

# Determination of Fumonisin B<sub>1</sub> and B<sub>2</sub> in Corn Products

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(Received: February 23, 2005; Accepted: April 28, 2005)

## ABSTRACT

An analytical method using immunoaffinity column and HPLC was developed for determination fumonisins in corn and corn products. The detection limits for fumonisin B<sub>1</sub> (FB<sub>1</sub>) and fumonisin B<sub>2</sub> (FB<sub>2</sub>) were 0.03 ppm and 0.07 ppm, respectively. Spiked FB<sub>1</sub> in dried corn (kernel and flour), fresh corn, corn snack and corn flake are at 0.2-3.0 ppm level, with recovery ranged from 79.2-108.8% and relative standard deviation (RSD) of 2.9-21.9%. FB<sub>2</sub> spiked under the same condition as FB<sub>1</sub> had recovery ranges of 70.0-106.0% and RSD of 4.7-20.0%. A total of 76 samples were collected, including 20 dried corn (kernel or flour), 5 fresh corn, 15 corn snacks, 10 corn flakes, 5 corn starch, 5 canned corn from commercial markets and 16 raw corn materials were purchased from corn snack manufacturers. From the total 76 samples, 11 samples (14.5%) were detected with FB<sub>1</sub> and/or FB<sub>2</sub>. Seven samples of corn were at 0.05-0.13 ppm level, 1 fresh corn with 0.15 ppm, 2 corn snacks with 0.5 and 0.16 ppm, respectively, where as 1 corn raw material was at the 0.09 ppm level. The highest contamination was only 0.16 ppm. Nevertheless, no fumonisin was detected in corn flake, corn starch and canned corn samples.

Key words: fumonisin B<sub>1</sub>, fumonisin B<sub>2</sub>, corn products, immunoaffinity column, HPLC

## INTRODUCTION

Fumonisin is a mycotoxin which is a structurally related group of long-carbon chain compounds as indicated in Figure 1<sup>(1)</sup>. Fumonisin analogues have been identified and classified into fumonisin A<sub>1</sub>, A<sub>2</sub>, B<sub>1</sub>, B<sub>2</sub>, B<sub>3</sub>, and B<sub>4</sub> based on their chemical structure. Fumonisin B<sub>1</sub> (FB<sub>1</sub>), fumonisin B<sub>2</sub> (FB<sub>2</sub>), and fumonisin B<sub>3</sub> (FB<sub>3</sub>) are believed to be the most abundant naturally occurring analogues. Since fumonisins are alkaloids and polar compounds, so they can be dissolved in water, methanol, ethanol and acetonitrile. However they are insoluble in nonpolar solvents, such as acetone, chloroform, and hexane<sup>(2)</sup>. Because fumonisins are not fluorescent, they should be quantified with ortho-phthalaldehyde (OPA) reagent.

Fumonisin is produced mainly by *Fusarium moniliforme* (= *F. verticillioides*), *F. proliferatum*, and several other *Fusarium* species. It was found that water activity between 0.94-0.98 is ideal for growing *F. moniliforme* and *F. proliferatum*. In fact, the optimum pH and temperature for the growing *F. moniliforme* are 5.5 and 25°C, and for *F. proliferatum* are 7.0 and 30°C<sup>(3)</sup>. When water activity is below 0.92, growth-inhibited effect will be occurred.

Many kinds of cereals including corn, sorghum, rice and wheat are known to be infected by *Fusarium* species and produce fumonisins, particularly corn crops<sup>(3)</sup>. *F. moniliforme* is a soil-borne as well as a seed-borne pathogen of corn that inhabits in the field. Therefore, infection of *F. moniliforme* can infect the roots, stalks, and kernels of corn. Insect invasion on corn kernels can result in the production of fumonisins due to *Fusarium* invasion.

