Changes in the Dry Matter and Sugar Content of Nantes Type Carrots during Storage

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Summary: *Changes in the dry matter and sugar content occurring during the winter storage of Nantes type carrot hybrids grown on soils of different quality were studied in 1999/2000 and 2000/2001. The dry matter content of the varieties tested depended on the production site and on the weather conditions prevailing in the growing season. The increase in the dry matter content during winter storage reached 6 to 7 per cent in the crop grown in a dry year and 1.5 to 2 per cent in a rainy year. The sugar content was lower in the rainy year (1999) and on brown sand (Szatymaz) than in the rather dry year (2000) and on chernozem soil with residual forest (Tordas), respectively. The increase in sugar content (1 to 5 per cent) measured at the end of storage was related to the season's weather conditions.*

Key words: carrot – winter storage – dry matter-ratio of sugars

Introduction

Carrots are consumed on a rather small scale in Hungary. They are, however, of considerable dietary value and of increasing importance owing to the development in our eating habits. Today, not only the consumers but also the growers pay attention, besides yield indices, to the dietary value of the crop. The latter is due mainly to its carotene content, however, the dietary fibre content and the volatile oils are important, too.

In our trials we studied the behaviour of some Nantes type varieties in cold winter storage and the differences in the dry matter and sugar content of the single varieties as affected by soil type.

Literature

The taste of the carrot is determined by the ratio of monosaccharides (glucose,fructose) and disaccharides (saccharose)and by the volatile oil components.

The sugar components of the carrot, according to several authors, are seen in *Table 1*.

The total sugar content continuously increases in the phase of root growth, i.e. during 150 days from sowing, although reducing sugar (glucose and fructose) content decreases but sucrose content increases *(Simon* et al., 1979).

According to *Weichmann* (1987) the ratio of disaccharides to monosaccharides ranges from 1:1 to 2.5:1 in varieties of good keeping quality. A ratio of 0.5:1 has been found in varieties of poor keeping quality.

Table 1 Glucose, fructose and saccharose content in fresh carrots (g)

Authors	Glucose average (extreme values)	Fructose average (extreme values)	Saccharose average (extreme values)
	in 100 g fresh weight		
Souci et al. (1989)	1.40 (0.84–1.71)	1.29 (0.82–1.96)	1.90 (1.55–4.17)
Somogyi–Trautner (1974) (30 samples, Switzerland)	1.66 ± 0.38	1.47 ± 0.29	1.55 ± 0.71
Haila (et al., 1992) (18 samples, Finland)	1.41 (0.71–2.27)	1.36 (0.69–2.22)	2.56 (1.32–4.53)
Hofsommer–Gherardi (1985) (40 samples, Italy, Germany)	1.238 (0.56–1.77)	1.047 (0.39–1.47)	4.33 (2.58–6.56)
Evers (1989) Finland	1.75 (1.5–2)	1.55 (1.2–1.8)	4.0 (3.6–4.3)
Takácsné (1999)	0.10–3.02	4.2–9.5	

Besides genetic factors, the quantity and the composition of sugars depend on the conditions of carrot growing *(Hraskóné–Feketéné,* 1995). Proper soil cultivation in due time improves the alimentary value of carrots *(Terbe* et al., 2001).

Total sugar content slightly increases in humid cold storage *(Le Dily* et al., 1994)

As per *Kraxner* et al. (1983) the relative air humidity of the storage place didn't affect the changes in sugar content during storage but the length of storage did.

Material and method

Four Nantes type varieties were tested in the experiments: Bolero F_1, Ivor F_1, Tagus F_1, and Puma F_1.

Two growing sites were chosen: the Tordas Station of the National Institute for Quality Control (OMMI) and the horticultural farm of András Barna at Szatymaz. The data on the experimental sites are shown in *Table 2*.

Seed sowing and crop lifting were made by hand at both places, at the same date.

