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Milk adulteration with melamine in China: crisis and response

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Abstract

Objectives To addresses milk adulteration with melamine in China, and share lessons which both the government and the food industry can draw from this incident. *Methods* Searching information and data from academic databases, official papers and related websites. *Results* Melamine's high nitrogen content and its undefined toxicity to humans, encourages people to add it to food to increase the protein content. The adulteration has caused great impacts on the public health and milk industry in China. *Conclusion* Standardized production and reform of food safety supervision systems are needed to bring a higher degree of food safety in China.

Introduction

Milk and infant formula adulterated with melamine has been of high concern since September 2008. Several companies including some diary giants in China were implicated in this scandal, especially the Sanlu infant formula milk products that had made $>$ 294 000 babies sick, with nearly 51 900 hospitalizations and six infant deaths by the end of November 2008 [Ministry of Health (MOH), 2008]. This melamine milk crisis not only damaged the health of those infants, but also caused a great economic loss in food industry. In the following parts of this paper, we will introduce the background about the use and production of melamine in China, analyze the reasons why the adulteration happened and conclude the impacts of the crisis and the responses of the Chinese government. Finally, the lessons learned and further improvements on food safety will be discussed.

Background

Uses of melamine

Melamine ($C_3H_6N_6$) is an organic base with high nitrogen content (67% nitrogen by mass). It is a trimer of cyanamide with many industrial uses. It is combined with formaldehyde to produce melamine resin, a very durable thermosetting plastic used in Formica and melamine foam, which is a polymeric cleaning product. The end products include countertops, food containers, fabrics, glues, house wares and flame retardants. It is also used in the fabrication of melamine polysulfonate as a super plasticizer for making high-resistance concrete. Melamine is also a major component of pigment yellow 150 (a colorant for inks and plastics), fertilizers and derivatives of arsenical drugs for the treatment of African sleeping sickness (trypanosomiasis) (Barrett & Gilbert, 2006).

Production of melamine in China

Chinese melamine production started in 1958 and increased with an average rate of 22.8% in the period of 1980–1987. Between the late 1990s and the early 2000s, both consumption and production of melamine grew considerably in China (Jiaming, 2008). By early 2006, melamine production in China was reported to be in 'serious surplus' (Ruilin, 2006) and the amount of production was still less than the actual production capacity (Table 1). Currently, China is the world's largest exporter of melamine and its domestic demands reach 250 000 ton in 2005 and keep growing by 10–20% annually (Ye, 2008). Between 2002 and 2007, while the global melamine price remained stable, a steep increase in the price of energy sources had reduced the profitability of melamine manufacturing, which had already caused many melamine manufacturers to reduce their production (Jiaming, 2008).

Table 1 The production capacity and amount of melamine production in China (2002, 2004 and 2006) (China Chemical Industry News)

Year	2002	2004	2006
Capacity of production (tons)	220 000	346 000	609 000
Level of production (tons)	110 000	254 000	416 000

Why did people add melamine to milk?

The main reason for adding melamine into milk is to increase the protein count at less cost. Standard tests such as the Kjeldahl and the Duma's tests estimate protein levels by measuring the nitrogen content, so such tests can be misled by adding nitrogen-rich compounds such as melamine (Snyder, 2007). Farmers and producers can dilute the milk but still meet the requirement of high protein content by adding melamine, which make more benefit. Moreover, such concept that melamine has no toxic effects to human encourage adulterers include farmers and milk collectors to add melamine as the 'fake protein.'

Toxicity of melamine and its appearance in the food chain

Melamine is not an irritant when inhaled or in contact with the skin or eyes nor is it a sensitizer in guinea pigs and humans. The reported dermal lethal dose, LD_{50}, is > 1000 $mgkg^{-1}$ for rabbits. It is reported to have an oral LD_{50} of $> 3000\,mgkg^{-1}$ based on rat data, which makes it only minimally toxic (table salt has a similar LD_{50} value). Animal studies have demonstrated that melamine was not metabolized in rats and was excreted unchanged (Mast *et al*., 1983). In a 1945 study, large doses of melamine were given orally to rats, rabbits and dogs with 'no significant toxic effects' observed (Lipschize & Stokey, 1945). Furthermore, there did not seem to be any reported human case of acute toxicity directly caused by melamine before last year. Melamine first occurred in the food chain during the 1950s and 1960s. The use of melamine as a fertilizer for crops had been envisaged in the early 1950s (Hauck & Stephenson, 1964). Melamine used as non-protein nitrogen for cattle was described in a patent issued in 1958 (Colby & Mesler, 1958). However, in 1978, a study concluded that melamine 'may not be an acceptable non-protein nitrogen source for ruminants' because it's hydrolysis in cattle was slower and less complete compare to other nitrogen sources such as cottonseed meal and urea (Newton & Utley, 1978).