The fumonisin levels found in corn are influenced by various environmental factors such as temperature, humidity, drought stress and the extent of rainfall during the growth and harvesting periods. Post harvest storage of corn kernels under improper moisture conditions can also result in additional accumulation of fumonisins<sup>(2)</sup>. Generally, the fumonisin level will increase in corn products during storage as long as proper grain moisture and temperature are maintained<sup>(4)</sup>. The extent of contamination of corn varies with geographical location, and is found to be highest in the warmer regions of the world<sup>(5)</sup>. Susceptibility to fungal infection and subsequent contamination of the corn also depend on agricultural practices and genotypes<sup>(6)</sup>. Corn kernels with insect invasion are easily infected with molds and produce toxins. *Fusarium* species can invade corn kernels by inner route and produce fumonisins. A signifi-

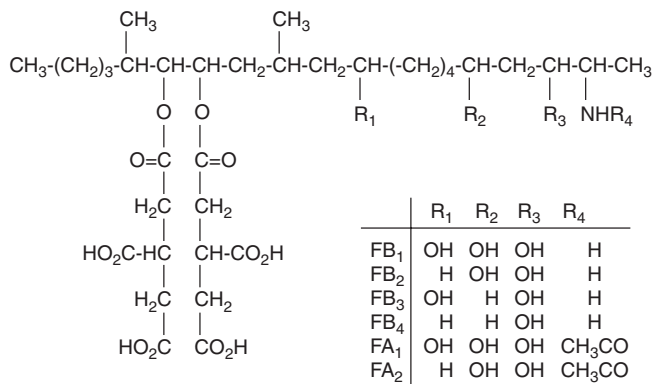


Figure 1. Chemical structure of fumonisins.

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cant percentage of healthy-looking corn kernels contain fumonisin levels of about 1 ppm or higher<sup>(4,7)</sup>.

FB<sub>1</sub> is believed to be the most toxic fuminin leading to most severely adverse health effects in animals<sup>(8)</sup>. When plants were contaminated by fuminisins, they could cause physiological damage, growth inhibition, and death in plants<sup>(9)</sup>. FB<sub>1</sub> can cause acute mycotoxicoses such as equine leukoencephalomalacia<sup>(10,11)</sup>, pig pulmonary<sup>(12)</sup>, hepatopathy, liver cancer and nephritic disease in several animal species, including farm animals<sup>(13-15)</sup>. FB<sub>1</sub> can also influence immunological function, cause liver and kidney damage, laggard growth or even death of poultry. Corn and fumonisins have also been associated with high incidences and increased risk of human esophageal cancer in South Africa and China, where corn and corn products are the main staple food. Investigators in South Africa have noted a correlation between high levels of fumonisin-producing molds on corn and esophageal cancer in human subgroups. The researchers detected high levels of FB<sub>1</sub> were detected in samples that had heavy mold contamination, and these samples also contained high levels of trichothecenes. Epidemiological studies currently available demonstrate only inconclusive associations between fumonisins and human esophageal cancer<sup>(16-18)</sup>.

Since the effect of fumonisins on human healthy has not been proved, worldwide regulations for fumonisins are still in a recommended phase. There are only America and Swiss that have recommended levels for fumonisins. The American advisory level for fumonisins (FB<sub>1</sub> + FB<sub>2</sub> + FB<sub>3</sub>) in corn and corn products intended for human consumption range from 2-4 ppm<sup>(19,20)</sup>, depending on the type of corn products. The Swiss provisional level for fumonisins (FB<sub>1</sub> + FB<sub>2</sub>) in corn and corn products intended for human consumption is 1 ppm<sup>(20)</sup>.

