# Final Report to Food Standards Agency

## Nitrate Surveillance Programme:

## May 2014 – April 2019

## Contract Number FS513408

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## Executive Summary

Every EU Member State is required to monitor and report levels of nitrate in specified foodstuffs as part of the European Commission regulation and the UK also requires this information in support of negotiations on the review of regulations. The requirement to carry out monitoring for nitrate in lettuce, spinach and rocket is being met by the UK Nitrate Surveillance Programme.

A total of 1000 samples were collected between May 2014 and April 2019. There were 553 domestic lettuce samples, 108 spinach samples, 76 rocket samples, 31 'other leafy green vegetables' and 232 imported samples.

Differences in nitrate concentration were observed between sample categories. Rocket had the highest concentration and iceberg lettuce had the lowest. Imported and domestic samples were broadly comparable. Mean nitrate concentration was relatively stable within categories when comparing with long term average values. A total of 2.99% of domestic samples exceeded the regulation limit, comprising produce from across categories, months and regions.

The overall percentage of domestic samples exceeding the regulation limit has significantly decreased over the last 15 years and has remained consistent, at approximately 3%, for the last 5 years (2014 - 2018). However, >10% of rocket samples exceeded the limit and the trend suggests that the annual number of rocket samples exceeding the limit is increasing.

Although some individual samples contained significant amounts of nitrate the surveillance programme has shown that the UK is largely producing leafy green vegetables with nitrate concentrations within the regulation limits.

The existing data could be examined more closely to identify relationships between tissue nitrate concentration, fertiliser input, crop husbandry and environmental factors. An improved understanding would enable industry to refine their growing practices and help the Food Standards Agency to better predict which crops are likely to exceed the maximum permitted nitrate limits.

## Introduction

Nitrates are chemicals that exist in plants, soils and water. The concentration of nitrate in plant tissues is variable but green leafy vegetables, when consumed raw can contain relatively high amounts. Concentration above a threshold value can pose a human health risk and high nitrate levels have been associated with certain types of cancer. Lettuce, spinach and rocket are important leafy vegetable crops in the UK and are the source plant material for this report.

Concerns regarding high concentrations of nitrate in the diet have led the European Commission (EC) to introduce maximum residue levels in lettuce, spinach and rocket. The EC limits represent a nitrates concentration threshold for consumer health but also a compromise based on individual Member States "national levels" in order to prevent intra-community trade barriers. The Contaminants in Food (England) Regulations 2013 implements the directly applicable EU Commission Regulation (EC) No. 1881/2006 and EC regulation 466/2001

A Commission Regulation (EC) No 1258/2011 came into force in December 2011. This Regulation set out new, permanent limits in green leafy vegetables; except the limits for rocket which applied specifically from 1 April 2012. It ends the previous temporary derogation which permitted the UK and some other EU countries to exceed maximum nitrate limits for fresh lettuce and spinach grown and intended for consumption on their own respective territories. Furthermore, the regulation now allows Member States to communicate results of the monitoring programme to the European Food Safety Authority (EFSA) on a regular basis, rather than the mandatory deadline of June 30 each year.

Every Member State is required to monitor and report levels of nitrate as part of a European Commission regulation and the UK also requires this information in support of negotiations on the review of regulations. The requirement to carry out surveillance for nitrate in lettuce, spinach and rocket has been met by the UK Monitoring Programme. This has been undertaken since May 1996 and reported in earlier MAFF (now Defra) and FSA Food Surveillance Information Sheets. Monitoring of UK grown lettuce, spinach and rocket is currently being led by RSK ADAS Ltd (ADAS) in partnership with NRM Laboratories.

## Quality Assurance

The study was conducted in compliance with the requirements of the Food Standards Agency, as set out in RRD27, February 2008. Sampling methodology conforms to the European Commission guidelines given in Commission Regulation EC/1882/2006 and with the quality assurance procedures adopted for the 2002-2007 surveys.

ADAS has its own in-house Quality Management System (QMS) developed to meet the requirements of externally accredited standards applied to parts of the business. Compliance with QMS is monitored through formal audit by the operationally independent Quality Management Group. ADAS is registered with Lloyd's Register Quality Assurance (LRQA) for: 'Provision of independent research, consultancy and contracting services, focused primarily on environmental management, regional development, agriculture, horticulture and the food supply chain, to Government, levy bodies and private sector companies'.

Chemical analysis carried out by NRM Ltd meets the requirements of the Joint Code of Practice for Quality Assurance in Research, complies with Commission Regulation (EC) No 1882/2006 and complies with the provisions of items 1 & 2 of Annex III to Regulations (EC) No 882/2004.

## Objectives

1 To collect a total of 1000 samples of fresh produce over the monitoring period, principally lettuce, rocket and spinach, including domestic and imported samples (approximately 200 samples per year).

2 To carry out the chemical determination of nitrate concentration in fresh tissue in accordance with the appropriate Directives.

3 To report results to the agency in an electronic format.

4 To ensure the participating growers receive a copy of their results.

## Methodology

### Site selection and grower representation

Sampling schedules were prepared by ADAS each year and agreed by the Food Standards Agency (FSA). The schedule ensured that sampling of fresh produce complied with the European Commission guidelines given in Regulation EC/1882/2006 and met with the requirement to spread the sampling over representative geographical regions throughout the UK. The schedule also ensured that seasonal growing trends were adequately reflected.

### Sample collection and transportation to the laboratory

Domestic and imported samples were collected by trained Sample Officers, in accordance with Commission Regulation EC/1882/2006. For domestic samples, a minimum of 10 heads of lettuce or 1.0 kg of spinach, rocket and other leafy green vegetables was randomly collected from various points within the lot by walking a 'W' pattern across the sampling area. Lot size did not exceed 2 ha and plants which were atypical of the lot (such as diseased plants) were avoided. Imported samples were collected from the wholesaler by taking one lettuce or a 'handful' of spinach and rocket out of each crate and ensuring that a minimum of ten separate crates from a batch were used. Samples were labelled with a unique identity which was fully traceable throughout the project and were maintained at $<10^{o}C$ during transportation to the laboratory.

### Crop husbandry details

Details were collected by the Sample Officers to accompany each sample. For domestic samples, details included grower, date and time sample was collected, variety or type, location, lot size and fertiliser input. Limited information was collected for the imported samples and included wholesaler, date of sample collection, country of origin, variety or type and any relevant labelling to ensure traceability.

### Sample preparation in the laboratory

Samples were checked upon receipt to ensure they had remained intact and had not degraded during transit. Samples were prepared in accordance with the requirements of EC Regulation 1882/2006. The whole sample was homogenised using a protocol developed by NRM Ltd. Four representative sub-samples were taken, (A, B, C and D). Sub-sample A was used immediately for analysis. Sub-sample B was kept refrigerated in case the sample exceeded the limit and repeat analysis was required. Sub-samples C and D were frozen and kept in storage for 12 months following the reporting of results, in case of dispute.

## Analytical analysis

Analysis commenced immediately after preparation and used a UKAS accredited method which fully meets the requirements of EC Regulation 1882/2006. The method is accredited to BS EN ISO 17025: 2005 and has been since 2000. The method uses an extraction procedure which involves freezing in liquid nitrogen prior to homogenisation. Detection is based on flow injection colorimetry and is currently used by NRM Ltd for analysis of all commercial samples. If a nitrate value was ≥ 90% of the maximum nitrate level (Table 1) for a particular product then a repeat extraction and analysis of refrigerated Sample B was triggered, to confirm the high value. Nitrate concentrations were expressed in milligrams of nitrate per kilogram of sample fresh weight (mg $kg^{-1}$).

Table 1. Maximum permitted concentrations of nitrates in lettuce, spinach and rocket.

| **Product** | **Maximum permitted levels ($NO_3$ mg $kg^{-1}$)** | |
|---|---|---|
| Fresh lettuce, iceberg type | Lettuce grown under cover | 2500 |
| | Lettuce grown in the open air | 2000 |
| Fresh lettuce, non-iceberg type | *Harvested 01 October to 31 March:* | |
| | Lettuce grown under cover | 5000 |
| | Lettuce grown in the open air | 4000 |
| | *Harvested 01 April to 30 September:* | |
| | Lettuce grown under cover | 4000 |
| | Lettuce grown in the open air | 3000 |
| Rocket | *Harvested 01 October to 31 March* | 7000 |
| | *Harvested 01 April to 30 September* | 6000 |
| Fresh spinach | | 3500 |
| Preserved or frozen spinach | | 2000 |
| Other leafy green vegetables | | n/a |

## Quality control (QC)

An in-house reference material was included with every batch of samples at a frequency of at least one in twenty. A spiked sample was also be included at the same frequency. A reagent blank was prepared with each batch of samples. A mid-range standard was included at the end of each batch to ensure any drift over the run was within acceptable limits (+/- 5%). All QC results were monitored to ensure they

conform to NRM's policy on Quality Control (i.e. precision, accuracy, 9 point bias, ascending or descending trends etc.). Results were reported to ADAS within five days of sample receipt.

**Communication of results to FSA**

Results were reported anonymously to the FSA on a monthly basis. Monthly mean values and running totals of maximum, minimum and mean nitrate levels grouped according to category were tabulated and have been included in the respective Annual Reports, along with the number of samples exceeding the maximum nitrate levels.

**Communication of results to growers and wholesalers**

A template letter was agreed with the FSA for the reporting of results to participants. ADAS reported the results directly to the grower/wholesaler and a copy of the letter was also sent to the FSA. If the nitrate level in a sample exceeded the maximum permitted limit then, following confirmation of the result by NRM, ADAS informed the responsible person at the Agency before reporting the result to the grower/wholesaler.

**Data analysis and reporting**

For each project year (01 May – 30 April) results were anonymised and summarised in Excel (v. 2013). Mean nitrate concentrations were calculated for each category of produce and long term mean data were calculated from 2002 -18. In 2012 and 2013 the programme focussed on spinach and rocket so no lettuce data were available for those years. Rocket samples were only included in the programme from 2012 onwards. Statistical summarisation and regression analyses were carried out using GenStat (18$^{th}$ edition). Annual reports were submitted to the Food Standards Agency in May of each year and data were also supplied on the EFSA template.

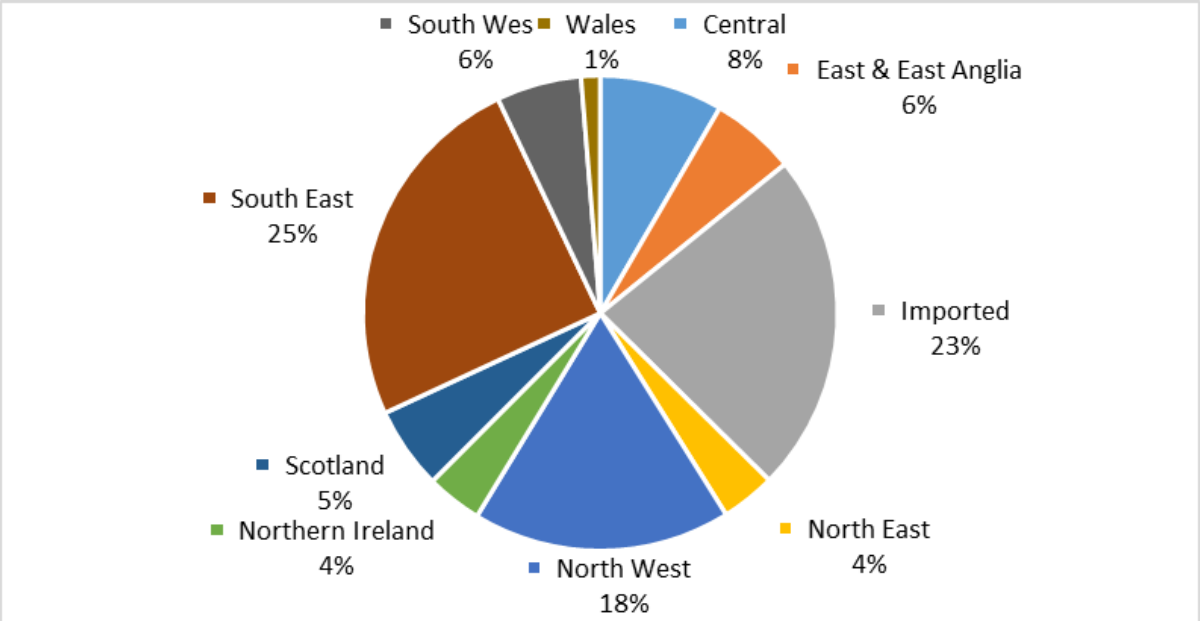
## Results

### Sample overview by region

A total of 1000 samples (768 domestic and 232 imported) were collected during May 2014 – April 2019 (Figure 1). Within the imported category the majority of samples were collected from either Spain or Italy and only a single sample came from Holland and the USA (Spain 59%, Italy, 36%, Portugal 3%, France 1%, Holland 0.5%, USA 0.5%).

