Trends, transferring, and sources of aquatic products Risks in China: Evidence from the sampling inspections by national and provincial CFDA

Q. Liang; J. Zhou; C. Jin; W. Zhou; Y. Wang

Zhejiang university, , China

Corresponding author email: jincangyu@zju.edu.cn

Abstract:

This paper maps the risks of aquatic products in different seasons, categorizes risk items, explores the transferring of risk items along the supply chain, and identifies actual risk sources of aquatic products in China, based on the data of regular sampling inspections for aquatic products conducted by national and provincial CFDA. Both descriptive analysis and crossing matrix analysis are used. Some explicit results are derived from the analyses. First, the quality and safety of aquatic products in China exhibit stable improving. Second, economically motivated adulterations by people's behaviors such as the use of drugs and chemical additives are the most important causes of risks for aquatic products. Third, risks at upstream parts transfer along the supply chain to the downstream. Fourth, the two riskiest stages causing food safety problem are manufacture and farming. Specifically, most risks for fresh aquatic products lie in farming, while those for processed products are at manufacture. However, the assignment of regulation strength and resources does not match with the distribution of risks. Stronger regulations such as the adoption of origin certificate at farms and more sampling inspections at manufacture are necessary to control for the risks of aquatic products.

Acknowledegment: The work was supported by the the project "Systemic Risk Management of Food Supply Chains in China", National Natural Science Foundation of China (No. 71773109, 71573227, 71633002); and the Project of Humanities and Social Science of the Ministry of Education in China (grant number 14YJC790089); Zhejiang Philosophy and Social Science (Grant No. 17NDJC193YB).

JEL Codes: I18, C82

Trends, transferring, and sources of aquatic products Risks in China: Evidence from the sampling inspections by national and provincial CFDA

Abstract: This paper maps the risks of aquatic products in different seasons, categorizes risk items, explores the transferring of risk items along the supply chain, and identifies actual risk sources of aquatic products in China, based on the data of regular sampling inspections for aquatic products conducted by national and provincial CFDA. Both descriptive analysis and crossing matrix analysis are used. Some explicit results are derived from the analyses. First, the quality and safety of aquatic products in China exhibit stable improving. Second, economically motivated adulterations by people's behaviors such as the use of drugs and chemical additives are the most important causes of risks for aquatic products. Third, risks at upstream parts transfer along the supply chain to the downstream. Fourth, the two riskiest stages causing food safety problem are manufacture and farming. Specifically, most risks for fresh aquatic products lie in farming, while those for processed products are at manufacture. However, the assignment of regulation strength and resources does not match with the distribution of risks. Stronger regulations such as the adoption of origin certificate at farms and more sampling inspections at manufacture are necessary to control for the risks of aquatic products.
Key words: Food safety risk; aquatic product; risk transferring; China; sampling inspections by CFDA

1. Introduction

The demand for food has been developing towards high quality and better nutrition. This trend brings up a rapid growing in production and consumption of aquatic products because of their high protein and low fat. The total output of aquatic products in the world increases from 134.1 million tons in 2004 to 167.2 million tons in 2014. The world average consumption of edible fish per capita was 16.2kg in 2004 and it arises to more than 20kg in 2014.[1] The production and fishing of aquatic products are complicated and the transportation and storage of fresh and frozen aquatic products are of high requirements. Aquatic products therefore exhibit high risks regarding the safety and quality and are the riskiest category of food (Bouzembrak and Marvin, 2015; Tähkäpää et al., 2015; Marvin et al., 2016).

China is the largest producer and exporter of aquatic products in the world.[2] More than 1/3 of total output of aquatic products in the world are produced by China.[3]

1 Data source: < World Marine and Fishery Production Report 2010> and < World Marine and Fishery Production Report 2016> by FAO.
2 Data source: <The State of World Fisheries and Aquaculture 2016>.
3 Data souce: Q&A for <The 13rd Five-year Plan for the Development of Marine and Fishery (2016-2020)> by the Ministry of Agriculture. http://www.gov.cn/zhengce/2017-01/06/content_5157432.htm#1

The safety of aquatic products in China has become an essential issue for both domestic and abroad consumers. Food safety incidents in China have been happening all the time and became more frequent in the past two decades, which causes the public's high concern (Liu et al., 2015). Aquatic products are not an exception. Export of aquatic products was influenced dramatically due to safety incidents (Sun, 2012; Zheng, 2012;). For example, European Union began to refuse all the aquatic products from China, due to multiple times of failings occurred during the tests for exported aquatic products in 2002. This refusal caused a loss of three to five million US dollars for aquatic product companies and an unemployment of nearly 50,000 labors in China.[4] Chinese government therefore launched a series of bylaws and regulations to improve food safety during the past decade, such as the new <Food Safety Law of People's Republic of China> (<Food safety Law> thereafter).