According to the Agricultural Statistics Yearbook 2001 published by the Council of Agriculture, Executive Yuan, ROC, corn is not a staple cereal among the per capita per year food supply and most parts of corn need to be imported<sup>(21)</sup>. Because Taiwan is in sub-tropical climate area, *Fusarium* spp. could grow well in warm and humid environment. Tseng *et al.* found only *F. moniliforme* produces FB<sub>1</sub> and FB<sub>2</sub> among *Fusarium* species isolated from the grains collected in Taiwan. Among the 38 strains of *F. moniliforme* isolated, 66% of *F. moniliforme* could produce fumonisins<sup>(22)</sup>. Tseng *et al.* also surveyed corn-based foodstuffs purchased from markets at various districts of Taiwan from 1994 to 1995, 33.9% of samples were found to be contaminated with FB<sub>1</sub> at 0.073-2.375 ppm level. Among the samples contaminated with FB<sub>1</sub>, 61.5% were also found to be contaminated with FB<sub>2</sub> at the range of 0.01-0.715 ppm<sup>(23)</sup>. On the other hand, Chung *et al.* surveyed corn products collected in Taiwan in 1995. Twenty-seven of 91 samples were found to be contaminated with fumonisins at the level 0.6-5.6 ppm<sup>(24)</sup>.

Cancer is the number one cause of death in Taiwan. Since consumption of mycotoxin contaminated food may be carcinogenic for people, Bureau of Food and Drug

Analysis (BFDA) surveyed alfatoxin contamination in food for years and also examined the contents of other mycotoxins. Purpose of this study was to establish the examination method and apply the method to survey the content of fumonisins in corn and corn products.

## MATERIALS AND METHODS

### I. Materials

#### (I) Sample Collection

Sixty samples of corn product including dried corn (kernel or flour), fresh corn, corn snack, corn flake, corn starch, canned corn from hyper-market, supermarkets, and convenience stores in north Taiwan. Sixteen samples of corn raw materials from 9 corn snack manufacturing plants were collected during May to October, 2002. Each sample was blended and mixed, packed in sealed bag, stored in freezer (-20 ± 2°C) and analyzed as soon as possible.

#### (II) Reagents and Apparatus

1. FB<sub>1</sub> and FB<sub>2</sub> standards were purchased from SigmaAldrich Cheme GmbH (Germany). Immunoaffinity columns FumoniTest™ were purchased from VICAM (Watertown, MA, USA). *O*-phthaldialdehyde (OPA), 2-mercaptoethanol (MCE), sodium dihydrogenphosphate dihydrate, sodium tetraborate, hydrochloric acid, phosphoric acid, sodium chloride, disodium hydrogen phosphate, potassium dihydrogen phosphate and potassium chloride were of reagent grade. Acetonitrile and methanol were of LC grade. Distilled, deionized water was used throughout the procedure.

#### 2. Prepared Reagents

- Extraction solvent: acetonitrile/methanol/water (25/25/50, v/v/v).
- Phosphate buffer saline (PBS): Dissolve 8.0 g of NaCl, 1.2 g of Na<sub>2</sub>HPO<sub>4</sub>, 0.2 g of KH<sub>2</sub>PO<sub>4</sub> and 0.2 g of KCl in 990 mL of water. Adjust pH to 7.0 with 2 M HCl, and dilute to 1 L.
- OPA reagent: Dissolve 40 mg of OPA in 1 mL of methanol, and dilute with 5 mL of Na<sub>2</sub>B<sub>4</sub>O<sub>7</sub> solution. Add 50 μL of MCE and mix. Store the mix in the dark for up to 1 week at room temperature in a capped amber vial.
- LC mobile phase: methanol/0.1 M NaH<sub>2</sub>PO<sub>4</sub> (77/23, v/v), adjusted to pH 3.35 with H<sub>3</sub>PO<sub>4</sub>.

