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The Chinese milk supply chain: A fraud perspective

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ABSTRACT

Food fraud has become a serious concern all over the world and especially in China. The melamine contaminated infant formula in 2008 has brought food fraud in the spotlights. This incident had grave consequences for the Chinese citizens as well as the Chinese milk industry. Fraud vulnerability assessments are the first step towards food fraud prevention and mitigation. To combat food fraud, one has to think like a criminal. In the current study, we determined the most vulnerable points in the Chinese milk supply chain, and examined the underlying causes. The fraud vulnerability perceived by 90 Chinese dairy farmers and 14 milk processors was evaluated with the SSAFE food fraud vulnerability assessment tool. Overall, actors perceived the milk supply chain as low to medium vulnerable to food fraud. Farmers appeared significantly more vulnerable than processors due to enhanced opportunities and motivations, and less adequate controls. Both geographical location of the farms and their size affected their perceived fraud vulnerability significantly.

1. Introduction

Food fraud is generally considered the illicit deception for economic gain using food, food ingredients or food packing (Spink & Moyer, 2011), and has attracted increasing attention from the food industry and regulators. Food fraud threatens food integrity in the form of manipulation of food products, food processing, information recording systems and also personal integrity (Manning, 2016). The consequences of food fraud incidents are various, and it takes extensive time to recover from fraud incidents.

Dairy products are an important source of protein and calcium in the human diet, which also holds for China. Due to the growing population and wealth in China, its dairy production increased by more than 20% annually from 1997, and reached 35 million tons in 2007 (Qian, Guo, Guo, & Wu, 2011). The melamine incident in 2008, when melamine was added to apparently inflate the protein content of animal feed and milk, was a dreadful turn for the Chinese dairy industry. Eventually, the melamine ended up in infant formula. Melamine cyanuric acid, a salt, is formed in the presence of melamine and cyanuric acid. Since this salt does not dissolve easily and forms crystals, it can lead to bladder and kidney stones, and subsequent acute renal failure. Infants are a particularly vulnerable group, because their organs have yet to form fully and their nutrition is more restricted (Pei et al., 2011). The melamine contamination of infant formula caused illness of 300,000 individuals, hospitalisation of 50,000 infants and six deaths (Graham-Harrison, 2009). Besides the severe health price paid by the consumers of the products, the estimated financial loss of Chinese dairy industry in 2008 from the melamine incident was RMB 20 billion (Wang, 2009). The milk production in China levelled off after the melamine incident instead of showing further growth (Li, 2016). The government imposed severe penalties on the people involved in the incident, including execution of two persons and life imprisonment of four persons (Xiu & Klein, 2010). Nevertheless, countries around the world banned the import of Chinese dairy products for an extended period. The incident had a large impact on the trust of Chinese consumers themselves too, many of which still seek for import infant formula instead of locally produced products today, a decade after the incident.

The melamine incident was a very visible and representative example of the numerous food fraud incidents that emerged across the Chinese food production chains. With rapid economic growth, the living standard has risen across Chinese citizens and this had consequential effects on their food and diets (Lam, Remais, Fung, Xu, & Sun, 2013). Chinese consumers are becoming more aware of food quality and safety issues (Ouyang, 2011). Although there has been an increasing focus on food safety governance in the past decade (Zhu,

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Huang, & Manning, 2019), food fraud incidents kept emerging (Zhang & Xue, 2016).

In the more distant past, science and industry focused primarily on fraud detection and methodology for detection. In the past five years, there is also more attention paid to prevention (Cadieux, Goodridge, & Spink, 2019). The latter requires better understanding of what drives food fraud. Some conceptualised food fraud (Spink & Moyer, 2011; van Ruth, Huisman, & Luning, 2017), others profiled food fraud incidents (Moore, Spink, & Lipp, 2012; Zhang & Xue, 2016). An important step towards fraud prevention is to understand the extent of the fraud vulnerability and determine which factors contribute to this vulnerability. Research has established that food fraud vulnerability could come from both the internal and external environment of a business, thus one needs to consider both the dark side of the own organisation as well as external threats (van Ruth et al., 2017). A food fraud vulnerability assessment (FFVA) tool can help to identify the weaker spots in the chain network, and thereby provides information on the potential factors contributing to food fraud (van Ruth, Luning, Silvis, Yang, & Huisman, 2018). Previously, we evaluated the fraud vulnerability in the milk supply chain in the Netherlands (Yang, Chen, et al., 2019).

Considering the previous milk fraud incidents in China and steps made towards improvements, it is of interest to examine the fraud vulnerability of actors in the Chinese milk supply chain today. In the current study we assessed the perceived fraud vulnerability by the main actors of milk supply chain, and underlying factors of Chinese milk businesses, 90 farmers and 14 processors, from the perspective of discerning the weakest spots. Thus, using the 'thinking like a criminal' approach (Levitt & Dubner, 2014), in term of food fraud vulnerabilities identification (Spink, 2019). We evaluated and compared the farmers and processors, but also examined the effect of geography and size of the farms. The perceived vulnerabilities of the Chinese actors were compared to those of their Dutch counterparts too.

2. Methodology

2.1. Participant recruitment

A two-step mixed method was adopted to collect data. First, a digital survey was conducted. Dairy farmers and processors were invited to participate in this survey via email and calls through the National Dairy Industry and Technology System. The first author presented at the annual meeting of National Dairy Industry and Technology System in 2017 and gave a brief introduction about the survey. The study focuses on fraud vulnerability of the milk supply chain, so only the farmers and processors involved in milk production were invited to participate in this survey. A total of 90 dairy farmers and 14 milk processors returned completed questionnaire. Subsequently, interviews with Chinese milk experts (n = 4) were conducted (using the same questionnaire), to get further insights on these fraud factors. These experts consisted of two farmers, one processor from the industry and one professor from academia.

