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Fertilization Systems in Organic Farming
(concerted action AIR3-CT94-1940)

Quality of plant products grown with manure fertilization

Proceedings of the fourth meeting in Juva / Finland,
July 6th to 9th, 1996,

edited by Joachim Raupp.

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Preface

Compared to the negative effects of agricultural practises on food quality, e.g. by veterinary pharmaceuticals, plant protection agents and related substances, the positive influences are less frequently under consideration. The question is, which agricultural practises can improve food quality in addition to the effects of the genetic capacity of modern varieties. In the present situation of a market oversupply with many food products in Europe, the question of how to improve quality may be of increasing importance. This is basically true for all types of agriculture. In particular, this is relevant to organic farming, to its conception of itself and to its marketing strategy.

There is no doubt that among all agricultural practises fertilization and plant protection play a central role for crop quality. After having evaluated fertilization effects on plant yield, soil life and symbiotic nitrogen fixation during three previous meetings, the task of our present meeting was to evaluate the quality of plant products as influenced by manure fertilization. We realized that this is impossible without assessing quality parameters and analytical methods. Hence, we not only discussed fertilization effects but also examined parameters and methods used in our long-term experiments.

The meeting was hosted by the Finish member of our group, Res. Prof. Dr. Artur Granstedt, at Partala Research Station. We are very grateful to Pirkko Roinila for her excellent organisation which was a main element of the informative and hospitable atmosphere of our meeting, beside the clear light of very long days in the Finish summer.

Joachim Raupp

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1. Quality investigations with the K-trial, Järna, and other Scandinavian fertilization experiments

By A. G. Granstedt [1] and L. Kjellenberg[2]

SUMMARY

In 1958, the Nordic Research Circle in Järna, Sweden, began a field experiment that lasted until 1990, i. e. 32 years. It included eight different fertilizer treatments and a four-fold crop rotation without repetitions:Spring wheat, clover/grass, potatoes, beets. The focus was primarily on aspects of crop quality, and the fertilizer application rates for the various treatments were adjusted to bring about comparable yields. Two "daughter experiments" emerged from the K-experiment and were run in parallel with the mother project during 1971-1976 in Uppsala and 1971-1979 in Järna. In these experiments a comparison was made between two systems, biodynamic farming and conventional farming.

The effects of the different fertilizer treatments on product quality found in the K-trial are in accordance with findings in the two "daughter experiments". Compared with the conventional treatments, the content of crude protein in the organic treatments was lower but the relative pure protein and the contents of essential amino acids were higher in potatoes and wheat. Resistance against decomposition and storage quality of potatoes were higher, and in wheat the starch quality seemed to be higher in the organic treatments.

INTRODUCTION

In 1958, the Scandinavian Research Circle in Järna, Sweden, began an agricultural field experiment to determine in what ways various types of fertilizers affect the final quality of grain and vegetable products. This field trial is called K-experiment. Various quality parameters and quality assessment methods were developed and tested during the experimental period which included 32 years (up to 1990). Several reports have been published (e.g. Pettersson *et al.*, 1992).

Two "daughter experiments" emerged from the K-experiment and were run in parallel with the mother project during 1971-1976 in Uppsala and 1971-1979 in Järna (referred to as UJ-experiments in the following text). In these experiments a comparison was made between two systems, biodynamic farming and conventional farming, in which both fertilizer regimes and crop rotations were studied (Pettersson, 1982; Dlouhy, 1981). Before that, the influence of these systems on quality parameters of potatoes under different climatic and soil conditions also had been studied in different parts of Scandinavia (Pettersson, 1970).

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DESCRIPTION OF THE K-EXPERIMENT

The K-experiment was located at 59° North, 17° East at an elevation of 10 m above sea level. The mean yearly precipitation was 550 mm, and the mean annual temperature was 6°C, with 6-8 snow-free months per year. The soil was a silty loam with an intermediate humus content.

Experimental layout: To ensure that the field experiment could be used for plant quality assessments while providing the flexibility to support other experiments that had yet to be designed, a very broad basis was adopted. This scheme included eight fertilization treatments, each with a four-fold crop rotation without repetitions (see Table 1). The size of each sub-plot was 36 m^2, with a net harvestable area of 27 m^2.

The crop rotation: Within each fertilization variant the following crops were rotated without interruption so that in any given year all four were present: spring wheat (undersown with clover/grass), clover/grass, potatoes and beets.

Fertilization scheme: To facilitate focusing primarily on aspects of crop quality which might arise from this experiment, the fertilizer application rates for the various treatments were adjusted to bring about comparable yields. This applies with respect to the variants 1,2,3,4 and 7. Variant 5 was not fertilized at all, and variants 6 and 8 represent incremental alterations in the inorganic NPK applications. The fertilization programme was as follows (Tables 1 and 2).

Table 1.1: The fertilization programme (nutrient application levels of total N, P and K in kg/ha/yr averaged for the years 1958-1990 in brackets).

K1. *Composted manure (82/38/76):* aged ½ year with the addition of biodynamic compost preparations 502-507; application of the spray preparations 500+501.
K2. *Composted manure(82/38/76):* same as in K1 but without 500+501.
K3. *Raw manure (95/30/91):* with 1% additions of horn and bone meal.
K4. *Raw manure + NPK (63/28/66):* ½ the K3 manure rate; ½ the K6 NPK rate, resp.
K5. *Control:* unfertilized.
K6. *Inorganic NPK (29/19/41)*
K7. *Inorganic NPK(59/36/81):* twice the level as in K6.
K8. *Inorganic NPK(114/36/81):* as K6, 4 times the N and twice the P and K levels.

Table 1.2: Break-down of the fertilization scheme within the rotation, in %.

Variant	Type	Wheat	Clover/grass	Potatoes	Beets
K1 & 2	Compost	-	-	40	60
K3	Manure	-	-	40	60
K4	Manure + PK	-	-	40	60
	N	20	-	40	40
K6, 7, 8	P K	-	-	40	60
	N	20	-	40	40

DESCRIPTION OF THE UJ-EXPERIMENT

In the UJ-experiment conventional (A) and biodynamic (B) treatments were compared with each other in two crop rotations as described below for the experiment in Järna (Table 3).

The crop rotation 1 represented a rotation without animals and crop rotation 2 represented a system with animals related to an organic system with 0.8 CU (cattle units)/ha (average 50 kg N/ha and year).

The field conditions were nearly the same as in the K-experiment. A split-split-plot design was used with three replications. All crops were grown each year. The soil was a silty loam well supplied with plant nutrients but with a low humus content. The weather was more dry as normal for the region during the first years of the experimental period and had a strongly negative effect on the yield of grain and ley.

During 1971-1976 a parallel project was carried out in Uppsala (called UJ-experiment Ultuna) with the same treatments as in Järna (for details see Dlouhy, 1981). The soil was an intermediate clay, well supplied with plant nutrients and moderately rich in humus.

Table 1.3: Crop rotation and fertilization scheme in UJ-experiment in Järna 1971-1979.

CONVENTIONAL SYSTEM ARTIFICIAL FERTILIZERS, HERBICIDES AND PESTICIDES				BIODYNAMIC SYSTEM ORGANIC MANURE			
Crop rotation A1	Nutrient application kg /ha/yr			Crop rotation B1	Nutrient application kg/ha/yr		
	N	P	K		N	P	K
Barley	80	20	35	Barley	60	50	55
Potatoes	120	100	265	Potatoes	120	80	110
Spring wheat	80	20	35	Spring wheat	70	60	65
Crop rotation A2				Crop rotation B2			
Ley				Ley			
Potatoes	100	80	225	Potatoes	100	65	95
Spring wheat	40	30	50	Spring wheat	50	30	45

CROP YIELD AND QUALITY IN K-EXPERIMENT (1958-1989) AND RELATED STUDIES COMPARING BIODYNAMIC AND CONVENTIONAL FARMING (1971-1979)

Variation in mean values was generally higher between years than between treatments but the relation between treatments for each single year was mostly the same for most of the parameters. Still, it has been possible to compare the results of biodynamic and conventional treatments in K-experiment with those from the above-described daughter projects. But with the reservation that the K-experiment was only a fertilization experiment, not a comparison between different farming systems.

Potatoes

The average tuber yield in the K-experiment was the same in the organic and conventional treatments (Fig. 1.1). The yield was only significantly lower in the unfertilized treatment (287 dt/ha). Years with higher precipitation, and thus with better conditions for the mineralization of nitrogen in organic manure, were more favorable for the organic treatments. In both UJ-experiments with shorter experimental periods the yield was significantly lower in the biodynamic treatments which partly was a result of higher yield losses caused by Phytophthora and the use of pesticides in the conventional treatments.

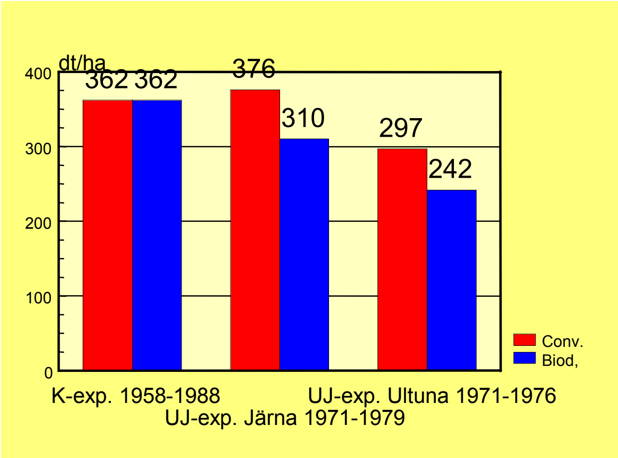


Fig. 1.1: Average yield of potatoes in different experiments

Dry matter content: The tendency to a higher dry matter content in the biodynamic treatment in the K-experiment was reproduced in both UJ-experiments and was highly significant in both B1 and B2 in relation to the conventionally fertilized systems A1 and A2 (Fig. 1.2).

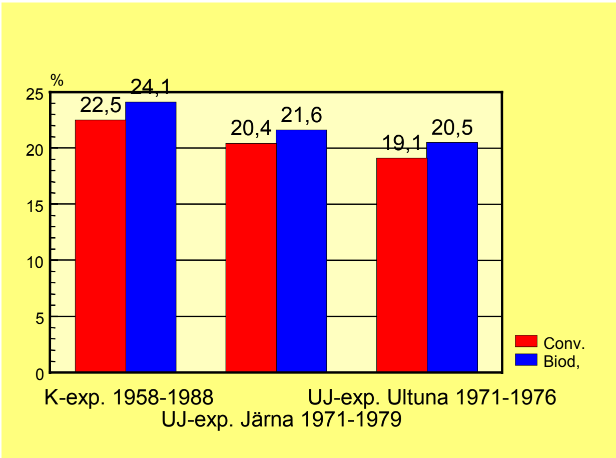


Fig. 1.2: Dry matter content in potatoes in percent of harvested weight; results of different experiments

Protein levels and protein quality: In terms of crude levels of protein a clear gradient was found from low levels in the organically grown samples to high levels in the conventionally grown ones. The crude protein content was also significantly higher in the inorganic treatments in both UJ-experiments (Fig. 1.3), but the content of relative pure protein was significantly higher in the biodynamic treatments than in the inorganic treatments (Fig. 1.4). The content of free amino acids was lower in the organic treatments. The higher protein quality in the organically grown potatoes was confirmed by comparing the relative content of essential amino acids. Also the biological value of protein calculated as EAA-index (Dlouhy, 1981; Pettersson, 1982) during the years of study was significantly higher for the biodynamic systems.

Darkening of tissue and extracts: In the K- and UJ-experiments both methods according to Pettersson (1982) were used for evaluating the browning of the potatoes. The UJ-experiments revealed that discoloration was more pronounced and developed faster in the minerally fertilized variants than in the organically ones and the differences were significant (Fig 1.5; p<0.01 in the UJ-experiments).

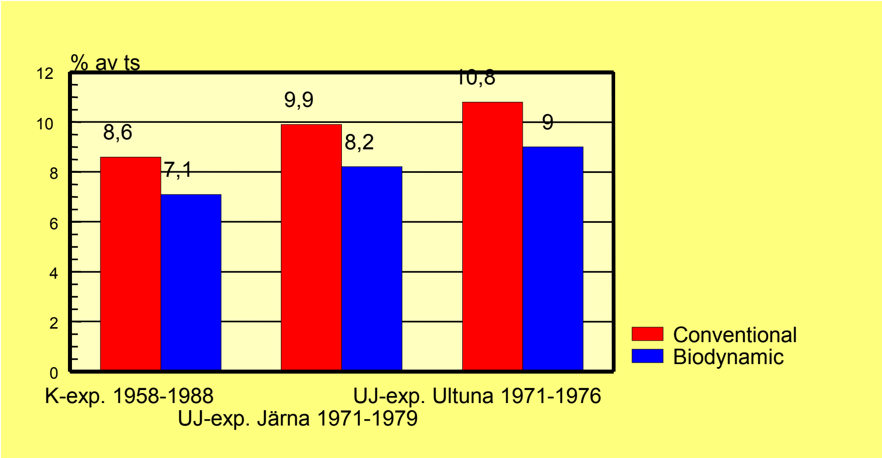


Fig. 1.3: Crude protein in potatoes in percent of dry matter; results of different experiments

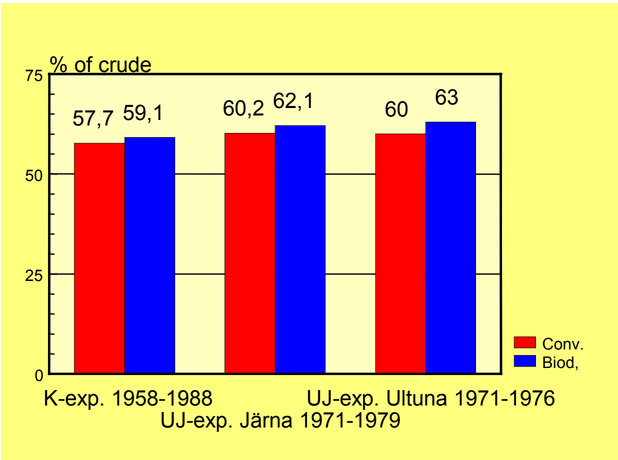


Fig.1.4: Relative pure protein in potatoes of different experiments

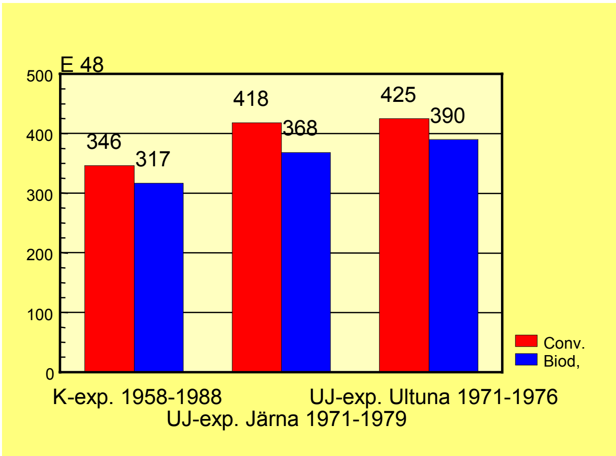


Fig. 1.5: Darkening of potato extract; extinction at 530 nm after 48 hours (E 48); results of different experiments

Extract decomposition: In this particular test of the resistance against the enzymatic and bacterial decomposition in diluted water extracts, the organically grown variants generally showed lower decomposition values than the others (Rd/Ro = the maximum decrease of the electrical resistance in percent of start value in extracts diluted 1:10 during 4-5 days, according to Pettersson, 1982). Similar results were obtained in the comparison of conventional and biodynamic treatments in the UJ-experiments (Fig. 1.6, $p<0.01$ in the UJ-experiments).

