Nitrate and nitrite in vegetables

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Preface

This literature survey is the English version of Corré, W.J., 1978. Nitraat en nitriet in groenten. Deel 1. Nitraat- en nitrietgehalten in verse en bewerkte groenten; een inventarisatie. Interne mededeling 44. Vakgroep Bodemkunde en Bemestingsleer, Landbouwhogeschool, Wageningen. 50 pp. and Corré, W.J., 1978. Nitraat en nitriet in groenten. Deel 2. Faktoren die het nitraat- en nitrietgehalte in groenten beïnvloeden. Interne Mededeling 46. Vakgroep Bodemkunde en Bemestingsleer, Landbouwhogeschool, Wageningen. 45 pp.

The literature cited has mainly been taken from sources in East and West Europe and North America. Most of it has been found in Horticultural Abstracts, Soils & Fertilizers, Nutrition Abstracts and Reviews and Food Science and Technology Abstracts. Only vegetables common in the regions mentioned are involved. The review roughly covers the period from 1965 - 1978.

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Contents

1 Introduction

In many foodstuffs nitrate and nitrite are present as natural components or as additives. These components are not harmless, and in order to determine the acceptability of nitrate and nitrite intakes, one ought to know their toxicity and incidence in foodstuffs. The role of nitrate and nitrite in human nutrition has already been studied for many years. At first infant-methomoglobinemia was the main motive for research. This has resulted in some countries in standards for the maximum contents of nitrate and nitrite in baby foods. More recently it has been suggested that nitrate and nitrite from foodstuffs play an important role in the formation of nitrosamines. As a result of this suggestion, an extensive study was made of nitrate and nitrite, first mainly

Table 1. Conversion scheme for various methods of expressing nitrate and nitrite contents.

nitrogenous substance	chemical formula	atomic or molecular weight	multiplication factors for the conversion from nitrogenous substance in column 1 to		
			NO_3-N	NO_3	KNO_3
nitrate-nitrogen	NO_3-N	14	1	4.43	7.21
nitrate	NO_3	62	0.23	1	1.63
potassium nitrate	KNO_3	101	0.14	0.61	1
			multiplication factors for the conversion from nitrogenous substance in column 1 to		
			NO_2-N	NO_2	$NaNO_2$
nitrite-nitrogen	NO_2-N	14	1	3.29	4.93
nitrite	NO_2	46	0.30	1	1.50
sodium nitrite	$NaNO_2$	69	0.20	0.67	1

as food additives, but the last few years also as natural components of foodstuffs. Especially vegetables were subjected to research, because over 80 percent of the total nitrate intake originates from vegetables. To minimize the chances of poisoning, the maximum acceptable daily intakes of nitrate and nitrite were fixed by the World Health Organization. Some countries also set standards for the maximum acceptable nitrate and nitrite contents of fresh and processed vegetables, while others are considering the legislation of standards.

This report briefly reviews the literature on toxicity of nitrate and nitrite, on standards already existing and on intake of nitrate and nitrite. As usually the intake of nitrate, and possibly also of nitrite, with vegetables is high, we searched the literature for nitrate and nitrite contents of various fresh and processed vegetables. The differences among the various vegetables and the range of contents for each vegetable are shown. Furthermore, factors affecting the nitrate and nitrite contents of fresh and processed vegetables are briefly surveyed. A more extensive list of the literature on the various factors has been compiled in the appendices.

In conclusion, we must make some remarks on the units used. All nitrate and nitrite contents in this review are expressed in milligrams of nitrate (NO_3) or nitrite (NO_2) per kilogram. Where possible, the contents were expressed in mg/kg fresh product. Contents from literature were recalculated when necessary. For the sake of convenience, the factors for conversion to other units are presented in Table 1.

2 The toxicity of nitrate and nitrite to man

2.1 The effects of nitrate and nitrite intake

The toxicity of nitrate is relatively low. No special harmful effects are known and it is rapidly excreted. With rats, acute death occurred for 50 percent of the test animals when a single dose of 3500 mg nitrate per kg body weight was injected into the stomach (Wright & Davison, 1964). Assuming the toxicity to man to be the same, the lethal dose for adults would be about 200 grams of nitrate. In spite of its low toxicity the occurrence of nitrate in foods can be dangerous because of a possible reduction of nitrate to nitrite.

Nitrite can cause methemoglobinemia and is therefore much more toxic than nitrate; 50 to 60 mg nitrite per kg body weight is equivalent to 3500 mg nitrate (Wright & Davison, 1964). Methemoglobin can completely revert to hemoglobin through methemoglobin-reductase (diaphorase) (Simon, 1970), so only acute nitrite-toxication causes methemoglobinemia. Nitrite might cause chronic toxication as a result of the formation of nitrosamines. These compounds can arise from the reaction between nitrite and secondary or tertiary amines. The part that nitrate and nitrite from vegetables play in the formation of nitrosamines, is not yet clear. A pH level over 5 inhibits the formation of nitrosamines (Mirvish, 1977). It is therefore unlikely that nitrosamines are formed in vegetables. As a matter of fact, nitrosamine formation was only found in vegetables when both nitrite and secondary amines were added and the pH was lowered (Keybets et al., 1970). After ingestion formation of these compounds can only take place in the stomach, as in the other parts of the gastrointestinal tract pH is too high. In vivo formation of nitrosamines after ingestion of nitrite and secondary amines has been observed in various test animals, but up till now there is no evidence that nitrosamines are formed in humans and it is not yet known what amounts of nitrite and secondary or tertiary amines the diet should contain to make a formation possible (Ishiwata et al., 1975, 1976; Lijinski et al., 1972; Wolf & Wasserman, 1972).

Conversion of nitrate to nitrite can occur before ingestion, in the gastro-intestinal tract or in saliva. When conversion occurs before ingestion, nitrite will be taken in and methemoglobinemia becomes possible. The circumstances under which the conversion of nitrate to nitrite in vegetables may take place will be discussed in Chapter 6.

Conversion in the gastro-intestinal tract is a bacteriological process, which sets in only when pH is not too low. In the human stomach the low pH will kill all nitrate-reducing bacteria.

Owing to the relatively high pH of the rumen, ruminants are much more sensitive to nitrate than non-ruminants (Wright & Davison, 1964). Also in the stomach of infants of under three months pH is relatively high. Although such a high pH is not optimal for nitrate reduction, only small digestive disturbances, which frequently happen at that age, might bring nitrate-reducing bacteria in the upper intestine, where the environment promotes the reduction of nitrate to nitrite. In older infants and in adults the pH of the stomach is low enough to eliminate all nitrate-reducing bacteria. Another reason why younger infants are more sensivite to methemoglobinemia is the fetal hemoglobin they still have in their blood. This type of hemoglobin is more susceptible to nitrite than is the normal hemoglobin. Also the regeneration of methemoglobin is slower because of a lack of methemoglobine reductase (Simon, 1970). Because of their relatively high food intake per kg body weight it is clear that these infants should receive special attention when standards are fixed for the nitrate and nitrite contents of foods.

Another possible environment for nitrate reduction is saliva. In this case reduction takes place in the mouth and the nitrate that is reduced does not directly originate from the ingested food, but from nitrate that has already been absorbed in the blood and is excreted again with the saliva. Up to 1975 it was generally believed that the nitrite content of saliva was always low, although it may vary per individual (about 6 to 10 mg/kg). The nitrate content was supposed to be about 25 mg/kg (e.g. White, 1975). In 1974 Kühn found a relation between nitrite contents of saliva and dental hygiene. However, also in this study the mean content was low, i.e. about 6 mg/kg. Since 1975 several publications have clearly demonstrated a relation between nitrate ingested with food and nitrite found in saliva. The earlier amounts are still correct, but only as a basic value for foods that are poor in nitrate. In saliva, after the ingestion of salted chinese cabbage, Harada et al. (1975) found that the nitrate content increased from 77 to 545 mg/kg and that the nitrite content increased from 12 to 75 mg/kg. Later, the same authors found similar results when other nitrate-containing foods were ingested. They also observed that the nitrite originated from bacterial activity in the mouth. The excreted saliva itself did not contain any nitrite (Ishiwata et al., 1975). Stephany & Schuller (1975) even found a maximum nitrite content of 175 mg/kg in saliva after the ingestion of purslane. Spiegelhalder et al. (1976) described a direct relationship between the amounts of ingested nitrate and the nitrate and nitrite contents of saliva. ingestion of 1 mg nitrate increases the nitrate content with 1.1 mg/kg and the nitrite content with 0.2 mg/kg. Tannenbaum et al. (1976) have shown that the nitrite content of saliva is dependent not only on the amount of nitrate ingested but also on the form and the concentration in which it is ingested. Further, the duration of the higher concentration is important. A higher concentration appears to persist longer when nitrate becomes available from foods at a slower rate, as for example from intact cells of fresh vegetables.

The data cited above are hard to compare. Nevertheless, in the above mentioned literature, a reasonable agreement exists between the ingestion of nitrate and the amounts of nitrate and nitrite found in saliva (Stephany, 1978). About 40 percent of the nitrate ingested appears to be excreted in the saliva whereas 5 to 7 percent is reduced to nitrite. A conversion factor of 6 percent seems to be a reasonable average. In other words, from 100 mg nitrate ingested 6 mg will be reduced to nitrite in the saliva, which eventually will lead to an ingestion of 4.4 mg nitrite.

2.2 Lethal, toxic and acceptable doses of nitrate and nitrite

Many authors have mentioned lethal, toxic and acceptable doses of nitrate and nitrite in foods (Table 2). All data in Table 2 are calculated for adults of 60 kg body weight. For other body weights the data have to be raised or lowered proportionately. This also holds for children over three months of age. In younger children, conversion of nitrate to nitrite in the gastro-intestinal tract can occur and a much lower dose of nitrate can therefore be toxic. Winton et al. (1971) calculated the amount of nitrite needed to convert 10 percent of the hemoglobin to methemoglobin. The 10 percent level is chosen since at this level the disorder first becomes clinically detectable. For adults and older children the corresponding amount of nitrite is 0.9 - 1.0 mg/kg body weight and for children of 1, 2 or 3 months old the values are 1.6, 1.0 and 0.9 mg/kg, respectively. Assuming an 80 percent reduction of nitrate to nitrite, these nitrite doses can result from 2.7, 1.7 and 1.5 mg nitrate/kg, respectively, which values are much lower than the toxic dose for adults. Symptoms of methemoglobinemia will appear only when the abovementioned doses are ingested at one time and the symptoms will disappear again after a few hours.

Generally the data of Table 2 are based on acute toxication caused by a single ingestion. A possible chronic toxication, partly in connection with the formation of nitrosamines, is only taken into account in the standards published by the Joint FAO/WHO Expert Committee on Food Additives (JECFA). These values represent the Acceptable Daily Intake (ADI). The lower value is the 'unconditional ADI', the higher one the 'conditional ADI'. The higher level may be acceptable under certain conditions but the unconditional ADI should never be exceeded over an extended period. When ADI is mentioned in this survey, it is always the unconditional ADI. An objection against the use of the JECFA standards is that they are set only for additives and that they do not account for the 'natural' amounts of nitrate and nitrite in foods and for the conversion of nitrate to nitrite in saliva. These standards are based on toxicological research with rodents, in whose saliva there is no conversion of nitrate to nitrite. Also, their natural food, mostly grains and other seeds, is very low in nitrate (Stephany, 1978). It therefore seems reasonable to comply with the Commissie Onderzoek Biologische Landbouwmethoden (a committee investigating alternative agricultural practices)

Table 2. Lethal, toxic and acceptable doses of nitrate and nitrite in mg for adults of 60 kg body weight.

reference	lethal		toxic		acceptable	
	NO_3	NO_2	NO_3	NO_2	NO_3	NO_2
Gilbert et al. 1946	9200-18400	.	2400	.	.	.
Sollmann 1949	.	.	3000-4000	.	600	.
Smith & Simpson 1957	25000-50000	15000	.	.	.	.
Kübler 1959	.	.	.	.	960-1200	.
Burden 1961	.	.	.	.	1060	800
JECFA[1] 1962	.	.	.	.	220-440	16-32
Wright & Davison 1964	200000	3000-3600	.	.	.	.
Simon 1970	.	.	5000	500	.	.
Achtzehn & Hawat 1970	.	1670-2670	.	330-1330	.	.
Winton et al. 1971	.	.	.	60	.	.
JECFA[1] 1974	.	.	.	.	220-440	8-16
Deeb & Sloan 1975	4800-18000	6600-9600	.	.	.	.
Selenka & Brand-Grimm 1976	8000-15000	.	2000	.	.	.

1 JECFA: Joint FAO/WHO Expert Committee on Food Additives.

(1976) and Stephany & Schuller (1977), in denoting 220 mg nitrate and 8 mg nitrite as the total acceptable daily intake, including nitrate and nitrite in vegetables and other foods and the nitrite that is formed from nitrate in the saliva. Assuming a conversion of 6 percent of the ingested nitrate to nitrite, an ingestion of 180 mg nitrate would be enough to cause an ingestion of 8 mg nitrite from the saliva, which means that the ADI for nitrate should be lowered. More toxicological research on the basis of present-day knowledge seems to be desirable, but it is not likely that the standards will change very much. In any case, the ADIs of nitrate and nitrite must match in such a way that it is impossible to exceed the ADI for nitrite through conversion in the saliva when acceptable amounts of nitrate are ingested.

2.3 Standards for nitrate and nitrite in foods

Partly in connection with several cases of infant methemoglobinemia from ingestion of nitrate, mostly from drinking water, standards were set for the maximum nitrate and nitrite contents of some foods (Lee, 1970; Committee on Nitrate Accumulation, 1972). The standards hold for cured meat, fish and cheese, for drinking water and in some countries also for vegetables. Also other foods, like bread and fruits, contain some nitrate, but the contents are too low to be of any importance.

2.3.1 Standards for food additives

The occurrence of nitrate and nitrite in meat, fish and cheese is the result of additives used to inhibit the growth of bacteria, especially *Clostridium botulinum*. The active inhibitor is nitrite, nitrate being effective only after conversion to nitrite. The use of additives is of course limited by law and standards are set for the maximum contents at the time of sale. In most countries a maximum content per kg product of 365 mg nitrate or 100 - 130 mg nitrite is permitted in meat and fish. In cheese the maximum nitrate content is mostly set at 7 mg/kg (Rochize, 1976). In the Netherlands a nitrate content of 1250 mg or a nitrite content of 330 mg per kg product is allowed in meat and fish, and in cheese the nitrate content permitted is 35 mg/kg. For the addition of nitrite only sodium chloride containing 0.6 percent sodium nitrite (by weight) is allowed. A quantity of 330 mg nitrite corresponds with about 80 grams sodium chloride and this level will therefore not often be found (Meester, 1974; Rochize, 1976). Today in the Netherlands hardly any nitrate is added to fish and meat (Inspecteur van de Volksgezondheid (Head of the Public Health Inspection), 1978).

2.3.2 Standards for drinking water

For drinking water the maximum nitrate content considered acceptable by the European Office of the World Health Organisation is 50 mg per liter. In France the allowed maximum is 70 mg per liter and in the United Kingdom it is even as high as 90 mg per liter. In other European countries and in the USA the standards are between 30 and 50 mg per liter (Thieleman & Hildebrandt, 1971). Nitrite is not allowed in drinking water, when present it is likely to have originated from bacterial contamination.
The actual nitrate contents of drinking water are mostly much lower than the allowed maxima. White (1975) mentioned a mean nitrate concentration of 0.71 mg per liter in the water of the hundred largest Public Water Supply Works in the United States. Herrmann (1972) estimated the normal nitrate concentration in water to be less than 10 mg per liter. In the Netherlands, Kolenbrander (1970) found a mean nitrate content of 7.3 mg per liter in the water of seven pumping-stations on pleistocene sandy soils, whereas no nitrate was detected in the water of fifteen other stations on the same soil type. An investigation

of fourteen-hundred shallow open wells in Brabant and Limburg (the Netherlands), however, revealed that only in about forty percent of the wells the water contained less than 50 mg nitrate per liter and in almost half of the wells the water contained nitrite (Trines, 1952). Thus, drinking water generally contains little nitrate, but exceptions occur, especially in shallow wells in which nitrate contents can be very high. For the calculation of the daily intake of nitrate, the Netherlands Ministry of Public Health and Environmental Hygiene assumes a nitrate content for water of 5 mg per liter (Inspecteur van de Volksgezondheid, 1978).

2.3.3 Standards for vegetables

The maximum acceptable nitrate content of vegetables has been standardized in only a few countries. In the German Federal Republic (GFR) and in France, standards exist for baby foods and in the German Democratic Republic (GDR) for fresh and processed vegetables. A few years ago, medical and agricultural experts of the GFR proposed an 'Angestrebte Grenzwert' (recommended limit) of 300 mg per kg fresh product for nitrate in vegetables to be used for the processing of baby foods and dietary foods for babies and children. From 1st January 1979, the official standard for the maximum acceptable nitrate content in the GFR for baby foods and dietary foods is 250 mg per kg product (Schwerdtfeger, 1977).

In France, since March 1976 the maximum acceptable nitrate content for baby foods has been 50 mg per kg, unless it is indicated clearly on the label that the foods are not fit for children under four months (Auffray & Pafique, 1976).

In the GDR, since 1973 there have been officially accepted standards for the nitrate content of vegetables (Table 3). Also for the nitrite content of fresh vegetables there is a standard of 5 mg/kg (Geyer, 1978; Schütt, 1977). In order to prevent nitrate contents from exceeding the levels mentioned in Table 3,

Table 3. Standards for nitrate content of vegetables in the German Democratic Republic. Nitrate content in mg/kg product. Data from Schütt, 1977.

		fresh vegetables	processed vegetables
children up to	'Richtwert'[1]	600	300
four months	'Höchstwert'[2]	900	450
older children	'Richtwert'	1000	700
and adults	'Höchstwert'	1200	900

1 'Richtwert': average acceptable nitrate content.
2 'Höchstwert': highest acceptable nitrate content.

in the contracts of the processing industry in the GDR with the spinach growers, the amount of nitrogen to be applied per hectare is set at a maximum of 80 kg. In spite of this regulation the nitrate content of fresh spinach sometimes appeared to be much higher than 1200 mg/kg, especially in autumn crops (Schütt, 1977; see also Table 6).

3 The intake of nitrate and nitrite

In 1907 Richardson estimated the nitrate intakes with two meals of different high-nitrate vegetables at 1000 and 1300 mg. Phillips (1968b) calculated 313 mg nitrate to be present in a meal rich in nitrate, whereas Fassėt (1973) calculated a possible intake of 300 mg nitrate and 30 mg nitrite with a single portion of spinach and processed meat. Ashton (1970) estimated a mean daily intake of 58 mg of nitrate per person with meat products, vegetables (except potatoes) and water. Rautu et al. (1972) estimated the mean daily intake of nitrate to be 245 mg with a minimum of 42 mg and a maximum of 838 mg. Walker (1975) calculated a nitrate intake of 115 mg per day, assuming the intake with water to be 55 mg per day, which is rather high. Based on statistical research White (1975) calculated for the USA a mean daily intake of 99.8 mg nitrate and 2.6 mg nitrite (see Table 4); daily saliva nitrite production was calculated to be 8.6 mg. In Norway the mean daily intake of nitrate and nitrite, also based on statistical data, was estimated to be 48 mg and 0.1 mg respectively (Höyem, 1974).

In Bavaria (GFR) the nitrate intake of adults was investigated by Möhler (1975) over a period of twenty weeks. The mean daily intake was 70 mg, with a range of 36 - 102 mg, depending on

Table 4. Intake of nitrate and nitrite from various dietary sources in mg/person/day. Data from Inspecteur van de Volksgezondheid, 1978 and White, 1975.

source	intake		
	nitrate		nitrite
	Netherlands	USA	USA
vegetables	98	} 86.1	0.2
potatoes	15		
fruits	.	1.4	0.0
milk and milk-products	1 (cheese)	0.2	0.0
bread	12 (cereals)	2.0	0.0
water	7	0.7	0.0
meat and fish	.	9.4	2.4
others	4	.	.
total	137	99.8	2.6

dietary habits of the persons investigated. The main nitrate sources were vegetables and potatoes. Möhler also referred to an investigation carried out in Rhineland Pfalz (GFR) in which a mean daily intake of 90 mg nitrate was found. For the GFR, Selenka & Brand-Grimm (1976) carried out statistical analyses and calculated a mean daily intake of nitrate and nitrite of 40 and 1.7 mg, respectively. Calculations based on data for prepared meals resulted in daily intakes of 75 mg nitrate and 3.3 mg nitrite, with a range of 55 - 95 mg for nitrate and of 2.5 - 3.9 mg for nitrite, depending on dietary habits. In these calculations, drinking water was assumed to be free of nitrate, a nitrate content of 35 mg/liter would have doubled the daily intake. Jägerstad & Nilsson (1977) determined the nitrate and nitrite intake in Sweden by analysing 140 complete daily meals. These meals were prepared by 10 male and 10 female test persons for one week as a duplicate of their own food intake. The mean daily intake of nitrate was 48 mg for males and 51 mg for females, the mean daily intake of nitrite 3.1 for males and 4.4 mg for females. Nitrate intakes ranged from 26 to 81 mg for males and from 36 to 80 mg for females, nitrite intakes ranged from 0.6 to 7.4 mg for males and from 3.2 to 6.0 mg for females. The mean daily intake of nitrate calculated by the Netherlands Ministry of Public Health and Environmental Hygiene was 137 mg (Inspecteur van de Volksgezondheid, 1978; see also Table 4). De Vos (1978) calculated mean daily intakes for nitrate and nitrite of 92 and 6 mg, respectively; the maximum nitrate intake was 177 mg, the nitrite intake ranging from 1 to 27 mg.

By analysing 100 complete daily meals, which were prepared in the same way as in Jägerstad & Nilsson's investigation Stephany & Schuller (1977) could determine the daily nitrate and nitrite intake in the Netherlands. The mean daily intake was 132 mg nitrate and 5.2 mg nitrite, with a range of 18 - 574 mg for nitrate and of 1.3 - 40.3 mg for nitrite. The higher values for nitrite probably result from conversion of nitrate during storage, since not everyone had the possibility of storing the duplicate meal immediately in a freezer. Daily nitrite intake did not exceed 10 mg in over 90 percent of the cases. The abovementioned data are condensed in Table 5.

To conclude, the following remarks must be made.
Only the investigations of Jägerstad & Nilsson (1977) and Stephany & Schuller (1977) are based on direct measurements, whereas the other values were derived from statistical data, theoretical computations and literature surveys. Although these calculations may be correct, still the results are not very reliable, since it is practically impossible to take into account, for instance, the changes in nitrate content resulting from the processing of vegetables. Besides, the ranges in food consumption (amounts per person, composition per person) are hardly known. With direct measurements the intake and its range can be precisely established. However, as the range is relatively wide a sample of one hundred data is still too small to yield a reliable estimate. The range will become even wider when seasonal influences on diet pattern and on the nitrate content of vegetables are taken into account.