The survey respondents represent nationwide participants in the main milk production area in China. As shown in Tables 1 and 2, the participants were scattered in the northern and eastern China, where more than 80% of raw milk and more than 75% of the processed milk is produced. Moreover, since the northern China is the main raw milk production area (more than 70% raw milk is produced there), the dairy farmers from the north covered ca. 80% of the farmer respondents (Table 1).

2.2. Adaptation of the SSAFE FFVA tool to the milk supply chain

A practical FFVA questionnaire, containing various factors contributing to food fraud, was developed previously (SSAFE, 2017). The original questionnaire contains 50 questions to evaluate the three key elements for the perpetration of food fraud, i.e. fraud opportunities, fraud motivations and controls. In other words: the possibility and willingness to offend by the availability of a suitable target to adulterate and the absence of retrains. The assessment of both internal and external environment of the business has been involved in the questionnaire. Only the economically motivated adulteration was considered with regard to fraud. The SSAFE questionnaire was adapted to dairy farms and processors for this study. Questions 6 and 7 in the original FFVA tool (SSAFE, 2017) were deleted because counterfeiting was not considered relevant for the milk production chain. As a result, 48 questions were used in the questionnaire (Table 3). In the questionnaire for the farmers, the questions (Q18-22, Q39-42) regarding the suppliers were changed into the corresponding ones about the customers, i.e. the processors. The questions about raw material (Q2-3, Q30-31) were omitted as feed was not considered in this study, and question 25 was removed because it replicated question 21 in this specific situation. This survey was conducted in the form of a self-assessment, and all the participants were required to answer the questionnaire considering their own situation.

2.3. Data analysis

The questionnaire comprised 48 questions and 3 optional answers to each question. A three-level score system was used for the answers. These answers depicted typical descriptions and reflected low, medium and high vulnerability situations associated with the related fraud factors. For the factors related to opportunities and motivations, the answers with score 1, 2 and 3 reflected a low, medium and high vulnerability level, respectively. For the controls-related factors, the answers with the score 1, 2 and 3 reflected a low, medium and high level of adequacy of control measures, which related to a high, medium and low level of vulnerability, respectively. The percentages of low, medium and high vulnerability scores for each fraud factor and tier group were calculated. The answers of each tier were used to evaluate the perceived vulnerability of that tier only. The fraud factors 2–3, 25 and 30–31 were not applicable to the farmers, so they were left out for the assessment for the farmers.

To summarize the overall results, the scores of each tier group were balanced to allow them to contribute to the same extent: the weighted frequency of provided answers of each question (F_i) was determined by the following formula,

$$\mathrm{Fi} = \sum_j {x_{ij}}/{n_j}$$

Where F_i is the frequency of score i (i = 1, 2, 3), x_{ij} is the number of observations which get score i in group j (j = farmers, processors), n_j is the total number of observations in group j. The score with the highest F_i for the common fraud factors were used generate the radar charts and present the overall results of the assessment.

As our study results in ordinal data, multiple correspondence analysis (MCA) was applied for exploratory analysis, and non-parametric Kruskal-Wallis tests were applied for the group comparisons and Mann-Whitney U-tests for pairwise comparisons ($P < 0.05$ was considered significant). MCA was performed by R 3.4.0 (R Foundation for Statistical Computing, Vienna, Austria), and the Kruskal-Wallis tests and Mann-Whitney U-tests were performed by SPSS v23.0 (IBM Statistics Inc., Armonk, NY, USA).

Only the common factors of both tier groups (n = 34) were used for making the radar chart, performing MCA and the statistical comparisons, i.e. the fraud factors 2–3, 18–22, 25, 30–31, 39–42 were left out since they were not comparable for the farmer and processor groups.

3. Results and discussion

3.1. Overall fraud vulnerability in the Chinese milk supply chain

The overall perceived vulnerability of the Chinese milk supply chain

Table 1
Demographic characteristics of the farmers in the study, and the related regional data in China.

Variable	Item	Number of farms (percentage) for this study	Regional data in China[a]		
			Distribution of raw milk production	Distribution of number of cows	Distribution of number of farms
Location (n = 90)	Central-North	54 (60%)	40%	33%	13%
	Northeast	10 (11%)	20%	17%	21%
	Northwest	10 (11%)	14%	13%	50%
	East	16 (18%)	12%	23%	3%
	Others	0 (0%)	14%	14%	13%
Size (n = 90)	Small (< 500 cows)	26 (28%)			
	Medium (500–1000 cows)	32 (36%)			
	Large (> 1000 cows)	32 (36%)			
Age of the respondents (n = 79) [b]	20–30	3 (4%)			
	30–40	19 (24%)			
	40–50	26 (33%)			
	50–60	24 (30%)			
	> 60	7 (9%)			
Number of farm employees (n = 82) [b]	1–10	12 (15%)			
	11–50	54 (66%)			
	51–100	10 (12%)			
	> 100	6 (7%)			

[a] Data retrieved from (Ministry of Agricultural P. R. China, 2016).
[b] Total participant number varies since some respondents did not provide the completed demographic information.

is presented by means of the modes for each fraud factor in Fig. 1. Furthermore, the relative frequencies of low, medium and high vulnerability scores for the assessments, overall and for each tier group, are shown in Fig. 2. The results are discussed below.

3.1.1. Opportunities

The radar chart of opportunities-related factors (Fig. 1) shows that the ease of adulteration (fraud factor 1) and detectability of milk fraud (fraud factor 5) were rated as medium to high risk and thus were considered to contribute more to overall fraud vulnerability than the

Table 2
Demographic characteristics of the processors in the study, and the related regional data in China.

