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Impacts of Milk Fraud on Food Safety and Nutrition with Special Emphasis on Developing Countries

Caroline E. Handford, Katrina Campbell, and Christopher T. Elliott

Abstract: Milk in its natural form has a high food value, since it is comprised of a wide variety of nutrients which are essential for proper growth and maintenance of the human body. In recent decades, there has been an upsurge in milk consumption worldwide, especially in developing countries, and it is now forming a significant part of the diet for a high proportion of the global population. As a result of the increased demand, in addition to the growth in competition in the dairy market and the increasing complexity of the supply chain, some unscrupulous producers are indulging in milk fraud. This malpractice has become a common problem in the developing countries, which lack strict vigilance by food safety authorities. Milk is often subjected to fraud (by means of adulteration) for financial gain, but it can also be adulterated due to ill-informed attempts to improve hygiene conditions. Water is the most common adulterant used, which decreases the nutritional value of milk. If the water is contaminated, for example, with chemicals or pathogens, this poses a serious health risk for consumers. To the diluted milk, inferior cheaper materials may be added such as reconstituted milk powder, urea, and cane sugar, even more hazardous chemicals including melamine, formalin, caustic soda, and detergents. These additions have the potential to cause serious health-related problems. This review aims to investigate the impacts of milk fraud on nutrition and food safety, and it points out the potential adverse human health effects associated with the consumption of adulterated milk.

Keywords: adulteration, food safety, health, milk fraud, nutrition

Introduction

Food fraud is a serious issue which has come under increased scrutiny as a potential food safety and public health concern in recent years (Spink and Moyer 2011). Regulators, food producers, retailers, and consumers all have an interest in safeguarding foods and ensuring they are safe, genuine, and of the highest quality. Nevertheless, food fraud has been conducted since ancient times, with evidence of laws dating back to Roman times regarding the adulteration of wine, through the addition of sweeteners and coloring agents, or dilution with water. At that time the scale of fraud was much more limited to a smaller geographical region (Armstrong 2009; Spink and Moyer 2011). Because of the growth and increasing complexity of the modern global food supply systems, this has heightened the risk of food fraud to include an entire global population, therefore having a major impact on the ability to protect consumer health (Moore and others 2012).

Food fraud is a broader term than adulteration (Figure 1). An adulterated food is one which may be spoiled or intentionally altered by illegal addition of a foreign chemical substance (the adulterant; Spink and Moyer 2011). Virtually all foods have the potential to be adulterated, but those that are more expensive or are produced under changeable weather and harvesting conditions are especially vulnerable (Sharma and Paradakar 2010). Economically motivated adulteration is a subcategory of food fraud and is a cause of public health risks (Spink and Moyer 2011). It has been defined as "the fraudulent, intentional substitution or addition of a substance in a product for the purpose of increasing the apparent value of the product or reducing the cost of its production" (FDA 2009). While the motivation for fraud is often financial, the impact is a real threat to public health; whether a public health incident does in fact follow, the adulteration causes the potential for harm (Spink and Moyer 2011).

Milk products are important components of the diets for many populations. The high nutritional value of milk has led to its high consumption worldwide, but increased demand has also made it prone to fraudulent activity. Moore and others (2012) recently analyzed the United States Pharmacopeial (USP) Convention food fraud database to determine the 25 food ingredients which are most prone to fraud worldwide. The USP database was originally developed to help identify food ingredients prone to fraud and to catalog analytical detection methods (USP 2015). Of the top fraudulent food ingredients, milk contributed to 14% of all scholarly records during 1980 to 2010; this was 2nd only to olive oil (16%; Moore and others 2012). Unscrupulous milk producers can

MS 20151220 Submitted 20/7/2015, Accepted 29/9/2015. *Authors are with the Inst. for Global Food Security, School of Biological Sciences, Queen's Univ. Belfast, 18-30 Malone Rd., Belfast, Northern Ireland, BT9 5BN, United Kingdom. Direct inquiries to author Handford (E-mail: chandford01@qub.ac.uk).*

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Figure 1–Types of food fraud.

increase their margins from the sale of milk through its dilution, extraction of valuable components such as milk fat, which is removed as cream, and the addition of cheap bulking additives such as low-quality flour to increase the value of total solids up to a level which goes unnoticed by consumers. Typically, milk is adulterated either for financial gain or due to poor hygiene conditions of processing, storage, transportation, and marketing. Milk adulteration has been widely reported in developing countries such as Pakistan, Brazil, India, and China (Xiu and Klein 2010; Faraz and others 2013; Shaikh and others 2013; Mu and others 2014; Singuluri and Sukumaran 2014). One of the oldest and simplest forms of milk fraud is through the addition of variable volumes of water to artificially increase its volume for greater profit; this can substantially decrease the nutritional value of milk, and if the water added is contaminated there is a risk to human health because of potential waterborne diseases (Kandpal and others 2012). To the diluted milk, adulterants such as skim milk powder, reconstituted milk, urea, rice flour, salt, starch, glucose, vegetable oil, animal fat, melamine, and whey powder can be added to increase the thickness and viscosity of the milk, and to maintain the composition of fat, carbohydrate, and/or protein (Campos Motta and others 2014; Singuluri and Sukumaran 2014; Soomro and others 2014). Milk is a perishable commodity so it is likely to get spoiled during transportation, particularly in summer months if effective refrigeration is not available. Therefore, ice (which may be contaminated itself) and some chemicals such as sodium bicarbonate, sodium carbonate, calcium hydroxide, caustic soda (sodium hydroxide), or chemical formalin are added to increase the shelf-life (Afzal and others 2011). In addition, detergents are added to enhance the cosmetic nature of milk as the foamy appearance diminishes when it is diluted with water. Calcium thioglycolate, potassium thioglycolate, or calcium salts of thioglycolic acid have been added to provide whiteness in milk and to give it a genuine appearance (Soomro and others 2014).

Milk fraud is one of the most serious issues facing the dairy industry; this not only causes major financial losses but also poses a significant risk to human health. The purpose of this review is to investigate the impacts of milk fraud on nutrition and food safety (chemical food safety risks will be the main focus of this article rather than those relating to spoilage since they are as relevant for unadulterated milk), and to examine the potential human health effects associated with the consumption of adulterated milk. To fully understand the nutritional consequences of fraud, the current global trends in total milk production and consumption are reviewed, along with the importance of milk in the human diet.

Global Trends in Total Milk Production and Consumption

Milk is nutritionally important as it contains all of the macro- and micronutrients required to sustain the life of the neonate and the young infant, as well as adding to the quality of the overall human diet (Konuspayeva and others 2009; Medhammer and others 2011). Thus, milk products are an important part of the diet for most populations globally.

