

Quality Changes of Blackcurrant Nectar Under Different Storage Conditions

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Abstract

Blackcurrant nectars were stored for 12 months: in cooling conditions (6-8°C); in ambient conditions (18-22°C); in thermostatic chamber (25-31°C); in thermostatic chamber (39-40°C).

Time and storage conditions had no effect on dry matter content, total solids, ash and total acidity. During 6 months of storage total phenols content decreased by 0-13% and then increased by 12-26%. After 12 months of storage level of vitamin C in blackcurrant nectars fell by 70% in the nectar stored in cooling conditions and by 75-87% in the remaining beverages. A continuous decline in antioxidant activity (against ABTS and DPPH) was observed throughout the storage period; the changes observed did not depend on storage conditions. An increase in colour parameters (L*, a*, b*, c*, h*) has been observed. Changes in the quality of nectar stored for 3 months in thermostatic chamber were greater than those noted in nectar stored for 12 months in cooling conditions.

Keywords: Fruits, Beverages, Stability, Antioxidant activity, Colour.



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Contribution/Originality

This study documents quality changes of blackcurrant nectar under different storage conditions. It provides information based on knowledge as to how bioactive compounds and colour changes during storage period how those very popular beverages should be stored. The most preferable storage conditions and period were determined for blackcurrant nectars.

1. Introduction

Of the processed fruits, juices and fruit beverages meet the greatest consumer acceptance [1]; their consumption not only quenches our thirst but also can protect circulatory system and reduce risk of cancer [2]. Juices obtained from dark-coloured fruits are especially popular due to the fact that in comparison to juices from light-coloured fruits they contain several more polyphenols which are constituents mainly responsible for antioxidant properties of juices [2, 3]. Fresh blackcurrant fruits show limited suitability for the direct consumption, which may be explained by seasonal harvest as well as their high sourness [4]. Due to characteristic composition blackcurrants are perceived to be the raw material of high biological value. They contain a lot of polyphenols including 0.25 g anthocyanins per 100 g fresh weight. Blackcurrant fruits are especially rich in hydroxycinnamic acid, p-coumaric acid, myricetin, quercetin and kaempferol glycoside [2, 4, 5]. These fruits have also extraordinary high vitamin C level; 100 g of their fresh mass contains almost 150 – 230 mg vitamin C [6].

The aim of this paper was to evaluate quality changes in blackcurrant nectar during 12 months storage in different chambers at various temperatures. Therefore, selected physicochemical parameters of blackcurrant nectars have been determined together with the level of vitamin C, total polyphenols, antioxidant activity and colour.

2. Material and Methods

2.1. Material

The study material consisted of commercial blackcurrant nectars (corresponding with the definition of Council of the European Union stated in Directive 2012/12/UE from 19.04.2012 produced by Tymbark GMW Sp. z o.o. Sp. K. Nectars were prepared from the concentrate of blackcurrant juice, sugar, apple acid and water. According to the assumption its total solids were at level 13.5 ± 0.5 g per 100 cm^3 . Nectars were then divided into four batches and stored for 12 months at different temperatures:

A – ambient conditions (temperature $18\text{-}22^\circ\text{C}$);

C – cooling conditions (temperature $6\text{-}8^\circ\text{C}$);

T1 – thermostatic chamber 1 (temperature $25\text{-}31^\circ$ and relative humidity $25\text{--}38\%$);

T2 – thermostatic chamber 2 (temperature $39\text{-}41^\circ\text{C}$, relative humidity 15% and constant light – which was not an analyzed factor since blackcurrant nectar was in Tetra-pack cardboard containers which could not let any light through).

Blackcurrant nectars were analyzed immediately after production and after every 3 months over the storage period.

2.2. Physicochemical Parameters

Dry matter content, total solids, ash and acidity were determined according to AOAC standards AOAC [7].

2.3. Antioxidant Properties

Total phenols were quantified with Folin-Ciocalteu reagent according to Singleton, et al. [8] using Hitachi UV-VIS Spectrometer type U-2900 (Hitachi, Tokyo, Japan). Total phenols were expressed in mg of (+)-catechin.

The contents of L-ascorbic acid and vitamin C were established by means of HPLC [9]. The analysis was performed using a liquid chromatograph D-7000 (Hitachi Merck, Tokyo, Japan) with UV-VIS detector (L-7420), pump (L-7100) and autosampler (L-7250). An Onyx Monolithic C18 column (100×4.6 mm) with precolumn (Phenomenex, Torrance, California, USA) has been employed. Elution was conducted using phosphoric acid (0.1M) at a flow rate of $1 \text{ cm}^3/\text{min}$. Absorbance was measured at 254 nm. A sum of L-ascorbic acid and L-dehydroascorbic acid was established after reduction by L-cysteine according to EN 14130:2003.