Variable	Item	Number of processors (percentage) for this study	Regional data in China[a]	
			Distribution of milk production	Distribution of milk processors
Location (n = 14)	Central-North	5 (36%)	30%	22%
	Northeast	3 (21%)	10%	13%
	Northwest	5 (36%)	12%	18%
	East	1 (7%)	24%	23%
	Others	0 (0%)	24%	25%
Number of employees (n = 11) [b]	100–500	6 (55%)		
	500–1000	2 (18%)		
	1000–10000	2 (18%)		
	> 10000	1 (9%)		
Age of company (n = 11) [b]	10–20	4 (36%)		
	20–30	4 (36%)		
	30–40	2 (18%)		
	> 40	1 (9%)		
Age of respondents (n = 9) [b]	20–30	1 (11%)		
	30–40	5 (56%)		
	40–50	2 (22%)		
	50–60	1 (11%)		
Working experience of the respondents (years) (n = 8) [b]	0–10	3 (38%)		
	11–20	3 (38%)		
	21–30	2 (25%)		
Annual production of liquid milk (ton) (n = 8) [b]	10,000–100,000	3 (38%)		
	100,000–1,000,000	4 (50%)		
	> 1,000,000	1 (12%)		

[a] Data retrieved from (Ministry of Agricultural P. R. China, 2016).
[b] Total participant number varies since some respondents did not provide the completed demographic information.

Table 3
The three key elements and 48 fraud factors of the food fraud vulnerability assessment.

Opportunities	Motivations	Controls
Technical opportunities	Economic drivers	Technical controls
1. Ease of adulteration	10. Supply and price of milk	30. Specificity and accuracy of the fraud monitoring system in place for incoming milk in the own company (processors only)
2. Availability of technology for adulteration of the raw milk (processors only)	11. Valuable components and attributes	31. Systematics and autonomy of verification of the fraud monitoring system for incoming milk in the own company (processors only)
3. Detectability of fraud in raw milk (processors only)	12. Economic health of the own company	32. Specificity and accuracy of the fraud monitoring system in place for the milk product in the own company
4. Availability of technology for adulteration of the milk product	13. Business strategy of the own company	33. Verification of fraud monitoring system for the milk product in the own company
5. Detectability of fraud in the milk product	17. Financial pressure imposed by the company on the farmers	34. Accuracy of the information system wrt mass balance control in the own company
	18. Supplier's (for the farmers, Customer's) economic health	35. Extensiveness of the tracing and tracking system in the own company
	19. Supplier's (for the farmers, Customer's) business strategy	39. Contractual requirements with supplier in the own company (for the farmers, customers)
	24. The economic health of the sector	40. Specificity and accuracy of the supplier's (for the farmers, customer) fraud monitoring system
	28. Level of competition in sector	41. Accuracy of the supplier's (for the farmers, customer) information system wrt mass balance control
	29. Price differences due to regulatory differences	42. Extensiveness of the supplier's (for the farmers, customer) tracking and tracing system
		48. Availability of a fraud contingency plan
Opportunities in time and place	Cultural and behavioural drivers	Managerial controls
6. Accessibility to production activities	14. Ethical business culture of the own company	36. Application of integrity screening of employees in the own company
7. Transparency of the chain network	15. Previous irregularities of the own company	37. Strictness of the ethical code of conduct in the own company
8. Relationships within the supply chain	16. Corruption level of the country in which the own company is active	38. Support of a whistle blowing system in the own company
9. Historical evidence of milk fraud	20. Supplier's (for the farmers, Customer's) ethical business culture	43. Social control and transparency across the chain network
	21. Supplier's (for the farmers, Customer's) previous irregularities	44. Established guidance for fraud prevention and control in the sector
	22. Victimization of the supplier (for the farmers, Customer)	45. Specificity of the national food policy
	23. Corruption level of the country in which the supplier/customer is active	46. Strictness of law enforcement in the local chain
	25. Customer's previous irregularities (processors only)	47. Strictness of law enforcement in the international chain
	26. Sector ethical business culture	
	27. Historical evidence of milk fraud, within sector	

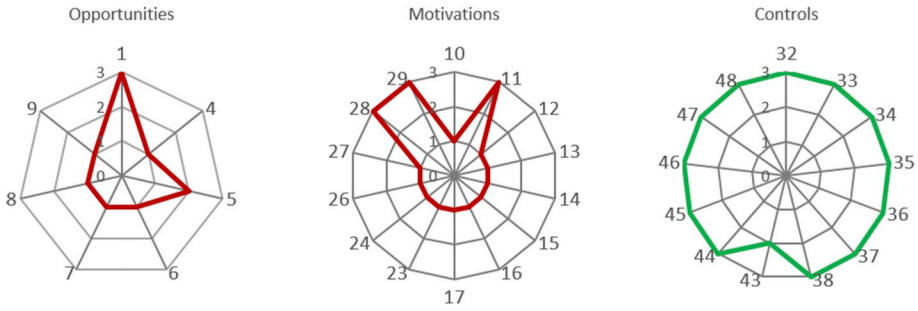

Fig. 1. Radar charts of modes for common fraud factors in the fraud vulnerability assessments over all respondents for opportunities (fraud factors 1–9), motivations (fraud factors 10–29), and control measures (fraud factors 32–48). Modes were weighted for the two tier groups to balance for group size. Explanation of fraud factor numbers is given in Table 3. Fraud factors which were not included in the assessments of both tier groups (factors 2–3, 18–22, 25, 30–31, 39–42) were omitted.