In recent decades, milk product consumption has rapidly increased in a number of developing countries, particularly in parts of East and Southeast Asia; even so, the level of consumption is still lower than in developed countries (FAOSTAT 2014). The composition of milk product consumption fluctuates across different regions worldwide; while processed milk products (including butter, cheese, and yogurts) are becoming increasingly important, liquid milk is still largely the most important product by volume. For example, annual per capita liquid milk consumption in the European Union (EU) was 61.6 L in 2013, compared with less than 40 L (and even as little as 5 L) in some Asian and African countries (Canadian Dairy Information Centre 2013). However, a number of factors are stimulating the increase in demand in developing countries, including economic growth, urbanization, national population growth, increased public interest in high-protein diets, increasing awareness and availability of milk products through the retail sector, and greater affordability due to increased disposable incomes. In addition, governmental support of milk consumption through school milk programs, the rising demand for cheese variety, new uses for milk-based ingredients, and an increase in niche market products have supported this development. Milk products are currently the main source of animal protein in the diet in South Asia (Food and Agricultural Organization of the United Nations (FAO) 2013; Longvah and others 2013).

In developing countries, milk production has matched the growth in demand for and consumption of milk. Consequently, over the last 3 decades, global total milk production has increased by nearly 50%, from 500 million metric tons in 1983 to 747 million tons in 2013 (FAO 2015). In Asia, total milk production has increased from 80 million tons in 1983 to 270 million tons in 2013. India is now the largest producer of milk worldwide (18%), followed by the U.S. (12%), and then China and Brazil (both at 4%; FAO 2015). Most countries produce milk for local consumption. However, the cost of production varies greatly depending on factors such as labor costs, animal genetics, on-farm technology, and fodder and water availability (More 2009). At the global level, cow milk production remains by far the most significant, representing 85% of global milk production in 2013 (FAO 2015).

In developed countries, almost all milk is produced by cows. However, noncattle milk is economically and nutritionally significant and forms an important part of milk consumption in several countries, particularly in developing countries where approximately one-third of milk production comes from buffalos, goats, camels, and sheep (Faye and Konuspayeva 2012). Buffalo milk accounted for 11% of the world's milk production in 2013, followed by goat (2%), sheep (1%), and camel milk (0.4%). The remaining share is produced by other milk species such as horses, donkeys, and yaks (FAO 2015).

India achieved an output of 132.4 million tons of milk (mainly from cows and buffalos) during 2012 to 2013, compared to 127.9 million tons in 2011 to 2012, which is a growth of 3.5%. Projections for the country's total milk production during the year 2013 to 2014 are approximately 138 million tons (Department of Animal Husbandry, Dairying & Fisheries 2014). The country accounts for approximately one-third of developing country production and 18% of the world's total milk production (FAO 2013, 2015). India is not only the leading producer but is also the largest consumer of milk in the world, consuming almost all of its own milk production. Over the last decade, the Indian milk products consumption market has grown at an annual rate of 6.8% (Mani 2013). Economic development has led to an increased demand for milk products, which are the preferred choice of products of animal origin due to the population being largely vegetarian. Milk products now account for approximately 12% of the total diet consumed in India (Longvah and others 2013). The National Dairy Development Board has said that the demand for milk is likely to be between 200 and 210 million tons in 2021 to 2022 and, therefore, annual average milk production needs to increase further to 6 million tons per year to meet the needs over the next 12 y. Consequently, the National Dairy Plan was approved in 2012 to help meet the projected national demands; this concentrates on improvements to genetics, animal nutrition, and procurement in the dairy sector (Mani 2013).

Consumption and production levels of milk products have also grown rapidly in East and Southeast Asia since the early 2000s, particularly in China, which has averaged a 12.8% annual growth rate since 2000, with the country producing 41 million tons of milk in 2010; this is mainly from cows and to a lesser degree buffalos (FAO 2012). Economic growth and urbanization have contributed to this growth, with milk products becoming an increasingly important source of protein and calcium for the Chinese community (Sharma and Rou 2014). There are variations in milk production and consumption levels between urban and rural areas and between regions, which may be accredited to historical differences and cultural preferences. Approximately 85% of China's milk is produced in North China, which has the most suited climate and the greatest availability of feed materials. The fact that 60% of the human population lives in the South of the country creates difficulty in matching production with demand. Moreover, urban areas have a much higher milk consumption than rural areas, which is probably due to the fact that much of the larger milk operations are in the bigger cities, such as Beijing and Shanghai, so there is greater availability in these areas (FAO 2013; Sharma and Rou 2014).

Methods for the Detection of Milk Fraud

Methods to detect adulterants in milk include measurement of freezing point depression, electrical admittance spectroscopy, single-frequency conductance measurements, digital image chromatography, ultraviolet (UV) visible light spectroscopy, and enzyme linked immunosorbent assay (Santos and others 2013; Musara and Pote 2014).

Targeted approaches provide specific information on specific adulterants and their abundance. Whereas untargeted approaches provide less information on the nature of the adulteration. Untargeted analysis of chromatographic and spectral data consists of reviewing the entire spectrum, and applying multivariate data analysis for the large number of variables and samples generated from these methods. A range of targeted analytical methods have been developed to identify specific foreign properties in milk; these include high-performance liquid chromatography with single-channel UV-absorbance detection (HPLC–UV), and size exclusion chromatography and HPLC–mass spectrometry (HPLC–MS; Jablonski and others 2014).

Developments in infrared spectroscopic (IR) instrumentation and the amalgamation with chemometric methods have made this method invaluable in determining food authenticity. IR is a quality assurance tool to determine functional and compositional analysis of food ingredients, process intermediates, and finished products (Santos and others 2013). Chemometrics is an interdisciplinary research that applies multivariate data analysis, which is often combined with data-rich instrumental techniques (such as MS and infrared spectroscopy) used qualitatively for categorizing unknown samples with comparable characteristics and quantitatively for determining adulterants in samples (Souza and others 2011; Santos and others 2013). IR is highly desirable for analysis of milk components because it is straightforward to use, it is able to analyze samples with minimal or no sample preparation, it provides rapid and online analysis, it has high sensitivity and specificity, and it is possible to run multiple tests on a single sample. Other spectroscopic methods, namely, mid-infrared (MIR) and near-infrared, have been applied for the determination of several milk properties, including milk composition (protein, fat, and lactose), though these studies are limited with regards to milk authenticity (Karoui and others 2010; Santos and others 2013). For example, MIR spectroscopy combined with 2-dimensional correlation has been applied to detect adulteration by adding melamine, urea, and glucose to milk. The peak positions and shapes show differences between the control and adulterated milk, therefore validating the potential of this method to detect milk adulteration (He and others 2010).

