AN INTEGRATIVE APPROACH TO STUDY THE SAFETY ISSUES OF FOOD PRODUCTS IMPORTED FROM CHINA

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A candidate for the degree of Doctor of Philosophy

And hereby certify that, in their opinion, it is worthy of acceptance.

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To those

Who have been tolerating me

Nurturing me

And loving me

Without any conditions

I am extremely grateful to you

And deeply sorry for my bad behaviors

Please continue to be with me

For I cannot imagine

Being without you

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The time I spent at Mizzou has been a marvelous experience. About four years ago, I entered a field which I had never thought I would become linked with before. Now I am submitting a Ph.D. dissertation in this field. It feels surreal. It is my advisors and colleagues that make this possible.

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ABSTRACT

The role of China as one source of U.S. food imports is becoming more and more important, but in recent years there have been several serious incidents about safety issues of food imported from China. This dissertation aims at finding solution for this problem from two different approaches: scientific and behavioral. In the scientific approach, surface enhanced Raman spectroscopy (SERS) coupled with two types of nanosubstrates was used to detect various chemical contaminants in real food matrices. The results showed that SERS has great potential in first-line food safety defense as a rapid, reliable, and accurate method. In the behavioral approach, we modeled food safety practices among Chinese in the United States and surveyed effects of technology advancement on Chinese food exporters' beliefs of business ethics. Among the various findings, the most important one was that the compliance with business ethics standards cannot be improved by technology advancement solely. This dissertation highlights the importance of connecting scientific research with behavioral intervention programs.

CHAPTER 1

INTRODUCTION

1.1. Identification and Significance of the Problem

China is emerging as one of the most prominent sources of U.S. food imports. Before 1999, the annual value of food imports from China was as little as less than one billion dollars (Gale and Buzby 2009); while in 2007, China turned out to be the third largest country exporting agricultural and seafood products to the U.S., just behind two neighboring countries of the U.S., Canada and Mexico (Becker 2008). From 1997 to 2007, U.S. imports of agricultural and food products from China have increased by 385% in weight and 390% in value, much more rapidly than total imports from overseas (Becker 2008). As Figure 1 shows, the annual value of food imports from China has been growing steadily and rapidly in recent years.

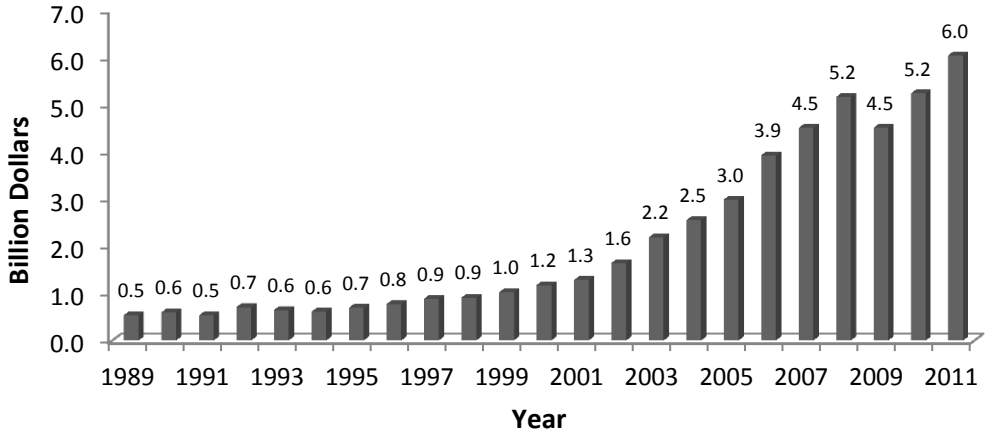

Figure 1. Annual Value of U.S. Food Imports from China, 1989-2011.
Adapted from Gale and Buzby (2009), with data of recent years obtained from the USDA Foreign Agricultural Service (2012).

Imported foods occupy a significant portion of the total U.S. food consumption. In 2005, 15% of the total volume of food consumed in the U.S. was imported (Jerado 2008). Consumption of some foods that have high import shares has been increasing rapidly in recent years. For example, from 2000 to 2005, consumption (in volume) of fish and shellfish increased by 79%, fruits and nuts by 32%, and vegetables by 13% (Jerado 2008). All these foods were among the major types of food imports from China, as shown in Table 1. Accordingly, fish and shellfish, fruit, and vegetable products account for the most refusals of Chinese food shipments ordered by the U.S. Food and Drug Administration (FDA) (Gale and Buzby 2009).

Table 1. Selected Food Imports from China, 2007.

Type	Value ($1,000)	Weight (metric tons unless specified)
Other fish & products (not listed below)	1,228,226	359,215
Fruit juices (kiloliters)	433,387	1,610,250
Fruit, processed	286,207	323,767
Shrimp & prawns	236,354	48,610
Mollusks	207,262	55,184
Other crustaceans	186,580	23,217
Vegetables, prepared or preserved	166,699	146,971
Salmon	111,322	27,119
Fresh vegetables, excluding potatoes	103,909	92,795
Vegetables, dried/dehydrated	103,862	70,711
Vegetables, frozen	72,417	93,545
Fruit, dried	56,519	13,079

Adapted from Becker (2008).

However, despite increasing volume of imported foods from China, there were some important safety incidents of those food products in recent years. On June 28, 2007, based on the results of inspections from October 2006, the FDA announced that all farm-

raised catfish, basa, shrimp, dace, and eel imported from China would be detained until shipments were proven to be free of residues from illegal drugs, such as malachite green, nitrofurans, fluoroquinolones, and gentian violet, which can be potentially harmful to human health and increase antimicrobial resistance (FDA 2007c). In 2004 and 2007, pet foods contaminated with melamine, a nitrogen-rich chemical commonly used to produce plastics, led to several nationwide recalls and resulted in at least 14 animal deaths resulted from renal failure, as confirmed by the FDA (Brown and others 2007; Cianciolo and others 2008; FDA 2009c). A year later in 2008, melamine was also implicated in the global scares of infant formula and other milk-related food products made in China, which sickened more than 294,000 children in China and caused the hospitalization of over 50,000 and at least 6 deaths of infants (Ingelfinger 2008). The FDA responded by issuing a Health Information Advisory recommending against feeding infant formula manufactured in China to infants (FDA 2008b). Although dairy products imported from China accounted for a very small portion of total dairy food consumption in the U.S. (Becker 2008), globalization of food manufacturing considered the U.S. one of the many countries affected by the melamine incident. In 2008, seven U.S. distributors issued recalls for various food products containing milk-related ingredients from China (Table 2).

Table 2. Recalls issued in 2008 involving melamine-contaminated dairy products.

Date recall issued	Company issuing the recall	Product(s) recalled
12/05/08	Walgreens	Teddy bears with chocolate bars
10/29/08	Everlasting Distributors, Inc.	Fresh Crispy Jacobina Biscuits
10/17/08	Lotte USA, Inc.	Koala's March Cookies
10/10/08	Hua Xia Food Trade USA, Inc.	YILI Brand Sour Milk Drink and Pure Milk Drink
10/03/08	Tristar Food	Blue Cat Flavor Drink
10/01/08	Sunny Maid Corp.	Mr. Brown 3-in-1 and 2-in-1 Powdered Packets in Bag Coffee Mixes
09/26/08	QFCO, Inc.	White Rabbit Candy

Adapted from Recalls, Market Withdrawals, & Safety Alerts. A list maintained by the FDA (2009b).

Along with the aforementioned food safety issues, other safety problems were also reported in the US imports. In recent years, three serious incidents involving Chinese products were especially worth mentioning: in 2007, toys were found to have excessive levels of lead (Bapuji and Beamish 2007; Story and Barboza 2007); In 2007, toothpastes were discovered to contain diethylene glycol (DEG), a toxic chemical causing renal failure (FDA 2007b, d); In 2008, heparin was contaminated by oversulfated chondroitin sulfate (OSCS), a chemical causing fatal allergic reactions (AFP 2008; FDA 2009a). All of these incidents caused massive recalls of contaminated products. The heparin incident even resulted in over 100 deaths in the U.S. (Akre 2008).

1.2. Current Countermeasures and Their Drawbacks

Since 1906, the tools FDA used to guard food safety and quality have not changed much. They include facility inspections and border inspections, as well as laboratory sample analysis and product safety reporting systems (FDA 2011). As U.S. food

consumption will rely more and more heavily on products of foreign origins in the future, the effectiveness of these measures will gradually abate.

The primary reason for the aforementioned issues is the cost. Despite the importance of food imports from China and their potential safety problems, careful scrutiny on these subjects has not been made fully possible yet. It was reported that due to lack of staff, the FDA inspected less than 2% of imported foods in recent years (Bridges 2007). Only 1.3% of imported fish, vegetables, fruit and other foods are inspected, all of which are foods imported from China in large quantities (Bridges 2007). Obviously, it is impossible for the FDA to inspect every shipment of food imports. Significantly increasing frequencies of inspection is not practical at this moment, either. Considering current economic conditions and the recent trend of the federal budget, it is not likely that the FDA will get adequate reinforcement in their workforce in the near future.

Another barrier to effective inspection of imported foods is technological limitations. Current analytical methods for testing prohibited substances are mainly based on chromatographic methods such as thin layer chromatography (TLC), gas chromatography-mass spectrometry (GC-MS), and high-performance liquid chromatography (HPLC). They are time-consuming, expensive, and labor-intensive. These methods usually require complex procedures of sample pretreatment and well-trained technicians to operate the instrumentation.

Furthermore, although novel analytical methods are more powerful than traditional methods and are consistently being developed and put into practice, implementation of them is not a fundamental approach to solve safety problems of food imports. In retrospect, when current methods made their debuts, they were state-of-the-art and extremely powerful weapons at that time, but they didn't really help prevent food

safety incidents from happening. While encouraging stories appear occasionally in science sections of newspapers, food safety incidents keep making the headlines. Over time, the power of these analytical methods does not seem to make intentional adulterators frightened of being caught.

1.3. The Answer: An Integrated Approach

Based on discussions in previous sections, the current food safety situation of foods imported from China can be summarized as follows:

- Foods imported from China play a critical and indispensable role in the U.S. food supply.
- Food imported from China has been surging in recent years, accompanied with an increasing amount of serious safety problems.
- In practice, current countermeasures are not effective enough to prevent such safety incidents from happening.
- Previous experience indicates that advancement in detection methods alone did not prevent food adulteration.

Therefore, a new approach is needed to battle the problem. It should be multi-faceted—in addition to continued efforts in development of analytical methods, it should pay more attention to the individuals who are involved in or are responsible for food safety incidents. Programs aiming at changing these individuals' behaviors could play a very important role in such an approach.

For two reasons, behavioral research and behavior-changing programs are especially suitable for safety problems of food imports from China. First, behavioral reasons are the main causes of these problems. According to the FDA statistics, most Chinese food imports are processed to some degree, and the most common problems cited by the FDA—"filth", unsafe additives, inadequate labeling, and lack of proper manufacturer registrations—are typically introduced during food processing and handling (Gale and Buzby 2009). Second, from a more general perspective, it is argued that food safety is closely related to human behavior; thus, an effective approach to reinforce food safety is to motivate individuals working in this field to comply with established rules and regulations (Yiannas 2009).

This dissertation describes the first few steps of developing an integrated approach that has two intertwined branches. On one hand, development of novel analytical methods is still very important. Given current situations, a rapid, sensitive, and accurate method is critically needed. One method that meets such requirements is surface-enhanced Raman spectroscopy (SERS). How SERS can be applied directly to several high-profile contaminants in different foods was studied. The steps and results are detailed in this dissertation. On the other hand, to make progress towards completion of Chinese food manufacturers' profile, two studies were conducted in the behavioral approach. The two studies were designed to aim at providing valuable information about two important aspects, respectively—how the individuals working in China's food industry perform in manufacturing and delivering their products. The first aspect was examined by assessing how safe the subjects prepare food and how well they know about safe food handling practices, i.e. their attitudes, knowledge, and practices about food safety. The second aspect was investigated by studying how the subjects handle business

affairs, i.e. their attitudes and beliefs in business ethics and their reactions when facing certain business situations. To link the scientific approach with the behavioral approach and to confirm that advancement in technology alone could not keep food safety incidents from happening, the second behavioral study included a special section to evaluate the effects of advancement in technology on the subjects' business ethics.

The framework of this dissertation is briefly depicted in Figure 2.

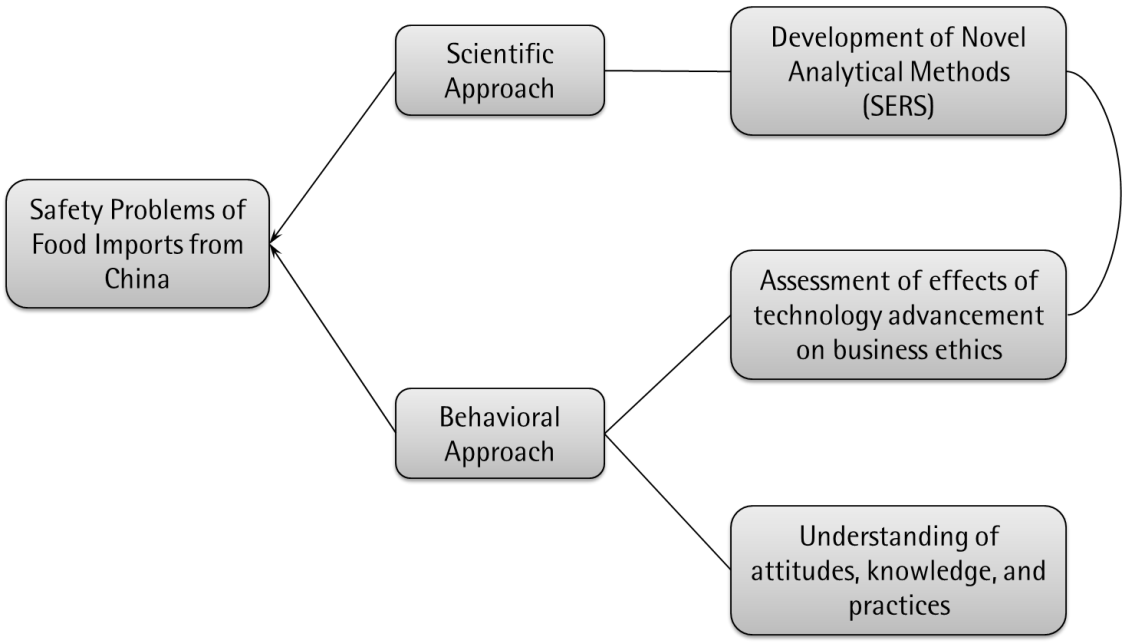

Figure 2. An integrative approach to study the safety problems of food imports from China.

CHAPTER 2

LITERATURE REVIEW

2.1. Scientific Approach

2.1.1. Contamination of several types of foods by pesticides and other chemicals

It was mentioned in Chapter 1 that melamine (2, 4, 6-triamino-1, 3, 5-triazine) was implicated in the pet and human food recalls in 2007 and in the global food safety scares in 2008 involving milk and milk-derived products. Cyanuric acid (1,3,5-triazine-2,4,6-triol), a chemical that is similar in structure as melamine, was also suggested to be involved in these incidents (Cianciolo and others 2008), but was not confirmed later. As shown in their molecular structures (Figure 3), both melamine and cyanuric acid have very high nitrogen contents (67% for melamine and 33% for cyanuric acid); thus, both of them could be added to foods and animal feed to boost the protein content. In the past, the dairy industry used the classic Kjeldahl method to determine the protein content, which only measures total nitrogen content and thus cannot distinguish nitrogen of adulterants from the protein nitrogen (Burns and Kahler 2007; Wong and Chiu 2008). Lack of fast and reliable detection methods worsened the great challenge posed by the melamine incident to global food safety.

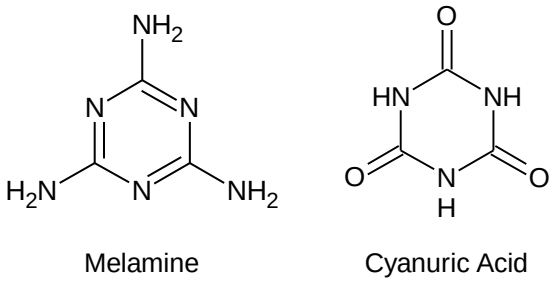

Figure 3. Molecular structure of melamine and cyanuric acid.

The food safety incidents caused by melamine occurred recently, but some other food safety problems have been lingering around for a long time, like contamination of foods by pesticide residues. Undoubtedly, the invention and improvement of pesticides have greatly advanced and even transformed agriculture, but the abuse and inadequate understanding of them have caused unforgettable tragedies, the most prominent of which may be the story of DDT (Mellanby 1992). Thanks to the efforts of scientists, regulatory officials, activists, and other related individuals, nowadays the risks of pesticides have been so thoroughly studied that regulatory agencies are very unlikely to approve a pesticide that would later prove to be a disaster. To some extent, the major problem of pesticides now lies no longer in pesticides themselves, but in the intentional or unintentional misuse of them by farmers, which may result in excessive pesticide residuals in agricultural products. Therefore, developing good detection methods for pesticides is one effective way to reinforce food safety.

According to Residue Monitoring Reports published by the U.S. FDA, pesticide residues exist in a large portion of certain types of fruits and vegetables (FDA 2006, 2007a, 2008a). The FDA found that from 2004 to 2008, more domestic fruit samples contained pesticide residues, suggesting that the use of pesticide in fruits is increasing (FDA 2012). These findings concur with and corroborate consumers' growing concern in

recent years about contamination of pesticides in fruits. Therefore, reliable and accurate detection methods for pesticides in fruits and vegetables are crucially needed. We chose three kinds of popular fruits and vegetables (apples, tomatoes, and strawberries) that have been found to frequently contain pesticide residues as our study subjects.

The pesticides we targeted on apples and tomatoes were organophosphosphate (OP) and carbamate (CB) compounds. They were selected based on the following reasons. These two groups of compounds have been used for decades to fight against pests to increase the yields of agricultural products. Because of their ability of inactivating acetylcholinesterase, OP and CB are considered to have potent neurotoxicity (He 2000; Gupta 2004; Costa 2006). Several studies suggest that chronic exposure to OP and CB, even at low to mild doses, may lead to long-term adverse neurobehavioral effects (Wesseling and others 2002; Costa 2006). OP and CB are indeed widely used in fruits and vegetable crops (Kegley and Wise 1998). Three popular OP and CB pesticides, azinphos-methyl, carbaryl, and phosmet, were chosen as subjects of this study.

The subjects of the strawberry study were determined using a practical approach. The USDA maintains an official list of the most frequently found pesticides on strawberries (Pesticide Action Network 2012). Three pesticides at the top of this list, captan, pyraclostrobin, and myclobutanil were selected as the subjects. Among them, captan and pyraclostrobin are carbamates, while myclobutanil is an organochlorine compound. Toxicity of these pesticides has been well studied, as demonstrated in the list.

Figure 4 shows molecular structures of the pesticides mentioned above.

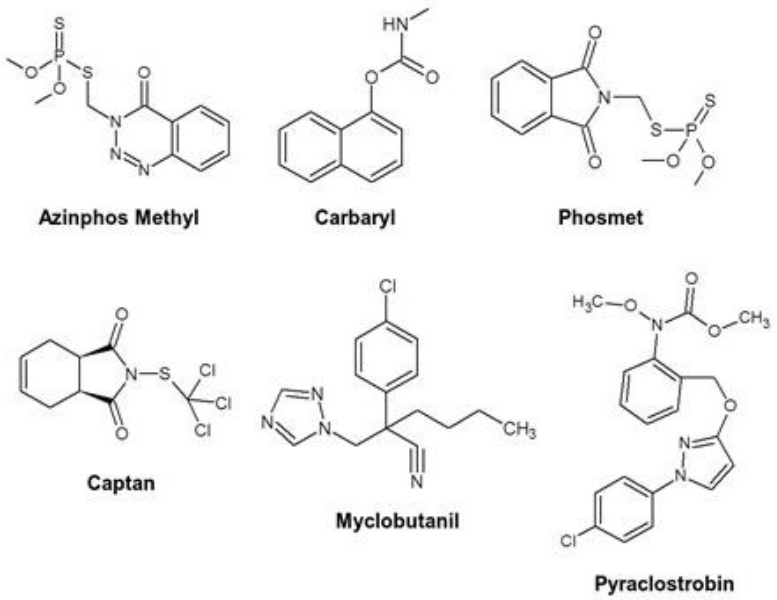

Figure 4. Molecular structures of pesticides targeted in the research.

2.1.2. Current advances in analytical methods for detecting melamine and pesticides

As stated in Chapter 1, official analytical methods for testing prohibited substances such as melamine and pesticides are becoming unsuitable for current situations. For example, official methods for melamine (developed by the FDA in the wake of the melamine incidents) are GC-MS methods (FDA 2009d); current methods adopted by Association of Official Analytical Chemists (AOAC) for detection of pesticides targeted in this research in fruits and vegetables are various TLC and GC setups (AOAC International 2005; Ortelli and others 2005; Rawn and others 2006).

Researchers have been constantly making efforts to address this question. To date, various novel techniques had been developed for melamine detection, including enzyme-linked immunosorbent assay (ELISA) (Garber 2008), capillary zone electrophoresis with diode array detection (Yan and others 2009), various mass spectrometry methods (Campbell and others 2007; Heller and Nochetto 2008; Huang and others 2009; Yang and others 2009; Zhu and others 2009), and mid- and near-infrared spectroscopy (Mauer and

others 2009; Balabin and Smirnov 2011). For pesticides, in recent years, we have witnessed advances in LC-MS (Liu and others 2005; Ortelli and others 2005; Grimalt and others 2007), fluorescence polarization immunoassay (Kolosova and others 2003), multienzyme inhibition assay (Walz and Schwack 2007), and biosensors (Zhang and others 2005; Valdés-Ramírez and others 2008).

In terms of detection capability, the methods listed above perform very well. They can detect trace amount of melamine and pesticide residues. Some of them can even reach the ppb levels. Yet, the most important properties for a method that truly fits first-line food safety assurance should possess—rapidness and simplicity— is still lacking. This is where the value of work presented in this dissertation lies.

2.1.3. Mechanism and applications of SERS

There are not too many analytical methods that can get the result quickly and still have satisfactory accuracy and reliability. Raman spectroscopy, one type of vibrational spectroscopy, meets these requirements. The basic mechanism of vibrational spectroscopy is that it detects molecular vibrations, which occur when atoms in a molecule are in periodic motion while the molecule as a whole has constant translational and rotational motion. Characteristic information on various chemical and biochemical components in a complex system can be obtained from the “fingerprint-like” Raman spectra while little or no sample preparation is required (LiChan 1996). Therefore, in recent years, there has been increasing interest in the use of this novel vibrational spectroscopic method as an analytical technique to evaluate food safety and quality. A detailed mechanism of Raman spectroscopy is elaborated on in the next section.

2.1.3.1. Raman spectroscopy

When light interacts with matter, the photons will interact with the molecule and scatter from it. The scattered photons can be observed by collecting light at an angle to the incident light beam and provided there is no absorption from any electronic transitions which have similar energies to that of the incident light, the efficiency increases as the fourth power of the frequency of the incident light (Smith and Dent 2005).

Raman spectroscopy uses a single frequency of radiation to irradiate the sample. The spectrometer detects the radiation scattered from the molecule that is different in energy from the incident beam. Unlike infrared, Raman scattering does not require matching of the incident radiation to the energy difference between the ground and excited states. In Raman scattering, the light interacts with the molecule and distorts (polarizes) the cloud of electrons around the nuclei to form a short-lived state called a "virtual state". This state is not stable and the photon is quickly re-radiated.

The energy changes detected in vibrational spectroscopy are those required to cause nuclear motion. If only electron cloud distortion is involved in scattering, the photons will be scattered with very small changes in frequency, as the electrons are comparatively light. This scattering process is regarded as elastic scattering and is the dominant process, which is called Rayleigh scattering. However, if nuclear motion is induced during the scattering process, energy will be transferred either from the incident photon to the molecule or from the molecule to the scattered photon (Kneipp and others 1999). In these cases, the process is inelastic and the energy of the scattered photon is different from that of the incident. This is called Raman scattering. It is inherently a weak process in that only one in every 10^6–10^8 photons undergoes Raman scattering (LiChan 1996).

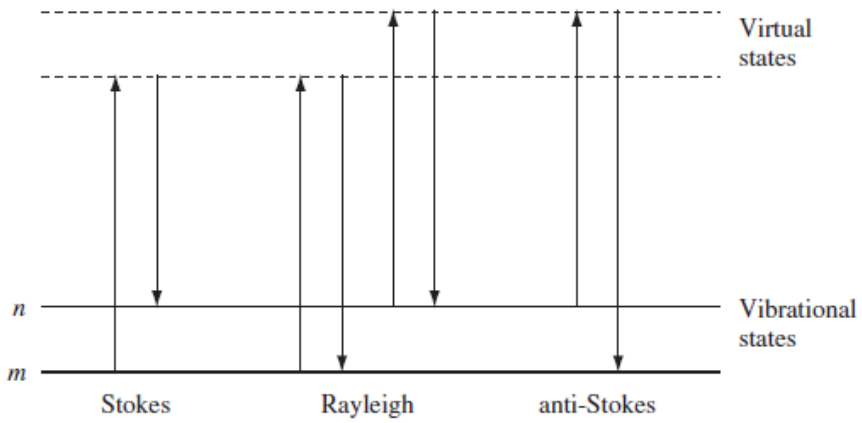

Figure 5. Rayleigh and Raman scattering processes.
m and *n* represent energy vibrational states.
Adapted from Smith and Dent (2005).