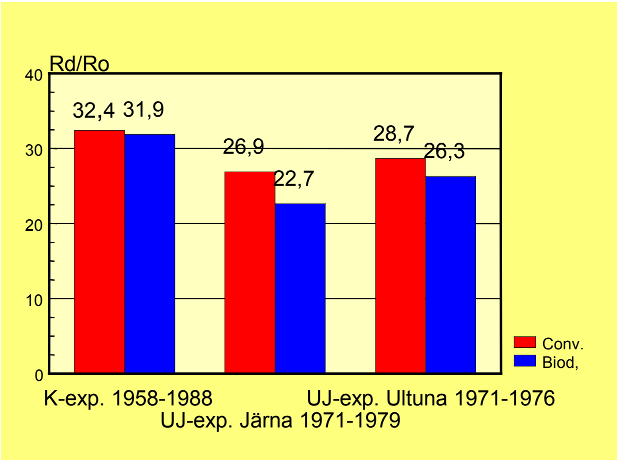


Fig. 1.6: Decomposition of potato extract measured as change of electrical resistance; results of different experiments (explanation of Rd/Ro in the text)

Storage losses: In the K-experiment storage losses caused by fungi and evaporation tended to be lower in the organic treatments (Fig. 1.7). In the UJ-experiment in Järna this difference was more pronounced ($p<0.05$ and $p<0.1$).

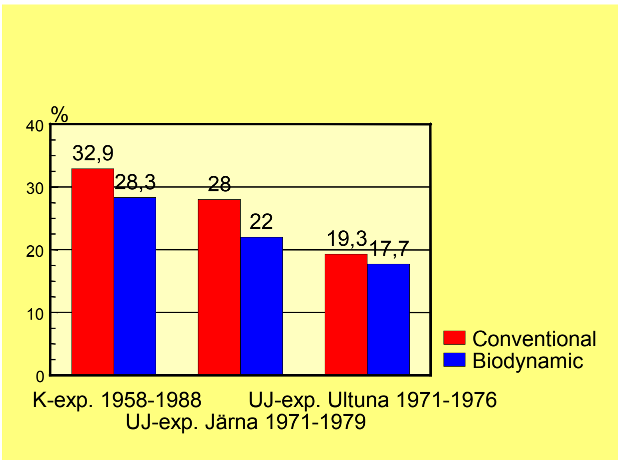


Fig. 1.7: Storage losses of potatoes after 6-7 months in percent of the original stored weight; results of different experiments

Field survey of *Phytophthora infestans*: The frequencies of infection were significantly lower in treatments K1 and K2 (composted manure) and in K5 as compared with K8 (high rate of NPK) and K3 and K4 (raw manure) in the 14 years when this parameter was studied.

Pathogen infection with *Phytophthora infestans* (studied only during 1966-1969): Although the spread of values was great with this method, a trend can be seen with lower values (lesser *in vitro* infection) in the organically grown samples to higher infection in the inorganic samples.

Morphology of stems: The number of horizontal stems differed appreciably between the treatments. Values tended to be lower in the organic variants and higher in conventional ones (Pettersson *et al.*, 1979). This indicates that a low number of horizontal stems corresponds with high product quality as it is expressed by the index. The method is described by Pettersson (1970). In the UJ-experiment in Järna (where this method was also used) the number of side (horizontal) stems was significantly lower in the biodynamic treatments.

Crystallization investigation: As with the foregoing results, this test (Engqvist, 1970; Pettersson, 1970) revealed a similar trend (Fig. 1.8). Organizational traits in the tissues have been evaluated better in the organically grown samples (higher Fk values) than in the conventional ones (In the K-experiment studied all years between 1966 -1989).

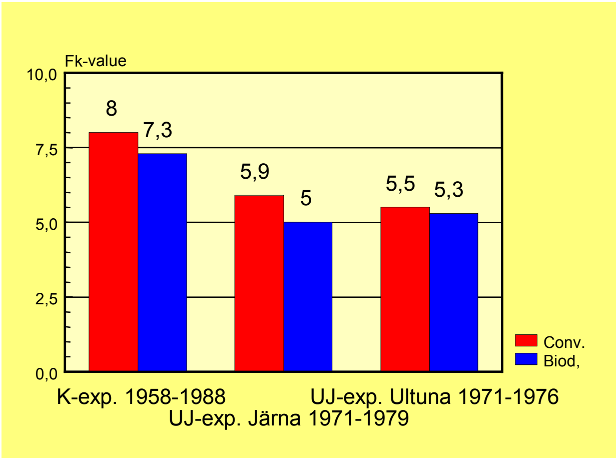


Fig. 1.8: Copperchloride crystallization with potato extract, Fk-values (Fk=fault unit according to Pettersson, 1970); results of different experiments

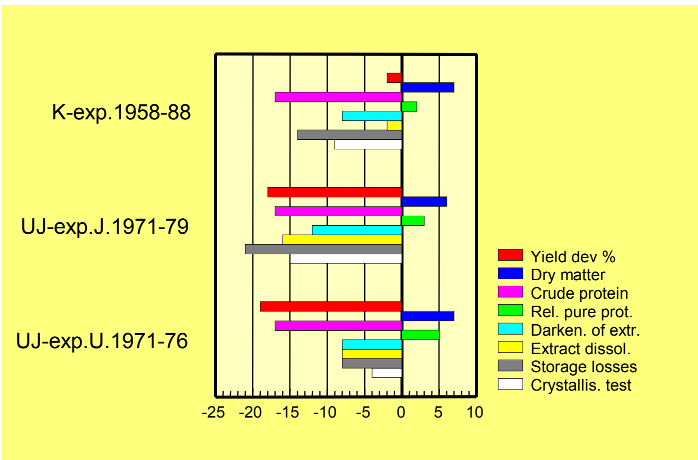
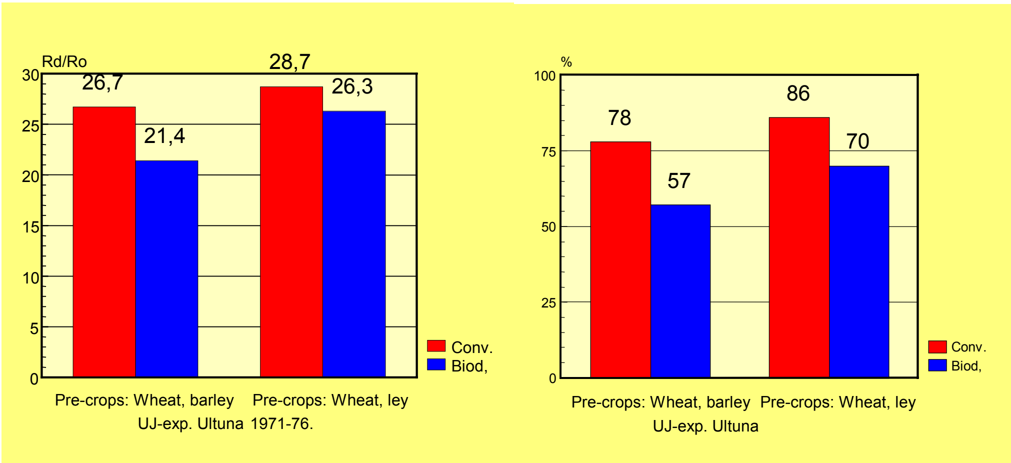


Fig. 1.9: K-experiment 1958-1989, UJ-experiment in Järna 1971-1979, UJ-experiment in Uppsala 1971-1976. Differences of quantitative and qualitative parameters of potatoes, in percent, between the biodynamic and the conventional treatments

In some of the studied quality parameters a difference was observed between ley and barley as a previous crop. A higher extract dissolution and higher nitrate content after ley (Fig. 1.10a and Fig. 1.10b) occurred in the UJ-experiment. This type of farming system effects was not possible to be studied in the K-experiment which was a pure fertilizing experiment.

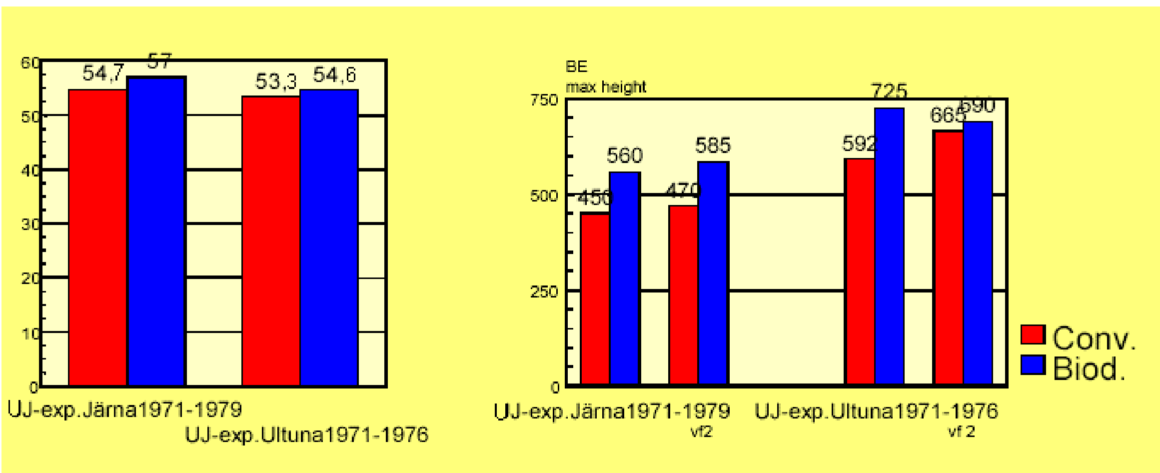


a b

Fig. 1.10 a: Decomposition of extract of potatoes measured through change of electrical resistance;
b: Nitrate content in percent of fresh weight in potatoes with and without ley as preceding crop in the UJ-experiment in Ultuna, Uppsala

WHEAT

The average yield levels in K1 and K8 were nearly the same. For K2, in which there was no application of biodynamic field preparations, the yield level was significantly lower, and the differences were highest during years with a low yield level. In the UJ-experiments, with shorter experimental periods, the yield levels were significantly lower in the biodynamic treatments. In wheat as well, the crude protein content was higher in the inorganic treatments in the K-experiment and in both UJ-experiments. However, the content of relative pure protein was higher in the biodynamic treatments in K-experiment and higher in the UJ-experiment in Järna ($p<0.01$ and $p<0.1$).



a b

Fig. 1.11 a: Index of essential amino acids
b: Amylase activity in wheat in the UJ-experiments

That the protein quality was higher in the organic treatments was also confirmed by the index of the essential amino acids (EAA-index, Fig. 1.11a), which was significantly higher in the biodynamically manured systems during the years when it was measured in the UJ-experiment. The resistance against extract dissolution was also higher in the biodynamic treatments in these studies. Also, the starch quality seemed to be higher in the biodynamic treatments in terms of falling number (in the K-experiment and the UJ-experiment in Järna, see Fig. 1.12) and amylogram (both UJ-experiments, Fig. 1.11b).

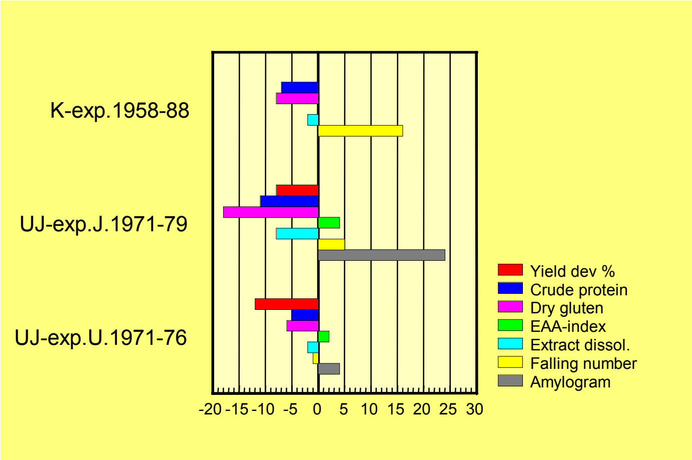


Fig. 1.12: K-experiment 1958-1988, UJ-experiment in Järna 1971-1979, UJ-experiment in Uppsala 1971-1976. Differences of quantitative and qualitative parameters of wheat in percent, between the biodynamic and the conventional treatments

Correlation between crude protein content and other parameters

In the UJ-experiment significant ($p<0.001$) correlations have been observed between crude protein content and most of the studied parameters (Pettersson, 1982). With potatoes: Dry matter content (negative, $p<0.001$), relative pure protein (negative, $p<0.01$), EAA-index (negative, $p<0.001$), ascorbic acid content (negative, $p<0.001$), cooking quality (negative, $P<0.01$), taste quality (negative, $P<0.001$), free amino acids (positive, $p<0.001$), extract dissolution (positive, $p<0.001$) and darkening of extract (positive, $p<0.001$). With wheat: EAA-index (negative, $p<0.01$), extract dissolution (positive $p<0.001$), falling number (positive $p<0.05$), gluten content and baking tests (positive, $p<0.01$).