Main risks of aquatic products are residue of drugs, heavy metals, poisonous and harmful additives, and microorganism (Luning et al., 2006; Phuong et al., 2007; De Silva et al., 2010; Chen & Fang, 2011; Qin et al., 2013; Song, 2015; Marvin et al., 2016). The market failure of food safety is caused by asymmetric information and lack of traceability. The low industrialization in the production and residents' preference for alive and fresh aquatic products in China result in even more difficulties in controlling and identifying key risks in supply chain (Zheng, 2009; Wu, 2010; Liu, 1997; Guo & Gao, 2008). A whole-process traceability system with clear responsibilities can be a tool for solving food safety issues (Caswell, 1996; Verbeke, 2001; Hobbs, 2004). However, the high cost of traceability system makes it extremely hard to be contructed and maintained (Golan et al., 2004; Meuwissen et al., 2003; Hobbs & Sanderson, 2007). An alternative way is to establish an effective supervision system by the government, e.g. by sampling inspection (Zhou & Zhang, 2011). The Ministry of Agriculture conducts samping inspection for products at farms, while China Food and Drug Administration (hereafter CFDA) is in charge of the sampling inspections for food duering circulation after farming.

The government's sampling inspection is one of effective means to provide information regarding food quality and safety for the public and detect risks in food supply chain (Liu et al., 2018). It is important that the government put into and allocate scare resources properly to enhance the effectiveness and efficiency of regulation and sequentially improve food safety(Yang et al., 2011). This paper maps the risks of aquatic products at different seasons in the past two years, categorizes risk items, and identifies actual risk sources of aquatic products in China based on the database of aquatic products sampling inspections conducted by national and provincial CFDA.

There are several ways to position this research in the literature of food safety and risks. First, it focuses on aquatic products rather than mixes up all the products, to more accurately identify the risks. Risks of different products probably lie in different stages and items, e.g. risks of grain are mainly in production, while those of pork

4 Data soure: http://www.huaxia.com/xw/dlxw/2002/04/226969.html

mostly source from manufacture (Liu et al., 2011; M Su et al., 2016). Second, we look beyond the location of the failing records and identify actual risks by tracing the sources of failing items along the supply chain. There are quite a few papers that describe the risk of aggregate or partilar varies of food based on the location of failing records (Liu et al., 2011; Liu et al.,2016; Liu et al.,2018), yet no existing literature explores the actual risks by tracing the sources of failing items. Third, this paper maps the overall as well as the seasonal development of aquatic products risks, applying CFDA's sampling inspection data which is comprehensively searched by web craping. The risks of food in China are broadly analyzed based on food safety incidents exposed by media (Wang & Gu, 2013; Liu et al., 2015; Zhou et al., 2016; Liu et al., 2016). However, media exposure contains insufficient information regarding the risk items and sources, and might purposely distorts the incidents as well. We therefore use the official statistical data published by national and provincial CFDA, which is more reliable and believable. In addition, some scholars emphasize that food safety is closely associated with climatic factors, yet few studies look at the risks of different seasons by comprehensive analyses on data (Zhang, 2015; Liu et al., 2018). Most studies evaluate the risk levels according to the annual numbers of failing records or incidents, which is far from accuracy.

The subsequent section is dedicated to methodology. Section 3 provides a map regarding the overall and seasonal risks of aquatic products in China, and further analyses the transferring and sources of risks. The risks of fresh and processed aquatic products are explored respectively in section 4. A discussion is provided in section 5, while the final section concludes.

2. Data

The data used in this paper are results of sampling inspection for aquatic products by national and provincial level CFDA, which is obtained by web data mining technology. CFDA is in charge of the circulation stages of supply chain, i.e. stages after farming such as manufacture, wholesale, and retail, while Ministry of Agriculture regulate the safety and conduct sampling inspection in farming. CFDA publishes the results of sampling regularly on official websites for food and drug safety information including the number of tests and failing records, as well as detailed information for each failing record with the location of test, name of individual or company tested, failing item, and so on. However, the results of sampling inspection at farms are not available. Hence, the data we mined contain only the after-farming tests information.

Tests for aquatic products are further distinguished, in order to evaluate the risks more accurately. We finally obtained a database comprised of 21498 test records for aquatic products with the duration from January, 2015 to February, 2017. The sampling inspections at circulation had been conducted by Administration of Quality and Technical Supervision rather than CFDA before 2015 and the data were not

avalable. Among all the test records, 1057 of them are failing records, accounting for 4.92% of test records.

3. Safety Risks of aquatic products in China

3.1. A map of overall development and trends of safety risks

Since risks of food safety are associated with the season, we categorize all the failing records into four groups, based on the time of tests. The results of tests are usually published two to three months after tests. Hence, the time of tests is roughly two to three months before the time of publication. In order to avoid the inaccuracy due to different test time by different departments, the database for the tests conducted by national CFDA, totally 18015 records, are used to map the overall development of aquatic product risks.