Table 5. Various estimates of the intake of nitrate and nitrite in mg/person/day.

reference	intake			
	nitrate		nitrite	
	mean	range	mean	range
Ashton (1970)	58	.	.	.
Rautu et al. (1972)	245	(42-838)	.	.
Höyem (1974)	48	.	0.1	.
Walker (1975)	90	.	.	.
White (1975)	99.8	.	2.6	.
Möhler (Bavaria) (1975)	70	(36-102)	.	.
(Rhineland Pfalz) (1975)	90	.	.	.
Selenka & Brand-Grimm (1976)	75	(55-95)	3.5	(2.5-3.9)
Jägerstad & Nilsson (1977)	48	(26-81)(m)[1]	3.1	(0.6-7.4)
	51	(36-80)(f)[2]	4.4	(3.2-6.0)
Stephany & Schuller (1977)	132	(18-574)	5.2	(1.3-40.3)
Inspecteur van de Volksgezondheid (1978)	137	.	.	.
De Vos (1978)	92	(. -177)	6	(1 -27)

1 m: male.
2 f: female.

In Section 2.2 it was already explained that it is practical, though perhaps not in conformity with theory, to set 220 mg nitrate and 8 mg nitrite as the maximum acceptable daily intakes. Consequently, the mean nitrate intake calculated by Rautu et al. (1972) would be very high. Stephany & Schuller (1977) found that for nitrate and nitrite the ADI was exceeded in 19 and 16 percent of the cases, respectively.

When calculating the nitrite intake, White (1975) was the only one to take the nitrate conversion in saliva into account. The mean daily intake, including saliva nitrite, was 11.2 mg. When one assumes that in saliva 6 percent of the ingested nitrate is converted to nitrite (Stephany, 1978), in the investigation of Stephany & Schuller (1977) the nitrite intake must be raised by 5.9 mg. The mean total daily nitrite intake would then be 11.1 mg. In the investigation of Jägerstad & Nilsson (1977) it must be raised by 2.1 mg for males and by 2.3 mg for females. Then the mean total daily nitrite intake would be 5.2 mg for males and 6.7 mg for females. So, when saliva nitrite is included, the mean daily nitrite intakes calculated from the data of Stephany & Schuller (1977) and White (1975) exceed the ADI. Assuming the above mentioned values to be correct, the conclusion must be drawn that the intake of nitrate and nitrite ought to be reduced.

In the Netherlands the intake of nitrate and nitrite is relatively high because of the high per capita consumption of vegetables.

4 Nitrate and nitrite contents of fresh and processed vegetables

In this chapter data are reviewed to get an impression of the contents of nitrate and nitrite observed in practice for different vegetable species. The data presented refer to both fresh and processed vegetables.

4.1 Nitrate contents

All data on nitrate contents of fresh vegetables are compiled in Table 6 according to species. The species are given in alphabetic order. Because data of different authors cannot always be compared, it was considered unjustified to calculate mean values. Besides, mean values would not be very useful in view of the wide range in contents, due to varying growth conditions. It is however possible to deduce what values nitrate contents can reach and how often these high contents occur.

On the basis of the data presented in Table 6 the species are arranged in groups with comparable nitrate contents (Table 7). Of course, the boundaries of these classes are only vague and the classification must therefore be considered as only semi-quantitative. A more detailed classification based on these data is not feasible. Even as it is now the positions of some species in the respective groups are based on the contents of only one or a few samples. A systematic study of the vegetable species, a large using number of samples would probably enable a more refined classification, or at least a sequence within the classes to be made.

A particular problem is formed by the variations in nitrate contents with the seasons. Such variations can indeed be measured, but there are also seasonal variations in patterns of vegetable consumption. It is therefore difficult to judge the importance of changes in nitrate contents in relation to nitrate consumption. Whatever changes occur, it is clear that certain vegetables often possess high or very high nitrate contents, i.e. contents that exceed by far the official maximum of 1200 mg/kg fresh product for fresh vegetables in the GDR (Table 3). Also a daily intake of 220 mg, which is acceptable (although not laid down in official regulations), will be reached by consuming only 100 g of a vegetable with a nitrate content of 2200 mg. Thus, contents of these orders must be regarded too high.

A possible lowering of the contents in the course of domestic or industrial processing will be discussed in Chapter 6. Nitrate contents of processed vegetables are compiled in Table 8. Although nitrate contents of fresh and processed vegetables are hardly comparable, we may state that in general processing leads to a decrease. For nitrate-rich vegetables the mean decrease is 20 - 25 percent. For vegetables with a low nitrate content it will be less. The amount lost during the preparation of frozen, canned or baby food products is of the same order of magnitude. For the preparation of vegetable juices the decrease is lower since the cell liquid, which is relatively rich in nitrate, is not lost but, in fact, collected.

4.2 Nitrite contents

When plants assimilate nitrate, it is first converted into nitrite. Since this conversion is relatively slow and further assimilation proceeds rather quickly, the nitrite contents of growing plants will be very low. One may assume the nitrite contents of vegetable crops at harvest to be not higher than 1 - 2 mg/kg fresh product (Achtzehn & Hawat, 1970). After harvest th normal, enzymatic assimilation stops, but now nitrate can be converted microbiologically to nitrite, which from then on will be assimilated only slowly. To what extent this conversion actually takes place, depends strongly on the circumstances under which the vegetables are stored and processed; with proper storage and processing only a very small amount of nitrite can be formed. As said before, nitrite contents in market vegetables of over 2 mg/kg occur only in a few cases. Particularly in spinach and beetroot higher values are found, but a value of 10 mg/kg is hardly even exceeded. Occasionally, also other vegetables contai more nitrite than 2 mg/kg (e.g. Gersons, 1976b; Hildebrandt, 1976; Siciliano et al., 1975).

In vegetables that have been processed by the industry the nitrite contents are generally somewhat higher than in fresh vegetables; contents of 2 or 3 mg/kg are normal and in spinach sometimes higher values are found. Frozen vegetables are generally higher in nitrite than canned vegetables. (e.g. Jackson et al., 1967; Kamm et al., 1965; Siciliano et al., 1975).

Other data about nitrite contents in fresh and processed vegetables are mentioned in the publications of Achtzehn & Hawat (1970), Adriaanse & Robbers (1969), Frankena (1968), Heisler et al. (1973), Hlavsova et al. (1969), Kenny & Walshe (1975), Klaushofer et al. (1967a), Lemieszek-Chodorowska et al. (1972), Richardson (1907) and Rooma (1971).

Table 6. Nitrate content of fresh vegetables in mg/kg fresh product. A.A. = Alternative Agriculture, s.e. = standard error, s.d. = standard deviation, R.A. = Received Agriculture.

reference	nitrate content		number of samples	remarks
	mean	range		
ASPARAGUS (*Asparagus officinalis* L.)				
Achtzehn & Hawat (1969)	50	30-70	.	
Maynard & Barker (1972)	108	.	.	
Rautu et al. (1972)	40	13-80	9	
Sinios & Wodsak (1965)	.	140-700	.	
BEETROOT or TABLE BEET (*Beta vulgaris* L. var. rubra L.)				
Achtzehn & Hawat (1969)	2360	1230-3680	.	
Van Breda (1975)	2500	.	17	
Cantoni & d'Aubert (1974)	.	280-305	.	
Hansen (1976b)	2246	1643-2723	4	
Hildebrandt (1976)	.	100-2160	.	
Hlavsova et al. (1969)	2700	730-4480	7	
Höyem (1974)	3457	2008-5243	5	
Jackson et al. (1967)	1654		1	
Kerkvliet (1976)	853		1	A.A.
Lee (1972)	2428	.	.	
Maynard & Barker (1972)	2598	.	.	
Michael (1974)	2300	.	.	
Richardson (1907)	2600	930-8060	7	
Rooma (1971)	1184	s.e. :103	15	
Sachse (1966)	200	.	.	
Siciliano et al. (1975)	3010	s.d. :688	.	
Smith (1966)	.	600-4500	.	
Soboleva (1969)	759	s.e.:200	10	
Spiegelhalder et al. (1976)	2320	1028-3697	6	
Stephany & Schuller (1977)	3100	497-6631	12	
Subbotin et al. (1970)	1240	s.e.:42	28	
BROCCOLI (*Brassica oleracea* L. var. italica Plenck)				
Hansen (1976b)	130		1	
Höyem (1974)	495	137-1020	4	
Jensen (1972)	789		1	
Kerkvliet (1976)	1175	1075-1270	2	A.A.
Lee (1972)	948	.	.	
Smith (1966)	.	400-850	.	
BRUSSELS SPROUTS (*Brassica oleracea* L. var. gemnifera (DC.) Schulz)				
Achtzehn & Hawat (1969)	10	10-30	.	
Council of Europe (1975)	85	0-170	2	

Table 6, continued. Nitrate content of fresh vegetables in mg/k fresh product.

reference	nitrate content		number of samples	remarks
	mean	range		
Hansen (1976b)	74	73-76	2	
Kenny & Walshe (1975)	0	.	9	
Kerkvliet (1976)	615		1	A.A.
Schuphan (1958)	4		1	
Simon et al. (1966)	40	0-80	2	
CABBAGE (*Brassica oleracea* L.)				
WHITE CABBAGE (var. alba DC.)				
Achtzehn & Hawat (1969)	240	30-520	.	
Boek & Schuphan (1959)	510	280-750	7	
Council of Europe (1975)	230	0-780	8	
Hansen (1976b)	1482	1440-1520	2	summer
	305	184-398	5	winter
Hildebrandt (1976)	.	50-980	.	
Hlavsova et al. (1969)	860	230-1290	23	
Jensen (1972)	67		1	
Richardson (1907)	200	35-490	5	
Rooma (1971)	105	s.e.:16	15	
Schuphan (1958)	65	31-99	2	
Sinios & Wodsak (1965)	.	200-450	.	
Soboleva (1969)	9	s.e.:1	10	
Spiegelhalder et al. (1976)	266		1	
Subbotin et al. (1970)	151	s.e.:11	40	
RED CABBAGE (var. rubra DC.)				
Achtzehn & Hawat (1969)	310	90-580	.	
Bergholm (1972)	104	.	2	
Boek & Schuphan (1959)	480	390-570	3	
Council of Europe (1975)	410	325-585	3	
Hansen (1976b)	316		1	winter
Hildebrandt (1976)	.	330-2680	.	
Spiegelhalder et al. (1976)	85		1	
SAVOY CABBAGE (var. sabauda (L.) Schulz)				
Achtzehn & Hawat (1969)	260	60-550	.	
Boek & Schuphan (1959)	510	270-870	6	
Council of Europe (1975)	860	45-40	8	
Hildebrandt (1976)	.	490-1410	.	
Hlavsova et al. (1969)	700	260-1480	22	
Jensen (1972)	521		1	

Table 6, continued. Nitrate content of fresh vegetables in mg/kg fresh product.

reference	nitrate content		number of samples	remarks
	mean	range		
Rooma (1971)	55	s.e.:6	15	
Smith (1966)	.	150-1650	.	
OXHEART CABBAGE (var. pyramidalis Mill. subvar. conica DC.)				
Council of Europe (1975)	1110	560-2205	8	
Hansen (1976b)	1948	1859-2036	2	summer
CABBAGE (variety not mentioned)				
Bergholm (1972)	73	.	2	
Garbouchev & Mitreva (1972)	305	170-440	2	
Höyem (1974)	711	120-1616	7	
Jackson et al. (1967)	317	158-471	2	
Kenny & Walshe (1975)	450	0-844	9	April
	459	130-1104	9	December
Lee (1972)	917	.	.	
Maynard & Barker (1972)	714	.	.	
Rautu et al. (1972)	352	90-705	10	
Richardson (1907)	204	35-487	5	
Siciliano et al. (1975)	784	.	.	
CARROT (*Daucus carota* L.)				
Achtzehn & Hawat (1969)	160	80-320	.	
Astier-Dumas (1973)	274	13-895	30	
Astier-Dumas (1976b)	299		1	
Auffray & Pafique (1976)	.	100-1500	.	
Cantoni & d'Aubert (1974)	.	400-947	.	
Hansen (1976b)	195	154-249	4	winter
	221	181-247	3	summer
Hlavsova et al. (1969)	400	34-1370	23	
Höyem (1974)	216	9-457	8	
Jackson et al. (1967)	18		1	
Kenny & Walshe (1975)	740	390-1277	9	April
	307	0-779	9	November
Kerkvliet (1976)	160	23-990	20	summer R.A.
	260	115-585	4	summer A.A.
	130		1	winter A.A.
Lee (1972)	337	.	.	
Maynard & Barker (1972)	139	.	.	
Rautu et al. (1972)	947	120-2850	10	
Richardson (1907)	66	40-89	3	
Rooma (1971)	268	s.e.:17	15	
Schuphan (1961)	26	0-70	19	

Table 6, continued. Nitrate content of fresh vegetables in mg/kg fresh product.

reference	nitrate content		number of samples	remarks
	mean	range		
Siciliano et al. (1975)	72	s.d.:56	8	
Sinios & Wodsak (1965)	.	280-600	.	
Smith (1966)	.	50-500	.	
Soboleva (1969)	40	s.e.:1	40	
Spiegelhalder et al. (1976)	730	126-1156	4	
Subbotin et al. (1970)	460	s.e.:21	68	
Vulsteke & Biston (1978)	244	124-560	17	
CAULIFLOWER (*Brassica oleracea* L. var. botrytis L.)				
Achtzehn & Hawat (1969)	340	120-670	.	
Bergholm (1972)	60	.	2	
Council of Europe (1975)	170	0-420	8	
Hansen (1976b)	163	123-202	4	
Hlavsova et al. (1969)	250	40-740	27	
Höyem (1974)	384	34-947	6	
Jackson et al. (1967)	53		1	
Jensen (1972)	253		1	
Kenny & Walshe (1975)	48	0-130	9	April
	61	22-87	9	December
Kerkvliet (1976)	480	145-810	2	
Lee (1972)	1054	.	.	
Pimpini et al. (1970)	2500	1280-4470	5	October } in dry matter
	1460	1110-2010	3	March } in dry matter
Richardson (1907)	151	27-399	3	
Rooma (1971)	42	s.e.:5	15	
Simon et al. (1966)	315	190-440	2	
Smith (1966)	.	100-1250	.	
Soboleva (1969)	108	s.e.:9	11	
Spiegelhalder et al. (1976)	60		1	
CELERIAC (*Apium graveolens* L. var. rapaceum (Mill.) DC.)				
Achtzehn & Hawat (1969)	680	290-1160	.	
Council of Europe (1975)	2630	2315-2945	2	
Hansen (1976b)	111	107-115	2	
Hlavsova et al. (1969)	1000	280-1690	13	
Rautu et al. (1972)	2900	70-6500	10	
Rooma (1971)	1400	s.e.:57	8	
Sinios & Wodsak (1965)	.	400-1700	.	
CELERY (*Apium graveolens* L. var. dulce (Mill.) DC.)				
Council of Europe (1975)	3200	50-5270	4	

Table 6, continued. Nitrate content of fresh vegetables in mg/kg fresh product.

reference	nitrate content mean	nitrate content range	number of samples	remarks
Höyem (1974)	2570	321-5179	3	
Inspecteur van de Volksgezondheid (1978)	4420	3070-5280	3	greenhouse
Jackson et al. (1967)	2785	2614-2957	2	
Jensen (1972)	1712		1	
Kenny & Walshe (1975)	2394	1234-3269	12	December
	3009	2555-3637	6	January
Kerkvliet (1976)	895	800-990	2	A.A.
Lee (1972)	1001	.	.	
Maynard & Barker (1972)	2317	.	.	
Richardson (1907)	1506	797-2899	5	
Siciliano et al. (1975)	2220	1600-2670	4	
Smith (1966)	.	500-3250	.	
Vulsteke & Biston (1978)	2017	992-3270	32	
CHERVIL (*Anthriscus cerefolium* (L.) Hoffm.)				
Council of Europe (1975)	4760	4170-5320	2	
Hansen (1976b)	517	392-766	3	
CHICORY (*Cichorum intybus* L.)				
Achtzehn & Hawat (1969)	129	80-150	.	
Kerkvliet (1976)	175	120-205	3	A.A.
CUCUMBER (*Cucumis sativus* L.)				
Achtzehn & Hawat (1969)	150	20-300	.	
Astier-Dumas (1973)	100	17-414	8	
Bergholm (1972)	104	.	2	
Hlavsova et al. (1969)	240	30-490	14	
Höyem (1974)	201	126-271	3	
Kenny & Walshe (1975)	234	130-563	6	
Rautu et al. (1972)	149	40-445	10	
Richardson (1907)	160	44-531	5	
Rooma (1971)	105	s.e.:14	15	outdoor
	496	s.e.:29	12	greenhouse
Siciliano et al. (1975)	24	.	.	
Soboleva (1969)	324	s.e.:29	19	greenhouse
CURLY KALE (*Brassica oleracea* L. var. lacineata (L.) Schulz)				
Achtzehn & Hawat (1969)	240	30-430	.	
Adriaanse & Robbers (1965)	1258		1	
Hansen (1976b)	418	87-1547	5	winter

Table 6, continued. Nitrate content of fresh vegetables in mg/kg fresh product.

reference	nitrate content mean	nitrate content range	number of samples	remarks
Hansen (1976b)	2689	621-5530	4	summer
Hildebrandt (1976)	.	180-910	.	
Jackson et al. (1967)	1857		1	
Kerkvliet (1976)	295		1	A.A.
Schuphan (1958)	324		1	August
	275		1	October
	300		1	February
	237	.	.	
Rooma (1971)	801	s.e.:3	10	greenhouse
Sinios & Wodsak (1965)	.	120-900	.	
Smith (1966)	.	650-4750	.	
EGGPLANT (*Solanum melongana* L.)				
Blanc (1976)	179	.	4	
Siciliano et al. (1975)	302	.	.	
ENDIVE (*Cichorum endivia* L.)				
Astier-Dumas (1973)	375	76-675	10	
	860	40-2800	7	
Council of Europe (1975)	1410	50-2430	7	
Hildebrandt (1976)	.	40-1140	.	
Inspecteur van de Volksgezondheid (1978)	730	400-950	3	
	835	190-1660	20	outdoor
	1445	890-2765	12	greenhouse
Jackson et al. (1967)	1290		1	
	546		1	escarol
Kerkvliet (1976)	1430	890-1950	5	July 1972 R.A.
	1170	960-1140	3	Jan. 1973 R.A.
	1720	790-3145	16	July 1973 R.A.
Kerkvliet (1976)	2490	2015-3200	17	March 1974 R.A.
	1600	540-2140	6	July 1974 R.A.
	515	10-2270	7	July 1972 A.A.
	1045	815-1445	5	Jan. 1973 A.A.
	1380	355-2550	6	July 1973 A.A.
	920	160-2360	10	July 1974 A.A.
Roorda van Eysinga & Maaswinkel (1978)	3310	2970-3850	14	greenhouse
Roorda van Eysinga & van der Meys (1978)	2640	1980-3310	.	greenhouse
Siciliano et al. (1975)	663	.	.	
Simon et al. (1966)	1330	1100-1500	3	
Spiegelhalder et al. (1976)	430		1	

Table 6, continued. Nitrate content of fresh vegetables in mg/kg fresh product.

reference	nitrate content		number of samples	remarks
	mean	range		
FRENCH BEAN or GREEN BEAN (*Phaseolus vulgaris* L.)				
Achtzehn & Hawat (1969)	220	160-320	.	
Auffray & Pafique (1976)	.	150-600	.	
Adriaanse & Robbers (1960)	61		1	
Bundesanstalt für Qualitätsforschung (1973)	.	87-550	.	
Hansen (1976b)	551	235-789	3	
Höyem (1974)	293	177-399	13	
Jackson et al. (1967)	246	198-273	3	
Maynard & Barker (1972)	152	.	.	
Richardson (1907)	443	44-664	4	
Rooma (1971)	540	s.e.:7	9	
Simon et al. (1966)	1080	.	.	
Sinios & Wodsak (1965)	.	400-1100	.	
Vulsteke & Biston (1976)	720	520-840	14	
GARDEN BEAN or BROAD BEEN (*Vicea faba* L.)				
Simon et al. (1966)	0	.	2	
GARDEN CRESS (*Lepidium sativum* L.)				
Astier-Dumas (1973)	1017	449-2747	20	
Jackson et al. (1967)	942		1	
Jensen (1972)	589		1	
GHERKIN (*Cucumis sativus* L.)				
Hansen (1976b)	377		1	
Möhler (1975)	.	1-300	.	
GREEN PEA (*Pisum sativum* L.)				
Achtzehn & Hawat (1969)	<10	.	.	
Höyem (1974)	4	0-12	21	
Maynard & Barker (1972)	113	.	.	
Rooma (1971)	6	s.e.:1	15	
Simon et al. (1966)	0	.	2	
Sinios & Wodsak (1965)	.	30-70	.	
LAMB'S LETTUCE (*Valerianella locusta* (L.) Betcke)				
Spiegelhalder et al. (1976)	4301		1	

Table 6, continued. Nitrate content of fresh vegetables in mg/kg fresh product.

reference	nitrate content: mean	nitrate content: range	number of samples	remarks
LEEK (*Allium porrum* L.)				
Achtzehn & Hawat (1969)	310	260-860	.	
Council of Europe (1975)	1340	325-4480	8	
Garbouchev & Mitreva (1972)	180		1	
Hansen (1976b)	174	103-244	2	
Inspecteur van de Volksgezondheid (1978)	655	280-1350	16	
Möhler (1975)	.	36-2040	.	
Richardson (1907)	443	399-487	2	
Rooma (1971)	577	s.e.:135	10	
Simon et al. (1966)	305	150-460	2	
Soboleva (1969)	728	s.e.:3	12	
Spiegelhalder et al. (1976)	417	115-719	2	
LETTUCE (*Lactuca sativa* L.)				
Achtzehn & Hawat (1969)	1200	800-1540	.	
Astier-Dumas (1973)	1514	678-2695	27	
Astier-Dumas (1976b)	1700	.	.	
Bundesanstalt für Qualitätsforschung (1972)	1860	.	.	
Bergholm (1972)	2400	472-5292	16	
Cantliffe & Phatak (1974b)	621	526-698	4	
Council of Europe (1975)	1960	920-2800	8	
Gersons (1976a)	3116	2740-3854	5	
	.	2190-2960	.	
Hansen (1976a)	4974	4610-5781	10	winter
	12336	11609-12826	7	winter
	10608	10032-11088	7	winter
Hansen (1976b)	4204	1547-10203	6	summer
	.	1889-4644	.	summer
Hlavsova (1969)	1120	320-2400	28	
Höyem (1974)	3525	1517-5099	4	
Inspecteur van de Volksgezondheid (1978)	3390	2455-4050	13	greenhouse
	2210	490-3930	14	
	2490	2040-3000	11	March 1974 R.A.
	1445	515-2040	8	July 1974 A.A.
Jackson et al. (1967)	664	488-893	5	
Jensen (1972)	4490	2512-6224	7	
Kenny & Walshe (1975)	2880	1732-4352	9	April
	3936	3191-4482	5	December

Table 6, continued. Nitrate content of fresh vegetables in mg/kg fresh product.