The distribution of samples by region was representative of the industry. Small fluctuations between years were seen but overall the number of samples collected each year, from each region, remained relatively stable. Samples were only collected from Wales in 2017 and 2018. In October 2017 the first UK case of Fusarium lettuce wilt (*Fusarium oxysporum* f.sp*. lactucae*) was reported on protected lettuce. The pathogen was identified as Race 4 which is a particularly aggressive strain of the fungus with no known treatment or varietal resistance available. The industry responded quickly to the threat by increasing their biosecurity and previously participating growers in the north-east requested that Sample Officers did not enter their premises. Samples were therefore not collected from this region during 2018-19.

Figure 1. Pie chart showing the percentage of samples collected from each region, May 2014 – April 2019 (n = 1000).

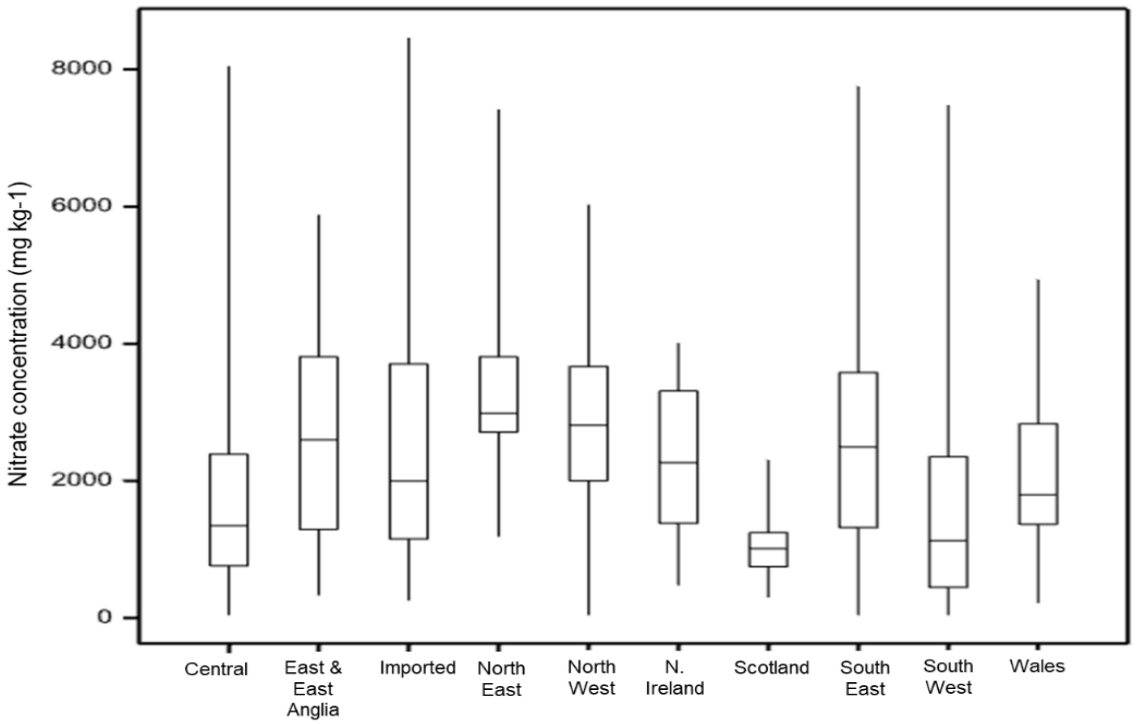


**Nitrate concentration by region**

Differences in the mean nitrate concentration were observed between the regions with the highest domestic mean concentration (3309 mg $kg^{-1}$) in the north east region and the lowest mean concentration (1048 mg $kg^{-1}$) in Scotland (Table 2). The range of nitrate concentration was greatest in imported samples (1048 mg $kg^{-1}$) and least in Scotland (2008 mg $kg^{-1}$) (Figure 2). Amongst the imported samples the range of nitrate concentration was greatest in Italian samples (Table 2). Amongst domestic samples the greatest range was found in the south east region.

Over the five year surveillance period, the mean nitrate concentration of imported samples was comparable to that of domestic samples; 2588 mg $kg^{-1}$ and 2396 mg $kg^{-1}$ respectively.

Figure 2. Chart showing the distribution of nitrate concentration within each region (n= 1000)




Twenty two domestic samples contained nitrate concentrations that exceeded the maximum permitted level. Scotland was the only region where no samples exceeded the maximum concentration and the south east had the most samples exceeding the limit. However, more samples were collected form the south east than any other region and Wales contained the highest proportion of samples exceeding the limit when considering the total samples collected from the region (Table 3). A total of 77 domestic samples had nitrate concentrations that fell within 10% of the maximum permitted level.

Table 2. Nitrate levels for domestic and imported samples, 2014 – 2018 (n = 1000)

| | | Nitrate concentration (mg kg-1) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Region** | **No. samples** | **Mean** | **Median** | **Minimum** | **Maximum** | **Range** | **Lower quartile** | **Upper quartile** |
| Central | 84 | 1790 | 1347 | 50 | 8052 | 8002 | 764 | 2390 |
| East & E. Anglia | 58 | 2620 | 2601 | 338 | 5885 | 5546 | 1292 | 3811 |
| North East | 37 | 3309 | 2988 | 1189 | 7422 | 6233 | 2711 | 3811 |
| North West | 176 | 2789 | 2811 | 50 | 6036 | 5986 | 2003 | 3669 |
| N. Ireland | 38 | 2242 | 2267 | 486 | 4015 | 3529 | 1384 | 3312 |
| Scotland | 56 | 1048 | 1014 | 306 | 2314 | 2008 | 752 | 1246 |
| South East | 248 | 2633 | 2493 | 50 | 7761 | 7711 | 1321 | 3582 |
| South West | 58 | 1718 | 1130 | 50 | 7484 | 7434 | 449 | 2352 |
| Wales | 13 | 2134 | 1797 | 221 | 4944 | 4724 | 1369 | 2832 |
| Imported: | 232 | 2588 | 2001 | 262 | 8465 | 8203 | 1155 | 3706 |
| (France) | (2) | (1481) | (1481) | (904) | (2058) | (1154) | (904) | (2058) |
| (Holland) | (1) | (3100) | (3100) | (3100) | (3100) | (0) | (3100) | (3100) |
| (Italy) | (84) | (3712) | (3596) | (346) | (8465) | (8119) | (1863) | (5705) |
| (Portugal) | (7) | (3008) | (3207) | (816) | (4437) | (3621) | (1654) | (4336) |
| (Spain) | (137) | (1893) | (1526) | (262) | (6305) | (6044) | (1036) | (2370) |
| (USA) | (1) | (2036) | (2036) | (2036) | (2036) | (0) | (2036) | (2036) |

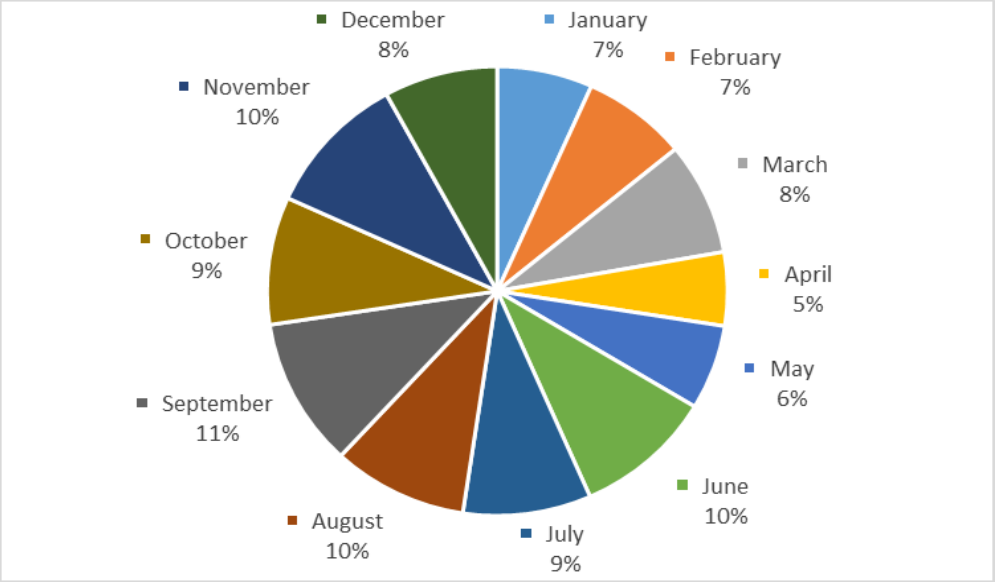
Table 3. Samples exceeding the regulatory limit shown by region, 2014 – 2018 (n = 768)

| Region | No. samples | No. samples within 10% of limit (inc. those exceeding limit) | No. samples exceeding limit following retest | Percentage within 10% of limit (inc. those exceeding limit) | Percentage of samples exceeding limit following retest |
|---|---|---|---|---|---|
| Central | 84 | 6 | 1 | 7.14 | 1.19 |
| East & East Anglia | 58 | 9 | 3 | 15.52 | 5.17 |
| North East | 37 | 7 | 2 | 18.92 | 5.41 |
| North West | 176 | 16 | 3 | 9.09 | 1.70 |
| N. Ireland | 38 | 8 | 1 | 21.05 | 2.63 |
| Scotland | 56 | 0 | 0 | 0.00 | 0.00 |
| South East | 248 | 27 | 8 | 10.89 | 3.23 |
| South West | 58 | 2 | 2 | 3.45 | 3.45 |
| Wales | 13 | 2 | 2 | 15.38 | 15.38 |

**Sample overview by month**

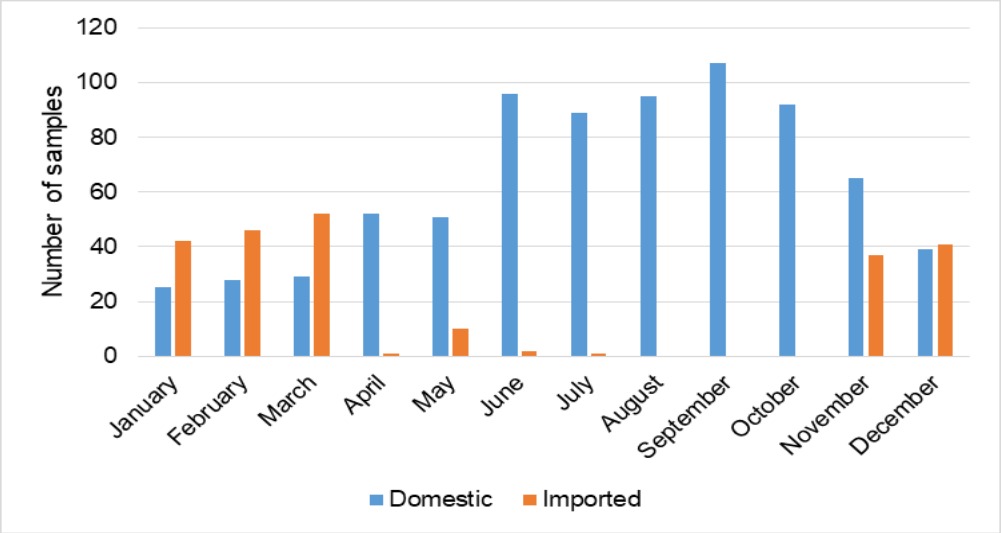
Samples were collected in each calendar month throughout the year (Figure 3). The number of samples was slightly lower in the winter months than in the summer months, in keeping with trends in consumer buying habits.

Figure 3. Pie chart showing the percentage of samples collected in each month, May 2014 – April 2019. Samples include both domestic and imported produce (n = 1000).




Although the overall number of samples collected each month remained relatively stable throughout year the availability of domestic leafy green vegetable crops during winter was approximately half when compared with availability during the summer months (Figure 4). The majority of imported produce was collected during November-March and made up over half of the winter samples.

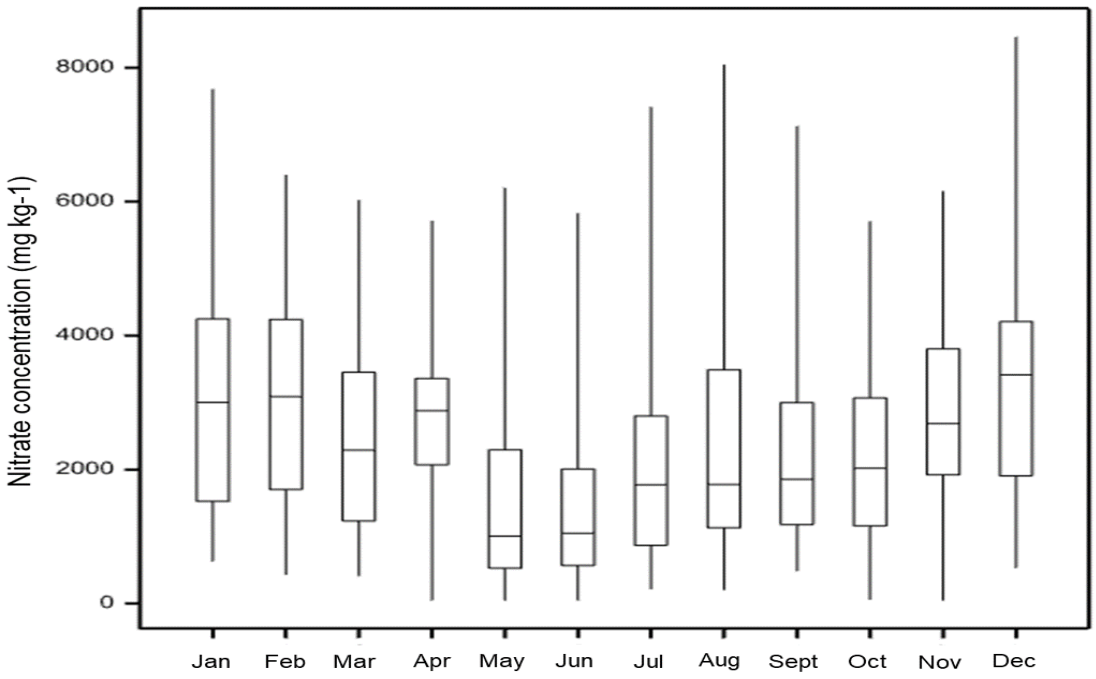
Figure 4. Chart showing the number of domestic and imported samples collected in each month, May 2014 – April 2019 (n = 1000).



