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Some aspects of the quality of carrots on different soil types

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Summary

Carrots are becoming an increasingly important crop in Ireland. High yields can be obtained, particularly on peat soils, but little information is available, as yet, on crop quality.

Three carrot cultivars were grown in peat and mineral soil in 1969 and 1970 and samples of each were harvested three times in 1969 and twice in 1970 at 2-week intervals. Chemical analyses showed that cultivars grown in mineral soil had higher levels of carotene, alcohol insoluble solids (AIS) and dry matter (DM) in all harvests than those grown in peat; values for shear were also generally higher. Contents of reducing sugar for carrots from mineral soil were higher in 1969 but lower in 1970.

Frozen samples from the 1969 experiments were cooked by a standard procedure and were presented to a taste panel. Those grown in mineral soil were rated higher for flavour and softer for texture than peat grown samples. Shear values also showed that both fresh and frozen carrots grown in peat were generally softer when raw, but firmer when cooked than those grown in mineral soils. No taste panels were carried out on samples in 1970, but shear values on cooked carrots showed that the unusual texture change observed in 1969 did not occur to the same extent in 1970.

Introduction

The carrot acreage in Ireland has risen from 1174 acres in 1961 to about 3000 acres in 1970. At the present time over a quarter of the total crop is processed and this figure is likely to increase by a large amount over the next few years. About 70% of the processed crop is dehydrated, the remainder being frozen and canned. Recent developments in production on peat have given yields in excess of 20 tons per acre and the potential for the development of low-cost, large-scale production on peatland is vast.

Because of the higher yields obtained in peat in comparison with mineral soil, it might be expected that quality of carrots grown in peat would be lower than that of

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roots grown in mineral soil. The present study investigates the carotene, reducing sugar and dry matter contents and shear values of three carrot cultivars grown on both peat and mineral soils. These chemical parameters are correlated with organoleptic response. Time of harvest and effect of carrot size on composition were also studied.

Materials and methods

Sampling and harvesting

Samples of carrot cultivars Nantes 1003, Amsterdam 5558 and Sweetheart, grown in peat and mineral soils were each harvested at random on three separate dates at 2-week intervals in the 1969 season. In 1970 the cultivars Nantes 1003, Touchon and Sweetheart were tested and were harvested twice. The number of days from sowing to harvesting in peat and mineral soil was the same for any particular cultivar. There were three field replicates in the experiment. Carrots for analysis were graded into large, medium and small on a weight basis in the 1969 season.

Chemical analysis

Subsamples of ten roots were washed, trimmed and rapidly comminuted in a Boku High Speed Mincer.

Dry matter (*DM*). 10 g of the chopped material were dried in an oven at 70°C and a vacuum of 560 mmHg to constant weight and the dry matter content calculated.

Carotene content. Carotene was extracted from a 5 g sample of comminuted material with successive portions of a 2 : 3 (v/v) mixture of acetone and petroleum ether (40–60°C). After extraction the extracts were made up to 200 ml and the carotene estimated on a Bausch and Lomb spectrophotometer at 430 mμ.

Reducing sugar and alcohol insoluble solids (*AIS*). 10 g samples of the comminuted material were canned in 80% aqueous alcohol. At a later date the AIS material was collected by filtration and dried in a vacuum oven at 70°C and 560 mmHg. Purity of the AIS material was tested by further boiling in a fresh portion of 80% alcohol. Reducing sugar was measured on the filtrate by the Schaffer Somogyi Method (Laboratory Method Sheet, 1967). In the 1970 season the AIS content of the roots was not measured.

Hydrolysis of AIS material. Fractionation of AIS material (2g) from both cooked and fresh carrots into pectic substances, hemicelluloses and cellulose was carried out using 0·01 M sodium hydroxide followed by 2 M sodium hydroxide according to the procedure used by Collins (1965) on apple AIS. The fractions were collected by filtration and dried in a vacuum oven at 70°C and 560 mmHg to constant weight.

Shear measurement

Ten roots were washed, trimmed and diced. 50 g samples were sheared in triplicate on a shear press fitted with a 5000 lb proving ring and maximum force reading dial.

In a separate experiment on the effect of the carrot skin on texture, shear values for dice from carrots with skin attached were compared with values for dice from carrots with skin removed. Only peripheral dice which had skin attached were used.

Shear estimations were also made on cooked carrots (skin removed) using 50 g samples. The readings were taken on 'warm' carrots immediately after cooking.