Figure 5 shows the basic processes which occur for one vibration. At room temperature, most molecules are present in the lowest energy vibrational level (*m*). Since the virtual states are not real states of the molecule but are created when the laser interacts with the electrons and causes polarization, the energy of these states is determined by the frequency of the light source used. The Rayleigh process does not involve any energy change and consequently the light returns to the same energy state. The Raman scattering process from the ground vibrational state *m* leads to absorption of energy by the molecule and its promotion to a higher energy excited vibrational state (*n*). This is called Stokes scattering. However, due to thermal energy, some molecules may be present in an excited state such as *n*. Scattering from these states to the ground state *m* is called anti-Stokes scattering and involves transfer of energy to the scattered photon. At room temperature, the number of molecules expected to be in an excited vibrational state other than any really low-energy ones will be small. Thus, compared to Stokes scattering, anti-Stokes scattering will be weak. The theoretic relative intensities of the two processes can be derived from the Boltzmann distribution (Kip and Meier 1990):

$$\frac{I_S}{I_{AS}} \propto \exp\left[\frac{h\nu_l}{kT}\right] \quad (1)$$

where I_S and I_{AS} are respectively the intensities of Stokes and anti-Stokes scattering, $h\nu_l$ is the difference of energy between the excited and the ground states, k is Boltzmann's constant (1.3807×10^{-23} J·K^{-1}), and T is absolute temperature. From this formula, it can be inferred that anti-Stokes scattering will increase relative to Stokes scattering as the temperature rises.

If the frequency of incident light is fixed, how much and how strong Raman scattering will occur solely depends on the molecule with which the incident protons interact. Therefore, using exciting protons that undergo Raman scattering, structural characteristics of the molecule can be interpreted. In a Raman spectrometer, a system of specially designed optical filters is used to show the existence of scattered protons with an altered frequency from the incident light.

2.1.3.2. SERS

SERS gives an enhancement of about 10^4 or higher in scattering efficiency over normal Raman scattering. SERS was initially observed in 1974 (Fleischmann and others 1974). The group of scientists reported strong Raman scattering from pyridine adsorbed from an aqueous solution onto a silver electrode roughened by means of successive oxidation–reduction cycles. Later on, it was determined that for SERS to occur, bonding or adsorption of an organic molecule to a roughened metal surface is essential (Albrecht and Creighton 1977; Jeanmaire and Van Duyne 1977).

Metal surfaces are covered with free electrons. At the surface, the positive charge is only on the metal side of the electrons. Consequently the electron density extends a considerable distance from the surface and there is also freedom of movement in a lateral

direction along it. When a light beam interacts with these electrons, they begin to oscillate as a collective group across the surface. These oscillations are termed surface plasmons. Surface plasmons from small uniform particles, or from surfaces that have a single periodic roughness feature, have a resonance frequency at which they absorb and scatter light most efficiently. The frequency varies with the metal and the nature of the surface. Both silver and gold plasmons oscillate at frequencies in the visible region and therefore, they are suitable for use with the visible and near-infrared (NIR) laser systems commonly used in Raman scattering. To get scattering, an oscillation perpendicular to the surface plane is needed and this is achieved by roughening the surface. This locates the plasmon in the valleys of the roughened metal surface and scattering is caused as the plasmons move up to the peaks (Smith and Dent 2005).

Currently, there are two different theories explaining the surface enhancement effect: electromagnetic enhancement and charge transfer enhancement (Kneipp and others 2002; Haynes and others 2005).

Electromagnetic enhancement theory assumes that the analyte is adsorbed onto or is held in close proximity to the metal surface, and an interaction occurs between the analyte and the plasmons. At a certain incident frequency (plasmon resonance frequency), the excitation of the surface plasmon greatly increases the local field surrounding the molecule absorbed on the metal surface. The freely moving electron cloud around the molecule significantly intensifies the polarization of the surface electrons. The electrons in the analyte molecule adsorbed on the surface interact with this cloud causing greater polarization around the molecule.

Charge transfer or chemical enhancement theory involves the formation of a bond between the analyte and the metal surface. This bond is believed to produce a surface

species which includes the analyte and some surface metal atoms. This makes it possible to transfer charge (electrons) from the metal surface into the analyte. The formation of this surface species will increase the molecular polarizability of the molecule considerably due to interaction with the metal electrons.

There is evidence to support both aforementioned theories for SERS. However, it is very difficult to differentiate between them. Clearly, chemical enhancement should occur only from molecules directly attached to the surface and consequently should increase only up to monolayer coverage. However, electromagnetic enhancement, although a longer range effect, drops off as $1/r^3$ with distance from the surface. Thus, most of the electromagnetic enhancement will also arise from adsorbates present on the surface up to monolayer coverage. The vast majority of evidence points to both effects having a part to play although it is generally believed that the electromagnetic enhancement may have a greater part to play than the charge transfer enhancement.

Nanosized particles can be used as SERS-active substrates because they have a very high surface-to-volume aspect ratio, which is an important parameter to ensure that a great number of probe molecules are captured in the close vicinity of the metal surface. To date, gold and silver are two most frequently used materials for fabrication of SERS-active nanosubstrates.

2.1.3.3. Application of SERS in food science

As previously stated, SERS is a much more sensitive method than conventional Raman with great potential to detect chemicals at ppb level or even a single molecule (Kneipp and others 2002). SERS has been used in rapid detection and characterization of various food contaminants and adulterants, including banned seafood drugs such as crystal violet and malachite green (He and others 2008a; Lai and others 2011), melamine

and its derivatives (He and others 2008b), and banned food dye Sudan-1 (Cheung and others 2010). SERS has also been applied to study foodborne microbes (Lu and others 2011).

The objective of studies in scientific approach presented in this dissertation was to use SERS coupled with novel nanosubstrates for rapid detection of contaminants (melamine and pesticides) extracted from foods (milk, apples, tomatoes, and strawberries). Multivariate statistical methods were used to analyze SERS spectral data and develop quantitative and qualitative models for data analysis.

2.2. Behavioral Approach

2.2.1. Modeling food safety practices among Chinese in the United States

2.2.1.1. Theory of planned behavior

Several psychological behavior theories have been successfully implemented in researches on health-related behavior. Among them, the most widely used ones are Health Belief Model (HBM), Theory of Reasoned Action (TRA) and its extension, Theory of Planned Behavior (TPB), Transteoretical Model (TTM), and Precaution Adoption Process Model (PAPM) (Glanz and others 2008). TPB is specifically useful in identifying factors that influence a specific behavior; thus, it is often selected as the theoretical base of exploratory studies that guide development of intervention programs. In this study, we aimed at identifying the factors that influence Chinese people's food safety practice and hopefully providing helpful information about how to prevent food safety incidents caused by foods imported from China via a behavioral approach, so TPB was chosen to help develop the instrument.

TPB holds the presumption that human behavior is related to attitudes and can be predicted from them (Ajzen 1991). According to TPB, human behavioral intention is a function of three factors: attitude toward behavior, subjective norms, and perceived behavioral control. Attitude toward behavior is an individual's personal evaluation of an action, that is, how positively or negatively the individual views the particular behavior. Subjective norms are an individual's perception of the society's normative opinion about an action. This construct reflects how greatly social pressure and significant others' beliefs on a particular behavior influence an individual's belief on whether he/she should carry out the behavior or not. Perceived behavior control, which is very similar to the concept of self-efficacy (Bandura 1997), is an individual's evaluation of his or her own ability to execute an action.

2.2.1.2. Applications of TPB in the field of food safety

Because of its emphasis of specificity, TPB has been applied to a wide range of behaviors. Researchers have used TPB to model behaviors such as seat belt use (Ali and others 2011; Tavafian and others 2011), weight gain prevention (Aylaz and others 2011), oral hygiene behavior (Buunk-Werkhoven and others 2011), suicide intervention (Gipson and King 2012), healthy diet (Jacobs and others 2011), volunteer receipt of H1N1 vaccine (Liao and others 2011), condom use (Steyn and others 2009), and many others.

However, TPB hasn't been used extensively in empirical studies aimied at understanding people's beliefs and practices of food safety. Of the few studies, an extended TPB model was used to predict food handlers' hand hygiene practices in Wales; and attitudes, subjective norms, and intention were identified as significant predictors (Clayton and Griffith 2008). In another study conducted in the United Kingdom, TPB was utilized to investigate chicken purchasing behavior in the context of perception of food

safety information, which showed that attitudes contributed to the intention to purchase (Lobb and others 2007). An Australian study found that attitudes and subjective norms were significant predictors of behavioral intention of safe food handling and that the intention was a strong predictor of behavior (Mullan and Wong 2009). In this study we evaluated the efficiency of TPB factors (attitude toward behavior, subjective norms, and perceived behavioral control or self-efficacy) for predicting safe food handling practices of our subjects. Since knowledge has been reported as both a significant predictor (Evans and others 1978; Kenkel 1991; Harnack and others 1997; Frank and others 1998; Cheung and others 1999; Achat and others 2005; Poutanen and others 2006) and insignificant predictor (Patterson and others 1996; Helweg-Larsen and Collins 1997; Arnold and others 2001; Gordon-Larsen 2001; Mirmiran and others 2007; Berten and Van Rossem 2009) of various health-related behaviors, we also assessed our subject's knowledge about safe food handling and tested whether those who achieved high knowledge scores exhibited better safe food handling practices.

2.2.2. Assessment of effects of technology advancement on Chinese food exporters' beliefs of business ethics

It has been firmly established that human behaviors originate from beliefs and attitudes (Ajzen and Fishbein 1980; Ajzen 2005). In our context, the (seemingly) abnormal behaviors of Chinese food adulterators or exporters mentioned above may be because they defy the norms of business ethics generally accepted in the west or they follow a different set of business ethics.

In this study, we tried to confirm the fact that advancement in technology does not necessarily lead to the disappearance of food safety problems in the context of Chinese

food exporters. We surveyed Chinese food exporters' beliefs of business ethics, hoping to find some information on the reasons behind this strange phenomenon. In particular, we assessed how much the Chinese food manufacturers will seek to *guanxi*, a characteristic component in Chinese business ethics, when faced with an incident. Our findings may be helpful in the process of resource allocation in the assurance of safety of imported food.

2.2.2.1. Chinese business ethics

Chinese business ethics today are the product of many unique factors. Drastic social changes in the past century result in equally significant shifts in culture. The traditional Confucian values, such as *ren* (capacity of compassion), *yi* (moral rightness), and *li* (etiquette and norms), have greatly diminished and are considered too antiquated to rise to complex challenges of modern business (Lam 2003; Ip 2009). Those haven't been abandoned, but combined with externally infused Marxist and capitalist values, become the backdrop of China's business stage nowadays (Lu 1997, 2008). The reform from a centrally-planned economy to a market economy initiated about three decades ago brings remarkably rapid economic development, but in terms of impact on economy, the government still eminently prevails over the market and is continuing to become more dominant in recent years (Freeman and Yuan 2011; Huang 2011; Meyer 2011). Chinese business ethics, nurtured in this particular situation, are different from those of western countries in many ways.

Some cross-cultural studies compared perception of various aspects of business ethics by individuals from western culture with Chinese people's perception of such topics. Generally, Chinese people tend to be more flexible or realistic than their western counterparts, as evidenced by the following studies. Compared to American students, Chinese respondents were more motivated by profit, showed more approval of practices

based on interpersonal relationships, and were more likely to use unethical means to achieve their profit objective (Whitcomb and others 1998). Chinese business students were more accepting of intentional omission of product service information that may benefit consumers than students from Korea, Finland, Egypt, and the U.S. (Ahmed and others 2003). They agreed more than U.S. students that today's business people sometimes have to conduct shady practices in order to survive (Peppas and Yu 2007). On a theoretical level, several empirical studies consistently demonstrated that the differences on ethical values and practices between Chinese and U.S. business people could be attributed to cultural factors (Ralston and others 1997; Douglas and Wier 2005; Cherry 2006; Shafer and others 2006).

2.2.2.2. *Guanxi*

One unique and important component of business ethics in China is *guanxi*. This word literally means interpersonal connections, but in a business setting it represents distinctive relationship-building and benefit-seeking processes the subtleties of which cannot be accurately described in English. One of the most authoritative definitions of *guanxi* is made by Davies (1995): *Guanxi* is "the social interactions within the network place and its members in the equivalent of an infinitely repeated game with a set of people they know." The components of *guanxi* have been explored by some researchers. Wong and Chan (1999) identified four constructs in *guanxi*-style interactions: adaptation, trust, opportunism, and favor, based on which a perceptual map was provided. Su and Littlefield (2001) keenly pointed out that in mainland China exist two types of *guanxi*: favor-seeking and rent-seeking. Nie and others (2011) broke the effects of *guanxi* on organization performance into three aspects: face, reciprocity, and affect. While some researchers considered the *guanxi* framework and business practices based on it as

origins of corruption and bribery (Steidlmeier 1999; Dunfee and Warren 2001; Luo 2008), others argued that in practice favor-seeking *guanxi* is not related to ethics issues (Su and others 2003) and that for an individual *guanxi* does not provide actual advantage (Fan 2002). In addition, Nie and others (2011) suggested that the use of *guanxi* by a business firm will eventually backfire, harming the firm's performance in the long run. Recently, a scale has been developed to measure the extent of *guanxi* (Yen and others 2011). It can be expected that more convincing studies will be conducted to clarify the content of *guanxi* and its relationship with business practices in the future.

CHAPTER 3

MATERIALS AND METHODS

3.1. Scientific Approach

3.1.1. Analytes and sample preparation

3.1.1.1. Detection of melamine and cyanuric acid extracted from milk

Melamine (99%, Acros Organics, Geel, Belgium) and cyanuric acid (99%, Alfa Aesar, Ward Hill, MA, USA) were purchased from Fisher Scientific Inc. (Pittsburgh, PA, USA). Liquid milk (2% reduced fat) was purchased from a local grocery store and used directly without any further treatment.

Melamine was spiked into liquid milk at various levels between 100 to 0 ppm (w/v). First, a stock solution of 100 ppm was prepared and stirred using a magnetic stirring bar for about 2 min. Then solutions of 80, 60, 40, 20, 10, 2, and 1 ppm were diluted from the 100 ppm stock solution. Cyanuric acid was spiked into liquid milk at the levels of 80, 40, and 20 ppm (w/v). Solution of 80 ppm was stirred using a magnetic stirring bar for about 5 min. Then 40 and 20 ppm solutions were prepared by dilution from the 80 ppm solution. Control samples were milk without adding melamine or cyanuric acid and were treated the same way as experimental samples in subsequent steps.

Extraction of melamine from milk samples was conducted based on a standard FDA method for melamine detection with some modifications (Smoker and Krynitsky 2008). Briefly, milk samples were sonicated using an ultrasonic processor equipped with a

6.5 mm tapered microtip (Sonics & Materials, Inc. Newtown, CT, USA) for 2 min with 30 s working and 10 s intervals at an amplitude of 30%. Acetonitrile was then added to the sample immediately after sonication in the same volume with each sample. Samples were briefly shaken followed by centrifugation (Omnifuge RT, American Scientific Products, McGraw Park, IL, USA) for 7 min at 3800 rpm and 25°C. Extraction of cyanuric acid from liquid milk was similar to that of melamine except that methanol was used for extraction instead of acetonitrile because methanol had been proven to be a better extractant for cyanuric acid (Yu and others 2009).

3.1.1.2. Detection of pesticides in apples, tomatoes, and strawberries

Pesticides (azinphos-methyl, phosmet, carbaryl, captan, pyraclostrobin, tetrahydrophthalimide, myclobutanil, and pyrimethanil) were purchased from Fisher Scientific Inc. (Pittsburgh, PA, USA). Two OP pesticides (azinphos-methyl and phosmet) and one CB pesticide (carbaryl) were used in the study of apples and tomatoes. The rest were used in the study of strawberries. Organic apples (Granny Smith), tomatoes, and strawberries were purchased from a local supermarket. Organic fruits were selected and cleaned to ensure that no pesticide residues existed on the samples.

Primary secondary amine (PSA)-bonded silica (100 g, bulk) was supplied by Supelco (Bellefonte, PA, USA). Reagent-grade anhydrous sodium chloride and magnesium sulphate were purchased from Fisher Scientific.

Pure pesticide solutions: 100 ppm (w/v) of azinphos-methyl, phosmet, carbaryl, captan, pyraclostrobin, tetrahydrophthalimide, myclobutanil, and pyrimethanil stock solutions were prepared using a mixed solvent system (acetonitrile : H_2O = 1 : 1, v/v). Solutions of 50, 10, 5, 1, 0.5, and 0.1 ppm pesticides were prepared by serial dilutions from the 100 ppm solution. The solvent without pesticides was used as the control.

Apples and tomatoes were weighed and their diameters were measured. Assuming that an apple or a tomato is of spherical shape, surface area of the fruit was calculated. Using these data, given designated pesticide concentration on a fruit (ppm, or equivalently, μg/g), the mass of pesticide (μg) that should be spiked on one cm^2 of fruit skin was obtained. Then certain amounts of pesticide solutions were dropped with a pipetter onto a piece of ~ 4 cm^2 fruit skin freshly peeled from the fruit. Extra care was taken to ensure even distribution of the solution on the fruit skin. The skin of the samples were then blown dry, cut into small pieces, and placed in conical tubes containing 4 mL of mixed solvent (acetonitrile : H_2O = 1 : 1, v/v). After vigorous vortexing for 1 min, the mixture was sonicated using an ultrasonic processor equipped with a 6.5 mm tapered microtip (Sonics & Materials, Inc. Newtown, CT, USA) for 5 min with 30 s working and 10 s intervals at an amplitude of 30%. Finally, the supernatant was filtered with a 0.22 μm syringe filter and the filtrate was used for SERS measurement.

Preparation of strawberry samples was based on the the QuEChERS (quick, easy, cheap, effective, rugged, and safe) method (Anastassiades and others 2003) modified and adopted by previous studies (Bolaños and others 2007; Lesueur and others 2008). The strawberries were chopped, homogenized and stored at -20°C until analysis. After thawing in a water bath at room temperature, samples were spiked with the corresponding volume of the working solution. A 10 g homogenized sample was put into a 50 mL conical tube. Then 10 mL acetonitrile was added and the tube was shaken vigorously for 1 min using a vortexer. Next, 1 g anhydrous NaCl and anhydrous and 4 g $MgSO_4$ were added and a second shaking was immediately performed. The sample then underwent centrifugation at 2750g for 6 min at room temperature (Omnifuge RT, American Scientific Products, McGraw Park, IL, USA). An aliquot of 1 mL of the upper

layer was placed in a 2.0 mL safe-lock micro test tube containing 25 mg of PSA and 150 mg of $MgSO_4$. The test tube was subsequently centrifuged at 3500 g for 1 min with a microcentrifuge (Eppendorf Minispin Plus, Eppendorf North America, Hauppauge, NY, USA). The supernatant was filtered with a 0.22 µm syringe filter and the filtrate was used for SERS measurement.

3.1.2. SERS substrates

Klarite™ SERS-active substrates (Renishaw Diagnostics Ltd., Glasgow, UK) were used in the studies of milk and strawberries. These devices were fabricated on silicon wafers coated with gold. A 6 mm × 10 mm chip including a 4 mm × 4 mm patterned SERS-active area and an unpatterned gold reference area was adhered to a standard 25 mm × 75 mm microscope slide. Pyramidal subunits begin as ~ 1.8 µm openings and arranged in a square lattice configuration at a separation of ~ 0.4 µm (Figure 6). Sharp edges, or "hot spots", of this gold metal surface can produce surface plasmon resonances induced by the incident excitation laser, generating an enormously enhanced electromagnetic field of signals that take place within the highly localized optical fields of metallic structures.

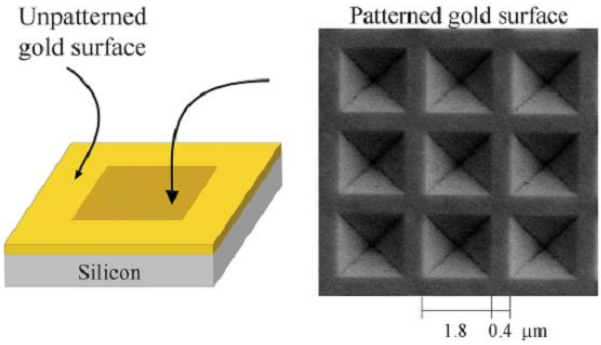

Figure 6. Scanning electron microscopy (SEM) micrograph of a Klarite™ gold substrate.

Q-SERS™ G1 substrates, obtained from Nanova Inc. (Columbia, MO, USA), were employed in the study of apples and tomatoes. Q-SERS™ substrates are gold-based nanostructures fabricated on a silicon wafer with dimensions similar to Klarite™ (Figure 7).

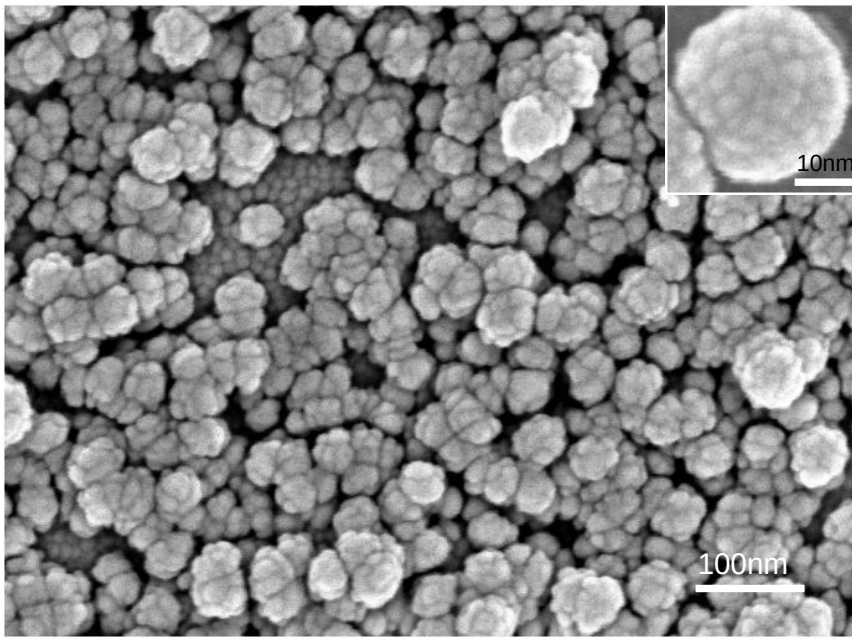

Figure 7. Scanning electron microscope image of a Q-SERS™ G1 substrate surfaces (Inset: high magnification image of an individual nanoparticle).

A volume of ~ 0.3–0.5 µL of SERS-ready samples prepared from previous steps were dropped on the surface of a substrate using a micropipette. The substrate, which was fixed on a glass slide, was then placed on a hot plate and heated at 35–40°C until the solvent completely evaporated.

3.1.3. SERS measurement

A Renishaw RM1000 Raman Spectrometer System (Gloucestershire, UK) equipped with a Leica DMLB microscope (Wetzlar, Germany) was used in this study. This system is equipped with a 785 nm near-infrared diode laser source. During the measurement, light from the high power (maximum at 300 mW) diode laser was directed and focused onto the sample at a microscope stage through a 50× objective. Raman scattering signals were detected by a 578 × 385 pixels CCD array detector. The size of each pixel was 22 µm × 22 µm. Spectral data were collected by WiRE 1.3 software (Gloucestershire, UK) for melamine and cyanuric acid and WiRE 3.2 for pesticides. Spectra of samples were collected using a 50× objective with 10 s exposure time, 50% focus, and ~ 20 mW laser power in extended mode for melamine and cyanuric acid. These conditions were the same for pesticides except that the focus was changed to 0%. Detection ranges were 500 to 1200 cm^{-1} for melamine and cyanuric acid, 550 to 1650 cm^{-1} for azinphos-methyl, 550 to 1800 cm^{-1} for phosmet, 600 to 1700 cm^{-1} for carbaryl, and 300 to 1700 cm^{-1} for other pesticides. The detection range was determined in a way that the range was as narrow as possible but no obvious signals were missed.

3.1.4. Data analysis

SERS spectral data were analyzed by Delight version 3.2.1 (D-Squared Development Inc., LaGrande, OR, USA). Data pre-processing algorithms including polynomial subtract and Savistky-Golay smoothing were employed to subtract the baseline shift and eliminate high frequency noises from the instrument.

3.1.4.1. Partial least squares (PLS) model

PLS is a multivariate statistical regression model. It was constructed to predict analyte concentrations in all tested samples. The PLS model was validated by leave-one-out cross validation, which uses all but one sample to build a calibration model and repeats for each sample in the data set (Martens and Næs 1992). The number of PLS latent variables was optimized based on the lowest root mean square error of prediction (RMSEP) values to avoid overfitting of spectral data:

$$\mathrm{RMSEP} = \sqrt{\frac{\sum_{i}^{n} (\hat{c}_i - c_i)^2}{n}} \qquad (2)$$

where n is the number of samples, $\hat{c}_i$ is the predicted melamine concentration (ppm), and c_i is the actual melamine concentration (ppm). The correlation coefficient (R) and RMSEP were used to evaluate the model. The higher the R value or the lower the RMSEP value is, the better predictability the model has.

3.1.4.2. Principal component analysis (PCA)

PCA is a statistical technique used to reduce a multidimensional data set to its most dominant features, to remove random variations (noise), and to retain the principal components (PCs) that explain most variations between sample treatments (Goodacre and others 1998). Spectral data were smoothed with a Gaussian function at 4 cm^{-1} followed by a second derivative transformation with a 12 cm^{-1} gap before PCA was conducted. PCA was used in studies of apples, tomatoes, and strawberries.

