



SZENT ISTVÁN UNIVERSITY

**THE EFFECT OF DIFERENT PRODUCTION TECHNOLOGIES ON
THE DIETARY VALUE OF CARROT VARIETIES**

Thesis of PhD work

Némethy Uzoni Hanna

Consultant:
Dr. Terbe István CsC

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Department of Vegetable and Mushroom Growing

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Preliminaries and objectives

Carrot doesn't belong to the vegetables grown and consumed on the largest scale in Hungary. It is, however, of considerable dietary value and is highly important in our meals.

The manifold uses of carrot in the processing industry and the development of eating habits towards the increased consumption of fruit and vegetables has directed increased attention to the crop.

Today, attention is paid not only to quantity indices, not even to the appearance (however, it is important, too,) but much rather to the nutritional value. Among the indices of the latter, carotene and nitrate content are of highest importance.

The demand for baby food and dietary products has considerably increased recently. They have to comply with exacting regulations required by law- first of all with a very low level of nitrate content – but the canning industry and the industry of quickfrozen products make even harder demands on the products in several cases than law.

In the present work, I have set myself the aim of finding solution to the reduction of nitrate content through production technological methods.

Increasing the carotene content without diminishing dry matter and sugar content is none the less important and will be probably of growing importance in the future.

The possibility of increasing sugar and carotene content by boron foliar fertilizers has been studied over two years. In the course of this experiment, testing volatile oils and flavour seemed to be necessary, too, as we have observed the phenomenon mentioned by several authors that the sweet taste may be considerably modified, or, in some cases, concealed by the bitter substances.

We haven't had the necessary laboratory equipment for testing the volatile oils, but we have made sensory analyses with the aid of our students under the guidance of the staff of the Laboratory for Sensory Analysis at the Faculty of Food Science. The try out of this method, widely applied in testing carrots in Western Europe already, has been one of the aims of my work, too.

The investigations have been carried out with the aim of throwing light

-on the nutritional value of the varieties when harvested at an early date (late summer)

-on the differences in the nutritional value of carrots grown on plain ground and on hills

-on the differences in the nutritional value of the same carrot varieties grown on different soils

-on the effect of production technology on keeping quality in storage.

Material and methods

The experiments were made with the three main carrot types:

Nantes type: Bolero F1, Ivor F1, Puma F1, Jaguar F1, Nantes

Berlikummer type: Barbados F1, Fertódi vörös

Flakker type: Danvers126, Szupra, Flakker

Data on the production technology applied in the experiments

The methods applied at the four sites of the experiments are shown in the following table:

Technological processes	Fertőd	Kecskemét	Budapest	Marcali
	OMMI. Res. Stat.	OMMI. Res. Stat..	KÉE Garden Buda	Home garden
Year	1995	1995	1995	1998, 1999
Cultivation method	plain ground/hills	plain ground/hills	plain ground/hills	plain ground
Forecrop	winter wheat	winter wheat	cucumber for pickling	winter wheat
Basic manure	40 t/ha stable manure	50 t/ha stable manure	-	-
Soil preparation	autumn deep ploughing, spring combinator, seedbed preparation, hilling with potato ridger	autumn deep ploughing, spring combinator, seedbed preparation, hilling with potato ridger	autumn digging, spring land planing, seedbed preparation, hilling with hand operated profilizer	autumn deep ploughing, spring combinator seedbed preparation
Date of sowing	April 2	April 26	April 5	April 19, 1998 May 15, 1998 March 14, 1999 May 24, 1999
Sowing appliance	vacuum seeder	vacuum seeder	hand drilling	hand drilling
Spacing	40 * 4 cm (70+5)*4	40 * 4 cm (70+5)*4	40 * 3 cm (70+3)*4	(50+20)*5
Irrigation method	sprinkler	sprinkler	hand operated hose pipe	hand operated hose pipe
Irrigation	4 * 25 mm	4 * 20 + 2 * 30 mm	5 * 20 mm	sprinkling for germination 5-5 mm 4 * 30 mm
Top dressing	none	none	3 * Voldünger	none
Harvest	after mechanical loosening lifting by hand	after mechanical loosening lifting by hand	by hand	by hand
Harvest date	November 1	October 30	July 25 October 30	1998. August 7 N1 September 6 N2 October 4 F 1999. July. 4 N September 19 F
Varieties tested	Ivor Danvers 126 Szupra	Ivor Danvers 126 Szupra	Ivor, Nanti Barbados Danvers 126. Szupra Fertődi vörös	Ivor, Boleró, Jaguar Puma Danvers 126, Flakker

Data of foliar fertilization with fertilizers containing boron

1, Savabór 0,5 %

Danvers 126, Flakker – 1998: July 16, August 7

1999: August 23, September 6

Bolero, Puma - 1999: May 25, June 9

2, Damisol 1 %

Bolero, Puma - - 1999: May 25, June 9.