Evaluation of cooked carrots

Because of different harvest dates it was necessary to blast freeze carrots for subsequent taste panel analysis. Samples of the diced, cooked carrots were evaluated for flavour and texture by a trained, six-member taste panel. The dice were all obtained from medium-sized carrots. All samples were cooked by adding 300 g of frozen diced carrot to 570 ml of boiling water in a beaker on a hot plate. Skin was removed from the roots before cooking. After cooking gently for 10 min the samples were collected in strainers and presented for evaluation. The panel members were instructed to rate samples as better or worse than standard in flavour, and firmer or softer than standard in texture, using a five-point hedonic scale. The cultivar Amsterdam, grown in mineral soil, was used as standard (score 0) and also as a coded sample. 50 g samples of the cooked dice were sheared and the results were compared with the taste panel evaluation. Samples from the 1970 trials were not submitted for organoleptic evaluation.

Histological examination

The specimens were prepared by paraffin sectioning according to standard microtechnical methods (Johansen, 1940). Sections were cut at 10–15 μ and stained with safranin–light green (Gurr, 1965).

Results

Evaluation of fresh carrots

The results (Table 1) show that peat grown carrots had significantly lower levels for DM, carotene, reducing sugar, shear and AIS than those grown on mineral soil. All levels, except reducing sugar, increased with successive harvests from roots grown on mineral soil; reducing sugar fell progressively. For peat grown samples only AIS and carotene increased with successive harvests while reducing sugar, DM and shear values increased between the first and second harvests but fell again between the second and third (Table 1).

In 1970 peat grown roots had also lower levels of DM, carotene and shear than those from mineral soil, but reducing sugar contents were slightly higher (Table 2). In contrast to results obtained in 1969, DM levels remained static in peat grown roots and fell in mineral grown roots in the second harvest; shear values also decreased between the first and second harvests.

TABLE 1. Values for DM, carotene, reducing sugar, shear and AIS (means of three cultivars and three field replicates) at three harvest dates on peat and mineral soil (1969)

	Harvest 1			Harvest 2			Harvest 3		
	Peat	't' test	Mineral	Peat	't' test	Mineral	Peat	't' test	Mineral
DM (%)	9·70	***	13·76	10·36	***	14·80	9·66	***	15·18
Carotene (mg/100g fresh weight)	6.82	***	15·46	8·42	***	18·89	10·44	***	20·89
Reducing sugar (%)	2·67	***	3·63	2·70	***	3·18	2·04	***	2·59
Shear (lb)	1226	***	1367	1274	***	1388	1262	***	1408
AIS (%)	3·88	***	5·97	4·14	***	6·09	4·22	***	6·22

*** Significant ($P = 0{\cdot}001$).

It should be noted that data in Tables 1 and 2 are means for three cultivars; however, figures for each individual cultivar were similar to the means in the Tables except for Nantes which had a much lower carotene content in both soil types in 1969 and only carotene increased with successive harvests. In 1970 roots of Nantes from peat soil were slightly firmer than those from mineral soil at the first harvest.

Large carrots grown in peat had higher levels of DM, carotene, shear and AIS and lower levels of reducing sugar than medium or small-sized roots grown in the same soil type. However, only some of the values were significantly different. In contrast, small roots grown in mineral soil had higher levels of DM and shear than medium or large-sized roots.

TABLE 2. Values for DM, carotene, reducing sugar and shear (mean of three cultivars and three field replicates) at two harvest dates on peat and mineral soil (1970)

	Harvest 1			Harvest 2		
	Peat	't' test	Mineral	Peat	't' test	Mineral
DM (%)	10·30	***	15·30	10·32	*	13·81
Carotene (mg/100 g fresh weight)	7·31	***	16·20	8·90	**	16·80
Reducing sugar (%)	3·19	N.S.	2·97	3·05	*	2·62
Shear (lb.)	1333	***	1448	1267	**	1333

* Significant ($P = 0{\cdot}05$). ** Significant ($P = 0{\cdot}01$). *** Significant ($P = 0{\cdot}001$). N.S., Not significant.

Evaluation of cooked carrots

Two sets of taste panels were carried out on cooked carrots in 1969, i.e. Amsterdam and Sweetheart (first harvest) from both soil types (Table 3) and Sweetheart and Nantes (third harvest) from both soil types (Table 4). The results show (Tables 3 and 4) that carrots grown on mineral soil were preferred for flavour while those grown on peat soil had a firmer texture after cooking than the samples from mineral soil. Reasonable correlation was obtained between panel response and sugar and shear values in the panel on the third harvest (Table 4), but in the panel on the first harvest the correlation coefficient between panel flavour response and sugar content was small (Table 3).