The failing rates of sampling inspections for aquatic products during January 2015 and January 2017 are displayed in Figure 1. In general, the failing rate is declining and developing towards stable. The promulgation of new <Food Safety Law> in Oct. 2015 puts emphasis on the governance and supervision of food safety and it is followed by <Administrative regulations for daily supervision and inspection of food production and operation> in March, 2016. The growing strength of administration might be one of the reasons leading to the decline of failing rate.

Two peaks appear in the summers of 2015 and 2016, indicating more risks of aquatic products due to high tempreture. Fishes and shrimps grow faster in summer and need more feeds than they do in other seasons, which causes the increase of harmful substances in the water and consequentially more diseases (Liu, 2007). More drugs therefore are used in summer to avoid diseases and death. However, the fluctuation is becoming gentler in 2016 than that in 2015.

The failing rate of fresh products and processed products are further distinguished. Risks in diffirent seasons of fresh and processed aquatic products are slightly different. Fresh products have an apparently lower failing rate than that of processed products. This may due to two reasons. First, more additives might be added during manufacture. Second, tests for processed products, just like other food, follow <Food Safety Law>, while the regulation for the safety of fresh products is of much weaker strength. The failing rate of fresh aquatic products in the fall of 2016 is higher than that in the summer, because of a special inspection program for aquatic product in that fall.

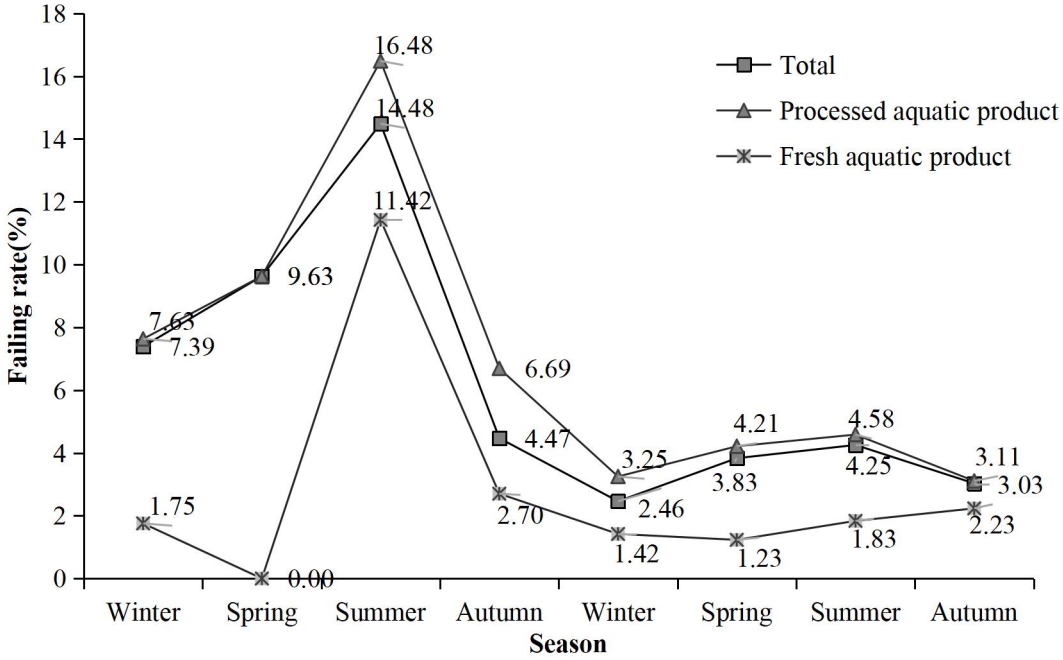

Fig. 1. Failing rates of sampling inspections for aquatic products in China (2015.1-2017.1).

Note: No failing records for fresh aquatic products in Spring of 2015 were found.

3.2. Failing records along supply chain and failing items

The distribution of tests records and failing records among various supply chain stages and sites are presented in table 1. Approximately two thirds (66.58%) of tests records are from retail, while slightly less than one third are from manufacture. Among all the 1057 failing records, around 55.25% of the failing records are detected in retail, followed by manufacture (21.85%) and wholesale (16.08%). Among all the retailers, supermarkets and shopping malls have the most failing records, accounting for around 42.19% of all the records.

Table 1

Distribution of test records and failing records among various supply chain stages.

