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Quality Assessment of Summer and Autumn Carrots from a Biodynamic Breeding Project and Correlations of Physico-Chemical Parameters and Features Determined by Picture Forming Methods

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Introduction

Assessment of product quality is of special significance in organic farming and includes the supervision of crop quality in different growing systems (e.g., Fleck *et al.* 1998) and the characterisation of different cultivars. Several methods have been developed and applied for this purpose, e.g., the physico-chemical analysis of crops, picture forming methods (PFMs) and plant observation. So far only limited information is available on the comparability of these methods. This contribution aims to compare the results of the analysis of physico-chemical parameters of summer and autumn carrots with features determined by PFMs by means of correlation analysis.

Material and Methods

Six summer and eight autumn carrot varieties from biodynamic breeders (D. Bauer, and Th. Heinze) and conventional breeders (Sperli, Quedlinburg) including open pollinating cultivars, F1-Hybrids and special selections were tested in a biodynamic breeding project established in 1998. These field experiments were carried out without replicates. The following parameters were determined in the plant samples collected at harvest time: dry matter, single carrot weight of autumn varieties, essential plant nutrients (N, NO_3, P, K, Mg, S, Ca) and different carbohydrates. Also a decomposition test according to Reinhold (1943) was carried out in order to assess storage quality (Samaras, 1978). Because of a misunderstanding between project partners single carrot weight was only determined for autumn carrots. Quality assessments applying PFMs such as copper chloride cristallisation and chromatography were carried out and quantified from Dr. U. Balzer-Graf (Balzer-Graf, 1999 a and b) according to Balzer-Graf (2000).

Results and Discussion

This contribution aims to compare the two methods rather than discussing the individual results obtained. This information is provided by Hagel *et al.* (2000 a and b) and Balzer-Graf (1999 a and b). The physico-chemical parameters of summer and autumn carrots (table 1 and 2) differed widely as did the results obtained by PFMs (table 3 and 4).

Correlation coefficients of parameters determined by physico-chemical analysis and PFMs are presented in tables 5 and 6. Due to low number of variants per regression (summer carrots: n = 6; autumn carrots: n = 8) sometimes even high correlation coefficients failed to turn out significant (e.g., P/Vitality for summer carrots: r = 0.81; fructosis/embryo-like: r = -0.79 (Table 5)). In order to illustrate the potential of relations for future projects using more variants these correlation coefficients were also mentioned in tables 5 and 6.

For summer carrots in general all nutritional elements indicated close relationships to features obtained by PFMs. E.g., for “Ripeness” determined by PFMs and the contents of K, Mg, S and Ca very high correlation coefficients from 0.93** to 0.97** were found (table 5). The closest significant correlation was found for Mg/Differentiation and Mg/Regeneration with r = 0.98 *** (table 5). Of course the strong relationship for Dry Matter/Ripeness (r = 0.87*) appears reasonable. Also the positive relation for % N/Ripeness (r = 0.90*) is consistent with findings from Wistinghausen (1979), who carried out time series analyses of carrots. But interestingly not for summer carrots (but for autumn carrots!) any significant correlations between parameters from PFMs and “Nitrate” were found (table 5 and 6).

Also the individual carbohydrates were more often correlated with features determined by PFMs in autumn than summer carrots (table 5 and 6). The reason could be related to an increased translocation rate of carbohydrates to the roots (as measured by content of dry matter) in autumn carrots due to the longer vegetation period (table 1 and 2). On the other hand a less pronounced relationship between mineral elements and PFMs in autumn carrots compared to summer carrots was found. With increasing single carrot weight the autumn carrots were judged more “Fruit-like” (r = 0.95***) and less “Vegetative” (r = -0.94***) by PFMs (table 6).

Table 1.: Mean content of dry matter (DM), loss of DM (%) in the decomposition test (DCT), N in % FM[1] (N), nitrate in ppm FM (NO3), nutrient elements (ppm in FM), carbohydrates in FM (%): glucosis (GLU), fructosis (FRU), monosaccharides in (MS), saccharosis in (SAC), total sugar (TS), monosaccharides:disaccharides (Mo:Di) of summer carrots in a biodynamic breeding project.