Because melamine resin is often used in food packaging and tableware, melamine residues at p.p.m. levels (1 part per million) in food and beverages have been reported due to migration from melamine-containing resins (Ishiwata *et al*., 1987). Small amounts of melamine have also been reported in foodstuffs as a metabolite product of cyromazine, an insecticide used on animals and crops (Sancho *et al*., 2005). Nonetheless, intake of melamine from the consumption of meat and eggs from animals inadvertently given animal feed contaminated with melamine and its analogs was very unlikely to pose a human health risk because of the low tissue concentration [US Food and Drug Administration (FDA), 2007]. Furthermore, there did not seem to be any reported human case of calculi directly caused by melamine.

Because of high nitrogen content (67%), melamine had been illegally added to food products in order to increase the apparent protein content as standard tests for estimation of protein level depends only on measuring total nitrogen content. This was first reported in 2007, which a pet food recall was initiated by several pet food manufacturers in the United States who had found that their products had been contaminated, causing serious illnesses or deaths in some of the animals that had eaten them (US Food and Drug Administration (FDA), 2008). Since then, melamine's chronic toxicity and its potential risk to humans called attention.

2008 Chinese milk contamination

In September 2008, several diary manufacturers were implicated in a scandal involving milk and infant formula, which had been adulterated with melamine, leading to kidney stones and other renal failure, especially among infants.

In China, many raw milk producers are small household farmers who were eager to maximize milk production yield under the pressure from low price and rising grain prices. Because the government has set standards for milk nutritional contents especially for infant formula in which higher protein contents were required, farmers preferably add melamine to milk to meet the requirement at much lower cost. Except farmers, middlemen between milk producers had been collecting substandard milk at low prices, also adding melamine to the milk and selling the tainted but 'high protein' milk to the dairy companies at a higher price (Anon., 2008). Besides, infants who mainly feed on formula milk intake the large amount of contaminated milk products and the minor structures of the kidney lead to kidney stones and other renal failure that seldom happen to adults.

Impacts of melamine milk crisis

The melamine milk crisis has caused another 'earthquake' in China. The impacts of the crisis include health damage to

infants and great economic loss for the dairy farmers, companies and the country.

Infants hospitalized from tainted milk

By the end of November 2008, at least six babies had died and more than 294 000 children suffered kidney and urinary problems by drinking formula contaminated with melamine. As of late November, 861 babies were still hospitalized [Ministry of Health (MOH), 2008]. According to statistics, 99.2% of the infants were younger than 3 years of age, only 0.8% of them were older than 3, and none of them was older than 4.

Domestic dairy industry faces a crisis

The loss to dairy companies has been tremendous. On September 19, 2008, the day after the contamination in liquid milk had been verified; the sale volume of the milk fell to the lowest and 8311.7 ton of unqualified milk products were withdrawn from the market. Pressure of recalling $>$ 10 000 ton of milk powder (Xinhua, 2008c) and claims for compensation had led to Sanlu Group bankruptcy. By mid-December, the nation's biggest liquid-milk producer, the Mengniu Group, claimed that their losses had reached 900 million yuan ($131.39 million).

Over the same period, the demand for raw milk significantly reduced, so that some dairy farmers had to dump milk and slaughter their animals. By November 6, 2008, around 130 Chinese milk producers were still closed, meaning about 20% of dairy producers in China were still inoperable 2 months after the scandal (Xinhua, 2008e). Moreover, the adulteration of infant formula ruined its long-established market credibility. Despite rising production, restoring market confidence still has a long way to go.

Dairy and other goods' exports see massive fall

Many countries and trade partners such as the European Union, the United States and Japan, issued an import alert against Chinese food and feed products that contain dairy ingredients, and banned imports of all Chinese dairy and related products. In October, only 1036 ton of dairy products were exported, dropped 92% year-on-year (Zhu, 2008a).