#### (III) Instruments and Analytical Condition

A Hitachi (Japan) HPLC system equipped with Hitachi L-7100 pump, a L-7480 fluorescence detector and a L-7200 autosampler were used. The column (150 × 4.6 mm,

Cosmosil 5C18-AR, 5  $\mu\text{m}$ , Nacalai, Japan), and the fluorescence detector wavelength settings were 335 nm (excitation) and 440 nm (emission). The mobile phase, methanol/0.1 M  $\text{NaH}_2\text{PO}_4$  (77/23, v/v) adjusted to pH 3.35 with  $\text{H}_3\text{PO}_4$  was pumped at a constant flow rate of 1.0 mL/min. Injection volume was 20  $\mu\text{L}$ .

## II. Method

### (I) Preparation of Standard Solution

Dissolve  $\text{FB}_1$  and  $\text{FB}_2$  standard with acetonitrile/ $\text{H}_2\text{O}$  (50/50, v/v) to make 100 ppm stock solution, then dilute the solution with acetonitrile/ $\text{H}_2\text{O}$  (50/50, v/v) to prepare a series of standard solution.

### (II) Extraction

Using a modification of the method by Visconti *et al.*<sup>(26)</sup>. Weigh 20 g of test portion of mixed sample into blender, add 50 mL of extraction solvent, and then homogenize for 2 min. Afterwards, centrifuge for 10 min at 2500  $\times g$  and filter supernatant through filter paper (Whatman No.4, 12 cm). Again extract remaining solid material by adding 50 mL of extraction solvent and repeat above procedure. Collect and combine the 2 filtrates and pipet 10 mL of filtrate into 50-mL centrifuge bottle. Add 40 mL of PBS and mix well. Filter diluted extract through microfiber filter (Whatman GF/A, 9 cm) and collect 10 mL of filtrate for cleanup through immunoaffinity column.

### (III) Immunoaffinity Column Clean Up

Follow manufacturer's instruction, connect a 10-mL syringe reservoir with a FumoniTest<sup>TM</sup> immunoaffinity column, pipet 10 mL of filtrate into syringe reservoir, let filtrate flow through column at ca 1-2 drops/sec and discard elute. Then wash the loaded immunoaffinity column with 10 mL of PBS at 1-2 drops/sec until air comes through column. Place 4-mL vial under column, elute fumonisins with 1.5 mL of LC grade methanol at 1 drop/sec. Evaporate methanol eluate to dryness under a gentle stream of nitrogen. Retain dried residue at 4°C for derivation and HPLC analysis.

### (IV) Derivation

Dissolve residue in 200  $\mu\text{L}$  of acetonitrile/ $\text{H}_2\text{O}$  (50/50, v/v) and then filtered by a 0.45  $\mu\text{m}$  microfilter for HPLC analysis. Transfer 50  $\mu\text{L}$  of sample solution or standard solution to 1-mL test tube, and add 50  $\mu\text{L}$  of OPA reagent. Mix solution for 30 sec with vortex mixer, and inject 20  $\mu\text{L}$  of derived solution into LC system in exactly 3 min after adding OPA reagent.

### (V) Identification and Quantification

$\text{FB}_1$  and  $\text{FB}_2$  standard were dissolved in acetonitrile/

$\text{H}_2\text{O}$  (50/50, v/v) to prepare a series of working solutions containing 0.05, 0.1, 0.2, 0.5, 1, 2, 4, 6 and 8 ppm of  $\text{FB}_1$  and  $\text{FB}_2$ . The standard curves were plotted based on peak area versus concentration. While using equal volume of OPA reagent for derivation, the concentration of  $\text{FB}_1$  and  $\text{FB}_2$  were injected into HPLC to become 0.025-4 ppm. The sample and standard derived solutions were accurately taken and injected into HPLC according to the analytical condition as described. The retention time and peak area were compared to those in standard curves. The amounts of  $\text{FB}_1$  and  $\text{FB}_2$  were calculated based on the standard curves.

$\text{FB}_1$  and  $\text{FB}_2$  concentration in the test sample was calculated using the following equation:

$$\text{FB}_1 \text{ or } \text{FB}_2 \text{ content (ppm)} = C \times V/M$$

C: concentration of  $\text{FB}_1$  or  $\text{FB}_2$  in sample derived solution.