Antioxidant activity was determined against DPPH and ABTS according to Pekkarinen, et al. [10] and Re, et al. [11] respectively using Hitachi UV-VIS Spectrometer type U-2900. The value of antioxidant activity was expressed as mM of Trolox equivalents.

2.4. Colour Analysis

The colour was determined by an instrumental method according to the CIE system using a Minolta CM-3500d (Minolta, Osaka, Japan) spectroscope and setting the following parameters: L^* - lightness ($L^*=0$ black, $L^*=100$ white); a^* - the proportion of green colour ($a^*<0$) or red ($a^*>0$); b^* - the proportion of blue colour ($b^*<0$) or yellow ($b^*>0$); C^* - saturation of colour; and h^* - hue angle.

2.5. Statistical Analysis

Analyses were carried out in three series and two replications ($n=6$). Results were interpreted statistically using two-factor analysis of variance on the basis of the Duncan's range tests to demonstrate significance between mean values at the significance level of $\alpha = 0.05$. Linear correlation cofactors between the level of antioxidant activity and vitamin C content or total phenols have also been established. The Statistica 8.0 (StatSoft, Tulsa, Oklahoma, USA) program was applied for calculations.

3. Results and Discussion

3.1. Physicochemical Parameters

According to the production principle, the examined non-stored blackcurrant nectar contained $13.5 \text{ g}/100 \text{ cm}^3$ total solids (Table 1). 100 cm^3 of such nectar had 13.71 g of dry matter and 0.13 g of mineral salts and the titratable acidity of 0.78 g expressed as citric acid. Time and temperature of storage had no effect on the parameters discussed.

Table-1. Physicochemical parameters per 100 cm^3 of blackcurrant nectars (at 0, 3, 6, 9 and 12 months of storage)

Parameter	Mariginal values	Mean value
Dry matter (g)	$13.67 \pm 0.06 - 13.75 \pm 13.75$	13.71
Ash (g)	$0.12 \pm 0.01 - 0.13 \pm 0.02$	0.13
Titrable acidity (g of citric acid)	$0.76 \pm 0.06 - 0.80 \pm 0.02$	0.77

mean \pm sd

3.2. Antioxidant Properties

It has been found that 100 cm^3 of non-stored blackcurrant nectar contained 98 mg (+)-catechin (Table 2). 100 cm^3 of raw blackcurrant juice contains 264-813 mg of total phenols and 213-244 mg of anthocyanins and the method of pulp processing applied prior to its pressing is a crucial factor determining the level of total phenols [12-14]. Taking into account the proportion of fruit juice in blackcurrant nectar, the content of phenols determined in the nectar examined is comparable with this reported in the literature. Total phenols content fluctuated throughout the storage period, although there were no significant differences due to the conditions of storage. Up to the 6th month of storage, the level of total phenols reduced by 0-13% compared to the fresh nectar (the loss being insignificant). On the other hand during further storage total phenols increased by 12-26% in the nectar analyzed. Piljac-Zegarac, et al. [3] observed a 32% degradation of phenolic compounds in the blackcurrant nectar due to the 30-day storage period in

cooling conditions, while [Oszmiański and Wojdyło \[4\]](#) reported a similar degradation in total phenols in blackcurrant juices during their 6 month's storage, which was followed by only a 15% decline in anthocyanins. Increase in total phenols observed in this study probably results from changes in the structure and activity of phenolic compounds occurring during storage. Folin-Ciocalteu reagent used for total phenols determination can react with individual forms of polyphenols in different proportions as well as with the Maillard reaction products formed during the 12 months storage period, which in turn leads to higher results obtained in the samples after storage than in those non-stored [\[15, 16\]](#).