CONCLUSIONS

Light and shadow

The studied quality parameters can be divided in three groups: chemical/biological, physiological and a third group called morphological parameters which can be studied in the morphology of the plant by means of picture formation methods (crystallization with $CuCl_2$). It can be assumed as an hypothesis that the lower quality in terms of the parameters studied here in the conventionally fertilized systems is similar to that which would have occurred if the crops had been cultivated in the shade. Likewise, the higher biological value of the protein, and the other results correlated with that, can be interpreted in the same direction as if growing conditions were more under bright light. In the interpretation, the organic treatments are compared with the effect of an increase in solar radiation, and likewise the effects of NPK-treatments are analogous to an increase in shade.

"Organization level"

The composition of the protein with a lower content of free amino acids and better storage properties, can be described as a “higher organization“ level which was a result of the organic and biodynamic fertilizing systems. It was possible to study the chemical, physiological and morphological parameters in relation to the plant as an organism in time by investigating products after harvest and later in the storage test. The higher biological value of the protein and lower content of free amino acids not used in protein synthesis, the better resistance against pests, darkening, extract dissolution and, later in the potatoes life cycle, lower storage losses can be interpreted as characteristics of a “high organization level“.

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2. Quality investigations with products of the long-term fertilization trial in Darmstadt

By J. Raupp[1]

INTRODUCTION

The fertilization trial reported here refers directly to the main topic of debate of the present meeting. The field experiment was initiated and started in 1980 in order to investigate the influence of organic and mineral fertilization on the quality of plant products. At the beginning the intention was not to set up a long-term experiment; it was scheduled for 4 years only. In these years interesting effects of the different fertilization treatments on soil properties were observed (Abele, 1987) which gave rise to the decision to continue the field trial with a modified fertilization concept (see Table 2.1) and to study soil biological and microbiological phenomena in more detail (Bachinger *et al.*, 1993; Bachinger, 1995 and 1996; Koop, 1993; Meuser, 1989; Meuser & Wessolek, 1989). With the modified concept the experiment is still in progress.

Table 2.1: Management and crop rotation periods of the long-term fertilization trial in Darmstadt

period	crop rotation	fertilization concept	total N amounts (low, medium, high level)
1st period	in each year:[1]	**comparable yields**	see Tables 2.2 and 2.3
1980-84	carrots, beetroot, potatoes, rye	with all types of fertilizers	
2nd period	in each year:	**equivalent amounts of total N**	cereals: 60, 100, 140 kg N/ha
1985/86 until now	red clover (alfalfa), spring wheat, potatoes[2], rye	with all types of fertilizers	root crops: 50, 100, 150 kg N/ha

[1]: 1981: barley instead of rye
[2]: since 1991, in the years before mostly carrots or beetroot

The two periods of the long-term trial can be distinguished regarding the levels of organic fertilization and the crop rotation (as reported in Raupp, 1995). The **experimental design** has been the same all the time. It consists of two factors,

- the **type of fertilization**, i.e. **CM** = composted cattle manure and urine, **CMBD** = composted cattle manure and urine of the same origin but with application of all biodynamic manure and field preparations, **MIN** = mineral fertilizer;
- the **level of fertilization**, i.e. **low**, **medium** and **high** (for the applied quantities see

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Tables 2.1, 2.2 and 2.3).
Both factors are combined to 9 treatments (3x3) practised in 4 replicates with each crop. The site conditions are characterized by a warm-dry climate (9.5 °C, 590 mm precipitation per year) and a sandy orthic luvisol with 87.2% sand in the topsoil.

In order to achieve comparable yields with organic and mineral fertilization in the first period, composted manure had to be used in relatively high amounts, because of the different nutrient availability of the two types of fertilizer. A different fertilization concept has been used in the second period since 1985/86, which is based on the application of equivalent amounts of total nitrogen with all types of fertilizer (MIN, CM and CMBD).

Investigations on food quality have been carried out in both periods. The results are evaluated critically in the present paper taking especially into consideration the problem of suitable parameters and analytical methods for quality assessment. In the following tables and figures significant differences are indicated by different letters at mean values.

Table 2.2: Total nutrient contents (kg/ha) of the fertilizer treatments to root crops in 1981-84, calculated with data of Abele (1987)

fertilizer		carrots			beetroot			potatoes		
type	level	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
MIN	1	60	60	150	80	60	100	60	60	120
	2	120	90	200	160	90	150	120	100	160
	3	180	120	250	240	120	200	180	140	200
CM/CMBD	1	96	48	144	128	64	176	96	48	132
1981	2	192	96	288	256	128	352	192	96	264
	3	288	144	432	384	192	528	288	144	396
CM/CMBD	1	115	58	122	186	99	186	84	65	130
1982	2	230	115	245	371	198	371	168	130	259
	3	346	173	367	557	298	557	252	194	389
CM/CMBD	1	117	54	108	72	60	125	54	45	94
1983	2	234	108	216	144	120	250	108	90	187
	3	351	162	324	216	180	374	162	135	281
CM/CMBD [1]	1	0	0	0	90	51	93	67 + 20	38	70
1984	2	0	0	0	179	102	186	134 + 40	77	139
	3	0	0	0	269	154	278	202 + 60	115	209

[1] potatoes: composted manure + horn meal

FIRST PERIOD: THE CONCEPT OF COMPARABLE YIELDS

Fertilization treatments and yields

The fertilizer amounts in the mineral treatments were constant in all years in the 1981-84 period, and varied only depending on crop. In the medium level, nutrient doses between 100/75/100 kg/ha N/P_2O_5/K_2O and 160/90/150 kg/ha N/P_2O_5/K_2O were given to rye and beetroot, respectively, or 120/90/200 kg/ha to carrots (Tables 2.2 and 2.3). The low fertilization level was 50% and the high one 150% of the medium level. This is the same gradation as was practised in the manure treatments.

Table 2.3: Total nutrient contents (kg/ha) of the fertilizer treatments to rye in 1981-84, calculated with data of Abele (1987)

fertilizer		rye		
type	level	N	P_2O_5	K_2O
MIN	1	50	50	75
	2	100	75	100
	3	150	100	125
CM/CMBD 1981	1	80	40	120
	2	160	80	240
	3	240	120	360
CM/CMBD 1982	1	96	48	102
	2	192	96	204
	3	288	144	306
CM/CMBD 1983 [1]	1	78+20	36+1	72+71
	2	156+40	72+1	144+141
	3	234+60	108+2	216+212
CM/CMBD 1984 [2]	1	50	21	12
	2	100	42	25
	3	150	63	38

[1] compost + urine
[2] *Ricinus* meal

The amounts of composted manure were especially high in the first and second years of this period. In the three fertilization levels of CM and CMBD 20, 40 and 60 t/ha manure were applied to rye, 24, 48 and 72 t/ha to potatoes and carrots and 32, 64 and 96 t/ha to beetroot. In the following 2 years of the first period half the amounts were given in each level, and carrots remained unfertilized in CM and CMBD in the fourth year, because the effect of the residual nutrients was sufficient. The quantities of nitrogen, phosphorus and potassium corresponding to the amounts of manure are calculated in Tables 2.2 and 2.3. The total amounts of nitrogen were about 60 to 95% higher in CM and CMBD compared to MIN. As regards phosphorus, in the low fertilization level the amounts were more similar in organic and mineral treatments; in the medium and high level around 40% more P_2O_5 was applied to rye, carrots and potatoes but up to 150% more to beetroot. As regards potassium, the biggest differences also can be seen in the medium and high level, reaching up to 180-240% more K_2O in the manure compared to the mineral treatments. More details are published by Abele (1987).

Altogether, with all crops the aim of comparable yields can be regarded as achieved in most cases (Table 2.4). With carrots one or both types of organic fertilization gave slightly higher yields (3-11% more) than the mineral treatment. The nutrient supply as an after-effect of the

Table 2.4: Yields of carrots, beetroot, potatoes and rye (dt/ha) and thousand seed weight of rye (g) in the period 1981-84 (Abele, 1987)

		MIN	CM	CMBD	low	med.	high
carrots	1981	713	710	759	692	726	764
	1982	602	667	637	605	657	645
	1983	736	784	860	731	792	858
	1984	615	625	631	573	632	666
beet-	1981	617	620	648	567	619	700
root	1982	618	724	693	544	710	782
	1983	682	648	732	562	702	798
	1984	624	574	612	519	602	688
pota-	1981	335	277	327	291	315	333
toes	1982	254	255	281	254	262	274
	1983	219	180	195	162	205	228
	1984	193	244	260	184	238	275
rye	1982	25.4	23.2	23.1	23.5	23.0	25.3
	1983	38.2	33.8	36.3	30.2	37.1	40.9
	1984	48.4	48.3	48.7	39.8	48.8	56.8
rye	1982	27.7	28.5	29.7	29.3	28.0	28.6
TSW (g)	1983	29.6	29.5	30.4	29.7	30.0	29.8
	1984	33.2	35.2	34.5	34.6	34.1	34.2

previous years obviously was sufficient, even in 1984, when CM and CMBD received no fertilization. In 1983 the biodynamic treatment gave an exceptionally high yield of 860 dt/ha which is 10 and 17% more than the other treatments. The beetroot yields were on average lower than the carrot yields. As a rule, yield differences between the mineral and both organic fertilizations are around 10% or less, without clear advantages or disadvantages of any treatment. The potato yields show a large variation over years. CMBD gave 195 to 327 dt/ha which is 8-18% higher than CM. The mineral fertilization had the highest yields in 2 years (21-22% more than CM), and showed no difference in one year. In 1984 the minerally fertilized plants suffered a severe attack by potato late blight; hence the yield in MIN was 21 and 26% lower than in the organic treatments. Only in 1984, the last year of this period, the rye yields were the same with all types of fertilization, at about 48 dt/ha. In the years before the yield was much lower, and MIN gave 5-13% more than CM or CMBD. The thousand seed weight of rye showed no clear effect of organic or mineral fertilization.

Taking account of the poor site conditions the yields in most cases are satisfactory. With all crops, increasing fertilizer levels had a very pronounced influence on yield in most years.

Quality Parameters

As product quality was the main topic of the first period a spectrum of diverse parameters was chosen in cooperation with experts in food quality research. The following parameters are examples referring to the vegetable products:

- chemical characteristics: contents of total nitrogen, nitrate, protein, free amino acids, phosphorus, potassium, sodium, magnesium, different sugar fractions, starch, organic acids, vitamin C, carotin, solanin;
- physical characteristics: skin stability of potato tubers;
- biochemical characteristics: enzyme activities, respiration, “aroma patterns”;
- microbiological/biochemical characteristics: degradation (dry matter loss, carbon dioxide development), darkening of potato extract.

Abele (1987) summarized his findings as follows:

- negative effects on quality parameters caused by higher levels of fertilization were smaller with application of composted manure compared to mineral fertilizer;
- application of biodynamic preparations together with composted manure partly had positive effects on quality and storage behaviour;
- under optimal storage conditions only small differences occurred;
- more clear differences have been observed after storage under stress conditions showing a better product quality of treatments with low fertilization level, composted manure or application of biodynamic preparations.

These statements suggest that there is a tendency towards better quality when composted manure instead of mineral fertilizer is used, although this is not provable in each particular case. Some of the observed effects varied depending on crop, year or experimental circumstances (storage conditions). Probable reasons have to be discussed. The question of to what extent the variety of a cultivated crop was a quality determining factor can not be taken into consideration here. With each crop only one variety was cultivated per year for reasons of space, and one or two varieties were used during the entire period. Some results will be described in the following to explain the above statements and to illustrate the difficulties of quality investigations.

The **nitrate content** of vegetables is not only a generally accepted quality parameter, it also has been determined already in a number of experiments on fertilization or on cropping systems as well as in comparison studies on organic vs. conventional farming at the farm and market level. In our experiment, as a rule the nitrate contents of carrots (Fig. 2.1), beetroot (Fig. 2.2) and potatoes (no figure) were lower with manure than with mineral fertilization. The lowest nitrate contents occurred in the first year 1981 (this indicates the poor mineralization ability of the sandy soil and the low intensity of its cultivation in the time before the experiment had started) and with the low fertilization levels of CM or CMBD.