The storage of the roots took place at the Fertőd Station of OMMI in 1999/2000 and in 2000/2001, too. After lifting, the roots were put into plastic crates and kept in cold storage of 1–2 °C temperature and 90 per cent relative humidity. Dry matter and sugar content were measured at harvest, once during storage and at the end of storage.

Dry matter content determination: The weighed, grated samples were dried at 105 °C till constant weight. The residue was reweighed and the dry matter calculated.

Sugar content determination: The quantities of sugars were determined by the Luff-Schoorl method from raw, grated samples.

At the end of storage, the total shrinkage loss of the roots was measured and the appearance classified.

Results and discussion

Changes in the dry matter content of the roots during storage

The dry matter content of the varieties and the changes occurring during storage are shown in *Tables 3* to *6* and in *Figures 1* to *3*.

In 1999, low dry matter content was found in Ivor F_1 (9.96–11.74%) at both trial sites.The dry matter of Tagus F_1 was almost equal at Tordas and Szatymaz (14.02–15.08%).

In 2000, the second year of the trials, no significant differences were found between the dry matter content of the varieties (13.47–13.78%) grown on chernozem soil with residual forest. Similarly small differences were found in the dry matter content of the varieties grown on brown sand at Szatymaz.

Table 2 The most important data on the production

	TORDAS		SZATYMAZ	
soil type:	chernozem soil with residual forest		brown sandy soil	
Soil hardness after Arany:	44		28	
	First year	Second year	First year	Second year
Precipitation during the vegetation period	415 mm	152 mm	428 mm	69 mm
Sowing date	1999.05.08.	2000.05.10	1999.04.30	2000.05.08.
Harvest date	1999.09.20.	2000.10.05	1999.09.20.	2000.10.05
Date of chemical analysis during winter storage	2000.02.14.	2001.01.24.	2000.02.14.	2000.01.24.
End of winter storage	2000.05.02.	2000.03.21.	2000.05.02.	2001.03.21.

Table 3 Dry matter content of Nantes type carrot varieties at Tordas, storage season 1999/2000 (%)

Variety	At harvest	During storage	At the end of storage
BOLERO F1	16.34	15.95	17.17
IVOR F1	11.74	15.52	18.03
TAGUS F1	14.02	14.31	16.22
PUMA F1	14.63	13.11	15.56

Table 4 Dry matter content of Nantes type carrot varieties at Szatymaz, storage season 1999/2000 (%)

Variety	At harvest	During storage	At the end of storage
BOLERO F1	11.31	12.36	13.31
IVOR F1	9.96	9.97	11.42
TAGUS F1	15.08	12.65	13.56
PUMA F1	10.53	11.68	11.69

Table 5 Dry matter content of Nantes type carrot varieties at Tordas, storage season 2000/2001 (%)

Variety	At harvest	During storage	At the end of storage
BOLERO F1	13.47	18.99	20.35
IVOR F1	13.66	15.28	16.01
TAGUS F1	13.78	15.69	17.28

Table 6 Dry matter content of Nantes type carrot varieties at Szatymaz, storage season 2000/2001 (%)

Variety	At harvest	During storage	At the end of storage
BOLERO F1	12.59	15.35	16.72
IVOR F1	10.85	12.85	14.13
TAGUS F1	11.23	13.00	16.55