Table-2. Antioxidant properties of blackcurrant nectars (per 100 cm³, mean value ± sd, n=6)

Parameter	Period of storage	Type of storage					mean
		Non stored	A	C	T1	T2	
Total polyphenols (mg)	0	98±0	98 ^a				
	3		87±14	93±3	94±3	85±8	90 ^a
	6		99±5	94±2	93±2	91±3	94 ^a
	9		110±12	115±5	122±10	113±8	115 ^b
	12		114±4	117±9	124±9	118±17	118 ^b
	mean		98 ^{ns}	102 ^{ns}	105 ^{ns}	108 ^{ns}	102 ^{ns}
L-ascorbic acid (mg)	0	15.6±0.4	15.6 ^a				
	3		8.0±0.5	14.1±0.5	8.3±0.4	8.0±0.2	9.6 ^b
	6		6.9±0.5	13.3±0.7	7.9±0.3	7.9±0.3	8.9 ^c
	9		6.6±0.4	12.6±0.5	7.6±1.0	2.7±0.4	7.4 ^d
	12		1.0±0.1	3.5±0.4	1.4±0.1	0.4±0.1	1.6 ^e
	mean		15.6 ^a	5.6 ^b	10.9 ^c	6.3 ^d	4.8 ^e
Vitamin C (mg)	0	17.9±1.7	17.9 ^a				
	3		11.2±0.6	15.9±0.4	10.8±0.7	10.2±0.4	12.0 ^b
	6		11.1±0.7	13.9±0.6	10.7±0.8	8.4±0.7	11.0 ^c
	9		10.0±0.2	13.2±0.5	10.1±0.4	3.2±0.3	9.1 ^d
	12		4.4±0.4	5.4±0.7	4.2±0.2	2.3±0.2	4.1 ^e
	mean		17.9 ^a	9.1 ^b	12.1 ^c	8.9 ^b	6.0 ^d
Antioxidant activity against ABTS (mmol TE)	0	28.3±0.8	28.3 ^a				
	3		23.1±0.7	22.6±0.7	22.1±0.7	23.6±0.12	22.9 ^b
	6		16.1±0.4	17.0±0.5	15.9±0.6	17.5±0.6	16.6 ^c
	9		4.7±0.6	5.0±0.6	4.0±0.5	4.0±0.7	4.4 ^d
	12		3.7±0.0	3.9±0.2	3.3±0.3	2.9±0.1	3.4 ^e
	mean		28.3 ^a	11.9 ^b	12.1 ^b	11.3 ^b	12.0 ^b
Antioxidant activity against DPPH (mmol TE)	0	2.9±0.3	2.9 ^a				
	3		2.6±0.1	2.6±0.1	2.6±0.1	2.3±0.1	2.5 ^b
	6		2.4±0.1	2.3±0.0	2.4±0.1	2.2±0.1	2.4 ^b
	9		1.0±0.2	1.3±0.0	1.0±0.2	1.1±0.1	1.1 ^c
	12		0.9±0.0	1.0±0.1	0.9±0.0	1.0±0.0	1.0 ^c
	mean		2.9 ^a	1.8 ^b	1.8 ^b	1.7 ^b	1.7 ^b

^{a, b, c, d, e} – different letters represent significant differences between least square means (at P < 0.05), ns – not significant

100 cm³ of analysed non-stored nectar contained 17.9 mg vitamin C, 87% of which was L-ascorbic acid. According to [Graversen, et al. \[17\]](#), commercial blackcurrant beverages have 24 mg vitamin C per 100 cm³. It has been observed that changes in the level of vitamin C were the lowest in the nectar stored in cooling conditions (C) with a mean decline of 32%; however, over first three months, vitamin C content fell by 11% compared to its initial level and in the successive 6th, 9th and 12th month of storage by 22%, 26%, and 70%, respectively. Extent of degradation and degradation rate were comparable for nectars stored in ambient conditions and in the thermostatic chamber 1(T1); after 1-year's storage, vitamin C content compared to the initial level was only 25%. The largest losses in vitamin C were found in nectar stored in the thermostatic chamber 2 (T2) and were respectively 43%, 53%, 82% and 87% in the 3th, 6th, 9th and 12th month of storage compared with non-stored nectar. Between the 6th and the 9th month of storage, the level of vitamin C in nectars stored in the thermostatic chamber 2 (T2) fell below the level stated after 12 month in the nectar stored in cooling conditions (C). Studies of [Ozkan, et al. \[18\]](#) as well as [Nawirska-Olszańska, et al. \[19\]](#) confirm low stability of vitamin C in fruit juices. Simultaneously, according to the above authors, the degradation rate of this compound depends on type of fruits used for the production of juice and consequently their chemical composition and is exceptionally high for berry fruits.