Milk Fraud in the Developing World: 4 Cases Outlining the Impact on Nutrition, Food Safety, and Consumer Confidence

Milk fraud has occurred throughout history and continues to be a serious global issue. This is generally related to bovine milk from dairy cows and buffalos as they contribute to the vast majority of milk production worldwide. Recent scholarly reports have revealed that fraudulent milk products can be found in many regions worldwide, particularly in developing countries such as India where the scale of milk production is vast, yet they have a high level of unregulated practices (Moore and Others 2012; Lipp and Moore 2013; Ayza and Yilma 2014; Padala and others 2014). An overview of milk fraud scandals across the developing world is presented in Table 1. Conversely, in developed countries, such as the EU and U.S., there is a much lower concern of milk fraud. The EU has one of the highest food safety standards in the world and, thus, cases of milk fraud are scarce. The Rapid Alert System for Food and Feed Safety provides information when risks to public health are detected in the food chain, and as such provides details of the few incidents of milk fraud that have occurred in the EU, including an attempted illegal import of milk from China, which had been adulterated with melamine (European Commission 2015). Similarly, the U.S. has applied very high food safety standards, and, this along with their short supply chains and monitoring of the product quality has vastly reduced the risk of milk fraud.

Malpractice or negligence occurring in developing countries appears to go largely undeterred due to a lack of stringent control by the food safety authorities (Padala and others 2014). This fraud may be greatly reducing the health benefits of milk product consumption and presenting potential health hazards to many consumers.

India

In India, adulterated and synthetic milk issues have been widely reported in the mass media and this has been supported by reports from scientists and government authorities (Lipp and Moore 2013). Bhatt and others (2008) surveyed a total of 365 households in Uttar Pradesh, India, to quantify their children's daily intake of milk, analyze milk samples from their household to test for the presence of urea, vegetable oil, and detergent, and to determine their effect on health. In total, 365 children were surveyed; 70 children were of the age group 1 to 5 y, 150 were aged 6 to 18 y, and 145 were 19 to 22 y. A further 160 samples of milk were collected from different local market vendors and stalls. The mean intake of milk by children of the age group 1 to 5 y was 160 mL/d, for the age group of 6 to 18 y it was 500 mL/d, and for the age group of 19 to 22 y it was 800 mL/d. Fraud detection in milk samples with urea and detergent ranged from 8% in rural areas to as high as 40% in urban areas. The most common problems reported among the children surveyed were in relation to eyesight, diarrhea, and headaches. In the age group of 1 to 5 y most of the children were dependent on their mother's milk and therefore they showed the least effect on their health. In the age group of 6 to 18, 28% of urban children were affected by headache, while only 4% of rural children were affected. Eyesight problems and diarrhea were more prevalent, affecting more than half (57%) of urban and 16% of rural children. However, the 19 to 22 age group was the most affected group overall, with 38% of children in urban areas and 12% of rural children affected by headaches. Eyesight problems and diarrhea affected 52% of urban children as compared to 12.5% in rural areas. The milk fraud could have contributed to such health problems described here due to the concentration of urea and detergent present (Table 3).

The more recent national survey on milk adulteration 2011 (a snapshot survey) by the Food Safety and Standards Authority of India (FSSAI 2012) revealed that the total number of samples conforming to the FSSAI standards were 565 (31.5%), while 1226 (68.4%) samples failed to meet them. In some states, the level of noncompliance was 100%. Milk samples from rural areas performed better, with 31% being noncompliant as compared to urban areas where more than two-thirds (68.9%) failed to meet the set standards. The problems were also shown to be much greater for milk sold in bulk than packaged milk. The national survey also exposed water as being the most common adulterant used in milk in India, which resulted in the samples having much lowered nutritional values. Of the total nonconformant samples, 574 (46.8%) samples belonged to the category of low-solid nonfat (SNF) and this was due to dilution of milk with water. These findings were in line with an earlier study conducted by Grace and others (2009) on milk safety in North East India, which found that dilution with water was present in milk from all dairies, with considerable variation in the level of dilution, ranging from 2% to 20%. The FSSAI survey also revealed that the 2nd highest nonconformity was skimmed milk powder, which was in 548 (44.7%) samples, while glucose was present in 477 samples. Glucose was most likely added to milk to enhance its SNF. The milk samples were also shown to be adulterated with substances which produce more hazardous health effects, including detergents which were found in 103 (8.4%) samples. It was perceived that due to a lack of hygiene and sanitation in milk handling and packaging, detergents (used for cleaning) are not removed (indicating poor cleaning of milk containers) and find their way into milk. In a recent study by Singuluri and Sukumaran (2014), all of the samples tested negative

Table 1–Overview of milk fraud scandals across the developing world.

Reference	Country	Aim of the study	Product and number of samples	Main findings	Author's conclusions
Bhatt and others (2008)	India	-To detect the presence of harmful adulterants in milk.	-365 children were surveyed. -The homemaker of each household was interviewed for the child's milk intake. -Milk was collected from each household and analyzed for urea and detergent. -160 samples of milk were also collected from various markets, vendors, and stalls.	-The presence of urea, detergents, and vegetable oil were detected in the milk samples. -Headaches were reported in children aged 6 to 18 y (urban, 28% and rural, 4%) and 19 to 22 y (urban, 38% and rural, 12%). -Eyesight problems were reported in all age groups; 1 to 5 y (urban, 11%; and rural, 3%), 6 to 18 y (urban, 57% and rural 16%), and 19 to 22 y (urban, 52% and rural, 12.5%). -Diarrhea was reported in all age groups; 1 to 5 y (urban, 47.5%; and rural, 22%), 6 to 18 y (urban, 57.3% and rural 16.6%), and 19 to 22 y (urban, 52% and rural, 12.5%).	-Synthetic milk is shown to have a lower or higher pH than normal milk depending on the adulterants used. -Children had problems with their eyesight, and also suffered from headaches and diarrhea. -Urban areas (where the demand for milk is much higher) were much more affected than rural areas.
The National Survey on Milk Adulteration, FSSAI (2012)	India	-To ascertain the quality of milk and identify the commonly used adulterants in milk throughout the country.	-1791 milk samples were collected and analyzed from 33 states.	-1226 (68.4%) samples failed to meet FSSAI standards. -Water is the most common adulterant used in milk in India (shown in 46.8% of nonconforming samples). -Powdered milk is also reconstituted to meet the milk supply demands (skim milk powder was present in 44.7% of nonconforming samples). -The presence of detergent was also detected in milk samples.	-Water is the most common adulterant used in India. -Powdered milk is reconstituted to meet the milk supply demands. -The presence of detergents suggest a lack of hygiene and sanitation in milk production.
Kandpal and others (2012)	India	-To determine whether the raw milk samples have been diluted with water or adulterated with other substances.	-60 samples of raw milk (open and branded) were collected from canteens from education public places and milk vendors.	-80% of all raw milk samples were shown to be diluted with water. -All of the samples also showed the presence of urea and detergents.	-This study demonstrates a need to improve hygiene practices throughout the supply chain, and implement more effective monitoring regimes.
Singuluri and Sukumaran (2014)	India	-To expose various common adulterants in milk samples collected from public and educational institutions.	-50 milk samples were tested for a range of adulterants.	-The level of adulteration ranged greatly with the lowest percentage for sucrose (22%) and the highest for skim milk powder (80%). -The level of adulteration with neutralizers, sodium chloride, and urea were 26%, 82%, and 60%, correspondingly. -32% of samples tested positive for both formalin and hydrogen peroxide. -Detergent was found in 44% of samples.	-A vast number of samples did not conform to the legal standards set by the FSSAI. -The results suggest that the adulterants were added during the production or processing of milk.
Barham and others (2014)	Pakistan	-To test for various adulterants in market milk.	-100 unprocessed milk samples were collected and analyzed.	-Water was the most common adulterant detected in 73% of samples; this was followed by detergent (32%), cane sugar (22%), caustic soda (20%), and rice flour (17%). -The level of adulteration done at different intermediaries was: dairy shops (4.2%), milk collectors (3.5%), middlemen (3.2%), processors (2.5%), and milk producers (1.1%).	-Water was found to be the most common adulterant found in the majority of market milk samples. -The level of adulteration at dairy shops, milk collectors, and middlemen was found to be greater than at the processors and milk producers.