3.1.4.3. Detection limit (DL) and recovery percentage

The detection limit (DL) with 99.86% confidence interval can be calculated from the PLS calibration curve based on characteristic peaks in SERS spectra using the following formula (Strickland and Batt 2009):

$$\mathrm{DL} = 3\sigma / m \tag{3}$$

where σ is the standard error of predicted concentration and m is the slope of the calibration curve. In a PLS model, σ equals to RMSEP.

Concentrations of pesticide solutions extracted from fruit samples were determined via PLS using the calibration curve. The recovery percentage was calculated with quantified pesticide concentrations divided by spiked pesticide concentrations.

DL determination in the above fashion and calculation of recovery percentage were performed in the studies of apples and tomatoes described in Chapter 4.1.2.

3.2. Behavioral Approach

We conducted two studies in this approach. As discussed in Chapter 1, motivating individuals working in food industry to comply with established rules and regulations may be an effective approach to address the safety problems of Chinese food imports. To modify the behavior of the target group of people—those who participate in manufacturing of foods that are to be exported to the U.S. from China, their current beliefs, attitudes, and behavior about food safety need to be understood first. In the first study, we studied these issues. We have proposed that an integrative approach is the best solution to safety problems of foods imported from China. For this argument to be valid, it must be shown that advancement in technology alone could not lead to changes in

behavior of Chinese food exporters. We made an effort to prove this in the second study, which was designed to investigate whether or not awareness of technology investment could affect the business ethics of Chinese individuals working in the food industry. General beliefs about business ethics were also surveyed in the second study.

3.2.1. Study 1: Modeling food safety practices among Chinese in the United States

Reaching Chinese food exporters may be challenging, but their opinions can be surveyed indirectly because people live under the same culture tend to share similar ways of thinking. Human culture is defined as "the patterned ways of thought and behavior that characterize a social group, which are learned through socialization processes and persist through time" (Coreil 2009). This definition points out that an individual's beliefs, attitudes, and behavior can be directly traced back to the culture he/she belongs to and that people who belong to one culture may share similar beliefs, attitudes, and behavior. Applying these principles, by surveying general Chinese people, information of Chinese food exporters can be obtained since the food exporters are a part of Chinese society and also live under the Chinese culture. Therefore, properties of certain groups of Chinese people, for example, those who live in the U.S, can be viewed as a reflection of those of Chinese food exporters.

Because of the importance of food imports of China, it is in our interest to study the knowledge, beliefs, attitudes, and practices of them in the aspect of safe food handling. As a convenient alternative, Chinese people living in the U.S were chosen as subjects. To our knowledge, no similar studies have been conducted so far.

3.2.1.1. Instrument

An English questionnaire was developed based on several previous studies. The questionnaire included questions designed to measure all dependent and independent variables in the model. The questionnaire was then translated in Chinese by the researcher. To ensure accurate translation, the Chinese version questionnaire was translated back to English by a commercial translation company. The two English version questionnaires were then compared and their discrepancies were observed and repaired. The Chinese version questionnaire was modified accordingly. Two Chinese native speakers were given the Chinese version questionnaire, which was further modified based on their opinions.

Several sources were integrated to develop the questionnaire. Questions from a questionnaire developed by an American university to measure people's attitude, knowledge, and practices in the aspect of food safety were adapted to investigate attitude toward behavior, self-efficacy, safe food handling practices, and knowledge of safe food handling. Another source of questions to measure attitude toward behavior was a set of scales developed by Medeiros and others (2004). Some questions from Lin and Sneed (2005) were adapted to complete self-efficacy measurement. Questions from Lau (2009) were included in the final questionnaire to evaluate safe food handling practices.

3.2.1.2. Items measuring the variables

Knowledge of safe food handling (KNO) was measured via 11 multiple choice questions and four 5-point Likert scale items. In multiple choice questions, participants were asked to choose answers to a given question, for example, "How do you think you should dry your hands after washing". In Likert scales, participants were asked to choose

to what degree (from “strongly disagree” to “strongly agree”) they agree with a statement, such as “Improper storage of foods may be hazardous to health”.

Safe food handling practices (PRC) were measured by 33 5-point Likert scale items. Participants were asked to indicate their frequency (from “never” to “always”) of performing safe food handling activities such as “I wash my hands with soap and water before handling any foods.”

All TPB factors were measured via 5-point Likert scales. Statements followed the format “Most people who are important to me think that I should properly handle food” (from “strongly disagree” to “strongly agree”). There were six items measuring attitude toward behavior (ATB), three items measuring subjective norms (SN), and six items measuring perceived behavioral control or self-efficacy (SE).

3.2.1.3. Data collection

After obtaining approval from Campus Institutional Review Board (IRB), the Chinese version of questionnaire was posted on an Internet survey web site, and its link was shared on an e-mail distribution list which nearly all Chinese living in a college town in the U.S. midwest subscribed to. To collect more responses, it was encouraged that participants share the link to as many Chinese people living in the U.S. as possible. The questionnaire was kept on the web site for one and half months before responses were collected, coded, and analysed using PASW Statistics 18. Scores of each variable were calculated by taking the sum of scores of items measuring that variable. One hundred and seventy-one responses were received during the time the questionnaire was posted on the survey web site, but only 124 participants answered all questions. Only completed responses were used in the data analysis.

3.2.1.4. Regression analyses

A multiple linear model was regressed. Safe food handling practices was regressed on knowledge of safe food handling and the three TPB indicators, attitude toward behavior, subjective norms, and perceived behavioral control or self-efficacy. Normality of residuals, multicollinearity, and homoscedasticity were checked by analysis of collinearity tolerance statistics and residual plots following initial regression attempts. No statistical phenomena undermining the assumptions of multiple linear regression were observed.

3.2.2. Study 2: Assessment of effects of technology advancement on Chinese food exporters' beliefs of business ethics

3.2.2.1. Instrument

The questionnaire was initially developed in English and was translated to Chinese by one researcher. There were four sections in the questionnaire. The first section was two scenarios designed to assess the participants' decisions when facing specific situations related to food safety. Since this study adopted a quasi-experimental design, two versions of the questionnaire were developed—one for the control group, another for the experimental group. The two groups' questionnaires differed only in the first scenario of this section. For the control group, the participants were presented a scenario in which current methods for detection of food contaminants adopted by U.S. federal agencies "must be conducted in a lab by professionals" and "usually takes days to get the final result". The scenario also stated that "because of the disadvantages, the federal agencies can test only a small portion of foods imported to U.S." For the experimental group, the participants were lead to believe that a powerful, accurate, and fast method which "has a detection rate of nearly 100% and can be conducted on-site" and is "very easy ... to be

applied to nearly all kinds of food products and chemicals" has been adopted by U.S. federal agencies. After being presented the scenario, the participants were asked respond to six 5-point Likert scale questions (from "very unlikely" to "very likely") asking to what degree they will adjust their business practice given the information described in the scenario. The second scenario described a food safety crisis, followed by six 5-point Likert scale questions (from "very unlikely" to "very likely") assessing what decisions would respondents possibly make in the situation. The scenarios and questions were developed by us independently. The second section contained 18 questions measuring participants' attitude towards business ethics and *guanxi*. These questions were all 5-point Likert scales (from "strongly disagree" to "strongly agree") and were adapted from previous reports researching business ethics of Chinese (Shafer and others 2006; Peppas and Yu 2007). The third section included one open-ended question asking participants' opinion about China's food safety problem ("what do you think is the fundamental reason for China's food safety problems?"). The last section was used to collect demographic information of participants.

3.2.2.2. Data collection

IRB application was submitted and applied before data were collected. Sixty working professionals from four food companies in southern China participated in this study. Their daily duty is dealing with exporting affairs in their companies and they all have a working knowledge of food manufacturing. All these companies export food products to the U.S.

The sample was divided equally into control and experimental groups, resulting in 30 individuals in each group. The participants were given hard copies of the Chinese version of the questionnaire according to the group they belong to and were instructed to

finish their questionnaires in their spare time and give them back to the distributor. There were 28 valid responses in the control group and 30 in the experimental group. The responses were then coded and input into a computer for further analysis.

3.2.2.3. Methods of analysis

Frequencies were calculated for the demographic data. Responses to the first scenario were analyzed by calculating and comparing mean scores for each statement for the control and experimental groups. Tests of significance (independent samples T-test for equality of means) were performed to determine if significant differences existed ($p < 0.05$). Mean and standard deviation (SD) of responses to other questions were calculated to provide descriptive statistical information. A principal components factor analysis was performed using data of the second section to extract the dimensions of the results. Forty respondents provided valid responses to the open-ended question. These responses were categorized and their frequencies were counted.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Scientific Approach

4.1.1. Detection of melamine and cyanuric acid extracted from milk

Different concentrations of melamine in milk samples were extracted and analyzed by SERS. Average SERS spectra (n = 5) of melamine extracted from milk samples are shown in Figure 8. The most prominent peak of melamine was at around 685 cm^{-1}, which was present in the SERS spectra collected from the extracts of samples spiked with different concentrations of melamine, but absent in the control. The melamine peak is not discernible in the SERS spectra acquired from samples with melamine concentrations below 20 ppm. Coupled with Klarite™, SERS was able to rapidly and directly detect melamine concentrations as low as 20 ppm in milk by observing whether the melamine peak is present in a spectrum or not.

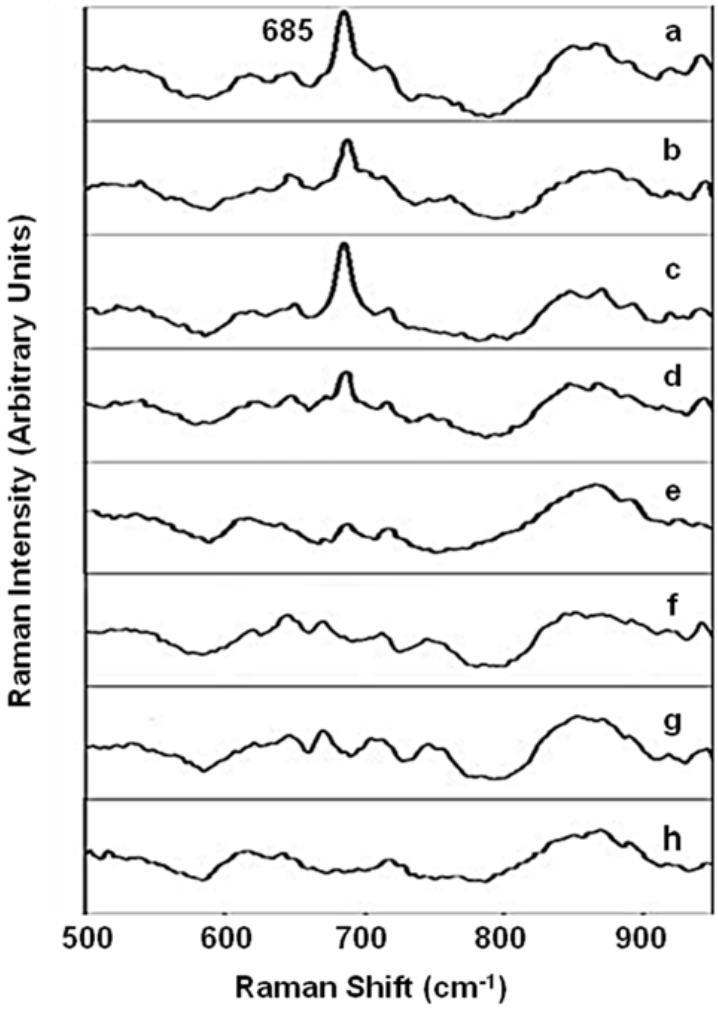

Figure 8. Average SERS spectra (n = 5) acquired from extracts of milk containing different concentrations of melamine.
From top to bottom: 100 ppm (a), 80 ppm (b), 60 ppm (c), 40 ppm (d), 20 ppm (e), 10 ppm (f), 2 ppm (g) and 0 ppm (h). Measurements were conducted from 500 to 1200 cm^{-1} with a 10 s exposure time and ~ 20 mW laser power. Spectrum were presented with smoothing at 4 cm^{-1} and baseline adjustment by subtracting a 2nd order polynomial function.

Second derivative transformation can separate overlapped peaks, eliminate baseline effects, and enhance spectral resolution, making it a common tool in spectral analysis. Figure 9 shows the second derivative transformation of SERS spectra acquired from some low concentrations of samples in Figure 8. Second derivative transformation of SERS spectra of 100 ppm and 0 ppm melamine in milk were also included to serve as the

positive and negative control. Figure 9 depicts clear differences at ~685 cm^{-1} between the spectra of the negative control (0 ppm) and those of milk samples spiked with low concentrations of melamine (2 ppm and 10 ppm). Because the characteristic melamine peak at ~685 cm^{-1} consistently exists in the second derivative transformed spectra of milk spiked with 2, 10, and 100 ppm, the possibility that spectral differences between the negative control and spiked samples are due to random noises can be ruled out. On November 28, 2008, the U.S. Food and Drug Administration (FDA) concluded that levels of melamine and its analogues below 2.5 ppm in foods and levels of melamine or one of its analogues alone below 1.0 ppm in infant formula do not raise public health concerns (FDA 2008c, d). Therefore, SERS combined with gold substrate, with the aid of proper data analysis techniques, can detect trace amounts of melamine in most food products except infant formula.

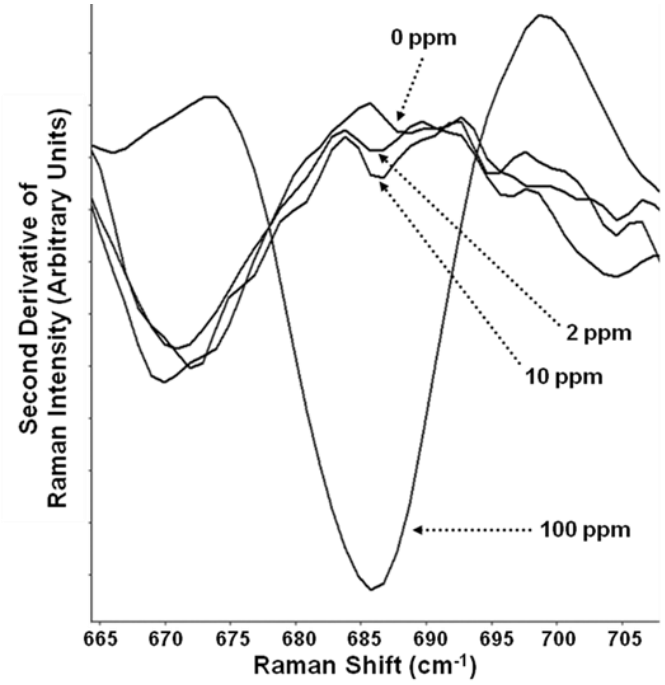

Figure 9. Second derivative transformation of average SERS spectra (n=5) acquired from the extracts of milk containing different concentrations of melamine.

RMSEP values obtained from the PLS models with different latent variables are shown in Figure 10. The spectral data were pre-processed with smoothing at 4 cm^{-1} in whole spectral region. The lowest RMSEP value was achieved when six latent variables were used, suggesting that the optimal number of latent variables to construct a PLS model is six. Figure 11 shows the PLS prediction results (n = 170) by plotting predicted melamine concentrations against spiked melamine concentrations. The prediction result was obtained with R = 0.88 and RMSEP = 15.9 ppm (1.59×10^{-5}), indicating that satisfactory quantitative results for melamine contamination in milk by SERS could be obtained.

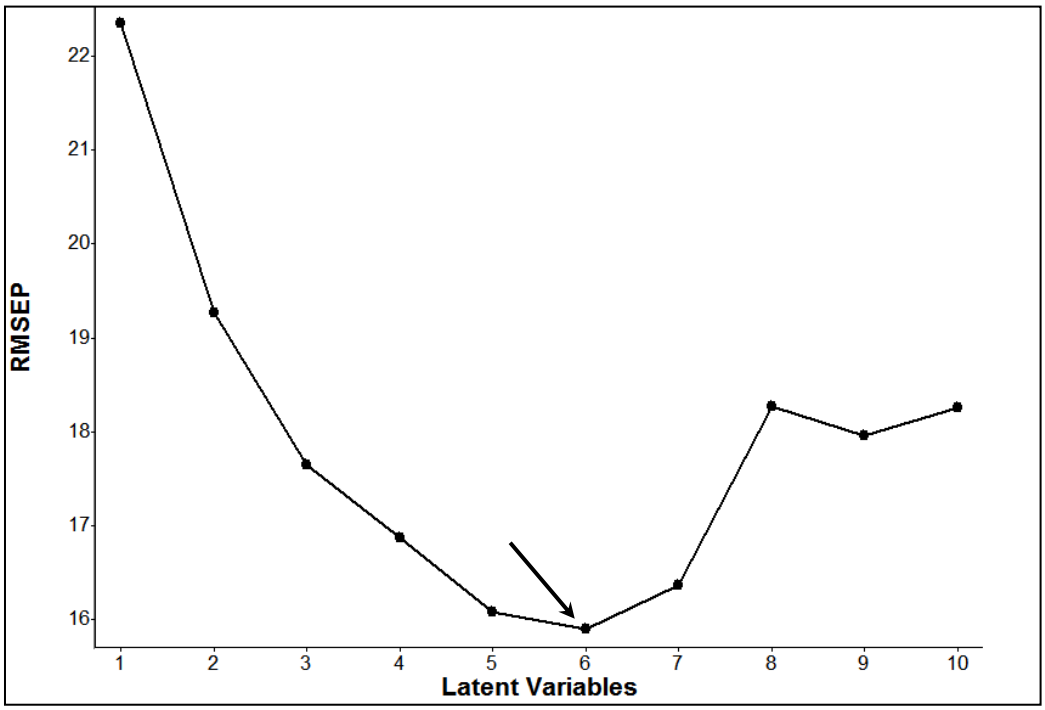

Figure 10. Root mean square error of prediction (RMSEP) values obtained from the partial least squares (PLS) models with different latent variables (milk study).

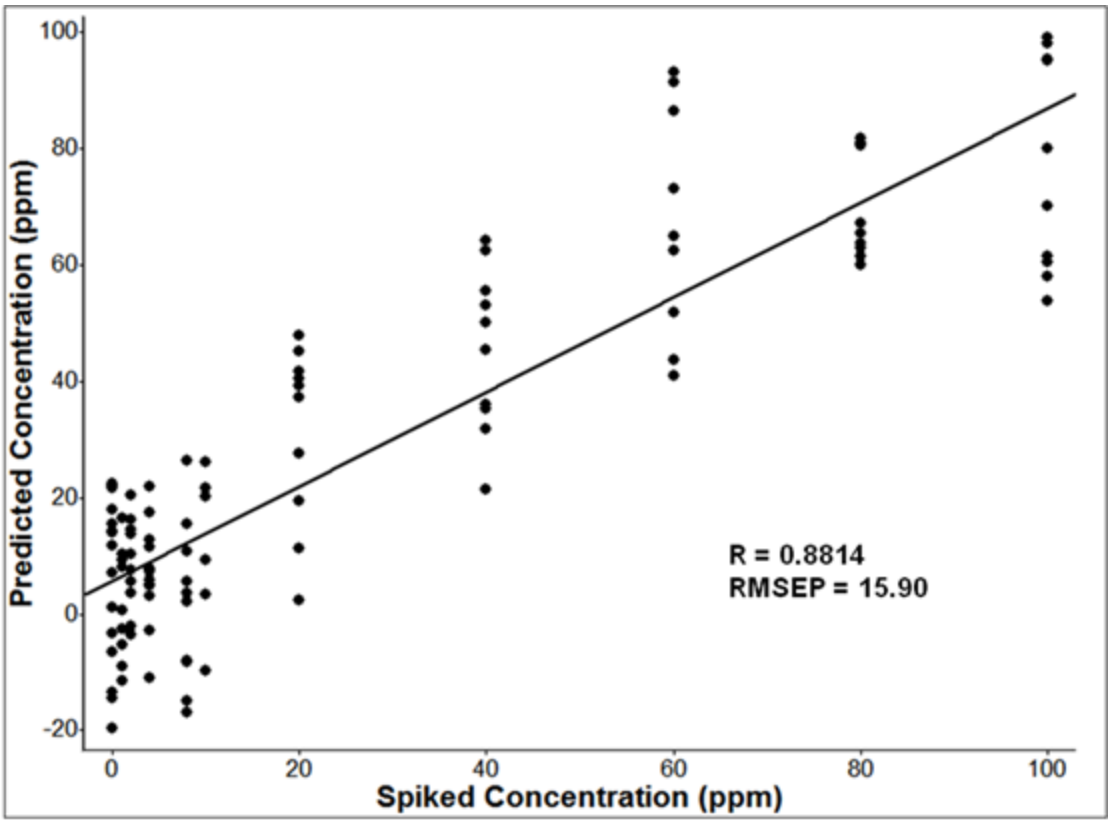

Figure 11. Predicted melamine concentration (ppm) vs. spiked melamine concentration (ppm) using the PLS model.
Parameters: smoothing 2 cm^{-1}, baseline adjustment by subtracting a 2nd order polynomial function; 6 latent variables; spectral region 500–1200 cm^{-1}; spectral number n = 170.

Similar to melamine, different concentrations of cyanuric acid in milk were extracted and analyzed by SERS. Figure 12 shows average SERS spectra (n = 3) of cyanuric acid extracted from milk samples. A prominent peak at around 684 cm^{-1} was present in the 80 ppm spectrum but not in the 40 ppm and 20 ppm ones. Because the peak was so strong, it was unlikely that its absence in spectra (Figure 12b and 12c) was because lower concentration of cyanuric acid could not be detected by SERS. In this study, to observe enol–keto tautomerism of cyanuric acid, 100 ppm pure cyanuric acid solution was prepared using a solvent system (methanol : water = 1 : 1, v/v) which was similar to the method previously used (He and others 2008b). As shown in Figure 13,

cyanuric acid undergoes tautomerism within 15 min after dissolving in a methanol/water solution (1 : 1, v/v). The spectrum shown in Figure 13a was acquired immediately after cyanuric acid powders were dissolved and it exhibited a characteristic peak at 684 cm^{-1}, which is identical to the peak shown in the spectrum of Figure 12a. However, in a spectrum acquired from the same sample after 15 min (Figure 13b), the 684 cm^{-1} peak disappeared and a new prominent peak appeared at ~ 702 cm^{-1}.

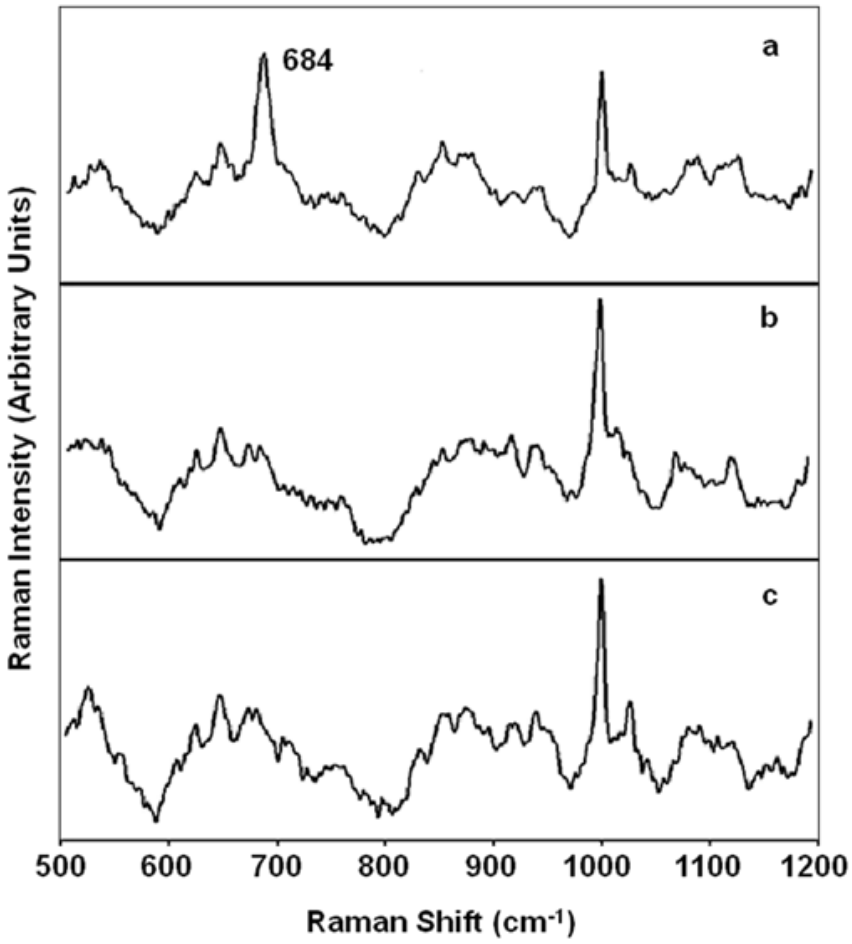

Figure 12. Average SERS spectra (n = 3) acquired from the extracts of milk containing different concentrations of cyanuric acid.
From top to bottom: 80 ppm (a), 40 ppm (b), and 20 ppm (c). Measurements were conducted from 500 to 1200 cm^{-1} with a 10 s exposure time and ~ 20 mW laser power. Spectra were presented with smoothing at 4 cm^{-1} and baseline adjustment by subtracting a 2nd order polynomial function.