Antioxidant activity in 100 cm³ of the blackcurrant nectar analysed was 28.3 mmol TE against ABTS and 2.9 mmol TE against DPPH (Table 2). The comparable level of antioxidant activity in non-stored raw blackcurrant juices was reported by [Oszmiański and Wojdyło \[4\]](#) as well as [Szajdek, et al. \[14\]](#). Throughout 12 months storage, antioxidant activity against both ABTS and DPPH in the examined nectars dropped significantly; although, storage conditions had no effect on this parameter. During first three months of storage antioxidant activity against ABTS fell by 18-22% with a continuous decline observed over the further storage period to reach 38-44%, 82-86% and 86-90% in the 6th, 9th and 12th month of storage, respectively. A decline in antioxidant activity against the DPPH free radical noted in first six months of storage was comparable to that determined against the ABTS radical and was 12-20%, and 38-34% in the third and the sixth month respectively. Later, in the 9th and 12th month a fall in antioxidant activity was respectively 56-66% and 65-69%. The greatest changes in antioxidant activity against both ABTS and DPPH were observed between the 6th and 9th month of storage. [Oszmiański and Wojdyło \[4\]](#) reported losses in activity against ABTS cation radical of 28 – 39% throughout 6 months' storage, with greater changes being recorded during chilled storage than at 30°C. They have also noted a reduction in activity against DPPH radical of 13% after 6 months of storage in cooling conditions and of 8% at the same period of storage but at 30°C. On the other hand

Piljac-Žegarac, et al. [3] observed almost 50% decline in antioxidant activity against DPPH in blackcurrant nectar after the 30-day storage period at cooling conditions. A fall in antioxidant activity recorded in the examined blackcurrant nectar corresponded with a visible reduction in the levels of total phenols and vitamin C. It was found that the value of the linear correlation coefficient between total phenols and antioxidant activity against both ABTS and DPPH was high ($r = 0.90$); lower values were detected when analysing relation between vitamin C content and antioxidant activity against ABTS ($r = 0.73$) and DPPH ($r = 0.74$).

3.3. Colour

Of the quality indicators assessed in blackcurrant nectars the colour parameters were the most sensitive to the conditions and length of storage. The analysed non-stored nectar showed a lightness (L^*) value of 2.2 (Table 3). That represents deeply dark colour of nectar which is characteristic for the nectars obtained from such fruit. Length and conditions of storage significantly affected brightness of the blackcurrant nectar. In comparison with the non-stored nectar, the smallest mean difference was found in nectar stored in cooling conditions (C), in which the value of L^* parameter fell by 15% throughout 1-year storage. A comparable change in lightness (a 40-60% mean decrease in the L^* parameter) occurred in

Table-3. Color of blackcurrant nectars (mean value \pm sd, n=6)

Parameter	Period of storage	Type of storage					mean
		Non stored	A	C	T1	T2	
L^*	0	2.02 \pm 0.03					2.02 ^a
	3		1.99 \pm 0.04	1.95 \pm 0.01	2.43 \pm 0.03	3.50 \pm 0.02	2.47 ^b
	6		2.39 \pm 0.04	2.48 \pm 0.02	2.77 \pm 0.02	4.79 \pm 0.08	3.11 ^c
	9		2.89 \pm 0.01	2.57 \pm 0.25	3.08 \pm 0.01	6.77 \pm 0.04	4.08 ^d
	12		3.25 \pm 0.03	2.31 \pm 0.03	3.58 \pm 0.01	9.14 \pm 0.42	4.57 ^e
	mean	2.02 ^a	2.38 ^b	2.33 ^b	2.97 ^c	6.05 ^d	
a^*	0	11.24 \pm 0.19					11.24 ^a
	3		10.62 \pm 0.23	10.75 \pm 0.04	12.96 \pm 0.15	18.64 \pm 0.09	13.24 ^b
	6		12.38 \pm 0.22	13.64 \pm 0.12	14.26 \pm 0.04	23.14 \pm 0.17	15.85 ^c
	9		9.72 \pm 0.04	23.47 \pm 0.98	15.90 \pm 0.10	26.21 \pm 0.12	18.82 ^d
	12		15.96 \pm 0.17	12.67 \pm 0.16	18.33 \pm 0.05	28.78 \pm 0.75	18.93 ^d
	mean	11.24 ^a	12.17 ^b	15.13 ^d	15.36 ^d	24.19 ^c	
b^*	0	3.31 \pm 0.04					3.31 ^a
	3		3.27 \pm 0.07	3.19 \pm 0.01	4.02 \pm 0.05	5.83 \pm 0.04	4.08 ^b
	6		3.96 \pm 0.08	4.10 \pm 0.03	4.61 \pm 0.03	8.09 \pm 0.14	5.19 ^c
	9		3.09 \pm 0.01	7.67 \pm 0.44	5.12 \pm 0.05	11.47 \pm 0.06	6.84 ^d
	12		5.43 \pm 0.04	3.81 \pm 0.05	5.99 \pm 0.02	15.56 \pm 0.73	7.70 ^e
	mean	3.31 ^a	3.93 ^b	4.69 ^c	4.93 ^c	10.24 ^d	
c^*	0	11.72 \pm 0.19					11.72 ^a
	3		11.11 \pm 0.24	11.22 \pm 0.05	13.57 \pm 0.16	19.53 \pm 0.09	13.86 ^b
	6		13.00 \pm 0.23	14.24 \pm 0.11	14.99 \pm 0.05	24.51 \pm 0.21	16.69 ^c
	9		10.20 \pm 0.03	24.68 \pm 1.07	16.71 \pm 0.11	28.63 \pm 0.12	20.05 ^d
	12		16.86 \pm 0.17	13.23 \pm 0.16	19.28 \pm 0.05	32.72 \pm 1.00	20.52 ^e
	mean	11.72 ^a	12.79 ^b	15.84 ^c	16.14 ^c	26.35 ^d	
h^*	0	16.42 \pm 0.05					16.42 ^a
	3		17.11 \pm 0.04	16.53 \pm 0.03	17.21 \pm 0.02	17.38 \pm 0.07	17.06 ^b
	6		17.72 \pm 0.07	16.74 \pm 0.06	17.92 \pm 0.06	19.27 \pm 0.17	17.91 ^c
	9		17.64 \pm 0.10	18.09 \pm 0.26	17.85 \pm 0.06	23.63 \pm 0.04	19.30 ^d
	12		18.78 \pm 0.05	16.73 \pm 0.07	18.10 \pm 0.04	28.38 \pm 0.50	20.50 ^e
	mean	16.42 ^a	17.81 ^b	17.02 ^c	17.77 ^b	22.16 ^d	