Stages	Test records	Percentage of test records	Failure records	Percentage of Failure records
Manufacture				
-Manufacture	6489	30.18%	231	21.85%
Wholesale				
-Wholesale market	653	3.04%	170	16.08%
Retail				
-Supermarket and shopping mall	9306	43.29%	446	42.19%
-Retail store	1512	7.03%	52	4.92%

-Wet market	2521	11.73%	69	6.53%
-Exhibition center	25	0.12%	9	0.85%
-Online store	117	0.54%	8	0.76%
Consumption				
-Restaurant	832	3.87%	72	6.81%
NA	43	0.20%	0	0.00%

All the failing items detected in national and provincial CFDA's inspections are categorized based on <Veterinary Pharmacopoeia of the People's Republic of China (2015 edition)>, <Codex General Standard for Food Additives Codex Stan 192-1995>, CCFH (Codex Committee on Food Hygiene), ICMSF (International Commission on Microbiological Specifications for Food), and GSC (General Standard for Contaminants). Six categories of failing items are identified, i.e. drugs, chemical additives, expired food and wrong labels, microorganisms, metal and heavy metal, and hypertoxic chemicals. Table 2 delineates the distribution of failing records among various categories based on particular failing items. Most of failing items are microorganisms, chemical additives, and drugs, accounting for 36.61%, 36.14%, and 13.62% respectively, while the other three categories account for around 10%.

Table 2
Failure records falling into each category of failing items.

Failure items	Frequency（%）
Drugs	13.62
Chemical additives	36.14
Expired food and wrong labels	6.43
Microorganisms	36.61
(Heavy) Metal	6.72
Hypertoxic chemicals	0.47
Total	100

3.3. Risk sources and transferring

3.3.1. Identifying sources of failing items

Even though most of failing records are detected in retail and manufacture, the sources of failing items may lie in different stages. Possible sources of failing items are identified based on their physical property and the evidence from the literature, which are shown in table 3. Drugs mainly include Quinolones, Furfuran, Metronidazole, Malachite green, Chloramphenicol, and Olaquindox, which are used in the growing of fresh water products (Chen, 2009; Zhai, 2007). Among them, Malachite green is also broadly used in transportation and temporary raising (Zhai, 2007). Chemical additives such as Sunset Yellow and Carmine are mainly used in

manufacture (Sun & Sun,2013). Volatile base Nitrogen (VBN) and (KDH) Acid represent the extend of spoilage which is associated with storage time, which are used probably in Manufacture, wholesale, or retail. Illegal labels might happen during manufacture and re-manufacture in wholesale. Microorganisms including Colibacillus, Aerobic bacterial Count, Staphylococcus Aureus and so on probably exist in manufacture and retail (Zhang et al., 2014). Mercury and Cadmium which are metal and heavy metal, and Inorganic arsenic are environmental sourced and exist in land and water in farming (Huang & Xu, 1998).

Table 3
Categories and sources of failing items.

Category	Failing items	Sources of failing items
Drugs	Quinolones	Farming
	Furfuran	Farming
	Metronidazole	Farming
	Malachite green	Farming/Manufacture/wholesale/retail/consumption
	Chloramphenicol	Farming
	Olaquindox	Farming
Chemical additives	Sunset yellow	Manufacture
	Carmine	Manufacture
	Tartrazine	Manufacture
	Sodium cyclamate	Manufacture
	Acesulfame potassium	Manufacture
	Butylated Hydroxytoluene（BHT）	Manufacture
	Sulfur dioxide/sulfite	Manufacture
	Potassium sorbate	Manufacture
	Sodium saccharin	Manufacture
	Benzoic acid and sodium benzoate	Manufacture
	Alums	Manufacture
Expired food and wrong labels	Illegal labels	Manufacture/wholesale
	(VBN)Volatile base nitrogen	Manufacture/wholesale/retail
	（KDH） Acid value	Manufacture/wholesale/retail
Microorganisms	Colibacillus	Manufacture/wholesale/retail
	Aerobic bacterial count	Manufacture/wholesale/retail
	Staphylococcus aureus	Manufacture/wholesale/retail
Metal and heavy	Mercury	Farming

metal	Plumbum	Farming/Manufacture
	Cadmium	Farming
Hypertoxic chemicals	N-nitrosodiethylamine	Manufacture/wholesale/retail
	Inorganic arsenic	Farming

3.3.2. Transferring of risks along supply chain

Based on the evidence regarding the possible sources of various failing items in table 3, we trace the source of failing item for each failing record. The results are presented in table 4. Risks of aquatic products transfer from upstream parts to downstream stages. Among all the failing records detected at manufacture, risks of around 7% of the records source from the farming and around 93% from manufacture. For those failing records detected at wholesale stage, only 0-11.91% are caused by that wholesale stage, while 71.49%-76.17% source from manufacture and around 16.60%-23.83% are residue from farming. As for the failing records detected at retailers, a small proportion of risks, i.e. 0-9.00%, are caused by retailers themselves, while most risks (71.84%-80.26%) are caused by behaviors during manufacture, followed by risks sourced from farming which accounts for 17.85%-21.04%. Failing records detected at consumption are mainly caused by manufacture, which accounts for 82.05%-83.33%.