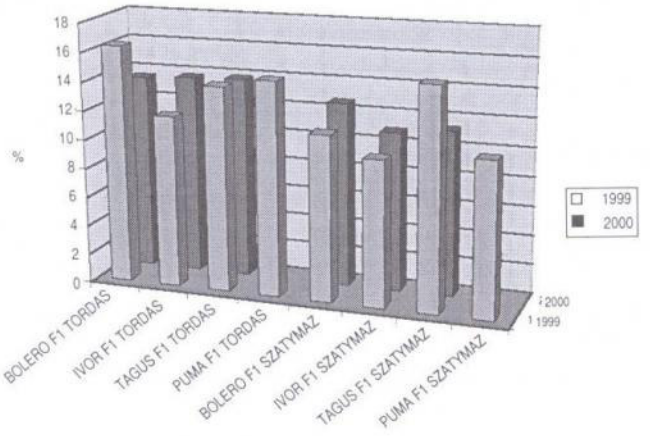

Figure 1 Dry matter content at harvest

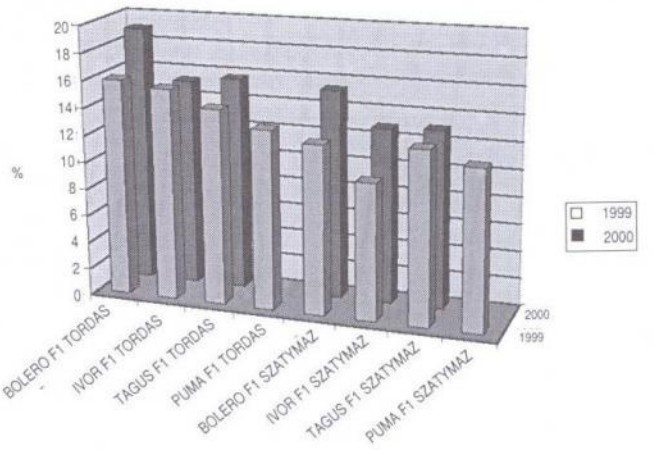

Figure 2 Dry matter content during storage

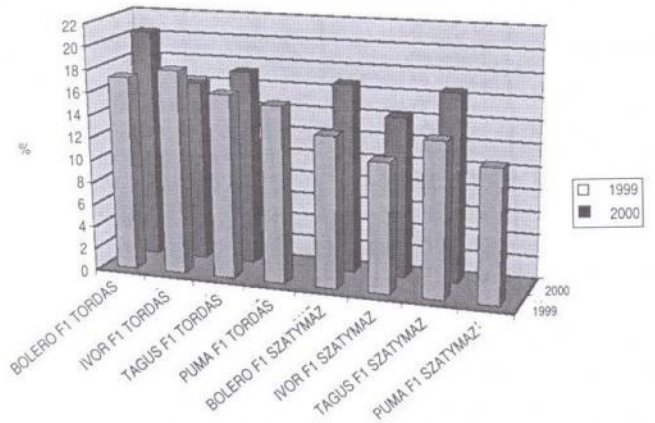

Figure 3 Dry matter content at the end of storage

During storage, (24. 01. 2001.) the dry matter content increased in each variety proportionally to the length of time because of loss of water. As regards dry matter increase, the differences between growing sites and varieties were insignificant.

In the first year of the trial, the dry matter content showed an increase of 1–2% till the end of storage, independently of the production site, with the exception of Ivor F_1 at Tordas where the increase reached 6.5%. In the second year, however, the increase in dry matter content was different at the two trial sites: it reached 5.5–7% in the varieties grown at Tordas and 3.5–5% in the varieties grown at Szatymaz.

Changes in the sugar content of the rooft during storage

The invert sugar content, the ratio of reducing sugars to disaccharide in the varieties tested and the changes occurring during storage are shown in *Tables 7* to *10* and in *Figures 4* to *7*.

At harvest 1999, the invert sugar content measured in roots grown on chernozem soil with residual forest at Tordas was in Bolero F_1 the highest (9.58%), followed by Puma F_1 (8.13%). The invert sugar content of Ivor F_1 and Tagus F_1 was much lower at that place. On the Szatymaz brown sand, however, the invert sugar content of Tagus F_1 was 7.9%, that of the other varieties was quite lower (4.38–5.58%). The most balanced invert sugar contents were found in Tagus F_1 (7.3–7.9%), and the reducing sugar content too, was almost the same at the two places. The disaccharide, monosaccharide ratio was 3.63–3.47 : 1, excellent for storage.