V: volume of derived solution (0.1 mL).

M: sample weight (0.1 g) in 0.1 mL of derived solution.

### (VI) Recovery Test

Uncontaminated corn, fresh corn, corn snack, corn flake (blank corn products) were spiked with  $\text{FB}_1$  and  $\text{FB}_2$  standard. The spiked samples were then kept in a hood for 1 hr to evaporate the solvent residue. Corn test sample with 0.5, 1.0, 2.0 and 3.0 ppm  $\text{FB}_1$  and  $\text{FB}_2$ , the fresh corn with 0.2 ppm  $\text{FB}_1$  and  $\text{FB}_2$ , and corn snack with 0.5 ppm  $\text{FB}_1$  and  $\text{FB}_2$  were prepared. The corn flake with 0.5 ppm  $\text{FB}_1$  and  $\text{FB}_2$  were prepared. Each concentration of spiked samples was prepared in triplicate. The preparation of derivation sample solution was as described. Recoveries for different sample were calculated after HPLC analysis.

### (VII) Detection Limit Test

Series of diluted concentrations of  $\text{FB}_1$  and  $\text{FB}_2$  standard solution were derived as described. The instrument detection limit (IDL) was estimated on the basis of signal to noise (S/N) ratio greater than 3. A suitable amount of  $\text{FB}_1$  and  $\text{FB}_2$  standard was spiked into blank corn meal and the derived sample solution was prepared as described. The method detection limit (MDL) was estimated on the basis of signal to noise (S/N) ratio greater than 3.

## RESULTS AND DISCUSSION

### I. Preparation of Derived Sample Solutions

The OPA derivatives of fumonisins, which are not fluorescent, need to be prepared for HPLC fluorescence detector. The fluorescence intensity of the OPA derivative is time dependent (Figure 2). Both  $\text{FB}_1$  and  $\text{FB}_2$  standards yield stable OPA derivatives after they reacted with OPA

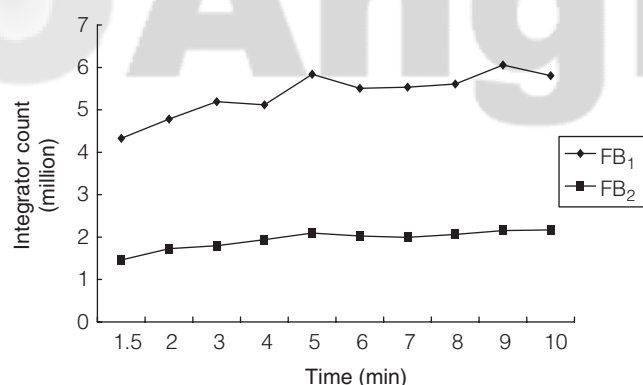


Figure 2. Stability of the FB<sub>1</sub> (1 ppm) and FB<sub>2</sub> (1 ppm) OPA derivatives.