Table 4

Transferring of risks among the supply chain.

Detected stage	Actual risk stage	Rate of Risk transferring
Manufacture	Farming	6.46-7.14
	Manufacture	92.86-93.54
Wholesale	Farming	16.60-23.83
	Manufacture	71.49-76.17
	Wholesale	0-11.91
Retail	Farming	17.85-21.04
	Manufacture	71.84-80.26
	Wholesale	0-9.00
	Retail	0-9.00
Consumption	Farming	10.26-17.95
	Manufacture	82.05-83.33
	Wholesale	0-6.41
	Retail	0-6.41

3.3.3. Risk sources of aquatic products

Based on the particular failing items and the possible sources of these items, we identify actual risk source stages and particular risk items in various stages, by crossing matrix analysis. The distribution of failing records based on risks sources and

items is displayed in table 4. Manufacture and farming are the two riskiest stages. Most risks are sourced from manufacture, such as the use of chemical additives and Microorganisms due to improper storage, followed by the use of drugs and the existence of metal and heavy metal at farming. Expired food and wrong labels at manufacture/wholesale and retail are also possible risks.

Table 5
Distribution of failing records based on risk sources and failing items.

Risk source \ Risk item	Drugs	Chemical additives	Expired food and wrong labels	Microorganisms	(Heavy) Metal	Hypertoxic chemicals	Percentage （%）
Farming	124	0	0	0	61	4	14.58
Manufacture	0	485	0	498	0	1	75.85
Farming/manufacture	0	0	0	0	12	0	0.93
Farming/wholesale	17	0	0	0	0	0	1.31
Manufacture/wholesale/retail	0	0	76	0	0	0	5.86
Farming/manufacture/retail	18	0	0	0	0	0	1.39

4. Risk sources of fresh and processed products

We further distinguish fresh and processed products and explore their risk sources respectively. The transferring and sources of risks for fresh and processed aquatic products along supply chain present different features.

4.1. Risks of fresh products

Table 6 shows the transfering of risks for failing records detected at each supply chain stage. For the wholesale market, around 0-32.61% of failing records are caused by wholesalers themselves, while risks of 67.39-100% of failing records actually source from farming. We are not able to distinguish the sources of part of risk items such as Malachite green between manufacture or wholesale itself. Risk items of around 86.41-99.03% of the failing records detected in retail source from farming, followed by that 0.97-13.5% source from manufacture. For the failing records at consumption sites such as restaurants, 61.54-100% of risks source from farming. To sum up, the most risks of fresh aquatic products lie in farming.

Table 6
Transferring of fresh aquatic product risks along supply chain.

Detected stage	Risk source stage	Rate of Risk transferring（%）
Wholesale	Farming	67.39-100
	Manufacture	0-32.61
	Wholesale	0-32.61
Retail	Farming	86.41-99.03
	Manufacture	0.97-13.59
	Wholesale	0-12.62
	Retail	0-12.62
Consumption	Farming	61.54-100
	Manufacture	0-38.46
	Wholesale	0-38.46
	Retail	0-38.46
	Consumption	0-38.46

Particular risk items of fresh aquatic products in various stages are identified by crossing matrix analysis and the results are displayed in table 7. Among all the failing records, at least 79.36% of risk items source from farming and the rate can be as high as 100%. Some drugs such as Malachite green are broadly used in both farming and various circulation stages of fresh products. Hence, we are not able to identify the exact stage where Malachite green sources. Drugs such as Furfuran, Metronidazole, Quinolones are the main items causing the risks of fresh aquatic products at farming, followed by metal and heavy metal.

Table 7
Risky stages and particular items of fresh aquatic product.

Risks / Stages	Drugs	Chemical additives	(Heavy) Metal	Hypertoxic chemicals	Percentage（%）
Farming	102	1	23	3	79.36
Farming/manufacture/ wholesale	15	0	0	0	9.26
Farming/manufacture/ wholesale /retail	13	0	0	0	8.02
Farming/manufacture/ wholesale/retail/ consumption	5	0	0	0	3.08
Total	135	1	23	3	

4.2. Risks of processed products

Different from fresh aquatic products, risks of processed aquatic products mainly lie in manufacture. Actual risk sources are identified based on the particular failing

items and the results are shown in table 8. Risk items of failing records detected in each stage are mostly sourced from manufacture, e.g. 93.01% in manufacture, 92.70-97.08% in wholesale, and 86.02-95.55% in retail.

Table 8
Transferring of processed aquatic products risks along supply chain.