Summer Carrots	DM	DCT	N	NO3	P	K	Mg	S	Ca	GLU	FRU	MS	SAC	TS	Mo:Di
MICHEL (Bauer[2])	12.1	56	0.16	115	359	2333	131	226	469	1.67	1.30	2.97	2.83	5.79	1.05
MICHEL (Sperli)	10.5	53	0.12	155	273	1976	125	189	419	2.15	1.70	3.85	2.02	5.87	1.91
FRÜHBUND (Bauer)	12.1	51	0.14	156	259	2271	125	228	422	2.06	1.66	3.72	2.94	6.67	1.27
FRÜHBUND (Sperli)	10.8	46	0.12	186	258	1941	117	179	385	2.15	1.76	3.92	2.28	6.19	1.72
Mean of OP[3] Cultivars	11.4	52	0.14	153	287	2130	124	206	424	2.01	1.61	3.62	2.52	6.13	1.49
ANGLIA F1	9.8	49	0.11	137	229	1632	98	155	359	2.35	1.73	4.08	2.02	6.10	2.03
NANDA F1	11.0	48	0.12	128	249	1695	104	158	393	2.24	1.62	3.86	2.85	6.72	1.35
Mean of Hybrids	10,4	49	0,12	133	239	1663	101	157	376	2,30	1,68	3,98	2,44	6,41	1,69

Table 2.: Mean content of dry matter (DM), single carrot weight (SCW), % loss of DM in decomposition test (DCT), % N in FM[1] (N), ppm nitrate in FM (NO3), nutrient elements (ppm in FM), carbohydrates in FM (%): glucosis (GLU), fructosis (FRU), monosaccharides (MS), saccharosis (SAC), total sugar (TS), monosaccharides:disaccharides (Mo:Di) of autumn carrots from a biodynamic breeding project.

Autumn Carrots	DM	SCW	DCT	N	NO3	Ca	K	P	S	Mg	GLU	FRU	MS	SAC	TS	Mo:Di
RODELIKA 97 (Bauer[2])	14.6	143	41	0.15	80	441	2295	329	191	131	0.60	0.51	1.11	7.47	8.58	0.15
RODELIKA 97 NUSSIG (Bauer)	12.7	165	37	0.15	91	381	2492	284	158	119	1.30	1.08	2.39	4.62	7.00	0.52
ROBILA (Heinze)	13.1	122	51	0.18	280	464	2590	315	219	154	0.65	0.66	1.31	5.45	6.76	0.42
LANGE ROTE STUMPFE (Quedlinburg[2])	12.2	118	52	0.17	235	442	2578	357	212	129	0.92	0.79	1.71	4.24	5.95	0.40
LANGE ROTE STUMPFE (Bauer)	11.8	108	55	0.15	369	467	2589	297	194	118	1.14	0.86	2.00	4.05	6.06	0.49
DUWICKA	11.1	53	64	0.14	223	310	3158	334	138	120	1.70	1.71	3.41	2.81	6.22	1.21
Mean of OP[3] Cultivars	12,6	118	50	0,16	213	418	261	319	185	129	1,05	0,94	1,99	4,77	6,76	0,53
TINO F1	10.1	74	45	0.12	211	430	1421	202	164	130	1.37	1.07	2.44	3.22	5.67	0.76
NEVIS F1	10.1	87	38	0.11	349	385	1901	241	145	94	1.40	1.11	2.50	2.93	5.43	0.85
Mean of Hybrids	10,1	67	42	0,12	280	408	1661	222	155	112	1,39	1,09	2,47	3,08	5,55	0,81

[1] FM fresh matter; [2] breeder, [3] OP = open pollinating

Table 3.: Quality parameters according to picture forming methods of summer carrots from a biodynamic breeding project. Index ranging from 0 (very low) to 100 (very high). (from Balzer-Graf, 1999)

Summer Carrots	Carrot typical	Differen-tiation	Vitality	Ripe-ness	Regene-ration	Embryo-like	Vege-tative	Dying	Leaf-like
MICHEL (Bauer[1])	60	50	70	80	60	40	0	10	0
MICHEL (Sperli[1])	60	45	55	60	40	0	0	20	0
FRÜHBUND (Bauer)	50	45	60	70	40	30	0	0	20
FRÜHBUND (Sperli)	50	40	45	50	30	0	10	0	10
ANGLIA F1	30	20	20	20	0	0	40	50	0
NANDA F1	40	20	40	40	0	0	40	40	0

[1] breeder

Table 4.: Quality parameters according to Picture Forming Methods of autumn carrots from a biodynamic breeding project. Index ranging from 0 (very low) to 100 (very high). (from Balzer-Graf, 1999)

