Risk Assessment Study on

Nitrate and Nitrite in Vegetables Available in Hong Kong

~ Summary~

Purpose

This paper summarises the main findings of the risk assessment study on nitrate and nitrite in vegetables available in Hong Kong.

Background

2. In 2008, an 8-month-old baby in Hong Kong suffered from methaemoglobinaemia (also known as Blue Baby Syndrome, a rare condition under which haemoglobin is unable to carry oxygen to body tissues and causes skin and lips to turn blue) after consuming congee with Chinese spinach that contained high level of nitrite. Nitrite can be produced by bacteria from nitrate naturally present in the vegetable due to improper handling and storage of food. This incident has aroused public awareness of nitrate contamination in local vegetables.

3. Nitrate and nitrite occur naturally in the environment and can be produced endogenously in animals and humans. They are also used as fertilisers and food additives in processed foods.

4. The nitrate and nitrite concentrations in vegetables depends on a number of factors including species variation, season, light, temperature, method of growth and nitrogen fertiliser used as well as the storage and processing methods (e.g. peeling, washing and cooking).

5. High levels of nitrate in vegetables is a worldwide problem. Very high concentration (over 5 000 mg/kg) of nitrate in vegetables especially leafy vegetables has been reported in different places such as Mainland China as well as various countries in Europe.

6. Nitrate itself is relatively non-toxic. However, its metabolites, nitrite may affect the ability of haemoglobin to carry oxygen and cause methaemoglobinaemia in rare cases. It is very unlikely for individuals other than young infants to develop methaemoglobinaemia due to excessive consumption of vegetables with high nitrate and nitrite levels. Young infants are more susceptible to nitrite-induced methaemoglobinaemia because of the immaturity of digestive and the methaemoglobin reductase systems.

7. Nitrate and nitrite themselves are not carcinogenic to humans. However, nitrite might react with amines to form carcinogenic nitrosamines in the stomach. On the other hand, vitamin C and certain antioxidants in vegetables can inhibit the formation of nitrosamines.

<u>Beneficial health effects of vegetables</u>

8. Vegetables provide biologically active substances as well as nutrients like pro-vitamin A, vitamin C, folate, calcium, iron, potassium, magnesium, fibre, etc. The World Health Organization stated that eating fruit and vegetables decrease the risk for cardiovascular disease, obesity, type 2 diabetes and cancer, particularly cancers of the gastrointestinal tract.

It recommends intake of a minimum of 400 g of fruit and vegetables per day for the prevention of chronic diseases. The Department of Health in HK also promotes the consumption of at least two servings of fruit and three servings of vegetables every day (2 plus 3 a day) as part of a balanced diet for optimal health.

Safety reference values

9. There is no acute reference dose established for nitrate or nitrite by The Joint Food and Agriculture Organization /World Health Organization Expert Committee on Food Additives (JECFA). JECFA established an acceptable daily intake (ADI) of 0-3.7 mg/kg bw (expressed as nitrate ion) for nitrate and 0-0.07 mg/ kg bw, (expressed as nitrite ion) for nitrite. However, in view of the well-known benefits of vegetables and the lack of data on the possible effects of vegetable matrices on the bio-availability of nitrate, the JECFA considered it to be **inappropriate** to compare exposure to nitrate from vegetables directly with the ADI and hence to derive limits for nitrate in vegetables directly from it.

Regulatory control on nitrate and nitrite as contaminant & food additives

10. Codex has not established any food safety standard for nitrate and nitrite as food contaminants.

11. As for nitrate and nitrite used as food additives, there are both Codex and local standards for various cheese products and cured meat products. The maximum permitted levels of nitrate and nitrite in specified foods is stipulated in the local Preservatives in Food Regulation (Cap. 132

BD)

The Study

12. Our study aims to (i) examine the nitrate and nitrite levels of vegetables on Hong Kong market, (ii) explore the effects of preparation and cooking methods on nitrate levels in vegetables, and (iii) assess the associated health risk posed to the population through exposure to nitrate from vegetables. It covered 73 types of commonly consumed fresh vegetables. The laboratory analysis was conducted by the Food Research Laboratory of the CFS. The main findings are highlighted in the following paragraphs.

13. Results showed there was a large variation in mean concentrations of nitrate in different vegetables from a low of 5 mg/kg in oyster mushroom (range <4-9 mg/kg) to a high of 4 800 mg/kg in Chinese spinach (range 3 700-6 300 mg/kg). The nitrate concentrations of different groups of vegetables in descending order were leafy vegetables > root and tuber vegetables > fruiting and legume vegetables. The nitrate concentrations of majority (>80%) of vegetables are less than 2 000 mg/kg but 3 types of leafy vegetables namely Chinese spinach, Shanghai cabbage, and petiole Chinese cabbage contained relatively high levels (>3 500 mg/kg) of nitrate. On the other hand, the nitrite concentrations of vegetables were generally very low, with less than 1 mg/kg on average (details are shown in Annex). The results of this study are generally in line with those found in Mainland and other countries.