other factors, which were all rated low risk on average. It is widely acknowledged that milk, as a liquid material with complex composition, is easy to manipulate (NSF Safety and Quality UK Ltd, 2015; Yang, Chen, et al., 2019). There are various on-site methods available for fraud screening, such as rapid detection of melamine, aflatoxin, antibiotic and veterinary drug residue (Jaiswal, Jha, Kaur, Borah, & Ramya, 2018; Karczmarczyk, Baeumner, & Feller, 2017; McGrath et al., 2015; Naik et al., 2017; Zhou et al., 2014). However, the confirmation of milk authenticity still needs advanced techniques in the laboratory and is, therefore, usually time-consuming. The potential fraudster might take advantage of the ease of adulteration together with the weakness of detectability to perpetrate irregularities out of sight. Overall, there seem to be some technical opportunities, but the fraud opportunities in time and place for milk production are relatively low (Fig. 2).

3.1.2. Motivations

Among the various motivations-related factors studied, the economic drivers were perceived as medium risk level, and cultural and behavioural drivers were perceived as low risk level on average (Fig. 2). The intensive competition across the sector has put high pressure on the participants to achieve their goals. This competition is both domestic and international. There are more than 600 dairy processors in China, and some of them are in a predominant position (Li, 2016). The economy scale and the marketing power allow the large size companies to pursue aggressive business strategies (Xiu & Klein, 2010). On the contrast, the medium and small processors face large challenges to

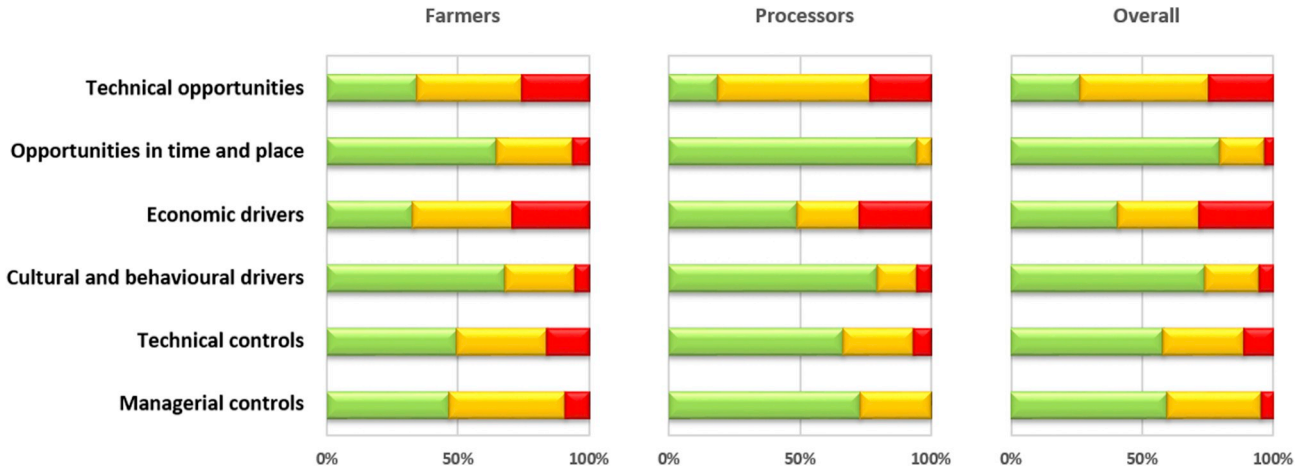

Fig. 2. The relative frequencies of vulnerability scores of fraud factors from all respondents for the six fraud factor categories (technical opportunities, opportunities in time and space, economic drivers, cultural and behavioural drivers, technical controls and managerial controls) and for the two tier groups (for farmers $n = 90$, for processors $n = 14$). Overall results present weighted frequencies for farmers and processors. The low, medium and high vulnerability portions are coloured green, orange and red, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

survive in the fierce competition. In addition, the increasing international trade makes the competition more intense. The drop of trust in domestic milk after the melamine incident drove groups of consumers to prefer imported milk products (El Benni et al., 2019), which further intensified the competition across the sector nationally.

Pricing differences due to regional differences or global supply shortages can increase the fraud vulnerability (Moyer, De Vries, & Spink, 2017). Prices of raw milk and milk products in China have been higher than those of other countries for many years. This price gap may motivate milk processors to use cheaper milk powder as replacements, which in turn may increase the competition at farm stage and make the milk more vulnerable to fraud.

3.1.3. Controls

Most controls are considered as being highly adequate by the milk actors on average (Fig. 1). Well-established control measures can counteract the vulnerability generated from opportunities and motivations (van Ruth et al., 2017), and role-play as deterrence for the potential offenders. An appropriate deterrence mechanism can stimulate fraud mitigation to move from fraud detection to fraud prevention (Manning, 2016). Our study shows that the social control and transparency of the network (fraud factor 43) is considered less adequate. Social control, which can be in various forms, such as promise keeping, information exchanging and cooperative problem solving, can, to some extent, substitute formal control in domestic buyer-supplier business relationships in China (Li, Xie, Teo, & Peng, 2010). Zhang et al. (2015) highlighted that the consumers' high tolerance of illegal behaviour and the lack of cross-market defence for dishonest companies in China would make Chinese food enterprises easier victims of food fraud. This is in line with our results.

To summarize and considering overall, average results, the milk supply chain in China is considered medium-low vulnerable to food fraud. However, there are differences between actors, tier groups and groups with different business characteristics. These matters will be further discussed in the next sections.