reference	nitrate content		number of samples	remarks
	mean	range		
Kerkvliet (1976)	1480	890-2380	10	July 1972 R.A.
	3245	2190-5205	18	Jan. 1973 R.A.
	1360	485-2260	20	July 1973 R.A.
	3310	1935-4340	15	March 1974 R.A.
	1710	840-2055	13	July 1974 R.A.
	565	380-815	5	July 1972 A.A.
	4075	3070-4605	3	Jan. 1973 A.A.
	900	145-1430	8	July 1973 A.A.
	1560	215-2160	20	July 1974 A.A.
Lee (1972)	279	.	.	
Lemieszek-Chodorowska et al. (1972)	.	90-3520	72	
Maynard & Barker (1972)	736	.	.	
Möhler (1975)	.	870-2700	10	
Rautu et al. (1972)	935	180-3150	5	
Richardson (1907)	1674	399-3543	5	
Rooma (1971)	3005	s.e.:35	20	
Siciliano et al. (1975)	1210	1100-1400	3	
Simon et al. (1966)	.	860-2100	12	
Sinios & Wodsak (1965)	.	800-1800	.	
Smith (1966)	.	150-6000	.	
Soboleva (1969)	195	s.e.:5	16	outdoor
	2177	s.e.:93	11	greenhouse
MELON (*Cucumis melo* L.)				
Jackson et al. (1967)	387	176-598	2	
Richardson (1907)	40		1	
Wilson (1943)	433		1	pressed juice
MUSHROOM (*Agaricus bisporus* (Lange) Singer)				
Achtzehn & Hawat (1969)	110	40-250	.	
Bergholm (1972)	73	.	3	
Jensen (1972)	412		1	
Siciliano et al. (1975)	63	.	.	
ONION (*Allium cepa* L.)				
Achtzehn & Hawat (1969)	20	10-30	.	
Hansen (1976b)	1303	357-2250	2	
Hlavsova (1969)	127	0-520	16	
Jackson et al. (1967)	310	308-312	2	spring onions
	18		1	white onions
	79		1	yellow onions
Kenny & Walshe (1975)	0	.	9	May

Table 6, continued. Nitrate content of fresh vegetables in mg/kg fresh product.

reference	nitrate content mean	nitrate content range	number of samples	remarks
Kenny & Walshe (1975)	0	.	9	December
Maynard & Barker (1972)	61	.	.	
Rautu et al. (1972)	74	0-240	14	
Richardson (1907)	229	18-841	4	
PARSLEY (*Petroselinum crispum* (Mill.) Airy-Shaw)				
Achtzehn & Hawat (1969)	1390	200-2460	.	leaves
	530	320-790	.	root
Council of Europe (1975)	1605	170-3475	8	leaves
Hansen (1976b)	138		1	leaves
	119		1	root
Hlavsova (1969)	555	0-1860	11	leaves
Jackson et al. (1967)	1698		1	leaves
Lemieszek-Chodorowska et al. (1972)	.	20-2985	64	root
Rautu et al. (1972)	1540	224-3400	10	leaves
	583	0-4120	10	root
Richardson (1907)	1112	752-1471	2	leaves
Rooma (1971)	1896	s.e.:251	9	leaves
	1096	s.e.:156	10	root
Spiegelhalder et al. (1976)	915		1	leaves
POTATO (*Solanum tuberosum* L.)				
Achtzehn & Hawat (1969)	40	30-70	.	
Auffray & Pafique (1976)	300	40-1000	.	
Bergholm (1972)	64		1	
Cantoni & d'Aubert (1974)	.	70-112	.	
Heisler et al. (1973)	120	7-360	99	
Hlavsova et al. (1969)	130	16-450	19	
Höyem (1974)	46	9-93	8	
Jackson et al. (1967)	57	35-79	2	
Kenny & Walshe (1975)	56	0-87	9	May
	22	0-43	6	August
	35	0-43	9	September
Maynard & Barker (1972)	182	.	.	
Möhler (1972)	.	9-390	.	
Richardson (1907)	77	40-106	5	
Rautu et al. (1972)	119	5-370	15	
Rooma (1971)	18	s.e.:2	15	
Soboleva (1969)	24	s.e.:1	31	
	190	s.e.:25	16	
Stephany & Schuller (1977)	130	8-334	42	

Table 6, continued. Nitrate content of fresh vegetables in mg/kg fresh product.

reference	nitrate content mean	range	number of samples	remarks
Subbotin et al. (1970)	342	s.e.:8	52	
PUMPKIN or SQUASH (*Cucurbita maxima* Duch.)				
Jackson et al. (1967)	291		1	
Richardson (1907)	698	310-1373	4	
Siciliano et al. (1975)	459	34-678	3	
Smith (1966)	.	400-2250	.	
Soboleva (1969)	90	s.e.:1	12	
PURSLANE (*Portulaca oleracea* L.)				
Council of Europe (1975)	6150	4110-8975	5	
RADISH (*Raphanus sativa* L. var. radicula Pers. (radish) & var. niger (Mill.) Pers. (black radish))				
Achtzehn & Hawat (1969)	1650	350-3520	.	black radish
Astier-Dumas (1973)	712	87-1568	4	
Cantliffe & Phatak (1974b)	593	516-764	4	
Hildebrandt (1976)	.	60-300	.	
Jackson et al. (1967)	1492	1250-1734	2	
Lemieszek-Chodorowska et al. (1972)	.	77-2095	40	
Maynard & Barker (1972)	1742	.	.	
Rautu et al. (1972)	2840	510-6300	10	
Richardson (1907)	1830	531-3056	6	
Rooma (1971)	1205	s.e.:80	9	outdoor
	1365	s.e.:27	15	greenhouse
	1906	s.e.:52	20	black radish
Roorda van Eysinga & van der Meys (1978)	2900	2220-3870	5	
	3790		1	black radish
Siciliano et al. (1975)	.	2400-3000	.	
Smith (1966)	.	850-9000	.	
Soboleva (1969)	589	s.e.:3	8	outdoor
	1326	s.e.:79	9	greenhouse
Spiegelhalder et al. (1976)	2132	1244-3295	5	
	2210	462-3799	7	black radish
Staatliche LUFA Karlsruhe (1973)	1900	1500-2600	.	
	1700	1200-2200	.	
	2200	1900-2500	.	
	1800	1600-2100	.	

Table 6, continued. Nitrate content of fresh vegetables in mg/kg fresh product.

reference	nitrate content mean	range	number of samples	remarks
Subbotin et al. (1970)	3587	s.e.:59	10	
	2701	s.e.:69	10	black radish
RHUBARB (*Rheum rabarbarum* L.)				
Kenny & Walshe (1975)	1516	714-2468	6	
Maynard & Barker (1972)	394	.	.	
Rooma (1971)	2420	s.e.:206	15	
Wilson (1943)	3227	1000-5454	2	pressed juice
Wilson (1949)	3182	1818-4545	2	pressed juice
SCORZONERA (*Scorzonera hispanica* L.)				
Achtzehn & Hawat (1969)	310	170-400	.	
SPINACH (*Spinacia oleracea* L.)				
Achtzehn & Hawat (1969)	1240	220-2700	.	
	1775	1000-2760	20	
Adriaanse & Robbers (1965)	1410		1	
Astier-Dumas (1976b)	823	371-1275	.	
	.	50-4000	.	
Becker (1965)	1510	35-2640	8	
Cantoni & d'Aubert (1974)	.	797-1500	.	
Dillier & Heierli (1970)	1205	429-1876	8	
Dillier & Heierli (1971)	1200	410-2200	11	
Frankena (1968)	1405	1215-1593	4	
Garbouchev & Mitreva (1972)	120	.	.	summer
	540	230-710	3	winter
Gersons (1976b)	1897	1155-2748	8	
Hansen (1976b)	1940	923-3324	5	
Herrmann (1969)	.	82-1710	.	
Hildebrandt (1976)	.	210-2840	.	
Höyem (1974)	2005		1	
Inoue (1972)	.	360-3300	.	
Inspecteur van de Volksgezondheid (1978)	3745	3685-3930	3	
	2580	860-3440	9	
Jackson et al. (1967)	238	.	2	
Kenny & Walshe (1975)	1360	217-2468	6	August
	1641	1442-1793	3	January
Kerkvliet (1976)	4170	3255-5120	17	March 1974 R.A.
	3125	2665-3725	6	April 1974 R.A.
	480	300-690	4	June 1973 A.A.

Table 6, continued. Nitrate content of fresh vegetables in mg/kg fresh product.

reference	nitrate content mean	range	number of samples	remarks
Kerkvliet (1976)	2745	2565-2925	2	March 1974 A.A.
	1270	360-2180	2	June 1974 A.A.
Lee (1972)	2073	.	.	
Lemieszek-Chodorowska et al. (1972)	.	77-2095	40	
Maynard & Barker (1972)	2269	.	.	
Meineke (1972)	2460	2300-2600	3	
Minotti (1978)	549	298-1050	20	
Möhler (1975)	.	190-2300	.	outdoor
	.	1800-5000	.	greenhouse
Phillips (1968a)	1892	1368-2277	3	
Rautu et al. (1972)	1159	130-6700	9	
Richardson (1907)	1922	310-3809	5	
Riehle & Jung (1966)	267	195-302	5	
Roorda van Eysinga & van der Meys (1978)	3910	3730-4040	4	greenhouse
Schuphan (1961)	129	2-431	47	
Schuphan & Schlottmann (1965)	279	123-385	3	
Schütt (1977)	2440	1100-4090	.	autumn 1972
	1300	400-1730	6	spring 1973
	2350	1400-3410	6	autumn 1973
	1970	800-3700	14	autumn 1975
Siciliano et al. (1975)	2220	s.d.:375	.	
Simon et al. (1966)	.	70-2100	.	
Sinios & Wodsak (1965)	.	300-1800	.	
Spiegelhalder et al. (1976)	1931	1398-3368	7	
Voogt (1969)	1570	290-3480	11	
Wilberg (1972)	2310	s.d.:290	12	R.A.
	2670	s.d.:400	12	A.A.
Witte (1967a)	340	50-1280	63	winter
	630	20-2040	70	spring
Witte (1970)	1520	250-2900	60	autumn
SWEET PEPPER (*Capsicum annuum* L.)				
Achtzehn & Hawat (1969)	140	80-180	.	
Bergholm (1972)	68	.	5	
Hlavsova et al. (1969)	90	0-230	21	
Jackson et al. (1967)	195	110-352	4	
Rautu et al. (1972)	66	16-150	10	
Siciliano et al. (1975)	62	.	.	
Spiegelhalder et al. (1976)	227		1	

Table 6, continued. *Nitrate content of fresh vegetables in mg/kg* fresh product.

reference	nitrate content		number of samples	remarks
	mean	range		
SWEET POTATO (*Ipomoea batatas* Lam.)				
Jackson et al. (1967)	50		1	
Maynard & Barker (1972)	0	.	.	
Richardson (1907)	66	27-128	6	
TOMATO (*Lycopersicon esculentum* Mill.)				
Achtzehn & Hawat (1969)	<10	.	.	
Astier-Dumas (1973)	7	0-47	10	
Auffray & Pafique (1976)	10	.	.	
Bergholm (1972)	56	.	2	
Hlavsova et al. (1969)	37	0-110	22	
Jackson et al. (1967)	72	48-110	4	
Jensen (1972)	150		1	
Kenny & Walshe (1975)	117	43-173	9	May
	4	0-13	7	December
Kerkvliet (1976)	75	61-92	6	A.A.
Maynard & Barker (1972)	87	.	.	
Rautu et al. (1972)	61	0-140	10	
Richardson (1907)	54	27-89	5	
Rooma (1971)	22	s.e.:2	15	
Soboleva (1969)	33	s.e.:1	13	
TURNIP (*Brassica napus* L. var. napobrassica (L.) Rchb.)				
Achtzehn & Hawat (1969)	<10	.	.	
Kenny & Walshe (1975)	329	87-650	9	May
	104	43-238	9	November
Richardson (1907)	1045	89-2899	5	
Rooma (1971)	458	s.e.:54	15	
TURNIP CABBAGE (*Brassica oleracea* L. var. gongylodes L.)				
Achtzehn & Hawat (1969)	1290	970-1540	.	
Hildebrandt (1976)	.	40-440	.	
Hlavsova et al. (1969)	1080	350-3260	26	
Schuphan (1958)	162	155-167	2	
Simon et al. (1966)	830	260-1400	2	
TURNIP TOPS (*Brassica campestris* L. var. rapa (L.) Hartm.)				
Roorda van Eysinga & van der Meys (1978)	6560		1	greenhouse

Table 7. Classifiation of vegetables according to nitrate content of the fresh product.

1 Species with contents mostly lower than 200 mg/kg
- asparagus
- chicory
- garden bean
- green pea
- mushroom
- potato
- sweet pepper
- sweet potato
- tomato

2 Species with contents mostly lower than 500 mg/kg
- broccoli
- cauliflower
- cucumber
- eggplant
- gherkin
- melon
- onion
- scorzonera
- turnip

3 Species with contents mostly lower than 1000 mg/kg
- cabbage (white, red and savoy)
- carrot
- curly kale
- French bean
- parsley (root)
- pumpkin

4 Species with contents mostly lower than 2500 mg/kg
- cabbage (oxheart)
- celeriac
- endive
- garden cress
- leek
- parsley (leaves)
- rhubarb
- turnip cabbage

5 Species with contents frequently higher than 2500 mg/kg
- beetroot
- celery
- chervil
- lamb's lettuce
- lettuce
- purslane
- radish & black radish
- spinach
- turnip tops

Table 8. Nitrate content of processed vegetables in mg/kg fresh product. s.d.: standard deviation.

reference	nitrate content mean	nitrate content range	number of samples	type of product
ARTICHOKE (*Cynara scolymus* L.)				
Siciliano et al. (1975)	12	s.d.[1]:1	2	frozen
ASPARAGUS (*Asparagus officinalis* L.)				
Siciliano et al. (1975)	16	s.d.:9	6	frozen
Richardson (1907)	14	0-27	2	canned
Siciliano et al. (1975)	3		1	canned
BEETROOT or TABLE BEET (*Beta vulgaris* L. var. rubra L.)				
Astier-Dumas (1973)	1577	774-2978	20	boiled
Lee et al. (1971)	218	168-290	4	canned
Siciliano et al. (1975)	1450	s.d.:249	4	canned
Benk (1974)	.	1783-3576	6	juice
	.	945-4130	8	juice
Sachse (1966)	300	.	2	juice
Spiegelhalder et al. (1976)	1758	1389-2201	13	juice
Commonor (1968)	370	.	5	baby food
Fishbein et al. (1970)	245	s.d.:97	.	baby food
Kamm et al. (1965)	976	637-2160	6	baby food
Liedtke & Meloan (1976)	2140		1	baby food
BROCCOLI (*Brassica oleracea* L. var. italica Plenck)				
Bergholm (1972)	338	238-433	3	frozen
Jackson et al. (1967)	550	506-594	2	frozen
Siciliano et al. (1975)	464	s.d.:17	6	frozen
	573	s.d.:164	4	frozen
BRUSSELS SPROUTS (*Brassica oleracea* L. var. gemnifera (DC.) Schulz)				
Bergholm (1972)	117	.	4	frozen
Council of Europe (1975)	16	0-50	5	frozen
Siciliano et al. (1975)	84	s.d.:66	7	frozen
Council of Europe (1975)	100		1	canned
CABBAGE (RED) (*Brassica oleracea* L. var. rubra DC.)				
Council of Europe (1975)	180		1	frozen
	300	220-410	4	canned
CARROT (*Daucus carota* L.)				

Table 8, continued. Nitrate content of processed vegetables in mg/kg fresh product.

reference	nitrate content mean	range	number of samples	type of product
Jackson et al. (1967)	194		1	frozen
Siciliano et al. (1975)	97	s.d.:39	5	frozen
Bohm (1966)	191	100-270	6	canned
Jackson et al. (1967)	98	90-106	2	canned
Sachse (1966)	.	.-50	.	canned
Selenka & Brand-Grimm (1976)	82	60-114	4	canned
Siciliano et al. (1975)	205	s.d.:129	18	canned
Bergholm (1972)	260	.	5	juice
Sachse (1966)	70	.	.	juice
Spiegelhalder et al. (1976)	376	233-667	4	juice
Stolley et al. (1977)	410	290-530	2	juice
Uhlig (1969)	105	70-140	2	juice
Achtzehn & Hawat (1969)	150	90-280	.	baby food
Bergholm (1972)	160	.	3	baby food
Bohm (1966)	96	32-240	4	baby food
Commonor (1968)	26	.	7	baby food
Fishbein et al. (1970)	38	s.d.:10	.	baby food
Kamm et al. (1965)	101	57-167	8	baby food
Leidtke & Meloan (1976)	66		1	baby food
Stolley et al. (1977)	.	55-215	9	baby food normal
	.	50-185	5	baby food juice
Uhlig (1968)	110	14-310	60	baby food
CAULIFLOWER (*Brassica oleracea* L. var. botrytis L.)				
Siciliano et al. (1975)	254	s.d.:56	5	frozen
CELERY (*Apium graveolens* L. var. dulce (Mill.) DC.)				
Vulsteke & Biston (1978)	1410	720-2265	32	canned
Tannenbaum et al. (1976)	1200		1	juice
CHERVIL (*Anthriscus cerefolium* (L.) Hoffm.)				
Council of Europe (1975)	970		1	frozen
	535	190-1045	5	canned
CURLY KALE (*Brassica oleracea* L. var. lacineata (L.) Schulz)				
Council of Europe (1975)	535	110-1115	8	frozen
Siciliano et al. (1975)	2770	s.d.:750	3	frozen
Jackson et al. (1967)	1858	1542-2174	2	canned
Siciliano et al. (1975)	1600	s.d.:871	3	canned

Table 8, continued. Nitrate content of processed vegetables in mg/kg fresh product.

reference	nitrate content		number of	type of
	mean	range	samples	product
FRENCH BEAN or GREEN BEAN (*Phaseolus vulgaris* L.)				
Bergholm (1972)	254	.	3	frozen
Jackson et al. (1967)	198		1	frozen
Kenny & Walshe (1975)	186	173-217	3	frozen
Siciliano et al. (1975)	270	s.d.:41	4	frozen
Jackson et al. (1967)	222	148-306	4	canned
Selenka & Brand-Grimm (1976)	117	40-200	7	canned
Siciliano et al. (1975)	100	s.d.:68	5	canned
Vulsteke & Biston (1978)	294	180-415	13	canned
Fishbein et al. (1970)	43	s.d.:10	.	baby food
Kamm et al. (1966)	163	70-313	3	baby food
Liedtke & Meloan (1976)	182		1	baby food
GARDEN CRESS (*Lepidium sativum* L.)				
Jackson et al. (1967)	2438		1	canned
GREEN PEA (*Pisum sativum* L.)				
Bergholm (1972)	82	.	4	frozen
Jackson et al. (1967)	62		1	frozen
Kenny & Walshe (1975)	0	.	3	frozen
Siciliano et al. (1975)	20	s.d.:7	4	frozen
Jackson et al. (1967)	40	26-53	2	canned
Selenka & Brand-Grimm (1975)	8	4-17	6	canned
Richardson (1907)	25	0-58	4	canned
Siciliano et al. (1975)	6	s.d.:2	3	canned
Commonor (1968)	2	.	3	baby food
Liedtke & Meloan (1976	63		1	baby food
INDIAN MUSTARD or MUSTARD GREENS (*Brassica juncea* Coss.)				
Siciliano et al. (1975)	2390	s.d.:868	4	frozen
	1360	s.d.:334	2	canned
LEEK (*Allium porrum* L.)				
Astier-Dumas (1973)	121	23-290	20	boiled
LETTUCE (*lactuca sativa* L.)				
Simon et al. (1965)	300	260-320	4	baby food

Table 8, continued. Nitrate content of processed vegetables in mg/kg fresh product.

reference	nitrate content mean	nitrate content range	number of samples	type of product
MELON (*Cucumis melo* L.)				
Siciliano et al. (1975)	533	s.d.:146	4	frozen
MUSHROOM (*Agaricus bisporus* (Lange) Singer)				
Siciliano et al. (1975)	12	6-17	2	canned
ONION (*Allium cepa* L.)				
Siciliano et al. (1975)	81	33-128	2	frozen
Jackson et al. (1967)	143		1	canned
PODDED PEA (*Pisum sativum* L.)				
Siciliano et al. (1975)	13	s.d.:1	2	frozen
POTATO (*Solanum tuberosum* L.)				
Astier-Dumas (1973)	101	9-225	32	boiled
Selenka & Brand Grimm (1975)	109	16-308	14	boiled
Jackson et al. (1967)	132	123-141	2	frozen
Siciliano et al. (1975)	150		1	frozen
Jackson et al. (1967)	143		1	canned
Siciliano et al. (1975)	65	49-77	3	canned
PUMPKIN or SQUASH (*Cucurbita maxima* Duch.)				
Siciliano et al. (1975)	160	s.d.:20	2	frozen
Jackson et al. (1967)	343		1	canned
Richardson (1907)	266		1	canned
Commonor (1968)	126	.	3	baby food
Fishbein et al. (1970)	84	s.d.:28	5	baby food
Kamm et al. (1965)	287	44-409	5	baby food
Liedtke & Meloan (1976)	952	.	.	baby food
PURSLANE (*Portulaca oleracea* L.)				
Council of Europe (1975)	3705	3385-4395	3	canned
RHUBARB (*Rheum rabarbarum* L.)				
Jackson et al. (1967)	387		1	frozen
SPINACH (*Spinacia oleracea* L.)				