Autumn Carrots	Carrot typical	Differen-tiation	Vitality	Fruit-like	Root-like	Stabi-Lity	Vege-Tative	Ageing
RODELIKA 97 (Bauer[1])	80	80	70	90	80	60	0	0
RODELIKA 97 NUSSIG (Bauer)	80	70	70	80	80	60	0	20
ROBILA (Heinze[1])	70	60	70	60	60	50	0	20
LRSt[2] (Quedlinburg[1])	50	50	60	50	60	50	20	20
LRSt[2] (Bauer)	40	40	50	40	40	40	30	30
DUWICKA	40	80	60	0	60	50	60	20
TINO F1	20	10	30	20	20	20	60	60
NEVIS F1	30	20	40	20	20	30	60	60

[1] breeder; [2] LRSt = LANGE ROTE STUMPFE

Table 5.: Correlation coefficients for the relationships between parameters of physico-chemical analysis and picture forming methods of summer carrots in a biodynamic breeding project.
Number of variants per regression: $n = 6$. Statistical significances: $p < 0.05$ (*); $p < 0.01$ (**); $p<0.001$ (***)

	Carrot-typical	Differen-tiation	Vitality	Ripe-ness	Regene-ration	Embryo-like	Vege-tative	Dying	Leaf-like
DM		0.65	0.86 *	0.87 *	0.70	0.88 *	-0.61	-0.69	
DCT	0.63	0.63	0.71	0.71	0.73	0.75	-0.69		
N	0.69	0.76	0.88 *	0.90 *	0.86 *	0.96 **		-0.60	
NO3									
P	0.74 *	0.70	0.81	0.80	0.82 *	0.76	-0.60		
K	0.79	0.92 *	0.93 **	0.96 **	0.94 **	0.88 *	-0.89 *	-0.82 *	
Mg	0.95 **	0.98 ***	0.96 **	0.97 **	0.98 ***	0.68	-0.97 **	-0.82 *	
S	0.72	0.88 *	0.90 *	0.93 **	0.90 *	0.90 *	-0.86 *	-0.77	
Ca	0.84 *	0.80	0.95 **	0.94 **	0.88 *	0.82 *	-0.74		
Glucosis	-0.75	-0.77	-0.88 *	-0.88 *	-0.87 *	-0.87 *	0.68		
Fructosis			-0.64	-0.62		-0.79			
Saccharosis						0.70			
Total Sugar									
Mo:Di			-0.71	-0.70		-0.81			

Only correlation coefficients > ±0.50 are listed

Different characteristics between the two sets of carrot variants were also noticed with regard to relations between the decomposition test (DCT) and PFM parameters. Only summer carrots showed reasonably high (though not significant) correlation coefficients from 0.63 to 0.75 (table 5). In contrast for autumn carrots all correlation coefficients were below 0.50 (therefore not shown in table 6).

The very often high and significant correlations between physico-chemical parameters and features determined by PFMs are striking and underline the technical accuracy of both methods. The results clearly confirm PFMs as a suitable tool for quality assessment which provide reliable results. This is also corroborated by the investigations of Balzer-Graf (2000) who showed that it is possible to distinguish crops from different growing systems by PFMs.

Table 6.: Correlation for the relationship between parameters of physico-chemical analysis and picture forming methods of autumn carrots in a biodynamic breeding project.
Number of variants per regression: n = 8. Statistical significances: p < 0.05 (*); p < 0.01 (**); p<0.001 (***)

	Carrot typical	Differen- tiation	Vitality	Fruit- like	Root- like	Stabi- lity	Vege- tative	Ageing
SCW	0.87 **		0.68	0.95 ***	0.67	0.66	-0.94 ***	-0.55
DM	0.92 **	0.75 *	0.86 **	0.88 **	0.86 **	0.84 *	-0.91 **	-0.90**
DCT								
N		0.55	0.53		0.63	0.65		-0.71 *
NO3	-0.78 **	-0.61	-0.68	-0.71 *	-0.74 *	-0.63	0.68	0.60
P	0.54	0.78 *	0.78 *		0.73 *	0.80 *		-0.86 **
K		0.67	0.73 *		0.54	0.61		-0.62
Mg								
S				0.55			-0.60	
Ca								
Glucosis	-0.59			-0.79 *			0.74*	0.55
Fructosis				-0.68			0.58	
Saccharosis	0.80 *	0.54	0.65	0.87 **	0.69	0.65	-0.81 *	-0.73 *
Total Sugar	0.86 **	0.74 *	0.75 *	0.79 *	0.80 *	0.76 *	-0.76 *	-0.81 *
Mono:Di	-0.65			-0.89 **			0.84 **	
Only correlation coefficients > ±0.50 are listed								

Conclusions

High and significant correlation coefficients were found between quality parameters of summer and autumn carrots from a biodynamical breeding project determined by physico-chemical analysis and PFMs. This indicates close relationships between the two quality approaches which should be investigated further in future work.

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