Furthermore, the export of other Chinese food products was also stunted. According to the local custom reports in October, the growth in agricultural products exported from Qingdao, a major port for agricultural product exporting, fell 87% compared with the monthly average in the first 9 months of the year. Similarly, in Guangzhou, a major port in South China, frozen fish and poultry exports dropped 64% year-on-year.

Response of the Chinese government

China's State Council, the Cabinet, instigated a first-class national food safety emergency response to deal with the tainted Sanlu milk powder incident. The State Council has set up a national leading group comprising officials from the Health Ministry, the quality watchdog and local governments to deal with the incident. The measures taken are as follows.

Organization of medical teams to diagnose and treat calculus in infants in time throughout the country and compensation scheme for sick

The government provided free medical treatment to all sick babies and shouldered all the costs (Xinhua, 2008d). More than 1600 medical teams and 8000 people were sent to the grass-roots level to search for sick babies. More than 4500 medical institutions all over the country have participated in infant screening. Two hundred and fifty-four provincial and 2985 city medical institutions have been established in which infants can be examined and treated for free. The government has formed a team, which consists of officials of several central government departments to handle compensation issues (Xinhua, 2008b). A compensation scheme for families of sickened and dead babies is under review. The 22 dairy companies whose products were found contaminated with melamine will raise the money to set up a medical fund to cover expenses for lingering illnesses until the child reaches 18 (Zhu & Xiaohuo, 2008). Parents of victims will also receive one-off compensation.

A thorough overhaul of dairy and feed makers instigated

Following identification of the problem the government immediately halted production at the Sanlu Group. An investigation team consisting of the health ministry and other departments was organized to investigate the cause and the quality watchdog General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) conducted an all-round overhaul of baby milk powder producers across the country. All the links, including milk powder production, dairy farms, raw milk collection and dairy processing were placed under supervision. AQSIQ checked all the brands of baby formulae circulating in the market and immediately pulled those disqualified products off the shelves (Zhu, 2008a). China also sent $>$ 369 000

person-time inspectors to carry out inspections on feed manufacturers nationwide. The goal was to root out those using excessive amounts of the chemical melamine (Xinhua, 2008a). Two hundred and thirty-eight illegal feed makers have been closed down and inspectors investigated 278 illegally operating companies and farms. A total of 3682 ton of substandard feed was confiscated and destroyed.

Establishing new regulations and new standards

On October 9, 2008, China's State Council issued a series of quality control regulations for dairy products, including control of milk-yielding animals, raw milk collection and the production and sale of dairy food. Quality watchdogs were required to carry out regular inspections of dairy products. Health authorities would be responsible for setting up national safety standards and hygiene requirements for dairy foods, along with standardized national quality testing methods (State Council of PRC). For the first time, China regulated the maximum limit of melamine in baby formula milk (1 $mgkg^{-1}$), in liquid milk including raw milk, milk powder and other formula milk powder (2.5 $mgkg^{-1}$) and in other foods containing 15% and above milk (2.5 $mgkg^{-1}$) (Ministry of Health, Ministry of Industry and Information Technology, Ministry of Agriculture, etc.). The national standard method (including a rapid high performance liquid chromatography method) for determination of melamine in raw milk and dairy products (Standardization Administration of the PRC, 2008a, b) were issued by the AQSIQ and SAC (Standardization Administration of the PRC). Testing institutes could choose a method appropriate to product type and limit restrictions.

Protection of the dairy farmers' benefits

Several measures have been taken to encourage farmers to stay in the milk producing business. The Chinese government set aside 300 million yuan ($44.03 million) in emergency subsidies to help farmers who lost money during the incident. The money largely supported farmers in five major dairy-production provinces of Hebei, Liaoning, Shanxi, Shandong and Henan as well as Inner Mongolia Autonomous Region, who suffered financial losses after disposing of raw milk. Additionally, farmers will receive 500 yuan (about $73.00) annually in feed subsidy for each cow they own. A policy-supported insurance system for dairy herds has also been established, (Zhu, 2008b) and credit support to cattle breeders and dairy farmers' cooperatives is also encouraged.