^{a, b, c, d, e} – different letters represent significant differences between least square means (at $P < 0.05$)

the nectar stored under ambient conditions (A) and in those from the thermostatic chamber 1 (T1). The assessment of particular periods of analyses leads to the conclusion that the value of L^* parameter in the nectar stored in the thermostatic chamber 1 (T1) steadily rose that in turn resulted in gradual brightening of nectars. At the same time, there was no such clear tendency for the nectar stored in cooling conditions since in this case, compared to the non-stored blackcurrant, the value of L^* parameter fluctuated between plus and minus in the successive dates of analyses. The greatest brightening of nectar was noticed during its storage in the thermostatic chamber 2 (T2), where a 4-fold increase in the L^* value was found in comparison with non-stored product.

The examined non-stored blackcurrant nectar showed the high proportion of red (a positive a^* value) and yellow (a positive b^* value) colour. During storage the colour plane shifted further towards redness and yellowness, which was expressed by an increase in the values of a^* and b^* parameters. It has been found that a mean change in a^* and b^* parameters was smallest in the nectars stored in ambient conditions (A) and the highest in the nectars stored in thermostatic chamber 2 (T2), in the latter, in the 12th month of storage there was a 2.5-fold and 5-fold increase in a^* and b^* value respectively compared with the non-stored nectar. A mean level of a^* and b^* values was comparable in the nectars stored in cooling conditions (C) and in thermostatic chamber 1 (T1).

C^* and h^* parameters, which indicate on saturation and hue of colour, are derivatives of L^* , a^* and b^* values; therefore, trends in their changes observed in the examined blackcurrant nectars were similar to those noted in the aforementioned parameters.

Changes in the values of all the discussed colour parameters were greater during 3 months of storage in the thermostatic chamber 2 (T2) than 12 months of storage in other conditions. Sokół-Lętowska and Kucharska [20] also

confirmed substantial changes in colour of blackcurrant juice stored during 110 days in both a storehouse with a temperature of 10°C the one with a temperature of 30°C.

4. Conclusion

During 12 months storage basic composition of blackcurrant nectars did not fluctuate, however antioxidant properties and colour showed significant changes. The greatest changes were observed in nectars stored at 39-41°C and the lowest in those kept in cooling conditions (6-8°C). Nectars stored at ambient temperature (18-22°C) and at 25-31°C showed similar extent and dynamics of quality changes. Throughout 12 months of storage, a decline in the quality of nectars stored in cooling conditions (6-8°C) was comparable to the fall noted in the nectars stored for 3 months at 39-41°C and for 9 months in both ambient conditions 18-22°C and at 25-31°C.

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