Detected stage	Risk source stage	Rate of Risk transferring（%）
Manufacture	Farming	6.99
	Manufacture	93.01
Wholesale	Farming	2.92
	Manufacture	92.70-97.08
	Wholesale	0-4.38
Retail	Farming	4.45
	Manufacture	86.02-95.55
	Wholesale	0-9.53
	Retail	0-9.53
Consumption	Manufacture	100

Risks of each stage and particular risk items of processed products are identified by crossing matrix analysis and the results are presented in table 9. Among all the failing records, at least 89.81% of risk items source from manufacture. Chemical additives and microorganisms are the two main risk items of processed aquatic products.

Table 9
Risky stages and particular items of processed aquatic product.

Risks / Stages	Drugs	Chemical additives	Expired food and wrong labels	Microorganisms	(Heavy) Metal	Hypertoxic chemicals	Percentage（%）
Farming	4	0	0	0	36	1	4.54
Manufacture	0	376*	17	387*	31	0	89.81
Manufacture/ wholesale	0	0	6	0	0	0	4.98
Manufacture/ wholesale/retail	0	0	44*	0	0	1	0.66
Total	4	376	67	387	67	1	

* represents three risk items detected most frequently.

5. Discussion and policy implication

The safety of aquatic products in China are developing towards stable improvement. The government plays an important role in regulating food market and reducing food safety risks. Chinese government launched a series of measures since 2000, e.g. special programs for drug residues of aquatic products, comprehensive enforcements of aquatic product quality safety regulations, as well as the promulgation of new national <Food Safety Law> and <Administrative regulations for daily supervision and inspection of food production and operation>, etc. These stronger regulation strength for food safety brings up the falling of failing rate of sampling inspections for food in the past two years.

Despite the effectiveness of governmental regulation in food safety, there is some space for the improvement of efficiency. Allocation of regulation strength and resources does not match with the distribution of risks along supply chain. The rate of tests, failing rate of tests, and rate of risk sources are summarized in table 10. For the circulation stages, nearly a half of the tests by national and provincial CFDA are conducted at retail, yet the failing rate in retail is medium (10.85%) and the risk level at retail is relatively low (0-7.25%). The government puts more resources in retail because retailers are directly connected with consumers who tend to exert more pressure on the government to check the safety of food in retail.

Although wholesale have the highest failing rate according to the results of tests, most of risks are transferred from upstream stages. Manufacture is the riskiest stage, which causes up to 75.85%-84.03% of the failing. However, the test rate of manufacture is only 27.93%. Stronger regulation in terms of sampling inspection and punishment needs to be put in manufacture, in order to enhance the efficiency of regulation.

Farming is the riskiest stage for fresh products and also one of the high risk stages for processed products, yet the rate of tests at farming is much lower than those at circulation stages. Take one of the largest aquatic products producers, Zhejiang province, as an example. There were totally 2807 tests conducted by the Ministry of Agriculture and provincial Ocean and Fisheries Bureau in 2016. The number of scaled farmers for fresh water grow products is more than 20,000. That is to say, the rate of tests is much lower than 10%, which is significantly lower than that at circulation.

Food safety in farming and in circulation are administrated by different governmental departments. This separation might cause incomplete information between the two departments and some opportunistic behaviors in between such as the transportation between farm and market. Nowadays Chinese government is pushing the adoption of origin certificate for agro-products, which yet faces challenges.[5] A customer who buy aquatic products from a farm tends to mix up the products with those from other farms, which makes the provision of origin certificate by the farm risky if products from other farms have no certificate or are unsafe. Hence,

[5] An origin certificate is issued by a local cooperative, a company, township government, or village committee. It contains the data of issue, number of the certificate, address, name, and contact information of the farm, quality test results, and so on.

it is important to make sure the adoption of these practices is formally required by law and bylaws. Also it is desirable to establish an entry threshold at the markets for products from farms in order to reversely force those who buy products from farms to ask for the origin certificate.

Table 10
Rate of tests, failing rate, and rate of actual risk stages of aquatic products.

Stages	Rate of tests (%)	Failing rate (%)	Rate of risk sources (%)
Farming	—	—	14.58-18.21
Manufacture	27.93	3.58	75.85-84.03
Wholesale	3.93-13.14	12.54	0-8.56
Retail	49.42	10.85	0-7.25

6. Conclusion and policy implication

This paper maps the risks of aquatic products in different seasons in 2015 and 2016, categorizes risks items, explores the transferring of risk items along the supply chain, and identifies actual risk sources of aquatic products in China, based on the data of regular sampling inspections conducted by national and provincial CFDA. Some explicit results are derived from the analyses. The quality and safety of aquatic products in China are improving, considering the decreasing of failing rate of sampling inspections. The risks of fresh products are relatively lower than that of processed products.