At the medium and high fertilization levels, the manure fertilized **carrots** had around 160 ppm FM nitrate (between 115 and 200 ppm), apart from the small values in the first year. With mineral fertilization, however, the carrots had in the same years (1982-84) on average 227 and 325 ppm at the medium and high level, respectively. This is 142 and 203% compared to the organically fertilized carrots. The highest value in all years was 369 ppm with mineral and 200 ppm with manure fertilization

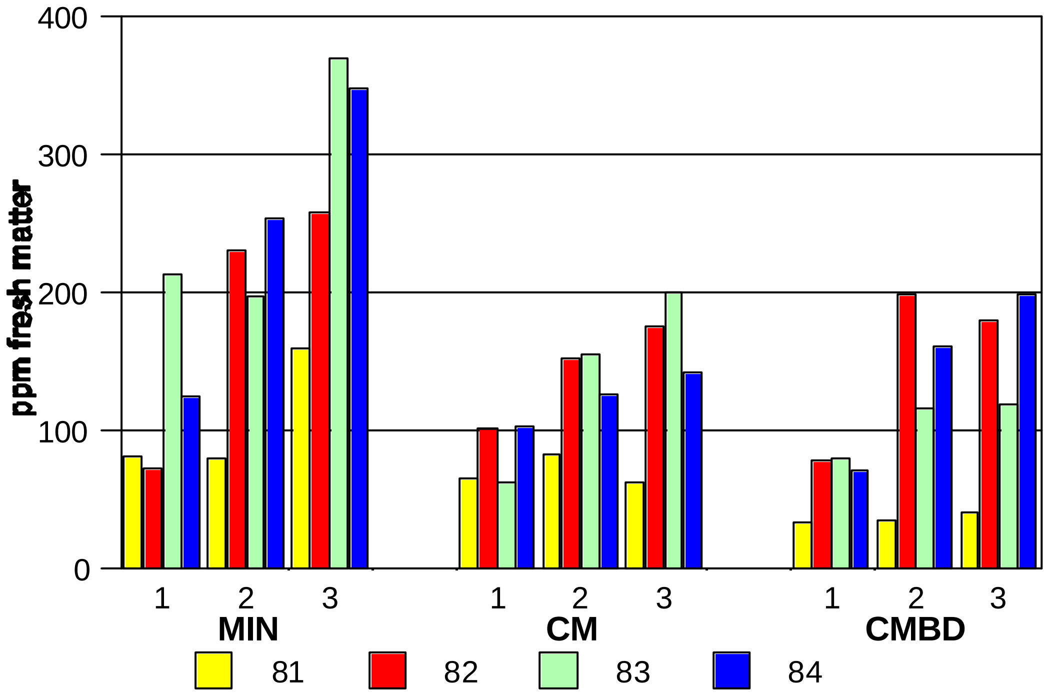

Fig. 2.1: Nitrate content in **carrots** (ppm FM) in 1981-84 depending on type and level of fertilization (Abele, 1987)

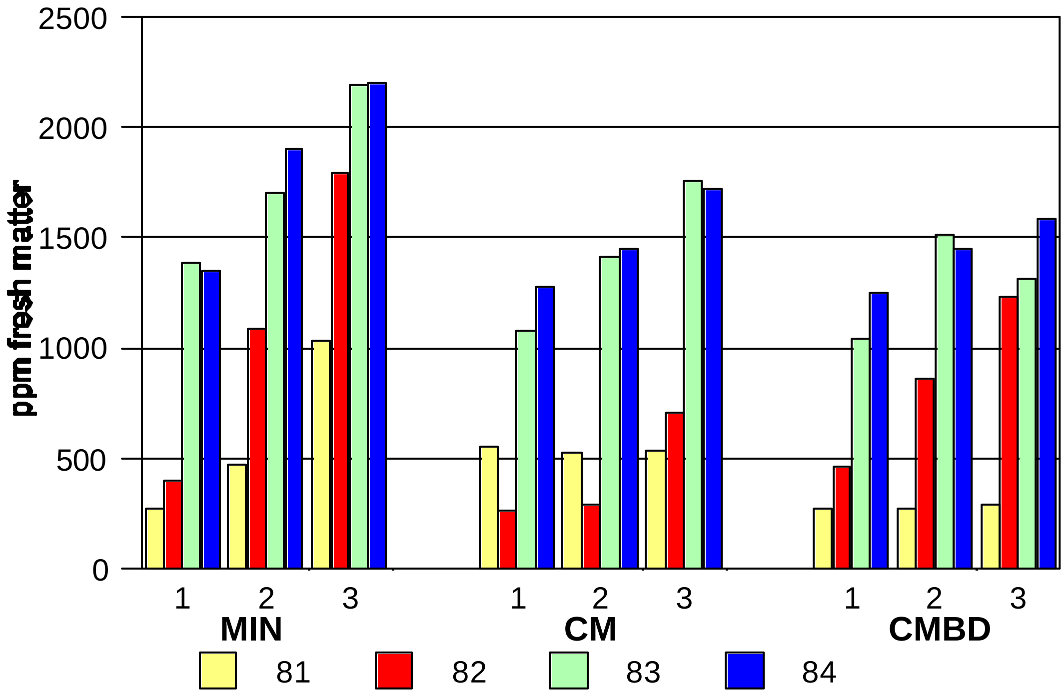

Fig. 2.2: Nitrate content in **beetroot** (ppm FM) in 1981-84 depending on type and level of fertilization (Abele, 1987)

Whereas the manure fertilization of carrots caused no clear difference in nitrate content between the medium and high application level, the higher amount of mineral fertilization increased the nitrate content by 41% (from about 230 to 325 ppm).

In **beetroot** the nitrate contents were generally higher but also relatively low in the first and second year (Fig. 2.2). Apart from MIN3 which had the highest values in both years, the results remained below 550 ppm FM in 1981 and below 1250 ppm in 1982. In the following two years nitrate contents were considerably higher and reflected the impact of increasing fertilization levels in the mineral as well as in the organic treatments. In all levels and both years MIN had the higher values. For the medium mineral fertilization 1708 and 1903 ppm FM were determined in the two years, i.e. 117 and 131% of the results of the corresponding manure treatments. The highest contents of these years were found in MIN3 with 2186 and 2200 ppm nitrate.

The finding of higher nitrate contents in minerally compared to organically fertilized vegetables is supported by other investigations with spinach (Ahrens *et al.*, 1983; Schudel *et al.*, 1979) and lettuce (Lairon *et al.*, 1983). Sometimes the nitrate accumulation in minerally fertilized crops may be temporary and can be reduced to a similar level as with organic fertilization if the growth period is long enough, as Smith & Hadley (1989) observed with lettuce. In some of these experiments, however, the organic and mineral treatments did not realize the same yield level, because the applied total nitrogen amounts were equal or similar for both types of fertilizers. In these cases it could be argued that the high nitrate contents are not a direct effect of mineral fertilization but rather of the more intensive growth and higher yield in the mineral treatment. In contrast to that, in our experiment the same yield level was achieved with organic and mineral fertilization, but nonetheless the nitrate content was lower in the organic treatment.

Vegetable products of organic farming have lower nitrate contents than conventional vegetables. Comparing 18 samples of each production system, 92 ppm nitrate have been found in organically grown carrots but 357 ppm in conventional ones (Pommer & Lepschy, 1985). In an 8 year trial growing biodynamic and conventional vegetables higher nitrate contents have been analysed in the conventional treatment in some years and crops (Reinken, 1983). Kallenbach (1987) reported on the same trial that leafy vegetables contained only half as much nitrate as conventional products. Based on own investigations and on a survey of literature other reports have also found that vegetables from organic farming contain less nitrate (Regierungspräsidium Stuttgart, 1986/87; Meier-Ploeger & Vogtmann, 1989). Vogtmann *et al.* (1984) and most of the other authors quoted here suppose the fertilization practices in conventional and organic farming to be responsible for different nitrate contents in products.

Altogether the nitrate content in vegetable can be regarded as a suitable parameter to indicate the effects of fertilization systems. The situation is somewhat more complicated with the biochemical and microbiological parameters which are used to describe the storage capability and behaviour of plant products. Partly the tests are difficult to carry out, partly the results are hard to interpret. One of the oldest approaches to quantifying storage ability (without spending some months for a storage period) is to use **degradation tests**. Normally

The sample is incubated under controlled temperature and humidity conditions for some days or 2-3 weeks. The dry matter loss or visual modifications (changed colour, growth of microbes) during incubation are usually taken as characteristics of the sample.

In the first period of our experiment, degradation tests were carried out with carrots, beetroot and potatoes analysing dry matter losses of grated material, respiration (carbon dioxide development) or darkening of potato juice. Because of technical and work-load reasons it was impossible to do each test in each year with each crop.

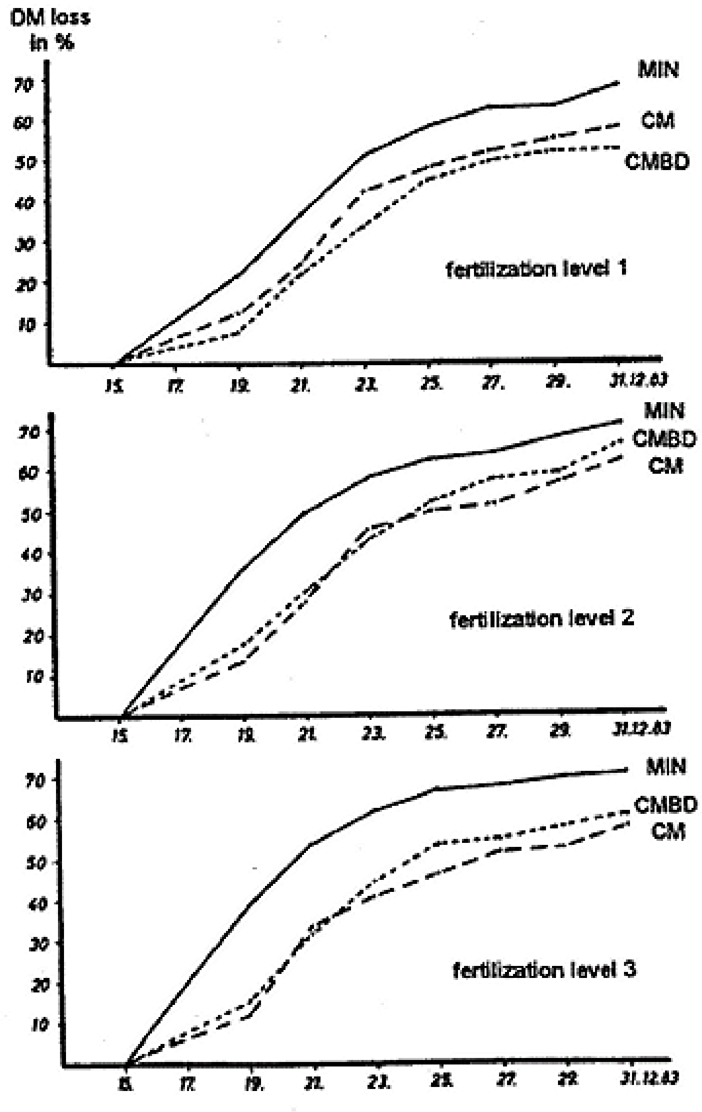

Fig. 2.3: Dry matter losses (%) of carrots in the 1983 degradation test depending on type and level of fertilization (Abele, 1987)

Figure 2.3 shows the **dry matter losses** of carrots in 1983. With all 3 fertilization levels the mineral treatments had higher losses than both manure treatments. Especially with the high level an intensive degradation of MIN can be noticed during the first days, whereas the processes appear to take place slower with the organically fertilized carrots. At the end of the test circa 55-60% of the dry matter was lost in CM and CMBD and 65-70% in MIN. The curves of CM and CMBD were very close to each other.

High dry matter losses suggest an increased metabolic activity which should lead to an intensive respiration. However, no clear differences in **respiration activity** were observed with the samples stored under optimal conditions (Abele, 1987). The author undertook additional tests with destroyed tissue and under **poor storage conditions** with carrots of the same year. Five months after harvest carrots cut in half were put into perforated plastic bags and stored for 3 weeks at 15°C. Most of the medium and high minerally fertilized carrots became dark brown, and the tissue was partly dissolved, whereas the carrots of all manure treatments showed only some small brown patches; the tissue was evidently less degraded. Similar differences in favour of organic fertilization were observed in 1981 when carrots cut in half were put into covered preserving jars and kept at room temperature for 5 weeks. Abele (1987; page 215-216) documented these observations by impressive pictures showing slightly or not much changed carrots of the manure treatments, while the others became quite unappetizing.

Degradation tests with beetroot that had been grated (in 1983) or cut into pieces (in 1981) gave in principle the same results (Abele, 1987; page 219-220). All samples seemed to be more degraded than the carrots, but only the MIN samples looked completely dark with rot or white with fungi. However, dry matter losses of the grated beetroot in the degradation test did not vary depending on the fertilization type, and the respiration activity during degradation (measured with samples of 1983 and 1984) showed the opposite ranking in both years. As with carrots, no clear differences in respiration occurred during optimal storage.

With potatoes a degradation test was carried out in one year (1981), storing tuber pieces in preserving jars at room temperature. With increasing mineral fertilization the extent of dark and rotten material was larger; the manure fertilized potatoes looked less changed and did not deteriorate in the higher fertilization levels (Abele, 1987; page 223). Further degradation tests (at 20°C) showed no clear effects of fertilization as regards dry matter loss (measured in 1983) and respiration (measured in 1983 and 1984). When complete tubers were stored at low temperature (6°C; in 1982 and 1983) the respiration activity of the mineral treatment was slightly lower than in CM and CMBD in both years.

Summarizing the findings of degradation tests, these showed that

- the tests did not give the same results with all vegetable crops or in all years; the results of carrots and beetroot were similar in some cases;
- tests with cut or grated vegetables kept at warm temperatures can distinguish samples better than tests under optimal storage conditions;
- microbial attack seems to be a more reliable parameter than respiration or dry matter loss of the sample.

Another parameter tested with potatoes was the **tissue strength** of the tubers. Abele

(1987) used a modified penetrometer which gave a load of 1 kg on 0.5 cm5 and measured how deep it penetrated into the tuber. All manure treatments showed the same stability without a perceptible effect of the fertilization level (Fig. 2.4). The MIN samples only had the same value of about 2.5 mm penetration depth at the low fertilization level. The tubers of the medium and high level were softer, the mark was up to 3.9 mm deep. Average tuber weight and tuber size distribution were fairly similar in all treatments (Abele, 1987; page 171). Hence, the measured difference can be accepted as characteristic of tissue stability. Unfortunately the author gives no information about which tubers he selected for the test and in which orientation he used them.