Table 8, continued. Nitrate content of processed vegetables in mg/kg fresh product.

reference	nitrate content		number of	type of
	mean	range	samples	product
Astier-Dumas (1973)	83	22-360	30	boiled
Becker (1965)	1050	340-1480	7	frozen
Bergholm (1972)	1455	632-2343	16	frozen
Bohm (1966)	1100	220-1770	9	frozen
Council of Europe (1975)	1275	890-1545	4	frozen
Frankena (1968)	647		1	frozen
Hawat & Achtzehn (1972)	515	410-620	2	frozen
Jackson et al. (1967)	667	594-739	2	frozen
Klaushofer et al. (1967b)	.	149-1019	3	frozen
Meineke (1972)	1400	1060-1660	3	frozen
Riehle & Jung (1966)	143	41-273	4	frozen
Sachse (1966)	.	600-900	15	frozen
Schaller et al. (1969)	1119	238-2620	29	frozen
Schuphan & Schlottmann (1965)	905	268-1498	5	frozen
Selenka & Brand-Grimm (1975)	411	298-697	4	frozen
Siciliano et al. (1975)	2140	s.d.:283	4	frozen
Simon et al.(1965)	535	320-800	4	frozen
Sinios & Wodsak (1965)	.	800-1400	22	frozen
Thier (1967)	.	62-1770	.	frozen
Becker (1965)	795	150-1815	15	canned
Bohm (1966)	752	400-1120	6	canned
Council of Europe (1975)	1136	755-1535	10	canned
Frankena (1968)	1374		1	canned
Gersons (1976b)	1436	1240-1631	4	canned
Hawat & Achtzehn (1972)	960	300-1480	4	canned
Jackson et al. (1967)	473	396-550	2	canned
Kövary & Kövary (1969)	.	0-1175	43	canned
Lee et al. (1971)	83	15-150	2	canned
Phillips (1968b)	866		1	canned
Reinton (1974)	1000	.	6	canned
Richardson (1907)	1143	266-1949	5	canned
Riehle & Jung (1966)	85	57-106	4	canned
Sachse (1966)	.	700-2700	15	canned
Siciliano et al. (1975)	573		1	canned
Simon et al. (1965)	975	780-1120	4	canned
Simon et al. (1966)	.	40-1900	32	canned
Sinios & Wodsak (1965)	.	300-1220	14	canned
Sistrunk & Cash (1974)	850	630-1010	7	canned
Thier (1967)	.	82-1460	.	canned
Becker (1965)	670	160-1260	8	baby food
Bohm (1966)	520	88-1460	11	baby food
Commonor (1968)	56	.	4	baby food
Fishbein et al. (1970)	66	s.d.:21	.	baby food
Frankena (1968)	820		1	baby food

Table 8, continued. Nitrate content of processed vegetables in mg/kg fresh product.

reference	nitrate content mean	range	number of samples	type of product
Kamm et al. (1965)	1370	1074-1665	5	baby food
Liedtke & Meloan (1976)	518		1	baby food
Phillips (1968b)	779		1	baby food
Reinton (1974)	650	.	7	baby food
Riehle & Jung (1966)	150	83-306	4	baby food
Simon et al. (1966)	760	82-1210	27	baby food
Uhlig (1968)	731	30-1920	63	baby food
SWEET PEPPER (*Capsicum annuum* L.)				
Jackson et al. (1967)	132		1	
Siciliano et al. (1975)	50	s.d.:40	3	
THOUSAND HEAD KALE or COLLARD GREENS (*Brassica oleracea* L. var. acephala DC.)				
Siciliano et al. (1975)	2450	s.d.:1400	4	frozen
	2640	s.d.:856	2	canned
TOMATO (*Lycopersicon esculentum* Mill.)				
Jackson et al. (1967)	58	11-106	2	canned
Richardson (1907)	47	18-75	2	canned
Jackson et al. (1967)	30	11-63	3	juice
TURNIP TOPS (*Brassica campestris* L. var. rapa (L.) Hartm.)				
Siciliano et al. (1975)	3460	s.d.:358	3	frozen
Jackson et al. (1967)	1511	1199-1822	2	canned
Siciliano et al. (1975)	2230	s.d.:541	2	canned
GARDEN VEGETABLES				
Kamm et al. (1965)	178	82-268	5	baby food
Liedtke & Meloan (1976)	226		1	baby food
Uhlig (1968)	320	170-470	2	baby food
MIXED VEGETABLES				
Bergholm (1972)	152	.	4	baby food
Kamm et al. (1965)	99	92-106	2	baby food
Liedtke & Meloan (1976)	53		1	baby food
Phillips (1968b)	182		1	baby food
Spiegelhalder et al. (1976)	137	27-246	2	baby food
Uhlig (1968)	275	120-430	2	baby food

5 Factors affecting the nitrate accumulation in vegetables during growth and development

5.1 Morphological and genetic factors

5.1.1 Differences among species

The differences in nitrate accumulation among species are to a great extent conditioned by the morphology of the species or the morphology of the harvested plant parts. Cultural practices do not affect these differences. As nitrate is taken up by the roots and is mostly reduced in the leaves, xylem (transport tissue) contains more nitrate than other tissues. It is true in general that the nitrate content is lowest in floral parts, but present in increasing amounts in fruits or grains, leaves, roots and petioles or stems, in that order (Maynard et al., 1976). Root or stem parts with storage tissue (like in radish, potato and beetroot) can have either high or low nitrate contents. Within plant parts nitrate contents are higher in older tissue (Maynard et al., 1976). Even when the harvested products are morphologically identical, large differences in nitrate content can be found. It is not easy to establish these differences because of variances in length of the growing period and consequently in weather conditions and nitrogen supply. Even when the growing period is the same, it still remains a question whether differences in cultural practices do not lead to a different nitrate content. Furthermore, differences found under certain circumstances will not necessarily be observed under all other circumstances. Much research has been done with different species but only in a few cases are the results comparable.

Maynard & Barker (1971) introduced the 'critical nitrate level' as a measure of differences between species. It is the nitrate content found in a crop that received a nitrogen dressing enough to give ninety percent of maximum yield. The authors considered this yield to be an acceptable minimum. In an experiment with sand cultures to which nutrient solutions were added, the 'critical nitrate levels' of leaf lettuce, radish and spinach (variety America) amounted to 400, 1500 and 1800 mg per kg fresh product, respectively. However, in 1974 under similar conditions, the same authors found a 'critical nitrate level' for spinach (variety America) of only 750 mg per kg fresh product. The critical nitrate levels mentioned are obviously so strongly influenced by other factors than nitrogen dose that quantitative data are difficult to interpret. A number of qualitative differences between species are more evident. Accumulation of nitrate was noted to start in leaf lettuce at a relatively high nitrogen dressing, whereas in radish-roots nitrate accumulation already started with low nitrogen doses and relatively low yields. Both species accumulated much nitrate at high nitrogen doses. Spinach accumulated nitrate in the same measure as leaf lettuce, except that the nitrate content of spinach was lower at high nitrogen doses and slightly higher at low nitrogen doses (Maynard & Barker, 1971).

Terman et al. (1976) described relationships between total nitrogen and nitrate nitrogen contents of plants grown in several pot experiments in the greenhouse. They found discontinuous regression models to be most satisfactory to fit the entire range of relationships between total nitrogen and nitrate nitrogen. Spinach was found to accumulate nitrate when the total nitrogen content exceeded 4.5 percent of dry matter, whereas in mustard leaves accumulation started when total nitrogen exceeded 4.0 percent of dry matter. Using data from Peck et al. (1974) they calculated that the minumum total nitrogen contents that must be exceeded to find nitrate accumulation for leaf blades, petioles and roots of beetroot were 3.3, 1.5 and 2.0 percent of dry matter, respectively. At high total nitrogen contents spinach had the highest nitrate contents.

Other comparable differences in nitrate accumulation between species are described by Blanc (1976), Cantliffe (1972b) and Cantliffe & Phatak (1974b). For less comparable data see also Table 6.

5.1.2 Intraspecific differences - varietal differences

Differences among cultivars are easier to judge than differences among species, but also here variations in length of growth period play an important role. When on the one hand a number of cultivars are harvested at the same time it is not at all sure that every cultivar has the same degree of maturity (physiological age). When on the other hand the cultivars are harvested at exactly the same degree of maturity, the differences found may have to be ascribed to varying weather conditions, nitrogen supply etc. In addition, differences among cultivars are not necessarily the same under all circumstances (for instance: summer vs. winter, greenhouse vs. outdoor).

A clear example of the first problem is given by van Maercke & Vereecke (1976). They analysed the total nitrogen and the nitrate contents of seven spinach cultivars. In 1973 all cultivars were harvested at one time when the first cultivar started bolting. In 1974 the cultivars were not harvested at the same time but at the same degree of maturity (at the moment bolting began). The results are presented in Table 9.

When all cultivars were harvested simultaneously (1973), the total nitrogen contents were almost equal, whereas when harvesting was carried out at different times (1974), the total nitrogen contents decreased as cultivars were harvested later; only Maveto had a rather high total nitrogen content although it was harvested late. In 1973, the nitrate contents were more variable than the total nitrogen contents. In 1974 the nitrate contents decreased as the cultivars were harvested later. The decrease in

Table 9. Total nitrogen and nitrate content in leaf blades of seven spinach cultivars when simultaneously harvested (1973) and when harvested at the same growthstage (1974). Total nitrogen (N) and nitrate (NO_3) content in mg/kg dry matter. Data from van Maercke & Vereecke (1976).

varieties in order of early to late bolting	1973		1974	
	total nitrogen content	nitrate content	total nitrogen content	nitrate content
Indures	50400	8839	48900	5204
Hybride no. 7	52100	15956	44800	2737
Nobel	52100	14353	39000	2369
Viking	53300	12072	36800	1763
Nores	53500	12719	32000	2276
Verbeterde reuzen	55200	14096	33300	1346
Maveto	54300	11705	38200	1298

nitrate content with time is a common phenomenon when the nitrogen fertilizer dose is low or medium. With a high nitrogen fertilizer dressing, the nitrogen supply to the plant at maturity is still so high that the nitrate content will increase until the moment of harvesting (see also Table 16).

In the USA much research has been done to investigate the influence of leaf type on the nitrate contents of spinach. The results of a greenhouse experiment of Maynard & Barker (1974), who worked with three cultivars with different leaf type, are demonstrated in Table 10. It can be seen that the nitrate contents decrease in the following sequence: America, Heavy Pack, Hybrid 424.

Olday et al. (1976) ascribed the difference in nitrate contents

Table 10. Leaf nitrate content of three spinach cultivars with different leaf types as a function of nitrate supply. Nitrate content in mg/kg fresh product. Data from Maynard & Barker (1974).

nitrate concentration in nutrient solution (mmol/l)	cultivar		
	America (savoyed)	Heavy Pack (semi-savoyed)	Hybrid 424 (smooth)
6	120	204	75
9	403	474	89
12	1138	1032	257
18	1975	1399	859
24	2360	1550	1129
48	3251	2378	2037

between the smooth and savoyed-leaf cultivars to the significantly higher nitrate reductase activity in the leaves of Hybrid 424 than in the leaves of America, at a high nitrogen supply. Barker et al. (1974) investigated six different cultivars of each of three leaf types, in the field and in the greenhouse. The results of the field experiment are shown in Table 11. As is shown, significant differences between leaf types were found. However, within each leaf type there was also a great deal of variation, especially in the group 'semi-savoyed'. Selection of a cultivar from a given group, therefore, does not yet provide any guarantee for a certain content of nitrate. It was generally found that the nitrate contents of all savoyed-leaf cultivars were higher than those of smooth-leaf cultivars. At high nitrogen fertilizer doses the differences between cultivars became relatively smaller. At the same dose of nitrogen applied, nitrate accumulation was higher when yield was lower. Table 11 further indicates that a high nitrate content in the leaf blades always coincides with a high nitrate content in the petioles and that the latter content always is considerably higher than the former. When based on fresh weight the nitrate contents of leaf blades and of petioles would differ less, since the dry matter content of the leaf blades is higher than that of the petioles. Nevertheless a difference would remain (see also Table 12).

The nitrate content of the total aerial plant part will strongly depend on the weight percentage of the petioles. Van Maercke & Vereecke (1976) demonstrated that there were significant differences in petiole length for the different cultivars. Although this must have influenced the weight percentage of the petioles, no data are available to verify this. Differences in nitrate accumulation between cultivars have been found in other species. Further data are not presented here; relevant literature can be found in Appendix 1.

Table 11. Nitrate content in spinach according to leaf type and amount of nitrogen applied in the field. Nitrate content in mg/kg dry matter. Data from Barker et al. (1974).

plant part	leaf type	nitrogen applied (kg/ha)		
		56	168	280
leaf blades	savoyed	3500	4000	5300
	semi-savoyed	2700	3100	3500
	smooth	1800	2700	3100
petioles	savoyed	21700	36800	43000
	semi-savoyed	17300	26600	32300
	smooth	8900	23500	27900

Table 12. Effect of various amounts of nitrogen on the nitrate content in lettuce, spinach and radish, grown on muck soil in a greenhouse under winter conditions. Nitrate content in mg/kg fresh product. Data from Cantliffe & Phatak (1974b).

	nitrogen applied (g/m^2)		
	0	14.7	29.4
lettuce	2945	2832	2719
spinach (blades)	2066	2056	2561
spinach (petioles)	2236	2218	2430
radish (roots)	2603	2758	3097

5.2 Environmental factors and cultural practices

Extensive research has been done on the influence of environmental factors on nitrate accumulation in vegetables. Attention has been focused mainly on fertiliser practices, especially on dressing with nitrogen, but also other factors, like light intensity, temperature, herbicides have been considered. Appendix 1 is a compilation of literature on the influence of the different environmental factors.
Recent literature about this subject is also reviewed by Lorenz (1978), Maynard (1978), Maynard et al. (1976), Minotti (1978), Venter (1978a) and Venter (1978b).

5.2.1 The amount of nitrogen

It is clear that dressing with nitrogen will enhance the supply of nitrogen to the plant. Whether or not this leads to an accumu-

Table 13. Effect of various amounts of nitrogen on the nitrate content of some vegetables in a field experiment. Fertilizer: NH_4NO_3. Nitrate content in mg/kg fresh product. Data from Splittstoesser et al. (1974).

	nitrogen applied (kg/ha)			
	22	45	112	448
lettuce (leaves)	797	1107	2037	2391
mustard (leaves)	2170	2923	3454	4960
collard (leaves)	3189	4429	5137	5359
cabbage (head)	155	177	797	797
snap bean (pods)	709	709	753	1284
beet (root)	531	531	709	664
tomato (fruit)	0	0	0	0
pepper (fruit)	177	177	266	133

Table 14. Effect of nitrogen on the nitrate content of some vegetables in a pot trial. Nitrate content in mg/kg fresh product. Data from Dressel (1976a).

	nitrogen applied (mg/pot)	
	0	250
spinach	103	450
lettuce	19	263
carrots	22	43
tomatoes	4	6

lation of nitrate depends on the nitrogen source, the amount of available nitrogen (including the residual soluble nitrogen in the soil), the plant species, the plant part considered and on other environmental factors that will be discussed later. How responses to nitrogen dressing can vary, is shown in Tables 12, 13 and 14.

5.2.2 The source of nitrogen

With respect to the influence of the source of nitrogen there are three points of special importance:
1. How fast will the nitrogen become available to the plant?
2. Does it become available in the form of nitrate or ammonium?
3. When nitrogen is available in the form of ammonium, what will be the rate with which it is converted to nitrate?

When there is a difference in the rate with which nitrogen becomes available, one should not compare nitrate accumulations for just one dose of nitrogen. A comparison must be based on equal total amounts of available nitrogen or on applied nitrogen doses producing the same yield. The difference in rate of becoming available is most pronounced when soluble inorganic fertilizers like calcium nitrate are compared with organic fertilizers like dung or compost. With inorganic nitrogen fertilizers, the nitrogen supply is high at the beginning of the growth period and decreases in the course of this growth period. The decrease will be faster as less nitrogen is applied. With organic nitrogen fertilizers the nitrogen supply is often low at the beginning of the growth period, but will usually increase in spring and summer because of accelerated mineralization as a result of higher temperatures. At a low or medium dose of nitrogen, applied as inorganic fertilizer, nitrate accumulation will at first be relatively high, but in the course of the growth period the nitrogen supply and hence also the nitrate content will decrease. With organic fertilizers the nitrate content at first is low, but during the growth period it increases, even to values higher than those reached with inorganic fertilizer. At high doses of inorganic nitrogen fertilizer the nitrogen supply stays high over the entire growth period and the nitrate content also stays high or might even increase. When high doses of organic fertilizer nitrogen are applied, nitrate accumulation will be less (Bundesanstalt für Qualitätsforschung, 1973).

Maga et al. (1976) investigated the influence of organic and inorganic nitrogen fertilizers on the nitrate contents of spinach. Their results are presented in Table 15. These data show how difficult it is to simply compare the doses used with different nitrogen sources. However, it is clear that with the low dose the difference in yield is relatively larger than the difference in nitrate content, and that with the higher dose the difference in nitrate content is relatively larger. Thus when applying doses that result in equal yields, one can assume that at a low dose an organic fertilizer would cause higher nitrate contents, and at a high dose an inorganic fertilizer would cause higher nitrate contens.

The use of organic and inorganic nitrogen sources is also dealt with in some other publications but as no yields are given, the nitrate contents are difficult to evaluate. In practice the level of the nitrate content seems to be often somewhat lower when only organic materials are used, but the differences are small and probably also the yield level is somewhat lower (Wilberg, 1972; Commissie Onderzoek Biologische Landbouwmethoden, 1976).

In the above sections we have ignored the question whether the nitrogen will become available for the plant in the form of nitrate or of ammonium. The influence of variation in type of available nitrogen can best be investigated by comparing soluble inorganic nitrogen fertilizers, containing either ammonium or nitrate, or both substances. Van Maercke (1973) tested the effect of different nitrogen fertilizers at different dosages on the nitrate contents of spinach in a field experiment. Some of the results are presented in Table 16. It can be seen that the nitrate contents decrease during the growth period and that there is little difference between the effect of ammonium sulphate and calcium nitrate. This finding can be explained by taking into account the conversion of ammonium to nitrate in the soil by nitrifying bacteria. Although ammonium is applied, the plant

Table 15. Effect of amount and source of nitrogen on the nitrate content and yield of spinach. Nitrate content in mg/kg dry matter, fresh yield in 10^3 kg/ha. Fertilizers: $(NH_4)_2SO_4$ and dried blood. Data from Maga et al. (1976).

N-dose (kg/ha)	N-source	nitrate content	fresh yield
0		3100	4.5
140	organic	9300	11
140	mineral	10200	14
420	organic	21300	16.5
420	mineral	35900	20

Table 16. Effect of amount and source of nitrogen on the nitrate content of spinach during the growth period in a field experiment in spring. Nitrate content in mg/kg fresh product. Data from van Maercke (1973).

N-dose (kg/ha)	N-source	harvest date			
		1-6	11-6	17-6	22-6
0		262	153	60	87
100	$(NH_4)_2SO_4$	1548	776	470	748
100	$Ca(NO_3)_2$	1965	1023	789	702
200	$(NH_4)_2SO_4$	1905	1085	1444	1613
200	$Ca(NO_3)_2$	2421	2270	1745	1396

hardly comes into contact with the ammonium because of this conversion.

In theory, when only ammonium-nitrogen is taken up, there would be no nitrate problem, but as was shown above, in practice this is not feasible. Tronickova & Vit (1970, 1972) even found higher nitrate contents in spinach when dressed with ammonium sulphate than when dressed with calcium nitrate. At a high nitrogen dose (300 kg/ha) Pimpini et al. (1971) found that in cauliflower the older plant parts had higher nitrate contents when the nitrogenous fertilizer was calcium nitrate instead of ammonium sulphate. In the edible plant part, however there was no difference in nitrate content. An explanation for this is: when ammonium sulphate is the nitrogenous fertilizer, the amount of available nitrate in the soil is low at the beginning of the growth period. During the growth period the ammonium in the soil is converted to nitrate and the plant parts developing in this period have an equal or even higher nitrate content than when calcium nitrate is used. Similar results have been found by Minotti (1978) in head lettuce (see also Table 23). At the beginning of the growth period the nitrate contents are lower with ammonium sulphate than with sodium nitrate, whereas at the end of the growth period nitrate contents were found to be higher with ammonium nitrate, at least when low or moderate nitrogen doses are applied. The rate at which the ammonium in the soil is converted to nitrate can be such that at the end of the growth period the nitrate supplies from an ammonium-nitrogen or a nitrate-nitrogen fertilizer are about the same. With ammonium application it may even be higher.

For ammonium-nitrogen to have any suppressive effect on nitrate accumulation, the conversion of ammonium in the soil to nitrate (nitrification) must be stopped or strongly retarded. This can be done with nitrification inhibitors. These chemicals inhibit the

Table 17. Fresh yield and nitrate content of spinach leaves as affected by source of nitrogen and nitrapyrin, applied to plants in a growth chamber experiment. Fresh yield in g/pot, nitrate content in mg/kg dry weight. Data from Mills et al. (1976a).

nitrogen applied (mg/pot)		fresh yield		nitrate content	
NH_4N	NO_3-N	A[1]	B[2]	A	B
400	0	29	21	26570	7530
300	100	35	33	35430	22590
200	200	44	41	57570	44290
100	300	47	47	78830	69090
0	400	48	45	90340	92110

1 A: no nitrapyrin applied.
2 B: 10 mg nitrapyrin applied/pot.

activity of nitrifying bacteria. In the soil, nitrification inhibitors are not very stable, so their effect will diminish with time unless they are periodically re-applied. When ammonium-nitrogen is applied together with a nitrification inhibitor, hardly any nitrate accumulation takes place. Comparing the yield in this case with the yield obtained with application of nitrate-nitrogen, we will find that the former is somewhat depressed. The reason for this is not so much the slight phytotoxicity of nitrification inhibitors, but rather the growth stagnation which occurs when nitrate is lacking. It seems impossible to replace nitrate entirely by ammonium without losing yield. The effect of replacing nitrate by ammonium and the effect of applying a nitrification inhibitor are shown in Table 17. The table demonstrates that nitrapyrin causes a slight decrease in yield and a strong decrease in nitrate contents. Replacing nitrate by ammonium reduces yield strongly when more than half of the nitrogen applied is ammonium. Ammonium drastically reduces nitrate contents. When nitrogen is applied half as ammonium and half as nitrate, the yield decrease is about 10 percent and the decrease in nitrate content 50 or 40 percent, with or without the application of a nitrification inhibitor, respectively. Although rather promising results were obtained with this regime in pot trials, few field experiments have been carried out to verify these results under field conditions.

5.2.3 The time of application of nitrogen

Most of the time enough nitrogen is applied before sowing or planting to cover the complete growth period. Split application of the nitrogen is also possible. The reasoning behind this latter practice is that the nitrogen supply can be better adapted to the needs of the crop. During a long growth period nitrogen can easily leach from the soil, especially in winter, and a split application must be preferred. For crops with a short growth period, as is the case with most vegetables, this practice is questionable. According to Barker et al. (1971) a split application of nitrogen decreases nitrate accumulation, but the time of the later application in this experiment was only one week before harvest. Therefore time for nitrogen uptake was very short and only a small part of this applied nitrogen will have been taken up, with hardly any possible influence on yield. The authors even stated that there was no significant effect of any treatment variable on yield. In this case probably no application at all would have been most effective in reducing nitrate accumulation without reducing yield.

This is a typical example of the meaninglessness of comparing nitrate contents when yield data are lacking. When the total dose of nitrogen is carefully adapted to the needs of the crop, it is to be expected that any postponement in applying the nitrogen will result in a yield decline and a rise in nitrate content. (e.g. Maga et al., 1976; Nicolaisen & Haar, 1964; Peck et al., 1974). The effects of fast and slow releasing nitrogen sources are comparable in this respect.

5.2.4 Other nutrients

Phosphate was found to have no or only little effect on the nitrate accumulation (Barker & Maynard, 1971; Brown & Smith, 1966, 1967; Maynard et al., 1976; Schuphan, 1965). In general, also potassium has little effect on nitrate accumulation (Barker & Maynard, 1971; Brown & Smith, 1966, 1967). In some trials nitrate accumulation increased with increasing potassium application wheras in others it decreased.

There is no evidence that sodium, calcium or magnesium have any direct effect on nitrate accumulation (Maynard et al., 1976). Sulphur is incorporated in sulfhydryl groups, which were found to be essential for nitrate reductase activity. Sulphur deficiency therefore might lead to increased nitrate contents (Maynard et al., 1976).

Chloride seems to cause a decrease in nitrate accumulation, since its uptake is antagonistic to nitrate (Boek & Schuphan, 1959; Cantliffe & Goodwin, 1974). Nurzinsky et al. (1976) found appreciably lower nitrate contents in spinach when potassium was applied as potassium chloride instead of as potassium sulphate.

Molybdenum is a component of the enzyme nitrate reductase and, hence, molybdenum deficiency was found to strongly increase nitrate accumulation (Cantliffe et al., 1974; Hildebrandt, 1976; Maynard et al., 1976). Deficiency in manganese and copper probably will stimulate nitrate accumulation (Hildebrandt, 1976). Also boron-deficiency seems to increase nitrate accumulation (Hulewicz & Mokrzecka, 1971).

Table 18. Effect of light intensity on the nitrate content of spinach leaves in a growth chamber experiment. Nitrate content in mg/kg dry weight. Data from Cantliffe (1972a).

light intensity (W/m^2)	nitrate content
151	15100
103	15100
69	21700
26	55800

1 W/m^2 = 23.3 ft-c.

5.2.5 Light

Light plays a very important part in nitrate metabolism within plants (Beevers & Hageman, 1972). It therefore is one of the main factors determining the nitrate contents. The nitrate contents in plants are affected by light intensity, photoperiod and possibly also by light duration within the photoperiod.