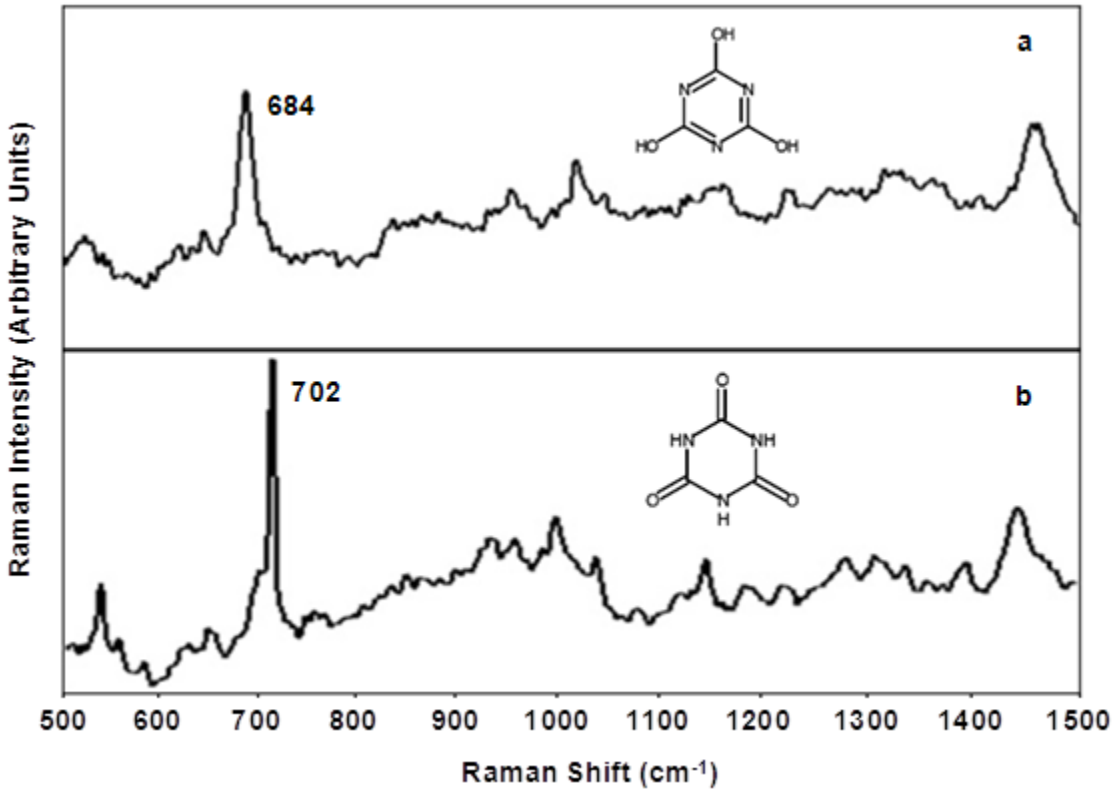

Figure 13. Representative SERS spectra of 100 ppm pure cyanuric acid solution (methanol : water = 1 : 1, v/v) showing enol-keto tautomerism.
The spectrum (a) was acquired immediately after solid cyanuric acid dissolved; the spectrum (b) was acquired ~15 min later. Measurements were conducted from 500 to 1500 cm^{-1} with a 10 s exposure time and ~ 20 mW laser power. Spectra were presented with smoothing at 4 cm^{-1} and baseline adjustment by subtracting a 2nd order polynomial function.

It was previously demonstrated that the LOD of the same SERS method for detecting pure melamine in aqueous solutions was estimated to be much lower, ~ 33 ppb (0.033 µg/ml) (He and others 2008b). The reason why low concentrations of melamine in complex food systems are not easy to detect by SERS is because melamine molecules, when dissolved in milk, will bind to milk constituents via hydrogen bonding, forming compounds that cannot be easily broken down by sonication. The melamine molecule has a strong inclination towards hydrogen bonding. For example, melamine binds to cyanuric acid via a self-assembly process, forming a two-dimensional sheet-like network (Seto and

Whitesides 1993; Ranganathan 1996; Greig and Philp 2001; Perdigao and others 2006). Because of this property, melamine is used to make binding agents, some of which were found in feed for farmed fish, shrimp and livestock (Martin 2007). Therefore, melamine molecules in milk may bind to casein, the predominant phosphoprotein in milk. For instance, casein can be incorporated into modified melamine-formaldehyde resin (Belmares and Caldwell 2005; Raval and others 2006).

Figures 12 and 13 demonstrate the phenomenon of keto-enol tautomerism of cyanuric acid in organic solvent. Because the only difference between spectra a and b of Figure 13 is that the latter one was obtained about 15 min later than the former one, the shift of peak from 684 cm^{-1} to 702 cm^{-1} was attributed to changes occurring in the sample molecular structure. The spectrum (Figure 13b) is consistent with the SERS spectrum of the keto form of cyanuric acid (isocyanuric acid) obtained from solid cyanuric acid (He and others 2008b), indicating that cyanuric acid molecules were in the keto form. The keto form is dominant in the solid state or in neutral to acid solutions (Wojtowicz 2004). Water and methanol have a catalytic effect on assisting the keto form to transform to the enol form (Liang and others 2007). Therefore, it is believed that shortly after dissolving in methanol/water solution, the keto form transformed to the enol form, which was reflected in spectrum Figure 13a; while, after some time, the enol form shifted back to the more stable keto form which was reflected in the spectrum Figure 13b. Considering that the spectrum of 80 ppm solution in Figure 12 was obtained first, followed by 40 and 20 ppm solutions subsequently, this could explain why the 684 cm^{-1} peak, the characteristic peak of cyanuric acid in the enol form, was present only in the 80 ppm spectrum but not in the 40 and 20 ppm ones. Cyanuric acid in the 80 ppm solution was mainly in the enol form; while for the 40 and 20 ppm solutions, by the time they were measured, cyanuric acid

molecules were mainly in the keto form. Figure 12 also suggests that the SERS methods are suitable for detecting the keto form of cyanuric acid. Additional efforts are needed to develop appropriate techniques to detect cyanuric acid in milk.

It was previously demonstrated that melamine signals were very weak on conventional Raman spectroscopy for pure melamine solution with a concentration of as high as 1261.2 ppm (He and others 2008b). Based on the height of the peak at 683 cm^{-1}, SERS can enhance the signals for approximately 3×10^4 fold, thus making them strong enough for further analysis (He and others 2008b). Considering the loss during the extraction of melamine from real food samples such as milk, conventional Raman would not provide satisfactory signal levels. Instead, SERS should be used.

Better results could be obtained by developing more effective extraction methods. In this study, we used acetonitrile for extraction of melamine in milk. Other organic solvent systems may be utilized for melamine extraction as well. For example, extraction with 2.5% aqueous formic acid was used in a method developed by the FDA (Turnipseed and others 2008). Another approach that may help improve the detection capability of SERS is to develop more sensitive SERS-active substrates. As only a few commercial SERS-active substrates are available in the market nowadays, more work is needed to develop better performing and cost-effective substrates in SERS applications.

4.1.2. Detection of pesticides in apples and tomatoes

To confirm that no interfering signals were introduced by solvents or other factors, SERS spectra of the three pesticides (azinphos-methyl, carbaryl, and phosmet) in both solution and solid forms were obtained and compared, as shown in Figure 14. For all three pesticides, signals of solution and solid forms agree well with each other, indicating that

the solvent used did not produce interfering signals in measurement. The intensity of some peaks in spectra obtained from the solution was apparently different from their counterparts in spectra obtained from the solid (e.g. a peak at 730 cm^{-1} in carbaryl spectra and peaks in 580-740 cm^{-1} region in phosmet spectra). This may be due to the interaction between solute and solvent molecules. These peaks were not used for quantification analysis.

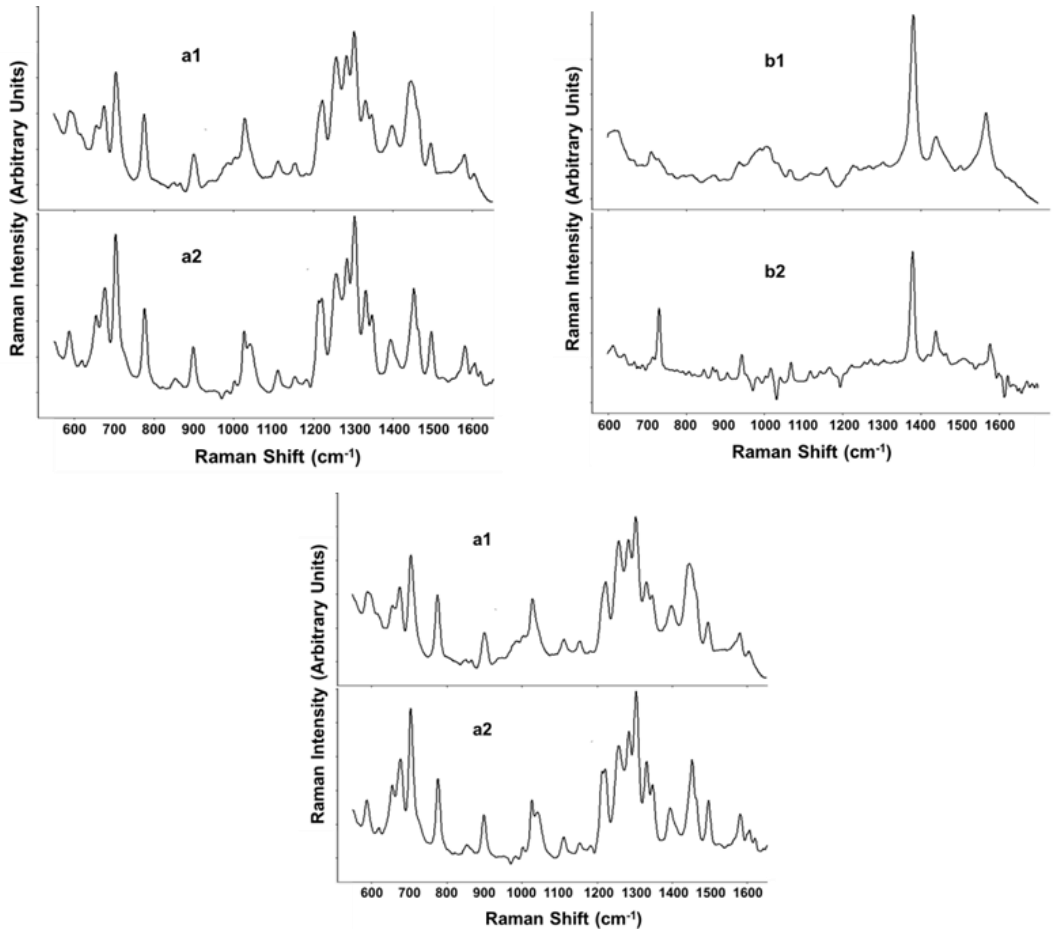

Figure 14. Average SERS spectra (n = 8) of pesticide solutions and solid (study of apples and tomatoes).
a1: azinphos-methyl solution; a2: azinphos-methyl solid; b1: carbaryl solution; b2: carbaryl solid; c1: phosmet solution; c2: phosmet solid). The concentration of all solutions is 50 ppm. Measurements were conducted with a 10 s exposure time and ~ 20 mW laser power. Spectra were presented with smoothing at 4 cm^{-1} and baseline adjustment by subtracting a second order polynomial function.

SERS was used to measure solutions containing different concentrations of three pesticides. Average SERS spectra (n = 8) of carbaryl are shown in Figure 15, while similar results were obtained for the other two pesticides (data not shown). The carbaryl spectra are highly consistent with a previous report using Ag nanoparticle-coated Si nanowire as SERS substrate, in which the intensity of 1380 cm^{-1} and 1440 cm^{-1} peaks decreased as the concentration of carbaryl decreased (Wang and others 2010). Band assignments were summarized in Table 3 based on other published data (Trotter 1977; Fischer and others 1997; Boese and Martin 2004; Socrates 2004). For example, a strong peak at 1380 cm^{-1} may be due to the symmetric vibration of the naphthalene ring. The naphthalene ring of carbaryl is mono-substituted, and the 1440 cm^{-1} peak may be from unspecified vibrations of this ring. Another strong peak at 1565 cm^{-1} can be attributed to the stretching of C=C double bonds in the naphthalene ring. In general, our results agreed well with previous reports.

Spectra of carbaryl solutions were preprocessed using second derivative transformation. Figure 16 shows the most prominent feature at 1380 cm^{-1} in the spectra. This figure demonstrates that SERS is able to differentiate spectral patterns between different concentrations of carbaryl in a mixed solvent. A drawback of this approach is that it may not provide a direct discrimination between samples containing relatively high concentrations of pesticides (larger than 10 ppm). As shown in Figure 16, the height of the peak at 1380 cm^{-1} does not differ much between the spectral samples of 10 and 50 ppm, which is also the case for the other two pesticides.

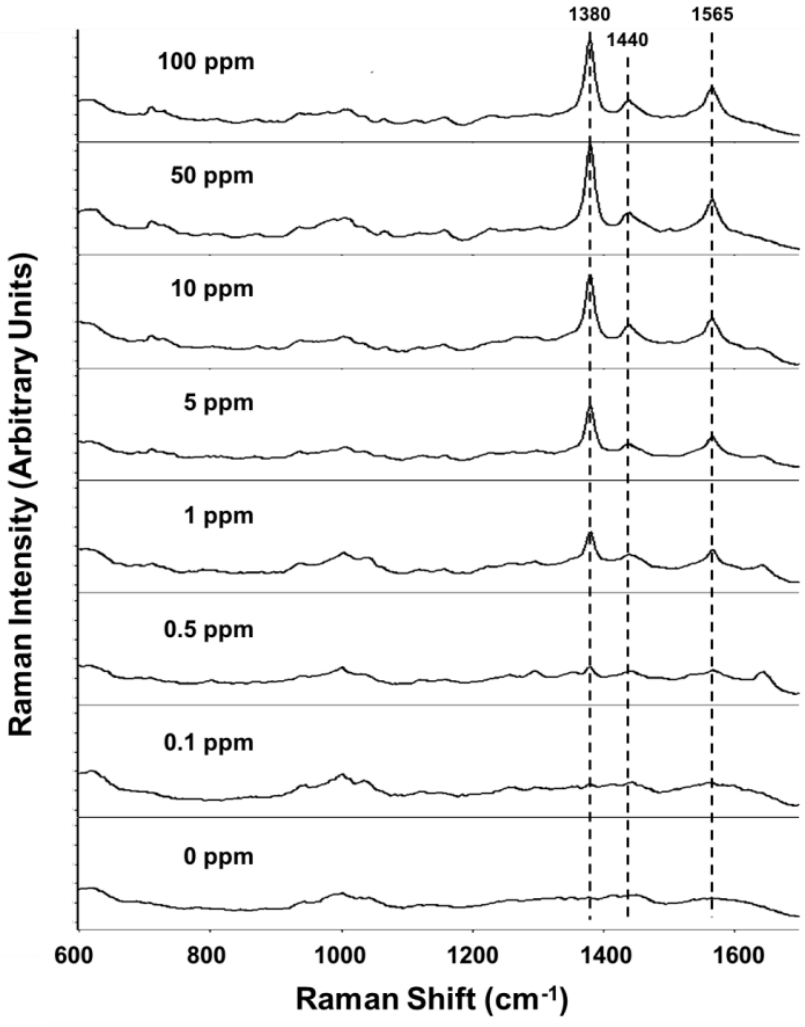

Figure 15. Average SERS spectra (n = 8) of carbaryl solutions with different concentrations. Measurements were conducted with a 10 s exposure time and ~ 20 mW laser power. Spectra were presented with smoothing at 4 cm^{-1} and baseline adjustment by subtracting a second order polynomial function.

Table 3. Band assignments of major peak in SERS spectra acquired from azinphos-methyl, carbaryl, and phosmet.

(1) Azinphos-methyl

Band (cm^{-1})	Assignment
587w	δ(C=O)
674m	υ(P=S)
703s	benzene ring breathing
775s, 897m	1,2,3-triazine ring breathing
1026m	asymmetric P–O–C deformation vibration
1221s	γ(C–H) in P–O–CH_3
1258s	υ(C–N) in S–CH_2–N
1283m, 1302s	υ(C–N) in O=C–N
1332w	1,2,3-triazine ring breathing
1399w	γ(C–H) in S–CH_2–N
1450s	υ(N=N)
1495w, 1576vw	1,2,3-triazine ring breathing

(2) Carbaryl

Band (cm^{-1})	Assignment
1380vs	symmetric ring vibration
1440m	Unspecified ring vibration of mono-substituted naphthalene
1565s	υ(C=C) in naphthalene ring

(3) Phosmet

Band (cm^{-1})	Assignment
606s	δ(C=O)
653m	δ(P=S)
675m	υ(P=S)
712m	benzene ring breathing
1014m	asymmetric P–O–C deformation vibration
1191m	γ(C–H) in P–O–CH_3
1260m	υ(C–N) in S–CH_2–N
1409w	γ(C–H) in S–CH_2–N
1714m	υ(C=O)

w: weak; m: medium; s: strong; v: very

υ: stretching; δ: in-plain deformation vibration; γ: out-of plane deformation vibration

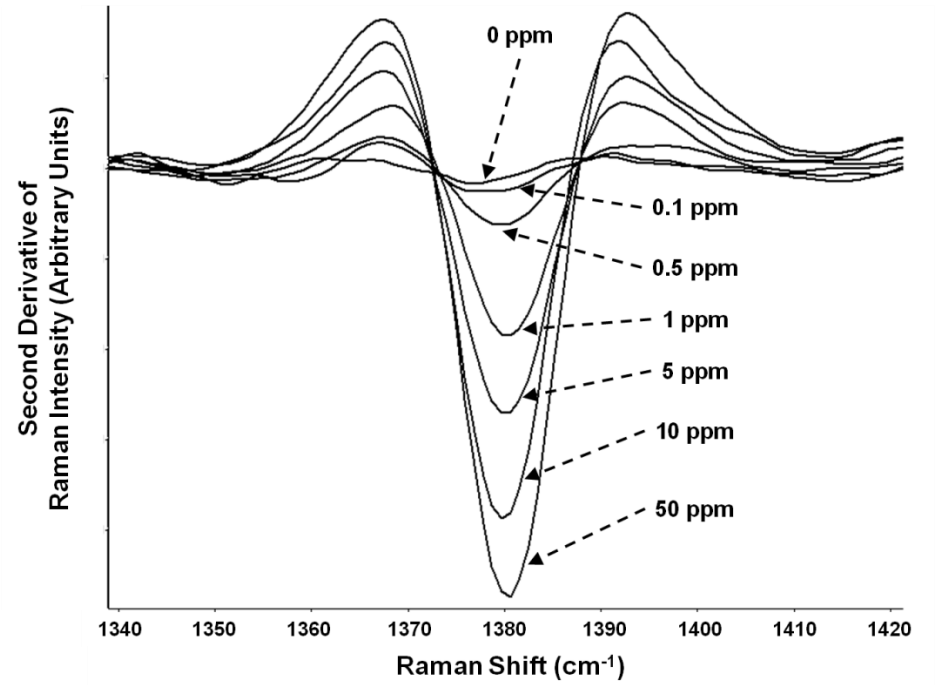

Figure 16. Part of second derivative transformation of average SERS spectra (n = 8) acquired from different concentrations of carbaryl solutions.

PLS analysis was applied on spectra of all three pesticide samples. RMSEP values obtained from the PLS models of carbaryl with different latent variables are shown in Figure 17. The spectral data were pre-processed with smoothing at 4 cm^{-1} in the whole spectral region. The lowest RMSEP value was achieved when five latent variables were used, suggesting that the optimal number of latent variables to construct a PLS model is five. The optimal number for building PLS models is 5 for azinphos methyl and 6 for phosmet. PLS prediction results for carbaryl (n = 54) are shown in Figure 18 by plotting predicted pesticide concentrations against actual pesticide concentrations (R = 0.84; RMSEP = 1.954×10^{-5}). For azinphos-methyl and phosmet, R values are 0.98 and 0.85, and RMSEP values are 7.269×10^{-6} and 1.823×10^{-5}. With R values all larger than 0.83, results of PLS analyses suggest that PLS can serve as a reliable method to quantify pesticides.

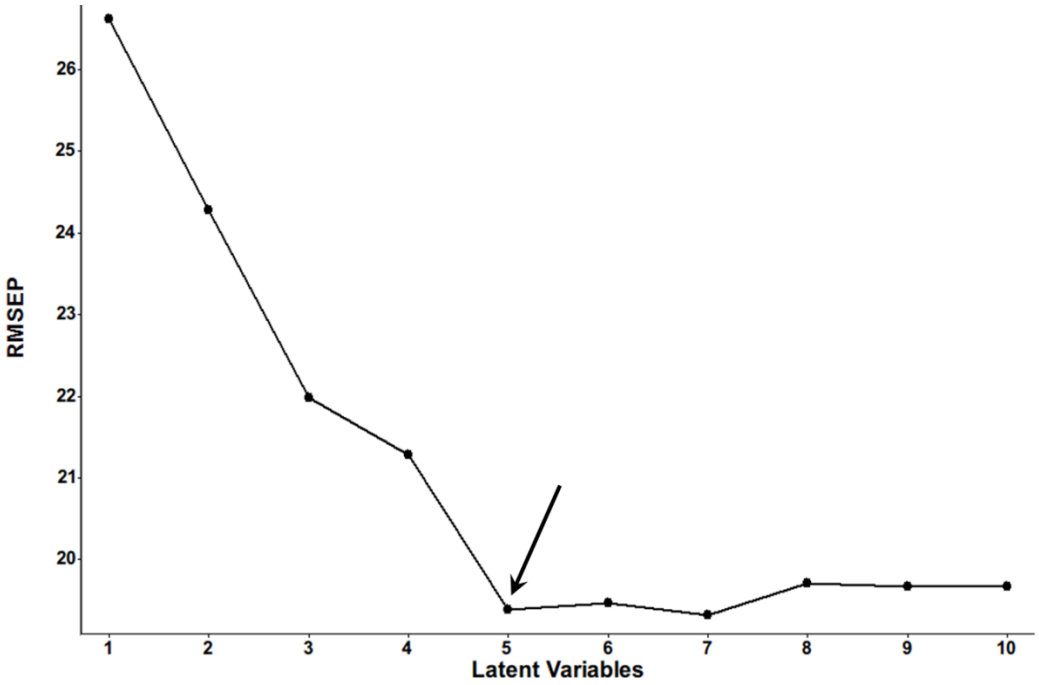

Figure 17. Root mean square error of prediction (RMSEP) values obtained from the partial least squares (PLS) models based on carbaryl spectra with different latent variables.

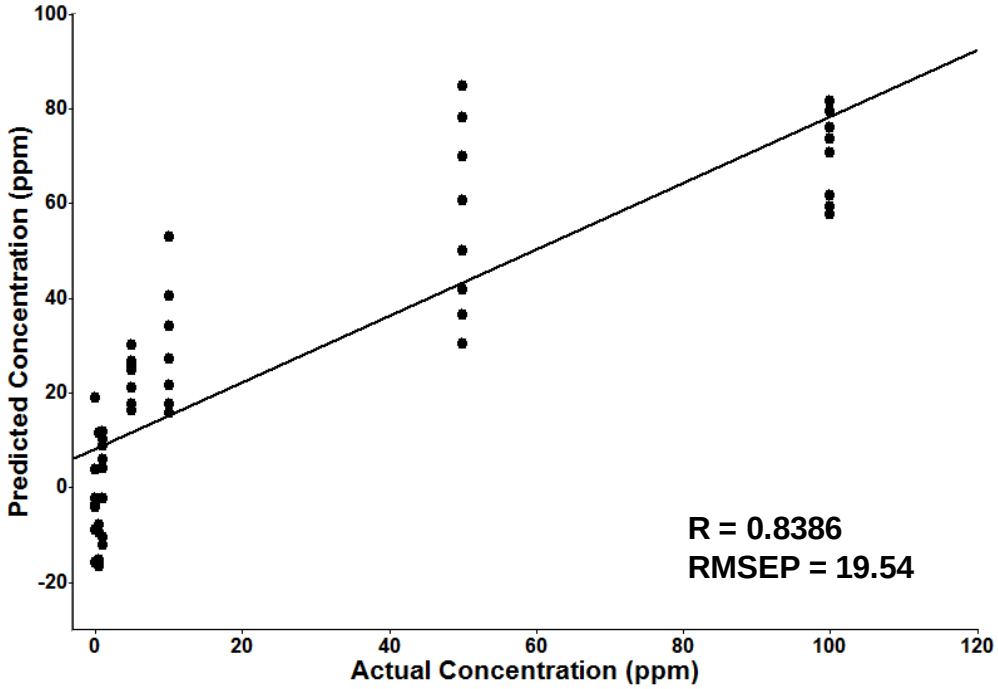

Figure 18. Predicted carbaryl concentration (ppm) vs. actual carbaryl concentration (ppm) using the PLS models.
Parameters: Smoothing 4 cm^{-1}, baseline adjustment by subtracting a second order polynomial function; 5 latent variables; spectral region: 1200–1700 cm^{-1}; spectral number n = 54.

PCA was conducted based on the spectra acquired from all three pesticides to investigate if SERS can differentiate between pesticides. The results of using the first two PCs to classify samples are shown in Figure 19, indicating that PCA with the first two PCs could be used to discriminate three pesticide samples quite well. Although Figure 19 shows clear segregation between the three pesticide samples, a small portion of samples overlapped each other. Because a SERS spectrum reflects the characteristics of chemical structure of the analyte, it is possible that one of the PCs can be assigned to common chemical groups. Both azinphos-methyl and phosmet are organophosphorus compounds and possess a functional group ($S=P(OCH_3)_2$), so when using the first two PCs to classify them, overlapping of data clusters may occur. In contrast, carbaryl does not contain such a phosphorus group, but it has a naphthalene structure, which is similar to aromatic rings that the other two pesticides have. This would explain why some of the carbaryl samples overlapped those of phosmet and azinphos-methyl. SERS spectra acquired from higher concentrations of samples exhibited more significant differences from each other because richer information of chemical structures of the analytes was reflected in the SERS spectra.