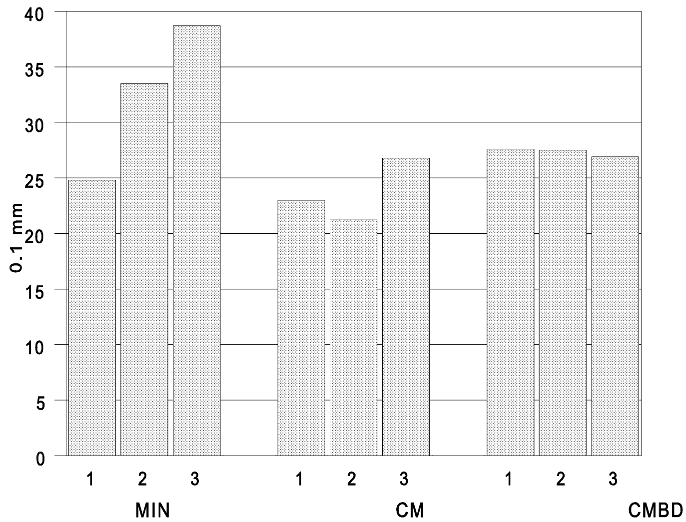

Fig. 2.4: Tissue strength of potato tubers after storage (harvested 1981): penetration depth of a load of 1 kg / 0.5 cm² (Abele, 1987)

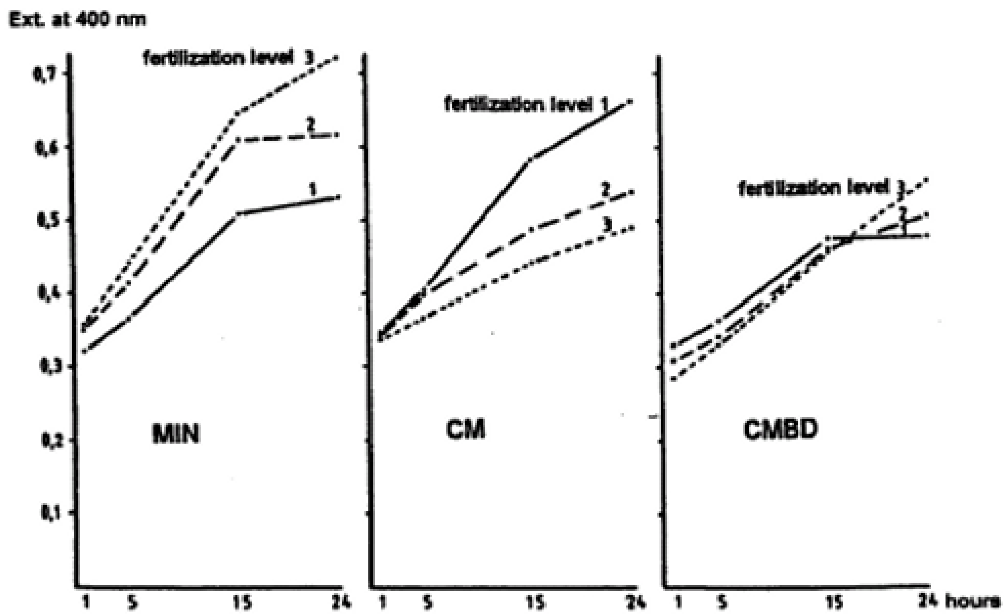

Fig. 2.5: Darkening of potato juice; extinction at 400nm wavelength during one day (Abele, 1987)

Another parameter specially used to describe potato quality was the **darkening of juice**, which is connected with the phenol oxidase activity (Abele, 1987). Abele used squeezed and centrifuged juice evaluated photometrically after 1 to 24 hours. In spite of centrifugation the juice was a little cloudy, and so an undisturbed reading was only possible in one year (1981).Clear differences only emerged towards the end of the test (Fig. 2.5). After 24 hours in the medium and, more pronounced, with the high fertilization level the MIN juice was darker than the samples of CM and CMBD. With the low level the CM juice was darker than the others. When mineral fertilization is increased the darkening seems to be intensified.

In other reports, darkening of cooked potatoes from manure and manure compost treatments has shown hardly any difference compared to an unfertilized control treatment, whereas darkening after mineral fertilization has been found to be about twice as much (Pettersson & Engqvist, 1964). A much darker juice was also found with conventional compared to biodynamic potatoes in a 9 year trial in Sweden (Pettersson, 1982).

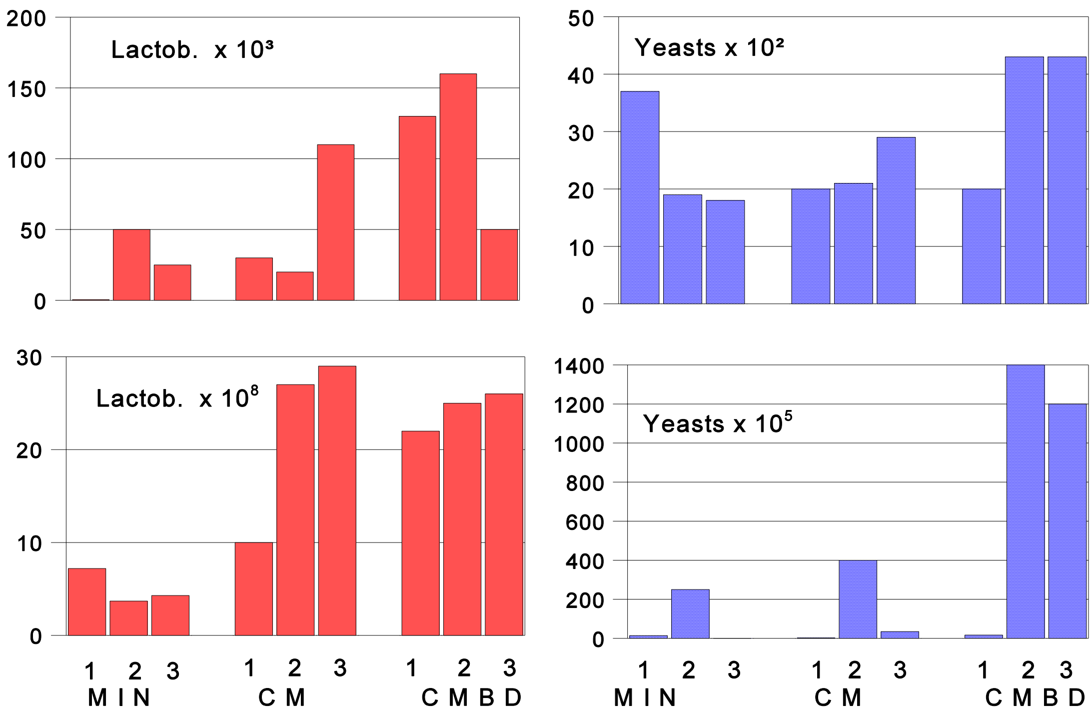

Fig. 2.6: Population densities of *Lactobacillus* (left diagrams) and yeasts (right diagrams) in a rye meal water mixture (above) and in a spontaneous sour dough of rye (below) (Abele, 1987)

Consumers do not like the discolouration (both of raw and cooked tubers). But a definite significance of potato darkening for human nutrition is not known. Therefore, the difficulty with this parameter is its interpretation rather than any unability to detect fertilization effects. One last parameter is to be presented here which also points to a dilemma of interpretation. Probably with respect to the bread baking process Abele (1987) investigated the population density of **useful microorganisms** with rye samples. In a mixture of rye meal and water the numbers of *Lactobacillus* organisms and yeasts were counted. Afterwards the same countings were done in the ‘sour dough’ originating spontaneously from the set-up mixture kept warm for 3 days. Altogether the population densities were higher with the manure treatments and in many cases more developed with the biodynamic treatment CMBD than with CM (Fig. 2.6).

Abele (1987) did not discuss or interpret the different population densities, so it should be done here. As both groups of microorganisms play an important role in dough and bread production, a sample with high numbers has to be classified positively expecting that this meal will make the production process easier, quicker or will help to improve it by some other path. However, if the samples were beetroot instead of rye the same result of high numbers of microorganisms will normally be classified negatively. In this case the test is called degradation test, and the high degree of microbial attack indicates a poor durability as outlined above. The opposite interpretations are not a matter of microbiology, for the organisms involved can be the same in both cases. *Lactobacillus* species can produce sour dough with rye as well as sour vegetable with beetroot. A positive or negative evaluation also can not be concluded from the plant product, as from the rye kernels' point of view it makes no difference to be digested by *Saccharomyces cerevisiae* (which is estimated by bakers and brewers) or by *Aspergillus flavus* (which is feared as an aflatoxin producer).

In every case the evaluation is only based on **human priorities**, expectations and considerations of usefulness. This is not only true as regards product durability or digestion but also for parameters like the contents of vitamin C or nitrate. All these (and many others) finally make sense only in relation to human (or animal) nutrition and its requirements of what is needed and what is harmful. Product quality under these aspects is first of all defined by human priorities, and is just as constant (as human beings are) on the one hand and as variable (by individual, cultural, historical factors etc.) on the other hand.

If it is accepted that food quality has a human, a social dimension, other political, social, psychological and economic criteria have to be elaborated and considered - even criteria which can not be analysed with the product itself but lie outside of it. This means that all circumstances and consequences of food production, processing, distribution and consumption systems need to be used as quality parameters in addition to product contents. A comprehensive approach in this sense is the concept of Leitzmann & Sichert-Oevermann (1988).

If *human* (not product) criteria actually decide whether degradation is positive (i.e. if useful for food production or feeding) or negative (because decayed vegetables cannot be eaten or sold any more), it is impossible to interpret high and low degradation as *generally* negative or positive, respectively, this being an immanent characteristic of the product. Abele (1987; page 132-136) and some other authors, however, support this general view stressing the positive association of a less degraded product which demonstrates its maturity, stability, its coming to rest. But this view appears to be unsuitable to interpret all different situations of degradation and, therefore, yields no determinants of food quality.

SECOND PERIOD: FERTILIZATION WITH TOTAL NITROGEN EQUIVALENTS

At the beginning of the second period soil biology was the focus of attention. But investigations on food quality were done as well.

Fertilization treatments and yields

Since 1985/86 another fertilization concept is used which is based on the calculation of equivalent amounts of total nitrogen in MIN compared to CM and CMBD. By this the organic treatments receive much lower amounts of manure than in the first period. The gradation of fertilization levels is 50, 100, 150 kg N/ha to root crops and 60, 100, 140 kg N/ha to cereals. These levels represent 0.9, 1.4 and 1.8 livestock units per hectare, respectively.

The yields of all crops varied greatly from year to year. Depending on crop the organic and mineral fertilization realized different yield ratios (Table 2.5). The average yields of potatoes and rye were higher with mineral fertilization. The manure treatments only achieved 87 and 66% of MIN with these two crops; i.e. the winter cereal was particularly limited by the organic fertilizer. Quite another yield pattern was observed with spring wheat, which gave on average the same yield of 33 dt/ha with all types of fertilization. Increasing levels of fertilization caused higher yields with all crops, but spring wheat yield was more constant also with regard to this. Further influences of fertilization and site conditions on yields are reported elsewhere (Raupp *et al.* 1994; Raupp, 1996).

Table 2.5: Average yields (dt/ha) of rye (6 years), spring wheat (10 years) and potatoes (5 years) in the period since 1985 depending on fertilization

	fertilization type			fertilization level		
	MIN	CM	CMBD	low	medium	high
rye	36.4 a	27.3 b	28.5 b	25.8 a	30.9 b	35.5 c
spring wheat	35.0	35.2	35.6	33.4 a	35.5 ab	36.7 b
potatoes	273 a	246 b	262 a	229 a	264 b	287 c

Biochemical and microbiological parameters

Stimulated by the **degradation tests** of the first period, similar investigations have been carried out during the last years. The results with potatoes of 1993 are shown in Table 2.6. The decomposition of grated tubers was quantified by the dry matter loss after 10 and 14 days of incubation, and the change of extracted material was quantified by darkening (extinction) and by electrical conductivity. In accordance with the results reported above no substantial differences occurred in the dry matter loss at both dates, but were indeed apparent in the extract darkening after 48 hours (Abele did his last reading after 24 hours.). The extracts of tubers from minerally fertilized plants were darker than extracts of the manure treatments. Increasing fertilization levels also caused a more intensive darkening of the extracts. The organic fertilization gave lower electrical conductivity values too, but the differences to MIN were only significant on day 3 of the test. Conductivity was clearly also increased by higher amounts of fertilizers. Potatoes grown in the next year showed differences in extract conductivity in the same way but to a lesser extent, in most cases not being significant (Schulz & Köpke, 1995).

Table 2.6: Quality parameters of potatoes in 1993 depending on fertilization: degradation after 10 and 14 days (% DM loss), darkening (extract extinction at 970nm) after 48 hours, electrical conductivity (μS/cm) on days 1, 3 and 9 (Sabiwalsky, 1995)

	fertilization type			fertilization level		
	MIN	CM	CMBD	low	med.	high
degradation 10	26.6	29.4	23.7	25.7	26.6	27.4
degradation 14	37.4	35.6	32.1	30.5	37.6	36.9
darkening	105.31 a	71.67 b	65.2 b	75.82 a	80.36 ab	86.01 b
conductivity 1	718	689	689	652 a	719 b	725 b
conductivity 3	1239 a	1158 ab	1117 b	1105	1203	1205
conductivity 9	1331	1272	1258	1206 a	1318 b	1337 b

As already discussed the dry matter loss during incubation is not a suitable parameter to express the decomposition of a sample material. Therefore, it doesn't mean anything if this parameter shows no differences, while other parameters show differences. But even when results show differences in the same way, as darkening and conductivity do here, the significance of parameters and results needs to be discussed.

Darkening of potato tubers is based on various enzymatic processes with phenolic acids and oxygen being involved (references quoted by Brouwer, 1976). In destroyed tissue these reactions take place more intensive (perhaps more easily, perhaps more rapidly), or the dark substances are not or not effectively metabolized. For that reason it can be regarded as a capability of a vital - or rather intact - tuber to stay less coloured after being destroyed or damaged. This capability has been found to be more pronounced with samples of manure fertilized compared to minerally fertilized plants. However, it was not possible yet to find any correlations between darkening and other parameters of durability or vitality. Thus, the significance of phenol oxidation and re-metabolization in plant products is not completely understood. The darkening of potatoes is a parameter that is able to reflect fertilization effects; the background of food quality and product vitality of this parameter needs further investigation.

An increasing **electrical conductivity** is assumed to be an indicator of decomposition of organic matter because of the formation of ions and charged molecules when protein, carbohydrates etc. are mineralized. But this parameter is not very specific, neither concerning the substances being decomposed, nor concerning the acting principles (enzymes, organisms). Results can not be interpreted with respect to these factors. It has been observed that the conductivity rises quickly at the beginning of incubation. After some days a final level is reached without further change. The reason might be that some mineralized substances are simultaneously used to synthesize other (less charged or uncharged) organic compounds. This part of the process is also poorly understood for extracts of plant products. Another question is why the observed differences caused by fertilization treatments are less constant from year to year. A possible reason might be that the saprophytic microflora involved in the decomposition vary depending on sample and experimental conditions. Altogether a number of questions has to be answered in order to develop the parameter of electrical conductivity for quality assessment.

Table 2.7: Spoilage, contents of nitrate and free amino acids and degradation of beetroot in 1986 (Hermanns-Sellen, 1989)

	MIN	CM	CMBD	average
	weight % spoilage after storage			
low	6	13	12	10.3
medium	5	35	15	18.3
high	1	10	12	7.7
average	4.0 a	19.3 b	13.0 b	
	nitrate (mg/g DM) after harvest			
low	23	23	29	25.0
medium	32	18	24	24.7
high	44	22	27	31.0
av.	33.0 a	21.0 b	26.7 ab	
	free amino acids (mg/g DM) after harvest			
low	28	13	19	20.0
medium	42	10	10	20.7
high	57	16	19	30.7
av.	42.3	13.0	16.0	
	degradation (% DM loss) **before** storage			
low	34	30	35	33
medium	36	27	35	33
high	38	33	32	34
av.	36	30	34	
	degradation (% DM loss) **after** storage			
low	36	32	37	35
medium	35	30	35	33
high	33	35	36	35
av.	35	32	36	

The **beetroot** of 1985 and 1986 was investigated after harvest in autumn and in the next spring after storage (Hermanns-Sellen, 1989). In Table 2.7 some of the results are listed. Only the beetroot of 1986 is taken into account because in the other year the yield level and growth conditions were quite unusual (extremely dry weather and severe damage caused by hail and by nematodes resulted in one quarter of the yield in 1985 compared to 1986).