14. The preparation and cooking experiments showed that soaking vegetables (Chinese flowering cabbage, Chinese spinach, and celery) in water was not effective in reducing nitrate. However, nitrate concentrations were reduced significantly after these vegetables were blanched for 1 to 3 minutes (12-31% reduction) in boiling water.

15. When assessing risk from nitrate in vegetable, both the potential risk of nitrate and the benefits of eating vegetables have to be considered. The European Food Safety Authority in 2008 considered that benefits of vegetable and fruit consumption outweigh any perceived risks from the consumption of nitrate and nitrite in these foods. In addition, negative correlation was found between nitrate intake and gastric cancer which may be due to the known strong protective effect of vegetables and fruits. However, reducing nitrate contamination in vegetables can represent added value for vegetable already rich in essential nutrients. Therefore, it is prudent to reduce dietary nitrate and nitrite intake by maintaining a balanced diet and avoiding over-indulgence in high-nitrate vegetables and foods that contain nitrate or nitrite as food additives.

16. The levels of nitrate and nitrite found in vegetables in this study were unlikely to pose any immediate health risk to the general population. However, some clinical data showed that consumption of vegetable with high nitrate levels and incorrect storage of homemade purees of vegetables resulting in nitrite accumulation were identified as potential causes of nitrite-induced methaemoglobinaemia in infants. The age at risk is not limited to the first 4 to 6 months of life. This indicated that health risk to

infants from consuming improperly handled, high-nitrate vegetables cannot be ruled out.

17. In order to maximise the health benefits from eating vegetables, measures have to be taken to reduce the nitrate and nitrite exposure while maintaining the recommended intake of vegetables of the public.

Advice to public

1. Maintain a balanced diet with at least two servings of fruit and three servings of vegetables every day and eat a wide variety of vegetables including leafy vegetables, brassica vegetables, root and tuber vegetables, fruiting vegetables, legume vegetables, etc.

2. Handle and cook vegetables properly (i.e. keep vegetables under refrigeration if they are not being cooked immediately; cook vegetables soon after chopping or mashing; wash, peel, vegetables; blanch high nitrate containing vegetables in water and discard the cooking water before consumption.)

3. WHO recommends exclusive breastfeeding for infants up to 6 months of age with appropriate complementary foods afterwards. Generally, infants about 6 months of age are ready for solid foods. Infant foods such as vegetable puree and vegetable congee should be prepared for immediate use. If storage is needed, they should be kept in freezer (at or below -18^{o}C) to avoid accumulation of

nitrite due to contamination of bacteria of the food.

Advice to trade

1. Farmers are advised to observe good agriculture practice (GAP) to minimize nitrate concentrations in vegetables.

2. The trade should obtain vegetables from reliable sources and maintain proper records to enable source tracing when required.

3. The trade should store vegetables in either the refrigerator or cool and dry places to avoid accumulation of nitrite due to spoilage of the vegetables.

July 2010
Centre for Food Safety
Food and Environmental Hygiene Department

Annex

Nitrate and Nitrite Concentrations in Vegetables (mg/kg)

Vegetables	Number of samples	Nitrate		Nitrite	
		Mean	Range	Mean	Range
Leafy Vegetables (including Brassica Leafy Vegetables)	**20 (types)**	**2 100**	**79-6 300**	**1.2**	**ND-9.1**
Baby Chinese cabbage	10	2 100	540-2 800	0.6	ND-1.2
Bean shoot[a]	5	260	120-430	0.5	ND-0.9
Ceylon spinach[b]	5	1 100	79-2 300	ND	ND
Chinese spinach/Chinese amaranth[b]	5	4 800	3 700-6 300	1.7	0.9-2.6
Chinese cabbage/Tiennsin cabbage	10	1 300	480-2 900	0.6	ND-1.2
Chinese flowering cabbage	10	2 400	1 200-3 500	3.3	ND-7.8
Chinese kale	10	1 600	340-2 700	1.6	ND-5.9
Chinese lettuce	10	1 300	670-1 800	0.5	ND-1.3
Chinese wolfberry	10	2 400	1 400-3 000	1.1	ND-1.7
Coriander	10	3 200	1 800-5 000	0.6	ND-1.1
European lettuce	10	950	600-1 400	0.5	ND-1.0
Green water spinach	10	870	190-2 500	0.5	ND-1.2
Indian lettuce	10	1 300	510-1 900	0.5	ND-0.9
Leaf mustard	10	3 300	2 100-4 500	1.2	ND-2.2
Petiole Chinese cabbage/Petiole bok choi	10	4 100	2 300-5 400	2.6	ND-9.1
Red Chinese spinach[b]	5	2 000	94-3 900	1.3	0.8-1.9
Shanghai cabbage	10	3 600	2 300-5 100	2.2	ND-5.0
Spinach	10	3 100	1 100-4 700	2.3	ND-5.7
Watercress	10	1 300	580-2 200	0.7	ND-1.9
White water spinach[b]	5	1 200	290-2 400	0.6	ND-1.6
Brassica (Cole or Cabbage) Vegetables,	**3 (types)**	**620**	**16-2 800**	**0.5**	**ND-0.9**