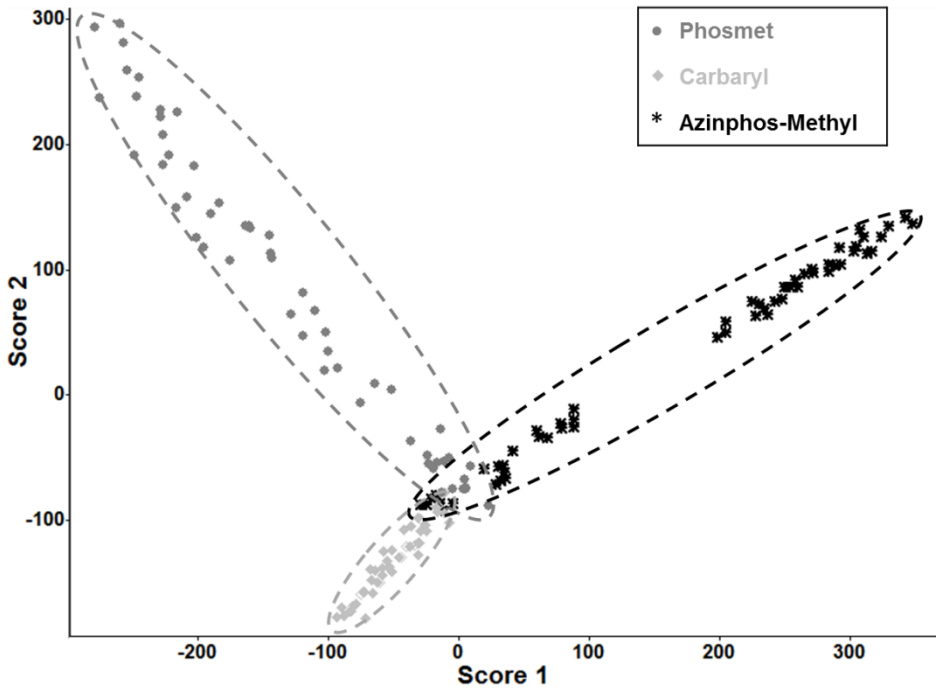

Figure 19. Classification of azinphos-methyl, carbaryl, and phosmet using the first two principle components (PCs).

SERS was used to detect carbaryl, phosmet, and azinphos-methyl extracted from real food samples. Detection limits for the pesticides were calculated by Equation (2) mentioned in Chapter 3.1.4. As an example, the calibration curve of carbaryl extracted from apple skin is shown in Figure 20. Results of the detection limit for three pesticides are summarized in Table 4, indicating that satisfactory prediction results could be obtained by SERS. Maximum residue limits (MRLs) of the three pesticides tested in this study have been established for apples and tomatoes by the Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO), as shown in Table 5 (FAO/WHO 1967, 1984, 2009). Comparing the MRLs with the results in Table 4, it can be concluded that the SERS method meets the requirement of carbaryl and phosmet. For azinphos-methyl, more efficient extraction procedures and better-performing substrates is needed to improve the results.

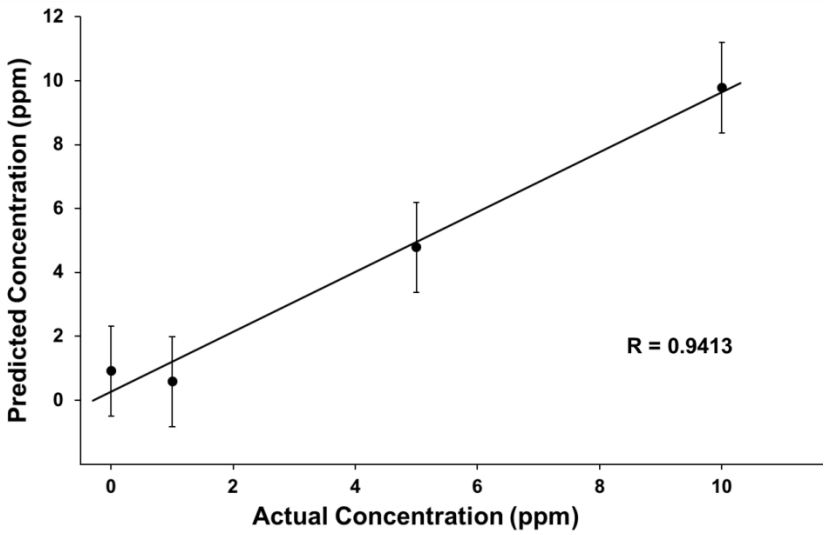

Figure 20. Calibration curve of carbaryl extracted from apple skin using the PLS models, showing standard error.
Parameters: Smoothing 4 cm^{-1}, baseline adjustment by subtracting a second order polynomial function; 4 latent variables; spectral region: 1340–1420 cm^{-1}; spectral number n = 30.

Table 4. Calculation of detection limits (DL) of SERS methods for carbaryl, phosmet, and azinphos-methyl extracted from apple and tomato samples.

Sample: Apple

	R	Standard Error (RMSEP)	Slope	DL (ppm)
Carbaryl	0.94	1.41	0.94	4.51
Phosmet	0.87	1.77	0.82	6.51
Azinphos-methyl	0.88	1.89	0.85	6.66

Sample: Tomato

	R	Standard Error (RMSEP)	Slope	DL (ppm)
Carbaryl	0.82	1.19	0.67	5.35
Phosmet	0.91	0.83	0.86	2.91
Azinphos-methyl	0.91	0.84	0.85	2.94

Table 5. Maximum residue limits (MRLs) of carbaryl, azinphos-methyl, and phosmet in apples and tomatoes established by FAO/WHO.

Pesticide	Maximum residue limits (ppm)	
	Apple	Tomato
Carbaryl	6-10	5
Phosmet	10	N/A
Azinphos-methyl	1	2

It has been argued that a thicker waxy outer layer of tomato skin favors penetration of pesticides because the layer contributes to the stability of pesticides in it (Gunther and Blinn 1955). This claim was supported by the fact that after being applied to whole tomatoes, most of dimethoate, profenofos, and pirimiphos-methyl, all of which are organophosphorus pesticides, were found to be retained in the skin of tomatoes (Abou-Arab 1999). Also, peeling reduces over 83% of the three organophosphorus pesticides in tomatoes (Abou-Arab 1999). For apples, it was shown that 24 h after application, over 85% of azinphos-methyl and phosmet residues are located in the skin and the outside 2 mm of the apple flesh (Wise and others 2009). Therefore, our method of peeling the fruit and applying pesticide solutions onto the skin did not cause significant sampling errors compared to common approaches such as extracting pesticides from whole fruit homogenates.

To calculate the recovery of pesticides, we took an approach different from common chromatographic methods in which the calibration curves obtained from pure pesticide solutions were used to quantify the analyte extracted from food samples. For quantification analysis based on PLS, some studies suggest that the standards and unknown samples should be of the same matrix composition (Sentellas and others 2001). Therefore, we used the calibration curve obtained from pesticides extracted from real foods to predict the concentrations of the samples, and calculated the recovery percentage accordingly (Table 6). The recoveries were satisfactory for samples with concentrations around or larger than their corresponding detection limits (77.7 to 124.3%). In comparison, several previous studies using different methods to detect these pesticides in fruits and vegetables show recoveries ranging from 70% to 110% (Kolosova and others 2003; Liu and others 2005; Zhang and others 2005; Grimalt and others 2007; Walz and

Schwack 2007). While these methods do show better detection limits (ranging from 15 ppb to 3 ppm for different pesticides in various food matrices), it must be noted that complex and time-consuming processes should not be incorporated as part of the sample preparation procedure of SERS as the rapidness is the main advantage of SERS methods.

Table 6. Recovery of pesticide concentration (%) in apples and tomatoes.

Sample: Apple

Pesticide	Spiked (ppm)	Quantified (ppm)*	Recovery (%)
Carbaryl	5	4.87 ± 1.55	97.4
	10	9.76 ± 1.72	97.6
Phosmet	5	3.88 ± 1.98	77.7
	10	9.05 ± 2.12	90.5
Azinphos-methyl	5	6.22 ± 1.66	124.3
	10	8.26 ± 1.33	82.6

Sample: Tomato

Pesticide	Spiked (ppm)	Quantified (ppm)*	Recovery (%)
Carbaryl	5	3.89 ± 1.11	77.7
Phosmet	5	4.45 ± 1.37	89.0
Azinphos-methyl	5	4.50 ± 1.07	90.1

* Quantified values are shown as mean ± standard deviation (n = 6).

4.1.3. Detection of pesticides in strawberries

All results are presented using myclobutanil as an example.

Figure 21 shows average SERS spectra (n=8) of myclobutanil in various concentrations. The intensities of several peaks apparently increase with concentration, as indicated in the figure. Similar results were obtained from captan and pyraclostrobin samples. As far as we know, there haven't been any previous reports using Raman spectrometry to study these pesticides, so we tentatively assigned notable bands to various

molecular vibrations based on general Raman principles (Krishnakumar and Xavier 2004; Socrates 2004). The results are shown in Table 7. Characteristic functional groups (e.g. $–CCl_3$ of captan, trizaole ring of myclobutanil, and imidazole ring of pyraclostrobin) in the structures of these pesticides can be identified from Raman spectra. These results show that Raman spectroscopy is able to identify the three pesticides in pure form.

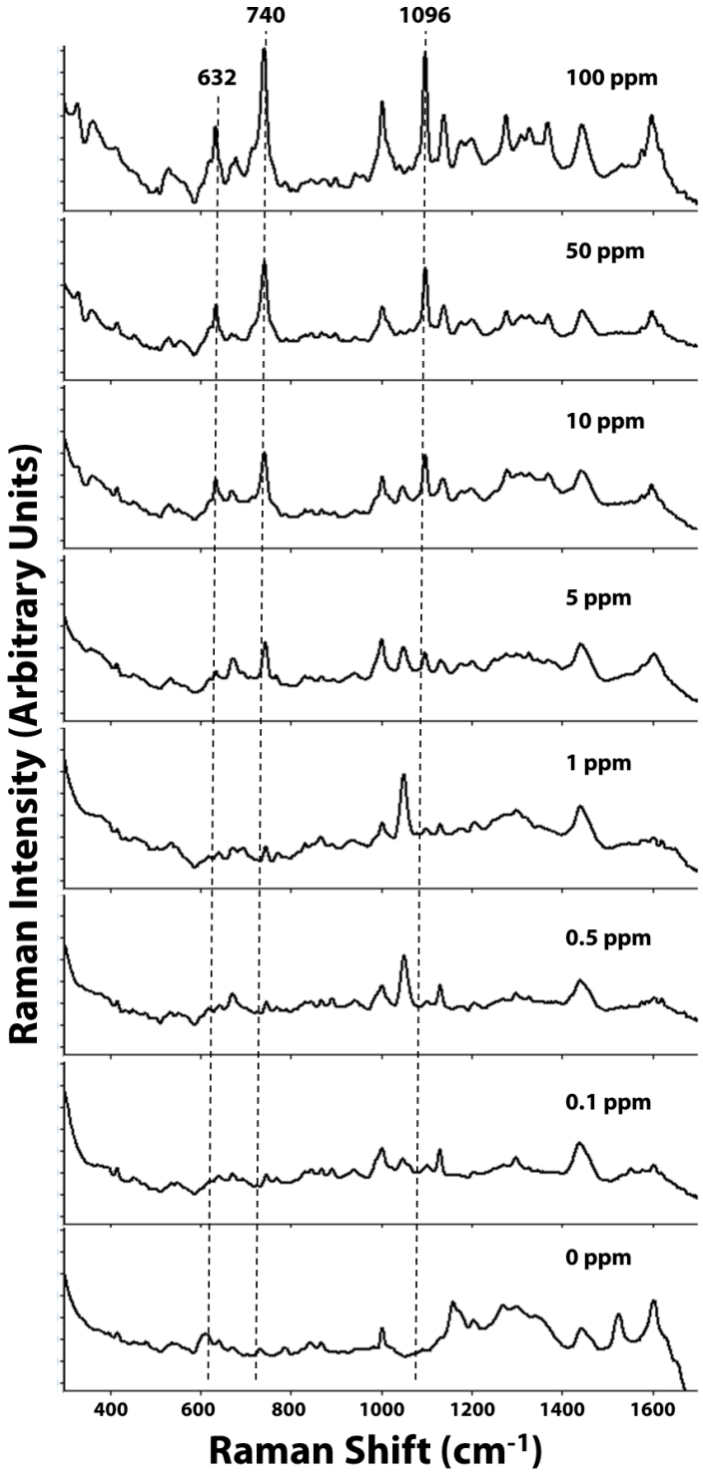

Figure 21. Average SERS spectra (n = 8) of myclobutanil solutions with different concentrations. Measurements were conducted with a 10 s exposure time and ~ 20 mW laser power. Spectra were presented with smoothing at 4 cm^{-1} and baseline adjustment by subtracting a second order polynomial function.

Table 7. Band assignments of major peaks in SERS spectra acquired from captan, myclobutanil, and pyraclostrobin.

(1) Captan

Band (cm^{-1})	Assignment
336m	C–C (ring) skeletal vibration
454vs	$–CCl_3$ deformation vibration
623vs	N–C=O in-plane bending
1020s	υ(C–S)

(2) Myclobutanil

Band (cm^{-1})	Assignment
360w	γ(N–C–N) in triazole ring
632m	δ(C–C–CN)
740vs	γ(C–H) in benzene ring
1001s	triazole ring in-plane bending
1096vs	combined ring and C–Cl stretches (para-substitution)
1138m	υ(C–C–C)

(3) Pyraclostrobin

Band (cm^{-1})	Assignment
750m	γ(C–H) in benzene ring
937vs	γ(C–H) in $–N–O–CH_3$ and imidazolyl–$O–CH_3$
1052w	rocking vibration of $–COOCH_3$
1095m	combined ring and C–Cl stretches (para-substitution)
1394s	υ(N–CO–O)
1600s	Imidazole I band

w: weak; m: medium; s: strong; v: very
υ: stretching; δ: in-plane deformation vibration; γ: out-of plane deformation vibration

To determine the detection capability of Raman spectroscopy on these three pesticides, spectra were transformed using secondary derivatives and intensities of characteristic peaks at different concentrations and were compared. Figure 22 shows the 740 cm^{-1} peak of myclobutanil after secondary derivative transformation. As depicted, 0.1 ppm samples can be distinguished from 0 ppm (control) samples, and intensity of the peak increased as the concentration goes higher. However, 0.1 and 0.5 ppm samples

cannot be distinguished from each other, indicating the limitation of Raman spectroscopy. The lowest discernible concentration is 5 ppm for captan and 1 ppm for pyraclostrobin.

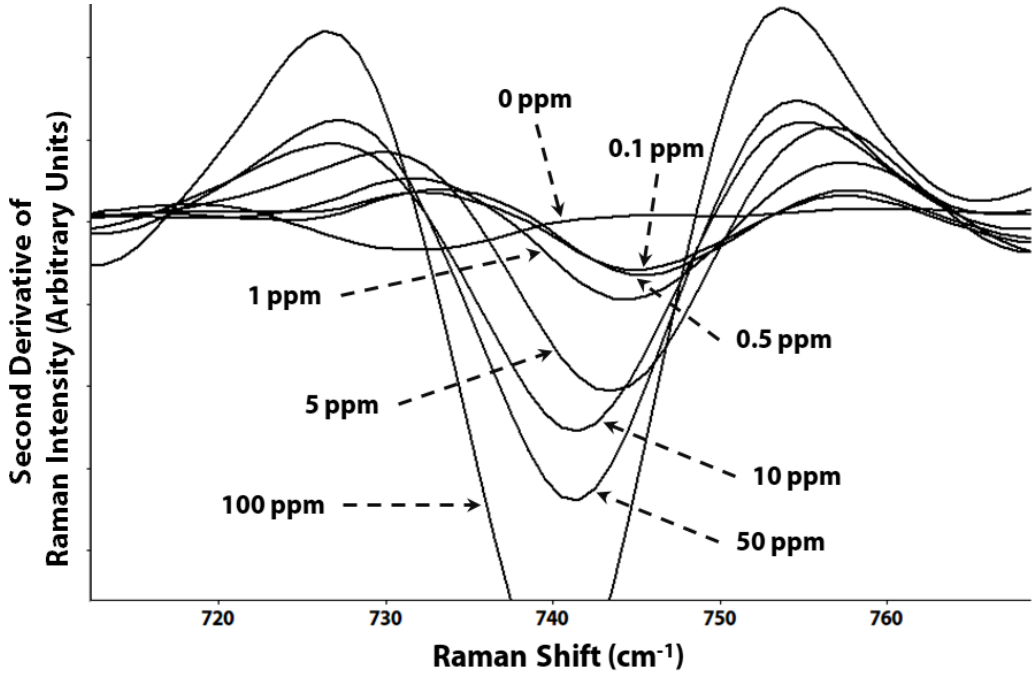

Figure 22. Part of second derivative transformation of average SERS spectra (n = 8) acquired from different concentrations of myclobutanil solutions.

Like previous studies, PLS analysis was conducted. Figure 23 shows RMSEP data of myclobutanil spectra and Figure 24 shows the prediction results (n = 62). The spectra were pre-processed with smoothing at 4 cm^{-1} followed by the subtraction of a second order polynomial. It was best to use eight latent variables to build a PLS model for myclobutanil. This number was eight for captan and seven for pyraclostrobin. Detection limits of SERS methods for the three pesticides were calculated with parameters of PLS models according to Equation (2) mentioned in Chapter 3.1.4. The parameters and

results of DL calculation are summarized in Table 8. The R and slope values are satisfactory for all three pesticides.

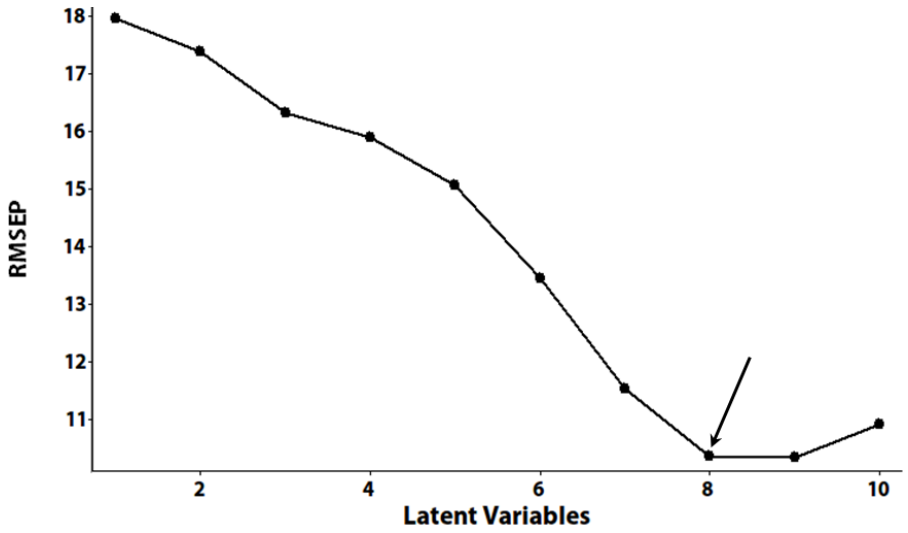

Figure 23. Root mean square error of prediction (RMSEP) values obtained from the partial least squares (PLS) models based on myclobutanil spectra with different latent variables.

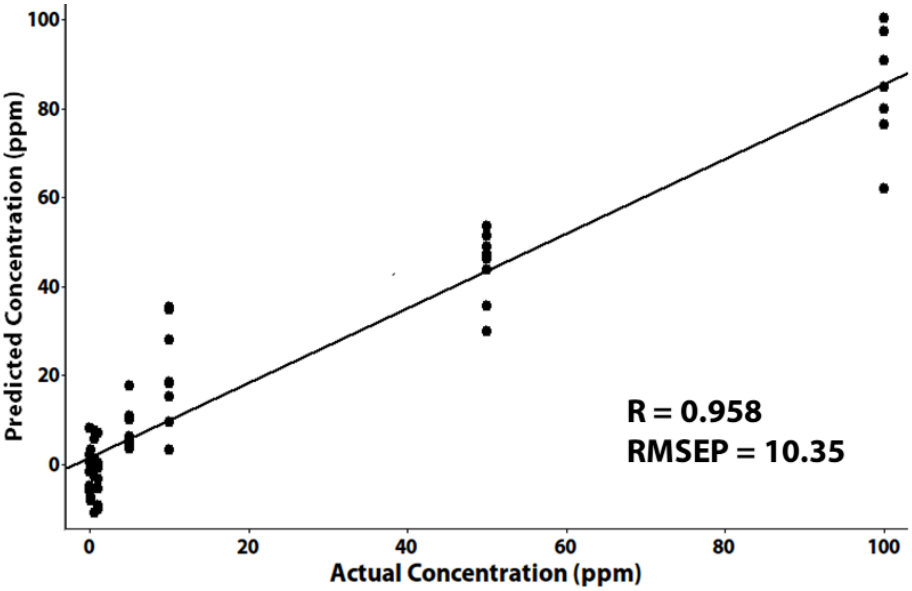

Figure 24. Predicted myclobutanil concentration (ppm) vs. actual myclobutanil concentration (ppm) using the PLS models.

Table 8. Calculation of detection limits (DL) of SERS methods for captan, myclobutanil, and pyraclostrobin in pure form.

	R	Standard Error (RMSEP)	Slope	DL (ppm)
Captan	0.98	6.87	0.99	20.82
Myclobutanil	0.96	10.35	0.84	36.96
Pyraclostrobin	0.89	14.85	0.81	55.00

Figure 25 presents the results of using the first two PCs to classify the three pesticides. The subjects were differentiated well. Because several functional groups of myclobutanil also exist in pyraclostrobin (e.g. p-Chlorophenyl and heterocycle), myclobutanil overlaps more with pyraclostrobin than with captan.

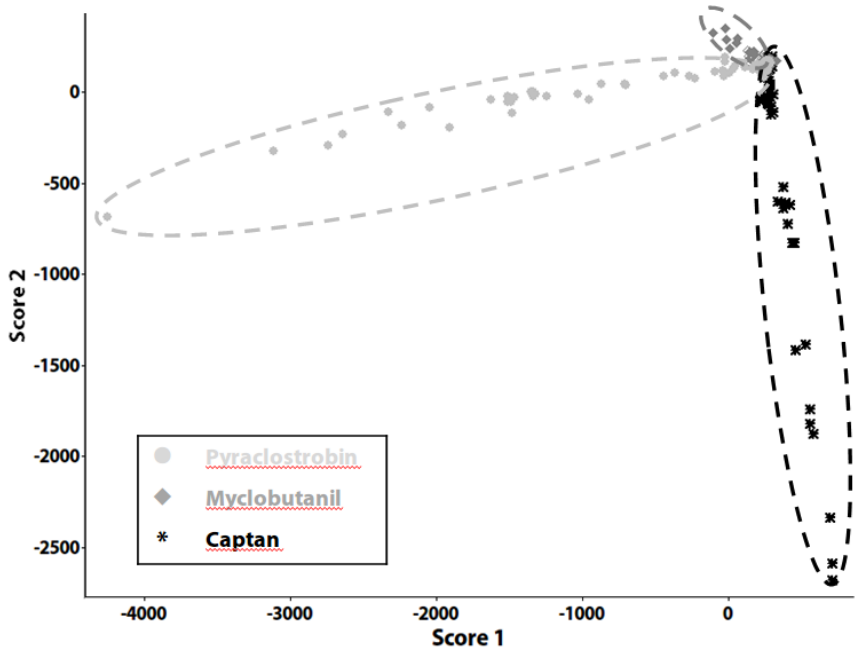

Figure 25. Classification of captan, myclobutanil, and pyraclostrobin using the first two principle components (PCs).

Next, we applied SERS methods to detect captan, myclobutanil, and pyraclostrobin in strawberries. Figure 26 shows a representative part obtained from strawberries spiked with myclobutanil. The 10 ppm spectrum can be discriminated from

the 0 ppm one, which is also the case for captan and pyraclostrobin. According to the U.S. Code Federal Regulations (CFR) Title 40 Part 180 (U.S. EPA 2012), MRLs for captan, myclobutanil, and pyraclostrobin in strawberries are 20 ppm, 0.5 ppm, and 1.2 ppm, respectively. The SERS methods meet the requirements for detection of captan in strawberries and possess great potential to be further developed to detect other pesticides.

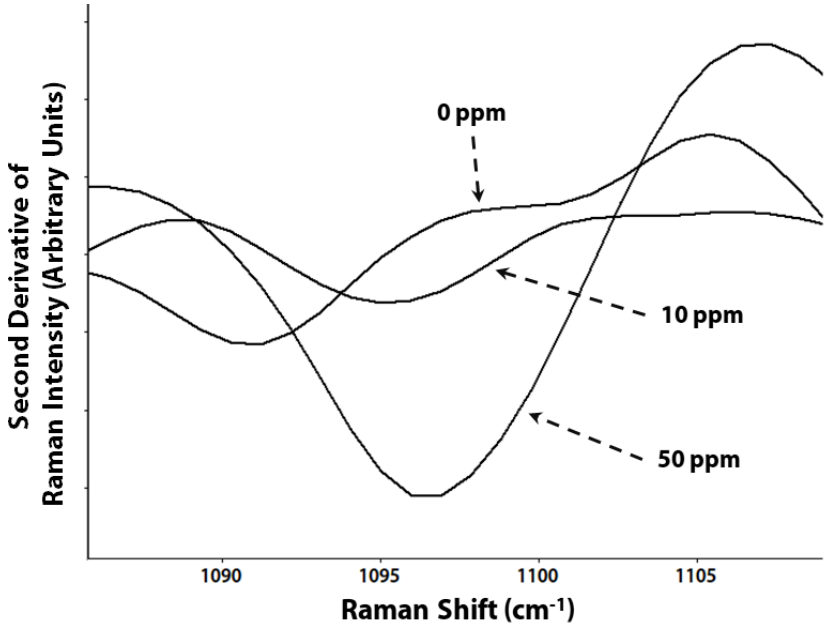

Figure 26. Part of second derivative transformation of average SERS spectra (n = 8) acquired from the extracts of strawberries containing different concentrations of myclobutanil.

