# Application of near infrared spectroscopy for quality evaluation of vegetables in China

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## Introduction

Near infrared s(NIR) pectroscopy is a new components analytical method that has been rapidly developed during the last 20 years. With the development of research work, NIR has developed from the qualitative analysis and half-quantitative analysis stage to the quantitative analysis stage; from the analysis of a large quantity of samples stage to the minor quantity analysis stage; samples that can be analysed by reflection or transmission detection change from solid flower to solid, liquid, dextrin and non-destructive whole samples. This method is becoming an ideal analysis method in the area of modern agriculture and biology, because of its simple, highly efficient, non-complex pretreatment and no chemical reagent needed. The main shortcoming is that the mathematics model is one to one instead of widely used. The mathematics model must be set up differently according to different material (such as rice, wheat, Chinese cabbage, cucumber, apple, pear, etc.) and different analysis components (such as protein, fibre, sugar, vitamins, etc). Setting up the model is the primary step of NIR.

NIR is a fast and non-destructive analytical method that has been developed by American scientist Karl. H. Norris.[1] NIR has been used in China for several years. The first NIR instrument was introduced into China in the 1970's. At that time , it was used mainly on cereal and fodder components analysis. Presently, there are about 300 various types of NIR spectrometers in China, 55% of them are located in agricultural research institutes, 30% in colleges, 10% in cereal or food research institutes, fodder or flour factories, 5% in tobacco cooperatives or other departments. In the 1980's, much work has been conducted concerning fodder and cereal quality evaluation.[2] However, the use of NIR in the field of non-destructive nutritional analysis of vegetables was not initiated until the end of the 1980's when we first made this attempt at the Beijing Vegetable Research Centre. In the last ten years, we have set up such non-destructive methods for a variety of vegetables, such as Chinese cabbage, cucumbers, tomatoes, pumpkins, strawberries, apples, etc.,[3–7] which have been extensively used in the routine nutritional analysis, breeding for quality as well as plant germplasm and evaluation of these fruits and vegetables.

China has a rich resource of vegetable germplasm, as well as a long history of vegetable cultivation.[8] Statistical data show that there are 213 families, 815 genera and 1822 species of vegetable germplasm in China. Only 5% is being used, so there is great potential and vast prospects for its use. As one major source of Chinese non-staple food supplies, vegetables can provide most of the dietary fibres and various kinds of vitamins and minerals. Some components in these plants have even proved

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to be valuable with regard to anticarcinogeneity, human immunity promotion, aging prevention and health care.[9,10] For these reasons it has become a major concern and subject of research for breeders to bring out new cultivars with improved nutritional quality continuously. As NIR is a fast and non-destructive analytical method, it may be used to evaluate a large quantity of samples and thus speed up the progress of breeding and help to produce more desirable vegetable cultivars.

## Determination of nutritive constituents in Chinese cabbage, rape and edible amaranth

Chinese cabbage is a principal variety of vegetable in the northern area of our country. The rape and edible amaranth can be provided around the country all year. Improvement in the quality of Chinese cabbage, edible amaranth and rape have become one of the most important tasks for vegetable breeding scientists. There are about ten thousand breeding materials to be analysed every year. Beijing Vegetable Research Centre helps them to solve the problem. We used a model 6250 NIR spectrometer to determine the moisture, crude protein (CP), neutral detergent fibres (NDF), reducing sugars (RD), vitamin C (VC), Vitamin E (VE) and β-carotene in Chinese cabbage, edible amaranth and rape. The above components of one sample can be finished in a minute and the results were similar to those of chemical analysis. This method has been applied as a routine analysis method.

## Non-destructive analysis of the main components in cucumber, pumpkin, tomato, Balsam pear and pepper

There are a great number of breeding materials in cucumber, pumpkin, balsam pear, pepper and tomato which need to be evaluated with regard to nutritional composition, every year. Because of the requirements for quality breeding, nutritive evaluation and quality control of food processing, using NIR with fibre optics, we have analysed, non-destructively, dry matter, RS and VC in intact cucumber; soluble solid, total sugars, organic acid, VC, sucrose, glucose, fructose, citric acid, L-malic acid in intact tomato; β-carotene and VE in intact pumpkin; dry matter, VC, VE and β-carotene in intact balsam

**Table 1. Vegetable or fruit varieties and constituents studied using NIR.**

| | |
|---|---|
| Chinese cabbage | Moisture, crude protein, neutral detergent fibres, vitamin C, reducing sugars |
| Rape | β-carotene, vitamin C, vitamin E |
| Edible amaranth | Dry matter, vitamin C |
| Cucumber | Dry matter, reducing sugars, vitamin C |
| Tomato | Soluble solid, total sugar, organic acids, vitamin C, citric acid, L-malic acid, succinic acid, sucrose, glucose, fructose |
| Pumpkin | β-carotene, vitamin E |
| Balsam pear | Dry matter, vitamin C, vitamin E, β-carotene |
| Pepper | Dry matter, vitamin C |
| Strawberry | Sucrose, glucose, fructose, citric acid, L-malic acid, vitamin C |
| Apple | Sucrose, glucose, fructose, L-malic acid, Brix |