**Nitrate concentration by month**

When considering both domestic and imported samples, differences in the mean nitrate concentration were observed between months with the highest mean concentration (3283 mg $kg^{-1}$) in December and the lowest mean concentration (1454 mg $kg^{-1}$) in June (Table 4). The range of nitrate concentration was relatively consistent through the year and was greatest in December (7928 mg $kg^{-1}$) and lowest in March (5613 mg $kg^{-1}$) (Figure 5).

Figure 5. Chart showing the monthly distribution of nitrate concentration across all samples, May 2014 – April 2019 (n = 1000).




The mean nitrate levels in imported samples collected during summer and winter months were comparable (2542 mg $kg^{-1}$ summer and 2591 mg $kg^{-1}$ winter). When only the domestic samples were considered there was a greater separation in mean nitrate concentration between months (Figure 6). A clear seasonal effect was seen whereby the highest mean nitrate levels were observed during the winter months and the lowest mean levels were seen in summer. The range of nitrate concentration was also influenced by month and samples were most variable and had the widest range in summer (Jun – Oct) (Figure 7).

Table 4. Nitrate levels for monthly samples, 2014 – 2018 (n = 1000)

| | | Nitrate concentration (mg kg$^{-1}$) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Month** | **No. samples** | **Mean** | **Median** | **Minimum** | **Maximum** | **Range** | **Lower quartile** | **Upper quartile** |
| January | 67 | 3032 | 3003 | 634 | 7686 | 7052 | 1527 | 4250 |
| February | 74 | 3063 | 3090 | 432 | 6406 | 5974 | 1703 | 4240 |
| March | 81 | 2510 | 2289 | 415 | 6028 | 5613 | 1235 | 3453 |
| April | 53 | 2675 | 2877 | 50 | 5720 | 5670 | 2072 | 3360 |
| May | 61 | 1540 | 1006 | 50 | 6215 | 6165 | 527 | 2296 |
| June | 98 | 1454 | 1050 | 50 | 5831 | 5781 | 566 | 2008 |
| July | 90 | 2124 | 1775 | 221 | 7422 | 7201 | 870 | 2798 |
| August | 95 | 2521 | 1778 | 206 | 8052 | 7845 | 1131 | 3491 |
| September | 107 | 2310 | 1856 | 486 | 7131 | 6645 | 1177 | 3000 |
| October | 92 | 2187 | 2021 | 60 | 5713 | 5653 | 1160 | 3071 |
| November | 102 | 2815 | 2686 | 50 | 6164 | 6114 | 1921 | 3801 |
| December | 80 | 3282 | 3416 | 536 | 8465 | 7928 | 1909 | 4208 |

Figure 6. Chart showing the monthly distribution of nitrate concentration in domestic samples, May 2014 – April 2019 (n = 768).

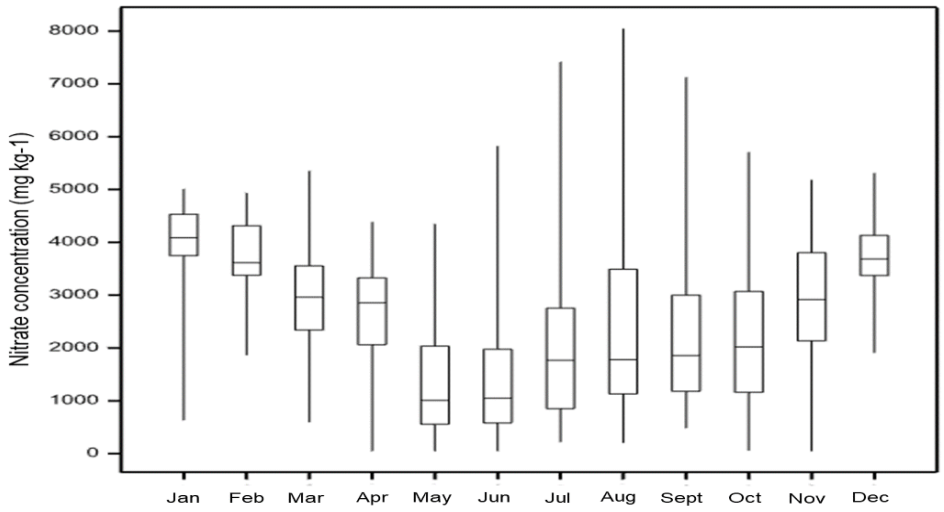
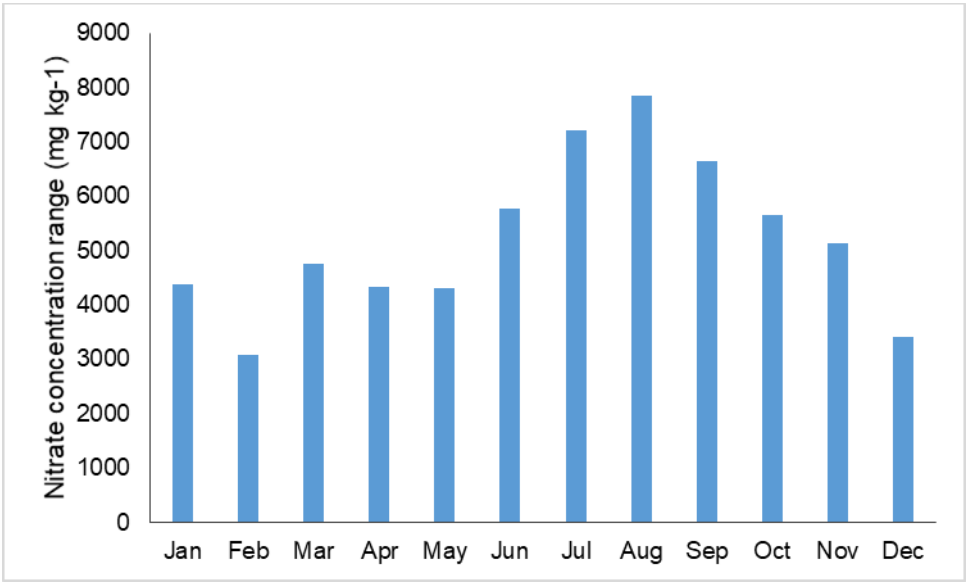



Figure 7. Chart showing the seasonal influence on the range of nitrate concentration in domestic samples, May 2014 – April 2019 (n = 768).




Twenty two domestic samples contained nitrate concentrations which exceeded the maximum permitted level. March, May, November and December were the only months when no samples exceeded the maximum concentration (Table 5). September was the month when the highest proportion of samples exceeded the limit (8.41%) but the highest proportion of samples falling with 10% of the limit was observed in January (28%).

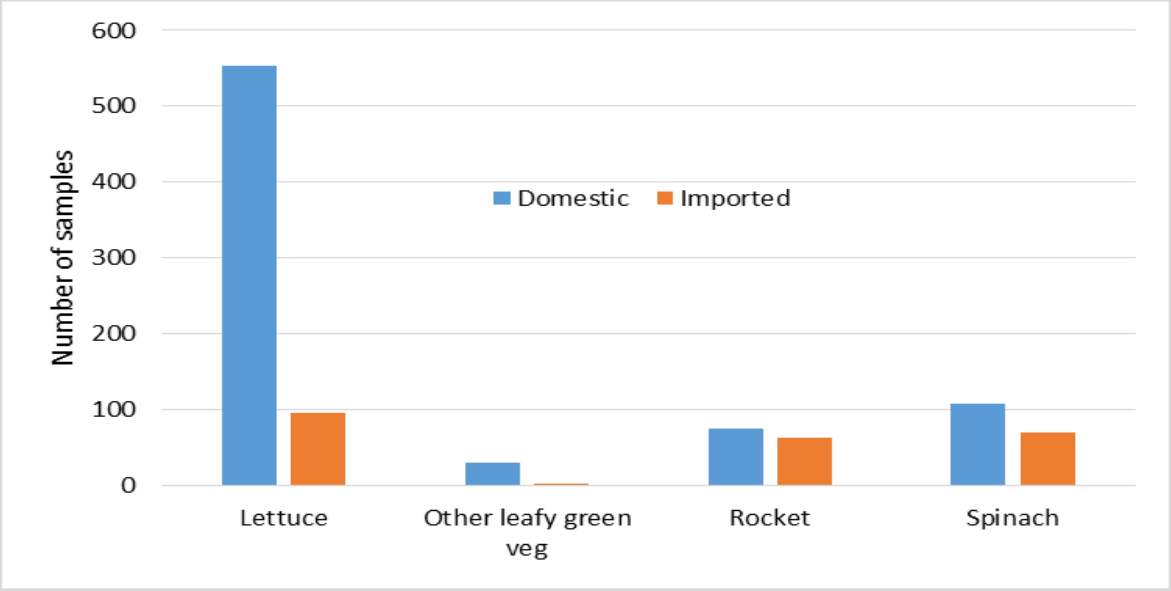
Table 5. Domestic samples exceeding the regulatory limit, shown by month, 2014 – 2018 (n = 768)

| Month | No. samples | No. samples within 10% of limit (inc. those exceeding limit) | No. samples exceeding limit following retest | Percentage within 10% of limit (inc. those exceeding limit) | Percentage of samples exceeding limit following retest |
|---|---|---|---|---|---|
| January | 25 | 7 | 2 | 28.00 | 8.00 |
| February | 28 | 3 | 1 | 10.71 | 3.57 |
| March | 29 | 2 | 0 | 6.90 | 0.00 |
| April | 52 | 4 | 1 | 7.69 | 1.92 |
| May | 51 | 0 | 0 | 0.00 | 0.00 |
| June | 96 | 6 | 1 | 6.25 | 1.04 |
| July | 89 | 7 | 2 | 7.87 | 2.25 |
| August | 95 | 13 | 3 | 13.68 | 3.16 |
| September | 107 | 17 | 9 | 15.89 | 8.41 |
| October | 92 | 7 | 3 | 7.61 | 3.26 |
| November | 65 | 5 | 0 | 7.69 | 0.00 |
| December | 39 | 6 | 0 | 15.38 | 0.00 |
| *Total* | *768* | *77* | *22* | *10.03* | *2.86* |

**Sample overview by crop and category**

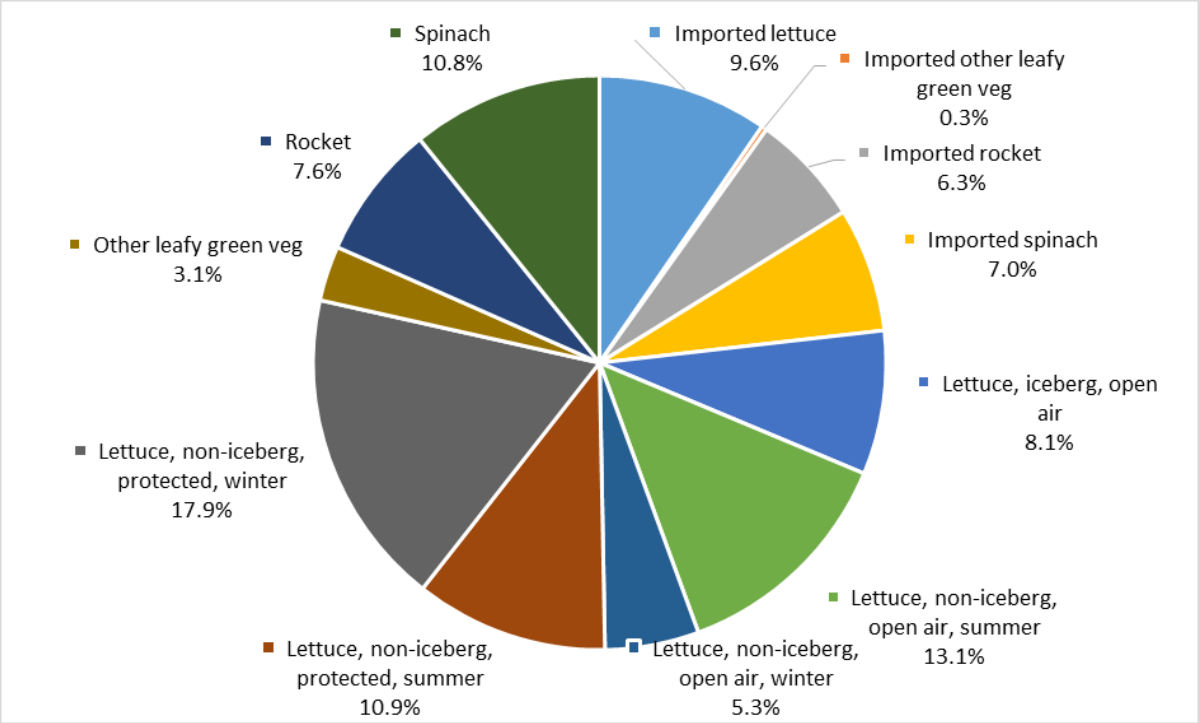
A total of 1000 samples were collected from May 2014 - April 2019; 649 lettuce, 139 rocket, 179 spinach, 33 other leafy green vegetables. The number of domestic and imported samples were comparable for spinach, rocket and other leafy green veg but many more domestic lettuce samples were collected than imported (Figure 8).