Unlike apples and tomatoes which retain most of the pesticides in their low-permeable skin (discussed in Chapter 4.1.2), strawberry skin is very soft and does not offer such protection. Because pesticides are injected into the soil before planting strawberries (Wollan 2010) and strawberries grow very close to the ground, strawberries are prone to be constantly contaminated by pesticides in soil. These factors make pesticides penetrate easily into strawberry fruit and difficult to extract using simple steps. Therefore, for SERS methods to become an efficient method for detection of pesticides in

strawberries and other similar berries, there is still some work to be done. In summary, our results show that SERS is a promising approach to detection of pesticides in strawberries.

4.2. Behavioral Approach

4.2.1. Study 1: Modeling food safety practices among Chinese in the United States

Demographic information of participants is shown in Table 9. Of 124 participants, 51 were male and 73 were female. Twenty-three participants identified their current health status as “excellent”, 63 as “very good”, 26 as “good”, and 12 as “fair”. No participants considered their current health status “bad”. Sixty participants held an advanced degree (M.S., Ph.D., J.D., M.D., etc.); 29 were enrolled in graduate or professional schools; 23 completed college education but not higher levels; 10 were studying in a university; 1 completed high school; 1 only had a junior high school education. Forty-three participants reported that they received some food safety education within last 5 years. Nearly half of the participants (59) were between 25 to 29 years old. The respondents’ origin was asked in the questionnaire (“Which province/municipal city of China do you come from?”). The respondents were mainly from Beijing (42), followed by Tianjin (12), Shanghai (9), Guangdong (6), and Jiangsu (6). These provinces/municipal cities are generally considered as more economically developed in China.

Table 9. Demographic characteristics of participants (food safety practice study, $n = 124$).

Variable	%
Sex	
Male	41.1
Female	58.9
Self-estimated Current Health Status	
Excellent	18.5
Very good	50.8
Good	21.0
Fair	9.7
Bad	0
Education	
Junior high school	0.8
Senior high school	0.8
Studying in a university	8.1
Having received a college degree	18.5
Studying in graduate/professional school	23.4
Having received an advanced degree	48.0
Received education on food safety during past 5 years	
Yes	34.7
No	65.3
Age	
20 to 24	15.2
25 to 29	47.6
30 to 34	15.3
35 to 39	7.3
40 to 44	7.3
45 to 49	2.4
50 to 54	3.2
55 to 59	1.6

Means and standard deviations of ATB, SN, SE, PRC, and KNO are shown in Table 10. Higher scores indicated stronger beliefs (ATB, SN, and SE), better compliance to safe food handling practice principles (PRC), and better safe food handling knowledge (KNO). All scores were relatively high (more than 60% of full score), suggesting that the participants generally hold positive attitudes toward safe food handling practices, consider social norms important, possess high level of self-efficacy, perform safe food handling practices well, and have good knowledge about safe food handling. To assess internal reliability, Cronbach's alpha was calculated for ATB, SN, SE, and PRC. The

results are also listed in Table 10. All variables demonstrated a satisfactory reliability level, as evidenced by Cronbach's alpha values of larger than 0.7 (Nunnally 1978).

Table 10. Descriptive statistics of several variables (food safety practice study, $n = 124$).

Variable	Mean	SD	Cronbach's alpha
ATB	25.80	3.39	0.70
SN	12.59	2.51	0.85
SE	25.55	3.67	0.75
PRC	124.26	15.10	0.85
KNO	55.04	6.31	

ATB: attitude toward behavior; SN: subjective norms; SE: self-efficacy; PRC: safe food handling practices; KNO: knowledge of safe food handling
Ranges of possible score: ATB: 8 to 40; SN: 3 to 15; SE: 6 to 30; PRC: 33 to 165; KNO: 4 to 86.

A multiple linear regression model was fitted using PRC as the dependent variable and ATB, SN, SE, and KNO as the independent variables. Fitting results are shown in Table 11, including unstandardized regression coefficients (B), standardized regression coefficients (β), R, R^2, and adjusted R^2. The model was statistically significant ($R = 0.59$, $p < 0.001$) and explained 35% ($R^2 = 0.35$) of total variance of safe food handling practices. Analysis of variance results indicated that ATB ($B = 1.38$, $\beta = 0.31$, $p < 0.01$) and SE ($B = 0.97$, $\beta = 0.24$, $p < 0.05$) were significant indicators of PRC. Therefore, attitude toward behavior and self-efficacy contributed to safe food handling practices significantly.

Table 11. Multiple linear regressions of safe food handling practices on TPB variables and knowledge.

Independent Variables	B	β
ATB	1.38**	0.31
SN	0.59	0.10
SE	0.97*	0.24
KNO	0.23	0.10
$R = 0.59^{***}$, $R^2 = 0.35$, adjusted $R^2 = 0.33$		

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; $n = 124$.
TPB: Theory of Planned Behavior; PRC: safe food handling practices ATB: attitude toward behavior; SN: subjective norms; SE: self-efficacy; KNO

Although we did not limit participants to a certain group of individuals, most of them were college and graduate students, as implied by age (15.2% of total participants were from 20 to 24 years old, 47.6% were from 25 to 29, and 15.3% were between 30 and 34). In the place where the study was conducted, the majority of Chinese students were born in China and they came to the U.S. just to attend school. They grew in the Chinese culture, the same as Chinese food exporters. Therefore, their attitude, knowledge, and practice may closely resemble those of Chinese food exporters'. Surveying Chinese exporters is ideal, but participants in this study still hold representability to some extent.

It was demonstrated in our study that attitude toward behavior and self-efficacy were strong indicators of food safety practices among Chinese. The two factors were also identified as significant predictors of some other behaviors, such as HIV-related sexual risk behavior (Basen-Engquist and Parcel 1992), oral health behavior (Tedesco and others 1991), adoption of healthy eating and dietary behavior (Hearty and others 2007), and utilization of information technology by hotel employees (Lam and others 2007). Our study also provided evidence supporting the TPB model being used to understand and

predict people's safe food handling practices, which agree with some previous researches (Clayton and Griffith 2008; Mullan and Wong 2009).

Subjective norms, on the contrary, did not contribute significantly to food safety practices among Chinese. This is in accordance with some previous studies, which identified subjective norms as either very weak or a non-significant predictor of intention and behavior (Godin and Kok 1996; Armitage and Conner 2001; Jenner and others 2002). Trafimow and Finlay (1996) divided people into two groups, arguing that while behaviors of most individuals were primarily driven by attitudinal factors, a minority of people were more likely to perform behaviors based on normative factors. However, no further studies have identified characteristics of such a "minority group". Another explanation attributed the weak capacity of subjective norms to using only one item to measure it (Armitage and Conner 2001). In our questionnaire, there were three items measuring subjective norms, so the methodology should not be a problem. The failure of subjective norms to act as a significant predictor may be due to the demographic characteristics of the subjects. In our study, the participants were mainly of relatively young age (62.8% were under 30 years old). Compared to their parents, this generation of Chinese grew up in very different conditions: more support from family due to the one-child policy, more affluent lifestyle resulted from China's dramatic economic growth, and more opportunities to observe and interact with the world. Altogether, these factors made the decision-making process of Chinese young people more independent and more focused on individual value (Xu 2002; Xi and others 2006). Thus, it became natural that their behavioral intention involved little or none subjective norms. To test this inference, a similar study focusing on older Chinese adults can be conducted.

Knowledge was not a significant predictor of safe food handling practices. This is consistent with a previous study reporting that consumers' knowledge of specific hygiene practices did not positively reflect their actual behavior (Clayton and others 2003). The reason for such disparity may be threefold. The first reason is demographic characteristics of the participants. Two studies aiming to understand adolescents' health-related behavior (dietary and sexual) revealed that better knowledge did not necessarily lead to improved health behavior (Mirmiran and others 2007; Berten and Van Rossem 2009), which is in agreement with our results obtained from a young sample. Behavior of young people may be less steady and more affected by some other factors rather than knowledge. The second reason is that food safety behavior is not always "rational", or under volitional control, as some researchers argued (Clayton and others 2003); thus, knowledge about food safety is not necessarily translated into food handling practices. The third reason is that the promoting effect of knowledge on actual behavior may be mediated by other factors. In a study evaluating outcomes of a heart disease prevention education campaign, strong knowledge-behavior correlation was only found in people with a high level of cognitive involvement (i.e. they tend to think more deeply about information they received and are more involved in the issue) (Chaffee and Roser 1986). In longitudinal studies, self-efficacy (Rimal 2000, 2001) and perceived risk (Rimal 2001) were found to enhance knowledge-behavior correlation in regard to cardiovascular disease prevention. More research is needed to discover the underlying mechanisms. The disparity between knowledge and health-related behavior suggests that although the teaching of knowledge in food safety education programs is essential, factors other than knowledge deserve more attention.

A number of issues weaken the strength of this study. First, the sample size is relatively small and the majority of participants were of relatively young age, highly educated, and from developed areas of China. Thus, the sample may not be representative enough of the Chinese population living in the U.S. Second, distribution of the questionnaire via the internet is convenient, but may be perceived less formal by participants, which may lead to inaccurate answers. Third, self-reported behavior was used in the study, so the significant predictors we identified may not serve as strong factors for actual (observed) behavior (Redmond and Griffith 2003).

4.2.2. Study 2: Assessment of effects of technology advancement on Chinese food exporters' beliefs of business ethics

Demographic information of participants is summarized in Table 12. There were 58 participants in total. Most participants (72.4%) were female. The range of age of participants was typical young professionals. Accordingly, the participants have 1 to 6 years (3.2 ± 2.6) of industrial experience. Most of the participants (81.0%) obtained a college degree.

Table 12. Demographic characteristics of participants (business ethics study).

Total number	58
Sex	
Male	16 (27.6%)
Female	42 (72.4%)
Education	
High school	5 (8.6%)
College	47 (81.0%)
Advanced degree	6 (10.3%)
Age [a]	26 ± 3.2
Industrial experience [b]	3.2 ± 2.6

a, b: two and thirteen respondents did not disclose corresponding information, respectively. Age and industrial experience are reported as mean ± standard deviation in years.

The first scenario of the questionnaire was designed to assess the effects of technology advancement on business ethics. The result of this part is summarized in Table 13. Among responses provided by the participants, only one question showed a significant difference.

Table 13. Comparison between responses to questions of the first scenario given by control and experimental groups.

Statement	Group	Mean	SD	*t*	*p*
Change nothing in your business practice. Continue your current practice of buying adulterated raw materials.	Control Experimental	1.79 1.40	1.17 0.56	-1.59	0.12
Make sure that your subordinates will not learn about the information.	Control Experimental	2.43 3.00	1.43 1.26	1.62	0.11
Make sure that your supervisor will not learn about the information.	Control Experimental	2.21 3.47	1.50 1.00	0.75	0.46
Share the information with you supervisor, admit that you have been using problematic raw materials to reduce cost, and discuss possible countermeasures.	Control Experimental	3.64 3.83	1.52 1.15	-0.54	0.60
Resign without revealing any reasons.	Control Experimental	2.21 2.87	1.17 1.07	-2.22	0.03*
Admit that you have been using problematic raw materials and resign.	Control Experimental	2.82 2.93	1.33 1.14	-0.34	0.73

* $p < 0.05$. *n*: control 28, experimental 30. All statements were presented to participants using Likert scales (from 1, "very unlikely" to 5, "very likely").

Change nothing in your business practice. Continue your current practice of buying adulterated raw materials. Although the experimental group showed a lower score than the control group (1.40 vs. 1.79), indicating that the participants were less likely to adopt this measure when learning that a powerful method is available for use, but the difference was not significant. The participants appeared to highly disagree with this statement, as evidenced by mean scores of over four in the control and experimental groups.

Make sure that your subordinates will not learn about the information and *Make sure that your supervisor will not learn about the information.* Results of these two questions showed no difference in participants (2.43 vs. 3.00, 2.21 vs. 3.47, respectively). Degree of agreement to these two statements was mostly neutral. Interestingly, participants of experimental group tended to agree with these statements more than their control group counterparts, although non-significantly.

Share the information with your supervisor, admit that you have been using problematic raw materials to reduce cost, and discuss possible countermeasures and *Admit that you have been using problematic raw materials and resign.* These two statements were the most difficult questions in this scenario. Agreeing with them suggests the respondent's belief in business ethics standards was strong. The participants achieved high scores in the first statement (control group 3.64, experimental group 3.83), but their scores of the second statement were neutral (control group 2.82, experimental group 2.93). No significant differences were found between the control and experimental groups.

Resign without revealing any reasons. The participants showed a significant difference in responses to this question between the control and experimental groups (2.21 vs. 2.87). Participants in the experimental group agreed with this statement more than those in the control group.

The purpose of the rest of the questions in the questionnaire was to evaluate the participants' beliefs on business ethics. These questions included a scenario of crisis management and a section of scales directly measuring beliefs on business ethics. Some questions in the scales were reverse scored to facilitate factor analysis. In this case, the

higher score in the scales indicates better compliance to business ethics standards.

Descriptive statistics of these questions are summarized in Tables 14 and 15.

Table 14. Responses to Scenario 2 questions.

Statement	Mean	SD
Declare that this is just an accident and that the company's products are safe.	3.64	1.37
Use *guanxi* to quench dissatisfactory voices, including ordering the media to stop coverage and deleting posts on the internet.	2.98	1.23
Voluntarily recall all products from the market.	4.33	0.91
Invest more to prevent of such incidents from happening.	3.98	1.12
Use *guanxi* to persuade the officials of the regulatory authority to alter the testing results.	2.16	1.06
Issue a sincere public apology.	4.52	0.73

$n = 58$. All statements were presented to participants using Likert scales (from 1, "very unlikely" to 5, "very likely").

Table 15. Responses to business ethics scales.

Statement	Mean	SD
Doing what is ethically right is good business in the long run.	4.66	0.69
Business people working in my field tend to ignore ethical considerations when doing business.[a]	3.62	1.07
Whatever is good business is good ethics.[a]	4.43	0.68
As a result of stiffer competition today, many business people find themselves forced to resort to practices which are considered shady, but which appear necessary to survive.[a]	3.59	0.99
Business people exist for the sole purpose of creating and delivering value satisfaction at a profit to themselves. Therefore, business decisions should be made without regard to moral issues.[a]	4.29	0.75
The most important concern for a firm is making a profit, even if it means bending or breaking the rules.[a]	3.97	0.88
To remain competitive in a global environment, business firms will have to disregard ethics and social responsibility.[a]	4	1.06
If survival of a business enterprise is at stake, then you must forget about ethics and social responsibility.[a]	4.12	0.84
Efficiency is much more important to a firm than whether or not the firm is seen as ethical or socially responsible.[a]	3.36	1.05
If the consumers are unhappy, nothing else matters.	3.52	0.98
Being ethical and socially responsible is the most important thing a firm can do.	3.91	0.88
The overall effectiveness of a business can be determined to a great extent by the degree to which it is ethical and socially responsible.	3.72	0.93
Business ethics and social responsibility are critical to the survival of a business enterprise.	4.24	0.73
Business has a social responsibility beyond making a profit.	4.34	0.69
Social responsibility and profitability can be compatible.	4.29	0.68
Importance of guanxi (in addition to the second and fifth statements in Scenario 2)		
Guanxi is extremely important in my business practice.[a]	2.07	0.81
Without seeking to *guanxi*, I can still be successful in business.	2.71	0.92

a: reverse scored. $n = 58$. All statements were presented to participants using Likert scales (from 1, "strongly disagree" to 5, "strongly agree").
Questions related to *guanxi*: high score indicates that the participant valued *guanxi* as not important, suggesting a high level of compliance to business ethics standards.

In the crisis management scenario, most participants agreed that they would take positive actions such as issuing a public apology, voluntarily recalling products, and making more investments to keep food safety incidents from happening. Also, they appeared unlikely to take advantage of *guanxi* when facing a food safety crisis. In the section of business ethics measurement, the majority of participants disagreed with reverse-scored statements (the lowest mean score of one single item in this part was 3.36). Consistently, they showed medium to high level of agreement to other statements in this section (the lowest mean score of one single item in this part was 3.52). The last two questions about importance of *guanxi* showed consistent results. Most participants believed that "*guanxi* is extremely important in my business practice" (mean score 2.07, reverse scored). They also disagreed with the statement "without seeking to *guanxi*, I can still be successful in business" (mean score 2.71, reverse scored). These results suggest that the participants valued *guanxi* highly in their business career.

A principal components factor analysis was conducted using responses of business scale questions with varimax rotation. Table 16 shows the results of factor loadings (loadings less than 0.3 was omitted). There were five factors with eigenvalues larger than one. Internal reliability of these factors was shown in the table using Cronbach's alpha values, all of which were relatively adequate (from 0.61 to 0.82) except for the fifth factor (0.27). Combined together, the five factors explained approximately 63% of the total variance.

Table 16. Factor analysis of business ethics scales.

Statement	Factor loadings				
	1	2	3	4	5
Business ethics and social responsibility are critical to the survival of a business enterprise.	0.84				
Social responsibility and profitability can be compatible.	0.83				
The overall effectiveness of a business can be determined to a great extent by the degree to which it is ethical and socially responsible.	0.75				
Business has a social responsibility beyond making a profit.	0.6				
The most important concern for a firm is making a profit, even if it means bending or breaking the rules.	0.5	0.49			
Being ethical and socially responsible is the most important thing a firm can do.	0.49		0.57		
Whatever is good business is good ethics.		0.77			
If survival of a business enterprise is at stake, then you must forget about ethics and social responsibility.		0.7			
To remain competitive in a global environment, business firms will have to disregard ethics and social responsibility.		0.63			
Business people exist for the sole purpose of creating and delivering value satisfaction at a profit to themselves. Therefore, business decisions should be made without regard to moral issues.		0.62		0.36	
As a result of stiffer competition today, many business people find themselves forced to resort to practices which are considered shady, but which appear necessary to survive.		0.44		0.58	0.36
Efficiency is much more important to a firm than whether or not the firm is seen as ethical or socially responsible.		0.42		0.58	
If the consumers are unhappy, nothing else matters.			0.75		
Doing what is ethically right is good business in the long run.			0.69		
Business people working in my field tend to ignore ethical considerations when doing business.				0.84	
Without seeking to *guanxi*, I can still be successful in business.					0.79
Guanxi is extremely important in my business practice.					0.73
Percentage of total variance explained	18.9	16.0	9.8	9.7	8.2
Cronbach's alpha	0.82	0.80	0.61	0.66	0.27

The first factor explained about 18.9% of the total variance. The factor addressed the importance of both business ethics and social responsibility. Items loaded on this dimension included “being ethical and socially responsible is the most important thing a firm can do”, “the overall effectiveness of a business can be determined to a great extent

by the degree to which it is ethical and socially responsible", and "business ethics and social responsibility are critical to the survival of a business enterprise". There were also some items addressing the compatibility of ethics and social responsibility in this factor ("social responsibility and profitability can be compatible" and "business has a social responsibility beyond making a profit").

The second factor explained approximately 16.0% of the total variance and focused on the superiority of profit, efficiency, and survival over business ethics and social responsibility. This factor included statements such as "if survival of a business enterprise is at stake, then you must forget about ethics and social responsibility" and "to remain competitive in a global environment, business firms will have to disregard ethics and social responsibility". One item ("the most important concern for a firm is making a profit, even if it means bending or breaking the rules") loaded on both the first and the second factors, which may be due to the item's emphasis on both importance and profit-making.

The third factor accounted for about 9.8% of the total variance. This factor seemed to largely overlap with the first factor. Statements loaded on it included "if the consumers are unhappy, nothing else matters" and "doing what is ethically right is good business in the long run", both of which acknowledged the importance of business ethics. In addition, the statement "being ethical and socially responsible is the most important thing a firm can do", which obviously spoke the importance of social responsibility, loaded on both the first and the third factors.

The fourth factor was responsible for about 9.7% of the total variance. It mainly implied personal choice between profit-making and business ethics. The statement "business people working in my field tend to ignore ethical considerations when doing

business" loaded on this factor. Some items indicating decision-making ("as a result of stiffer competition today, many business people find themselves forced to resort to practices which are considered shady, but which appear necessary to survive" and "business people exist for the sole purpose of creating and delivering value satisfaction at a profit to themselves; therefore, business decisions should be made without regard to moral issues") were included in this factor in addition to the second factor.

The fifth factor explaining about 8.2% of the total variance was about *guanxi*. The two items related to *guanxi* ("without seeking to *guanxi*, I can still be successful in business" and "g*uanxi* is extremely important in my business practice") both loaded on this factor. One item ("as a result of stiffer competition today, many business people find themselves forced to resort to practices which are considered shady, but which appear necessary to survive") was included in the second, fourth and fifth factors because its statement fell in these three categories: the superiority of survival over ethics, personal choice, and interpersonal interaction. The low Cronbach's alpha (0.27) of this factor may be due to the complexity of *guanxi*. Unlike the other four factors, *guanxi* is a complicated concept itself, so it was possible that the three items included in the fifth factor did not describe one single aspect of *guanxi*.

The answers to the open-end question ("what do you think is the fundamental reason for China's food safety problems?") were categorized and the results are summarized in Figure 27. Out of 40 participants who gave valid responses to the question, 20 (50.0%) believed that lack of business and social responsibility is one of the fundamental reasons for China's food safety problems. Nineteen (47.5%) blamed an incompetent government ("the government fails to do its job in regulation"). Sixteen (40.0%) thought excessive pursuit for profits ("food companies prioritize profits too

much") is the answer. Other notable answers included too little punishment ("punishment for violating laws is not harsh enough", 35.0%), corruption (15.0%), and incomplete law system ("related laws and standards haven't been established", 12.5%). These top reasons provide some potential targets for intervention programs, strategies, and policies that aim to solve China's food safety problems, as well as safety problems of food products imported from China by the U.S.

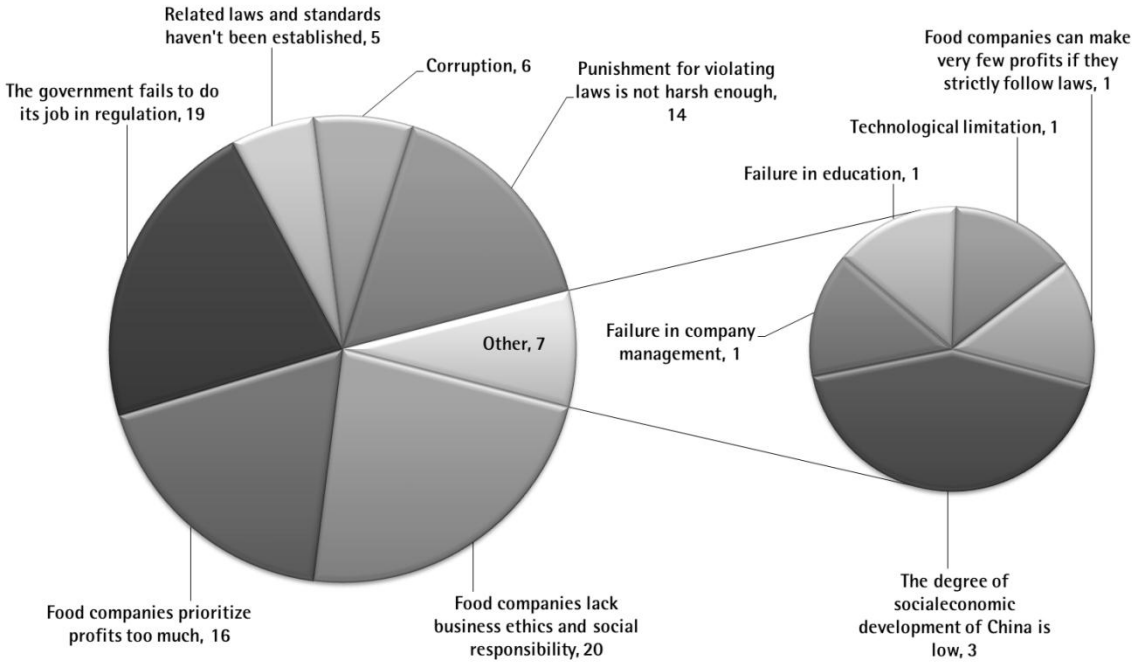

Figure 27. Reasons for China's food safety problems, provided by participants.
The number indicates how many participants listed the corresponding reason in their answers to the open-end question.

The results of the first scenario were rather complicated. That advancement in technology would result in better compliance with business ethics was confirmed in one statement. After learning the information of advancement in technology, the participants would more likely to actively leave the job. The information of technology advancement

also nonsignificantly increases the tendency of participants to actively change their faulty business practice. These results could be attributed to participants' backgrounds. For example, the participants may consider it very difficult to keep the information, which is easily accessible online nowadays, from coworkers, so they didn't choose "make sure that your subordinates/supervisor will not learn about the information". Being working professionals, they may be more concerned about their jobs than actual business practice, which is possibly the reason why the control and experimental groups showed significant differences on the statement "resign without revealing any reasons" but not "change nothing in your business practice".