In this case the durability was evaluated as the percentage of **spoilage**, i.e. the weight of rotted in relation to healthy beetroot after storage (4.5 months at low temperature). With the mineral treatment spoilage losses of 4% were considerably lower than with manure fertilization (13 and 19%). The contents of **nitrate** were much higher after mineral fertilization, 33 instead of 21 or 27 mg/g dry matter. The **free amino acid** contents differed in the same way, 42 mg/g dry matter in MIN but only 13 and 16 mg/g in CM and CMBD. Both nitrogen fractions were determined after harvest and reflect the intensity of nitrogen supply to the plants. According to the above mentioned concept of maturity and stability of a product expressed by its well-balanced components, the higher nitrate and free amino acid contents in the mineral treatments should lead to the expectation of a poor durability. But the opposite occurred here.

The dry matter losses in **degradation tests** were evaluated before and after storage. The values were around 33-34% in all treatments at both dates and showed no correlation to the results of spoilage losses. This observation supports the conclusion that the dry matter loss of grated and incubated samples is not a viable quality parameter.

Protein quality of wheat

In contrast to vegetables the durability of cereals is not an issue. Instead, many quality parameters of cereals deal with matters that are important for bread production and for alcoholic fermentation technology. Whereas protein quality largely depends on the genetic constitution of the plants, the amount of (crude) protein can be influenced by fertilization. For this reason in conventional farming the late fertilizing of nitrogen is recommended (e.g. Kübler, 1994). As expected the different nutrient dynamics of organic and mineral fertilization also affects protein parameters.

Table 2.8: Quality parameters of **spring wheat**, averages of 1985-88: contents of crude protein (%), gluten (%), rising number, maltose content (%), thousand seed weight (g), hectolitre weight (kg/hl) (Raupp *et al.* 1994)

fertilization	% CP	% gluten	rising	% maltose	g TSW	kg / hl
MIN	11.7 a	29.0	14.9 a	1.89 a	38.9 a	76.6 a
CM	11.1 b	29.4	12.8 b	1.79 b	41.5 b	78.5 b
CMBD	11.2 b	29.6	13.2 b	1.74 b	41.5 b	78.4 b
low	10.5 a	24.8 a	11.5 a	1.74 a	42.3 a	78.6 a
medium	11.2 b	28.3 b	13.6 b	1.79 a	40.6 b	78.0 a
high	12.3 c	32.7 c	14.2 b	1.88 b	39.0 c	76.8 b

In the years 1985-88 some parameters of baking quality were investigated (Raupp *et al.*, 1994). Mineral fertilization increased the parameters of rising number, maltose and crude protein content a little, which is assessed positively for baking (Table 2.8). (The rising number according to Berliner is an indicator of the capability of taking up water but not to be confused with the sedimentation value according to Zeleny. With the same sample the Zeleny value is higher than the Berliner number.) The higher fertilization levels had the same effects as mineral fertilization. The grain characteristics of thousand seed weight and hectolitre weight were more developed in CM and CMBD. The lower crude protein contents with the manure treatments partly may have been a consequence of the somewhat larger grain size. The gluten content showed no effect of the type of fertilization; it only was increased from 24.8 up to 32.7% by the higher fertilization levels.

In one year winter wheat was cultivated instead of rye. Protein content was also increased by mineral fertilization, 13.8% in MIN instead of 10.8% in CM; manure with the biodynamic preparations gave more protein, 11.2% (Table 2.9). In contrast to spring wheat the gluten content in winter wheat was much higher with mineral (38.6%) compared to manure fertilization (28.7 and 28.1%). Gluten elasticity showed no effect. The various levels of fertilization

Table 2.9: Quality parameters of **winter wheat** in 1993: content of protein (%), gluten (%) and gluten elasticity (cm/g) (Kieffer, 1995)

	MIN	CM	CMBD	av.
		% protein		
low	11.3	10.4	10.4	10.7 a
medium	13.8	10.5	10.8	11.7 ab
high	16.2	11.4	12.3	13.3 b
av.	13.8 a	10.8 c	11.2 b	
		% gluten		
low	29.2	27.4	26.1	27.6 a
medium	41.2	28.4	27.1	32.2 b
high	45.5	30.2	31.1	35.6 c
av.	38.6 a	28.7 c	28.1 b	
		gluten elasticity (cm/g)		
low	9.3	8.9	8.7	9.0
medium	10.1	10.0	9.3	9.8
high	10.4	8.9	10.1	9.8
av.	9.9	9.3	9.4	

had the same influences on protein and gluten contents as described with spring wheat.

Both cereals show the importance of sufficient amounts of fertilizer in order to achieve high protein and gluten contents. The difference between organic and mineral fertilizer, however, is clearly expressed only with winter wheat. In this case mineralization of manure probably is limited because the growing period is partly during the cold season, in contrast to spring wheat. Another reason might be the different position in the crop rotation. Winter wheat coming after potatoes was not very favoured, but spring wheat in 2 of the 4 years (1985-88) came after alfalfa. The positive effect of a crop rotation including alfalfa has also been observed by Borghi *et al.* (1995).

Feeding experiments with rabbits

Feeding experiments with animals are one of the most complex tools for food quality assessment. While relatively complicated and costly to carry out, these tests are quite close to the real purpose of foods, although animals instead of human beings are the test organisms, which implies that no particular effects on humans can be identified. The parameters evaluated with the animals are normally health and fertility.

In feeding experiments with rabbits, carrots from the mineral and the manure treatments have been compared (Brandenburger, 1994). Two different tests were performed: i) food preference tests with carrots being the only component and ii) trials with 3 subsequent generations fed with a complete diet of organically or conventionally cultivated components including the carrots of our field trial.

The **food preference test** was carried out twice. The author gives no information whether the organic carrots were taken from CM or CMBD or from a mixture of both. In the first trial the rabbits preferred the organically fertilized carrots on 8 of the 12 days. However, in the second test the intake of both samples was very similar (Fig. 2.7). The regression lines were very close to each other. In both trials differences were not statistically significant, leading to the conclusion that the type of fertilization did not clearly influence the carrots. In addition to the characteristics of the carrots certain experimental circumstances possibly contributed to the results. Looking at the symbols in Figure 2.7 a considerable variation of food intake in both tests and of both samples is evident which makes it difficult to obtain significant differences between the samples. Furthermore, it is conceivable that diet peculiarities which the animals are used to have an influence on their preference during the test. The rabbits were kept conventionally in the time before the test. Thus, if typical things exist and can be recognized by the animals, the MIN carrots should have been in favour. In both tests different animals were used; hence, a habituation to one or the other sample was not possible.

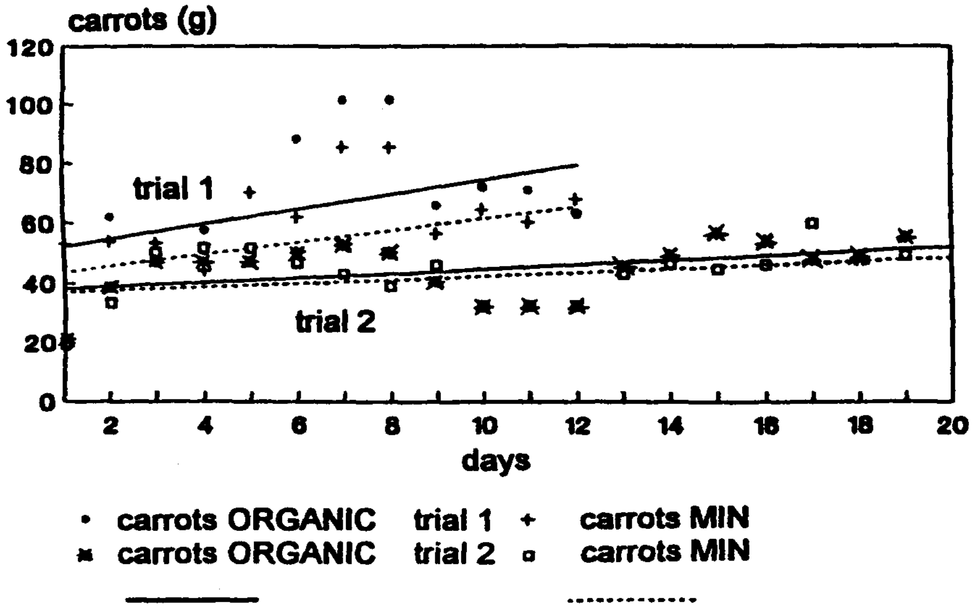

Fig. 2.7: Daily intake of carrots (g) in food preference tests with minerally (MIN) and manure (organic) fertilized carrots offered to rabbits (Brandenburger, 1994)

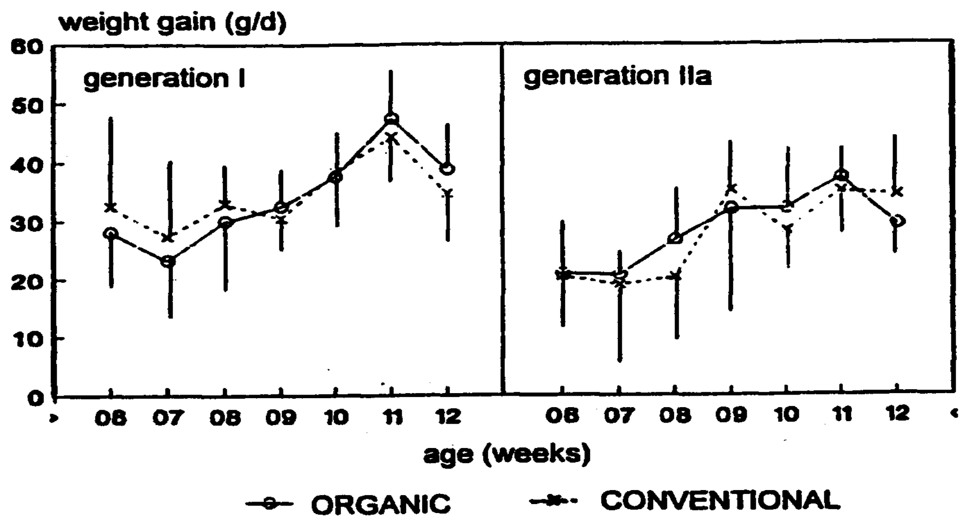

Fig. 2.8: Daily weight gain (g/d) of young rabbits fed with an organically or conventionally grown diet (Brandenburger, 1994)

In the other experiments extended over 3 generations cumulative effects and habituation were basically possible. But nonetheless most of the results were not quite clear. As an example the **daily weight gain** after weaning is shown in Figure 2.8. Because of large standard deviations growth rate has to be regarded as similar in both groups. The figure illustrates that individual differences among the animals might be an important factor, which can only be equalized by higher numbers of animals per group and strictly controlled conditions.

The results of the **fertility parameters** Brandenburger (1994) investigated were summarized by him as follows (differences were statistically significant except where otherwise stated):

- in the CONVENTIONAL group the offspring had higher weights at birth in generation I and higher weights at weaning and daily weight gains in generation IIb;
- in generation IIa the higher weights at weaning were observed in the ORGANIC group;
- in all three generations higher percentages of deadborn offspring occurred in the ORGANIC group;
- pregnancy rates and litter size were higher in the ORGANIC group, after natural mating as well as after artificial insemination (differences were not statistically significant);
- no similar or equal effects were observed in all generations.

Beside the experimental problems of feeding experiments the interpretation of these and other results has to be discussed thoroughly. The results are of a certain importance to animal nutrition. But apart from this, with which meaning can the findings about litter size, pregnancy rate etc. of rabbits be transferred to the circumstances of human beings?

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3. Quality investigations in the long-term DOC-trial

By Th. Alföldi [2], P. Mäder [1], U. Niggli [1], E. Spiess [3], D. Dubois [2] and J.-M. Besson [2]

SUMMARY

Since 1978, we are comparing the three farming systems – biodynamic (D), organic (O) and conventional (C) – in a long term field trial (DOC-trial). The systems differ mainly in fertilisation and plant protection. Tillage, varieties and crop rotation are the same for all systems. The seven year crop rotation consists of potatoes, winter wheat 1, beetroot, winter wheat 2, barley and two years of grass-clover-meadow. The conventional treatment is managed according to integrated production, i. e. in the DOC-trial no extreme production systems are compared. Crop yield and quality as well as effects on soil processes have been evaluated. In this paper we focus on quality investigations. The results for each crop are based on at least three cropping years.

Market quality (sizing) of biodynamically and organically grown potatoes was 25 % lower compared to the conventional potatoes, whilst the proportion of marketable beetroot was the same in all systems. Potassium content of potatoes and beetroots was 20 % lower in both biological treatments, but the magnesium content was lower only for potatoes. The nitrate content of organically grown beetroot was 25 % lower compared to the conventional beetroot. The content of vitamin C, saccharose and storability of beetroot was not significantly affected by the systems. The grains of wheat and barley of the biological treatments (D and O) had a higher calcium content than the grains of the conventional treatment (C). Neither the protein content nor the baking capacity of wheat was different among the farming systems. For grass-clover, the biodynamic and organic treatments had lower potassium but higher calcium and magnesium values than the conventional treatment.

Holistic methods for quality visualisation, like the picture creating method, allowed for a distinct grouping and identification of encoded samples. However, for a qualitative valuation of these methods further research is necessary.

INTRODUCTION

Consumers of organically grown food expect a higher product quality, in the sense that it is not only produced in an environment-friendly way but also of a better nutritional value. Organically and conventionally grown crops can be compared analysing products offered on the market, products from selected organic and conventional farms or crops cultivated

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within comparison trials (Vetter *et al.*, 1987). There are numerous investigations on the quality of conventionally and organically grown products. However, comparisons were rarely done with the same variety being produced under similar environmental conditions (Woese *et al.*, 1995).