Of the crop harvested in 2000, the highest invert sugar content measured in roots grown on Tordas chernozem soil with residual forest was found in Tagus F_1 (8.34%). On Szatymaz brown sand the sugar content was lower in all the tree varieties (5.67–6.48%) than at Tordas. However, the values for Ivor F_1 and Bolero F_1 were approximately 1% higher than in 1999. The sugar content of these two varieties shows fluctuation as a function of year and production site.

Table 7 Sugar content in Nantes type carrot varieties at Tordas, storage season 1999/2000 (%)

Variety	At harvest				During storage				At the end of storage			
	Sugar content %											
	reducing sugar	sucrose	sugar ratio	invert sugar	reducing sugar	sucrose	sugar ratio	invert sugar	reducing sugar	sucrose	sugar ratio	Invert sugar
BOLERO F1	3.18	6.40	2.01: 1	9.58	2.30	6.97	3.03: 1	9.27	2.48	6.98	2.79: 1	9.38
IVOR F1	2.40	3.28	1.36: 1	5.68	3.36	4.85	1.43: 1	8.21	2.50	5.94	2.37: 1	8.44
TAGUS F1	1.63	5.67	3.47: 1	7.30	3.27	4.02	1.22:1	7.29	2.69	5.46	2.02: 1	8.15
PUMA F1	2.88	5.25	1.82:1	8.13	3.49	3.5	1.00: 1	6.98	3.08	4.84	1.57: 1	7.92

Table 8 Sugar content in Nantes type carrot varieties at Szatymaz, storage season 1999/2000 (%)

Variety	At harvest				During storage				At the end of storage			
	Sugar content %											
	reducing sugar	sucrose	sugar ratio	invert sugar	reducing sugar	sucrose	sugar ratio	invert sugar	reducing sugar	sucrose	sugar ratio	Invert sugar
BOLERO F1	1.63	3.75	2.3: 1	5.38	3.68	2.60	0.7: 1	6.28	2.88	2.80	0.97: 1	5.68
IVOR F1	1.73	2.65	1.53: 1	4.38	2.97	1.40	0.46: 1	4.37	2.50	1.99	0.79: 1	4.49
TAGUS F1	1.68	6.29	3.63: 1	7.91	2.30	3.58	1.55:1	5.88	1.74	3.96	2.28: 1	5.70
PUMA F1	2.40	3.18	1.32:1	5.58	3.09	2.5	0.81: 1	5.59	1.82	3.36	1.84: 1	5.18

Table 9 Sugar content in Nantes type carrot varieties at Tordas, storage season 2000/2001 (%)

Variety	At harvest				During storage				At the end of storage			
	Sugar content %											
	reducing sugar	sucrose	sugar ratio	invert sugar	reducing sugar	sucrose	sugar ratio	invert sugar	reducing sugar	sucrose	sugar ratio	Invert sugar
BOLERO F1	1.15	6.67	5.8: 1	7.82	4.84	7.89	1.6: 1	12.77	4.18	9.02	2.15: 1	13.2
IVOR F1	0.77	7.14	9.28: 1	7.91	3.18	7.45	2.33: 1	10.63	2.78	7.53	2.7: 1	10.31
TAGUS F1	1.06	7.28	6.86: 1	8.34	2.69	7.21	2.68: 1	9.90	1.63	8.89	5.45: 1	10.52

Table 10 Sugar content in Nantes type carrot varieties at Szatymaz. storage season 2000/2001 (%)

Variety	At harvest				During storage				At the end of storage			
	Sugar content %											
	reducing sugar	sucrose	sugar ratio	invert sugar	reducing sugar	sucrose	sugar ratio	invert sugar	reducing sugar	sucrose	sugar ratio	Invert sugar
BOLERO F1	3.18	3.30	1.03 : 1	6.48	2.21	5.81	2.62 : 1	8.02	3.78	5.49	1.45 : 1	9.27
IVOR F1	2.50	3.17	1.27 : 1	5.67	3.08	3.9	1.26 : 1	6.98	3.11	4.67	1.5 : 1	7.78
TAGUS F1	2.21	4.07	1.84 : 1	6.28	3.47	4.22	1.21 : 1	7.69	2.5	7.08	2.82 : 1	9.58

The disaccharide, monosaccharide ratio was high (5.8–9.28 : 1) on chernozem soil with residual forest. The ratio was significantly lower on brown sand (1.03–1.84 : 1).