The effect of light intensity is very clearly demonstrated in Table 18. Under low light intensity (like in winter time) a strong nitrate accumulation was found, whereas under higher light intensities nitrate contents decreased. The effect of light is relatively larger at moderate nitrogen doses; at low nitrogen doses the nitrate contents will be low, even under low light intensities and at high doses nitrate will accumulate even under high light intensity. However, the nitrate contents will be higher under low light intensity. With the nitrogen fertilizer doses applied in practice nowadays, a significant effect of light intensity is to be expected (Boek & Schuphan, 1959; Cantliffe 1972a, 1973a; Möhler, 1975).

Daylength (photoperiod) has the same influence on the nitrate accumulation as has light intensity (Cantliffe, 1972b). Some researchers also found a decrease in nitrate content in the course of the day, whereas others did not find any difference. Minotti & Stankey (1973) working with young beetroot plants reported a decrease in nitrate content of over 50 percent during the day. Cantliffe (1972b) also found a decrease in the pods of snap bean and in radish leaves, but in radish-roots and spinach no changes in nitrate contents were discovered during the day. Under high light intensity, nitrate contents of spinach and lettuce were found to be lower in the afternoon than in the morning; under a low light intensity no decrease was observed by Schwerdtfeger (1974).

5.2.6 Temperature

The effect of temperature on nitrate accumulation cannot be predicted precisely, because the processes of absorption, translocation and assimilation are all affected. Other factors like

Table 19. Effect of cultivar and temperature on nitrate content of spinach in a growth chamber experiment. Nitrate content in mg/kg dry weight; nitrogen dose 200 mg/kg soil; fertilizer ammonium nitrate. Data from Cantliffe (1972c).

temperature (^{o}C)	cultivar	
	Virginia Savoy	Northland
5	6200	7090
10	11510	9740
15	30560	13290
20	41190	40300
25	75290	70410
30	51810	27460

light, soil moisture and nitrogen availability interact with temperature (Maynard et al., 1976). In general, nitrate contents in plants increase with increasing temperature, but at temperatures above about 30 ^{o}C nitrate uptake is strongly inhibited (Cantliffe, 1972c). Since nitrate reductase activity also decreases at these temperatures (Viets & Hageman, 1971), even higher nitrate contents are possible, but mostly a decreased nitrate accumulation will be observed. The effect of temperature on nitrate content of spinach is demonstrated in Table 19. Frota & Tucker (1972) noticed increasing nitrate absorption rates in lettuce with increasing temperature of root or air.

In addition, the indirect effect of temperature on nitrate absorption is very important, since mineralization and nitrification of soil nitrogen, and thus nitrate availability, are strongly influenced by temperature.

5.2.7 Water relations

Since nitrate reductase activity is depressed more by water stress than is nitrate aborption (Viets & Hageman, 1971; Wright & Davison, 1964), drought mostly leads to an increased nitrate accumulation. Because of irrigation practices, extended periods of low soil-moisture availability will be an exception in vegetable growing. Short dry periods, however, still can affect nitrate absorption because nitrate in the soil becomes more concentrated and also capillary rise of soil water can increase the nitrate supply. This situation could lead to a higher nitrate absorption and possibly to nitrate accumulation (Maynard et al., 1976). The experiments of Augustin et al. (1977) confirm this; they found that the nitrate contents of potatoes could be tripled when irrigation was insufficient.

Maynard et al. (1976) also suggest an effect of atmospheric humidity on the nitrate accumulation. A low humidity accelerates transpiration and thus water transport within the plant. In this way nitrate can be transported faster to sites where it can be reduced (mainly the leaf blades). When this reduction is inhibited in some way, nitrate accumulation will occur. Nitrate accumulation can also take place when water transport within the plant is reduced. Such a reduction can have its cause in a reduced uptake from a dry soil or in a reduced transpiration due to high atmospheric humidity.

5.2.8 Concentration of carbon dioxide in the air

The influence of carbon dioxide on nitrate assimilation is complex and not completely understood. However, there is evidence that an increasing carbon dioxide concentration causes a reduction in nitrate accumulation (Huffaker & Rains, 1978; Maynard et al., 1976). This aspect is not important in vegetables grown outdoors, but might be of interest in greenhouse cultures.

5.2.9 Herbicides

Cantliffe & Phatak (1974a) investigated the effect of herbicides on weed control, yield and nitrate accumulation in spinach. Only

Table 20. Effect of different herbicides on weed control, fresh yield and nitrate content in leaf-blades and roots of beetroot. Yield in 10^3 kg/ha; nitrate content in mg/kg dry matter. Data from Phatak & Cantliffe (1975).

herbicide	number of broad-leaf weeds[1]	fresh yield	nitrate content	
			leaf-blades	roots
weeded check	0	12.3	10190	32330
pebulate	4	14.5	14170	32330
cycloate	3	10.3	15060	31890
EPTC	8	8.0	15940	34540
TCA	21	5.4	15500	28790
CDEC	17	6.8	14610	20810
chlorpropham	14	1.9	11960	21700
propachlor	8	6.4	10630	27460
solubor	9	4.7	15500	23940
lenacil	2	5.4	19490	32330
IMC 3950	1	11.1	11510	27460
pyrazon (pre-plant)	1	6.8	19490	32770
pyrazon (post-plant)	19	4.5	14170	21700
CNP	2	4.3	17710	36310
pebulate + pyrazon	3	13.2	11960	31440
TCA + pyrazon	1	8.1	13730	38530

1 per 0.093 m^2.

three of them (cycloate, alachlor and lenacil) provided acceptable weed control and yields. As a result of the use of these herbicides the nitrate contents (on a dry weight basis) in spinach were 3 or 4 times higher than in hand-weeded and non-weeded controls. The other herbicides under investigation did not increase nitrate contents to such a degree. Some of them did not cause any change in nitrate contents at all. As compared with a weeded control, lenacil significantly raised the fresh yield of spinach.

Phatak & Cantliffe (1975) checked the effects of herbicides on weed control, yield and nitrate content in beetroot. The results are shown in Table 20. Most herbicides gave good weed control, but also decreased yields. No or hardly any yield decrease was observed for pebulate, cycloate, I.M.C. 3950 and the combination of pebulate and pyrazon. The use of these herbicides resulted in increased nitrate contents in the leaf-blades, but not in the roots. Some of the other herbicides even reduced the nitrate contents of roots, but also yields were lower in these cases.

Research carried out by Singh et al. (1972) revealed that herbicides with s-triazines as the active component, like simazin and triazin, did not affect the nitrate content of bush beans and spinach. According to Viets & Hageman (1971), however, nitrate absorption would be stimulated by simazin. Also 2,4-D (2,4-dichlorophenoxyacetate) would promote nitrate accumulation, but in this case by depressing nitrate reductase activity (Viets & Hageman, 1971). Some herbicides appear to promote nitrate accumulation, but not much is known about the physiological background of this effect. It seems desirable to check the influence of a new herbicide on nitrate accumulation before its legalization.

5.2.10 Location

In this concept, location must be seen as both the soil type on which and the region in which the vegetables are grown. Little research has been done so far on the influence of soil type on nitrate contents of vegetables. Geyer (1978) is one of the few authors who took this variable into account. He compared three soil types and found the nitrate contents of white cabbage, carrots and head lettuce to be lowest on the most sandy soil type, in which organic matter content was lowest as well.

Vegetables, grown on a certain soil type, but in different regions may vary in nitrate content, even when agricultural practices are exactly the same. Boek & Schuphan (1959) showed results of experiments with spinach, carried out simultaneously in the northern and in southern parts of the GFR. The nitrate content of spinach grown in the north were found to be systematically higher. The authors suggested that this difference is due to the higher irradiation in the south during the growth period. As temperatures were higher in the south, and therefore nitrate contents were expected to be higher, they stated that in practice light is a more important factor in determining nitrate contents than is temperature. In greenhouses irradiation is lower and temperature higher than in the open, so vegetables from green-

Table 21. Effect of amount of nitrogen and harvest date on the nitrate content of spinach. Nitrate content in mg/kg fresh product. Data from Eerola et al. (1974).

nitrogen dose (kg/ha)	harvest date	
	June 25	September 5
0	276	830
60	1061	2238
120	1568	2553
180	2662	3205
240	2871	3994

houses will be higher in nitrate contents than vegetables grown outdoors at the same time.

5.2.11 Season

Seasonal variations in nitrate contents also are connected with temperature and especially with light intensity. The variations can be quite large, as is shown by the following examples. Eerola et al. (1974) harvested spinach on June 26 and on September 5. With all nitrogen doses applied, the nitrate contents were found to be higher in the September crop, which had been raised during a warmer and darker period. The data are presented in Table 21. Knauer & Simon (1968) compared the nitrate contents of spring and autumn spinach. Autumn spinach had a higher nitrate content and, besides, the effect of the nitrogen dose on the nitrate content was much more pronounced in autumn than in spring. Their results are shown in Table 22.

Table 22. Effect of amount of nitrogen and growth season on the nitrate content of spinach. Nitrate content in mg/kg dry weight. Data from Knauer & Simon (1968).

nitrogen dose (kg/ha)	nitrate content			
	Experiment I		Experiment II	
	spring	autumn	spring	autumn
60	2100	6700	2000	4400
120	2480	15500	4200	11400
180	2220	24700	4700	22500

5.2.12 Changes in nitrate content of a plant during the growth period

Within a plant the oldest parts always have the highest nitrate contents and nitrate contents will increase with age, if other circumstances remain unchanged. However, when the nitrogen dose matches the needs of the crop, the nitrogen supply decreases with time and consequently the nitrate content decreases. Weather conditions (light, temperature, rain etc.) interact strongly, so the nitrate content of a crop can vary considerably during the growth period. How the nitrate contents vary with time does not really matter very much to a vegetable grower. Far more important for him is the moment of harvest, which is strongly determined by his desire to obtain a good marketable crop. Also phenomena like bolting can play a significant role in this.

Yet, it is of course highly important to know how variations in nitrate content can be influenced in such a way that the nitrate content is as low as possible at the moment of harvest. With data of Minotti (1978), Table 23 illustrates how changes in nitrate contents during the growth period can be influenced by variations in nitrogen dose and nitrogen source. For crops with a longer growth period, like carrot and beetroot, the moment of harvest is not so critical. With such species there is more of an opportunity to make use of changes in nitrate contents in such a way that at harvest time the crop has a low nitrate content. In these vegetables the nitrate contents are also relatively high in the beginning of the growth period, but from the moment on that the plants are harvestable the nitrate contents always decrease with increasing plant age (Gersons, 1977; Geyer, 1978; Nicolaisen & Haar, 1964).

Table 23. Effect of amount and source of nitrogen and plant age on the nitrate content of head lettuce. Nitrate content in mg/kg dry weight. Data from Minotti (1978).

nitrogen source	nitrogen dose (kg/ha)	harvest date		
		May 23	June 17	July 5
	0	5310	5760	4430
$NaNO_3$	56	17710	25690	8860
$NaNO_3$	112	20370	33660	14170
$NaNO_3$	224	27010	42510	49600
$(NH_4)_2SO_4$	56	6200	12840	10190
$(NH_4)_2SO_4$	112	6640	16390	18160
$(NH_4)_2SO_4$	224	4870	15500	21700

6 Factors affecting the nitrate and nitrite contents of vegetables during processing and storage

6.1 Processing

Vegetable growers aim at producing a good yield and the harvest must be considered as the first processing. At the moment of harvesting, the nitrate content is determined mainly by growth-factors, but manipulation during harvesting can affect the nitrate content as well.

Firstly, the moment of harvest can be important. The day the crop will be harvested is mostly so much determined by yield and by visible qualitative characteristics (like bolting) that a criterion like nitrate content, which is of course invisible, can receive little consideration. Also the hour of the day at which the harvest takes place, can influence the nitrate content, since at an advanced hour (afternoon) sometimes lower nitrate contents are found as a result of increasing nitrate-reductase activity. The portion of the plant that is harvested, is also important. Such a portion is, of course, mainly determined by the species, but can often be changed somewhat, for example, by leaving a longer or shorter part of the petioles of spinach on the field or by cutting away more or less old leaves of e.g. lettuce, endive, cabbage, leek, etc. In general, vascular tissue and older tissue have relatively higher nitrate contents, and thus leaving a longer part of the petioles on the field or removing older leaves will decrease the nitrate content of the harvested crop.

Harvesting forms part of the cultural practices, but processing in the strict sense cannot be seen as such. In the strict sense of the word, processing must be considered as a means of making vegetables suitable for consumption or storage. Research in this field has been focused strongly on spinach; other vegetables, like celery, carrots, French beans, beetroot and tomatoes are included only seldomly.

When fresh vegetables are prepared for direct consumption, selecting and picking, washing and boiling or stewing are the more usual processes. During selection and picking for example wilted and damaged leaves of lettuce or spinach, stem-parts of cabbage and rinds of cucumbers will be removed. The way in which this can have an influence on the nitrate content has already been mentioned. Because mostly older leaves or stem-parts will be removed, it may be assumed that such removals will reduce the nitrate content to some extent. Astier-Dumas (1976b), however, gave an example of an increase in nitrate content: from 166 mg/kg in fresh carrots to 229 mg/kg in picked carrots.

During washing, cell liquids, especially from damaged cells, can be lost, and thus the nitrate content can decrease. With spinach Achtzehn & Hawat (1971b) found that washing reduced nitrate contents from 1230 to 1180 and from 1100 to 1040 mg/kg fresh product. It is also possible that slightly wilted vegetables absorb some water during washing. In such cases fresh weight will increase and so the nitrate content per kg fresh product will decrease. The nitrate content per kg dry matter, however, will remain unchanged, which will probably be the case also with the amounts of nitrate ingested.

When vegetables are boiled, considerable quantities of nitrate can be lost to the water. In experiments with spinach and carrots, losses of 50 percent or more have been reported (Astier-Dumas, 1976a; Kenny & Walshe, 1975). In these experiments very much water was used and losses of Vitamin C appeared to be of about the same order of magnitude. In practice the aim is to diminish losses of vitamins. For this reason, as little water as possible is used and the nitrate contents will consequently decrease little or not at all (Frankena, 1968). When vegetables are stewed no water will be removed and, hence, only little changes in nitrate contents will occur. In vegetables with low dry matter contents, like spinach, proper stewing will only be possible after removal of some water, and losses of nitrate in the same order as with boiling will result.

In industrial processing, the most important procedure with respect to nitrate content is blanching, which is a scalding of the vegetables in water or in steam during a short period. The quantity of nitrate lost from spinach by blanching depends on the method of blanching (in water or in steam) (Achtzehn & Hawat, 1971a; Schuphan et al., 1967), the quantity of water used (van de Brink et al., 1968), the temperature (Heintze et al., 1975; Sistrunk & Cash, 1975), the duration of blanching (Achtzehn & Hawat, 1971a; Heintze et al., 1975) and on the nitrate content of the fresh product (Eerola et al., 1974; Schuphan, 1974; Richter & Handke, 1972). The use of water (vs. steam), more and hotter water, longer blanching and a higher nitrate content lead to higher proportional losses of nitrate. In vegetables other than spinach, the proportional losses of nitrate do not always depend on the nitrate content (Vulsteke & Biston, 1978). Blanching of spinach leads to nitrate losses of 15 - 60 percent on a dry-weight basis. Because blanching also leads to a decrease in water content, the nitrate losses calculated on a fresh weight basis were lower: about 0 - 30 percent (see also Table 24). Sometimes blanching is found to result in increased nitrate contents. After blanching French beans, Vulsteke & Biston (1978) found a mean decrease in nitrate content of 20 percent on a fresh weight basis.

During further industrial processing of vegetables after blanching, the nitrate content mostly decreases somewhat more. Lee et al. (1971) and Sohier et al. (1976) reported total nitrate losses of 40 - 50 percent (on a dry-weight basis) when spinach was canned. Gersons (1976b) found a decrease in nitrate content of 30 to 40 percent (on a fresh weight basis) when spinach was preserved in pots. When spinach was frozen Meineke (1972) found nitrate losses of 30 - 50 percent, but Gersons (1976b) only found

Table 24. Effect of washing and blanching on the nitrate content of spinach. Nitrate content in mg/kg fresh product and in mg/kg dry matter. Data from Achtzehn & Hawat (1971b) and from Gersons (1976b).

reference	nitrate content					
	before washing		after washing		after blanching	
	fresh product	dry matter	fresh product	dry matter	fresh product	dry matter
Achtzehn &	1230	16390	1180	16150	1550	11500
Hawat	1100	15500	1040	15300	1120	10770
Gersons	2667	.	1805	.	2092	.
	1950	.	1266	.	1347	.
	1840	.	1505	.	1208	.
	1220	.	1489	.	1302	.
	4024	.	3413	.	2938	.
	.	.	1202	.	1135	.
	.	.	758	.	821	.

decreases of 1 - 30 percent on a fresh-weight basis. When French beans and celery were canned, Vulsteke & Biston (1978) observed nitrate losses of respectively 15 - 50 and 30 - 50 percent on a fresh-weight basis, respectively, while Lee et al., (1971) found nitrate losses of 10 - 40 percent on a dry-weight basis when beetroot was canned.

Further comparable data were not available in the literature reviewed, but the nitrate contents of fresh vegetables (Table 6) and those of processed vegetables (Table 8) may be compared to get a general, although not very reliable, idea of changes in nitrate contents during processing. When this comparison was made in Chapter 4, it was concluded that for nitrate-rich vegetables a nitrate loss of 20 - 25 percent on a fresh-weight basis was a reasonable average. This conclusion seems to agree well with the abovementioned data.

Formation of nitrite during processing occurs only incidentally and even then only temporarily (Gersons, 1976b), so that in processed vegetables nitrite contents are always very low (Section 4.2). Literature about processing is compiled in Appendix 2.

6.2 Storage

When fresh or processed vegetables from newly-opened containers are stored, nitrate may be converted into nitrite. Schuphan & Schlottmann (1965) mentioned an 'intramolecular respiration', occurring with high temperature and lack of oxygen, in which nitrate while serving as an electron acceptor is converted to nitrite. This process might occur during transport when in tightly packed spinach, the temperature starts to rise. Van de Brink et al. (1968) found conversion of nitrate into nitrite at high temperautures (up to 120 °C) in spinach during processing. This could be an indication of intramolecular respiration. In other literature sources, only the possibility of conversion of nitrate into nitrite by microbial action was described. The nitrite formed can be further converted by microbial action. In the presence of oxygen nitrite may be converted to ammonia, without oxygen it may be converted to (gaseous) nitrogen. These two conversions proceed more slowly than the conversion of nitrate to nitrite, which means that an accumulation of nitrite can be expected in vegetables.

In the microbial conversion of nitrate to nitrite, three phases can be distinguished. The changes in nitrite contents during these phases are demonstrated in Figure 1. In the first phase, only a very slow conversion takes place. This phase will last shorter as circumstances are more favourable for the growth of nitrate reducing bacteria. After a certain time the growth of the bacteria is suddenly accelerated and in a short time much nitrite is formed. In the third phase, the nitrite content decreases again because of a slower conversion, due to a lack of nitrate (Klaushofer et al., 1971b). Whether or not a high nitrite content will be found depends on whether or not the second phase is reached. How fast this stage is reached, depends on several factors.

The growth of bacteria is closely related to temperature. When the temperature is below 0 °C (in a freezer) no nitrite can be formed, and in a refrigerator nitrite will be found only after a relatively long time. When the temperature is 20 °C or higher, substantial quantities of nitrite can be formed relatively fast (e.g. Eerola et al., 1974; Hildebrandt, 1976). Data from Hilde-

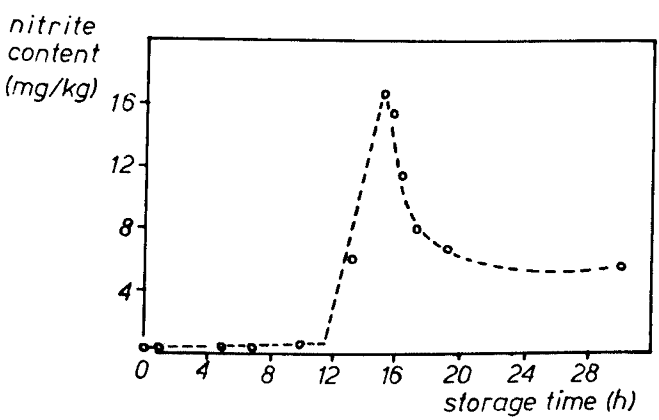

Figure 1. Storage time and nitrite content in mashed spinach stored at 25 °C. Nitrite content in mg/kg fresh product; storage time in hours. From Klaushofer et al. (1971b).

Table 25. Effect of storage temperature and time of storage on the conversion of nitrate to nitrite in spinach. Nitrate and nitrite contents in mg/kg fresh product. Data from Hildebrandt (1976).

time of storage (days)	5 °C		22 °C	
	nitrate content	nitrite content	nitrate content	nitrite content
0	1720	8	1720	8
1	1680	6	1680	5
2	1680	6	1620	55
5	1760	10	1320	130

brandt are presented in Table 25. More humid conditions, caused for instance by washing the vegetables or harvesting a wet crop, also stimulate the formation of nitrite (Achtzehn & Hawat, 1970). On the other hand, the conversion of nitrate to nitrite can be slowed down because under more humid conditions the temperature will not increase so rapidly (van Burg et al., 1967, 1969). Packing vegetables, either air-tight or not, stimulates the formation of nitrite because of a possible increase in temperature or humidity or a decrease in the concentration of oxygen (Achtzehn & Hawat, 1970; Gersons, 1976a). In a damaged and especially in a homogenized product, nitrite formation will occur faster, since the growth of bacteria is stimulated by cell liquids that are set free (e.g. Heisler et al., 1974; Hildebrandt, 1976). This also means that nitrite formation will occur faster in processed vegetables from freshly opened containers and in home-boiled vegetables than in undamaged, fresh vegetables. After thawing of deep-frozen vegetables, nitrite formation will start faster than after opening containers with sterilized vegetables,

Table 26. Effect of initial nitrate content on tin content of tomatoes after six months of storage in cans. Nitrate and tin contents in mg/kg fresh product. Data from Hoff & Wilcox (1970).

nitrate content	tin content
18	67
18	80
39	115
49	224
75	148
80	215
84	189
301	445

Table 27. Nitrate content and tin content of green beans of various origins after twelve months of storage in cans. Nitrate and tin contents in mg/kg fresh product. Data from Gersons (1969).

nitrate content	tin content
99	72
220	144
312	147
400	207
424	213

since deep freezing stops all bacterial activity, but does not kill all bacteria. (Brugger, 1968).

In almost every case in which high nitrite contents were found, vegetables were considered to be inedible ('spoiled') (e.g. Gersons, 1976a; Keybets, 1968). Yet, on rare occasions high nitrite contents have been found in edible vegetables: about 1000 mg/kg in one sample of homogenized beetroot (Heisler et al., 1974) and 100 mg/kg in one sample of fresh spinach that had been stored for one week at 5 °C (Meineke, 1976). Thus, prudence in this matter is always necessary.