**Table 2. Summary of calibration and prediction for vegetables and fuit.**

| Variety | | *MR* | *SEC* | *R* | *SEP* | Bias |
|---|---|---|---|---|---|---|
| Chinese cabbage | CP | 0.9958 | 0.398 | 0.994 | 0.353 | –0.06 |
| | NDF | 0.9852 | 0.134 | 0.978 | 0.127 | –0,03 |
| | Reducing sugars | 0.9821 | 0.098 | 0.974 | 0.108 | –0.02 |
| | Vitamin C | 0.9814 | 0.510 | 0.981 | 0.548 | 0.118 |
| | moisture | 0.9940 | 0.067 | 0.975 | 0.068 | 0.01 |
| Rape | β-carotene | 0.9939 | 9.47 | 0,993 | 8.38 | 1.93 |
| | Vitamin E | 0.9911 | 1.05 | 0.995 | 1.25 | –0.55 |
| Edible amaranth | Dry matter | 0.9837 | 0.156 | 0.980 | 0.170 | 0.02 |
| | Vitamin C | 0.9911 | 1.72 | 0.989 | 1.93 | –0.22 |
| Cucumber | Dry matter | 0.9916 | 0.085 | 0.977 | 0.092 | –0.01 |
| | Reducing sugars | 0.9930 | 0.068 | 0.992 | 0.077 | 0.01 |
| | Vitamin C | 0.9932 | 0.368 | 0.992 | 0.386 | 0.05 |
| Tomato | Soluble solid | 0.9940 | 0.049 | 0.990 | 0.057 | –0.02 |
| | Organic acidc | 0.9830 | 0.006 | 0.967 | 0.007 | –0.0001 |
| | Total sugar | 0.9870 | 0.029 | 0.979 | 0.037 | 0.002 |
| | Vitamin C | 0.9900 | 0.441 | 0.987 | 0.440 | 0.118 |
| | Sucrose | 0.9920 | 0.025 | 0.979 | 0.020 | –0.004 |
| | Glucose | 0,9788 | 0.030 | 0.987 | 0.040 | 0.01 |
| | Fructose | 0.9879 | 0.022 | 0.955 | 0.022 | 0.001 |
| | Citric acid | 0.9952 | 0.003 | 0.989 | 0.003 | 0.0004 |
| | L-Malic acid | 0.9935 | 0.005 | 0.991 | 0.004 | –0.002 |
| | Suceinic acid | 0.9966 | 0.493 | 0.998 | 0.442 | –0,09 |
| Pumpkin | β-carotene | 0.9980 | 2.87 | 0.996 | 3.08 | 0,07 |
| | Vitamin E | 0.9956 | 0.025 | 0.998 | 0.018 | –0.001 |
| Balsam pear | Dry matter | 0.9883 | 0.19 | 0.980 | 0.197 | –0.01 |
| | Vitamin C | 0.9976 | 1.26 | 0.995 | 1.45 | 0.69 |
| | Vitamin E | 0.9918 | 15.2 | 0.990 | 16.1 | –3.87 |
| | β-carotene | 0.9987 | 3,58 | 0.998 | 4.31 | –0.47 |
| Pepper | Dry matter | 0.9930 | 0.225 | 0.989 | 0.274 | –0.05 |
| | Vitamin C | 0.9987 | 0.832 | 0,998 | 0.856 | 0,04 |
| Strawberry | Sucrose | 0.9920 | 0.021 | 0.981 | 0.020 | –0.002 |
| | Glucose | 0.9914 | 0.035 | 0.989 | 0.038 | –0.014 |
| | fructose | 0.9888 | 0.065 | 0.978 | 0.041 | 0.006 |
| | Citric acid | 0.9954 | 0.044 | 0.989 | 0.040 | 0.018 |
| | L-malic acid | 0.9944 | 0.029 | 0.971 | 0.026 | 0.004 |
| | Vitamin C | 0.9980 | 0.727 | 0.992 | 0.747 | 0.019 |
| Apple | Sucrose | 0.9970 | 0.070 | 0,996 | 0.085 | 0.006 |
| | Glucose | 0.9920 | 0.061 | 0.990 | 0.057 | 0.007 |
| | Fructose | 0.9920 | 0.186 | 0,990 | 0.178 | 0.020 |
| | L-malic acid | 0.9960 | 0.020 | 0.997 | 0.021 | 0.002 |
| | Brix | 0.9840 | 0.360 | 0.970 | 0.450 | –0.09 |

*MR*: multiple correlation coefficient of calibration; *SEC*: standard error of calibration; *R*: correlation coefficient of prediction; *SEP*: Bias-corrected standard error of prediction pear; dry matter, vitamin C in intact pepper. Compared with the chemical methods, the level of accuracy are satisfactory for routine analysis.

## Uses for the analysis of nutritive constituents in intact strawberries and apples

At the Beijing Vegetable Research Centre studies have been conducted using NIR fibre optics to determine sucrose, glucose, fructose, citric acid, L-malic acid and vitamin C content in intact strawberries and Brix, sucrose, glucose, fructose and L-malic acid content in whole apples. Results were similar to those using chemical methods.

Details of non-destructive methods developed for types and constituents are presented in Tables 1 and 2.

Much work has been done on the development of NIR methods to determine a great number of components in vegetables and fruit in China. More than 40 mathematical models have been set up including, 11 vegetable species and nearly 20 kinds of components which can be widely used in practical situations. Using NIR methods, more than 10,000 samples are analysed and 100,000 analysis data have been provided. It is important for routine analysis and quantitative breeding. For example, NIR quantitative analysis has been a great help with the new cultivars, like Chinese cabbage, Beijing No.3 and tomato Jinhong 1. However, large-scale practical applications in quality control have not yet been obtained. On the other hand, some instruments have not been performing well and some users did not have the means to establish good calibrations and had to rely on technical assistance, or to be provided with ready-to-use calibrations. The main work of NIR on vegetable qualitative analysis research is to set up more vegetable mathematical models, which can be used more in vegetable nutrients analysis, qualitative breeding and germplasm evaluation.

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