Economically motivated adulteration by people's behaviors is the most important causes of risks for aquatic products. In particular, drugs are used in farming to prevent alive aquatic products from illness and to increase output, while additives are used in manufacture to obtain good looking and long time storage, which are the two main items cause the failing in sampling inspections.

Risks at upstream parts transfer along the supply chain to the downstream and present a major threat to the public health. The two riskiest stages causing food safety problem are manufacture and farming. Specifically, most risks for fresh aquatic products lie in farming, while those for processed products are at manufacture. Most of risks for processed products source from the manufacture, yet limited regulation resources are assigned to conduct sampling inspections at manufacturers. The government puts the most efforts in the regulation of retailers, which might be necessary because consumers' concern focuses more on products at retailers. However, the government needs to look further into the actual sources of risks and exert more regulations to control for the risks.

Farms in China are known to be highly distributed and opaque, which makes the supervision on farming difficult and costly. It is beneficial that small farmers act collectively via the foundation of cooperatives or contract with companies to achieve the safety in farming by instruction and supervision from cooperatives and companies.

In addition, stronger regulation such as the adoption of origin certificate by the government is necessary to push the improvement of aquatic products quality and safety at farming.

Acknowledgements

The work was supported by the the project “Systemic Risk Management of Food Supply Chains in China”, National Natural Science Foundation of China (No. 71773109, 71573227, 71633002); and the Project of Humanities and Social Science of the Ministry of Education in China (grant number 14YJC790089); Zhejiang Philosophy and Social Science (Grant No. 17NDJC193YB).

References

Bouzembrak, Y., & Marvin, H. J. P. (2015). Prediction of food fraud type using data from Rapid Alert System for Food and Feed (RASFF) and Bayesian network modelling. *Food Control*, 61, 180–187.

Boxall, A., Blackwell, P., Cavallo, R., Kay, P., & Tolls, J. (2002). The sorption and transport of a sulphonamide antibiotic in soil systems. *Toxicology Letters*, 131(2), 19-28.

Briggs, G. G., Bromilow, R. H., & Evans, A. A. (1982). Relationships between lipophilicity and root uptake and translocation of non-ionised chemicals by barley. *Pest Management Science,* 13(5), 495-504.

Caswell, J. A., & Mojduszka, E. M. (1996). Using informational labeling to influence the market for quality in food products. *American Journal of Agricultural Economics*, 78(5), 1248-1253.

Chiţescu CL, Nicolau AI, Römkens P, & Van Der FelsKlerx HJ. (2014). Quantitative modelling to estimate the transfer of pharmaceuticals through the food production system. *Journal of Environmental Science & Health Part B,* 49(7), 457.

Golan, E., Roberts, T., Salay, E., Caswell, J., Ollinger, M., & Moore, D. (2004). Food safety innovation in the united states: evidence from the meat industry. *Agricultural Economics Reports,* 831.

Hobbs, J. E., & Sanderson, K. (2007). Traceability and quality verification in the canadian beef industry: where to from here?. *Journal of Food Distribution Research,* 38(1).

Hobbs, J. E. (2004). Information asymmetry and the role of traceability systems. *Agribusiness,* 20(4), 397–415.

Liu, A., Shen, L., Tan, Y., Zeng, Z., Liu, Y., & Li, C. (2017). Food integrity in china: insights from the national food spot check data in 2016. *Food Control,* 84.

Liu, Y., Liu, F., Zhang, J., & Gao, J. (2015). Insights into the nature of food safety issues in beijing through content analysis of an internet database of food safety incidents inchina. *Food Control,* 51, 206-211.

Luning, P. A., Devlieghere, F., Verhé, R., Luning, P. A., Devlieghere, F., & Verhé, R. (2006). Safety in the agri-food chain. Safety in the agri-food chain.

Marvin, H. J. P., Bouzembrak, Y., Janssen, E. M., Fels-Klerx, H. J. V. D., Asselt, E. D. V., & Kleter, G. A. (2016). A holistic approach to food safety risks: food fraud as an example. *Food Research International,* 89, 463-470.

Meuwissen, M. P. M., Velthuis, A. G. J., Hogeveen, H., & Huirne, R. B. M. (2003). Traceability and certification in meat supply chains. , 21(2), 167-181.

Phuong, N. T., Le, X. S., Thinh, N. Q., Chau, H. H., Cao, T. A., & Hau, N. M. (2007). Economics of aquaculture feeding practices: Viet Nam. Economics of aquaculture feeding practices in selected Asian countries.

Qiang, L., Wen, L., Jing, W., & Yue, D. (2011). Application of content analysis in food safety reports on the internet in china. *Food Control,* 22(2), 252-256.

Silva, S. S. D., & Davy, F. B. (2010). Success Stories in Asian Aquaculture. Springer Netherlands.