Quite another problem in the storage of vegetables, in which nitrate is involved, is detinning. Detinning can occur when canned vegetables are stored. In this case neither nitrate nor nitrite, but dissolved tin is the component most hazardous to humans. In the absence of oxygen and when pH is below 5.5 (Strodtz & Henry, 1954) nitrate can be used as an electron acceptor and so the layer of tin inside the cans can be oxidized and dissolved. Nitrate is probably reduced to dinitrogen oxide (N_2O) or even to ammonia (NH_3) (Gersons, 1969). When the layer of tin is damaged, other metals present in the outer layers of the can can also be dissolved, and so even lead may be found in vegetables (Miyazaki et al., 1967). In most canned vegetables, pH is well above 5.5 and no detinning will be observed. Severe detinning is common only in French beans (Gersons, 1969; Johnson, 1966; Strodtz & Henry, 1954) and especially in tomato products (e.g. Farrow et al., 1971; Johnson & Orth, 1967). Detinning is also mentioned with spinach (Lambeth et al., 1969) and to a lesser extent with indian mustard and turnip tops (Strodtz & Henry, 1954) and sweet potatoes (Smittle & Scott, 1969). The rate of detinning depends on pH, nitrate content and the availability of the nitrate, which is high in tomato paste or juice and lower in French beans and other vegetables. Some data about nitrate contents and detinning are presented in Tables 26 and 27.

Literature on the nitrate problem in relation to storage of vegetables is compiled in Appendix 2.

7 Conclusions

1. There appear to be a number of vegetables which frequently have high nitrate contents.
2. When these vegetables form a sizeable portion of the daily food intake, the nitrate intake per day will be high.
3. Nitrogen supply (fertilizer nitrogen plus soil nitrogen) and light are the most important factors affecting the nitrate content of vegetables.
4. Processing can considerably decrease the nitrate content, but usually the contents of other components, like vitamins and proteins, will be decreased simultaneously as well.
5. Under certain conditions, storage can lead to high nitrite contents in still edible vegetables.

Summary

In many foodstuffs, both nitrate and nitrite occur as natural components or as additives. Nitrate is hardly toxic, but conversion into nitrite is possible within foodstuffs: before ingestion, in the gastro-intestinal tract of infants under three months of age, and in saliva. Nitrite can cause methemoglobinemia. Also carcinogenic nitrosamines might be formed in foodstuffs or in the human body as a result of a reaction between nitrite and secondary or tertiary amines. A daily intake of 220 mg nitrate and 8 mg nitrite per person (60 kg body weight) seems to be an acceptable standard. When foodstuffs high in nitrate are ingested, the ADIs for nitrate and nitrite are sometimes exceeded. Formation of the latter is due to the conversion of nitrate into nitrite in saliva. About 80 - 90 percent of the nitrate ingested originates from vegetables; the nitrite ingested originates mainly from food additives and from the conversion of nitrate to nitrite in saliva. Nitrate contents of a number of vegetables are often very high, whereas those of processed vegetables are generally about 20 - 25 percent lower. Both fresh and processed vegetables have generally very low nitrite contents. During growth, the nitrate contents of vegetables are affected by a number of factors, of which nitrogen supply and light conditions are most important. Other factors affecting the nitrate content are: species, variety, nutrients other than nitrogen, temperature, moisture conditions, carbon dioxide, herbicides, location and season. After harvest, the nitrate and nitrite contents can be changed by factors related to processing and storage. Processing generally causes the nitrate content to decrease appreciably, boiling and blanching being most effective. During processing, hardly any nitrite is formed. In stored vegetables, nitrate can be converted into nitrite by microbial action. This conversion is strongly retarded by low temperature and good ventilation. Under other circumstances, nitrite can be easily formed, especially in processed vegetables. Vegetables high in nitrite are generally no longer edible, but exceptions occur. In canned vegetables with a low pH, even quite low nitrate contents can cause detinning.

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References

Achtzehn, M.K. & H. Hawat, 1969. Die Anreicherung von Nitrat in den Gemüsearten - eine Möglichkeit der Nitratintoxikation bei Säuglingen? Die Nahrung 13: 667 - 676 (with English summary).

Achtzehn, M.K. & H. Hawat, 1970. Zur Nitritbildung in Gemüse und Gemüsezubereitungen. 1. Mitt. Rohspinat. Die Nahrung 14: 383 - 394 (with English summary).

Achtzehn, M.K. & H. Hawat, 1971a. Einfluss industrieller Vorbehandlung auf den Gehalt essentieller und nicht-essentieller Inhaltstoffe im Spinat. Die Nahrung 15: 527 - 537 (with English summary).

Achtzehn, M.K. & H. Hawat, 1971b. Zur Nitritbildung in Gemüse und Gemüsezubereitungen. 2. Mitt. Säuglingsfertignahrung auf Spinat-Basis. Die Nahrung 15: 787 - 796 (with English summary).

Adriaanse, A. & J.E. Robbers, 1969. Determination of nitrite and nitrate in horticultural and meat products and soil samples. Journal of the Science of Food and Agriculture 23: 321 - 325.

Ashton, M.R., 1970. The occurence of nitrates and nitrites in foods. The British Food Manufactering Industries Research Association (BFMIRA), Leatherhead, Surrey. Literature Survey 7. 28 pp.

Asif, M.I. & J.K. Greig, 1972. Effects of seasonal interactions of nitrogen, phosphorous and potassium fertilizers on yield and nutrient content of snap beans (*Phaseolus vulgaris* L.) Journal of the American Society of Horticultural Science 97: 44 - 47.

Astier-Dumas, M., 1973. Le problème des nitrates apportés par l'alimentation. Annales d'Hygiene de Langue Francaise, Médecine et Nutrition 9: 79 - 90.

Astier-Dumas, M., 1976a. Evolution de la teneur en nitrates, vitamine-C, magnesium et fer, au cours de la cuisson de l'épinard. Annales de la Nutrion et de l'Alimentation 29: 239 - 244 (with English summary).

Astier-Dumas, M., 1976b. Cuisson à l'eau et teneur en nitrates, de quelques végetaux. Annales de la Nutrion et de l'Alimentation 30: 683 - 688 (with English summary).

Auffray, A. & J. Pafique, 1976. Comment réduire la teneur en nitrates dans les aliments de l'enfance. Annales de la Nutrion et de l'Alimentation 30: 701 - 705 (with English summary).

Augustin, J., R.E. MacDole & G.C. Painter, 1977. Influence of fertilizer, irrigation and storage treatments on nitrate-N

content of potato tubers. American Potato Journal 54: 125 - 136.
Aworh, O.C., P.E. Brecht & P.L. Minotti, 1978. Nitrate and nitrite levels in fresh spinach as influenced by post-harvest temperatures. Journal of the American Society for Horticultural Science 103: 417 - 429.
Barker, A.V., 1975. Organic vs. inorganic nutrition and horticultural crop quality. Hort Science 10: 50 - 53.
Barker, A.V. & D.N. Maynard, 1971. Nutritional factors affecting nitrate accumulation in spinach. Communications in Soil Science and Plant Analysis 2: 470 - 478.
Barker, A.V., D.N. Maynard & H.A. Mills, 1974. Variations in nitrate accumulation among spinach cultivars. Journal of the American Society for Horticultural Science 99: 132 - 134.
Barker, A.V., N.H. Peck & G.E. MacDonald, 1971. Nitrate accumulation in vegetables. I: Spinach grown in upland soils. Agronomy Journal 73: 126 - 129.
Becker, K.F., 1965. Nitrat- und Nitritgehalt von Spinat. Bundesgesundheitsblatt 8: 246 - 248.
Beevers, L. & R.H. Hageman, 1972. The role of light in nitrate metabolism in higher plants. Photophysiology 7: 85 - 113.
Bengtsson, B.L., 1968. Effect of nitrification inhibitor on yield and nitrate content of spinach. Zeitschrift für Pflanzenernährung und Bodenkunde 121: 1 - 4.
Bengtsson, B.L, 1969. Effect of blanching on mineral and oxalate content of spinach. Journal of Food Technology 4: 141 - 145.
Benk, E., 1974. Beitrag zur Kenntnis der Zusammensetzung des Saftes der Roten Rübe (Rote Beete). Industrielle Obst- und Gemüseverwertung 59: 325 - 326.
Bergholm, J., 1972. In: Schuphan, W., 1972. Effects of application of inorganic and organic manures on the market quality and on the biological value of agricultural products. In: Effects of intensive fertilizer use on the human environment. FAO Soils Bulletin 16: 222.
Blanc, D., 1976. Aptitudes à l'accumulation des nitrates de quelques productions maraîchères. Annales de la Nutrion et de l'Alimentation 30: 667 - 672 (with English summary).
Board, P.W., 1973. The chemistry of nitrate-induced corrosion of tinplate. Food Technology in Australia 25: 15 - 16.
Bodiphala, T. & D.P. Ormrod, 1971. Factors affecting the nitrate content of vegetable and fruit foods. Canadian Institute for Food Science and Technology Journal 4: 6 - 8.
Boek, K. & W. Schuphan, 1959. Der Nitratgehalt von Gemüsen in Abhängigkeit von Pflanzenart und einigen Umweltfaktoren. Qualitas Plantarum et Materiae Vegetabiles 5: 199 - 208 (with English summary).
Bohm, E., 1966. Beitrag zur Bestimmung und Beurteilung von Nitraten in Lebensmittel, insbesondere in Spinat und andere Gemüsen, in Fleisch- und Wurstwaren, sowie in Trink- und Tafelwassern. Deutsche Lebensmittel Rundschau 62: 293 - 304.
Bolotov, M.P. & E.A. Soboleva, 1971. (Reduction of nitrates to nitrites in beet juice). Voprosy Pitanija 30 (6): 48 - 50

(in Russian, with English summary).

Breda, E., 1975. *Letter to growers of 'Demeter' red beets* 2-6-1975. Institut für biologisch-dynamische Forschung, Darmstad. Cited by Commissie Onderzoek Biologische Landbouwmethoden, 1976.

Brink, N.D.H. van de, D.R.A. Coster & H. Drost-de Wijs, 1968. Nitraat en nitriet in spinazie. Voeding en Techniek 2: 1122 - 1126.

Brown, J.R. & G.E. Smith, 1966. Soil fertilization and nitrate accumulation in vegetables. Agronomy Journal 58: 209 - 212.

Brown, J.R. & G.E. Smith, 1967. Nitrate accumulation in vegetable crops as influenced by soil fertility practices. Missouri Agricultural Experiment Station. Research Bulletin 920. 43 pp.

Brown, J.R., V.N. Lambeth & D.G. Blevins, 1969. Nutrient interaction effects on yield and chemical composition of spinach and green beans. Missouri Agricultural Experiment Station. Research Bulletin 963. 20 pp.

Brugger, G., 1968. Spinat - eines der wertvollsten Gemüse oder eine Giftpflanze. Industrielle Obst- und Gemüseverwertung 53: 285 - 292.

Bundesanstalt für Qualitätsforschung pflanzlichen Erzeugnisse (BAQ) in Geisenheim/Rheingau, 1972. Tätigkeitsbericht 20 Jahre BAQ: 1951 - 1971. 95 pp.

Bundesanstalt für Qualitätsforschung pflanzlicher Erzeugnisse (BAQ) in Geisenheim/Rheingau, 1973. Jahresbericht 1973. 28 pp.

Burden, E.H.W.J., 1961. The toxicology of nitrates and nitrites with particular reference to the potability of water supplies. The Analist 86: 429 - 433.

Burdine, H.W. & C.B. Hall, 1974. Nitrate and nitrite content of carrots grown on the organic soils of the everglades area of Florida. Soil and Crop Science Society of Florida Proceedings 33: 33 - 36.

Burg, P.F.J. van, E.H. Groot, G.H.M. Keller & G.J.G. Rauw, 1967. De stikstofbemesting van spinazie in verband met opbrengst en kwaliteit. Onderzoek 1967. Landbouwkundig bureau der Nederlandse Stikstofmeststoffen Industrie, 's Gravenhage. Verslag B 163. 12 pp.

Burg, P.F.J. van, E.H. Groot, G.H.M. Keller & G.J.G. Rauw, 1969. Stikstofbemesting spinazie, 1968. Landbouwkundig Bureau der Nederlandse Stikstofmeststoffen Industrie, 's Gravenhage. Verslag B 187. 14 pp.

Cantliffe, D.J., 1972a. Nitrate accumulation in spinach grown under different light intensities. Journal of the American Society for Horticultural Science 97: 152 - 154.

Cantliffe, D.J., 1972b. Nitrate accumulation in vegetable crops as affected by photoperiod and light duration. Journal of the American Society for Horticultural Science 97: 414 - 418.

Cantliffe, D.J., 1972c. Nitrate accumulation in spinach grown at different temperatures. Journal of the American Society for Horticultural Science 97: 674 - 676.

Cantliffe, D.J., 1973a. Nitrate accumulation in table beets and spinach as affected by nitrogen, phosphorus and potassium nutrition and light intensity. Agronomy Journal 65: 563 - 565.
Cantliffe, D.J., 1973b. Nitrate accumulation in spinach cultivars and plant introductions. Canadian Journal of Plant Science 53: 365 - 367.
Cantliffe, D.J. & P.R. Goodwin, 1974. Effects of nitrogen rate, source and various anions and cations on nitrate accumulation and nutrient constituents of table beets. Agronomy Journal 66: 779 - 783.
Cantliffe, D.J. & S.C. Phatak, 1974a. Effects of herbicides on weed control and nitrate accumulation in spinach. Hort Science 9: 470 - 472.
Cantliffe, D.J. & S.C. Phatak, 1974b. Nitrate accumulation in greenhouse vegetable crops. Canadian Journal of Plant Science 54: 783 - 788.
Cantliffe, D.J., G.E. MacDonald & N.H. Peck, 1974. Reduction of nitrate accumulation by molybdenum on spinach grown at low pH. Communications in Soils Science and Plant Analysis 5: 273 - 282.
Cantoni, C. & S. d'Aubert, 1974. Nitrati, nitriti e alimenti. Industrie Alimentari 13: 81 - 92 (in Italian, with English summary).
Carter, J.N. & S.M. Bosma, 1974. Effect of fertilizer and irrigation on nitrate-nitrogen and total nitrogen in potato tubers. Agronomy Journal 66: 263 - 266.
Ciećko, Z., 1974. (Study over fertilize potatoes variety Bem II. Organic and inorganic nitrogen content of potato tubers). Zeszyty Naukowe Akademii Rolniczo-Technicznej W Olsztynie 124 (7): 197 - 216 (in Polish, with English summary).
Commissie Onderzoek Biologische Landbouwmethoden, 1976. Alternatieve landbouw: Inventarisatie, evaluatie en aanbevelingen voor onderzoek. Eindrapport. Pudoc, Wageningen. 398 pp.
Committee on Nitrate Accumulation, 1972. Accumulation of nitrate. National Academy of Sciences, Washington D.C. 106 pp.
Commoner, B., 1968. Progress Report for Grant ES-00139 NIEHS. Cited by Lee (1970).
Council of Europe, 1975. Document: Neth. 419/ September 1975, PA/SP (74) 33, App. B, Pt. 2. Public Health Committee, Sub-committee on the Health Control of Foodstuffs, 19th Session. 6 pp.
Darwinkel, A., 1975. Aspects of assimulation and accumulation of nitrate in some cultivated plants. Agricultural Research Reports 843. Pudoc, Wageningen. 64 pp.
Deeb, B.S. & K.W. Sloan, 1975. Nitrates, nitrites and health. Illinois Agricultural Experiment Station. Bulletin 750. 52 pp.
Diehl, J.F. & A. Wedler, 1977. Konventioneller und alternativer Landbau - vergleichende Untersuchungen über die Qualität der Ernteprodukte. Bundesforschungsanstalt für Ernährung Karlsruhe. Bericht 1977-1. 143 pp. (with English summary).
Dillier, A. & W. Heierli, 1970. Nitratgehalt in Blattspinat. I.

Industrielle Obst- und Gemüseverwertung 55: 11 - 12.
Dillier, A. & W. Heierli, 1971. Nitratgehalt in Blattspinat. II. Industrielle Obst- und Gemüseverwertung 56: 316 - 318.
Dragland, S., 1976. (*Nitrogen requirement in cabbage grown at high soil moisture status*). Forskning og Forsuk i Landbruket 27: 375 - 391 (in Norwegian, with English summary).
Dressel, J., 1976a. Relationship between nitrate, nitrite and nitrosamines in plants and soil. Qualitas Plantarum 25: 381 - 390.
Dressel, J., 1976b. Abhängigkeit Qualitätsbeeinflussender pflanzlicher N-haltiger Inhaltstoffen von der Düngungsintensität. Landwirtschaftliche Forschung Sonderheft 33/II: 326 - 334 (with English summary).
Dressel, J. & J. Jung, 1970. Der Einfluss der Düngung auf verschiedene Inhaltstoffe von Spinat. Ernährungs-Umschau 17: 524 - 527.
Eerola, M., P. Varo & P. Koivistoinen, 1974. Nitrate and nitrite in spinach (*Spinacia oleracea* L.) as affected by application of different levels of nitrogen fertilizer, blanching and storage after thawing of frozen product. Acta Agricultura Scandinavica 24: 286 - 290.
Ehrendorfer, K., 1964. Einfluss der Stickstofform auf Mineralaufnahme und Substanzbildung bei Spinat. Bodenkultur 15: 1 - 13 (with English summary).
Ehrendorfer, K., 1973. Einfluss eines varierten K/Na- und NO_3/Cl-Angebotes auf Substanzbildung, Mineralstoffaufnahme und Oxalsäurebildung bei Spinat (*Spinacia oleracea* L.). Zeitschrift für Pflanzenernährung und Bodenkunde 135: 44 - 57 (with English summary).
Farrow, R.P., J.H. Johnson, W.A. Gould & J.E. Charbonneau, 1971. Detinning in canned tomatoes caused by accumulations of nitrate in the fruit. Journal of Food Science 36: 341 - 345.
Fasset, D.W., 1973. Nitrates and nitrites. In: Toxicants occurring naturally in foods. National Academy of Sciences. Washington D.C.: 1 - 25.
Fishbein, L. et al., 1970. Nitrate - Nitrite Study Status Report. Memorandum, NIEHS. Cited by Lee (1970).
Frankena, A., 1968. Veranderingen in de nitraat- en nitrietgehalten van spinazie tijdens de bewaring. Doctoraalverslag. Vakgroep Humane Voeding. Landbouwhogeschool, Wageningen. 21 pp.
Fratoni, A. & C.F. Miuccio, 1967. Ricerche sulla formazione di nitriti in Spinacia oleracea in deverse condizioni di cottura e di conservazione. Quaderni delle Nutrizione 27: 95 - 117 (with English summary).
Frota, J.N.E. & T.C. Tucker, 1972. Temperature influence on ammonium and nitrate absorption by lettuce. Soil Science Society of America Proceedings 36: 97 - 100.
Garbouchev, I. & N. Mitreva, 1972. Research on the effect of intensive fertilizer use on human environment in Bulgaria. In: Effects of intensive fertilizer use on the human environment. FAO Soils Bulletin 16: 225 - 234.
Gersons, L., 1969. Invloed van de bemesting op de kwaliteit van

verwerkte tuinbouwprodukten. Jaarverslag 1969, Sprenger Instituut, Wageningen: 34 - 37.

Gersons, L., 1976a. Voorkomen van nitraat en nitriet in verse sla. Intern Rapport 1960, Sprenger Instituut, Wageningen. 7 pp.

Gersons, L., 1976b. Voorkomen van nitraat en nitriet in geconserveerde spinazie. Intern Rapport 1961, Sprenger Instituut, Wageningen. 10 pp.

Gersons, L., 1977. Nitraat en nitriet in wortelen van een bemestingsproefveld. Intern Rapport 1993, Sprenger Instituut, Wageningen. 6 pp.

Geyer, B., 1978. Untersuchungen zur Wirkung hoher Stickstoffgaben auf den Nitratgehalt von Freilandgemüse. Archiv für Gartenbau 26: 1 - 13 (with English summary).

Gilbert, C.S., H.F. Eppson, W.B. Bradley & O.A. Beath, 1946. Nitrate accumulation in cultivated plants and weeds. Wyoming Agricultural Experiment Station. Bulletin 277. 40 pp.

Graifenberg, A. & S. Leoni, 1970. (Nitrogen fertilization and nitrate accumulation in *Cichorum endivia* L. latifolium Hegi). Revista Ortofrutticoltura Italiana 54: 505 - 515 (in Italian, with English summary).

Grujić, S. & R. Kastori, 1974. Einfluss der verschiedenen Mineralstoffernährung auf den Nitrat- und Nitritgehalt im Spinat. Proceedings of the IV International Congress on Food Science and Technology, Madrid. Volume III: 272 - 277.

Habben, J., 1973. Einfluss der Stickstoff- und Kaliumdüngung auf Ertrag und Qualität der Môhre (*Daucus carota* L.). Landwirtschaftliche Forschung 26: 156 - 172 (with English summary).

Hall, C.B., J.R. Hicks & R.E. Stall, 1977. Nitrites in inoculated carrot juice as a function of nitrate content and temperature. Journal of Food Science 42: 549 - 550.

Hansen, H., 1976a. Inholdet af nitrat og protein i hovedsalat (*Lactuca sativa* var. capitata (Butterhead salat)) dyrket under forskellige vilkår. Tidsskrift for Planteavl 80: 370 - 380 (with English summary). English version: The content of nitrate and protein in lettuce (*Lactuca sativa* var. capitata (Butterhead salad)) grown under different conditions. Qualitas Plantarum 28: 11 - 17, 1978.

Hansen, H., 1976b. Kvaelstofgødskningens indflydelse på grønsagers kemiske sammensaetning. Tidsskrift for Planteavl 80: 697 - 711 (with English summary). English version: The influence of nitrogen fertilization on the chemical composition of vegetables. Qualitas Plantarum 28: 45 - 63, 1978.

Harada, M., H. Ishiwata, Y. Nakamura, A. Tanimura & M. Ishidate, 1975. In vivo formation of nitrosocompounds. I. Changes in nitrite and nitrate concentrations in human saliva after ingestion of salted Chinese cabbage. Journal of Food Hygienic Society of Japan 16: 11 - 18.

Hawat, H. & M.K. Achtzehn, 1968. Zeitschrift für Lebensmittelchemie und gerichtliche Chemie 23: 105.