Protection of the right of consumers

The government required every batch of dairy products made after September 14, to undergo melamine checks before entering the market (Zhu & Bolin, 2008). All dairy products made before that date had been removed from the shelves to be tested for melamine, and they could be sold again only after they had passed quality tests and were labelled as safe. To protect the rights of consumers, a Quality Safety (QS) standard had been adopted since September 18, 2008 (Zhang, 2008). This regulation claims that every batch of milk product produced after September 18, 2008 must be tagged QS after an inspection which had proved the quantity of melamine in the food was within legal limits. Only those products tagged with the QS standard could be sold in the market. All stores and supermarkets were required to post the lists of qualified businesses and their products, and set up a special counter to guarantee sufficient supplies of quality and safe milk products.

Lessons

The melamine milk case exposed many weaknesses in food safety supervision and the market management system in China and lessons should be drawn for the both parties, government and the food industry. In brief, ineffective supervision, untimely self-regulation to the emerging crisis by enterprises, low awareness of food safety and non-standardized production (Ministry of Agriculture, National Development and Reform Commission, etc) are the main weaknesses.

The main reason for ineffective supervision is the ineffective food safety control system. Too many departments are in charge of food safety, which causes overlapping of responsibilities and creates problems for law enforcement, and there often are conflicts of interest within agencies and governments at various levels. A lack of coordination and information exchange among agencies leads to an ineffective administration that causes many incipient faults. Thus, even the pet food recall did not arouse wide awareness of melamine's misuse and hazard in the food sector.

Crisis management by an enterprise is closely related to its credibility and responsibility to society, but many Chinese enterprises have not developed the capability to react properly. Sanlu provided a bad example of crisis management and information transparency. Sanlu had lied about its contaminated baby formula for months while thousands of infants got sick and at least three died. After more calculi cases were reported, Sanlu still refused to take responsibility and did not openly admit its products were toxic until September 11, 9 months after the first complaint (Xinhuanet, 2008).

Low awareness of food safety and unstandardized production were demonstrated in different aspects. Firstly, awareness of food safety in China, especially for farmers and rural consumers is still insufficient and limited; hence, the affected children and babies are mostly from rural areas. Secondly, the industry has shortages of skilled laboratory staff, food safety technicians with relevant knowledge of Hazard Analysis Critical Control Point (HACCP) and management technicians for on-farm work. Additionally, there is also a shortage of specialists with knowledge and experience in setting up coordinated supply chains, developing sustainable arrangements among partners in the chain and making suitable arrangements for contract farming.

Further work is still required

China is now facing not only the requirement to respond to the crisis, but also the need to thoroughly reform its food safety supervision system and dairy-production processes. More work is needed to build an effective supervision system, to support enterprise building crises-react capacities, to improve awareness of food safety and to enhance the formation of coordinated supply chains and a standardized industry.

Several areas have been identified for development:

1. To strengthen coordination and reduce overlap in the multi-agency food safety control system in China.
2. To improve the monitoring network by better integrating the efforts of different departments and laboratories.
3. To separate agencies' responsibilities to enable them to be carried out independently without potential intra-agency conflicts of interest.
4. To strengthen the management of melamine and other forbidden inputs via tracking and tracing throughout the supply chain and to assist farmers in the proper use of such inputs.
5. To strengthen the enforcement of regulations, by focusing on eliminating conflicts of interest at the local level, combined with more surveillance on farms and in local markets.

Clearly, a joint effort by both the public and private sector will enhance a good food safety control. It is recommended that government support speeding up the establishment of fee-for-service testing laboratories, technical services and legitimate private certifiers. Trade and industry associations can also play an important role (Shepherd, 2005). To strengthen the cooperation with those associations, the government should organize periodic consultations with such associations on issues of food safety and provide targeted grants for their activities promoting food safety.

Improving awareness of food safety among both producers and consumers is another step. The government should play a more important role in educating the public about hygiene, safe use of additives and chemicals and the Good Agricultural Practice (GAP). Web-based information about food safety in general, rapid alert systems and databases about possible health hazards can be very useful.

To enhance the formation of coordinated supply chains and a standardized industry, the first step should be training by specialists to improve GAP and Good Manufacture Practice and introduce HACCP in targeted areas (Food Safety and Agricultural Health Standards: Challenges and Opportunities for Developing Country Exports, 2005). Support should be given to producers that aim at promoting quality and safety and improving marketing links. Finally, in the case of the large number of small-scale farmers involved in the industry, strengthening their participation in coordinated supply chains should be give priority.

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