Figure 8. Chart showing the number of domestic and imported samples collected for each crop type, May 2014 – April 2019 (n = 1000).




Domestic lettuce samples were sub-divided into iceberg (81 samples) and non-iceberg categories (472 samples). All iceberg lettuce were collected from the field and none were grown in a protected environment. Non-iceberg samples were further divided into open air summer (01 April – 30 September, 131 samples), open air winter (01 October – 31 March, 53 samples), protected summer (109 samples) and protected winter (179 samples). There were also 108 fresh spinach, 76 rocket and 31 other leafy green vegetable samples which comprised chard, bulls-blood, baby leaf, land cress and kale. Only one rocket sample was collected during the winter months (late march) and it fell within the permitted nitrate concentration so for the sake of this report it has been added to the summer sample category. A total of 232 imported samples were tested, 96 of which were lettuce, 70 spinach, 63 rocket and 3 other leafy green veg. The category of lettuce was not determined for imported samples (Figure 9).

Figure 9. Pie chart showing the percentage of samples collected for each category, May 2014 – April 2019 (n = 1000).




**Nitrate concentration by category**

Imported samples had the greatest range in nitrate concentration (8203 mg $kg^{-1}$) (Table 6) and upon closer examination it was seen that the range was influenced strongly by the rocket samples (Figure 10). Other types of imported crop had lower mean nitrate concentrations and a smaller range of values across the year. For imported rocket samples 4.76% (3 out of 63 samples) would have exceeded the permitted limit compared with 9.21% (7 out of 76 samples) of domestic rocket. 12.70% of imported samples (8 out of 63) fell within 10% of the regulation limit compared with 22.37% of domestic samples (17 out of 76). 11.43% of imported spinach (8 out of 70 samples) would have exceeded the limit compared with 3.70% (4 out of 108 samples) of domestic spinach. 15.71% of imported samples (11 out of 70) fell within 10% of the regulation limit compared with 7.41% of domestic samples (8 out of 108). Imported rocket and spinach samples had a slightly higher nitrate concentration compared with domestic rocket and spinach samples. Imported lettuce was lower in nitrate concentration (1387 mg $kg^{-1}$) compared with domestic lettuce samples (2286 mg $kg^{-1}$) but information about the type of lettuce was not collected so it is not possible to comment on the number that would have exceeded the limit if the regulation was applied to imported lettuce.

Table 6. Nitrate levels for each sample category, 2014 – 2018 (n = 1000)

| Category | No. samples | Nitrate concentration (mg kg$^{-1}$) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Mean | Median | Minimum | Maximum | Range | Lower quartile | Upper quartile |
| Iceberg, open air | 81 | 967 | 930 | 104 | 2943 | 2839 | 733 | 1170 |
| Iceberg, protected | 0 | - | - | - | - | - | - | - |
| Non-iceberg, open air, summer | 131 | 1218 | 1136 | 50 | 3830 | 3780 | 705 | 1553 |
| Non-iceberg, open air, winter | 53 | 1668 | 1455 | 50 | 3397 | 3347 | 1149 | 2314 |
| Non-iceberg, protected, summer | 109 | 2830 | 2877 | 229 | 7422 | 7193 | 2298 | 3363 |
| Non-iceberg, protected, winter | 179 | 3519 | 3572 | 60 | 5713 | 5653 | 2992 | 4222 |
| Spinach | 108 | 1766 | 1736 | 50 | 4944 | 4894 | 1003 | 2382 |
| Rocket | 76 | 4131 | 4276 | 62 | 8052 | 7990 | 2842 | 5199 |
| Other leafy green veg | 31 | 2275 | 1776 | 50 | 7001 | 6951 | 1022 | 3229 |
| Imported (all) | 232 | 2588 | 2001 | 262 | 8465 | 8203 | 1155 | 3706 |
| *Imported lettuce* | *96* | *1387* | *1181* | *262* | *4740* | *4478* | *851* | *1798* |
| *Imported spinach* | *70* | *2188* | *2067* | *432* | *4780* | *4348* | *1597* | *2680* |
| *Imported rocket* | *63* | *4906* | *5289* | *346* | *8465* | *8119* | *3877* | *6027* |
| *Imported other leafy green veg* | *3* | *1662* | *2058* | *530* | *2396* | *1867* | *912* | *2312* |

Within the domestic sample categories rocket had the highest mean nitrate concentration (4131 mg $kg^{-1}$), the highest maximum nitrate concentration (8052 mg $kg^{-1}$) and the greatest range of values (7990 mg $kg^{-1}$) (Table 6 and Figure 11). Rocket also exceeded the maximum nitrate concentration the most with 9.21% (7 out of 76 samples) failing and 22.37% of samples falling within 10% of the maximum (Table 7).

Non-iceberg type lettuce grown in a protective environment was the category with the next highest mean nitrate level, range and number of samples exceeding the maximum limit. Winter samples had a higher mean concentration than summer samples (3519 mg $kg^{-1}$and 2830 mg $kg^{-1}$). However, the range was higher for summer samples and the proportion of samples exceeding the limit was higher during the summer months (5.50% summer, 1.12% winter). The number of samples falling within 10% of the permitted limit was comparable between categories (16.51% summer, 13.97% winter).

Iceberg lettuce grown in the field had the lowest mean nitrate concentration of all the categories (967 mg $kg^{-1}$) and the smallest range. Only one sample (1.23%) exceeded the maximum permitted limit. The only category where no samples exceeded the permitted limit was non-iceberg lettuce grown in the field, in winter.

Figure 10. Chart showing the distribution of nitrate concentration for different sample categories, May 2014 – April 2019 (n = 1000).

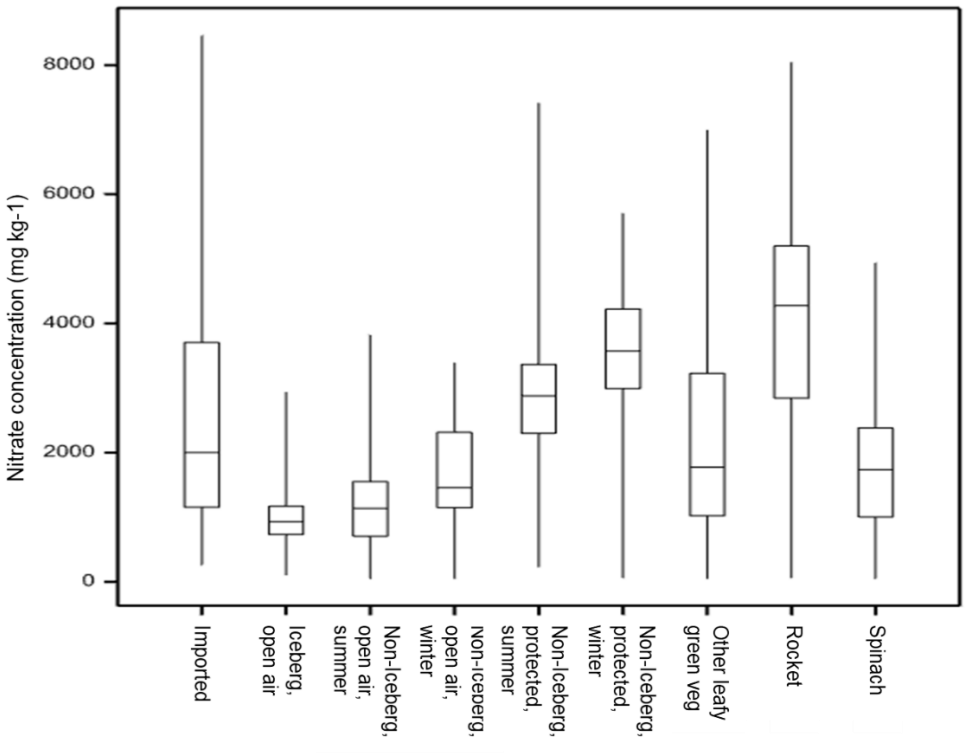


Figure 11. Chart showing the range of nitrate concentration for each sample category, May 2014 – April 2019 (n = 1000).

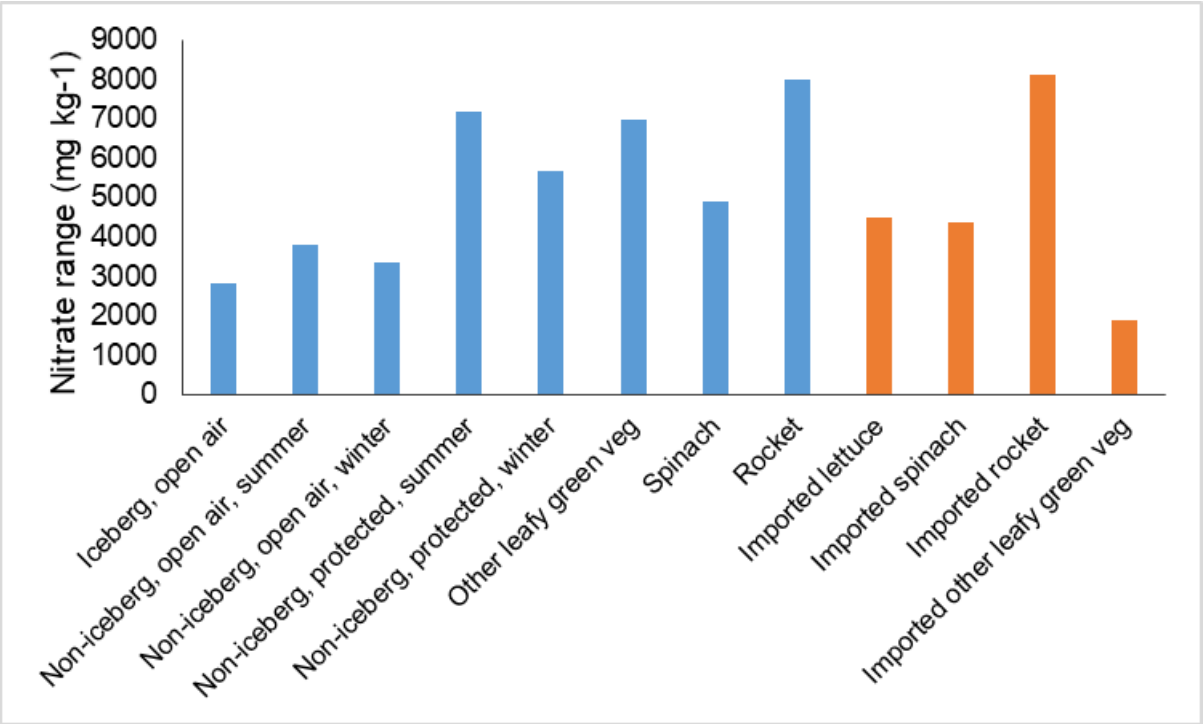


Table 7. Domestic samples exceeding the regulatory limit shown by category, 2014 – 2018 (n = 768)

| Category | No. samples | No. samples within 10% of limit (inc. those exceeding limit) | No. samples exceeding limit following retest | Percentage within 10% of limit (inc. those exceeding limit) | Percentage of samples exceeding limit following retest |
|---|---|---|---|---|---|
| Iceberg, open air | 81 | 3 | 1 | 3.70 | 1.23 |
| Iceberg, protected | 0 | 0 | 0 | 0 | 0 |
| Non-iceberg, open air, summer | 131 | 6 | 2 | 4.58 | 1.53 |
| Non-iceberg, open air, winter | 53 | 0 | 0 | 0.00 | 0.00 |
| Non-iceberg, protected, summer | 109 | 18 | 6 | 16.51 | 5.50 |
| Non-iceberg, protected, winter | 179 | 25 | 2 | 13.97 | 1.12 |
| Spinach | 108 | 8 | 4 | 7.41 | 3.70 |
| Rocket | 76 | 17 | 7 | 22.37 | 9.21 |
| * Other leafy green vegetables | 31 (n/a) | n/a | n/a | n/a | n/a |
| *Total* | *737* | *77* | *22* | *10.45* | *2.99* |

* Other leafy green vegetables not subject to regulation limits for maximum nitrate concentration

When all domestic samples except for the 'other leafy green veg' category were considered (n= 737), there was no significant relationship between the number of samples collected within a category and the number of samples which exceeded the regulatory limits (P= 0.48, data not shown). Likewise, the number of samples collected did not significantly influence the range of nitrate concentration (P= 0.14, data not shown). However, the number of samples that exceeded the maximum nitrate limit within each category showed a significant and positive correlation with both the range of nitrate concentration (P= 0.003, variance accounted for 75.1%) (Figure 12) and the mean nitrate concentration (P= 0.035, variance accounted for 47.8%) (Figure 13).