Hawat, H. & M.K. Achtzehn, 1972. Photometrische Nitratbestimmung mit Rhenium und α-Furyldioxin im Spinat und Spinaterzeug-

nissen. Die Nahrung 16: 359 - 363 (with English summary).
Heintze, K., R. Duden, A. Fricker, K. Paulus & H. Zahm, 1975. Der Einfluss thermischer Behandlung von Spinat im Temperaturbereich bis 100 °C auf den Gehalt an wesentlichen Inhaltstoffen. III: Veränderungen der N-Fraktion. Lebensmittelwissenschaft und -technologie 8: 17 - 19 (with English summary).
Heisler, E.G., J. Siciliano, S. Krulick, W.L. Porter & J.W. White, 1973. Nitrate and nitrite content of market potatoes. Journal of Agricultural and Food Chemistry 21: 970 - 973.
Heisler, E.G., J. Siciliano, S. Krulick, J. Freiberg & J.H. Schwartz, 1974. Changes in nitrate and nitrite content and search for nitrosamines in storage-abused spinach and beets. Journal of Agricultural and Food Chemistry 22: 1029 - 1032.
Herrmann, K., 1969. Deutsche Apotheker Zeitung 109: 201. Cited by Walker (1975).
Herrmann, K., 1972. Über den Nitrat- und Nitritgehalt des Gemüses, Obstes und Wassers und deren Bedeutung für die Ernährung. Ernährungs-Umschau 19: 398 - 402.
Hicks, J.R., R.E. Stall & C.B. Hall, 1975. The association of bacteria and nitrites in carrot juice. Journal of the American Society for Horticultural Science 100: 402 - 403.
Hildebrandt, E.A., 1976. Zur Problematik der Nitrosamine in der Pflanzenernährung. Dissertation Justus Liebig Universität, Giessen. 211 pp.
Hlavsova, D., J. Tucek & B. Turek, 1969. (To the content of nitrates and nitrites in some sorts of Czechoslovak vegetables). Ceskoslovenska hygiena 14: 207 - 210 (in Czechoslovak, with English summary).
Hoff, J.E. & G.E. Wilcox, 1970. Accumulation of nitrate in tomato fruit and its effect on detinning. Journal of the American Society for Horticultural Science 95: 92 - 94.
Höyem, T., 1974. Nitrate and nitrite in Norwegian food. Proceedings of the IV International Congress on Food Science and Technology, Madrid. Volume III: 466 - 470.
Huffaker, R.C. & D.W. Rains, 1978. Factors influencing nitrate acquisition by plants; assimilation and fate of reduced nitrogen. In: White, P.L. & D. Robbins (editors): Nitrogen in the environment, Volume 2. Academic Press, New York: 1 - 43.
Hulewicz, D. & E. Mokrzecka, 1971. Ertragsabhängigkeit des Spinats und einiger seiner wertbestimmender Bestandteile von der Düngung. Zeitschrift für Pflanzenernährung und Bodenkunde 130: 214 - 224 (with English summary).
Inoue, Y., 1972. Hiroshima Daigaku Igaku Zasski 23: 549. Cited by Walker (1975).
Inspecteur voor de volksgezondheid, 1978. Document: CRV(78)9.5. Nitraat in eet- en drinkwaren. 7 pp.
Ishiwata, H., A. Tanimura & M. Ishidate, 1975a. Studies on in vivo formation of nitroso compounds. III. Nitrite and nitrate concentrations in human saliva collected from salivary ducts. Journal of Food Hygienic Society of Japan

16: 89 - 92.
Ishiwata, H., A. Tanimura & M. Ishidate, 1975b. Studies on in vivo formation of nitroso compounds. V. Formation of dimethylnitrosamine from nitrate and dimethylamine by bacteria in human saliva. Journal of Food Hygienic Society of Japan 16: 234 - 239.
Ishiwata, H., P. Boriboon, M. Harada, A. Tanimura & M. Ishidate, 1975c. Studies on in vivo formation of nitroso compounds. IV. Changes of nitrite and nitrate concentrations in incubated human saliva. Journal of food hygienic society of Japan 16: 93 - 98.
Ishiwata, H., P. Boriboon, Y. Nakamura, M. Harada, A. Tanimura & M. Ishidate, 1975d. Studies on in vivo formation of nitroso compounds. II. Changes of nitrite and nitrate concentration in human saliva after ingestion of vegetables or sodium nitrate. Journal of Food Hygienic Society of Japan 16: 19 - 24.
Ishiwata, H., A. Tanimura & M. Ishidate, 1976. Studies on in vivo formation of nitroso compounds. VI. In vitro and in vivo formation of dimethylnitrosamine by bacteria isolated from human saliva. Journal of Food Hygienic Society of Japan 17: 59 - 65.
Jackson, W.A., J.S. Steel & V.R. Boswell, 1967. Nitrates in edible vegetables and vegetable products. Proceedings of the American Society for Horticultural Science 90: 349 - 352.
Jägerstad, M. & R. Nilsson, 1977. Intake of nitrate and nitrite of some Swedish consumers as measured by the duplicate portion technique. In: Tinbergen, B. & B. Krol (editors): Proceedings of the Second International Symposium on Nitrite in Meat Products, September 1976, Zeist. Pudoc, Wageningen: 283 - 287.
Jensen, P.T., 1972. Forskellige vegetabiliers inhold af nitrat og nitrit. Medlemsblad for den Danske Dyrlaegeforening 55: 459.
Johnson, J.H., 1966. Internal can corrosion due to high nitrate content of canned vegetables. Proceedings of the Florida State Horticultural Society 79: 239 - 242.
Johnson, J.H. & P.G. Orth, 1967. Total and nitrate nitrogen and solids content of processed tomatoes as affected by fertility and variety. Proceedings of the Florida State Horticultural Society 80: 313 - 317.
Joint FAO/WHO Expert Committee on Food Additives (JECFA), 1962. Evaluation of the toxicity of a number of antimicrobials and antioxidants. 6th. Report JECFA, WHO Technical Report Series 228. 104 pp.
Joint FAO/WHO Expert Committee on Food Additives (JECFA), 1974. Evaluation of certain food additives. 17th. Report JECFA, WHO Technical Report Series 557. 37 pp.
Jurkowska, H., 1971. Effects of dicyanodiamide on the content of nitrate and oxalic acid in spinach. Agrochimica 15: 445 - 453.
Kamm, L., G.G. MacKeown & D. Morrison Smith, 1965. New colorimetric method for the determination of the nitrate and

nitrite content of baby foods. Journal of the Association of Official Agricultural Chemists 48: 892 - 897.

Kenny, T.A. & P.E. Walshe, 1975. Nitrate and nitrite contents of vegetables and fruit in Ireland. Irish Journal of Agricultural Research 14: 349 - 355.

Kerkvliet, J.D., 1976. Nitraatgehalten van gewoon en biologisch geteelde groenten. Keuringsdienst van Waren voor het gebied Haarlem, September 1976. 23 pp.

Keybets, M.J.H., 1968. Het isoleren en aantonen van N-nitrosoaminen in spinazie. Doctoraalverslag. Vakgroep Humane Voeding, Landbouwhogeschool, Wageningen. 52 pp.

Keybets, M.J.H., E.H. Groot & G.H.M. Keller, 1970. An investigation into the possible presence of nitrosamines in nitrite-bearing spinach. Food and Cosmetics Toxicology 8: 167 - 171.

Kick, M. & G.G. Massen, 1973. Der Einfluss von Dicyandiamid und N-serve in Verbindung mit Ammoniumsulfat als N-Dünger auf die Nitrat- und Oxalsäuregehalte von Spinat (*Spinacia oleracea* L.). Zeitschrift für Pflanzenernährung und Bodenkunde 135: 220 - 226 (with English summary).

Kilgore, L., A.R. Stasch & B.F. Barrentine, 1963. Nitrate content of beets, collards and turnip-greens. Journal of the American Dietetic Association 43: 39 - 42.

Klaushofer, H., W. Bergthaller & A. Schaller, 1967a. Ergebnisse von Untersuchungen hinsichtlich der Keim- und Nitritkonzentration von rohen Spinatblättern. Die Kälte 20: 435 - 438. Cited by Achtzehn & Hawat (1970).

Klaushofer, H,. W. Bergthaller & A. Schaller, 1968. Ergebnisse von Untersuchungen hinsichtlich der zeit- und temperaturabhängigen Veränderungen der Keim- und Nitritkonzentration bei der Lagerung von aufgetautem, hitzebehandeltem Tiefgefrier-Spinatpüree. Die Kälte 21: 233 - 240.

Klaushofer, H., K. Kaschik & A. Schaller, 1971a. Ergebnisse von Untersuchungen hinsichtlich des Einflusses der Nitratkonzentration auf die zeitabhängigen Veränderungen der Keim- und Nitritkonzentration von aufgetautem, hitzebehandeltem Tiefgefrier-Spinatpuree. I. Confructa 16: 177 - 184.

Klaushofer, H., K. Kaschik & A. Schaller, 1971b. Ergebnisse von Untersuchungen hinsichtlich des Einflusses der Nitratkonzentration auf die zeitabhängigen Veränderungen der Keim- und Nitritkonzentration von aufgetautem, hitzebehandeltem Tiefgefrier-Spinatpuree. II. Confructa 16: 260 - 274 (with English summary).

Klaushofer, H., E. Stadler & A. Schaller, 1967b. Der Einfluss des Auftauens sowie nachfolgender Lagerung auf Keim- und Nitritkonzentration von unzubereitetem Tiefgefrier-Spinatpüree. Die Kälte 20: 63 - 70. Cited by Klaushofer et al., 1971b.

Klett, M., 1968. Untersuchungen über Licht- und Schattenqualität in Relation zum Anbau und Test von Kieselpreparaten zur Qualitätshebung. Institut für biologisch-dynamische Forschung, Darmstadt. 117 pp.

Knauer, N., 1970. Beeinflussung der Qualität von Spinat durch

pflanzenbauliche Massnahmen. Ernährungs-Umschau 17: 5 - 8.
Knauer, N. & C. Simon, 1968. Ueber den Einfluss der Stickstoffdüngung auf den Ertrag sowie Nitrat-, Mineralstoff- und Oxalsäuregehalt von Spinat. Zeitschrift für Acker- und Pflanzenbau 128: 197 - 220 (with English summary).
Kolenbrander, F.J., 1970. Heeft de uitspoeling van kunstmest invloed op de kwaliteit van het grondwater der waterleidingbedrijven? Stikstof 6: 141 - 149.
Kövary, I. & G.A. Kövary, 1969. (The analyses of quick frozen spinach puree). Hutöipar 16: 109 - 116 (in Hungarian, with English summary).
Kübler, W., 1959. Werden Säuglinge durch den Nitratgehalt mineralisch gedüngter Gemüse gefährdet? Qualitas Plantarum et Materiae Vegetabiles 5: 297 - 306 (with English summary).
Kuhlen, H., 1962. Das Nitratgehalt von Spinat in Abhängigkeit von der Stickstofdüngung und anderen ökologische Faktoren. Proceedings of the XVIth. International Horticultural Congress. Volume II: 216 - 222.
Kühn, H.J., 1974. Untersuchung über den Nitritgehalt im Speichel in Abhängigkeit von Zahnzustand und Zahnpflege. Dissertation Universität, Heidelberg. Cited by Spiegelhalder et al., 1976.
Lambeth, V.N., M.L. Fields, J.R. Brown, W.S. Regan & D.G. Blevins, 1969. Detinning by canned spinach as related to oxalic acid, nitrates and mineral composition. Food Technology 23: 840 - 842.
Lee, C.Y., 1972. Nitrogen compounds in vegetable foods. In: Environmental contaminants in foods. Proceedings of Sixth Annual Symposium, November 18, 1971. Special Report 9.
Lee, C.Y., R.S. Shallenberger, D.L. Downing, E.S. Stoewsand & N.H. Peck, 1971. Nitrate- and nitrite- nitrogen in fresh, stored and processed table beets and spinach from different levels of field nitrogen fertilization. Journal of the Science of Food and Agriculture 22: 90 - 92.
Lee, D.H.K., 1970. Nitrates, nitrites and methemoglobinemia. Environmental Research 3: 484 - 511.
Lemieszek-Chodorowska, K., I. Michalak, W. Pukorska, W. Lisowska J. Kotlarek, M. Cywinska, H. Kula, K. Mazurkiewicz, M. Jarysz, K. Kosinska, H. Modrzejewska & T. Kujawska, 1972. (Estimation of nitrites and nitrates in some home-raised vegetables). Roczniky Pantswowego Zakladu Higieny 23: 549 - 555 (in Polish, with English summary).
Liedtke, M.A. & C.E. Meloan, 1976. Rapid screening determination of nitrate in baby food using the nitrateselective electrode. Journal of Agricultural and Food Chemistry 24: 410 - 412.
Lijinsky, W., E. Conrad & R. van de Bogart, 1972. Carcinogenic nitrosamines formed by drug/nitrite interactions. Nature 239: 165 - 176.
Lorenz, O.A., 1978. Potential nitrate levels in edible plant parts. In: Nielsen, D.R. & J.G. MacDonald (editors): Nitrogen in the environment. Volume 2. Academic Press, New York. p. 201 - 219.

Lorenz, O.A. & B.L. Weir, 1974. Nitrate accumulation in vegetables. In: White, P.L. & D. Robbins (editors): Environmental quality and food supply. Futura Publications, Mount Kisco, New York. p. 93 - 103.

Luh, B.S., N. Ukai & J.I. Chung, 1973. Effects of nitrogen nutrition and day temperature on composition, color and nitrate in tomato fruit. Journal of Food Science 38: 29 - 33.

Lutsoya, K.I. & M.Y. Rooma, 1971. (Nitrates and nitrites content in vegetables during their storage and processing). Voprosy Pitanija 30 (4): 80 - 83 (in Russian, with English summary).

Maercke, D. van, 1973. Stikstofbemesting en het nitraatgehalte van spinazie. Mededelingen van de Faculteit Landbouwwetenschappen Rijks Universiteit Gent 38: 486 - 503 (with English summary).

Maercke, D. van & M. Vereecke, 1976. Morfo-fysiologische en chemische studie van enkele spinazierassen. Landbouw Tijdschrift 29: 1235 - 1254.

Maga, J.A., F.D. Moore & N. Oshima, 1976. Yield, nitrate levels and sensory properties of spinach as influenced by organic and mineral fertilizer levels. Journal of the Science of Food and Agriculture 27: 109 - 114.

Matar, Y., H.W. Döring & H. Marschner, 1975. Auswirkungen von NaCl und Na_2SO_4 auf Substanzbildung, Mineralstoffgehalt und Inhaltstoffe bei Spinat und Salat. Zeitschrift für Pflanzenernährung und Bodenkunde 138: 295 - 307 (with English summary).

Maynard, D.N., 1978. Critique-of 'Potential nitrate levels in edible plant parts'. In: Nielsen, D.R. & J.G. MacDonald (editors): Nitrogen in the environment. Volume 2. Academic Press, New York. p. 220 - 231.

Maynard, D.N. & A.V. Barker, 1971. Critical nitrate levels for lettuce, radish and spinach. Communications in Soil Science and Plant Analysis 2: 461 - 470.

Maynard, D.N. & A.V. Barker, 1972. Nitrate content of vegetable crops. Hort Science 7: 224 - 226.

Maynard, D.N. & A.V. Barker, 1974. Nitrate accumulation in spinach as influenced by leaf-type. Journal of the American Society for Horticultural Science 99: 135 - 138.

Maynard, D.N., A.V. Barker, P.L. Minotti & N.H. Peck, 1976. Nitrate accumulation in vegetables. Advances in Agronomy 28: 71 - 118.

Mazur, T. & Z. Ciećko, 1974. (Nitrogen fertilization of potatoes Flisak variety I. Effect of increase of nitrogen on yield and chemical composition of potato tubers). Zeszyty Naukowe Akademii Rolniczo-Technicznej W Olsztynie 126 (7): 151 - 165 (in Polish, with English summary).

Mazur, T. & M. Rzasa, 1974. (The effect of increased nitrogen fertilization on yield and nitrogen-compounds content of potato tubers of the Merkur variety). Zeszyty Naukowe Akademii Rolniczo-Technicznej W Olsztynie 124 (7): 123 - 150 (in Polish, with English summary).

Meester, J., 1974. Nitrate and nitrite allowances in meat products. In: Tinbergen, B. & B. Krol (editors): Proceedings of the International Symposium on Nitrite in Meat Products, September 1973, Zeist. Pudoc, Wageningen. p. 265 - 268.

Meineke, R.D., 1972. Veränderungen verschiedener Inhaltstoffe in frischem und tiefgefrorenem Spinat - *Spinacia oleracea* L.- bei der Verwendung in der Gross- und Kleinküche. Dissertation Justus Liebig Universiteit, Giessen. 129 pp.

Merkel, D., 1975. Oxalatgehalt und Kationen-Anionen-Gleichgewicht von Spinatpflanzen in Abhängigkeit vom NO_3: NH_4-Verhältnis in der Nährlösung. Landwirtschaftliche Forschung 28: 34 - 40 (with English summary).

Michael, G., 1974. Biologischer Landbau aus wissenschaftlicher Sicht. Fragen der Umweltschutz 13. Dokumentationsstelle Universität Hohenheim. Cited by Commissie Onderzoek Biologische Landbouwmethoden (1976).

Mills, H.A., A.V. Barker & D.M. Maynard, 1976a. Effects of nitrapyrin on nitrate accumulation in spinach. Journal of the American Society for Horticultural Science 101: 202 - 204.

Mills, H.A., A.V. Barker & D.N. Maynard, 1976b. Nitrate accumulation in radish as affected by nitrapyrin. Agronomy Journal 68: 13 - 17.

Minotti, P.L., 1978. Critique - of 'Potential nitrate levels in edible plant parts'. In: Nielsen, D.R. & J.G. MacDonald (editors): Nitrogen in the environment. Volume 2. Academic Press, New York. p. 232 - 252.

Minotti. P.L. & D.L. Stankey, 1973. Diurnal variation in the nitrate concentration of beets. Hort Science 8: 33 - 34.

Mirvish, S.S., 1977. N-nitroso compounds: Their chemical and in vivo formation and possible importance as environmental carcinogens. Journal of Toxicology and Environmental Health 2: 1267 - 1277.

Miyazaki, M., 1975. Studies on the accumulation of nitrate in tomato fruit for canning. Scientia Horticulturae 3: 109 - 128.

Miyazaki, M., S. Kunisato, Y. Iwamoto, T. Horio & I. Mayuzumi, 1967. (Studies on the accumulation of nitrate in horticultural products. I. The Accumulation of nitrate in tomato fruits). Journal of the Japanese Society for Horticultural Science 37: 178 - 184 (in Japanese, with English summary).

Möhler, K., 1975. Das Nitrat-Nitritproblem in der menschlichen Ernährung. Bayerisches Landwirtschaftliches Jahresbuch Sonderheft 52/1: 43 - 47.

Moore, F.D. ,1973. N-serve nutrient stabilizer: A nitrogen management tool for leafy vegetables. Down Earth 28: 4 - 7.

Nicolaisen, W. & R. Haar, 1964. Untersuchungen über den Einfluss einer Nitratdüngung auf dem Gesamtstickstoff- und Nitratgehalt von Möhren. Gartenbauwissenschaft 29: 463 - 480 (with English summary).

Nicolaisen, W. & H. Zimmermann, 1968. Der Einfluss der Sticksstoffdüngung auf den Nitratgehalt von Spinat unter wechselnden klimatischen Bedingungen. Gartenbauwissenschaft 33: 353 - 380 (with English summary).

Nurzynski, J., 1976. (Effect of the chloride and sulphate form of potassium on the quantitative and qualitative aspects of the yields of some vegetable crops on garden peat). Biuletyn Warzywnictwa 19: 105 - 118 (in Polish, with English summary).

Olday, F.C., A.V. Barker & D.N. Maynard, 1976. A physiological basis for different patterns of nitrate accumulation in two spinach cultivars. Journal of the American Society for Horticultural Science 101: 217 - 219.

Pavlek, P., P. Durman, R. Heneberg & D. Horgas, 1974. (Effect of some climatic factors upon the yield and dry matter and nitrate content of the studied spinach varieties). Poljoprivredna Znanstvena Smotra 33 (43): 133 - 141 (in Yugoslavian, with English summary).

Peck, N.H., A.V. Barker, G.E. MacDonald & R.S. Shallenberger, 1971. Nitrate accumulation in vegetables. II. Table beets grown in upland soils. Agronomy Journal 63: 130 - 132.

Peck, N.H., D.J. Cantliffe, R.S. Shallenberger & J.B.Bourke, 1974. Table beet (*Beta vulgaris* L.) and nitrogen. New York Agricultural Experiment Station. Search 4: 1 - 25.

Phatak, S.C. & D.J. Cantliffe, 1975. Effects of herbicides on weed control and nitrate accumulation in table beets. Hort Science 10: 271 - 273.

Phillips, W.E.J., 1968a. Changes in the nitrate and nitrite contents of fresh and processed spinach during storage. Journal of Agricultural and Food Chemistry 16: 88 - 91.

Phillips, W.E.J., 1968b. Canadian Institute for Food Science and Technology Journal 1: 98.

Phillips, W.E.J., 1969. Lack of nitrite accumulation in partially consumed jars of baby food. Canadian Institute for Food Science and Technology Journal 2: 160 - 161.

Pimpini, F., F. Venter & A. Wünsch, 1970. Untersuchungen über den Nitratgehalt in Blumenkohl. Landwirtschaftliche Forschung 23: 363 - 370 (with English summary).

Pimpini, F., F. Venter & A. Wünsch, 1971. Der Einfluss verschiedener Stickstoff-Formen und steigender Stickstoff-Mengen auf den Gehalt an Gesamt-Stickstof und Nitrat in Blumenkohl. Gartenbauwissenschaft 36: 511 - 523 (with English summary).

Rausa, G. & L. Zabeo, 1972. (The importance of nitrate and nitrite contents in fresh or frozen spinach in the hygiene of foods). Igiene Moderna 65: 584 - 612 (in Italian, with English summary).

Rautu, R., A. Ungareanu & A. Sporn, 1972. (Contributions to the determination of the nitrate supply in the food ration). Igiena 21: 460 - 468 (in Rumanian, with English summary).

Regan, W.S., V.N. Lambeth, J.R. Brown & D.G. Blevins, 1968. Fertilization interrelationships on yields, nitrate and oxalic acid content of spinach. Proceedings of the American Society for Horticultural Science 93: 485 - 492.