Tähkäpää, S., Maijala, R., Korkeala, H., & Nevas, M. (2015). Patterns of food frauds and adulterations reported in the eu rapid alert system for food and feed and in finland. *Food Control,* 47(47), 175-184.

Verbeke, W. (2001). Beliefs, attitude and behaviour towards fresh meat revisited after the belgian dioxin crisis. *Food Quality & Preference,* 12(8), 489-498.

XiaojunWang, DongLi, & XianliangShi. (2012). A fuzzy model for aggregative food safety risk assessment in food supply chains. *Production Planning & Control,* 23(5), 377-395.

Chen, C.F.(2009). Problems regarding the use of antibiotics fishery drugs and aquatic product quality safety. *Feed Industry,* 30 (4):1-5.

Chen, Y.S., & Fang, J.R.(2011). An empirical analysis on the influencing factors of the marine fish farmer's behavior of drugs using.*Chinese Rural Economy*, 8, 72-80.

Guo, M., & Gao, J. (2008). Research on the consumption characteristics of aquatic products in China's coastal areas: Evidence from Shanghai and Dalian. 2008 Chinese Fisheries Economics Experts Forum.

Huang, H.Y., & Xu, Y.S. (1998). Monitoring of mercury\cadmium\lead\arsenic contamination condition of aquatic products in Zhuhai City. *Chinese Journal of Public Health(Chin J Publ Heal),*14(1): 23-24.

Liu, C., Zhang, H., & An, Y.F. (2011). Weak stage, essential reasons, critical control point of food quality and safety in China: An empirical analysis based on 1460 food quality and safety incidents. *Issues in Agricultural Economy*, 1, 24-31.

Liu, F.L.(2007). Causes and prevention measures of fish disease outbreak in hot summer. *Journal of Fujian Fisheries,*4,48-49.

Liu, Q., Zhou, J.H., & Yan, Z.(2016).The risk identification of pork's quality and safety of China from the supply chain perspective and policy implications: Based on the empirical analysis of 1 624 food quality safety cases.*Chinese Journal of Animal Science,* 52(2):60-65.

Liu, Y.D. (1997). Fresh aquatic products markets in Asian. *China fisheries,* 8, 39-40.

Qin, N., He, W., Wang, Y., He, Q.S., Kong, X.Z., Ouyang, H.L., & Xu, F.L.(2013) Residues and health risk of polycyclic aromatic hydrocarbons in the water and aquatic products from Lake Chaohu. *Acta Scientiae Circumstantiae*, 33(1), 230-239.

Song, J.M.(2015). Effects of fishery drugs on the quality and safety of aquatic products.*Chinese Fisheries Economics,*4, 39-42.

Sun, B.(2012).Preliminary study on the quality safe traceability system of aquatic products. *Chinese Fisheries Economics,*30(1):57-61.

Sun, J.Y., & Sun, B.G.(2013).Thoughts about China's food additive and food safety. *Journal of Agricultural Science and Technology,*15(4), 1-7.

Wang, C.W., & Gu, H.Y.(2013). The food safety situation of our country and policy implications: comparative analysis based on incidents statistic,monitoring and consumers' perception.*Social Science,* 7, 24-38.

Wu, L.H., Xu, L.L., & Yin, S.J.(2015). Introduction to 2015 China development report on food Safety. Beijing：Peking University Press (Chapter 4).

Wu, R.Q.(2010). Reflection on promoting sustainable development of freshwater aquaculture. *Chinese Fisheries Economics,* 5, 94-98.

Yang, C.F., Liu, L.M., & Dong, Y.G. (2011). Allocation of food safety regulation resources and performance improvement. *Chinese Journal of Health Inspection,* 18(2), 128-132.

Zhai, Y.X., Zhang, C., Ning, J.S., & Geng, X.(2007). Survey of malachite green residue in aquatic product. *Marine Fisheries Research,* 28(1):101-108.

Zhang, G.C.(2015). Influencing factors of aquatic products quality and safety in farming. *Animal Husbandry and Feed Science,* 36(8), 94-95.

Zhang, Z.J., Zhang, W.B., Qiang, X.J., Zhao, R.M., Jin, F., & Lu, Y.Y.(2014). Application of real-time PCR in the detection of foodborne pathogens. *Food and Nutrition in China,* 20(8), 17-19.

Zheng, J.M.(2009). The transformation of fishery production organizations in China based on internatonal experiences. *World Agriculture,* 8, 11-13.

Zheng, S.N.(2012). Research on the comparisons of the international competitiveness of aquatic product between Fujian and Taiwan.(Doctoral dissertation, Fujian Agriculture And Forestry University).

Zhou, J.H., & Zhang, S.D. (2011). The construction of traceability system for vegetable quality safety: From two-dimensional perspectives of suppliers and regulation departments. *Issues in Agricultural Economy,* 1, 32-38.