Figure 12. Graph showing that more samples exceeded the maximum permitted nitrate limit when categories of produce had a greater range of nitrate concentration (P= 0.003).

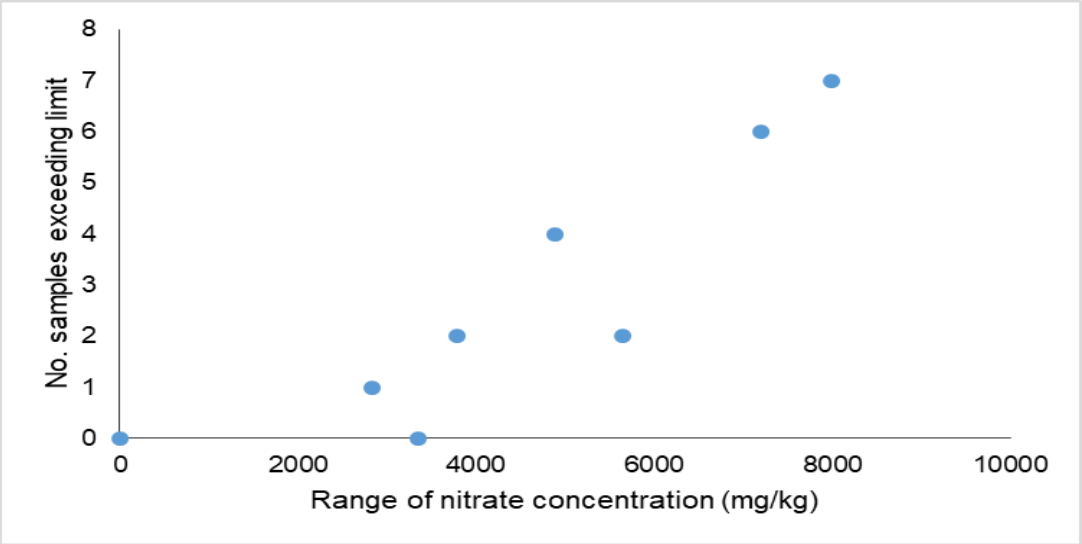
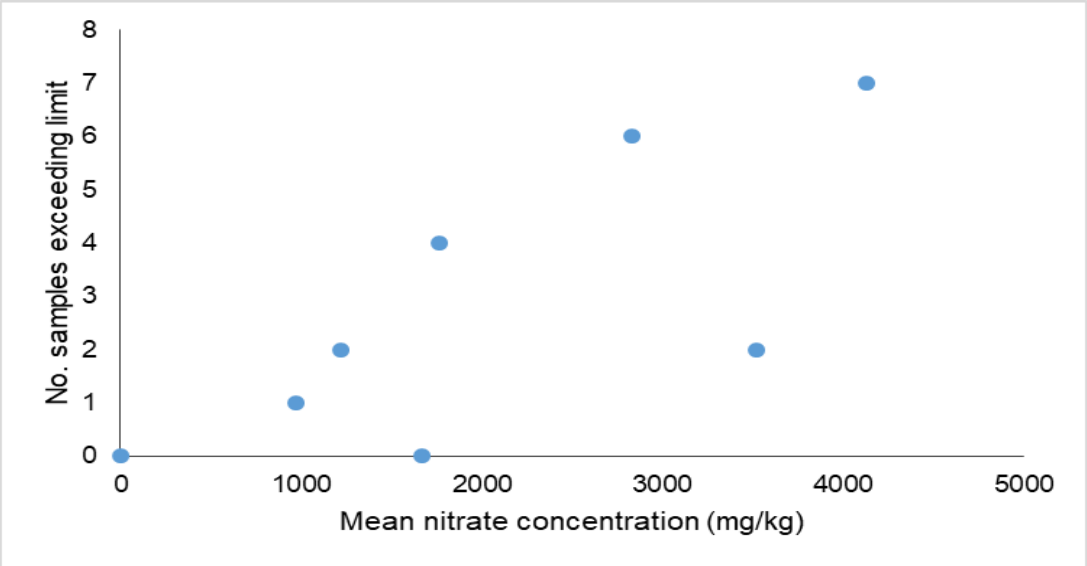



Figure 13. Graph showing that more samples exceeded the maximum permitted nitrate limit when categories of produce had a higher mean nitrate concentration (P= 0.035).



**Long term trends in nitrate concentration**

The 2018 mean annual nitrate concentration in non-iceberg protected winter samples (2727 mg $kg^{-1}$) was lower than the long term average (LTA) (3492 mg $kg^{-1}$) and is the second consecutive year that the mean annual concentration decreased. Mean annual nitrate concentration for non-iceberg protected summer samples (2496 mg $kg^{-1}$) was also below the LTA for a second year. In contrast to trends from 2002- 2016, where fluctuations in nitrate concentration, between years, for non-iceberg protected summer samples are usually greater than in winter samples (Figure 14a & 14b).

Mean annual nitrate concentrations in 2018 rose above their respective LTAs for both summer and winter samples of non-iceberg open air lettuces. Non-iceberg open air winter samples had a 2018 mean annual concentration of 1983 mg $kg^{-1}$ compared with a LTA of 1853 mg $kg^{-1}$. Summer samples had a lower LTA of 1285 mg $kg^{-1}$ and a mean annual nitrate concentration of 1520 mg $kg^{-1}$. Mean annual nitrate concentration in iceberg type lettuce was higher in 2018 than any previous year 2002 – 2017 although this category of sample has remained the most consistent and deviated little from the LTA when considering the wider data set (Figure 14c, 14d & 14e).

After the 2017 mean annual concentration for spinach samples was below the LTA, in 2018 the mean annual concentration rose to 1814 mg $kg^{-1}$, above the LTA (1739 mg $kg^{-1}$). This value was closer to the values recorded for 2013 – 2016 than the 2017 data. The mean nitrate concentration for rocket in 2018 was 3375 mg $kg^{-1}$, a decrease on the previous year and below the long term average (3989 mg $kg^{-1}$) (Figure 14f & 14g).

Figure 14 a. Non-iceberg, protected, winter (2002 - 2018)

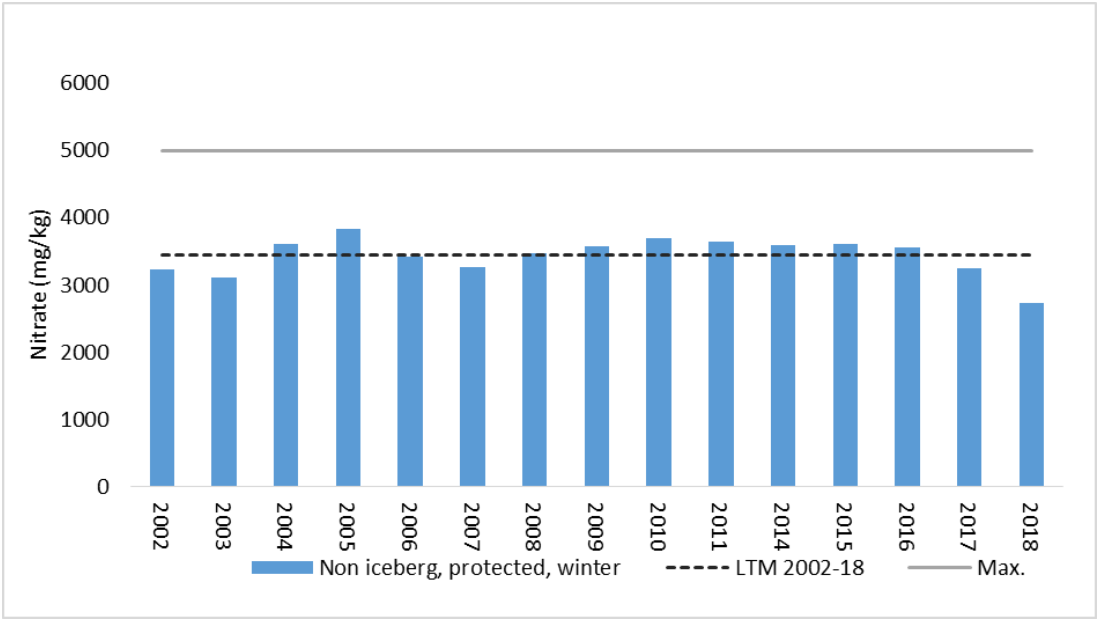


Figure 14 b. Non-iceberg, protected, summer (2002 - 2018)

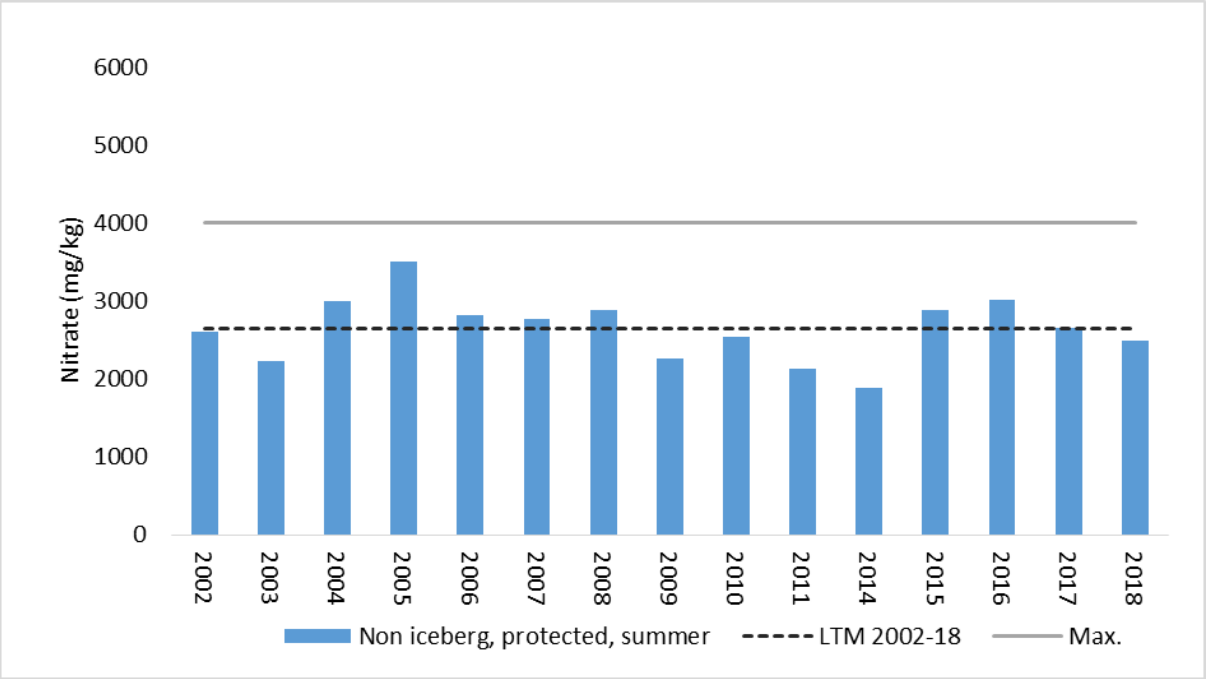



Figure 14 c. Non-iceberg, open air, winter (2002 - 2018)

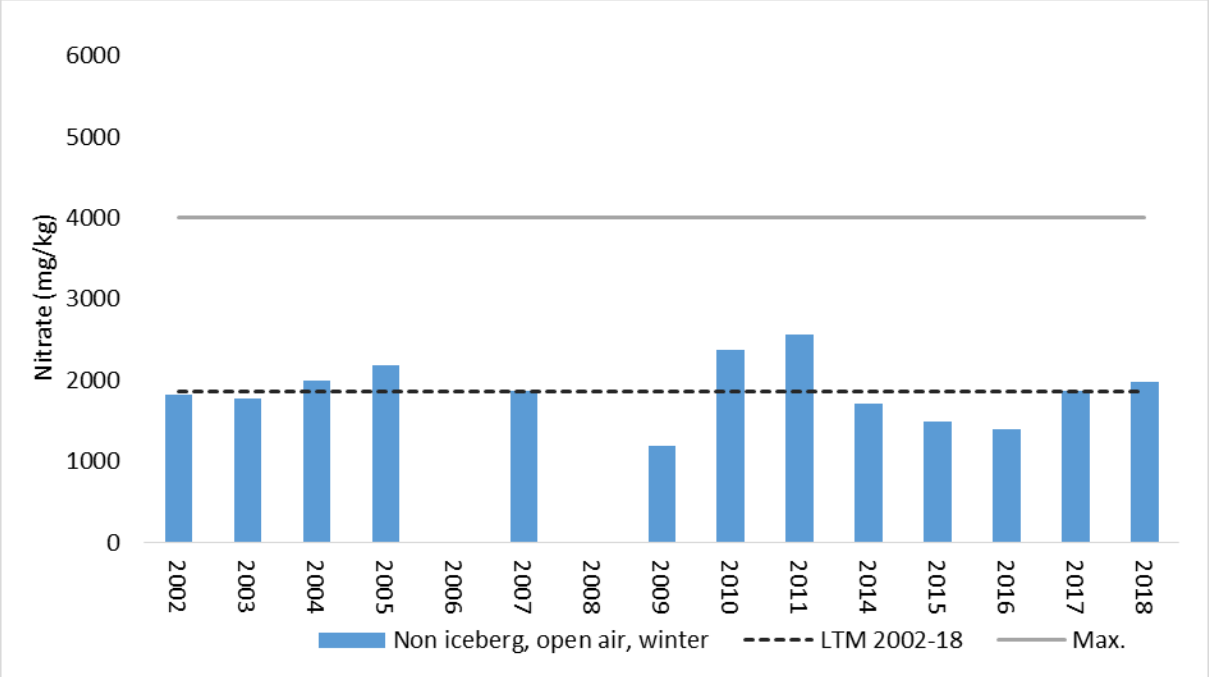


Figure 14 d. Non-iceberg, open air, summer (2002 - 2018)

