the compared preserves. The one-year storage period significantly reduced the quality of preserves of New Zealand spinach, although the quality of the preserves of spinach was unaffected. The culinary preparation improved the organoleptic traits of the products. The scoring of the preserve ready for consumption was at the level of "good" (3.96-4.21 point). Thus, canned products obtained the final scoring by almost 1 point lower than cooked frozen products of the same raw material [12].

Table 4. Results of the sensory analysis of the canned spinach and New Zealand spinach

Quality discriminant	Conversion factor		Spinach		New Zealand spinach	
			Time of storage (months)			
			1	12	1	12
Preservation of shape	2	a	4.5	4.4	4.1	4.0
		b	4.3	4.2	4.0	3.8
Colour	5	a	4.0	4.0	3.9	3.7
		b	4.1	4.0	3.8	3.6
Firmness	3	a	4.6	4.7	4.3	4.3
		b	4.5	4.5	4.5	4.4
Aroma	5	a	4.0	3.9	4.2	4.0
		b	3.9	3.7	4.1	3.9
Taste	5	a	3.5	3.3	3.6	3.3
		b	4.5	4.4	4.3	4.1
Total score	20	a	4.03	3.94	4.00	3.79
		b	4.21	4.11	4.13	3.96
LSD p=0.05		a	0.135			
		b	0.103			
			0.090	0.108	0.120	0.146

a – canned spinach and New Zealand spinach not prepared for consumption,
b – canned spinach and New Zealand spinach prepared for consumption

CONCLUSIONS

The results of the work show that the two spinach species are valuable raw material for the production of canned products. The products differed in their nutritive value but their organoleptic traits were similar. The preserves of New Zealand spinach contained 34-35% less dry matter and hence less nutritive compounds than the preserves of spinach. On the other hand they contained slightly less nitrites.

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