Head Cabbages, Flowerhead Cabbages					
Broccoli	10	420	280-670	0.5	ND-0.9
Cauliflower	10	250	25-720	0.5	ND-1.1
European variety cabbage	10	1 200	16-2 800	0.5	ND-0.9
Stalk and Stem Vegetables	**6 (types)**	**830**	**8-4 600**	**0.6**	**ND-4.4**
Asparagus	10	21	14-37	0.5	ND-1.3
Bamboo shoot[b]	5	130	54-240	ND	ND
Celery	10	1700	390-3 200	ND	ND
Chinese celery	10	3100	1 800-4 600	0.6	ND-1.2
Mung bean sprouts	10	18	8-37	1.3	ND-4.4
Soybean sprouts	10	20	10-32	0.5	ND-1.6
Bulb Vegetables	**7 (types)**	**520**	**5-2 300**	**1.3**	**ND-21**
Blanching chives	10	320	76-620	0.7	ND-1.8
Bud chives	10	310	37-540	0.9	ND-2.1
Chinese chives	10	1500	120-2 300	1.2	ND-4.0
Garlic bulb	10	18	9-33	0.8	ND-1.8
Garlic spears	10	780	81-2 300	4.0	ND-21
Onion	10	13	5-36	0.5	ND-1.1
Spring onion	10	680	100-1 400	0.7	ND-1.4
Legumes Vegetables	**5 (types)**	**140**	**ND-830**	**0.5**	**ND-1.4**
Common bean	23	470	170-830	0.5	ND-1.0
Green soybean	10	18	5-34	0.6	ND-1.2
Green String beans	10	190	23-420	ND	ND
Snow pea	10	13	ND-26	0.6	ND-1.2

Sugar snap pea	10	10	7-13	0.6	ND-1.4
Root and Tuber Vegetables	**13 (types)**	**720**	**ND-4 100**	**1.1**	**ND-8.9**
Beetroot[b]	5	3 000	1 600-4 100	7.6	3.1-8.9
Carrot	10	220	43-490	0.5	ND-1.1
Ginger	10	1 300	790-1 800	0.8	ND-3.7
Kudzu	10	230	120-390	0.5	ND-1.2
Lotus root	10	33	9-60	1.3	ND-2.6
Potato	10	180	100-270	0.8	ND-1.7
Radish, Chinese green	10	1 900	1 400-2 600	0.4	ND-0.8
Radish, Chinese red	10	300	60-740	ND	ND
Radish, Chinese white	10	1 400	630-2 200	0.5	ND-0.9
Sweet potato	10	43	ND-220	ND	ND
Taro	10	570	49-1 300	0.5	ND-1.1
Water chestnuts	10	20	11-36	0.7	ND-1.5
Yam bean	10	170	39-400	0.5	ND-1.1
Fruiting Vegetables, Cucurbits	**7 (types)**	**370**	**11-1 400**	**0.6**	**ND-2.2**
Bitter gourd	10	380	99-730	0.7	ND-1.7
Cucumber	10	110	28-260	0.5	ND-0.9
Hairy gourd	10	250	190-340	0.6	ND-1.2
Pumpkin	10	260	11-810	0.8	ND-2.2
Sponge gourd	10	260	30-470	ND	ND
Wax gourd/Winter melon	10	520	260-1 000	0.5	ND-1.0
Zucchini/Jade melon	10	840	480-1 400	0.7	ND-1.3

Fruiting Vegetables, Mushrooms	**6 (types)**	**14**	**ND-140**	**0.7**	**ND-2.5**
Chicken-leg mushroom	10	5	ND-11	0.5	ND-0.9
Gold-needle mushroom	10	6	ND-12	0.8	ND-1.5
Oyster mushroom	10	5	ND-9	1.1	ND-2.5
Shiitake mushroom	10	6	ND-13	ND	ND
Straw mushroom	10	16	11-29	0.5	ND-1.0
White button mushroom	10	43	17-140	1.0	ND-2.2
Fruiting Vegetables, Other than Cucurbits and Mushrooms	**6 (types)**	**93**	**ND-470**	**0.9**	**ND-2.9**
Eggplant	10	350	250-470	0.8	ND-1.5
Bell pepper	10	77	9-180	1.1	ND-1.7
Long pepper	10	57	9-150	0.9	ND-1.6
Tomato	10	57	ND-180	0.5	ND-0.9
Small red pepper	10	9	ND-24	1.3	ND-2.9
Sweet corn	10	7	ND-16	0.5	ND-1.1

Notes: -ND denotes not detected.

-Limits of detection (LOD) for nitrate ions is 4 mg/kg and for nitrite ions is 0.8 mg/kg

-Mean values are calculated by assigning ND results as half LOD

-Results are rounded to 1 or 2 significant figures depends on the detection limit.

-[a] winter samples only

-[b] summer samples only