(Continued)

Table 1–Continued.

Reference	Country	Aim of the study	Product and number of samples	Main findings	Author's conclusions
Soomro and others (2014)	Pakistan	-To investigate different adulterants and their impact on chemical characteristics of market milk.	-20 milk samples each from the milk producer, milk collector, milk vendor, and dairy shops were analyzed for various adulterants.	-The adulteration of extraneous water in milk was found to be: milk producer (60%), milk collector (53.5%), milk vendor (62.7%), and dairy shops (56.9%). -Fat content of milk obtained from different intermediaries failed to reach the minimum level of fat (6.1%) of control milk samples. -Average protein content of milk from the different intermediaries was lower than the control milk samples.	-The majority of milk samples from different intermediaries were found to be adulterated with extraneous water. This was shown to have an influence on the chemical characteristics of the milk samples, except for their lactose content.
Faraz and others (2013)	Pakistan	-To determine the chemical composition of the milk available in local markets. -To test the hygienic status of the market milk. -To detect for different adulterants in market milk.	-60 samples of unprocessed market milk were obtained from canteens of educational institutes and public places.	-67% of all milk samples reported the presence of soil. -97% and 93% of the milk samples obtained from canteens of educational institutes and public places were adulterated with water. -Adulteration with urea was reported in 63% and 87% of samples. -Adulteration with formalin was reported in 23% and 27% of samples, while cane sugar was in 87% and 97% of samples. -Hydrogen peroxide was also found in 3% of samples from public places.	-Milk was shown to be subjected to adulteration with water, urea, hydrogen peroxide, formalin, and cane sugar.
Liu and others (2010)	China	-To conduct a population-based screening and follow-up investigation involving residents of a rural area located near the manufacturer of Sanlu dairy products (the main source of the melamine-contaminated products).	-An ultrasound-based screening in September 2008 of 7933 children aged below 36 mo. -Information was obtained from the mothers of affected children concerning their consumption of melamine-contaminated products between June and August 2008.	-Overall incidence of urinary tract abnormalities among the children tested was 0.61%. The mean exposure dose of melamine was approximately 116 mg per day. 43 (89.6%) of the 48 affected children were asymptomatic, while 2 displayed symptoms and were hospitalized, and 3 displayed symptoms but did not undergo treatment. -For 46 of the children 6-mo follow-up information was accessible; this information showed that renal abnormalities remained in 5 children but were resolved in the others.	-Most of the affected children were asymptomatic. -The majority of the children affected by the toxic chemical melamine made a full recovery over time without the need for specific treatment. -Renal abnormalities persisted in 12% of the affected children.
Schoder (2010)	East Africa	-To prove the existence of melamine in milk powder and infant formula exported to the African market.	-A total of 49 milk samples were collected and analyzed between October and December 2008. 27 samples were international brand name products.	-6% (3 of 49) of all samples tested and 11% (3 of 27) of all international brand name products revealed melamine concentrations up to 5.5 mg/kg of milk powder. -This amount represents about twice the tolerable daily intake as suggested by the U.S. Food and Drug Administration.	-Based on this study, it is assumed that the number of affected children in Africa is substantial.
Souza and others (2011)	Brazil	-To assess the use of chemometric techniques for monitoring the authenticity and quality of UHT milk in Brazil.	-100 samples of Brazilian UHT milk processed in industrial plants located in different states.	-55% of samples were adulterated with urine, and 44% with formaldehyde. -Adulteration with hydrogen peroxide was 30%, while chlorine was 12%. -With the exception of starch, all the samples showed the presence of at least one adulterant.	-The use of chemometric methods has been shown as a possible additional alternative for monitoring the authenticity of UHT milk.

for glucose, though the extents of fraud for sucrose and skimmed milk powder were 22% and 80%, respectively. The level of fraud with sodium chloride, neutralizers (including carbonates and bicarbonates of different alkalis), and urea were 82%, 26%, and 60%, correspondingly. It was indicated that neutralizers may have been added to disguise the acidity values of poorly cooled milk to pass it off as fresh, while sodium chloride could have been used to mask the high water content and urea to give false measurements of protein content in the milk. Other adulterants were detergents (44%), hydrogen peroxide, and formalin (each 32%).

Pakistan

Recent reports in Pakistan have also shown widespread fraud of milk products, with 80% of the total milk sold in packages or in bulk being adulterated (Akhtar 2015). Several studies have reported a wide variety of adulterants being added to milk for sale to consumers, meaning that it is of substantially poorer quality with a lower nutritional value and toxic substances present. A study conducted by Barham and others (2014) found water to be the most common adulterant (73%) in the majority of the 100 milk samples analyzed from the city of Mirpurkhas, Pakistan; these results are similar to recent reports from India (FSSAI 2012; Singuluri and Sukumaran 2014). Further, the water used is typically muddy instead of clean tap water in order to increase density and maintain the viscosity of the milk, therefore posing a further and serious risk to human health. In the Barham and others (2014) study, several of the milk samples were also positive for multiple substances, including detergent (32%), cane sugar (22%), caustic soda (20%), rice flour (17%), sodium chloride and skimmed milk (each 15%), hydrogen peroxide (13%), starch (12%), formalin (11%), urea and vegetable oil (each 10%), boric acid (8%), ammonium sulfate (6%), glucose (5%), sorbitol (4%), and arrowroot (1%). Another recent study by Soomro and others (2014) examined a total of 80 milk market samples from the city of Badin, Pakistan for the presence of a range of adulterants, including water, skim milk powder, neutralizers, and thickening agents, and their impact on chemical characteristics of market milk. Among these samples, only water was found in the majority of samples, and this appeared to affect the chemical characteristics of the milk. The moisture content of the market milk samples was found to be considerably higher to that of the control samples, while the average fat content of the market milk samples did not reach the minimum level of fat of control samples. However, the average protein content of the market milk samples appeared higher than the control samples. A study by Faraz and others (2013) showed that 97% and 93% of the milk samples from canteens of educational institutes and public places, respectively, included additional water. The study also reported the presence of soil in approximately 67% of all milk samples tested, which, again, may have been deliberate or merely due to carelessness. Various adulterants such as urea, formalin, hydrogen peroxide, and cane sugar were also present in the milk samples.