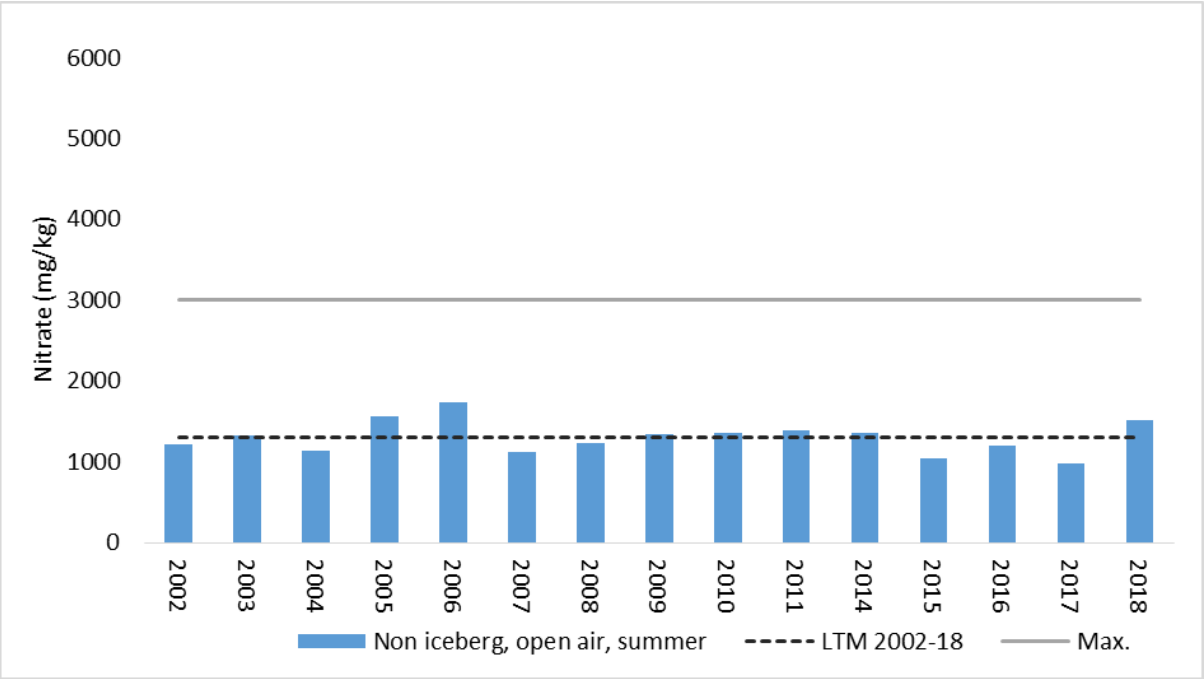



Figure 14 e. Iceberg, open air (2002 - 2018)

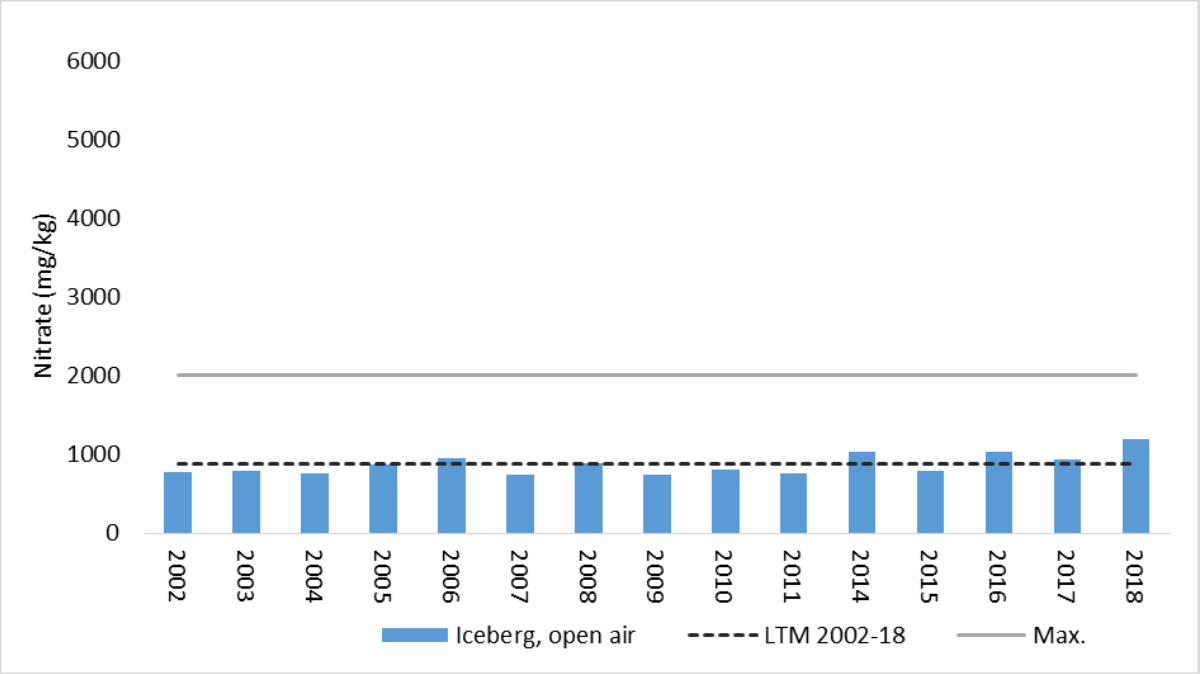


Figure 14 f. Fresh spinach (2002 - 2018)

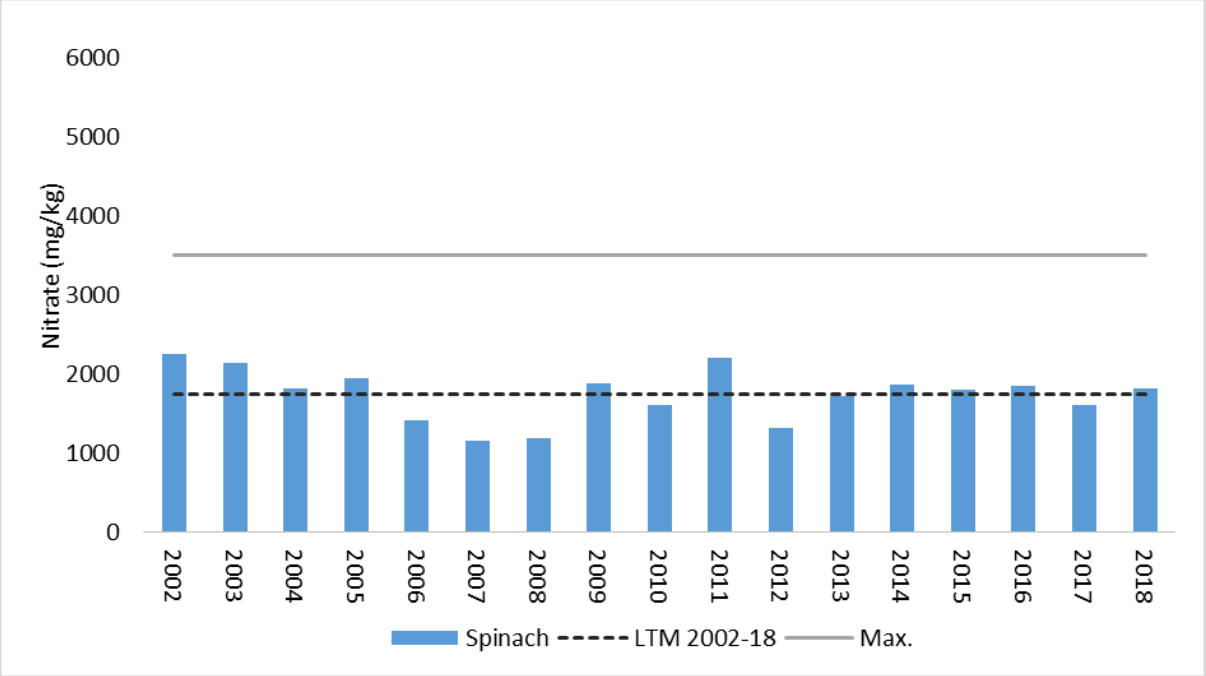



Figure 14 g. Rocket (2012 - 2018). Data not available prior to 2012

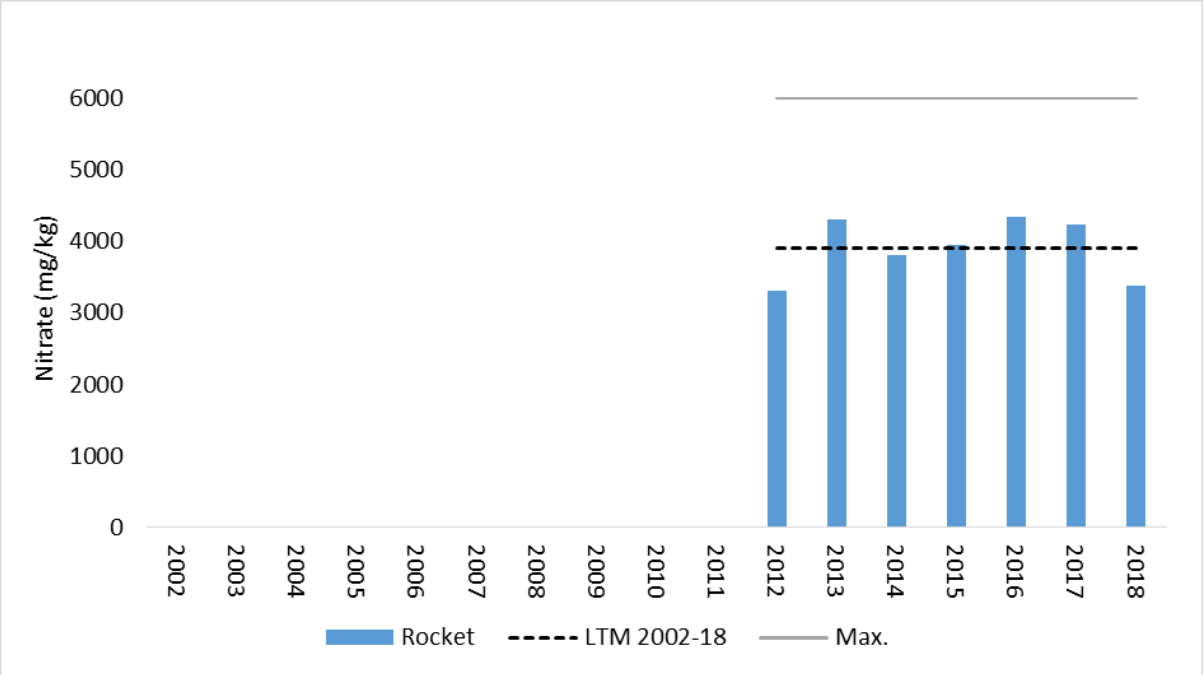
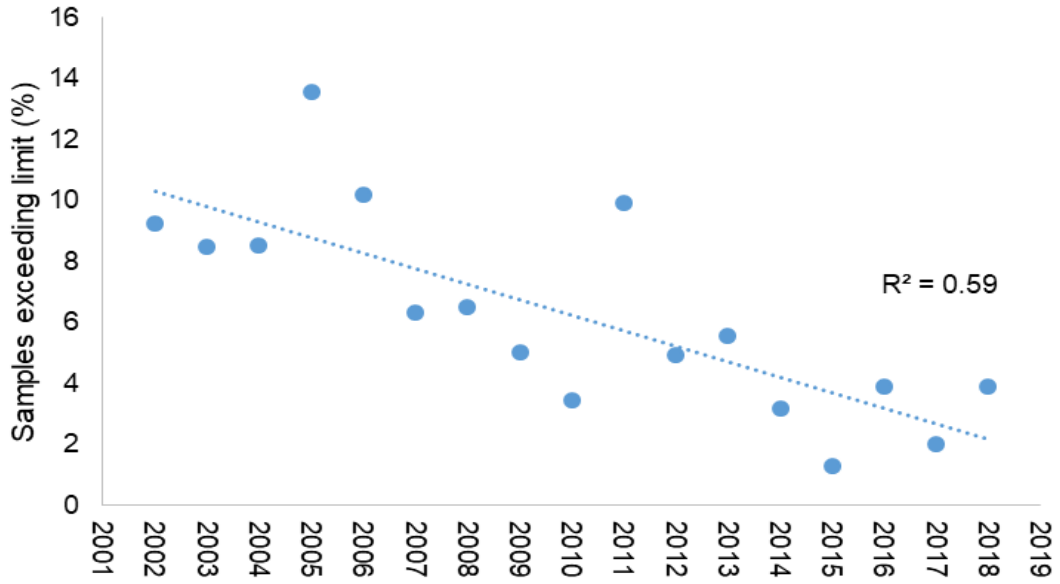



Figure 14 a-g. Long term trends in mean nitrate concentration for each category of domestic produce. Blue bars represent mean nitrate concentration for each year, solid grey line represents the maximum permitted nitrate concentration and the black dotted line represents the long term average nitrate value (calculated from 2002-2018). Axes have been standardised to a nitrate concentration value of 6000 mg/kg.