3.2. Differences in fraud vulnerability between tiers

An overview of the MCA for the fraud vulnerability of farmers and processors is presented in Fig. 3. We see that the farmers group is more widespread, whereas the processors group is more distinct and overlaps with some of the farmers. To examine statistical significance of the differences between the two tier groups, the mean rank for the two tier groups for each factor was presented (Table 4). Bar charts depicting the relative frequencies of low, medium and high scores are available as Supplementary material (Figs. S2A–S2C).

Eighteen common factors show no significant differences (Mann-Whitney *U*-test, $P > 0.05$) between the two tier groups (Table 4). Some of these factors contribute highly to the fraud vulnerability. These factors have already been discussed in section 3.1. when the average vulnerability profile of the Chinese milk chain was discussed. On the other hand, there are 16 common factors that show significant differences (Mann-Whitney *U*-test, $P < 0.05$) between the perspectives of the farmers and processors. These differently perceived factors include two opportunities-related factors, seven motivations-related factors and seven controls-related factors (Table 4).

3.2.1. Opportunities

The opportunities in time and place related factors transparency and relationship in the supply chain were rated significantly different by the farmers and processors. Most farmers indicated they knew their direct suppliers and customers well, but they had very limited information on the other actors in the supply chain. When the demand and supply became imbalanced about ten years ago, the farmers might have sold raw milk to short term partners or even independent milk brokers (Gale & Hu, 2009). The flexible business relationships require a high level of quality control and can increase fraud vulnerability in certain circumstances. On the contrary, the processors seemed to have more power to exchange information with other nodes in the chain, and have long term relationships with their business partners. One reason might be that a certain number of large-sized milk processors have set up the so-called "enterprise plus farmers" business model to secure milk supply and strengthen the farm management (NBSO, 2016). As a result, the processors can maintain long term relationships, and consequently could lower the risk caused by varying business relationships.

3.2.2. Motivations

Farmers perceived more (extensive) economic drivers and cultural and behavioural drivers than the processors (Fig. 2). Interestingly, these concern five economic driver related factors and two cultural and behavioural driver related factors (Table 4).

In regard to economic drivers, the two tiers differ particularly in opinion regarding the pricing of milk, economic health and financial pressure. All farmers presented significantly higher risk scores than the processors. This makes sense since the farm gate milk price is greatly influenced by various factors, such as supply and demand, milk composition and attributes, feed cost, labour cost and machine maintains, etc. (GAO, 2004). However, the most prevalent raw milk payment

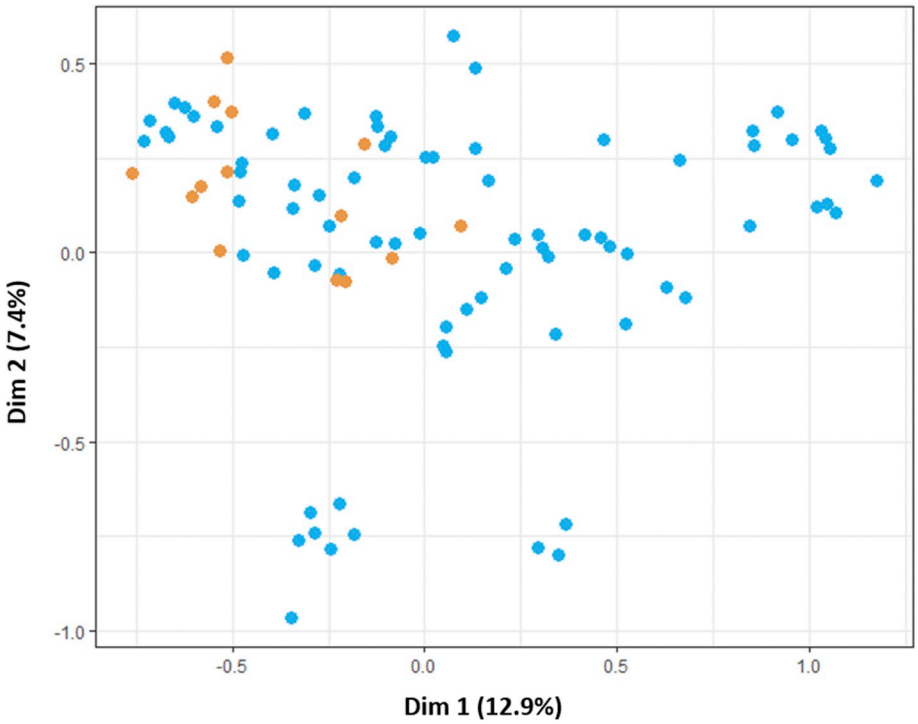

Fig. 3. Scores plot of the first two dimensions of multiple correspondence analysis on the food fraud vulnerability assessment data of the farmers (blue symbols) and processors (orange symbols). Fraud factors which were not included in the assessments of both tier groups (fraud factors 2–3, 18–22, 25, 30–31, 39–42) were omitted. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

mechanism in China is that milk processors determine the price according to the enterprise standards and market supply and demand. The milk companies have more power in price bargaining in this mechanism (Xiu & Klein, 2010). The maximization of profit in this system drives the processors to set the farm gate milk price marginally over the cost of producing, which results in considerable financial pressure for the producers (farmers). Both the high costs and low raw milk price make it more difficult for the farmers to achieve their expected financial goals. This is in agreement with the fact that the power of production, processing and marketing in the Chinese milk industry is imbalanced between farmers and processors (Wu et al., 2018). In contrast with the farmers' perspective, the majority of the processors considered that their suppliers (the farmers) experienced no serious financial pressure from them, the reason of which was that the processors believed the price could cover the cost of raw milk production. Farmers and processors also perceived the level of competition differently. This may be due to the current transition in the Chinese farming structure. This structure is shifting from being decentralized and scattered to intensive and large-size breeding (Wu et al., 2018). This transition might cause fierce competition among certain farms but does not directly affect the processors.