China

In China, food scandals are not new or surprising to the public, with arguably the most notorious incidents involving milk products. The past 3 decades have seen a rapid upsurge in milk production; and consumption of infant formula, in particular, has become hugely popular among Chinese consumers. Unscrupulous producers have taken advantage of this trend by selling lower-quality products for higher economic gain. Subsequently, a series of milk-related scandals have hit media headlines in recent years, causing issues of food safety and public health (Sharma and Rou 2014).

In 2004, it was reported that around 200 infants from China suffered from severe malnutrition and 13 died after they were fed fake formula, which had practically no nutritional value (BBC NEWS 2004). That incident, known as the "big head disease" scandal, because the malnourished infants' heads grew disproportionately to their bodies, was caused by uncontrolled greed. Investigations revealed 45 types of substandard milk powder and 10 brands of fake milk powder on sale in supermarkets in Anhui, a province of China. Although tests revealed no toxicity in any of the products, many of these did not meet the nutritional standards. Analysis of one formula found that it contained as little as one-sixth of the required amount of protein and other nutrients which are required for proper growth and development of infants. Iron and zinc were entirely absent (BBC NEWS 2004). The deaths of infants provoked a national clampdown on safety violations in China's food market. Consequently, manufacturers and wholesalers of fake infant formula were convicted (Grace 2004). On September 8, 2008, another milk-related scandal emerged when a local newspaper reported that 14 infants had been diagnosed with kidney stones. This unusual outbreak was linked to tainted infant formula, and it quickly unfolded to be one of the most significant food safety scandals in modern history, causing international concern. Investigations by local and central authorities discovered that Sanlu baby milk powder was contaminated with melamine, an industrial chemical usually used in coatings, glues, dishes, and kitchenware (Litao and Seng 2008). Melamine is nitrogen-rich and was added illegally to watered-down milk to increase the apparent protein content (Xiu and Klein 2010).

Nitrogen content is routinely used to estimate protein levels in milk and therefore is an agreed indicator of milk quality and assurance that it has not been watered down. On September 11, 2008, the Chinese government announced a recall of the infant formula from Sanlu Dairy Company, which at that time was one of China's largest milk producers, though it was later found that infant formula from 22 dairy companies tested positive for melamine (Chen 2009). Within days it was reported that more than 54000 children had become sick, and 4 infants had died due to kidney damage after being fed melamine-tainted infant formula (Xiu and Klein 2010). Fears were heightened when it was made known to the public that other milk products including milk, ice cream, and yogurts also contained melamine. Consequently, the United Nations issued an international alert, which resulted in other countries placing a ban on imports of Chinese milk products. The EU banned all Chinese-made baby food, while France took further action by banning all foods containing Chinese milk, as a precautionary measure. A total of 24 other countries in Asia, South America, and Africa banned the import of Chinese milk products (Parry 2008). Panic spread when it was revealed that Sanlu Dairy Company was aware of the problem for months and possibly as far back as December 2007, allowing around 900 million tons of toxic milk to leave its dairies (BBC NEWS 2009; Xiu and Klein 2010). It was only when its partner in New Zealand, Fonterra Cooperative Group Ltd. intervened that the production finally stopped. Fonterra notified Chinese government officials of the problem and a public recall of milk powder in China was issued. The toxicological profile of melamine and its related compounds were not fully known until it was too late (Moore and others 2012). The mechanism of the toxicity from melamine has been suggested to be similar to uric acid nephropathy in humans, where crystals block renal tubules resulting in acute renal failure (Skinner

Table 2–Overview of milk fraud incident types and their impact on nutrition.

Adulterant	Cause	Public health risk	Populations most at risk	References
Water	-Increased profits by diluting with water to increase the volume of milk.	-Acute malnutrition (potential stunting, underweight, wasting) and nutrition-related child mortality. -Severe cases of malnutrition have resulted in death.	-Infants and young children who are dependent on infant formula for their main source of nutrition. -Individuals from developing countries who are nutritionally vulnerable and so milk serves as a food aid.	BBC News (2004) Naandi Foundation (2011) FAO (2013) Barham and others (2014) Soomro and others (2014)
Skimmed milk powder	-Increased profits by increasing the total solids-nonfat content of diluted milk	-While the protein and lactose content is similar to whole milk, skim milk contains low levels of fat and fat soluble vitamins, which might impair growth and development in children.	-Infants and young children who are dependent on milk as a main source of nutrition. In the first 2 y of life a significant amount of energy consumed is being used for growth and development, that is, brain, muscle, and bone. -Individuals from developing countries where the diet may contain a very low fat intake.	Milner and Allison (1999) FAO (2013) Soomro and others (2014) Barham and others (2015) Singh and Gandhi (2015)
Sugars (that is, sucrose/glucose)	-Increased profits by increasing the lactometer reading to mask adulteration with water	-Can pose a risk for diabetics or borderline patients who might be consuming excess sugar as will raise their blood sugar levels.	-Diabetic/borderline diabetic patients.	Malik and others (2006) Afzal and others (2011) Singuluri and Sukumaran (2014)

This is not definitive list of all the adulterants used in milk. However, these are the main adulterants that have been detected in recent reports of milk fraud and which impact upon nutrition.

and others 2010). According to a survey conducted by the Beijing Municipal Health Bureau, nearly a quarter of infants in the Chinese capital consumed melamine-tainted formula before the products were withdrawn from sale. The door-to-door screening of more than 307000 Beijing families with children under the age of 3, found that around 75000 babies had been fed contaminated formula (Reuters 2008). The most significant consequence of the melamine contamination was that more than 290000 individuals (most of whom were infants and children) were poisoned and 6 infants died due to kidney damage; 99% of the children affected were reported to be less than 3 y old. Additionally, financial losses in the dairy industry were also vast to firms whose products had been contaminated. Major dairy companies such as Mengniu and Yili lost 80% of their sales in just 10 d after disclosure of the melamine scandal, and the Sanlu Dairy Company was declared bankrupt in December 2008 (Xiu and Klein 2010). Liu and others (2010) conducted a follow-up study in September 2008 with 7933 children younger than 36 mo of age who lived in a rural area in China where the dairy products most highly contaminated with melamine were sold. This study indicated that most of the children affected from the toxic effects of melamine recovered over time without specific treatment. However, renal abnormalities remained in 12% of the affected children.