In the middle of the storage period 1999/2000, from the varieties grown on chernozem soil Ivor F_1 showed an increase of 2.55%, Puma F_1 an increase of 1.15% in invert sugar content. The sugar content of the two other varieties was practically unchanged. The disaccharide: monosaccharide ratio increased in Bolero F_1 from 2.01:1 to 3.03:1 as compared to the values measured at harvest. In Tagus F_1 the ratio significantly decreased from 3.47:1 to 1.22:1.

The total sugar content of the varieties grown on brown sand showed minor variation, however, the disaccharide: monosaccharide ratio decreased because of the considerable increase in reducing sugar content.

Evaluating the results of the two years of the trial, the invert sugar content of every variety increased by 1 to 5%, except Tagus F_1 grown on brown sand. The reducing sugar content significantly increased in every variety from both growing sites.

The invert sugar content in the carrots measured at the end of the storage period 1999/2000 was almost equal to the total sugar content measured at harvest (except Tagus F_1 where the sugar content decreased by 2.21%). Saccharose content considerably diminished in comparison to the values measured at harvest.

In carrots grown on chernozem soil, the invert sugar content of Bolero F_1 and Puma F_1 scarcely changed as compared to the sugar content at harvest. An increase of 2.76% was found in Ivor F_1 and less than 1% in Tagus F_1.

The saccharose content was high in all the four varieties (4.84–6.98%).

The reducing sugar content increased during storage in every variety from both of the growing sites. It diminished at the end of storage, however, it was higher than measured at harvest (except Puma F_1 from Szatymaz and Bolero F_1 from Tordas.)

By the end of the storage season 2000/2001, the invert sugar content of every variety showed 2–5% higher values than at harvest. The saccharose content was in every variety higher than in 1999/2000. The saccharose content of the varieties grown on chernozem soil was 7.53–9.02%. The highest invert sugar content characterized Bolero F_1 (9,02%). The most balanced values were found in Tagus F_1 (7.08–8.98%).

Conclusions

The alimentary value of the Nantes type varieties as affected by growing site and year may be characterized on the basis of our measurings as follows:

Dry matter content

- The dry matter content of the varieties tested depends on the growing site and on the year.
- The dry matter content of the varieties is higher in dry years and on chernozem residual forest soil than in rainy years and on brown sand, respectively.
- The dry matter content of Bolero F_1 and Tagus F_1 is the highest and that of Ivor F_1 is the lowest among the varieties tested.
- The dry matter content of the carrot varieties grown in a dry year increases by 6–7%, that of the crop grown in a rainy year by 1. –2% during winter storage.
- The dry matter content of the varieties increases continuously during storage because of the reduction in weight caused by water loss.

Sugar content

- The two years averages of sugar content in the Nantes type hybrids tested were 8.28% in Bolero F_1, 7.88% in Tagus F_1, 7.08% in Ivor F_1 and 6,55% in Puma F_1.
- The invert sugar content of the varieties from both growing sites continuously increases during storage.
- The disaccharide:monosaccharide ratio found in the varieties grown on Tordas chernozem residual forest soil was better than in the varieties grown on brown sand.
- The ratio of sugars in Tagus F_1 was of the same value (3.5 : 1) at both growing sites at harvest 1999.
- Dry, warm weather in the growing season favours the increase in sugar content (2–5%) during storage. The increase is less high (1–3%) after a rainy season.
- The high initial disaccharide ratio diminishes during storage because of the significant increase in the quantity of monosaccharides while sucrose is relatively steady.

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