Regarding the cultural and behavioural drivers, farmers and processors differed significantly in vulnerability scores for the factors ethical business culture of the own company and the corruption level of the country they are active in. The farmers rated higher risk for both. Some of the farmers are smaller sized businesses than the processors. Small owner-managed businesses are very different in organisation compared to large corporations where ownership and management are separated. Although studies have not shown that these differences result in a direct different degree of (un)ethical behaviour, it has to be considered that the ethical values and inclinations of the small business owner will have far more direct consequences on the practices of the business as a whole (Longenecker, Moore, Petty, Palich, & McKinney, 2006). The difference in scores for the corruption level factor is more surprising, since all interviewed actors are active in China, and they may refer to the same corruption perception index. The gap between the two tier groups in rating the corruption level is probably due to the fact that farmers need to deal with different governmental agencies than processors, therefore they have different experiences with corruption. The difference in perceiving the corruption level perception may reflect the situated acceptance of corruption as part of doing business by the two tiers. It has been pointed out that the acceptability of (non-)criminal behaviour is one of the criterion for determining the risk of food crime in general (Manning, Smith, & Soon, 2016). Besides that, the respondents perceived China less corrupted than the result from Transparency International (2018) report. This might be explained by the desirability bias, that in social research regarding sensitive topics, providing three optional answers increases the respondents preference to project a favourable image to others and avoid embarrassment (Fisher, 1993).

To summarize, all economic and cultural and behavioural drivers that differed significantly in scores between farmers and processors, were rated higher by the farmers.

3.2.3. Controls

The scores of the farmers and processors differed significantly for six control factors, i.e. two technical controls and five managerial controls. For all more adequate controls were available perceived by the processors compared to the farmers.

First of all, the adequacy of the fraud monitoring systems and track and trace systems differed between the two tier groups. According to the interviews with the farmer experts, most farmers would have food safety controls in place that may also partially cover food fraud. Consequently, most farmers perceived the fraud monitoring system as medium-high adequacy (Supplementary material, Fig. S2C). . For instance, these measures require the raw milk to be recalled if it were found to be adulterated or contaminated. Most farmers perceived that they set up integrity screening for employees at key positions, established general ethical codes of conduct and had simple whistle blowing systems. However, it should be emphasized that over 80% of the farms in this study had more than ten employees, and the lack of systematic managerial controls in such intensive farming businesses adds to fraud vulnerability. For instance, scholars have stressed that an appropriate whistleblowing strategy is important to safeguard individuals, mitigate food fraud, and protect consumers from potential harm (Soon & Manning, 2017). The processors had more adequate controls in place

Table 4
Mean ranks of scores of the fraud factors from the food fraud vulnerability assessments for the farmers and processors, and the statistical relevance of differences between the two tier groups. Fraud factors which were not included in the assessments of both tier groups (factors 2–3, 18–22, 25, 30–31, 39–42) were omitted. Explanation of fraud factor numbers is given in Table 3. High ranks for opportunities and motivations, and low ranks for controls indicate higher vulnerability.

Fraud element	Fraud factor no.	Farmers (n = 90)	Processors (n = 14)	P-value
Opportunities	1	52	55	0.753
	4	51	64	0.076
	5	54	46	0.312
	6	53	50	0.548
	7	56	33	0.002*
	8	56	28	< 0.001*
	9	54	45	0.101
Motivations	10	55	38	0.034*
	11	53	53	1.000
	12	56	29	< 0.001*
	13	54	43	0.051
	14	55	38	0.011*
	15	53	50	0.368
	16	55	40	0.043*
	17	55	37	0.021*
	23	54	44	0.160
	24	55	36	0.010*
	26	54	42	0.108
	27	51	65	0.060
	28	50	68	0.027*
	29	53	51	0.848
Controls	32	50	66	0.047*
	33	52	56	0.599
	34	51	63	0.101
	35	50	68	0.020*
	36	49	74	0.002*
	37	49	75	0.001*
	38	50	68	0.028*
	43	51	62	0.135
	44	52	59	0.350
	45	50	68	0.022*
	46	51	62	0.085
	47	52	54	0.800
	48	49	77	< 0.001*

*Significant difference in a row (Mann-Whitney U-test, P < 0.05).

than the farmers (Table 4), as may be expected from businesses in the middle of the chain that may be victimized more easily by others.

Surprisingly, the coverage of food fraud by the national policy to cover was perceived differently by the two tier groups. The processors believed it was highly adequate, whereas the farmers believed it covered food fraud only generally. The melamine incident has raised attention to cover food fraud in the regulatory framework. Therefore, series of regulations and policies have been released by several national departments (supplementary material, Table S1A) for the milk processing enterprises. These regulations emphasise quality assurance for the processors, including record keeping for mass balance control, setting up a complete track and trace system, etc. However, it is recognized that some of the food policies aiming at food fraud are not enforced at farm level but only at the processor level explaining the different perceptions of the two tier groups. Thus, altogether, less adequate technical and managerial controls make the farmers more susceptible to food fraud than the milk processors.

Summarizing section 3.2, it is obvious that the farmers are more vulnerable to fraud than the processors for a wide range of indicators. The enhanced vulnerability is due to increased opportunities, increased motivations and less sufficient control measures.

3.3. Differences in fraud vulnerability between farms

The large number of farms allowed a further investigation into the relationship between farm business characteristics and fraud vulnerability. For a first exploration, MCA was carried out on the farm data to explore similarities and differences in the assessment score profiles. MCA plots, presented in Fig. 4, illustrate the effect of geographical location and business size. The plots show some clusters; for instance, the north-western farms (purple symbols) and a group of small sized central-north farms (green round symbols) show a distinct pattern. In order to research the influence of location and business size further, differences in factor scores between groups with different characteristics were examined for their significance (Tables 5 and 6).