Despite the official announcement by China's Ministry of Health that all affected milk powder batches had been confiscated and destroyed, locally sold contaminated milk powder and infant formula originating from China had been identified in several other countries (Kuehn 2009). Milk powder serves as a food aid to malnourished people in poverty-stricken countries in Asia, Africa, and Latin America, but is also recommended as a milk substitute for infants of mothers who are suffering from acquired immune deficiency syndrome (Schoder 2010). Africa is the world's largest importer of milk powder, with more than half of the world's milk powder production being sold to countries in the African continent each year, thus, making it potentially vulnerable to the consequences of China's melamine-tainted milk scandal in 2008 through product counterfeiting (Figure 1). This was confirmed in a study by Schoder (2010) who analyzed milk powder and infant formula samples, which were collected between October and December 2008, immediately after the melamine contamination of milk products became public. A total of 6% (3 of 49) of all samples tested and 11% (3 of 27) of all international brand name products revealed the presence of melamine. In 2010, the melamine scandal resurfaced in China, when a local manufacturer, Tiantian Dairy Co. Ltd., was closed after it repackaged and sold 170 tons of melamine-tainted milk powder that has been received as a "debt payment," according to the local government.

Following the melamine-contaminated milk scandal in China, a new toxic substance which is harder to detect in milk products was found in 2011. The practice of adding hydrolyzed leather protein to milk products was reported, thus worsening public concerns about the safety of Chinese milk products. Hydrolyzed leather is supposedly made from hydrolyzing scraps of animal skin and is added to milk by unscrupulous producers to increase the apparent protein content, thus disguising water-added products. This illegal practice is not as dangerous as adding melamine, but still presents food safety concerns on the account of the harmful chemicals (including sulfuric acid) that may be used in the extraction process. As such, the Center for Food Safety routinely conducts tests on milk products for hydrolyzed leather protein, in addition to melamine, under its surveillance program (Center for Food Safety 2011; Montague-Jones 2011).

Brazil

The rapid development of the Brazilian dairy market over the last decade has made it a target for food fraud. Increased demand in milk products was a direct consequence of a number of factors such as national population growth, increased disposable income, and changes in dietary habits. Another major change to the dairy industry was the importance of supermarkets coming to Brazil as distribution points; their importance was mainly prompted by the entry of ultra-high temperature (UHT) milk into the market. UHT milk came to attend to the consumers' comfort and convenience needs (Nahmias 2008). This is when Parmalat SpA's (an Italian world-leading multinational company) well-known UHT milk became hugely popular. In this year, 3 very important facts were perceived in the Brazilian dairy market: (1) the prices of the majority of milk products were ridiculously high, (2) the industry was suffering from a lack of oversight with only one-third of milk produced in Brazil being inspected by national consumer health program authorities, and (3) the Brazilian dairy industry was hit by an unexpected downturn when news of the fraud scandals broke. Brazilian consumers were informed that producers had adulterated the milk sold in local supermarkets. In Brazil, the milk from local dairy farms is sold to cooperatives. A cooperative is a business, which is owned and controlled by farmers who produce the milk. It was at 2 dairy cooperatives that the milk was adulterated with hydrogen peroxide, oxygenated water, and caustic soda to increase the volume of the product, which in turn increased a producer's profit from raw milk (milk that is neither submitted to previous treatment nor submitted to inspections). The adulterated milk was then sold as pure milk to end users or to dairy manufacturing companies. Parmalat SpA, one of the largest companies on the Brazilian dairy market, claimed to be a victim of this fraud. Although it was not directly responsible for selling and producing the milk, Parmalat SpA showed negligence by not properly evaluating the quality of the purchased raw milk and, therefore, suffered the consequences from the milk fraud. This scandal also proved how inefficient the inspection systems of quality (established by the agro-industrial government) were in Brazil by the fact that the fraudulent milk managed to reach supermarkets and end consumers. Almost immediately after the scandal hit media headlines the Brazilian Ministry of Agriculture ordered Anvisa (the Brazilian Sanitarian Vigilance Organization) to take every single milk carton and milk plastic bottles with the involved brand names off the market, which included Parmalat SpA. The financial consequences of the crisis for Parmalat SpA and other implicated companies were vast. Customers stopped purchasing Parmalat milk, afraid of consuming hydrogen peroxide, oxygenated water, or caustic soda. Despite this milk fraud scandal being nationally publicized, with ongoing reports of the case on television, on the Internet, and in the press, as well as great financial losses for those companies involved and the arrest of many individuals, reports of illegal fraud of UHT milk from various regions of Brazil are still reported (Ferreira 2014).

In a recent study by Souza and others (2011), a total of 100 samples of Brazilian UHT milk were analyzed for adulterants such as starch, chlorine, formaldehyde, hydrogen peroxide, and urine. With the exception of starch, all samples reported the presence of at least one adulterant. The highest values of nonconformities were found for urine (55%) and formaldehyde (44%), followed by hydrogen peroxide (30%) and chlorine (12%). Additionally, the presence of chlorine indicates a lack of rinsing sanitized equipment used in milking.

Milk Fraud and Public Health Effects

Some of the adulterants and malpractices associated with milk production have caused public health concerns and malnutrition. An overview of milk fraud incident types and their potential impacts on nutrition and food safety are presented in Table 2 and 3, respectively. The addition of water to milk decreases its nutritional value; for infants and children this may be a serious concern as they are at a critical stage of growth and development and are dependent on milk products for supplies of vital nutrients and so may be at risk of malnutrition. Indicators of undernourishment are manifested as child-stunting, underweight, wasting, and nutrition-related child mortality (FAO 2013). In China's "big head disease" scandal in 2004, after infants were fed a fake formula they rapidly lost weight. The infants were said to have developed "big head disease," which is a symptom of acute malnutrition, describing the lack of flesh on the limbs and torso, which appear to shrink in comparison with the cranium (BBC NEWS 2004). A further concern about the water used to dilute milk is that it is usually obtained from an unsafe and inexpensive source and may be contaminated with heavy metals, agricultural chemicals, or microorganisms. If milk of such poor standard is consumed it poses a serious threat to the health of its consumers (Kandpal and others 2012). If the water used in the adulterated milk is contaminated by pathogens, then this may well lead to infective diarrhea in children, which can hamper their growth and development besides providing them with fewer calories. Agriculture is an additional source of chemical contamination, with nitrate being the main contaminant. Nitrate can cause methemoglobinemia, or blue-baby syndrome, in formula-fed infants less than 3 mo of age (Fawell and Nieuwenhuijsen 2003; Fernández-Luqueño and others 2013; Mudgil and Barak 2013).