TABLE 3. Relationship between panel scores for flavour and texture on cooked carrots[1] (first harvest) and the sugar content and shear values of the raw and cooked samples respectively

Sample	Panel score[2] (flavour)	Reducing sugar (%) raw carrots	Panel score[2] (texture)	Shear (lb) (50 g cooked carrots)
Amsterdam (P)[3]	−1·25	2·22	+0·42	213
Amsterdam (M)	0	3·35	−0·75	138
Sweetheart (P)	−1·33	2·58	+1·25	231
Sweetheart (M)	+0·50	2·62	+0·08	156
Amsterdam (M, coded standard)	+0·17	3·14	−0·17	177
Correlation coefficient (rank)	0·50		0·85	
F-test (Panels) df = 1, SE = 0·08	N.S.		N.S.	
F-test (Samples) df = 4, SE = 0·13	***		**	

[1] Carrots frozen before cooking.

[2] Mean score of twelve estimations: two panels × six tasters, scoring system: +2, +1 = better in flavour or firmer in texture than standard; −1, −2 = poorer in flavour or softer in texture than standard; 0 = same as standard in flavour and texture.

[3] P = peat, M = mineral.

Since the texture readings reversed on cooking, i.e. peat grown carrots were softer before cooking, but firmer after cooking than their mineral soil counterparts, another experiment was carried out where fresh carrots were sheared, with and without skin, and were cooked without prior freezing. The texture change again took place (Table 5), and peat grown carrots were firmest after cooking while they were softest before cooking except in the case of Nantes, where peat grown carrots were slightly tougher than the mineral grown roots even before cooking.

TABLE 4. Relationship between panel scores for flavour and texture on cooked carrots[1] (third harvest) and the sugar content and shear values of the raw and cooked samples respectively

Sample	Panel score[2] (flavour)		Reducing sugar (%) raw carrots	Panel score[2] (texture)		Shear (lb) (50 g cooked carrots)
Sweetheart (P)[3]	−1·08		2·16	+1·92		273
Sweetheart (M)	0		2·60	−0·42		126
Nantes (P)	−0·83		2·21	+0·08		183
Nantes (M)	+0·50		2·45	−0·83		90
Amsterdam (M, coded standard)	+0·50		3·14	+0·42		126
Correlation coefficient (rank)		0·83			0·83	
F-test (Panels), df = 1, SE = 0·16	N.S.			N.S.		
F-test (Samples), df = 1, SE = 0·25	***			***		

[1] Carrots frozen before cooking.
[2] Mean score of twelve estimations: two panels × six tasters.
[3] P = peat, M = mineral.

TABLE 5. Shear values for carrots[1] cooked directly without freezing and for uncooked carrots with and without skin (1969)

Cultivar and soil type[2]	Shear (lb)			
	Uncooked (skin on) (50 g) I	Uncooked (skin off) (50 g) II	'Skin toughness' (difference) I − II	Cooked (50 g)
Amsterdam (P)	924	894	30	210
Amsterdam (M)	1158	966	192	162
Nantes (P)	1086	1050	36	204
Nantes (M)	1068	990	78	150
Sweetheart (P)	912	912	0	252
Sweetheart (M)	1146	1092	54	168

[1] Carrots of harvest three stored for two weeks at 4–5°C.
[2] P = peat, M = mineral soil.

Carrots grown on mineral soil had tougher skin (Table 5). In the 1970 experiments the 'reversal' in texture on cooking was only observed for the cultivar Touchon (Table 6). Roots of Nantes from peat soil were slightly firmer before cooking but much firmer after cooking than those from mineral soil. In the case of the cultivar Sweetheart no 'reversal' in texture between roots from the two soil types took place on cooking (Table 6).

TABLE 6. Shear values for uncooked and cooked carrots (1970)

	Shear (lb)	
Cultivar and soil type[1]	Uncooked (skin off) (50 g)	Cooked (skin off) (50 g)
Touchon (P)	984	183
Touchon (M)	1026	138
Nantes (P)	999	207
Nantes (M)	993	129
Sweetheart (P)	846	96
Sweetheart (M)	999	164

[1] P = peat, M = mineral soil.

Fractionation of AIS material

Fractionation of AIS material from uncooked carrots on peat and mineral soils gave almost the same levels of pectin, cellulose and hemicellulose when the results were expressed on a percentage basis. However, the recovery figure for peat grown samples (99%) was higher than for those grown in mineral soil (90%). The same pattern of AIS fractionation was obtained for the cooked carrots with a recovery figure of 99% for the samples grown in peat and only 83% for the samples from mineral soil.