3.3.1. Farm geography

3.3.1.1. Opportunities. Although four opportunities-related factors show significant differences between farmers from the different geographical areas (Table 5), the mutual differences appear of a more diverse nature. It seems that the farmers from the central-north

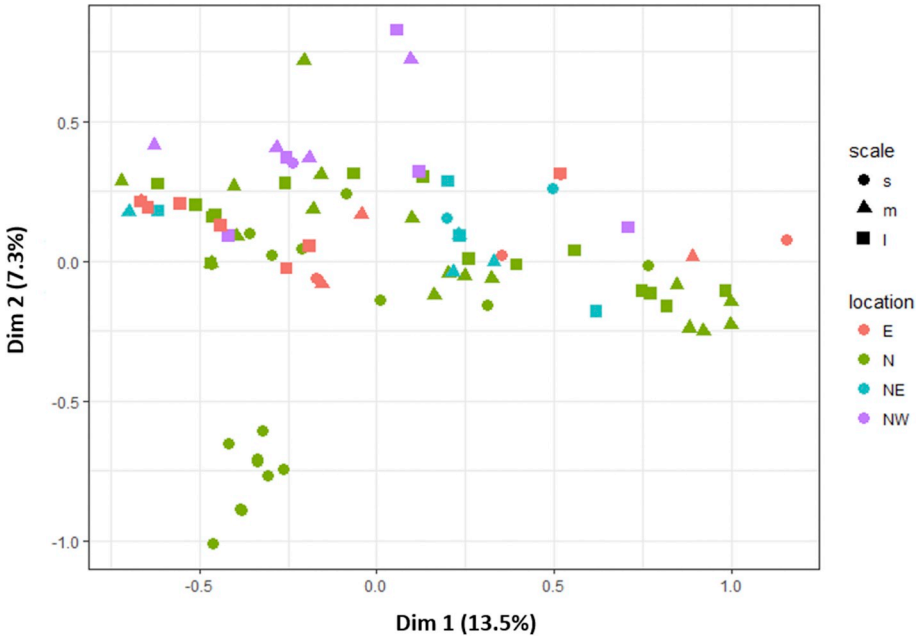

Fig. 4. Scores plot of the first two dimensions of multiple correspondence analysis on the food fraud vulnerability assessment data of the farmers coded according to their business characteristics. S, M and L stands for small, medium and large size enterprises, respectively. E, N, NE and NW stands for east, central-north, northeast and northwest of China, respectively.

Table 5
Mean ranks of scores of the fraud factors from the food fraud vulnerability assessments for the farmers, and the statistical relevance of differences between the farms based in different locations [a]. Explanation of fraud factor numbers is given in Table 3. High ranks for opportunities and motivations, and low ranks for controls indicate higher vulnerability.

Fraud element	Fraud factor no.	N (n = 54)	E (n = 16)	NE (n = 10)	NW (n = 10)	P-value
Opportunities	4	40 b	42 ab	60 a	64 a	0.002*
	5	49 a	43 ab	49 ab	27 b	0.031*
	6	42 b	46 ab	58 a	50 ab	0.019*
	8	53 a	39 ab	28 b	34 ab	0.001*
Motivations	10	42 b	41 b	45 ab	70 a	0.007*
	11	54 a	34 b	34 b	29 b	< 0.001*
	17	52 a	33 b	42 ab	34 ab	0.009*
	18	41 b	51 ab	43 ab	65 a	0.010*
	22	47 a	49 a	25 b	55 a	0.018*
	24	42 b	44 ab	65 a	48 ab	0.040*
	28	35 c	65 a	47 bc	66 ab	< 0.001*
	29	40 b	56 ab	40 ab	62 a	0.005*
Controls	36	40 b	48 ab	53 ab	65 a	0.015*
	37	42 b	40 ab	52 ab	66 a	0.020*
	38	40 b	55 ab	39 b	68 a	0.003*
	45	42 b	62 a	37 b	48 ab	0.008*

*Different letters behind ranks in a row indicate significant different (Kruskal-Wallis test followed by Mann Whitney U test, $P < 0.05$).
[a] N, E, NE, and NW stands for central-north, east, northeast and northwest of China, respectively.

Table 6
Mean ranks of scores of the fraud factors from the food fraud vulnerability assessments for the farmers, and the statistical relevance of differences between the farms of different sizes [a]. Explanation of fraud factor numbers is given in Table 3. High ranks for opportunities and motivations, and low ranks for controls indicate higher vulnerability.

Fraud element	Fraud factor no.	S (n = 26)	M (n = 32)	L (n = 32)	P-value
Opportunity	1	58 a	39 b	42 b	0.009*
Motivations	12	36 b	51 a	48 ab	0.036*
	14	56 a	40 b	43 ab	0.015*
	28	33 b	46 a	55 a	0.002*
	29	35 b	54 a	46 ab	0.005*
Controls	35	44 ab	38 b	54 a	0.025*
	38	36 b	46 ab	52 a	0.045*
	42	35 b	52 a	47 ab	0.015*
	45	36 b	45 ab	54 a	0.013*
	48	30 b	46 a	57 a	< 0.001*

*Different letters behind ranks in a row indicate significant differences (Kruskal-Wallis test followed by Mann-Whitney U-test, $P < 0.05$).
[a] S, M and L stands for small, medium and large sized farm, respectively.

considered the complexity of detectability of adulteration (fraud factor 5) as a higher risk factor as well as the relationships within the supply chain (fraud factor 8). Whereas those from the northeast and northwest rated the available technology of adulteration (fraud factor 1) and accessibility of farming activities (fraud factor 6) higher than their counterparts.