Danvers 126. Flakker 1999: August 23, September 6.

Data on the storage test:

Place: KÉE Buda, cellar

Relative humidity: 85-90 %

Temperature: 3-7 °C

Substrate: sand

Storage period: November 2 to March 30.

Methods of measuring and analysis

Laboratory tests

10 healthy, uninjured carrots of marketable quality and true to the measures of the variety have been chosen from each variety.

Dry matter content was calculated from samples dried on 105 °C.

Carotene content was determined from raw, grated samples by photometry.

Reducing sugar and total sugar content was determined by the Luff-Shoorl method, from raw, grated samples.

NO₃ content was determined from the dry substance with phenoldisulphon chemical agent by spectrophotometry.

Test carried out by the Laboratory for Sensory Analysis

For preference analysis pairs of samples have been distributed among jury members according to a scheme assuring the pairing of every single sample with every single sample. The jury members had to answer the question: "Which of the two samples do you prefer ? " in relation to every pair.

The test sheets have been summarized in a matrix and evaluated according to Friedman test.

The profile analysis has allowed the simultaneous analysis of several characteristics. The jury members evaluated the given property by scoring in a table of basic data.

Results

The effect of harvest dates and sowing dates on the dietary value

Dry matter

The Nantes type varieties produced some increase in dry matter content in both types of cultivation when harvested late.

The dry matter content of Barbados, a variety of relatively long growing season, reached its final level on the 110 day, in summer.

Fertődi vörös showed the remarkable feature that the relative dry matter reached a high level early, in spite of the long vegetation season of the variety. Root mass continued to increase intensively, however, the dry matter content decreased.

The varieties kept their healthy foliage till the end of the growing season. This was important in the formation of dry matter content measured at the end of the growing season as shown by Nantes and by the two Flakker types.

The experimental plots didn't receive any fertilizer during four months at the end of the growing season, nevertheless, the dry matter content of the Flakker type varieties increased. As regards the different production technologies, noteworthy effects of the cultivation on hills haven't been observed.

Sugar content

Besides the accumulation of sugar during ripening the increase in invert sugar content is important, too. When harvested in summer the highest sugar content was measured in Fertődi vörös and in Szupra, grown on plain ground. Cultivated on hills, the good sugar content of Szupra was prominent. Cultivated in plain ground the total sugar is lower than on hills in the varieties Ivor and Danvers 126. In the other varieties, the opposite was found.

In summer, invert and reducing sugar content was high in Fertődi vörös and in Szupra. Total sugar content diminished in Barbados in autumn as compared to summer, with both cultivation methods, and the percentage of invert sugar decreased i.e. the sugar ratio worsened. The total sugar content of Danvers 126 and of Szupra was higher than earlier in the season and the ratio of invert sugar increased, only a small decline could be observed in the Szupra variety. In autumn, the total sugar content of Danvers 126 was higher on plain ground than on hills, but that of Szupra was higher on hills than on plain ground.

In autumn, the total sugar content of the Nantes type varieties increased as compared to summer harvest. Sugar content was higher on plain ground, but the ratio invert sugar / reducing sugar worsened in growing on plain ground and improved in cultivation on hills. As a tendency, growing on hills caused small decrease in sugar content and insignificant worsening in the sugar ratio in some of the varieties.

Carotene content

Reduced carotene content was measured in carrots grown on hills, when harvested in summer and in autumn as well, with the exception of the variety Ivor, when harvested in summer.

The variety Barbados, of Berlikummer type, didn't show the quickly appearing and permanent high values that can be expected from this type.

The influence of the varieties was slighter than that of the different years and of the sowing and harvest dates.

Contrary to the reports of several authors, early harvest didn't adversely affect carotene content, with the exception of Danvers 126. Differences in weather conditions between Hungary and the West European countries may play a role here.

The hot summer can be one of the causes of the decrease in carotene content in the crop grown on hills. Not even healthy foliage was able to cover the surface of the hills. For

carotene formation however moderately warm environment is favourable. In the year of our experiments August was very hot.

Nitrate content

As regards varieties, Nantes was remarkable not only for the colour but also for the high nitrate content when harvested in summer. In the other varieties when grown on plain ground, nitrate content was near to 400mg/kg, the limit accepted even for baby food .

The lowest nitrate content was measured in Fertődi vörös. The nitrate content of Szupra grown on plain ground was fairly good, too. With the exception of Nantes, summer nitrate contents are higher in cultivation on hills than on plain ground

The results gained after autumn harvest were different from the results in summer. The nitrate content of the long season varieties was considerably lower on hills. Contrary, the nitrate content measured in Berlikummer was higher on hills than on plain ground.

The nitrate contents of Szupra and Barbados were high when harvested late. Szupra was worse on plain ground, Barbados on hill.