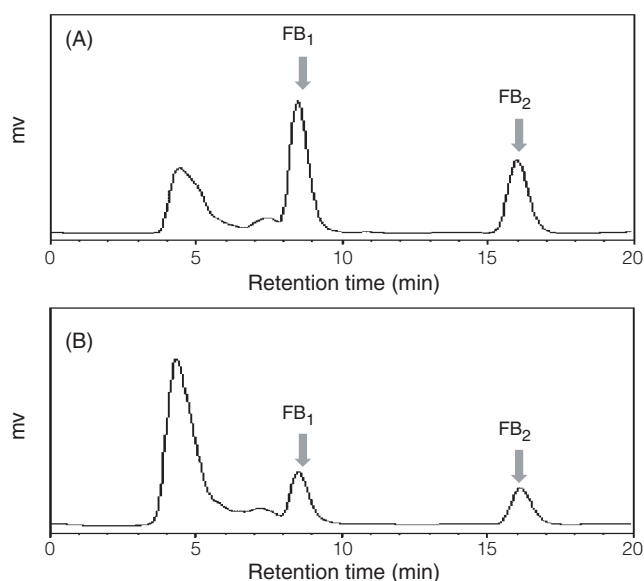


Figure 3. HPLC chromatograms of (A) FB<sub>1</sub> and FB<sub>2</sub> standards, (B) corn sample spiked with 1 ppm FB<sub>1</sub> and FB<sub>2</sub>. HPLC condition: column: 150 × 4.6 mm, Cosmosil 5C18-AR, 5 μm; mobile phase: methanol/0.1 M NaH<sub>2</sub>PO<sub>4</sub> (77/23, v/v), adjusted to pH 3.35 with H<sub>3</sub>PO<sub>4</sub>; flow rate: 1.0 mL/min; fluorescence detector: excitation at 335 nm and emission at 440 nm.

reagent for 3 min. Trucksess *et al.*<sup>(25)</sup> found the highest fluorescence intensity of OPA derivatives formed after 0.5 min reaction, but the OPA reagent was freshly prepared by their laboratory. We compared self-prepared OPA reagent and the reagent purchased from VICAM company, and found that VICAM OPA reagent could produce more stable derivatives. In order to prepare the VICAM OPA reagent for this study, we mixed the two solutions. The mixing reagent could be used for 5 days in amber bottle. According to the study of Trucksess *et al.*<sup>(25)</sup>, the day-to-day variability of the fluorescence intensity of the OPA derivative was about 10%. Within the same day, the variation of fluorescence intensity of OPA derivative of the same standard solution was about 3%.

The chromatograms of FB<sub>1</sub> and FB<sub>2</sub> standards, blank corn and spiked corn sample are shown in Figure 3. The

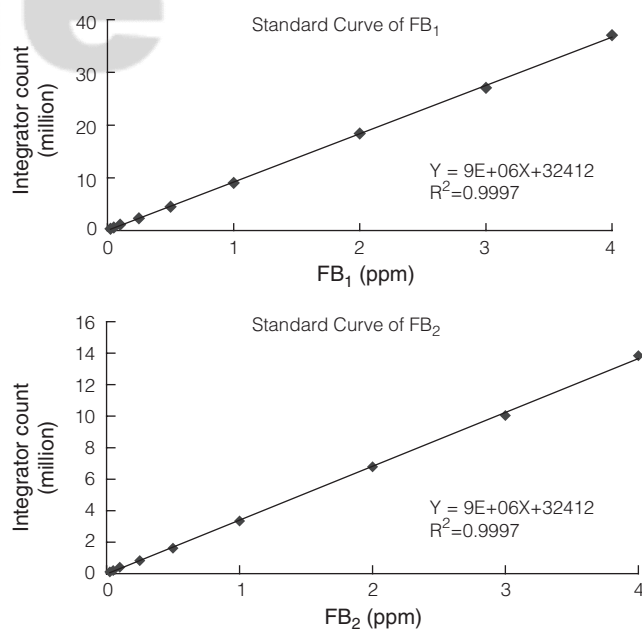


Figure 4. The standard curves for FB<sub>1</sub> and FB<sub>2</sub> derivatives by HPLC.

retention time for FB<sub>1</sub> and FB<sub>2</sub> was 8.4 and 16.1 min, respectively. FB<sub>1</sub> and FB<sub>2</sub> could be separated from other components of the sample solution. The HPLC condition was suitable for analyzing fumonisins in corn.