No significant difference was found in responses of the two most "radical" actions, and the degree of agreement for these actions was mostly neutral. These results strongly suggest that technology advance alone cannot improve individuals' compliance with business ethics standards; thus, supporting our claim that an integrative, comprehensive approach is essential to fight against China's food safety problems.

It should be noted that all participants showed medium to high levels of compliance to business ethics standards, as evidenced by scoring three or higher in most questions in the second scenario and . This might be surprising to some extent, considering the grave situation of food safety in China. Especially, in the crisis management scenario, ordinary actions to make such as "voluntarily recall all products from the market" and "issue a sincere public apology" were strongly agreed by the participants (mean score > 4.3). These responses were somewhat unexpected because these actions are not generally adopted by Chinese food companies that are responsible for some recent high profile food safety incidents. Two reasons could be proposed to explain this phenomenon. First, our participants had limited industrial experience, so

their attitudes and beliefs may not represent the mainstream of Chinese food industry. Also, self-reported results may not always faithfully reflect real-world situation. Second, food safety incidents have become a very hot topic in China for several years. Media coverage and discussion on social networks are extensive. Exposed in this situation, the participants may have subconsciously improved their level of compliance to business ethics standards.

Responses from questions related to *guanxi* in the second scenario suggested that the participants would not rely heavily on *guanxi* to handle the crisis, as indicated by mean scores of about 3 for the statement "use *guanxi* to quench dissatisfactory voices, including ordering the media to stop coverage and deleting posts on the internet" and 3.9 for "use *guanxi* to persuade the officials of the regulatory authority to alter the testing results". This is in stark contrast to the result that the participants valued *guanxi* highly in their business career, as evidenced by their responses to the two questions related to *guanxi* in the section of business ethics scales. This surprising inconsistency may be due to the nature of the participants, who are professionals with not much industrial experience (3 years on average). The participants may have too little experience with *guanxi* to feel its effects in business practices; thus, when they were asked to solve a problem *guanxi* was not one of the answers they would consider.

The results of factor analysis were roughly in accordance with previous reports which utilized similar instrument (Axinn and others 2004; Shafer and others 2006). In those studies, three factors were identified from factor analysis: importance, stockholder view, and compatibility (which included statements such as "Social responsibility and profitability can be compatible" and "Business has a social responsibility beyond making a profit"). Among them, importance and stockholder view are essentially the first and

second factors of our results. The reason why in our study some other factors were extracted and compatibility wasn't identified may be the relatively small sample size, difference in backgrounds of participants, and difference in instrument. The other two studies both recruited hundreds of participants who were American managers and MBA students from various countries (Axinn and others 2004; Shafer and others 2006).

This study has multiple limitations. First, the sample size is very small and the profiles of participants may not represent those of Chinese food industry workers. Studies with larger and more representative samples need to be conducted before any decisive conclusions can be made. Second, the study used a questionnaire to collect data about self-reported behavior, which may not reflect the participants' decision if they had the chance to solve problems in the real world. The relationship between one's view on *guanxi* and how this individual utilizes *guanxi* at work could be an interesting research topic.

CHAPTER 5

FUTURE RESEARCH AND CONCLUSIONS

5.1. Challenges of SERS in Detection of Food Contaminants

We have used SERS to detect important contaminants in various food matrices, including milk, apples, tomatoes, and strawberries. In general, SERS proved to be a rapid, accurate, and adequately sensitive technique in food analytical chemistry. While SERS has these advantages, there are some barriers to overcome before SERS can be widely applied as a mature method like HPLC, and mass spectrometry for real-world applications.

Unlike other methods such as IR and HPLC that have databases of enormous spectra for a wide range of chemical compounds, Raman (and SERS) spectral data of chemicals are still largely incomplete. Spectra of many important potential contaminants in foods are not available yet. Building a comprehensive spectral database is a demanding task that calls for great efforts of researchers before SERS can be put into real-world practice.

In some cases, consistency of SERS measurement is not satisfactory. It is not strange for two measurements taken from nearby areas of the same sample to yield different results. This is mainly due to the inconsistency in substrate surfaces. Construction of uniform and consistent nanostructures requires accurate and sophisticated techniques and it is challenging for chemical methods to achieve this goal.

The laser-carving approach to fabricate Klarite™ substrates is a good way but its cost is rather high.

Building quality substrates is only one side of the coin. The scarcity of choices of substrates is another problem. In a sense, the importance of substrates to SERS is similar to that of solvent systems to HPLC techniques. Just as HPLC solvent systems need to be fine-tuned for each analyte, there is no universal SERS substrate suitable for testing all chemicals. There are so many potential substances that can contaminate food products; thus, substrates with different characteristics are in critical demand to meet a variety of different needs. With only two commercially available substrates (Q-SERS™ and Klarite™), there remains a large gap to fill. In addition, the high price and non-reusability of substrates also impede the practicability of SERS technology.

SERS is known for its considerably fast speed of detection. Under many circumstances, SERS is superior to HPLC in terms of detection speed and easiness of sample preparation. However, when compared to ELISA kits in qualitative uses, SERS is neither significantly faster nor much easier to perform. In addition, requirements for sample preparation procedures in SERS are not easy to meet: they mustn't cost too much time, which impairs the major advantage of SERS—rapidness; yet they need to be effective enough to extract a fair amount of analytes from complex food matrices. The procedures of sample preparation adopted in this dissertation are based on procedures for other spectroscopic methods with some modifications, but the process of SERS measurement does not possess the strong extraction capacity these methods offer. Therefore, in a way, current sample preparation procedures for SERS are incompatible with subsequent measurement practices.

As shown in our studies, to interpret SERS data, extensive analyses (PLS, PCA, etc.) must be performed. This is not convenient and to some extent offsets rapidness of SERS methods. It is not difficult to develop software for automatic data analysis, but since SERS hasn't been applied widely, there is little demand for such software, hence Raman spectrometer manufacturers hasn't distributed much resource to this issue.

The cost of a spectrometer is another issue. A bench-top Raman spectrometer that might compare with a ~$50,000 HPLC in detectability may cost $100,000 or more. Portable Raman spectrometers cost less but their sensitivity may not be good enough for testing trace amounts of food contaminants. Taking in account current economic conditions, the food industry is more reluctant to invest in new technologies.

Furthermore, the culture of the food industry needs to be taken into consideration. In many ways, the food industry is conservative and does not usually embrace new technologies enthusiastically. Assurance of product safety and quality is much more important than innovation in the food industry. This is due to the nature of the food industry—its products directly interact with the human body so tiny faultiness in products could result in disastrous consequences. Even though some large companies have been investing heavily in the development of new products, when it comes to technologies that do not have a direct effect on revenue, they usually choose not to risk too much money. On the other hand, when there is novel technology available, the food industry is more cautious about applying it. This "safety first" culture, of course, is good practice, and should be upheld firmly. But it could be better if the food industry becomes a bit more adventurous by sampling more dishes freshly cooked in the labs.

5.2. Future Directions of SERS Development

Based on the discussions above, to further advance SERS in food safety assurance, the following tasks must be accomplished:

- Build a comprehensive spectral database of possible food contaminants;
- Develop high quality substrates, tailored to specific objects if possible;
- Establish effective and rapid procedures for extraction of contaminants from foods;
- Develop computer software suitable for automated analysis of Raman spectra;
- Lower the cost of bench-top and portable Raman spectrometers; and
- Persuade decision makers in the food industry to put more effort in supporting the development of SERS and other novel techniques.

5.3. Future Work in Behavioral Approach

The behavioral researches conducted in this dissertation are just preliminary studies of profiling food manufacturers and exporters in China. There are many ways in which further studies could be carried out to confirm our findings and to further understand these issues: larger scale, more representative samples (e.g. randomly drawn samples), longitudinal studies, different description of technology, etc. In addition, actual behavior may be used in lieu of self-reported behavior. In the long run, these studies may lead to education and/or intervention programs for individuals working in China's food industry.

5.4. Conclusions

In the scientific approach, SERS combined with two kinds of novel nanosubstrates, was applied to detect a variety of chemical contaminants (melamine, cyanuric acid, and various types of pesticides) in real food matrices including milk, apples, tomatoes, and strawberries. Most of the results meet the requirements set by FDA, FAO or WHO. Although there are still many challenges to overcome, SERS has great potential to catch up with ordinary analytical chemistry methods in detectability and robustness. In addition, compared to traditional methods, SERS measurement is much easier and faster to conduct. SERS will play an important role in first-line food safety defense, if adequate resources are allocated to its development.

In the behavioral approach, we modeled food safety practices among Chinese in the United States and surveyed effects of technology advancement on Chinese food exporters' beliefs of business ethics. In the first study, we found that attitude toward behavior and self-efficacy were significant indicators of safe food handling behavior. Another notable finding was that food safety knowledge was not a significant predictor of safe food handling practices. In the second study, the participants generally showed high levels of compliance with business ethics standards. Information about technology advancement had significant effects on decision about resigning but not as potent in actual business practice. Some evidence we found suggests that the compliance with business ethics standards cannot be improved by technological advancement solely. The participants put *guanxi* in a position that can greatly affect their business careers, but when facing a difficult problem they appeared to reject taking advantage of it. Some possible reasons for China's food problems were suggested by participants.

In this dissertation, attempts were made to link the scientific approach to the behavioral approach, which should be the norm for future decision-making processes related food safety. These two approaches should be considered not only simultaneously but collectively: Experts from both scientific and behavioral fields should collaborate extensively; thus, opinions they provide will involve input from the other field and be more practical and fundamental. To achieve this, more resources should be provided to the behavioral side to support researchers in this field to conduct more large-scale and novel studies. This will be a time- and labor-intensive process, but it is necessary. Even preliminary findings in the behavioral field could result in substantial benefit in early stages of decision-making.

Behavioral education should play a more important role in future training programs for food industry workers. Teaching them how to safely manufacture food products is undoubtedly essential, but it is the behavioral education that can guarantee that such safe practices will be stuck with all the time. Formation and enforcement of correct attitudes should be the center of such programs. In addition to food industry workers, the public need to be educated more using pertinent programs based on findings of behavioral researches.

Studies conducted in this dissertation cover a wide range of issues about safety problems of food products imported from China. If there were anything special about this dissertation, it would be that it underscores the importance of connecting scientific research with behavioral intervention programs. The problem is serious, and the solution to it can only be found via an integrative approach.

APPENDIX

1. INSTRUMENT OF BEHAVIORAL STUDY 1 (modeling food safety practices among Chinese in the United States)

a. Cover letter (English version)

Dear Study Participant,

China is one of the leading exporters of agricultural and seafood products to U.S. In 2007, China was the third largest country exporting these products to U.S., the first two being Canada and Mexico. Safety of foods imported from China has become an important issue in recent years. People's attitude towards food safety exerts great influence on their behavior of dealing with food. Since food producers' behavior will directly influence the quality and safety of food products, it is important to assess attitude and behavior among Chinese people regarding food safety.

We are conducting this study to collect data on attitude and behavior of Chinese students of University of Missouri. The results will serve as preliminary data of a large scale study which will ultimately contribute to an education program designed specifically to address the attitude and behavior of food products manufacturers in China. Your participation is completely voluntary and you may discontinue at any time without any penalty. Individual responses will not be identifiable. It may take about 15 minutes to complete all questions.

Your response is very important to the success of this study. We greatly appreciate your time and assistance. In case you have any questions about the study, please contact Dr. Seonghee Cho at (573) 882-0563 or choseo@missouri.edu. If you have any questions about the rights of individuals in this study or about the way it is conducted, you may contact the Campus Institutional Review Board at (573) 884-0663 or umcresearchcirb@missouri.edu.

Thank you for your help.

Sincerely,

Bin Liu
Research Assistant
Food Science Program
Food & Hospitality Systems
University of Missouri-Columbia

Seonghee Cho, PhD
Assistant Professor
Hotel & Restaurant Management
Food & Hospitality Systems
University of Missouri-Columbia

b. Cover letter (Chinese version)

亲爱的朋友：

您好。欢迎您参加我们的问卷调查。

中国是对美国出口农产品和海产品最多的国家之一。2007 年，中国对美国出口这些产品总量居世界第三位，仅次于加拿大和墨西哥。近年来，中国出口食品的安全已成为一个重要问题。人们对食品安全的态度对其处理处理食品的行为有着重大的影响。因为食品生产商的行为会直接影响到食品产品的质量和安全，所以对中国人群在食品安全方面的态度和行为进行评估，是非常重要的。

我们进行这项研究的目的，是为了收集密苏里大学的中国学生的态度和行为方面的数据。这些结果将作为一项大规模研究的先导数据，而这项大规模研究将最终会用于制订一份为中国食品制造商特别设计以对他们的态度和行为进行引导的教育计划。您的参与是完全基于自愿基础上的，您可以随时停止，并不会受到任何惩罚。我们并不能从回答辨别您的身份。完成所有问题大约需要 15 分钟。

您的回答对于这项研究的成功进行非常重要。我们对您花费时间提供帮助表示诚挚的感谢。如果您对这项研究有任何问题的话，请致电 (573) 882-0563 或发电子邮件至 choseo@missouri.edu 联系赵成喜（Seonghee Cho）博士。如果您对参与这项研究的个人的权利或对研究进行的方式有任何问题，请致电 (573) 884-0663 或发电子邮件至 umcresearchcirb@missouri.edu 联系校园制度评审委员会（Campus Institutional Review Board）。

感谢您的帮助。

此致

敬礼!

刘斌
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食品科学系
食品和酒店管理
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赵成喜博士
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c. Questionnaire (English version)

Section I: Food Safety Knowledge

Please circle ALL that apply to the given question.

1. Which are symptoms of foodborne illnesses?
    a. Diarrhea
    b. Vomiting
    c. Dizziness
    d. Nausea
    e. Fever
    f. Headache

2. In your opinion, to safely prepare food when should you wash your hands?
    a. Before eating
    b. Before handling foods
    c. After playing with pets
    d. After handling raw meat
    e. After using the toilet or changing diapers
    f. If my hands look dirty

3. Which of the following do you think are needed for proper hand washing?
    a. Cold running water
    b. Hand sanitizer (optional, does not count as error in grading)
    c. Soap
    d. 20 seconds of scrubbing hands
    e. Warm running water
    f. 15 seconds of scrubbing hands

4. How do you think you should dry your hands after washing?
    a. With a dish/hand towel
    b. With a blow dryer
    c. With a clean paper towel
    d. On my apron
    e. By shaking my hands
    f. On my clothing

5. In your opinion, what should you do to fresh fruits and vegetables before you eat or cook them?
    a. Wipe them gently with a clean paper towel
    b. Rinse them under running water
    c. Scrub firm skinned fruits and vegetables with a vegetable brush under running water
    d. Use a fruit and vegetable cleaning solution (such as Fit®)
    e. Use a mild bleach solution to clean whole fruits and vegetables
    f. Scrub melons with a mild soap and water

6. How do you think you can prevent cross-contamination?
    a. Wash cutting boards with hot soapy water after preparing each food item
    b. Dry cutting boards thoroughly after each use
    c. Use a sponge to thoroughly clean counter tops
    d. Keep raw meat above fruits and vegetables in the refrigerator
    e. Don't store cooked meat on an unwashed plate that held raw meat
    f. Clean surfaces only when they look dirty

7. In your opinion, which of the following are proper ways to handle leftovers?
    a. Leave leftovers on the counter as long as they have been thoroughly cooked
    b. Always refrigerate leftovers from a restaurant within four hours of getting home
    c. Store leftovers in big containers
    d. Use a refrigerator thermometer to be sure that your refrigerator is colder than 41ºF
    e. Always eat or discard leftovers within one week
    f. Refrigerate leftovers within two hours of food preparation

8. How do you think you should check to be sure that food is thoroughly cooked?
    a. Look at it to make sure it is the right color
    b. Touch it to see that it is hot enough
    c. Make sure it has been cooking for the correct amount of time
    d. Use a food thermometer
    e. Look at the center of the food not just the surface of the food
    f. Taste it to see if it tastes right

9. In your opinion, how should you defrost frozen food?
    a. At room temperature (counter top, table top, in a cold oven, or in a covered dish)
    b. In the refrigerator
    c. In cold or hot standing water and cook immediately

d. Under cold running water
e. In the microwave and cook immediately
f. In a cold part of the house

10. Which of the following temperatures do your think are correct for food preparation?
    a. Cold food should be held below 41°F
    b. Hot food should be held above 140°F
    c. Leftover foods should be reheated to 160°F
    d. Ground beef should be cooked to 150°F
    e. Chicken should be cooked to 165°F
    f. Casseroles should be cooked to 170°F

11. Which of the following is NOT safe to consume if stored at room temperature for over 4 hours?
    a. Cooked rice
    b. Cooked meat
    c. Whole apple
    d. Baked potato
    e. Cooked egg
    f. Cooked fish

Please choose how you agree with the following statements by circling the corresponding number. Choosing 1 means you "strongly disagree" with it and 5 means you "strongly agree" with it.

	Strongly Disagree				Strongly Agree
12. Foodborne illnesses are diseases that are transmitted to people by food.	1	2	3	4	5
13. Raw foods should be kept separate from cooked foods.	1	2	3	4	5
14. Defrosted foods may be refrozen only once.	1	2	3	4	5
15. Improper storage of foods may be hazardous to health.	1	2	3	4	5

Section II: Food Safety Practices

Please select an answer for every line. Please circle the number that represents what you do now. Choosing 1 means you "never do" with it and 5 means you "always do".

	Never				Always
16. I wash my hands with soap and water...					
before eating	1	2	3	4	5
before handling any foods	1	2	3	4	5
after playing with pets	1	2	3	4	5
after handling raw meat	1	2	3	4	5
after using the toilet or changing diapers	1	2	3	4	5
for at least 20 seconds before rinsing them off	1	2	3	4	5
17. I wash counter tops, cutting boards, dishes, and utensils with hot soap and water...					
before beginning food preparation	1	2	3	4	5
between cutting different food products, such as vegetables and chicken	1	2	3	4	5
after handling raw meat	1	2	3	4	5
18. I clean fruits and vegetables by...					
scrubbing firm skinned items	1	2	3	4	5
rinsing tender skinned items and greens	1	2	3	4	5
19. I keep raw meat, poultry, seafood, and their juices away from ready-to-eat foods...					
in the refrigerator	1	2	3	4	5
when using my cutting boards	1	2	3	4	5
when I prepare food	1	2	3	4	5

20. I make sure that food is safe to eat by...

checking the “sell by” and “use by” dates	1	2	3	4	5
following the “sell by” and “use by” dates	1	2	3	4	5
throwing away leftovers after 3-4 days	1	2	3	4	5

21. I make sure food is cooked properly by...

using a food thermometer to measure the internal temperature	1	2	3	4	5
cooking ground beef, pork, veal, or lamb until it reaches 160°F	1	2	3	4	5
cooking chicken, turkey, or duck until it reaches 165°F	1	2	3	4	5
cooking eggs until the white and yolk and firm	1	2	3	4	5
bringing soups, sauces, and gravy to 165°F when reheating	1	2	3	4	5

22. I make sure food is handled properly by...

using a food thermometer to be sure the refrigerator is below 41°F	1	2	3	4	5
chilling leftovers within 2 hours	1	2	3	4	5
refrigerating perishable foods as soon as I get them home from the store	1	2	3	4	5
defrosting foods using the refrigerator, microwave, and/or cold running water	1	2	3	4	5

23. When I believe food you bought is contaminated, I will...

continue to consume it as usual	1	2	3	4	5
throw it away	1	2	3	4	5
make complaints to the shop you	1	2	3	4	5

bought it from					
call the government department in charge	1	2	3	4	5
call an ambulance	1	2	3	4	5

24. Regarding to restaurants, I...

select a restaurant based on its reputation for good sanitation and cleanliness	1	2	3	4	5
ask to speak to a manager when dishes or utensils are dirty in restaurants	1	2	3	4	5

Section III: Food Safety Attitudes toward Proper Food Handling

Please answer each of the following questions by circling the number that best describes your opinion. Please read each question carefully. They may appear similar, but they do address different issues.

Proper Food Handling includes:

- Scrubbing sturdy fruits/vegetables
- Thoroughly rinsing tender skinned fruits/vegetables and leafy greens
- Washing cutting boards, knives, and preparation surfaces with soap and water to ensure no food particles are left behind
- Storing leftovers in portion-sized containers and refrigerating within two hours

25. I feel that safely preparing food is...

Bad	1	2	3	4	5	Good
Worthless	1	2	3	4	5	Valuable
Difficult	1	2	3	4	5	Easy
Unpleasant	1	2	3	4	5	Pleasant
Unimportant	1	2	3	4	5	Important

26. Properly handling foods _____.

	Strongly Disagree				Strongly Agree
takes too much time	1	2	3	4	5
is difficult without easy to clean cutting boards	1	2	3	4	5
is difficult because of the cost of necessary supplies (extra cutting boards, knives, cleaning supplies, etc.)	1	2	3	4	5
is difficult without enough space	1	2	3	4	5
is important to my family	1	2	3	4	5
is important to my friends	1	2	3	4	5
is important to my spouse	1	2	3	4	5
is important to my healthcare professional	1	2	3	4	5

27. Please indicate how often the following statements AFFECT proper food preparation for you. (circle the corresponding number)

	Rarely				Frequently
takes too much time	1	2	3	4	5
is not convenient	1	2	3	4	5
I properly handle to stay healthy	1	2	3	4	5
not having easy to clean cutting boards makes it difficult to properly handle foods	1	2	3	4	5
the cost of having extra cutting boards, knives, cleaning supplies, etc. prevents me from properly handling foods	1	2	3	4	5
not having enough space prevents me from properly handling foods	1	2	3	4	5
I value my spouse's opinion when handling foods	1	2	3	4	5
I value my family's opinion when handling foods	1	2	3	4	5
I value my friend's opinion when handling foods	1	2	3	4	5
I value my healthcare professional's opinion when handling foods	1	2	3	4	5

28. How much do you AGREE with the following statements?

	Strongly Disagree				Strongly Agree
most people who are important to me think that I should properly handle food	1	2	3	4	5
I plan to properly handle food	1	2	3	4	5
it is expected that I will properly handle food	1	2	3	4	5
the people in my life whose opinions I value would approve of food handling	1	2	3	4	5
it is my choice whether I properly handle foods	1	2	3	4	5
I will try to properly handle food	1	2	3	4	5
I am able to properly handle food	1	2	3	4	5
I am willing to change my food handling	1	2	3	4	5

behaviors when I know they are incorrect.					
I am willing to obtain more food safety knowledge.	1	2	3	4	5
It is more important to have tasty food rather than safe food.	1	2	3	4	5
After cutting raw meat or chicken, I like to wash the cutting board, knife, and counter top with hot soapy water before continuing cooking.	1	2	3	4	5
I am not interested in using a meat thermometer.	1	2	3	4	5

Section IV: Other Attitudes Related to Food Safety

Please circle ALL that apply to the given question.