Quality investigations with crops from comparison trials have the advantage that the origin of the samples is well known and so called "pseudo" biological products can be excluded. In contrast to crops from different farms, crops from plot trials are influenced exclusively by different management practices and therefore potential differences can be explained better. On the other hand, a generalisation of results from plot trials has to be done with care.

In addition to the quality aspects mentioned above (health value, environment-friendly production), the term food quality considers aspects with different significance depending on the context and expectations such as external quality, technological quality and nutritional value. Several authors included psychological and social components (e.g. Meier-Ploeger, 1995)

The DOC-trial was started in 1978 to compare the long term effects of biodynamic (D), organic (O) and conventional (C) farming systems on soil fertility, yield and product quality. This contribution summarises the results of the quality investigations during the second crop rotation period (1985-1991). The main topic of these investigations are chemical and physical analyses covering the aspects of technological and nutritional quality. Picture creating methods, food preference tests and storage trials were also included as holistic methods.

MATERIAL AND METHODS

For a detailed description of the experimental set up see Besson & Niggli (1991) and Alföldi *et al.* (1995). The quality parameters are listed in Table 3.1. The methods used are described in the corresponding references.

Table 3.1: Overview on crop quality parameters assessed in the DOC-trial.

Crop	Source	Parameter
Potatoes Beetroot	Besson *et al.*, 1991 Besson *et al.*, 1993	sizing (market quality), dry matter, starch, nitrogen, mineral and trace element content (P, K, Ca, Mg, Mn, Zn, Cu)[1]
Beetroots	Mäder *et al.*, 1993	*additional quality investigations:* nitrate, saccharose, vitamin C, storability, picture creating methods, food preference test
Wheat Barley	Spiess *et al.*, 1993 Besson *et al.*, 1992a	thousand seed weight (TSW), nitrogen, mineral and trace element content [1], baking quality
Grass-Clover	Besson *et al.*, 1992b	NEL- (energy), APD- (protein), nitrogen, mineral and trace element content [1]

[1] For mineral and trace element content P, K, Ca, Mg, Mn, Zn, Cu: see Spiess *et al.* (1995)

RESULTS AND DISCUSSION

In the following the results are listed according to the different quality aspects. The results are summarised in Figure 3.1 and 3.2. The relative differences (in %) between both biological treatments (D2 and O2) and the conventional treatment (C2) are shown.

Technological value

Sizing

In the average of three years, the proportion of marketable potatoes (42.5-70 mm sizing) in the biological treatments (D2 and O2) was about 25 % lower than in the conventional treatment (C2). A separation of sizing classes showed that the biological treatments also had a significantly higher number of tubers of the size 42.5-50 mm. There was an important correlation between the fertiliser level and the size of the tubers in all years. Disease incidence of tubers was similar with all treatments.

Among all treatments the proportion of marketable size classes of beetroot was the same (150-1000 g), but there were more beetroot of the biological treatments in weight class I (150-500 g) than in the conventional treatment. Neither the thousand seed weight nor the part of first quality grains of wheat and barley differed between the farming systems.

Storability

Storability tests were carried out with beetroot during three years and with potatoes in one year and did not reveal any differences. These tests were carried out in a natural cellar under very good conditions. In the comparison trial of Darmstadt, Abele (1987) found a better storability of organically fertilised beetroot, but only under suboptimal storage conditions (unfavourable temperature and humidity, cut samples).

Nutritional value

It is rather difficult to decide whether a certain content of minerals is to judge favourable or unfavourable for human nutrition, because standards of minimal and maximal contents of minerals exist only for animal nutrition (Spiess *et al.*, 1995). Furthermore, interrelations between different minerals often play a decisive role (Woese *et al.*, 1995). As it is not possible to make a valuation of the results, we discuss our findings with results from other comparison trials.

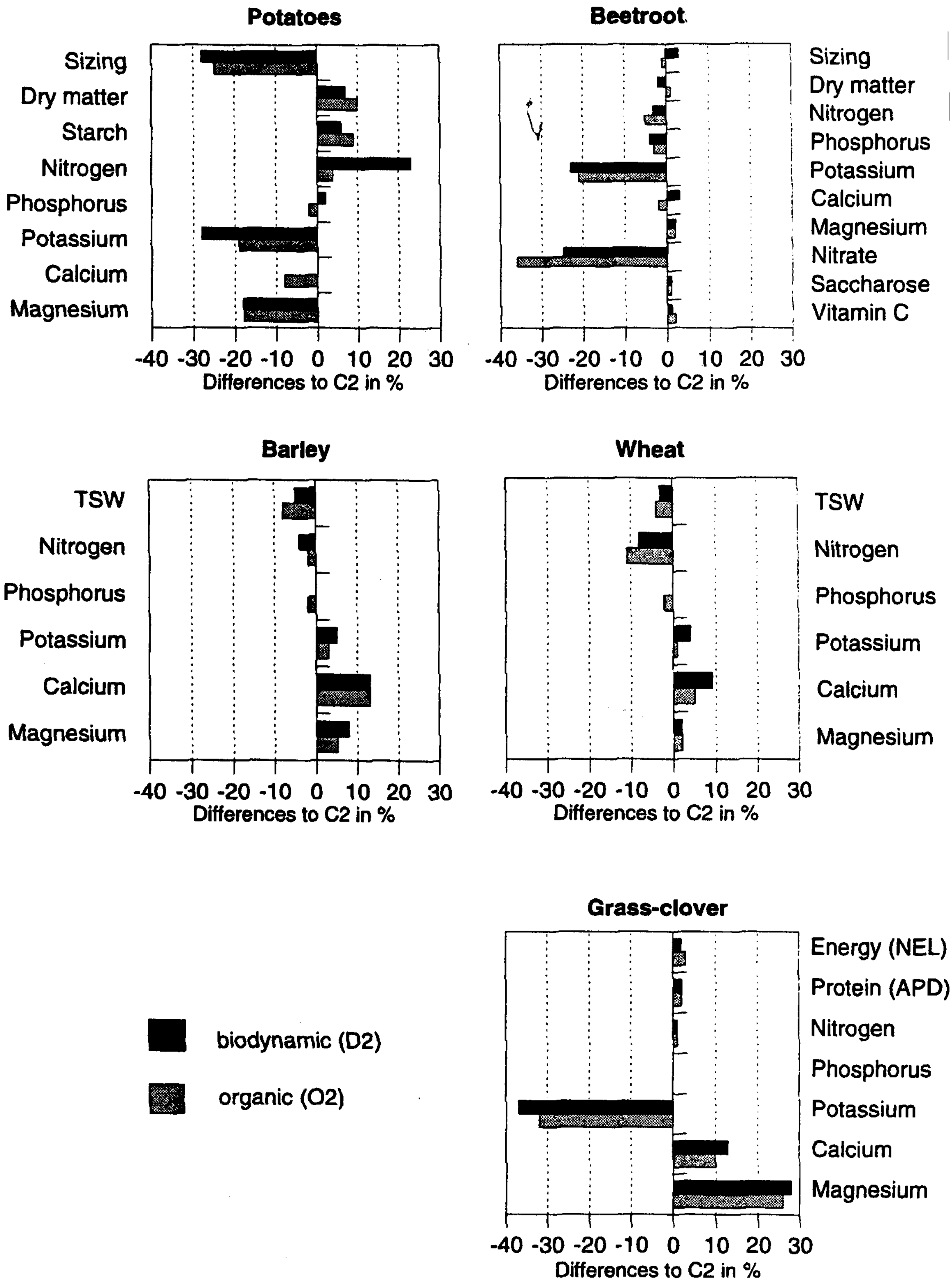

Fig. 3.1: Comparison of different quality parameters for crops of the DOC-trial. Differences of the treatments biodynamic (D2), organic (O2) compared to the conventional treatment (C2) in %. Average of three or six years (grass-clover) during the second crop rotation period.

Content of nitrogen and minerals

The nitrogen content of biodynamically grown potatoes was 25 % higher compared to the other treatments. The biodynamic and organic potatoes contained 20 % less potassium and magnesium, respectively. A lower content of potassium was also found in organically grown beetroot.

The comparison of nitrogen and mineral contents of organic and conventional potatoes and beetroot shows different results from study to study. In the Darmstadt-trial, where the fertilisation system was set up in a way that all treatments reach the same yield level, phosphorus and potassium contents were found to be considerably higher in the organically fertilised potatoes compared to the minerally fertilised crops (Abele, 1987). Wedler & Overbeck (1993) also found higher contents of nitrogen, potassium and magnesium in potatoes grown on the biodynamic farm Boschheide compared to potatoes from a neighbouring conventional farm. In the farm comparison study of Hansen (1981) conventional and biodynamic potatoes showed no differences in the content of nitrogen and minerals, whereas in conventional beetroot potassium content was higher than in biodynamic beetroot. In 72 samples of organically and conventionally grown potatoes, Vetter *et al.* (1983) did not find the mineral content to be significantly different. In the comparison trial of Auweiler neither with chemical analyses nor with holistic methods significant differences of crop quality from different farming systems could be detected (Reinken *et al.*, 1990).

In the DOC-trial, the nitrogen content of wheat was 10 % lower in the two biological treatments than in the conventional wheat. Woese *et al.* (1995) summarise that a tendency of lower nitrogen and protein content was observed in most comparison studies. However, the authors also stated that good baking quality in organic farming could be reached when appropriate varieties were chosen. In a baking test, carried out with wheat from the DOC-trial, no significant differences of the breads were observed (variety Ramosa, 1993). The farming systems did not influence the nitrogen content of the other crops in the DOC-trial. Further, wheat and barley grains of the biological treatments had higher calcium contents than the grains of the treatment C2. In his comparison study, Seibel (1982) observed no relevant differences for the mineral content of organically and conventionally produced wheat.

Clear differences of mineral content were measured for grass-clover. The biodynamic and organic treatment had lower potassium and higher calcium and magnesium values.

As shown in Figure 3.2, the manganese content of biodynamic and organic beetroot was 30 and 50 % lower, for the other crops a tendency to lower values in the biological treatments was observed. Spiess *et al.* (1995) calculated a negative correlation between the manganese content and the pH-value of the soils for most crops. Further, the level of fertilisation in each farming system had a stronger influence on the manganese content of crops than the cultivation system. The content of zinc was lower in the biological treatments for three out of five crops.

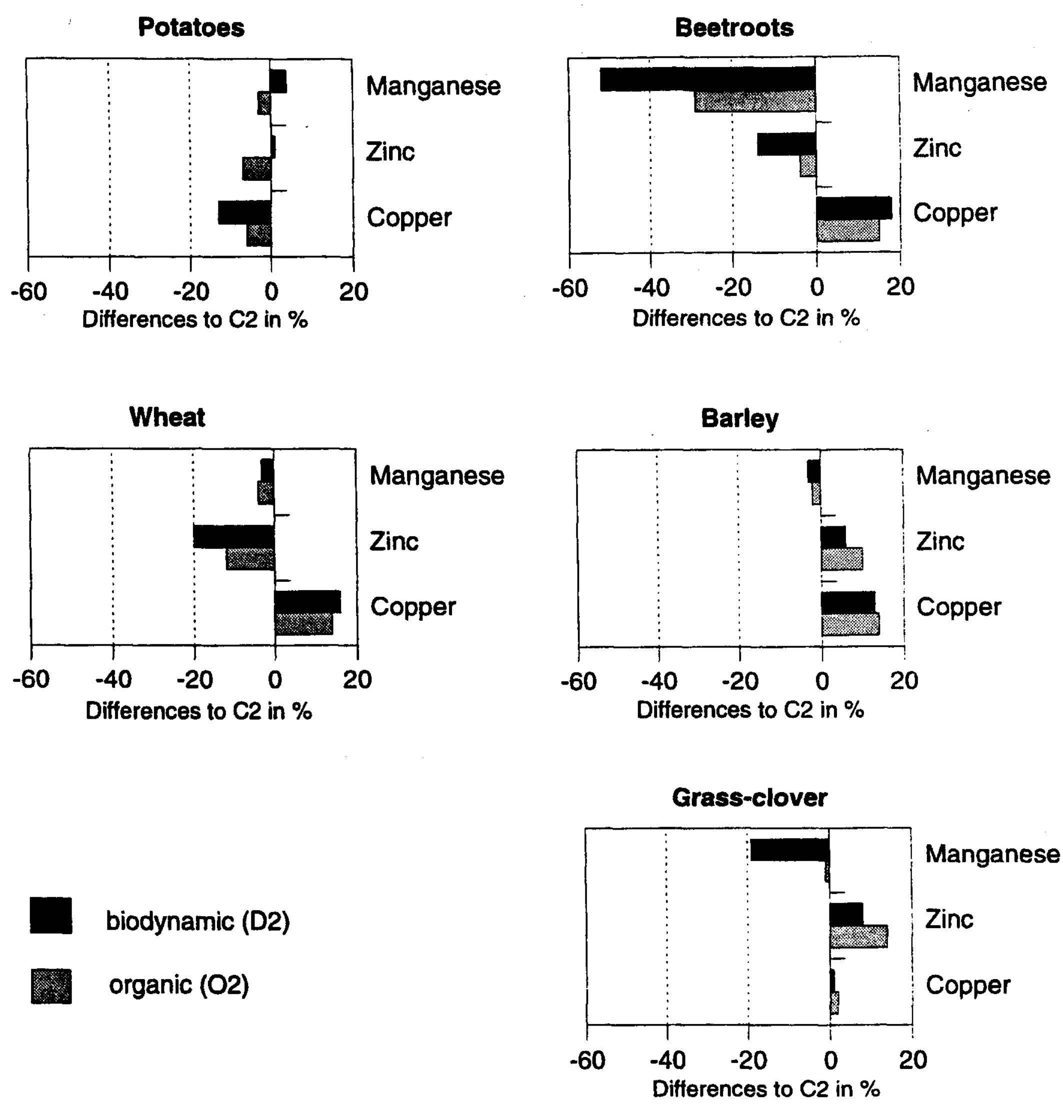

Fig. 3.2: Comparison of the content of manganese, zinc and copper in crops of the DOC-trial. Differences of the treatments biodynamic (D2) and organic (O2) compared to the conventional treatment (C2) in %. Average of three or six years (grass-clover) during the second crop rotation period.