Histological examination

Carrots from the 1969 trials grown in mineral soil had a pronounced ring of xylem tissue around the outside of the root. In contrast the samples grown in peat had fewer xylem vessels in the outside but more vessels in the internal part. Vessels in the carrots from peat were also larger than those in roots from mineral soil. No histological examination was made on roots from the 1970 experiments.

Discussion

The results show (Tables 1 and 2) that peat grown carrots were significantly lower in all the constituents measured at each harvest date except for reducing sugar in the

1970 season. When the results for Amsterdam, Sweetheart and Touchon were expressed individually, the pattern was similar, except that levels for some of the parameters were not signficantly lower in the three cultivars. Nantes, however, was exceptional to some extent in both seasons. The large differences in chemical composition between roots from the two soil types could have major implications for processing. Carotene levels are so widely different that any processed product comprising roots from the two soil types might not be acceptable because of colour differences. The lower dry matter content obtained for peat grown roots would also have implications for the dehydration process but might be offset to some extent by the higher yield obtained on the peat soil. Another obvious difference between roots grown on the two soil types was the effect of date of harvest on DM values; in 1969, DM values for roots from mineral soil increased with each successive harvest but for peat soil these values rose between the first and second harvest and fell between the second and third. The differences found in chemical composition may be due to the different rates of growth on the two soil types. The roots grown in peat were larger and had a much better supply of water because of the greater water holding capacity of the peat soil. However, further research into new cultivars for growing in peat is necessary in order to find cultivars which have a quality similar to those grown in mineral soil. This is most important since the peat is an excellent uniform growing medium and provides suitable conditions for mechanical harvesting. In addition, there are many areas of peatland in Ireland suitable for large scale intensive production.

The taste panels for flavour and texture showed that sugar content had a marked bearing on flavour and in general roots with a high sugar content were highly rated. Rank correlations between panel response and sugar and shear values were reasonably good, especially in the panel on the third harvest (Table 4).

The different rates of softening during cooking of roots from the two soil types is noteworthy. The shear values for peat grown samples were significantly lower than those for samples grown in mineral soil, before cooking (Tables 1 and 2); however, in most cases the latter softened more during cooking resulting in the peat grown samples being the firmest. The differences in texture were readily identified by the taste panel (Tables 3 and 4). It was thought that this unusual change in firmness might have been due to differences in skin toughness, since skin was removed in the cooked carrots but not in the fresh ones. The composition of AIS material or the effect of freezing might also have contributed to the texture change. However, the results (Table 5) show that roots from mineral soils had tougher skins, although even without skins they were still tougher than those from peat. The freezing process itself probably caused some of the texture change but since the change also took place in cooked carrots which were not frozen (Table 5) this suggests that other factors are also involved.

The texture change could not be explained on the basis of the AIS since both raw and cooked carrots from the two soil types had approximately the same percentage of pectins, celluloses and hemicelluloses in the AIS. More detailed studies, however, are required into the nature and location of the pectin.

Samples from the 1970 experiments were also cooked and in the case of the cultivars Touchon and Nantes the roots from peat soil did not soften nearly as much as those from mineral soil during cooking, which endorses the results obtained in 1969. In the case of the cultivar Sweetheart, however, roots from mineral soil were firmest before and after cooking, which contrasts with the 1969 result.

These data suggest that a number of complex factors seem to affect the softening of carrots during cooking. Mineral grown roots may be firmer than peat grown samples because of the more extensive ring of xylem tissue in the former. However, this 'outside' xylem ring might be more susceptible to breakdown during cooking than the internal xylem tissue. Since roots grown in peat seem to contain more internal xylem tissue than those grown in mineral soil this may affect the texture on cooking to some extent. It was not possible to carry out a histological examination of the roots in 1970, hence no information is available concerning the nature of the xylem tissue of the cultivar Sweetheart which did not follow the softening pattern obtained for the other cultivars in 1969 and 1970.

Rainfall may also contribute to the unusual textural behaviour. Both the summers of 1969 and 1970 were dry and carrots on mineral soil were growing under water deficient conditions when compared to peat grown roots since peat is a much better reservoir of moisture. This probably caused the higher dry matter figures in mineral grown roots and to some extent the firmer texture. Availability of water may also have influenced the location of xylem tissue in roots from the two soil types.

Conclusions

Carrot cultivars grown in peat soil had lower levels of DM, carotene, shear and AIS than those grown in mineral soil. This stresses the need for further research on cultivars which are suitable for growing in peat.

Roots grown in mineral soil were in general firmer before cooking but softer after cooking than those grown in peat soil. The phenomenon may be due to differences in the nature of the xylem tissue from roots grown in the two soil types.

Availability of moisture during the growing season may affect the composition, texture and vascular system.

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