Of the Nantes type, the very high nitrate content found in the variety Nantes lessened till autumn with both cultivation methods, but the values measured in Ivor increased on plain ground.

Nitrate content in Barbados increased till autumn, especially when grown on hills.

The long season varieties showed an increase in nitrate content on plain ground and a decrease on hills till autumn.

Comparison of the different sites of production

The results of the cultivation on different soils have led to the following conclusions:

Dry matter content

From the three sites of experiments the lowest values were measured at Fertőd, with both cultivation methods, and the highest values were registered at Kecskemét, with the exception of Danvers126, grown on flat ground. Growing on hills improved the dry matter content of the two long season varieties at Kecskemét. In Budapest, there were found small differences, in one of the varieties to the advantage of the cultivation on plain ground, in the other variety to the advantage of the cultivation on hills.

Sugar content

The lowest total sugar content was found at Fertőd. Of course, sudden heavy rains may have played a role in these results

Carotene content

Our findings have been contradictory to data published by several authors saying that the lowest carotene content may be found in carrots grown on sand. The worths measured at Fertőd were the lowest, independently from the cultivation method. The effect of the cultivation on hills hasn't been explicit in respect of varieties and sites.

Nitrate content

In the opinion of several authors nitrate content correlates with carotene content. Our tests haven't been in agreement with these findings.

Low nitrate accumulation hasn't been found in any of the varieties and of cultivation methods either. The high nitrate levels found in the carrots grown at Fertőd seem to verify the observation that hilling furthers the mineralization of nitrogen, and as a consequence, increases nitrate content. At Fertőd, hilling was repeatedly done because of the sudden heavy rains. This may be the cause of the high nitrate content of the carrots grown there.

Results in storage

Only one method of storage has been included into the experiments. The roots were stored in sand, in a cellar of 90 per cent relative air humidity, practically unchanged during winter.

In Danvers 126 considerable rotting was found, caused by serious storage diseases and indicated by the dry matter values, too. The results with the other varieties were relatively good, however, the results haven't proved the superiority of growing on plain ground or that of growing on hills. Bitter root taste was found according to workers clearing the cellar when the experiment was finished, however, laboratory tests haven't been made.

In the trials aimed at studying the effect of boron foliar fertilizers, experience has demonstrated that the sensory analysis allows the registration of the bitter taste also in interaction with the sweet taste. Future experiments with carrot should be extended to tests in this field.

The effect of foliar fertilization

Boron plays an important role in the development of root vegetables, however, we haven't found any significant increase in the dry matter or in the sugar content of any of the varieties tested. Damisol treatment improved the invert sugar and dry matter content, however, only the favourable effect on carotene content was significant.

In the long season varieties, the tendencies found in the two years of the experiment were different. As regards sugar content, the untreated plots were the best. This can be explained perhaps by the fact that the nutrient demands of the crop were not satisfied in general, as the plots didn't receive any basic manure.

Sensory analyses

The results of the preference tests haven't been full agreement with the laboratory results.

In the tests on dietary value, Bolero treated with Damisol ranked best. In sensory analysis, however, it occupied the second place because of lacking crispness.

From Flakker types, Danvers 126 proved to be the best in the summarized profile analysis because of its sweet taste and the absence of bitterness.

The examination of the applicability of this method may be recommended in other crops, especially in vegetables grown for fresh consumption.

New research results

-Growing on hills hasn't improved the dietary value of carrots, over and above its yield increasing effect already known.

-The carotene content reducing effect of summer hotness is more pronounced in cultivation on hills than on plain ground.

-Contrary to the earlier suppositions the boron fertilization doesn't increase the sugar and the dry matter content of the carrot root.

-Growing on hills may increase the nitrate content of the crop, especially when hilling is necessary during the growing season, too.

-The sensory qualifying analyses are solid scientific complements to the analyses of dietary value.

Conclusions, recommendations

The control of the dietary value of vegetables is spreading and will be generally accepted in the EU as is to be expected. This holds especially true for carrots, a crop of importance in dietary alimentation and as baby food, too.

Growing the crop on hills doesn't increase the percentage of dry matter and sugar content. However it increases dry matter and sugar production per unit of area as it significantly increases the yield.

Carotene content may be reduced by high temperatures prevailing in the hot summer period, if the hills aren't covered by the foliage. Thus, varieties of strong foliage growth should be chosen.

Increased nitrate content has been found in carrots grown on hills, especially when repeated hilling was necessary during the growing season because of erosion. When carrots are grown for baby food production, hilling must be avoided, even at the expense of green head formation.

As addition to the laboratory analyses of the dietary value of carrots, sensory analyses may be recommended. This needs an increased number of samples, as compared to laboratory analyses only, however, reliable complementary data would be furnished to the methods of measuring, applied so far.