## II. Establishment of Standard Curve

Twenty microliter of FB<sub>1</sub> and FB<sub>2</sub> OPA derivatives were injected at concentration of 0.025, 0.05, 0.1, 0.25, 0.5, 1, 2, 3 and 4 ppm, The fluorescence responses (peak area) were regressed with injected FB<sub>1</sub> and FB<sub>2</sub> mass and gave a standard curve shown in Figure 4. The linear equation were  $y = 9 \times 10^6x + 32412$  and  $y = 3 \times 10^6x - 21670$  for FB<sub>1</sub> and FB<sub>2</sub>, respectively, where  $x$  represents the concentration (ppm) of fumonisins and  $y$  represents peak area. Regression coefficients ( $R^2$ ) are 0.9997 and 0.9995 for FB<sub>1</sub> and FB<sub>2</sub>, respectively. Linearity is observed for both FB<sub>1</sub> and FB<sub>2</sub> standard curve at 0.025-4 ppm.

## III. Detection Limit Test

Hitachi HPLC was used in this study. The instrument detection limits (IDL) were 0.02 and 0.04 ppm for FB<sub>1</sub> and FB<sub>2</sub>, respectively. Converted to mass was 1 and 2 ng for FB<sub>1</sub> and FB<sub>2</sub>, respectively. The method detection limits (MDL) for corn products were 0.03 and 0.07 ppm for FB<sub>1</sub> and FB<sub>2</sub>, respectively (Table 1). Chu *et al.*<sup>(16)</sup> found that MDL of fumonisin (not specified FB<sub>1</sub> or FB<sub>2</sub>) for corn was 0.05 ppm, On the other hand, Trucksess *et al.*<sup>(25)</sup> detected FB<sub>1</sub> in canned corn and frozen corn, and obtained MDL of 0.025 ppm. Although above-mentioned studies all used immunoaffinity column for extraction and clean up fumonisins, different sample matrix and HPLC instruments supposedly affected the sensitivity.

IV. Recovery and Repeatability Test

Based on consumer's dietary habit, corn products categories surveyed in this study included dried corn (kernel or flour), fresh corn, corn snack, corn flake, corn starch and canned corn, etc. Among them, corn, fresh corn, corn snack and corn flake were chosen for recovery and repeatability study. The detailed recoveries are shown in Tables 2 and 3. Spiked FB<sub>1</sub> at 0.2-3.0 ppm level had recoveries in the range of 79.2-108.8%, and relative standard deviation (RSD) in the range of 2.9-21.9%. Spiked FB<sub>2</sub> in the same condition as FB<sub>1</sub>, recoveries of 70.0-106.0% and RSD of 4.7-20.0%.

Trucksess *et al.*<sup>(25)</sup> spiked FB<sub>1</sub> in canned corn and fresh corn at 0.05-0.2 ppm level. They observed recoveries of 76.7-81.3% and 75.8-88.3% and RSD of 4.9-11.9% and 8.2-13.6% for canned corn and fresh corn, respectively. Visconti *et al.*<sup>(26)</sup> had conducted a collaborative study, in which they determined FB<sub>1</sub> and FB<sub>2</sub> in dried corn and corn flakes by liquid chromatography with immunoaffinity column cleanup. Relative standard deviation for the *in vitro* repeatability (RSD<sub>r</sub>) of the corn analyses ranged from 19-24% for FB<sub>1</sub> and 19-27% for FB<sub>2</sub>; for the corn flakes analyses, RSD<sub>r</sub> ranged from 9-21% for FB<sub>1</sub> and 8-22% for FB<sub>2</sub>. Mean recoveries of FB<sub>1</sub> and FB<sub>2</sub> from dried corn spiked with FB<sub>1</sub> at 0.8 ppm and with FB<sub>2</sub> at 0.4 ppm were 76% and 72%, respectively; for corn flakes spiked at the

**Table 1.** Instrument detection limits (IDL) and method detection limits (MDL) of fumonisins analysis in corn by HPLC

	IDL	MDL
Fumonisin B <sub>1</sub>	0.02 ppm	0.03 ppm
Fumonisin B <sub>2</sub>	0.04 ppm	0.07 ppm

**Table 2.** Recovery of fumonisin B<sub>1</sub> added to corn and corn products

Product	FB <sub>1</sub> spiked (ppm)	Recovery <sup>a</sup> (%)	S.D.	RSD (%)
Corn	0.5	91.3	11.6	12.7
	1.0	90.7	6.9	7.6
	2.0	79.2	2.3	2.9
	3.0	79.9	11.8	14.8
Fresh corn	0.2	81.3	17.8	21.9
Corn snack	0.5	93.2	5.1	5.5
Corn flake	0.5	108.8	11.4	10.5

<sup>a</sup>n = 3.