Further quality investigations

Saccharose and vitamin C content of beetroot were similar in all farming systems (Fig. 3.1). Also beetroot of the comparison trial in Auweiler did not differ in their vitamin C content. Woese *et al.* (1995) reviewed analyses of vitamin C, mainly carried out for carrots and several leafy vegetables (spinach and lettuce). Half of the reported investigations revealed no differences, the other half showed a tendency of slightly higher vitamin C contents of organically grown vegetables. With reference to saccharose as well as to ructose and glucose, Woese *et al.* (1995) did not find any differences between farming systems in 16 comparison trials.

In the DOC-trial, the nitrate content of organically grown beetroot was 25% (D2) and 35% (O2) lower compared to C2. Woese *et al.* (1995) listed 39 comparison trials dealing with the nitrate content of vegetables of different farming systems. Only in one study a higher nitrate content was found in biological vegetables, all the other studies found clearly lower nitrate contents in biological vegetables. However, Woese *et al.* (1995) also pointed out that no conclusions can be drawn with respect to the toxicological relevance, as most of the nitrate values of these studies are related to the dry matter content, but thresholds are related to the fresh matter. The nitrate content of beetroots in the DOC trial was generally lower than the threshold value.

Energy and protein content of grass-clover (NEL and APD) was similar for all farming systems, whilst a clear difference depending on the fertlisation level was observed.

Content of dry matter and starch

The content of dry matter and starch of potatoes was slightly higher in the biological treatments (between 4 and 14 %). No differences were found for these two parameters in the Darmstadt trial (Abele, 1987). The dry matter content of beetroot from the DOC-trial was the same with all treatments. This is in accordance to Woese *et al.* (1995) who concluded in their literature study that for root and tuber crops generally no relevant differences between different farming system are observed, whilst for organically grown leafy vegetables dry matter content is higher.

Holistic quality assessment

Picture creating methods

Picture creating methods comprise copper chloride crystallisation and circular chromatogram according to Wala and the capillary dynamolysis according to Pfeiffer. These methods originate in anthroposophy. The aim of these methods is to assess the aspect of vitality of foodstuff. The pictures of samples to be investigated are compared with sequences of pictures of plants during well known, characteristic developing stages (e.g. germination, flowering, ripening, different stress situations). For further details to these methods see Balzer-Graf (1994).

In a blind test, encoded samples of beetroot of the different DOC-treatments had to be grouped and to be identified according to the farming system. In the first year (1987), all four samples of the same treatment were grouped correctly. In 1990, double samples of the biodynamic (D), of the mineral (M) and the unfertilised (N) treatment were identified correctly, whilst it was not possible to distinguish between the organic (O) and the conventional (C) treatment. In the following year a complete identification of the double samples was achieved (Table 3.2). The identification was also successful with wheat (1992 and 1993) and with potato samples (1988).

Table 3.2: Grouping of encoded samples of beetroot with picture creating methods

Year	Farming system
1987 [1]	$D_1 = D_2 = D_3 = D_4$ / $C_1 = C_2 = C_3 = C_4$
1990 [2]	$D_1 = D_2$ / $N_1 = N_2$ / $O_1 = C_1$ / $O_2 = C_2$ / $M_1 = M_2$
1991 [2]	$D_1 = D_2$ / $N_1 = N_2$ / $O_1 = O_2$ / $C_1 = C_2$ / $M_1 = M_2$

[1] Index 1-4: Replicates 1-4 of the treatments biodynamic (D) and conventional (C)

[2] Index 1-2: Bulked samples 1 and 2 of 4 field replicates. Samples divided with '=' have been associated to the same treatment.

Food preference test

In a food preference test, rats preferred beetroot of the organic treatment compared to beetroot of the biodynamic (D) and the conventional (C) treatment. Further test series with beetroot (cultivation year 1994) showed results which are difficult to explain as the rats did not show any preferences between organic and conventional beetroot, but preferred organic compared to biodynamic and to conventional beetroot. The reasons for different preferences are not known (Woese *et al*., 1995).

Outlook

Further methods for quality assessment such as emission of biophotons, electrochemical tests are going to be evaluated during the third crop rotation period of the DOC-trial. Preliminary results suggest that an identification of the farming systems is not yet possible with these methods.

CONCLUSIONS

Generally, quality investigations with vegetative crops (potatoes, beetroot and grass clover) show more often and higher differences in comparison to generative crops. However, the differences have to be claimed as small. Moreover, the valuation related to the nutritional value of crops appears to be difficult. It has to be taken into consideration that in the DOC-trial no extreme farming systems are compared, as the conventional system (C) – with respect to fertilisation, plant protection and crop rotation – is managed closely to an integrated farming system. Considering this, the successful identification of crops from different farming systems by the picture creating methods is of high importance. However this holistic approach needs further explanation. Crop samples of long-term trials are of great value for the evaluation of the reproducibility of new approaches to assess food quality.

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4. Discussion: Fertilization effects on product quality and examination of parameters and methods for quality assessment

Summarized by J. Raupp

FERTILIZATION EFFECTS ON CEREALS

Spring cereals have similar **yield levels** with organic and mineral fertilization, whereas winter cereals normally have lower yields with manure, compost etc. than with mineral fertilization.

As a rule the **crude protein** content in cereals is higher with mineral than with organic fertilization. Slurry, liquid manure and other organic fertilizers with a high nitrogen availability can increase the crude protein content on a similar level as it is achieved by mineral fertilizer. Application of liquid manure during flush is more effective than during tillering. The content of pure protein mostly is lower with mineral than with organic fertilization.

As regards the parameters of **baking quality** organic fertilization makes a lower gluten content and a tendency to a lower Zeleny value. The index of essential amino acids is about the same or slightly better with organic than with mineral fertilization. Gluten quality parameters, e.g. gluten elasticity, show no clear differences between organic and mineral fertilization.

Contents of **minerals** are about the same with organic and mineral fertilization, but in some cases increased values of calcium, phosphorus, magnesium and potassium have been observed.

Differences between organic and mineral fertilization generally are more pronounced in vegetative than in generative plant parts.

FERTILIZATION EFFECTS ON VEGETABLE

A **lower nitrate content** of organically fertilized vegetable compared to minerally fertilized or conventionally grown vegetable, mainly root crops, is an effect which has been observed quite often (in our experiments, other investigations and a number of literature surveys). That means, this effect occurs rather independent of site conditions, although the absolute amounts of nitrate in products can vary considerably depending on year, variety and crop.

Nitrate accumulation in products is a function of increasing supply of nitrate by fertilization and by mineralization of soil organic matter on the one hand and of reduced availability of assimilates on the other hand. Therefore, the higher the nitrogen availability is (mineral fertilizer > liquid manure = slurry > manure > compost) and the lower assimilation intensity is (e.g. by **site conditions** and **season effects**) the more the risk of nitrate accumulation rises.

Because of a considerable variation of season and site effects on mineralization intensity that can be controlled only within a limited range high nitrate contents sometimes can also occur with organically fertilized root crops.

Potassium content may be **lower** with organic than with mineral fertilization if potassium supply by the soil and input by fertilizer are low. This may be the case in particular with compost instead of fresh manure application as potassium losses during manure handling can be high.

There is a tendency of **increased magnesium** contents by organic compared to mineral fertilization, but it mainly depends on the magnesium content in manure.

No clear effect of fertilization on **vitamin C** content has been observed.

The **physical characteristics** of surface and tissue of potato tubers has been evaluated with different methods (see below for details). The effects are relatively small. Mineral fertilization, in particular in higher levels, seems to produce softer tissue (resistance against a constant force is lower) compared to manure fertilization. Skin stability (the force which is necessary to penetrate skin) seems to be improved by biodynamic preparations. Further research is necessary (see T1).

In most cases of the German, Swiss and Swedish experiments **storage tests** with complete, undamaged products carried out under optimal storing conditions showed no clear differences between organic and mineral fertilization. In **degradation tests** with cut or grated products under non-optimal storing conditions in most cases organically fertilized vegetables look less decomposed and less changed by microbial attack than minerally fertilized vegetables. Other parameters used in these degradation tests (e.g. dry matter loss, respiration intensity) provide no clear and repeatable differences which probably is because of methodological reasons (see below). In several investigations **darkening** of potato extracts has been lower with organic than with mineral fertilization. Darkening seems to be intensified by higher levels of fertilization.

No clear differences have been obtained in **feeding experiments** with organically and minerally fertilized products . Samples of different cropping systems (organic, conventional etc.) gave more pronounced effects in food preference tests, mostly in favour of organic farming.

PARAMETERS AND METHODS

The **dry matter** content is an important reference parameter, and it is somewhat significant as well to consumers who do not want to buy watery products. Dry matter content seems to be of a certain importance also to storage ability.

The following minerals are regarded as meaningful parameters of food quality:

- **nitrate**, **potassium**, **magnesium**, **calcium**, **phosphorus** and **chlorine** not only because of their significance for nutrition but also as indicators of plant cell properties and mineral dynamics of the cropping system;
- **sulphur** because of its significance for essential amino acids;
- **manganese**, **zinc** and **selenium** as important trace elements (concerning their relationship to fertilization see T2).

Storage experiments with complete products are useful if carried out according to the standards of organic farming (e.g. without chemical additives etc.). Considering the results obtained so far, the question is whether differences in quality other than extreme ones can be discovered under these conditions. Hence, storage or **degradation** in a **model system** (no complete products, no optimal storing conditions) may be helpful, as more clear differences are observed in such tests. However, concerning the relevance of the test system and the interpretation of degradation tests we had a long discussion of two different views without a final agreement. One group argued that stress behaviour of a product has a ceratin bridge to its quality as food because the ability to overcome an injury or to resist microbial decomposition is an indicator of the inherent vitality of a product. The other group took the position that stress behaviour has nothing to do with storage ability and quality because there is a discrepancy between results of storage losses (weight loss, spoilage) and results of degradation tests in petri dishes.

Supporting the first view (degradation tests basically are suitable quality indicators) the question is by which parameters degradation can be evaluated and what do the results say about quality (see T3)? No final answers could be given to these questions because of the basic disagreement over the role of degradation tests, but some aspects can be reported. The physiological background during degradation and microbial attack is rather unclear. It may be largely influenced by the circumstances of one single test if no standardized test system is used including a definite inoculation with microorganisms. By this means, the degree of microbial attack of a sample, quantified by a standardized scheme, could be a reliable parameter. Physiological parameters like darkening can also be useful, but the reason behind it and its significance for nutrition is unclear. A negative correlation between darkening and potassium content in tubers is not proved by our fertilization trials

The application of **picture creating methods** is a possibility to distinguish samples of different origin. But the meaning of a certain result, a certain picture is not quite clear. A high degree of experience and qualification of a person is necessary to carry out the tests and to interpret the pictures. Numerous samples of the same crop with a well known origin have to be processed in order to get reference pictures, before new samples can be assessed reliably. A commonly accepted methodology for several crops does not exist. Correlations to product components and constituents are uncertain. There is a lack of interpretation of the pictures concerning classical quality standards. Calibrating the pictures with the growth conditions of the crop (light - shadow; cosmic - earthly etc.) seems to be a valuable approach. For further tasks see T4.

Feeding experiments with animals are a suitable method to distinguish food products of different origin. However, fertilization of the crops seems to be only one factor causing different results with the animals, and probably it is not the most effective one. At any rate, products of different cropping systems (fertilization, plant protection etc.) of the Swiss experiment gave more pronounced results than products of the German experiment in which only fertilization is different. According to the present results fertility parameters of the animals do not reflect the origin of food components reliably, i.e. in every case. Possible reasons can be seen in the influences and limits of the experimental conditions (e.g. insufficient number of animals in the test groups, type of food the animals have been used to before the test, effects of the housing system etc.; see T5).

Other tests with relatively high costs and pre-conditions needed are **sensory tests** done by trained people. Carried out without this the tests have only a very restricted message. Sensory parameters are able to reflect quite complex characteristics of a product and, by this reason, are often times a useful and illustrative supplement of the analyses of single components. But it has to be considered that sensory tests are based strictly on product properties and do not reflect the individual surroundings and various expectations of eating.

A method which is rather difficult to perform and to interpret is **photon emission**. The method is possibly helpful in the assessment of physiological characteristics of organisms or parts of them. However, relatively less experience is available gained by few persons at present. Some investigations have been carried out already, but it cannot be decided definitely whether the method is capable to reveal food quality or fertilization effects (see T6).

Food processing is also a field of quality assessment methods, although the criteria mostly are not taken from nutrition. For example, parameters of **baking quality** are not relevant to human health. Besides, they have to be modified if applied to the processing of whole-meal for which these standards originally have not been worked out (see T7). Other parameters which are more meaningful and already developed shall be used, e.g. instead of crude protein, which only responds to late nitrogen supply of the crop, the index of essential amino acids is of greater importance to human nutrition. Nevertheless, the classical tests of baking quality show as a rule that products of organic farming are not inferior to conventional products.

A comprehensive approach to food quality can be to develop **quality indexes**. A weight list of parameters is a more solid assessment than results of one or single tests. The list should be specified for each product and should be based on parameters reflecting farming practices and cultivation techniques. In other words, parameters depending on fixed factors which can not or hardly be influenced by the farmer (like site conditions) are less useful from the agricultural point of view.

TASKS FOR FURTHER RESEARCH

T1: Effects of fertilization (and other cultivation factors) on histological parameters like tissue strength and skin stability of fruits and vegetables shall be investigated as regards effective analytical methods, physiological background of the parameters and their significance for crop production and nutrition.

T2: As trace elements are constituents of organic matter a better supply with organic than with mineral fertilization may be expected. However, our experiments do not prove this assumption. Detailed experiments on this question shall be carried out.

T3: Effective and standardized test systems for degradation tests shall be developed. This work shall include research on the physiology and microbiology of degradation of vegetables and the relationship between degradation and vitality of a product.

T4: The picture creating methods shall be investigated more intensive and developed as regards the deficits mentioned above.

T5: More effort shall be done to elaborate definite conditions and requirements for feeding experiments with animals as test systems for food quality assessment.

T6: The methodology, application and theoretical background of the photon emission needs further efforts in research and technical development.

T7: As regards baking quality modified or, if necessary, new parameters shall be worked out adapted to whole-meal processing. Investigations shall be carried out whether the current baking technology can be improved in view of the special case of whole-meal products.