29. Which of the following would affect your attitude towards food safety?
    a. Nothing
    b. News report
    c. Peers
    d. School education
    e. Government promotion
    f. Experts' opinion
    g. Parents

30. Which one should bear the responsibility of food safety assurance?
    a. Food companies
    b. Consumers
    c. Government agencies (FDA, USDA, etc.)
    d. Retailers
    e. School teachers
    f. Food safety professionals

31. When in need, where do you usually look for food safety knowledge and information?
    a.
        i. Specialized web sites (WebMD.com, Consumer Reports, etc.)
        ii. Web sites of government agencies (FDA, USDA, etc.)
        iii. Food companies' web sites
        iv. Retailers' web sites

v. News web sites
vi. No preference

b. School classes
c. Books
d. Newspapers and magazines
e. Television and/or radio
f. Other sources, please specify: _____

Section V: Demographic Information

Please select your gender: Male Female

Please rate your current health condition: Excellent Very good Good Fair Poor

Please indicate your education level: Middle school High school Currently attending college Received a college degree Currently attending graduate school or professional school Completed an advanced degree

Have you had any food safety education within the last five years: Yes No

Which province of China do you come from? _____

Which is your preferred language for printed materials? English Chinese Bilingual Other

In which year were you born? _____

d. Questionnaire (Chinese version)

第一部分：食品安全知识

以下题目为多选，请圈选出所有答案。

1. 以下哪些是食源性疾病的症状?
    a. 腹泻
    b. 呕吐
    c. 头晕
    d. 恶心
    e. 发热
    f. 头痛

2. 在您看来，为了保证烹饪过程中的食品安全，什么时候应该洗手?
    a. 吃饭前
    b. 用手拿食物前
    c. 和宠物玩耍后
    d. 用手拿生肉后
    e. 上厕所后或换尿片后
    f. 如果我的手看起来脏的话

3. 您认为以下哪些是正确的洗手过程所必需的?
    a. 冷流动水
    b. 手部消毒液
    c. 肥皂
    d. 揉搓双手 20 秒
    e. 温流动水
    f. 揉搓双手 15 秒

4. 您认为洗手后应该怎样把手弄干?
    a. 用一条毛巾擦干
    b. 用吹风机吹干
    c. 用一张干净的纸巾擦干

d. 在我的围裙上擦干
e. 甩手弄干
f. 在我的衣服上擦干

5. 在您看来，在食用或烹调新鲜蔬菜水果前，应该如何清洗它们?
    a. 用纸巾轻轻擦拭
    b. 在流动水下清洗
    c. 用刷子在流动水下用力擦洗有硬皮的蔬菜水果
    d. 用蔬菜水果清洁剂洗涤（如 Fit®）
    e. 用温和的漂白剂清洗整个水果和蔬菜
    f. 用温和的肥皂水擦洗瓜类

6. 您认为如何能防止交叉污染?
    a. 在准备每一种食材后都用热肥皂水清洗切菜板
    b. 每次使用后都将切菜板充分晾干
    c. 用海绵充分擦净厨桌台面
    d. 在冰箱中把生肉置于蔬菜水果上层
    e. 不将已烹调的肉类置于未清洗的盛放过生肉的盘子里
    f. 只在厨桌台面看起来脏时才进行清洗

7. 在您看来，以下哪种处理剩菜的方法是合适的?
    a. 只要剩菜是完全烹熟的，就可以将它们置于厨桌台面上保存。
    b. 总是在到家 4 小时之内将从餐馆带回的剩菜放入冰箱保存
    c. 将剩菜保存在大的容器中
    d. 用冰箱温度计来确保冰箱温度低于 5 ℃
    e. 总是在一周内将剩菜食用完毕，或者丢弃
    f. 在做饭后两小时内将剩菜冷藏

8. 您认为怎样检查才能确保食物被彻底烹熟?
    a. 观看食物，确保它变成正确的颜色
    b. 触摸以检查食物是否已足够热
    c. 确保食物的烹调时间正确
    d. 使用食品温度计
    e. 检查食物的中心而不只是看看食物的表面
    f. 尝一尝，看看食物的味道是否恰当

9. 在您看来，应该如何化冻食物?

a. 在室温下（厨桌台面、桌子上、冷烤箱里、或在有盖的盘子里）
b. 在冰箱里
c. 在冷或热的静水里，并马上烹调
d. 在冷流动水下
e. 用微波炉，并马上烹调
f. 在房子一处较冷的地方

10. 您认为以下哪些温度对于食物烹调来说是正确的?

a. 冷的食物应该在 5 ℃以下保存
b. 热的食物应该在 60 ℃以上保存
c. 热剩菜时应加热到 71 ℃
d. 烹调绞牛肉时应该加热到 65 ℃
e. 烹调鸡肉时应该加热到 74 ℃
f. 做砂锅时应该加热到 76 ℃

11. 以下哪些食物如果在室温下保存超过 4 小时，就不宜食用：

a. 煮熟的米饭
b. 熟肉
c. 整只苹果
d. 熟土豆
e. 熟鸡蛋
f. 熟鱼

请圈选相应的数字来表示您对以下陈述的赞同程度。选择 1 表示您“非常不同意”该陈述，而选择 5 则表示您“非常同意”它。

	非常不同意				非常同意
12. 食源性疾病是由食物传播给人类的。	1	2	3	4	5
13. 生食应同熟食分开。	1	2	3	4	5
14. 已化冻的食物只能再被冻起一次。	1	2	3	4	5

15. 不恰当地保存食物会对健康有害。	1	2	3	4	5

第二部分：实际生活中的食品安全

请为每一行的陈述选择一个答案。请圈选代表您现在的一般做法的数字。选择 1 表示您“从不做”，而选择 5 则代表“总是做”。

	从不				总是
16. 我用肥皂和水洗手……					
在吃饭前	1	2	3	4	5
在用手拿任何食物前	1	2	3	4	5
在和宠物玩耍后	1	2	3	4	5
在用手拿生肉后	1	2	3	4	5
在上厕所或换尿片后	1	2	3	4	5
在冲掉肥皂之前，至少洗 20 秒	1	2	3	4	5
17. 我用肥皂和水洗厨桌台面、切菜板、碟子和器皿……					
在开始准备食物前	1	2	3	4	5
在准备不同食物中间，如蔬菜和鸡肉	1	2	3	4	5
在用手拿生肉后	1	2	3	4	5
18. 我这样清洗蔬菜水果……					
用力擦洗硬皮的	1	2	3	4	5
漂洗软皮的和绿叶蔬菜	1	2	3	4	5
19. 我把生肉、禽类、海鲜以及它们的汁水同可直接食用的食物分开……					
在冰箱里	1	2	3	4	5
当用切菜板时	1	2	3	4	5
当我做饭时	1	2	3	4	5

20. 为确保所食用的食物是安全的，我采取以下做法……

检查保质期	1	2	3	4	5
遵守保质期	1	2	3	4	5
在三到四天后把剩饭菜丢掉	1	2	3	4	5

21. 为确保食物被正确烹饪，我采取以下做法……

用食品温度计测量食物的内部温度	1	2	3	4	5
烹调猪牛羊肉绞馅时加热到 71 ℃	1	2	3	4	5
烹调鸡肉、火鸡或鸭子时，加热到 74 ℃	1	2	3	4	5
烹调鸡蛋时加热到蛋清和蛋黄都变硬	1	2	3	4	5
重新加热汤、酱汁和肉汁时，加热到 74 ℃	1	2	3	4	5

22. 为确保食物被正确烹调，我采取以下做法……

用食物温度计来确保冰箱温度低于 5 ℃	1	2	3	4	5
将剩饭菜在 2 小时内冷藏	1	2	3	4	5
从商店回到家后马上将易腐坏的食物冷藏	1	2	3	4	5
用冰箱、微波炉和/或冷流动水化冻食物	1	2	3	4	5

23. 当我认为我买的食物已经被污染时，我会……

如常食用它	1	2	3	4	5
把它扔掉	1	2	3	4	5
向所购买的商店投诉	1	2	3	4	5
打电话给政府的相关部门	1	2	3	4	5
叫救护车	1	2	3	4	5

24. 关于餐馆，我……

根据卫生和洁净程度方面的名声来选择餐馆	1	2	3	4	5
当餐馆里的盘子和餐具不干净时，我会要求找经理	1	2	3	4	5

第三部分：关于恰当处理食品方面，对食品安全的看法

对以下每道问题，请圈选能够最佳描述您的意见的数字。请仔细阅读每一道问题。它们可能看上去很相似，但表述的的确是不同的事情。

恰当处理食物的方法包括：

- 用力擦洗坚硬的水果蔬菜。
- 彻底清洗柔软的蔬菜水果和绿叶菜
- 用肥皂和水清洗切菜板、刀具和厨桌台面以确保没有食物碎屑遗留
- 用容器将剩饭菜分份保存，并在两小时内冷藏

32. 我觉得安全准备食物是……

坏的	1	2	3	4	5	好的
没用的	1	2	3	4	5	有价值的
困难的	1	2	3	4	5	容易的
令人不快的	1	2	3	4	5	愉快的
不重要的	1	2	3	4	5	重要的

33. 恰当处理食物 _____.

	非常不同意				非常同意
要用太多时间	1	2	3	4	5
如果没有容易清洗的切菜板的话，是困难的	1	2	3	4	5
是困难的，原因是必要用具的费用（额外的切菜板、刀具、清洁用品，等等）	1	2	3	4	5

如果没有足够的空间，是困难的	1	2	3	4	5
对我的家庭来说是重要的	1	2	3	4	5
对我的朋友来说是重要的	1	2	3	4	5
对我的配偶来说是重要的	1	2	3	4	5
对我的专业健保人士来说是重要的	1	2	3	4	5
要用太多时间	1	2	3	4	5
如果没有容易清洗的切菜板的话，是困难的	1	2	3	4	5
是困难的，原因是必要用具的费用（额外的切菜板、刀具、清洁用品，等等）	1	2	3	4	5
如果没有足够的空间，是困难的	1	2	3	4	5
对我的家庭来说是重要的	1	2	3	4	5
对我的朋友来说是重要的	1	2	3	4	5
对我的配偶来说是重要的	1	2	3	4	5
对我的专业健保人士来说是重要的	1	2	3	4	5

34. 对您来说，以下叙述有多频繁地**影响**对食品采取恰当处理这一做法?

	很少				经常
要用太多时间	1	2	3	4	5
不方便	1	2	3	4	5
为了保持健康，我恰当处理食品	1	2	3	4	5
没有容易清洗的切菜板使得恰当处理食品很困难	1	2	3	4	5
我买不起额外的切菜板、刀具、清洁用品等等，所以不能恰当处理食品	1	2	3	4	5
没有足够的空间，所以我不能恰当处理食品	1	2	3	4	5
当我处理食品时，我很重视我配偶的意见	1	2	3	4	5
当我处理食品时，我很重视我的家庭的意见	1	2	3	4	5
当我处理食品时，我很重视我的朋友的	1	2	3	4	5

意见					
当我处理食品时，我很重视我的专业健保人士的意见	1	2	3	4	5

35. 您在何种程度上**同意**以下的说法?

	非常不同意				非常同意
对我来说很重要的人里，大多数都认为我应该恰当处理食品	1	2	3	4	5
我打算恰当处理食品	1	2	3	4	5
人们希望我会恰当处理食品	1	2	3	4	5
在我的生活中，我重视其意见的那些人会赞同对食物应进行恰当处理	1	2	3	4	5
我是不是恰当处理食品是我自己的选择	1	2	3	4	5
我会试着恰当处理食品	1	2	3	4	5
我能够恰当处理食品	1	2	3	4	5
当我知道我处理食物的做法不正确时，我愿意改正	1	2	3	4	5
我愿意获取更多食品安全方面的知识	1	2	3	4	5
对于食物来说，美味比安全更重要	1	2	3	4	5
在切生肉或鸡肉后，我喜欢用热肥皂水清洗切菜板、菜刀和厨桌台面，然后再继续做饭	1	2	3	4	5
我对使用肉食温度计不感兴趣	1	2	3	4	5

第四部分：其他关于食品安全的看法

以下题目为多选，请圈选出<u>所有答案</u>。

36. 以下哪些会影响您对食品安全的看法?

a. 无
b. 新闻报道
c. 同事朋友

d. 学校教育
e. 政府的推广活动
f. 专家意见
g. 父母

37. 以下哪些应承担起保证食品安全的责任?

a. 食品公司
b. 消费者
c. 政府
d. 零售商
e. 学校教师
f. 食品安全专家

38. 当需要时，您一般通过何种渠道获取有关食品安全的知识和信息?

a. 网站，请说明：
    i. 专门网站（WebMD.com, Consumer Reports 等）
    ii. 政府机构网站（FDA、 USDA 等）
    iii. 食品公司的网站
    iv. 零售商的网站
    v. 新闻网站
    vi. 没有特别偏好
b. 学校课程
c. 书籍
d. 报纸杂志
e. 电视和／或广播
f. 其他来源，请说明：_____

第五部分：背景信息

请选择您的性别： 男 女

请估计一下您现在的健康状况： 优秀 很好 好 一般 不好

请选择您的教育程度： 初中 高中 大学在学 获得大学学位
现在在研究生院或专业学院就读 获得高级学位

在过去五年里，您是否接受过食品安全方面的教育? 是 否

您来自中国的哪个省／自治区／直辖市? _____

您更喜欢印刷材料使用哪种语言? 英文 中文 双语 其它

您在哪一年出生? _____

2. INSTRUMENT OF BEHAVIORAL STUDY 2 (assessment of effects of technology advancement on Chinese food exporters' beliefs of business ethics)

a. Cover letter (English version)

Cover Letter

Researchers

- Seonghee Cho, Ph.D. Associate Professor, Hospitality Management, University of Missouri-Columbia
- Bin Liu, Ph.D. Student, Food Science, University of Missouri-Columbia

Project Title: How technology advancement may influence business ethics of Chinese managers working in food industry

Purpose of the study

This research is to investigate whether and to what degree a powerful novel analytical method for detection of contaminants in foods could affect business ethics of Chinese managers working in food industry. This research may provide useful information to policymakers on resource allocation and decision making.

Procedure of the research

The survey consists of four sections containing questions about business ethics, decision making in specific scenarios, opinions on food safety, and general demographic

information. It is estimated to take 10-15 minutes to complete the questionnaire. Please put your completed survey in the enclosed envelop and give it to the questionnaire distributor.

Anonymity

Your participation is completely **voluntary** and you may discontinue at any time without any penalty. Individual responses will not be identifiable. The information provided is **anonymous**. Your employment will not be affected if you choose whether or not to participate. No reference will be made in written or oral materials that could link you to this study.

Benefits and risks or discomforts

Your feedback will contribute to better food safety assurance. There are no major risks or discomforts we foresee by participating in this study, except time commitment.

More Questions about the study

Please address your questions to the questionnaire distributor or contact Seonghee Cho, Ph.D. at +1-573-882-0563 or email her at choseo@missouri.edu

Questions about your rights as a participant

If you have any questions regarding your rights as a participant in this research and/or concerns about the study, or if you feel under any pressure to enroll or to continue to participate in this study, you may contact the University of Missouri Campus Institutional

Review Board (which is a group of people who review the research studies to protect participants' rights) at +1-573-882-9585 or umcresearchcirb@missouri.edu.

A copy of this Informed Consent form will be given to you before you participate in the research.

b. Cover letter (Chinese version)

研究项目说明

研究人员

- 赵成喜博士，密苏里大学哥伦比亚分校酒店管理专业副教授
- 刘斌，密苏里大学哥伦比亚分校食品专业博士研究生

项目题目：技术进步如何影响中国食品行业经理层人员的商业道德

研究目的

本项目的目的是研究检测食品污染物的新型强力分析方法是否能影响中国食品行业经理层人员的商业道德，以及能在多大程度上影响。本项目会为政策制定者在资源分配和决策制定方面提供有用的信息。

研究过程

调查问卷分为四个部分，问题覆盖范围包括商业道德、在特定情境下的决策、对食品安全的看法和背景信息。完成问卷大约需要 10 到 15 分钟。完成全部问题后，请将您的问卷放入提供的信封中，交给问卷分发者。

保密性

您的参加是完全基于自愿的。您可以在任何时候中止回答，不会有任何后果。问卷答复是无法和个人对应的。所有在问卷中提供的信息是完全匿名的。您的工作跟您是否参加完全没有关系。我们不会提供任何将您同这项研究联系起来的书面及口头材料。

利益、风险和不适之处

您的反馈将对保障食品安全做出贡献。参加本研究没有任何风险或不适之处，除了要花一点时间。

更多问题

请将问题反馈给问卷分发者，或联系赵成喜博士：电话+1-573-882-0563 及电子邮件 choseo@missouri.edu。

您作为研究参加者的权利

如果您对您作为这项研究的参加者所拥有的权利及本研究本身有任何问题，或者您觉得是在压力下参加及完成的本研究，您可以联系密苏里大学校园研究审查委员会（Campus Institutional Review Board）。该委员会成员负责对研究进行评估以保护参加者的权利。联系方式：电话+1-573-882-9585 或电子邮件 umcresearchcirb@missouri.edu。

本知情同意书应在您参加研究之前发给您。

c. Questionnaire (English version)

Part I: Please read following materials and respond to the questions based on the instructions.

1. (Control Group)

   Li Ming's company does business in manufacturing and exporting food products to the U.S. Li Ming was a mid-level manager overseeing material purchasing and product manufacturing. To reduce costs, Li Ming has been intentionally buying cheap raw materials adulterated with illegal ingredients and directing his workers to use them to manufacture products. His record of effective cost reduction wins him massive bonus and an immediate prospect to be promoted to the executive level. The problems of food products manufactured under Li Ming's direction have never been discovered by U.S. federal agencies.

   Current methods adopted by FDA and USDA for detection of contaminants in foods are quite sensitive and accurate. However, the detecting process must be conducted in a lab by professionals and it usually takes days to get the final result. Because of the disadvantages, the federal agencies can test only a small portion of foods imported to U.S.

   (Experimental Group)

   Li Ming's company does business in manufacturing and exporting food products to the U.S. Li Ming is a mid-level manager overseeing material purchasing and product manufacturing. To reduce costs, Li Ming has been intentionally buying cheap raw materials adulterated with illegal ingredients and directing his workers to use them to manufacture products. His record of effective cost reduction wins him massive bonus and an immediate prospect to be promoted to the executive level. The problems of food products manufactured under Li Ming's direction have never been discovered by U.S. federal agencies.

   Recently, FDA and USDA have adopted a novel method developed by scientists for detection of contaminants in foods. It is very powerful: its detection limit is way below the official standard; its accuracy is trustworthy and robust; the whole detecting process takes less than 30 minutes. It has a detection rate of nearly 100% and can be

conducted on-site. Currently, it has been applied to milk, juice, fruits, and vegetables to detect chemicals such as melamine, pesticides, and antibiotics. It is very easy for this method to be applied to nearly all kinds of food products and chemicals, which is what the federal agencies are about to do.

If you were Li Ming and you learned the above information, Please indicate to what degree you will likely to adapt following measures (Choosing 1 means you will "very unlikely" do it and 5 means you "very likely" do it.)

	Very Unlikely	Unlikely	Neutral	Likely	Very Likely
a. Change nothing in your business practice. Continue your current practice of buying adulterated raw materials.	1	2	3	4	5
b. Make sure that your subordinates will not learn about the information.	1	2	3	4	5
c. Make sure that your supervisor will not learn about the information.					
d. Share the information with you supervisor, admit that you have been using problematic raw materials to reduce cost, and discuss possible countermeasures.	1	2	3	4	5
e. Resign without revealing any reasons.	1	2	3	4	5
f. Admit that you have been using problematic raw materials and resign.	1	2	3	4	5

2. You are a top executive in a food manufacturing company. One of your company's products has been found to contain illegal additives by a regulatory authority. People have learned the information and there is much voice of dissatisfaction on the internet. Please indicate to what degree you will likely to adapt following countermeasures (Choosing 1 means you will "very unlikely" do it and 5 means you "very likely" do it.)

	Very Unlikely	Unlikely	Neutral	Likely	Very Likely
a. Declare that this is just an accident and that the company's products are safe.	1	2	3	4	5
b. Use guanxi to quench dissatisfactory voices, including ordering the media to stop coverage and deleting posts on the internet.	1	2	3	4	5
c. Voluntarily recall all products from the market.	1	2	3	4	5
d. Invest more to prevent of such incidents from happening.	1	2	3	4	5
e. Use guanxi to persuade the officials of the regulatory authority to alter the testing results.	1	2	3	4	5
f. Issue a sincere public apology.	1	2	3	4	5

Part II: Please indicate the extent of **your agreement** with the following statement on a 5-point scale. Choosing 1 means you "strongly disagree" with it and 5 means you "strongly agree" with it.

	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
1. Doing what is ethically right is good business in the long run.	1	2	3	4	5
2. Business people working in my field tend to ignore ethical considerations when doing business.	1	2	3	4	5
3. Whatever is good business is good ethics.	1	2	3	4	5

4. As a result of stiffer competition today, many business people find themselves forced to resort to practices which are considered shady, but which appear necessary to survive.	1	2	3	4	5
5. Business people exist for the sole purpose of creating and delivering value satisfaction at a profit to themselves. Therefore, business decisions should be made without regard to moral issues.	1	2	3	4	5
6. The most important concern for a firm is making a profit, even if it means bending or breaking the rules.	1	2	3	4	5
7. To remain competitive in global environment, business firms will have to disregard ethics and social responsibility.	1	2	3	4	5
8. If survival of a business enterprise is at stake, you must forget about ethics and social responsibility.	1	2	3	4	5
9. Efficiency is much more important to a firm than whether or not the firm is seen as ethical or socially responsible.	1	2	3	4	5
10. If consumers are unhappy, nothing else matters.	1	2	3	4	5
11. Being ethical and socially responsible is the most important thing a firm can do.	1	2	3	4	5
12. The overall effectiveness of a business can be determined to a great extent by the degree to which it is ethical and socially responsible.	1	2	3	4	5
13. Business ethics and social responsibility are critical to the survival of a business enterprise.	1	2	3	4	5

14. Business has a social responsibility beyond making a profit.	1	2	3	4	5
15. Social responsibility and profitability can be compatible.	1	2	3	4	5
17. Guanxi is extremely important in my business practice.	1	2	3	4	5
18. Without seeking to guanxi, I can still be successful in business.	1	2	3	4	5

Part III: Please share your opinion on the following question.

What do you think is the fundamental reason for China's food safety problems?

Part IV: Demographic information

- Please select your gender: ☐ Male ☐ Female
- Please indicate your education level: ☐ Elementary school ☐ Middle school ☐ High school ☐ College ☐ Advanced degree
- How many years have you been in the industry? _____
- Which province of China do you come from? _____
- In which year were you born? _____

d. Questionnaire (Chinese version)

第一部分：请阅读以下材料，按说明回答问题。

1. (Control Group)

李明的公司从事食品生产，产品出口美国。李明是一名中层经理，主管原料采购和生产。为削减成本，李明有意购买掺假的廉价原材料，并让他手下的工人用这些原料生产成品。由于他在降低成本上成效卓著，他获得了巨额奖金，并极有希望即将晋升到高层。美国联邦机构从未发现在李明的领导下生产的食品中所存在的问题。

FDA 和 USDA 现在所采用的检测食品污染物的方法是灵敏而准确的。但检测必须由专业人员在实验室中完成，获得最终结果通常需要数天时间。由于这些不足，美国联邦机构只能检测所有进口到美国的食品的一小部分。

(Experimental Group)

李明的公司从事食品生产，产品出口美国。李明是一名中层经理，主管原料采购和生产。为削减成本，李明有意购买掺假的廉价原材料，并让他手下的工人用这些原料生产成品。由于他在降低成本上成效卓著，他获得了巨额奖金，并极有希望即将晋升到高层。美国联邦机构从未发现在李明的领导下生产的食品中所存在的问题。

最近，FDA 和 USDA 采用一种由科学家开发的新方法检测食品中的污染物。这种方法很强大：检测限远低于官方标准；结果准确、可靠、重复性好；检测用时少于 30 分钟。应用这种方法，食品污染物检出率可接近 100%，而且检测可现场进行，不必到实验室。目前，这种方法已被应用到牛奶、果汁、水果和蔬菜中，用于检测三聚氰胺、杀虫剂和抗生素等化学物质。这种方法很容易被用于几乎所有食品中的化学污染物检测，而美国联邦机构已有计划在近期进行推广。

如果您是李明，在获知以上信息后，请选择您**有多大的可能性**采用以下这些对策。选择 1 代表您“非常不可能”采用，选择 5 则代表您“非常可能”采用。

	非常不可能	不可能	一般	可能	非常可能
a. 并不改变工作上的做法。继续采购掺假的原材料。	1	2	3	4	5
b. 确保下级不会获知这些信息。	1	2	3	4	5
c. 确保上级不会获知这些信息。	1	2	3	4	5
d. 将这些信息告知上级，承认一直在使用有问题的原材料以削减成本，并商讨可能的对策。	1	2	3	4	5
e. 辞职，但并不公开原因。	1	2	3	4	5
f. 承认一直在使用有问题的原材料，并辞职。	1	2	3	4	5

2. 您是一家食品生产企业的高管。您公司的一个产品被监管机构发现含有非法添加物。公众已经知道了这个信息，在网上有很多不满的声音。在此情况下，请选择您**有多大的可能性**采用以下这些对策。选择 1 代表您“非常不可能”采用，选择 5 则代表您“非常可能”采用。

	非常不可能	不可能	一般	可能	非常可能
a. 宣布这只是事故，公司的产品是安全的。	1	2	3	4	5
b. 动用关系平息不满的声音，手段包括命令媒体停止报道和在互联网上删帖。	1	2	3	4	5
c. 主动召回市场上的所有产品。	1	2	3	4	5
d. 加大投资以避免类似事故再次发生。	1	2	3	4	5
e. 动用关系，游说监管机构官员修改检测结果。	1	2	3	4	5
f. 进行诚恳的公开道歉。	1	2	3	4	5

第二部分：请选择您对如下陈述的**同意程度**。选择 1 代表您“非常不认同”对应的陈述，选择 5 则代表您“非常认同”。

	非常不认同	不认同	既非不认同也非认同	认同	非常认同
1. 从长期来说，注重道德责任对生意是有益的。	1	2	3	4	5
2. 在我这一行工作的人，做生意时倾向于忽略道德责任上的考虑。	1	2	3	4	5
3. 只要能赚钱的生意，在道德上就没问题。	1	2	3	4	5
4. 因为现在竞争越来越激烈，许多商人不得不采用一些有问题的手段，但是为了生存，这也是必须的。	1	2	3	4	5
5. 商人的唯一目的是创造利润，满足自己。因此，做商业决定时不用考虑道德责任。	1	2	3	4	5
6. 对一家企业来说，最重要的是创造利润，即使那意味着要用变通的手段或违反规则。	1	2	3	4	5
7. 要在全球环境下仍然保持竞争力，商业公司就不得不将道德和社会责任放在一边。	1	2	3	4	5
8. 如果一家企业生死存亡都成问题，那就必须抛弃道德和社会责任。	1	2	3	4	5
9. 相比道德和社会责任上的形象，效率对企业来讲要重要得多。	1	2	3	4	5
10. 如果顾客不满意，那么其他事就都不重要了。	1	2	3	4	5

11. 负起道德和社会上的责任是一个公司能做的最重要的事。	1	2	3	4	5
12. 一个公司总体上运转得好坏与否，在很大程度上是由它在道德和社会上负责任的程度决定的。	1	2	3	4	5
13. 商业道德和社会责任对企业生存至关重要。	1	2	3	4	5
14. 企业在创造利润之外也应担负起社会责任。	1	2	3	4	5
15. 担负社会责任和盈利是能共存的。	1	2	3	4	5
17. 关系在我的商业活动中极端重要。	1	2	3	4	5
18. 如果不搞关系，我仍然能在商业上成功。	1	2	3	4	5

第三部分：请写下您对以下问题的看法。

您认为造成中国食品安全问题的根本原因是什么?

第四部分：背景资料。

- 请选择您的性别：☐ 男　　☐ 女
- 请选择您的教育程度：☐ 小学　　☐ 初中　　☐ 高中、中专等
  ☐ 大本、大专等　　☐ 研究生或更高学历
- 您在这个行业工作多少年了? _____
- 您来自中国的哪个省、直辖市或自治区? _____
- 您是哪一年出生的? _____

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