**Long term trends in samples exceeding the maximum permitted limit**

The percentage of domestic samples exceeding the regulation limit has shown a decreasing trend over the last decade (*P* = <0.001, se = 2.20) (Figure 15). The available data show that the percentage of samples exceeding the permitted nitrate concentration has fallen by approximately 3% every 5 years (2004-08 mean 9.03%, 2009-13 mean 5.78%, 2014 -18 mean 2.86%). However, a significant positive relationship was found between the total number of samples collected each year and the number of samples exceeding the regulation limit (P= 0.008, se= 5.79, variance accounted for 34.2%) (data not shown).

Figure 15. Graph showing the percentage of UK grown samples collected each year from 2002 – 2018 which exceed the regulation limit (P = <0.001, se = 2.20).




Only five iceberg samples out of the 429 collected since 2002 have exceeded the limit (Figure 16). Even fewer non-iceberg lettuces grown in open air in winter have exceeded the maximum nitrate concentration; the only sample exceeding the limit was recorded in 2007. Open air summer crops have largely remained below 10% with the exception of the 2006 season. The percentage of samples each year that exceed the limit within the non-iceberg protected crops has remained below 10% for the last seven years for both the summer and winter categories.

Spinach samples exceed the maximum permitted nitrate concentration set for the UK more frequently than other categories over the 2002 – 2018 period and the number of samples exceeding the limit is, on the whole, more variable than for lettuce crops. Rocket has only been included in the programme from 2012 onwards but the 7-year

trend suggests that the percentage of samples which exceed the maximum permitted nitrate concentration is increasing.

Figure 16 a. Non-iceberg, protected, winter (2002 - 2018)

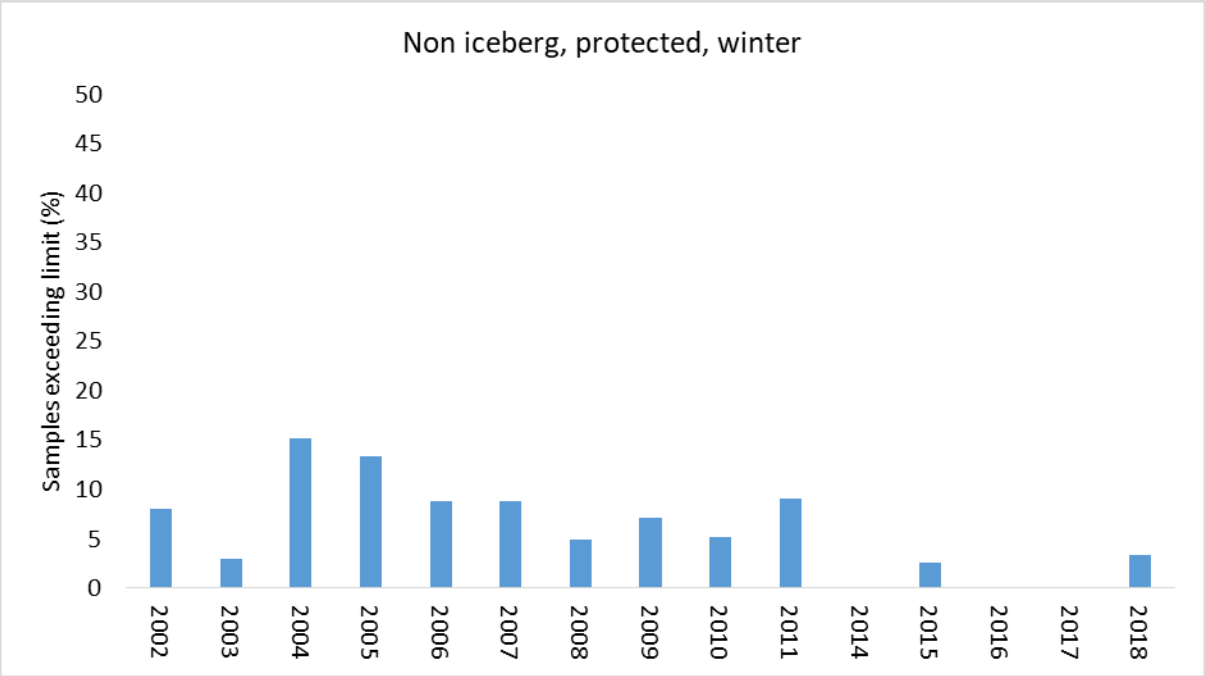



Figure 16 b. Non-iceberg, protected, summer (2002 - 2018)

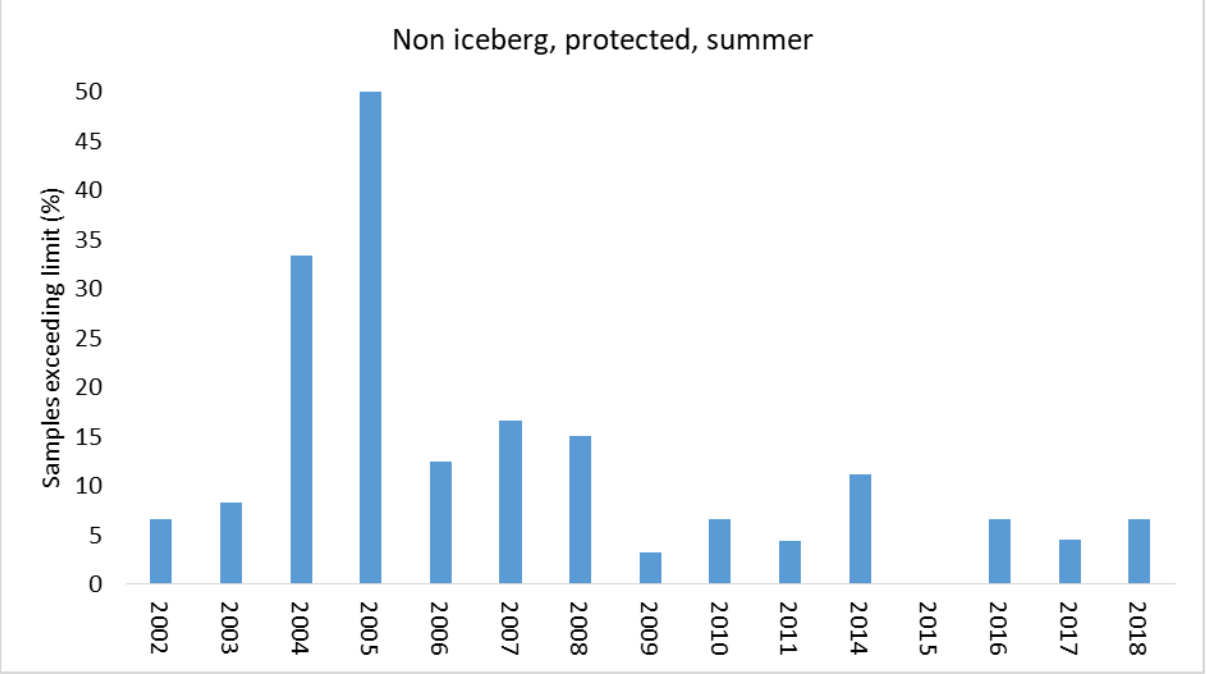


Figure 16 c. Non-iceberg, open air, winter (2002 - 2018)

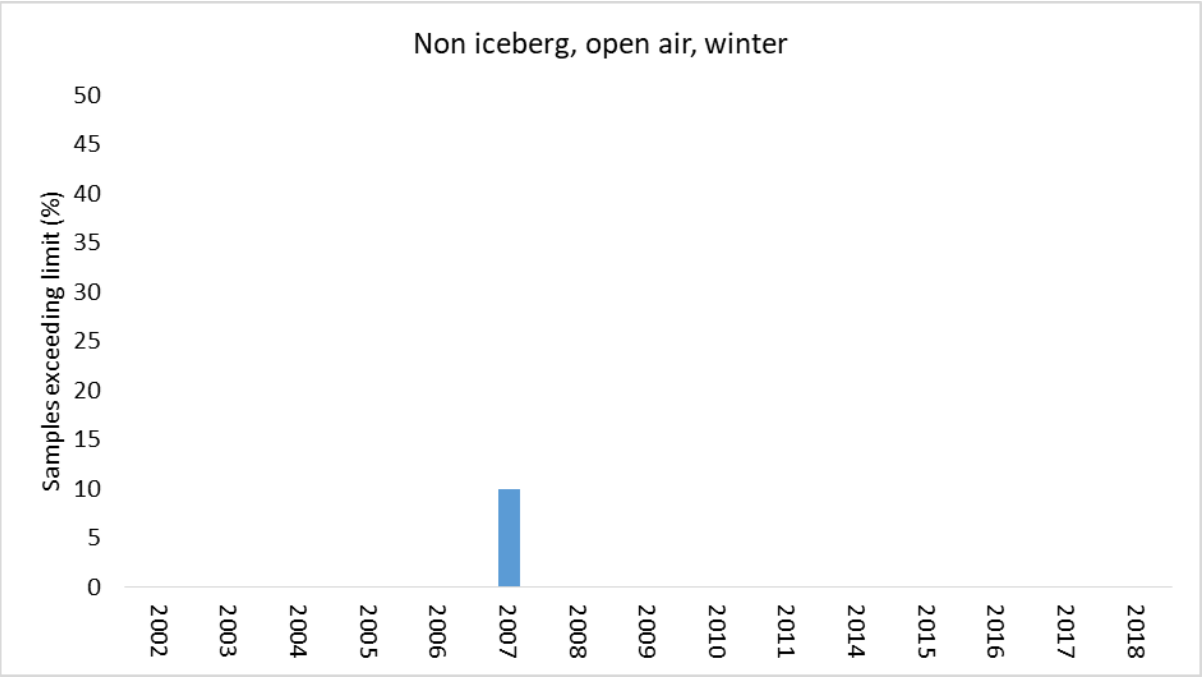



Figure 16 d. Non-iceberg, open air, summer (2002 - 2018)

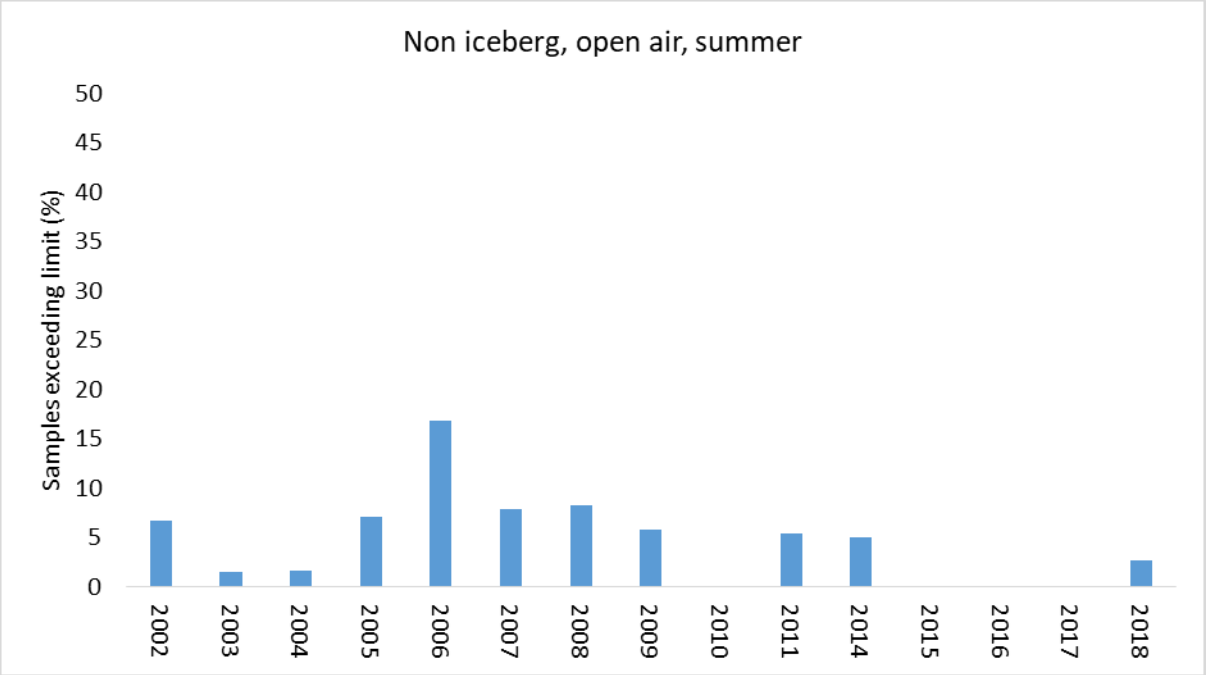


Figure 16 e. Iceberg, open air (2002 - 2018)