The chemicals and other contaminants being used as adulterants in milk have a wide range of acute and chronic effects on human health. The addition of sodium chloride (common salt) in milk can be problematic for those who have hypertension, heart conditions, and chronic kidney or liver ailments. They live under strict salt-rationing, and if they consume sodium unknowingly in milk it has the potential to cause harm (Khanna and Pandey 2013; Barham and others 2014). If the milk is adulterated with sugar then this may contribute to problems in diabetics through elevation of blood sugar levels. If such milk is regularly consumed by individuals who are already diabetic or have a cardiac problem, it can be hazardous (Malik and others 2006; Singuluri and Sukumaran 2014).

Formalin is highly toxic to humans in small amounts and is classified as a carcinogen. Its ingestion is known to induce acute poisoning, causing irritation, often leading to dry skin, dermatitis, headaches, dizziness, tearing eyes, sneezing and coughing, and even the development of allergic asthma. Exposure to large amounts has been linked to eye conjunctivitis, nasal and pharyngeal diseases, laryngospasm, and pulmonary edema, though these health effects are unlikely with the concentrations present in adulterated milk (Tang and others 2009; Gwin and others 2010). Hydrogen peroxide damages the gastrointestinal cells which can lead to gastritis, inflammation of the intestine, and bloody diarrhea (Afzal and others 2011; Singh and Gandhi 2015). Detergents have been shown to cause food poisoning and gastrointestinal complications (Tay and others 2013; Singuluri and Sukumaran 2014). Some detergents also contain the toxic ingredient dioxane, which is carcinogenic in nature (Mudgil and Barak 2013). Chlorine causes low blood pressure, nausea, vomiting, and abdominal pain (Hattersley 2000; Barham and others 2014). The presence of urea in milk above the cut-off limit (typically accepted at 70 mg/dL) may cause severe human health problems such as impaired vision, diarrhea, and malfunctioning of the kidneys. Moreover, unnecessary hairs might appear on the face, especially in women and children. It may also lead to swollen limbs, irregular heartbeat, muscle cramps, chills and shivering fever, and cancers, though these are less likely with the concentrations present in the adulterated milk. (Bhatt and others 2008; Trivedi and others 2009; Kandpal and others 2012). Melamine has low oral acute toxicity, but excessive exposure in animals and humans causes urinary stones, crystalluria, and acute renal failure. When humans consume it, infants and children are affected the most because of their milk dependence for nutrition, compounded by immaturity

Table 3–Overview of milk fraud incident types and their impact on food safety.

Category	Adulterant	Cause	Public health risk	Populations most at risk	References
Added substances to increase mass and nutritional content	Vegetable oil	-Replacement of milk fat with vegetable oil for economic gains.	-Vegetable oil may be adulterated with nut oils. Thus, it may cause skin reactions, wheezing, throat tightness, coughing, vomiting, and diarrhea in nut allergy sufferers. It can be life threatening for some individuals.	-Individuals who have allergies to nuts	Sicherer and others (1998) Singh and Gandhi (2015)
	Urea	-Increased profits by blending with other ingredients to produce synthetic milk. -Urea artificially increases the protein content.	-Indigestion -Diarrhea -Acidity -Malfunctioning of kidneys -Damage to intestinal tract and digestive system -Ulcers -Impaired vision	-Infants and young children especially girls as it hastens up the process of puberty. -It is also particularly harmful to pregnant women and the elderly.	Bhatt and others (2008); Trivedi and others (2009); Kandpal and others (2012)
	Melamine	-Increased profits by adding to milk to artificially increase the protein content.	-Toxic poisonings -Kidney stones -Hypertension -Edema -Acute renal failure -Bladder cancer -Severe cases have led to death	-Infants and young children due to their dependence on infant formula and the immaturity of their organs.	Hau and others (2009) Sharma and Paradakar (2010) Xiu and Klein (2010)
	Ammonium sulfate	-Increased profits by adding to milk to artificially increase the protein content.	-Nausea -Vomiting -Diarrhea -Adverse effects on the gastrointestinal, respiratory system, and skin -Sensory disturbances	-Infants and children who are dependent on milk as a their main source of nutrition	Ayub and others (2007) Barham and others (2014) Singh and Gandhi (2015)
Preservation action	Formalin	-Reduced electricity costs by extending the shelf-life of milk so it can be preserved for a very long time at room temperature.	-Vomiting -Diarrhea -Decreased body temperature -Dermatitis -Mood and balance alterations -Abdominal pain -Liver and kidney damage -Impaired vision	-Individuals from developing countries where cooling facilities are lacking.	Tang and others (2009) Gwin and others (2010) Afzal and others (2011) Singh and Gandhi (2015)
	Hydrogen peroxide	-Reduced electricity costs by extending shelf-life of milk without refrigeration.	-Nausea -Vomiting -Gastritis -Lethargy	-Individuals from developing countries where cooling facilities are lacking.	Afzal and others (2011) Singuluri and Sukumaran (2014) Singh and Gandhi (2015)
	Salicylic acid	-Reduced electricity costs by extending shelf-life of milk without refrigeration.	-Gastric irritation -Bleeding -Diarrhea -Severe cases of poisoning may result in death.	-Individuals from developing countries where cooling facilities are lacking -Children under the age of 3 whose membranes are extremely sensitive to such irritants	Singh and Gandhi (2015)
	Caustic soda (sodium hydroxide)	-Reduced electricity costs by extending shelf-life of milk without refrigeration	-Vomiting -Severe cases can cause burns on the lips, tongue, and harms the mucosa of the esophagus.	-Infants and young children who are dependent on milk as their main source of nutrition, and are more sensitive to harm of the esophagus.	Mordjikian (2001) Ryan and others (2006)
	Boric acid	-Reducing costs by increasing the shelf-life of milk	-Nausea -Vomiting -Headache -Diarrhea -Severe colic -Kidney damage	-Infants and young children due to the immaturity of their organs -It is highly toxic at far lower doses for infants compared with adults	See and others (2010) Barham and others (2014) Singh and Gandhi (2015)
	Benzoic acid	-Reducing costs by increasing the shelf-life of milk	-Nausea -Headache -Asthma -Urticaria -Pseudoallergy -Hyperactivity and behavioral disorders in children	-Individuals who are already allergy sufferers, particularly those with asthma. -Infants and children as they are more susceptible to behavioral disorders	Mota and others (2003) Qi and others (2009) Barham and others (2014) Singh and Gandhi (2015)

(Continued)

Table 3–continued.