Reinton, R., 1974. Nitrat- og nitrittinhold i norsk industriprodusert barnemat. Tidsskrift for Hermetikindustri 60:

196 - 199.
Richardson, W.D., 1907. The occurrence of nitrates in vegetable foods, in cured meats and elsewhere. Journal of the American Chemical Society 29: 1757 - 1767.
Richter, E. & S. Handke, 1972. Einfluss des Wasserblachierens auf den Nitratgehalt von Spinat. Zeitschrift für Lebensmitteluntersuchung und -forschung 141: 275 - 276 (with English summary).
Riehle, G. & J.Jung, 1966. Zum Vorgang der Nitritbildung in Spinat. Landwirtschaftliche Forschung 19: 231 - 242 (with English summary).
Rochize, S., 1976. Les nitrates et nitrites comme additifs aux aliments. Annales de la Nutrition et de l'Alimentation 30: 715 - 742 (with English summary).
Rooma, M.Y., 1971. (The content of nitrates, nitrites and hydroxylamines in food products). Gigiena i Sanitarija 36: 47 - 50 (in Russian, with English summary).
Roorda van Eysinga, J.P.N.L. & R. Maaswinkel, 1978. Het nitraatgehalte van diverse andijvierassen geteeld onder glas en eind februari geoogst. Proefstation voor de Groenten- en Fruitteelt onder Glas, Naaldwijk. Intern Rapport no. 30. 3 pp.
Roorda van Eysinga, J.P.N.L. & M.Q. van der Meys, 1978. Een onderzoek naar het nitraatgehalte in enkele onder glas geteelde voorjaarsgroenten. Proefstation voor de Groenten- en Fruitteelt onder Glas Naaldwijk. Intern Rapport no. 46. 6 pp.
Sachse, R., 1966. Nitrat-Nitrit in Frischgemüse und verzerhsfertigen Gemüsezubereitungen, ein Problem der Ernährungshygiene? Zeitschrift für die gesamte Hygiene und ihre Grenzgebiete 12: 243 - 247 (with English summary).
Sander, D.J. & A.V. Barker, 1978. Comparative toxicity of nitrapyrin and 6-chloropicolinic acid to radish and cucumber under different N-nutrition regimes. Agronomy Journal 40: 295 - 298.
Schaller, A., M. Thonhauser & W. Bergtaller, 1969. Ergebnisse von Untersuchungen hinsichtlich der Nitrat- und Nitritkonzentration in aufgetautem, ungelagertem Tiefgefrier-Spinatpüree. Die Kälte 22: 267 - 271.
Schuphan, W., 1958. Biochemische Stoffbildung bei *Brassica oleracea* L. in Abhängigkeit von morphologischen und antomischen Differenzierungen ihrer Organe. Zeitschrift für Pflanzenzüchtung 39: 127 - 186 (with English summary).
Schuphan, W., 1961. Zur Qualität der Nahrungspflanzen. Bayerische Landwirtschaftsverlag G.m.b.H. München. 170 pp. English version: Nutrional values in crops and plants, problems for producers and consumers. Faber & Faber, London, 1965. 280 pp.
Schuphan, W., 1965. Ertragsbildung und Erzeugung wertgebender Inhalts- und Schadstoffe in Abhängigkeit von der N- und P-Düngung. Landwirtschaftliche Forschung Sonderheft 19: 195 - 205.
Schuphan, W., 1974. The significance of nitrates in food and

potable waters. Qualitas Plantarum 24: 19 - 34.
Schuphan, W. & H. Schlottmann, 1965. Ueberdüngung als Ursache hoher Nitrat- und Nitritgehalte des Spinats (*Spinacia oleracea* L.) in ihrer Beziehung zur Säuglings-Methämoglobinämie. Zeitschrift für Lebensmitteluntersuchung und -forschung 128: 71 - 75.
Schuphan, W., B. Bengtsson, I. Bosund & B. Hylmö, 1967. Nitrate accumulation in spinach. Qualitas Plantarum et Materiae Vegetabiles 14: 318 - 330.
Schütt, I., 1977. Nitratuntersuchungen in Rohspinat und industrieller Säuglingsfertignahrung. Die Nahrung 21: 61 - 67 (with English summary).
Schwerdtfeger, E., 1974. Umweltbedingte Impulse als Enzyminduktoren in ihrer Auswirkung auf Pflanzeninhaltstoffe. Qualitas Plantarum 24: 263 - 280 (with English summary).
Schwerdtfeger, E., 1977. Das Nitrat-Nitrosaminproblem bei pflanzlichen Nahrungsmitteln. Qualitas Plantarum 27: 339 - 348 (with English summary).
Selenka, F. & D. Brand-Grimm, 1976. Nitrat und Nitrit in der Ernährung des Menschen. Kalkulation der mittleren Tagesaufnahme und Abschatzung der Schwankungsbreite. Zentralblatt für Bakteriologie, Parasitenkunde, Infektionskrankheiten und Hygiene. 1. Abteilung Original B 162: 449 - 466 (with English abstract).
Siciliano, J., S. Krulick, E.G. Heisler, J.H. Schwartz & J.W. White, 1975. Nitrate and nitrite content of some fresh and processed market vegetables. Journal of Agricultural and Food Chemistry 23: 461 - 464.
Siegel, O. & G. Vogt, 1974. Ueber die Bildung verschiedener Stickstoffverbindungen im Spinat (*Spinacia oleracea* L.) in Abhängigkeit von Art und Menge des gebotenen Stickstoffs. Landwirtschaftliche Forschung 27: 281 - 286 (with English summary).
Siegel, O. & G. Vogt, 1975a. Ueber den Einfluss langsam fliessender Stickstoffquellen auf den Aufbau der Stickstoffverbindungen in Spinat und Gerste. Landwirtschaftliche Forschung 28: 235 - 241 (with English summary).
Siegel, O. & G. Vogt, 1975b. Ueber den Einfluss eines Nitrifikationsinhibitors auf die Stickstoffverbindungen des Spinats. Landwirtschaftliche Forschung 28: 242 - 248 (with English summary).
Simon, C., 1970. Die alimentäre Methämoglobinämie im Säuglingsalter. Ernährungs-Umschau 17: 3 - 5.
Simon, C., H. Kay & G. Mrowetz, 1965. Ueber den Nitratgehalt von Spinat, insbesondere im Hinblick auf die Gefahr einer Methemoglobinämie. Deutsche Lebensmittel Rundschau 61: 75 - 78.
Simon, C., H, Kay & G. Mrowetz, 1966. Ueber den Gehalt an Nitrat, Nitrit und Eisen von Spinat und anderen Gemüsearten und die damit verbundene Gefahr einer Methämoglobinämie für Säuglinge. Archiv für Kinderheilkunde 175: 42 - 54 (with English summary).
Singh, B., O.O. Vadhwa, M.T. Wu & D.K. Salunkhe, 1972. Effects

of foliar application of s-triazines on protein, amino acids, carbohydrates and mineral composition of pea and sweet corn seeds, bush been pods and spinach leaves. Journal of Agricultural and Food Chemistry 20: 1256 - 1259.

Sinios, A. & W. Wodsak, 1965. Die Spinatvergiftung des Säuglings. Deutsche Medizinische Wochenschrift 90: 1856 - 1863.

Sistrunk, W.A. & J.N. Cash, 1974. Quality and nitrate-nitrite levels of canned spinach during storage. Arkansas Farm Research 23: 11.

Sistrunk, W.A. & J.N. Cash, 1975. Spinach quality attributes and nitrate-nitrite levels as related to processing and storage. Journal of the American Society for Horticultural Science 100: 307 - 309.

Smith, G.E. 1966. Causes of nitrate accumulation on plants and water supplies. Paper to the 18th Annual Midwest Fertilizer Conference, Chicago. Cited by Lee (1970).

Smith, S. & K. Simpson, 1957. Taylors's principles and practices of medical jurisprudence. Volume II. J. & A. Churchill, London. 292 pp. Cited by Burden (1961).

Smittle, D.A. & L.E. Scott, 1969. Internal can corrosion by processed sweet potatoes as affected by phenolase activity and nitrate concentration. Journal of the American Society for Horticultural Science 94: 649 - 654.

Soboleva, E.A., 1969. (The content of nitrates in vegetables). Gigiena i Sanitarija 34 (5): 37 - 40 (in Russian, with English summary).

Sohier, Y., A.M. Poumarat & P. Berges, 1976. Les nitrates dans les épinards en conserve, influence des traitements technologiques. Annales de la Nutrition et de l'Alimentation 30: 689 - 694 (with English summary).

Sollmann, T.H., 1948. A manual of pharmacology and its application to therapeutics and toxicology. Saunders Co. Philadelphia. 842 pp. Cited by Lee et al., 1971.

Sommer, K. & M. Mertz, 1974. Wachstum, Ertrag, Mineralstoffaufnahme von Pflanzen beeinflusst durch Ammonium oder Nitrat. Landwirtschaftliche Forschung 27: 8 - 30 (with English summary).

Spiegelhalder, B., G. Eisenbrand & R. Preussmann, 1976. Influence of dietary nitrate on nitrite content of human saliva: possible relevance to in vivo formation of N-nitroso compounds. Food and Cosmetics Toxicology 14: 545 - 549.

Splittstoesser, W.E., J.S. Vandemark & S.M.A. Khan, 1974. Influence of nitrogen fertilization upon protein and nitrate concentration in some vegetable crops. Hort Science 9: 124 - 125.

Staatliche Landwirtschaftliche Untersuchungs- und Forschungsanstalt Augustenberg in Karlsruhe-Durlach, 1973. Tätigkeitsbericht 1971/1972. 128 pp.

Stephany, R.W., 1978. Personal communication.

Stephany, R.W. & P.L. Schuller, 1975. De aanwezigheid van nitriet in menselijk speeksel en het N-nitrosamine probleem. Volksgezondheid, Verslagen, Adviezen, Rapporten 33/34, Berichten RIV en Liber Amicorum: 184 - 190.

Stephany, R.W. & P.L. Schuller, 1977. Some new data on the intake of nitrate, nitrite and volatile N-nitrosamines and on the occurence of volatile N-nitrosamines in human urine and veal-calves. Paper presented at the 5th. Meeting on Analysis and Formation of N-nitroso Compounds, August 1977, Durham, New Hampshire.

Stolley, H., C. Schlarge & W. Droese, 1977. Nitrat in Karotten für den jungen Säugling. Ernährungs-Umschau B 24: 362.

Strotz, N.H. & R.E. Henry, 1954. The relation of nitrates in foods to tin plate container corrosion. Food Technology 8: 93 - 95.

Subbotin, F.N., T.K. Masolnikova & K.A. Tomolina, 1970. (Influence of nitrates contained in the products of vegetable origin on the methemoglobin formation). Voprosy Pitanija 29 (5): 65 - 70 (in Russian, with English summary).

Subramanya, R., G. Vert & S. Honma, 1976. Hort Science 11: 297.

Tannenbaum, R.S., M. Weisman & D. Fett. 1976. The effect of nitrate intake on nitrite formation in human saliva. Food and Cosmetics Toxicology 14: 549 - 552.

Terman, G.O., J.C. Noggle & C.M. Hunt, 1976. Nitrate-N and total-N-concentration relationships in several plant species. Agronomy Journal 68: 556 - 560.

Thielemann, H. & R. Hildebrandt, 1971. Untersuchungen zur Herabsetzung des Nitratgehaltes von Trinkwasser unter Verwendung eines Ionausstauchers. Die Nahrung 15: 65 - 69 (with English summary).

Thier, H.P., 1967. Wertvolle und unerwünschte Inhaltstoffe des Spinats. Naturwissenschaftliche Rundschau 20: 525 - 529.

Trines, H., 1952. Verslagen en Mededelingen Volksgezondheid 1952: 481 - 503. Cited by Kolenbrander (1970).

Tronickova, E. & V. Vit, 1970. The effect of fertilizers on the nitrate content in several varieties of spinach. I. Vedecké Práce Výzkumných Ustavů Rostlinné Výroby Praha Ruzyne 16: 119 - 126.

Tronickova, E. & V. Vit, 1972. The effect of fertilizers on the nitrate content in several cultivars of spinach. II. Winter spinach. Vedecké Práce Výzkumných Ustavů Rostlinné Výroby Praha Ruzyne 17: 273 - 280.

Tychsen, K., 1976. Irradiance and nitrogen metabolism in spinach. Acta Agricultura Scandinavica 26: 189 - 195.

Uhlig, R., 1968. Beitrag zur Kenntnis des Nitrat-, Nitrit- und Vitamin C-gehaltes in Babykost-Gemüsekonserven. Industrielle Obst- und Gemüseverwertung 58: 187 - 193.

Venter, F., 1978a. Untersuchungen über den Nitratgehalt in Gemüse. Der Stickstoff 1978 (12): 31 - 38.

Venter, F., 1978b. Ueber den Nitratgehalt von Gemüse. Industrielle Obst- und Gemüseverwertung 63: 117 - 120.

Viets, F.G. & R.H. Hageman, 1971. Factors affecting the accumulation of nitrate in soil, water and plants. United States Department of Agriculture, Agricultural Handbook 413.

Voogt, P., 1969. Die Bestimmung von Nitrat im Spinat mittels einer nitratselektiven Elektrode. Deutsche Lebensmittel-Rundschau 65 (7): 196 - 198.

Vos, R.H. de, 1978. Additieven en chemische kontaminanten in ons voedsel. Voedingsmiddelentechnologie 11 (41): 24 - 26.
Vulsteke, G. & R. Biston, 1978. Factors affecting nitrate content in field-grown vegetables. Qualitas Plantarum 28: 71 - 87.
Walker, R., 1975. Naturally occuring nitrate/nitrite in foods. Journal of the Science of Food and Agriculture 26: 1735 - 1742.
Westvlaamse proeftuin voor industriële groenten, 1978. Verslag over de proeven uitgevoerd in 1976 en 1977. Onderzoek- en Voorlichtingscentrum voor Land- en Tuinbouw, Beitem-Roeselare. 176 pp.
White, J.W., 1975. Relative significance of dietary sources of nitrate and nitrite. Journal of Agriculture and Food Chemistry 23: 886 - 891. Correction in: Journal of Agricultural and Food Chemistry 25: 202 (1976).
Wilberg, E., 1972. Ueber die Qualität von Spinat aus 'Biologischen Anbau'. Landwirtschaftliche Forschung 25: 167 - 169 (with English summary).
Wilson, J.K., 1943. Nitrate in plants: its relation to fertilizer injury, changes during silage making and indirect toxicity to animals. Agronomy Journal 35: 279 - 290.
Wilson, J.K., 1949. Nitrate in foods and its relation to health. Agronomy Journal 41: 22 - 24.
Winton, E.F., R.G. Tardiff & L.J. McGabe, 1971. Nitrate in drinking water. Journal of the American Water Works Association 63: 95 - 98.
Witte, H., 1967a. Stickstoffgehalt des Spinates in der Praxis des Feldgemüsebaus. Mitteilungen der Deutsche Landwirtschaftliche Gesellschaft 82: 1658 - 1660.
Witte, H., 1967b. Nitrat- und Nitrituntersuchungen- Erfahrungen in Betriebslaboratorium der Gefrierkonservenindustrie. Industrielle Obst- und Gemüseverwertung 52: 367 - 369.
Witte, H., 1970. Nitratgehalt des Spinates - Zwei Jahre systematische Rohware-Untersuchungen. Industrielle Obst- und Gemüseverwertung 55: 7 - 11.
Wolff, I.A. & A.E., Wasserman, 1972. Nitrates, nitrites and nitrosamines. Science 177: 15 - 19.
Wright, M.G. & K.L. Davison, 1964. Nitrate accumulation in crops and nitrate poisoning of animals. Advances in Agronomy 16: 197 - 247.
Zimmermann, H., 1966. The influence of fertilization on the quality of spinach at various light intensities. Acta Horticulturae 4: 89 - 95.
Zink, F.W., 1965. Growth and nutrient absorption in spring spinach. Proceedings of the American Society for Horticultural Science 87: 380 - 386.

Appendices

Appendix 1

Compilation of literature about factors affecting the nitrate accumulation in vegetables during growth and development.

1 genetic factors
2 amount of nitrogen
3 source of nitrogen
4 time of application of nitrogen
5 other nutrients
6 light
7 temperature
8 water relations
9 herbicides
10 location
11 season
12 changes during growth

	1	2	3	4	5	6	7	8	9	10	11	12
Achtzehn & Hawat (1969)		x								x	x	
Asif & Greig (1972)		x			x						x	
Astier-Dumas (1973)											x	
Augustin et al. (1977)								x				
Barker (1975)		x	x									
Barker & Maynard (1971)		x			x							
Barker et al. (1974)	x	x										
Barker et al. (1971)	x	x	x	x								x
Bengtsson (1968)		x	x									
Blanc (1976)	x	x			x							
Boek & Schuphan (1959)	x	x			x	x				x		
Brink et al. (1968)		x										
Brown & Smith (1966)	x	x			x							x
Brown & Smith (1967)	x	x			x							
Brown et al. (1969)		x			x							
BAQ (1973)		x	x			x						
Burdine & Hall (1974)					x						x	x
Burg et al. (1967)		x										
Burg et al. (1969)		x										
Cantliffe (1972a)		x				x						
Cantliffe (1972b)	x	x				x						
Cantliffe (1972c)	x	x					x					

Compilation of literature about factors affecting the nitrate accumulation in vegetables during growth and development.

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10 location
11 season
12 changes during growth

	1	2	3	4	5	6	7	8	9	10	11	12
Cantliffe (1973a)		x			x	x						
Cantliffe (1973b)	x	x										
Cantliffe & Goodwin (1974)		x	x		x							
Cantliffe & Phatak (1974a)									x			
Cantliffe & Phatak (1974b)	x	x										
Cantliffe et al. (1974)		x			x							
Carter & Bosma (1974)		x	x		x			x				
Ciećko (1974)		x			x							
Darwinkel (1975)		x										
Diehl & Wedler (1977)			x								x	
Dillier & Heierli (1971)	x											
Dragland (1976)	x	x										
Dressel (1976a)		x										
Dressel (1976b)		x										
Dressel & Jung (1970)		x	x			x						
Eerola et al. (1974)		x									x	
Ehrendorfer (1964)		x	x		x							
Ehrendorfer (1973)		x			x							
Frota & Tucker (1972)			x				x					
Garbouchev & Mitreva (1972)		x			x							
Gersons (1969)	x	x										
Gersons (1977)		x			x							x
Geyer (1978)		x	x	x	x			x		x		x
Graifenberg & Leoni (1970)		x	x									
Grujic & Kastori (1974)		x			x							
Habben (1973)		x									x	x
Hansen (1976a)	x	x									x	x
Hansen (1976b)		x										
Heisler et al. (1973)	x	x										
Hildebrandt (1976)		x			x							
Hoff & Wilcox (1970)		x				x	x					
Hulewicz & Mokrzecka (1971)		x			x						x	

Compilation of literature about factors affecting the nitrate accumulation in vegetables during growth and development

	1	2	3	4	5	6	7	8	9	10	11	12
Johnson (1966)	x	x										
Johnson & Orth (1967)	x	x			x							
Jurkowska (1971)			x									
Kick & Massen (1973)		x	x									
Klett (1968)						x						
Knauer (1970)		x										
Knauer & Simon (1968)		x	x		x						x	
Kuhlen (1962)		x									x	
Lambeth et al. (1969)		x			x							
Lee et al. (1971)		x										
Lorenz & Weir (1974)	x	x									x	x
Luh et al. (1973)		x					x					
Maercke (1973)		x	x								x	
Maercke & Vereecke (1976)	x											
Maga et al. (1976)		x	x	x								
Matar et al. (1975)					x							
Maynard & Barker (1971)	x	x									x	
Maynard & Barker (1972)			x									
Maynard & Barker (1974)	x		x									
Mazur & Ciećko (1974)		x										
Mazur & Rzasa (1974)		x						x				
Meineke (1972)											x	
Merkel (1975)			x									
Mills et al. (1976a)		x	x									
Mills et al. (1976b)		x	x									
Minotti & Stankey (1973)						x	x					
Miyazaki (1975)	x	x	x	x	x	x					x	x
Miyazaki et al. (1967)		x	x		x							x
Möhler (1975)						x						
Moore (1973)			x									
Nicolaisen & Haar (1964)	x	x		x								x
Nicolaisen & Zimmermann (1968)		x		x							x	x
Nurzynski (1976)					x							
Olday et al. (1975)	x	x										
Pavlek et al. (1974)	x											
Peck et al. (1971)		x	x	x								x
Peck et al. (1974)		x		x								x
Phatak & Cantliffe (1975)									x			
Pimpini et al. (1970)	x											
Pimpini et al. (1971)		x	x									
Regan et al. (1968)		x			x							
Richter & Handke (1972)		x										
Roorda van Eysinga & Maaswinkel (1978)	x											

Compilation of literature about factors affecting the nitrate accumulation in vegetables during growth and development

1 genetic factors
2 amount of nitrogen
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10 location
11 season
12 changes during growth

	1	2	3	4	5	6	7	8	9	10	11	12
Roorda van Eysinga & van der Meys (1978)		x	x									
Sander & Barker (1978)			x									
Schuphan (1965)		x			x							
Schuphan (1974)		x				x						
Schuphan & Schlottmann (1965)		x										
Schuphan et al. (1967)	x	x	x			x				x	x	
Schütt (1977)											x	
Schwerdtfeger (1974)						x						
Siegel & Vogt (1974)		x	x									
Siegel & Vogt (1975a)		x	x									
Siegel & Vogt (1975b)			x									
Singh et al. (1972)									x			
Smittle & Scott (1969)	x	x										
Sommer & Mertz (1974)			x									
Splittstoesser et al. (1974)		x										
Subramanya et al. (1976)	x											
Terman et al. (1976)	x	x										
Tronickova & Vit (1970)	x	x	x	x							x	x
Tronickova & Vit (1972)	x	x	x	x							x	x
Tychsen (1976)						x						
Viets & Hageman (1971)		x			x	x	x	x	x			
Vulsteke & Biston (1978)		x	x	x						x		x
Westvlaamse proeftuin voor industriële groenten (1978)												x
Witte (1967a)											x	
Witte (1970)											x	
Wright & Davison (1964)								x				
Zimmermann (1966)		x		x								x
Zink (1965)												x

Compilation of literature about factors affecting the nitrate and nitrite contents of vegetables during processing and storage.

1 nitrate distribution within the plant
2 home processing
3 blanching
4 industrial processing
5 storage of fresh vegetables
6 storage of processed vegetables
7 detinning

	1	2	3	4	5	6	7
Achtzehn & Hawat (1970)					x		
Achtzehn & Hawat (1971a)	x		x				
Achtzehn & Hawat (1971b)			x	x			
Astier-Dumas (1976a)		x	x				
Astier-Dumas (1976b)		x					
Auffray & Pafique (1976)		x					
Aworh et al. (1978)					x		
Becker (1965)		x			x	x	
Bengtsson (1969)			x				
Bergholm (1972)	x						
Board (1973)							x
Bodiphala & Ormrod (1971)	x		x				
Boek & Schuphan (1959)	x						
Bolotov & Soboleva (1971)						x	
Brink et al. (1968)			x	x			
Burdine & Hall (1974)					x		
Burg et al. (1967)					x		
Burg et al. (1969)					x		
Cantliffe & Phatak (1974a)	x						
Cantliffe & Phatak (1974b)	x						
Dillier & Heierli (1970)	x		x				
Dillier & Heierli (1971)	x		x				
Dragland (1976)					x		
Eerola et al. (1974)			x			x	
Farrow et al. (1971)							x
Frankena (1968)					x	x	
Fratoni & Miuccio (1967)					x	x	
Gersons (1969)							x
Gersons (1976a)					x		
Gersons (1976b)			x	x			
Geyer (1978)	x						
Graifenberg & Leoni (1970)	x						
Hall et al. (1977)						x	
Hawat & Achtzehn (1968)					x	x	
Heintze et al. (1975)			x				

Compilation of literature about factors affecting the nitrate and nitrite contents of vegetables during processing and storage.

1 nitrate distribution within the plant
2 home processing
3 blanching
4 industrial processing
5 storage of fresh vegetables
6 storage of processed vegetables
7 detinning

	1	2	3	4	5	6	7
Heisler et al. (1974)					x	x	
Hicks et al. (1975)						x	
Hildebrandt (1976)					x	x	
Hoff & Wilcox (1970)							x
Johnson (1966)							x
Johnson & Orth (1967)							x
Jurkowska (1971)	x						
Kenny & Walshe (1975)		x					
Keybets (1968)					x	x	
Kick & Massen (1973)	x						
Kilgore et al. (1963)		x					
Klaushofer et al. (1971a)						x	
Klaushofer et al. (1971b)						x	
Klaushofer et al. (1968)						x	
Klett (1968)	x						
Knauer (1970)						x	
Lambeth et al. (1969)							x
Lutsoya & Rooma (1971)					x	x	
Maga et al. (1976)	x						
Meineke (1972)		x	x	x	x	x	
Mills et al. (1976a)	x						
Minotti & Stankey (1973)	x						
Miyazaki (1975)							x
Miyazaki et al. (1967)							x
Olday (1976)	x						
Phatak & Cantliffe (1975)	x						
Phillips (1968a)					x	x	
Phillips (1969)						x	
Pimpini et al. (1970)	x						
Rausa & Zabeo (1972)					x	x	
Richter & Handke (1972)			x				
Riehle & Jung (1966)					x		
Schuphan (1965)					x		
Schuphan (1974)	x		x		x		
Schuphan et al. (1967)			x				
Schütt (1977)			x				
Simon et al. (1966)					x	x	

Compilation of literature about factors affecting the nitrate and nitrite contents of vegetables during processing and storage.

	1	2	3	4	5	6	7
Singh et al. (1972)	x						
Sistrunk & Cash (1974)						x	
Sistrunk & Cash (1965)			x			x	
Smittle & Scott (1969)							x
Sohier et al. (1976)		x	x				
Strodz & Henry (1954)							x
Tronickova & Vit (1970)			x				
Venter (1978b)	x						
Vulsteke & Biston (1978)		x	x				
Witte (1967b)	x				x		