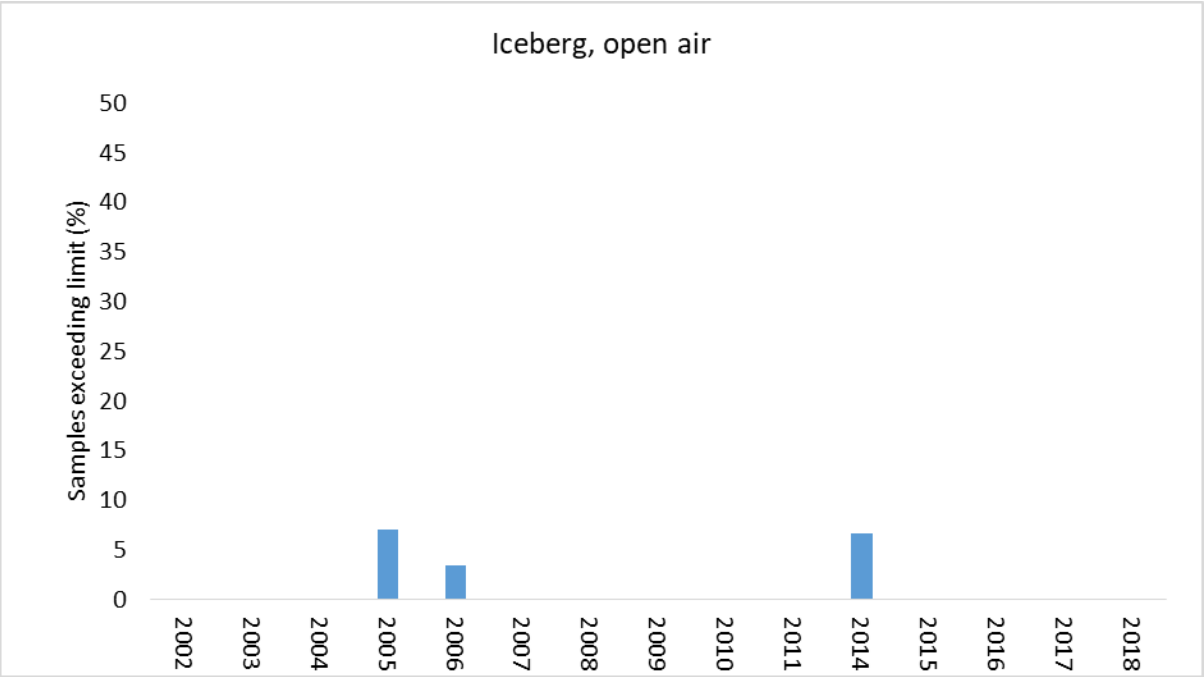



Figure 16 f. Fresh spinach (2002 - 2018)

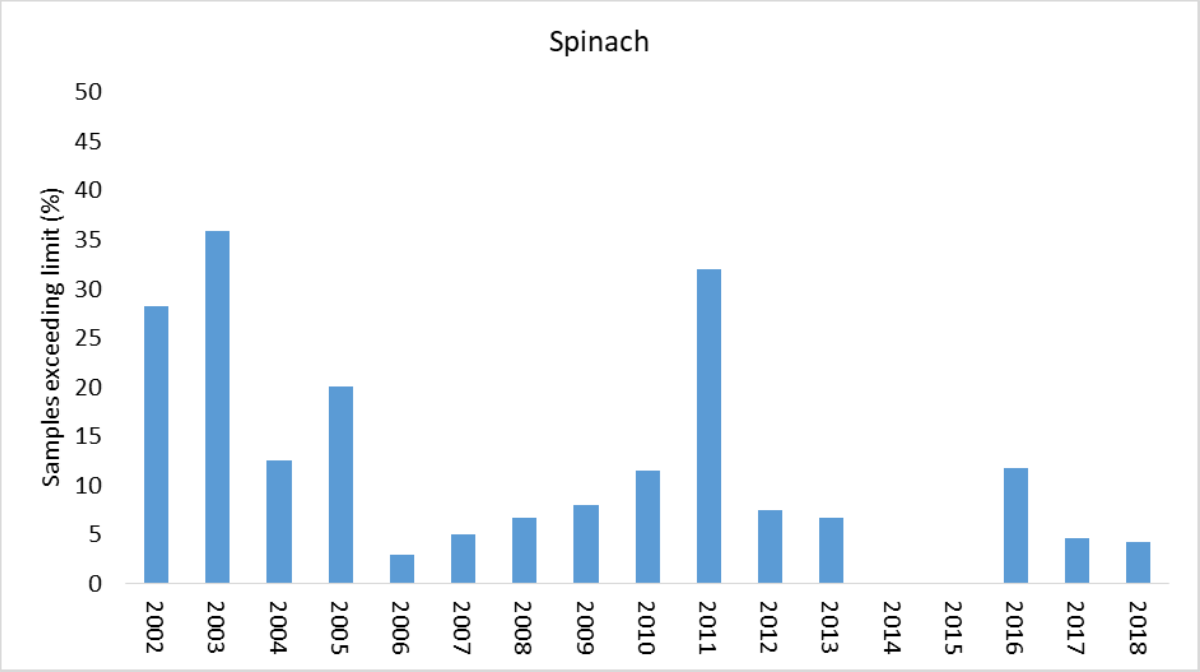


Figure 16 g. Rocket (2012 - 2018). Data not available prior to 2012

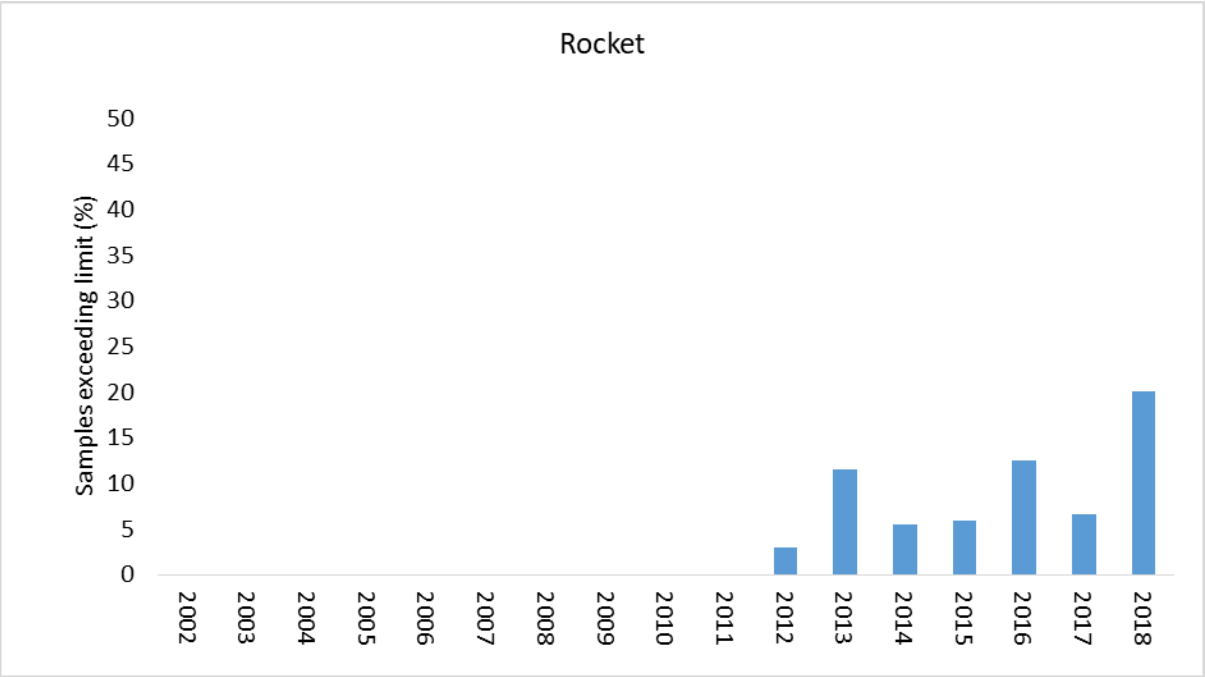



Figure 16. Long term trends in the percentage of samples that exceed the maximum permitted nitrate concentration (expressed as a percentage of the total number of samples collected for each category). Axes have been standardised to 50% and data reported from 2002 – 2018 with the exception of rocket, where data are not available prior to 2012.

During the most recent surveillance period (2014 – 2018) the percentage of samples within each category that exceed the regulation limit were loosely grouped into four sections; 0%, 0.1 - 3%, 3.1 – 7%, 7.1 – 10% (Table 8).

Table 8. The percentage of domestic samples exceeding the regulation limit during 2014 - 2018. Categories ranked from low to high.

| **Category** | **Percentage of samples exceeding regulation limit (2014 – 2018)** |
|---|---|
| Non iceberg, open air, winter | 0.0 |
| Non iceberg, protected, winter | 1.2 |
| Iceberg, open air | 1.3 |
| Non iceberg, open air, summer | 1.5 |
| Spinach | 4.1 |
| Non iceberg, protected, summer | 5.8 |
| Rocket | 10.1 |

## Conclusions

• The surveillance programme collected samples of leafy green vegetables from across months, regions and categories so the data are considered representative of the industry.

• The majority of samples collected were lettuce. Comparable numbers of spinach and rocket were collected and a small proportion of the samples were other leafy green vegetables such as chard and mixed baby leaf.

• There was a seasonal effect on nitrate concentration for domestic samples with the highest mean concentrations occurring during the winter months.

• Despite mean nitrate concentration being highest in the winter months, concentration varied the most during the summer months with the greatest range of values observed in July, August and September.

• Differences in nitrate concentration were observed between sample categories. Rocket had the highest concentration and iceberg lettuce had the lowest mean concentration. Imported and domestic samples were broadly comparable.

• Mean nitrate concentration was found to be relatively stable within categories of produce when looking across years and comparing with long term average values.

• The number of domestic samples found to exceed the regulation limit during 2014 – 2018 was approximately 3% and exceedencies occurred in all but one category of produce.

• The number of samples collected for each category did not influence the likelihood of samples within the category exceeding the regulation limit, nor did the month in which the sample was collected. However, across a wider surveillance period (2002 – 2018), a positive relationship was found between the total number of samples collected each year and the total number of samples that exceed the regulation limit.

• A high mean nitrate concentration and a large range in nitrate concentration were both found to significantly increase the number of samples exceeding the regulation limit.

• Maximum permitted nitrate concentrations are not in place for ‘other leafy green vegetables’ such as chard, kale and mixed baby leaf but some samples were found to contain relatively high concentrations.

• The overall percentage of samples exceeding the regulation limit has significantly decreased over the last 15 years but has remained fairly consistent, at approximately 3%, for the last 5 years (2014 - 2018).

• Few samples of non-iceberg winter, non-iceberg summer open air and iceberg open air lettuce exceeded the regulation limit during the last 5 years.

• During the same surveillance period, >10% of domestic rocket samples exceeded the limit and the trend suggests the annual number of samples exceeding the limit is increasing.

• Although some individual samples contain significant amounts of nitrate the surveillance programme has shown that the UK is largely producing leafy green vegetables with nitrate concentrations within the regulation limits.

• The mean nitrate concentrations observed for the different categories of produce are comparable with those from other European Union countries (Brkić et al.).

## Recommendations

• Continue the surveillance and ensure a minimum of 200 samples per annum are collected.

• Consider removing low risk categories such as iceberg type lettuce from the programme.

• Increase the number of samples collected for higher risk categories such as rocket.

• Include a wider range of vegetables and herbs in the programme which are reported in literature to have high nitrate concentrations, e.g. cabbage, dill, celery, beetroot and radish.

• Extend the data analysis. ADAS has been involved with the collection of leafy green vegetable samples for 17 seasons (2002 – 2018). During this time we have compiled a unique dataset and it is unlikely that a comparable data set exists elsewhere in the UK. The data includes not only information about sample type and nitrate levels but also variety, fertiliser inputs, lot sizes and meteorological data. If funding was available the data could be explored further to better our understanding of interactions between nitrate concentration, lettuce type, crop husbandry, agricultural practices, fertiliser input, edaphic factors and environmental factors including climate change scenarios. The outcome of such a study would enable industry to refine their

growing practices as well as helping the Food Standards Agency to better understand which crops were likely to exceed the maximum permitted nitrate limits.

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