3.3.1.2. Motivations. The results on motivations-related factors reveal that the farmers from the northwest considered the supply and price of milk to be very fluctuating, the competition as very intensive and they felt more financial pressure by their customers (fraud factors 10, 17, 28) than other farmers. Consequently, it makes sense that they were also worried about their economic health (fraud factors 18, 24). The current pricing system of raw milk, which is determined by processors, might be an underlying cause of the price fluctuation in northwest China.

3.3.1.3. Controls. It appears that the farms from the northwest of China had more extensive managerial controls (fraud factors 36–38) in place than the farmers from the central-north of the country. Furthermore, the farmers from the east were more satisfied with the national food policy, whereas those from the central-north and northeast of the country believed the policy could target fraud more specifically.

Geographical location of the farms seems to affect fraud vulnerability resulting from a number of fraud factors. However, not in one direction. No literatures were found in term of ranking the fraud vulnerabilities for the farmers from different geographical locations. Thus, one cannot pinpoint one extremely vulnerable region.

3.3.2. Farm size

3.3.2.1. Opportunities and motivations. The respondents from small sized farms considered milk adulteration to be more complex than those from medium and large farms (fraud factor 1). This may be related to general knowledge level available at the farms. It is interesting that the small sized farmers appeared in better economic health (fraud factor 12) and had to deal with a lower level of competition (fraud factor 28) than the medium sized farmers (Table 6). This is in agreement with data available on profitability of different sizes of farms. Studies showed that the average return on capital of small sized farms is higher (31%) than that of the medium sized ones (27%), whereas the return rate of large size farms is somewhere in between (Ministry of Agriculture P.R.China, 2016). Diverse costs including expense of feed, labour, land, etc. could impact the profitability of the farm (Wang, Liu, Makkar, Wei, & Xu, 2014) and may differ with farm size. As a result, it appears that perceived fraud vulnerability resulting from economic drivers is higher for the medium sized farms.

3.3.2.2. Controls. The controls related to the availability of a track and trace system (fraud factor 35), a whistle blowing system (fraud factor 38) and a contingency plan (fraud factor 48) were perceived as more adequate in the large and medium sized farms than at small farm level (Table 6). Since ca. 70% of the small farms are family businesses, it is likely that less budget for such control measures is available. This is in agreement with another survey which showed that the small sized farms in the northern area of China have less developed practices regarding information recording (Yang, Chen, & Kong, 2019). Small farms also had the impression that the national food policy is not covering food fraud well, whereas this was less pronounced for other sized farms. Small farms may not be in touch with authorities as often as the larger ones. To summarize, less adequate controls result in a higher perceived fraud vulnerability of small sized farms.

4. Concluding remarks

The milk supply chain in China is, on average, perceived as low to

medium vulnerable to food fraud according to the results of the current study. However, considerable differences between actors' perspectives exist. Farmers are more vulnerable than processors because of vulnerabilities resulting from increased opportunities, increased motivations and implemented less adequate control measures. When zooming in on the farmers, it appears that both farm location and size affect the perceived vulnerability profiles. Farmers in the northwest present for instance more economic drivers, and smaller sized farms have fewer controls.

Compared to the situation of the milk chain in the Netherlands (Yang, Chen, et al., 2019), the overall perceived fraud vulnerability seems fairly similar in China and is for instance lower than those of the spice or olive oil supply chain networks (van Ruth et al., 2017). There are differences between the perspectives of the tier groups in the two countries, however. The processors consider themselves more vulnerable in the Netherlands, while the farmers take on this role in China. Obviously, threats can come from outside or from within organizations (van Ruth et al., 2017). For farmers this would be more likely to come from within the organisation, whereas processors can be offenders themselves but can also be victimized. A more detailed comparison is difficult because of the major differences in traditional culture, political system, etc. between China and the Netherlands and need to be taken into account as well.

5. Considerations and recommendations

The SSAFE FFVA tool is originally designed as a self-assessment to determine the vulnerabilities of an individual business. It is easy to use by the external examiners to get an overall picture. However, for the research of in-depth analysis of sensitive factors, for instance ethical business culture and corruption level, the social desirability bias needs to be considered. The respondents are more likely to choose the answer to be viewed favourably by the others. For the research on further evaluation of the sensitive factors, it is recommended to use indirect questions or a Likert scale to reduce this bias.

In addition, this tool is developed in the western context. Chinese business culture, which emerged from Confucianism impacted by Socialism, emphasise on the relation of the family, the community and the greater society differs from Western traditions (Ip, 2009; Wu & Kirk Davidson, 2011; Zhang, Cone, Everett, & Elkin, 2011). It is recommended to consider the difference between the Chinese and Western economic and cultural practices to further evaluate cultural factors such as ethical business culture.

The current study provides an insight on the perceived fraud vulnerability and related fraud factors of dairy farmers and processors in China. In future work, it is of interest to carry out a wider food fraud vulnerability assessment for the other actors in the milk production chain, including e.g. feed suppliers, milk collectors, milk derived product manufacturers, retailers, food service, etc. to consider the full breadth of the Chinese milk supply chain.

CRediT authorship contribution statement

Yuzheng Yang: Conceptualization, Investigation, Formal analysis, Writing - original draft, Writing - review & editing. **Wim Huisman:** Conceptualization, Writing - review & editing. **Kasper A. Hettinga:** Methodology, Writing - original draft, Writing - review & editing. **Liebing Zhang:** Resources, Writing - review & editing. **Saskia M. van Ruth:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing.

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Appendix A. Supplementary data

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