Category	Adulterant	Cause	Public health risk	Populations most at risk	References
Buffers to adjust pH	Neutralizers (carbonates/ bicarbonates)	-Reducing costs by masking the pH and acidity values of badly preserved milk to pass it off as fresh	-Disrupt hormone signaling that regulate development and reproduction -Gastrointestinal problems such as vomiting and diarrhea	-Individuals in developing countries where cooling facilities are lacking	Beall and Scofield (1995) Rideout and others (2008) Barham and others (2014) Singuluri and Sukumaran (2014)
Residues from sanitation	Detergent	-Increased profits by adding to diluted milk to enhance cosmetic nature. -Accidental contamination through low maintenance of milk tanks.	-Gastro-intestinal complications, that is, abdominal pain and vomiting -Hypotension -Respiratory irritation -Cancers	-Individuals from developing countries where manufacturing standards may be poor.	Bhatt and others (2008) Afzal and others (2011) Mudgil and Barak (2013) Tay and others (2013) Singuluri and Sukumaran (2014) Singh and Gandhi (2015)

This is not definitive list of all the adulterants used in milk. However, these are the main adulterants that have been detected in recent reports of milk fraud and which impact upon food safety.

of their organs which renders them vulnerable (Hau and others 2009). In the case of China's melamine-tainted milk scandal in 2008, most of the children had symptoms of irritability, dysuria, urination difficulties, renal colic, hematuria, or kidney stone passage. Hypertension, edema, or oliguria also occurred in more severe cases (Xiu and Klein 2010). Carbonates and bicarbonates can cause disruption in hormone signaling that regulates development and reproduction (Singuluri and Sukumaran 2014). Sodium carbonate on ingestion may cause irritation along the digestive tract as well as causing vomiting and diarrhea (Mudgil and Barak 2013). Boric acid causes eye irritation, nausea, vomiting, diarrhea, kidney damage, skin problems, and central nervous system irritation (See and others 2010). Short-term exposure to benzoic acid can irritate the eyes, skin, and respiratory tract, and in sensitive persons can produce adverse effects such as asthma, metabolic acidosis, and convulsions (Qi and others 2009).

Individuals from developing countries are significantly more vulnerable to the consequences of milk fraud as they have a much lower range of food types to choose from and so are more reliant on single sources of nutrition. Therefore, it is possible, indeed likely, that milk fraud could be contributing to some of the health problems associated with malnutrition. This is an area that requires extensive research to collate evidence of this. Malnutrition is a major public health problem in many of these countries, with 90% of the world's stunted children residing in Africa and South Asia. Stunting results in slowed child growth and can impede brain development. Stunting, along with low birth weight, is also a risk factor for chronic disease in later life, such as hypertension, stroke, osteoporosis, diabetes, and cancer (such as colon cancer; FAO 2013). Furthermore, 70% of the world's wasted children are shown to live in Asia (this is where much of the milk fraud occurs), with the majority in South Asia (UNICEF, World Bank, and WHO 2012). Wasted children have a weak immune system and are at increased risk of severe malnutrition and death. Childhood malnutrition is shown to be an underlying cause in about 35% of all deaths in children under the age of 5. Macronutrient (protein) and micronutrient (vitamins and minerals) deficiencies remain highly prevalent in many parts of the world (FAO 2013). For example, micronutrient deficiencies continue to be of public health significance in India, and nearly half of the world's micronutrient-deficient population is found in India (Arlappa and others 2011). In India, milk products provide a critical source of nutrition and animal protein for a population that is largely vegetarian. Increased milk consumption in India has been seen as a means of treating malnutrition. According to the National Sample Survey 66th Round, July 2009 to June 2010, on the "Nutritional Intake in India" and "Household Consumption of Various Goods and Services in India," the contribution of milk and milk products to protein intake increased from 3% in the lowest decile class to 15% in the highest in the rural sector and from 5% to 18% in the urban sector (Mani 2013). Nevertheless, little improvement in the nutritional status of children has been shown. Apart from low dietary intake, it is possible that food fraud can contribute to dietary deficiency (Mani 2013). Therefore, in this instance, it is a distinct possibility that the high level (approximately 70%) of milk fraud in India has contributed to malnutrition problems, particularly among children (FSSAI 2012). In this paper, we have examined a number of recent studies (Bhatt and others 2008; Grace and others 2009; FSSAI 2012; Singuluri and Sukumaran 2014), which provide evidence to suggest that the adulterated milk in India (with its low nutritional value in conjunction with the wide range of harmful chemical contaminants that it contains) has the potential to hinder the growth and development of children as shown in Table 1 and 2. The Hunger and Malnutrition Survey monitored more than 100000 children in 112 districts across 9 states in India from October 2010 to February 2011. It showed that the proportion of children undernourished is high, with 42% of children under 5 y old being underweight (with a weight deficit for their age), 11% were wasted (acutely malnourished), and 59% were stunted (chronically malnourished). Of the children suffering from stunting, more than half are severely stunted. It is also shown that childhood malnutrition starts early in life. By the age of 24 mo, 42% of children were underweight and 58% were stunted. This report indicates that childhood malnutrition is still a major problem in India. In fact, one-third of the world's malnourished children live in India. In addition to malnutrition being the attributable cause of one-third to half of all child deaths, it contributes to stunted physical growth and development that last a lifetime (Naandi Foundation 2011).

Additional recommendations for the prevention of milk fraud, as well as improvement strategies include: better education for developing farmers and networks to avoid malpractice that could present as fraud; improved implementation of detection methods of milk fraud to improve the quality of the milk products as they are inexpensive enough for the developing world; and the implementation of additional antifraud measures during suppliers audits, for example, the supplier must verify that a whistleblower policy has been implemented, and auditors should collect and analyze milk samples to validate suppliers' claims.

Conclusions

The high nutritional value of milk and its relative low cost compared with other protein sources has made it form a significant part of the diet of many populations worldwide. However, increased demand globally has made milk prone to massive levels of fraudulent activity. Milk is a high-risk commodity of concern for fraudulent activities for financial gain whereby perpetrators may increase food safety hazards and diminish nutritional quality through intentional adulteration and/or malpractice under poor hygiene conditions, a lack of preservation, and no cooling facilities. Such types of fraud are becoming a common problem in many regions worldwide, particularly in developing countries like India and Pakistan, which have largely unregulated practices. Milk used for human consumption can be adulterated with inferior, cheaper materials or hazardous chemicals, including pond water, reconstituted milk powder, cane sugar, urea, melamine, glucose, and detergents. Milk may be adulterated to such an extent that there is significantly less nutritional value and it may also be toxic for public health, as shown in recent milk fraud scandals. Thus, more analysis is essential to generate awareness among the public about malpractices or negligence in milk production.

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Authors Contributions

C.H. drafted the manuscript and was involved in the design of the study. C.E. designed the study and assisted in the manuscript drafting. K.C. was involved in the study design and drafting.

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