**Table 3.** Recovery of fumonisin B<sub>2</sub> added to corn and corn products

Product	FB <sub>2</sub> spiked (ppm)	Recovery <sup>a</sup> (%)	S.D.	RSD (%)
Corn	0.5	74.8	11.9	16
	1.0	82.9	4.4	5.3
	2.0	76.2	7.1	9.3
	3.0	70.0	10.1	14.4
Fresh corn	0.2	76.4	15.1	20.0
Corn snack	0.5	81.0	3.8	4.7
Corn flake	0.5	106.0	11.4	10.8

<sup>a</sup>n = 3.

same levels recoveries were 110% and 97% for FB<sub>1</sub> and FB<sub>2</sub>, respectively. The recovery and repeatability results of this study are similar with previous studies.

V. Fumonisin Levels in Corn and Corn Products

Seventy-six samples were collected from markets and snack manufacturers, Table 4 shows detected samples of 7 categories of corn and corn products. There are 11 samples (14.5%) among 76 samples were detected FB<sub>1</sub> and/or FB<sub>2</sub>, fumonisins were not detected in corn flakes, corn starch and canned corn. Five dried corn samples, 1 corn snack sample and 1 sample of raw material of plant were detected with FB<sub>1</sub>. On the other hand, 5 samples were detected with FB<sub>2</sub>. Only 1 dried corn sample were contaminated with both FB<sub>1</sub> and FB<sub>2</sub> and the highest contamination 0.16 ppm was found in a corn snack (Table 5).

The limitation levels of fumonisin are not regulated in Taiwan yet, where as the advisory level of fumonisins varies from 1-4 ppm for different corn products in other countries. Based on the data of this survey, FB<sub>1</sub> and FB<sub>2</sub> levels in human foods derived from corn are quite low and corn products are not the staple food in Taiwan. At the present time, fumonisins in corn and corn products for

**Table 4.** Number of detected samples from corn and corn products

Product	Number of samples	Number of detected samples		
		FB <sub>1</sub>	FB <sub>2</sub>	Total <sup>a</sup>
Corn	20	5	3	7
Fresh corn	5	0	1	1
Corn snack	15	1	1	2
Corn flake	10	0	0	0
Corn starch	5	0	0	0
Canned corn	5	0	0	0
Corn raw material	16	1	0	1
Total	76	7 (9.2%)	5 (6.6%)	11 (14.5%)

<sup>a</sup>Total represents the sample number contaminated with fumonisins (FB<sub>1</sub> + FB<sub>2</sub>).

**Table 5.** Fumonisin levels in corn and corn products

Product	Sample number	Fumonisin (ppm)		
		FB <sub>1</sub>	FB <sub>2</sub>	FB <sub>1</sub> + FB <sub>2</sub>
Corn	C01	0.06	0.07	0.13
	C02	0.06	ND <sup>a</sup>	0.06
	C10	0.05	ND	0.05
	C12	0.07	ND	0.07
	C15	0.05	ND	0.05
	C19	ND	0.09	0.09
	C20	ND	0.08	0.08
Fresh corn	R02	ND	0.15	0.15
	S02	ND	0.16	0.16
Corn snack	S03	0.05	ND	0.05
	N08	0.09	ND	0.09

<sup>a</sup>Not detected.

human consumption in Taiwan presents negligible public health risk.

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