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Food poisoning by clenbuterol in China

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REVIEW ARTICLE

Abstract

Food poisoning events caused by clenbuterol residues have broken out frequently in recent years in China, stimulating great public concern. Although China's clenbuterol problems are not recent, the Chinese Government is now facing unprecedented pressure to tackle the issue, especially as its largest meat processing enterprise, the Shuanghui Group, was found to produce clenbuterol-contaminated food. Recurrence of clenbuterol abuse problems is evidence that the food safety supervision system in China has deficiencies. Here, we introduce China's historical clenbuterol problem, and then discuss the current food safety management system in China. We then make some suggestions towards the management and control of clenbuterol abuse.

Keywords: clenbuterol, food poisoning, China, history, meat, management

1. Introduction

Clenbuterol is a β2-adrenergic agonist which poses potential hazards to humans (Hahnau and Jülicher, 1996; Salleras *et al.*, 1995) and animals (Bakker *et al.*, 1998; Kearns and McKeever, 2002). China's problems with clenbuterol are not recent; the addition of clenbuterol to feeds was banned in China as early as 1997. But its illegal use to induce weight gain and a greater proportion of muscle to fat (MacLennan and Edwards, 1989) has remained widespread even after repeated prohibition, especially in the pig farming industry. Earlier this year, Shuanghui Group, which is China's top meat products processor (and one of the top three in the world) was mired in a food safety scandal, after its products were detected to contain clenbuterol (Li and Zhang, 2011) Food poisoning incidents caused by the ingestion of clenbuterol contaminated food have been reported in Hong Kong, Shanghai and Guangzhou, with the number of poisoned people reaching up to 2,455 from 1999 to 2005 according to what are no doubt incomplete statistics (Li and Zhang, 2011). Frequent food safety scares generated by clenbuterol residues in meat products intended for human consumption (Posyniak *et al.*, 2003) underline the necessity and urgency of effective clenbuterol monitoring and control throughout the manufacture of animal-derived food. Although the Chinese government has established an entire set of chemical residue standards, management systems and supervision system (Wang *et al.*, 2008), and Chinese leaders have responded with high-profile efforts to deal with food safety problems (Thompson and Hu, 2007), it is still challenging to improve the present restricted and inadequate food safety control system in China. Since there is no once and for all solution, China still has a long way to go.

This paper is organised as follows, we first introduce the history of clenbuterol application and illegal use, then identify challenges the Chinese government faces and measures it has taken in the face of clenbuterol abuse, and finally some advice will be given based on the actual situation in China.

2. History and application

Clenbuterol (4-amino-α-[t-butylaminomethyl]-3,5-dichlorobenzyl alcohol hydrochloride) is a long-acting, β2-adrenergic agonist, it is used as a bronchodilator to treat chronic obstructive pulmonary disease in the horse (Daubert *et al.*, 2007; Sasse and Hajer, 1978), and is currently the only the US Food and Drug Administration (FDA) approved drug to prevent bronchospasm in horses (Erichsen *et al.*, 1994), with details of usage available in documents of FDA (1998).

Besides its respiratory disease therapy usage, clenbuterol is also used in animals for both recreation and competition (Sasse and Hajer, 1978), such as horse racing (Ferraz *et al.*, 2007) and pigeon racing (Gaillard *et al.*, 1997), to enhance athletic performance.

Although the use of clenbuterol as a performance enhancing drug has a long history, some studies showed that acute and short-term clenbuterol ingestion failed to improve any indices of aerobic performance (Kallings *et al.*, 1991; Slocombe *et al.*, 1992), while long-term administration resulted in deleterious aerobic performance (Beekley *et al.*, 2003; Kearns and McKeever, 2002).

Dr. Gary Norwood, president of the American Association of Equine Practitioners wonders why clenbuterol is thought to be a performance enhancer, when its effects only help to bring the unhealthy lung back to a normal state (Jones, 1998). Some think this may be a reflection on how much undiagnosed lung pathology exists in the racehorse population, and clenbuterol is simply bringing the performance level back to normal (Jones, 1998).

Because of its unique adrenergic agonist effects and the ability to increase the lean muscle mass while decreasing fat accumulation (Cristino *et al.*, 2003; Ramos *et al.*, 2003), it is often illegally used for illicit profit in livestock industry to satisfy the current trends of consumer preferences for leaner meat (Buttery and Dawson, 1987). To act as a growth promoter, it may be added to feed in dosages 5-10 times higher than therapeutic levels (Pleadin *et al.*, 2010), and at 10-20 times its therapeutic respiratory dose rate, carcass composition can be improved (Ricks *et al.*, 1984). This kind of muscle-directed protein anabolic response has been found in cattle (Brambilla *et al.*, 2000), young lambs (Claeys *et al.*, 1989), broiler chickens (Dalrymple *et al.*, 1984), steers (Ricks *et al.*, 1984), rats (MacLennan and Edwards, 1989) and horses (Kearns *et al.*, 2001). This repartitioning of nutrients to improve the performance of meat-producing animals has had a profound effect in the meat industry.

β2-adrenergic agonist was introduced into human therapy in the 1970s, and used widely for bronchodilation (Gaillard *et al.*, 1997). Clenbuterol as a medication is approved for use in Europe in humans for asthma at a dose of 20-40 μg orally, twice daily (Lust *et al.*, 2011). Because of its ability to provide repartitioning effects, improve glucose homeostasis in humans with insulin resistance and diabetes (Castle and Yaspelkis, 2001), it is also suggested as a potential therapy to treat muscle wasting (Guldner and Klapproth, 2000) and as a potential anti-diabetic agent in humans (Castle and Yaspelkis, 2001). However, many β2-adrenergic agonists, including clenbuterol, have a low therapeutic index and are not generally used in humans (Montrade *et al.*, 1993).

Clenbuterol is sometimes ingested by bodybuilders to increase muscle protein deposition rate and enlarge muscle fibres (Lust *et al.*, 2011), because of its sympathomimetic, lipolytic, and anabolic effects (Chodorowski and Sein, 1997; Dumestre-Toulet *et al.*, 2002). Belgian body-building enthusiasts are reported to have used clenbuterol in addition to anabolic steroids frequently between 1988 and 1993 (Delbeke *et al.*, 1995). There are also people who use clenbuterol for its reported weight-loss effects (Daubert *et al.*, 2007).

Clenbuterol has a history of illegal use to enhance performance in weightlifting, racetrack, and other sports (Gaillard *et al.*, 1997; Kearns and McKeever, 2009). Many researchers are concerned about the performance-enhancing properties of such drugs (Palmer *et al.*, 1992; Wadler, 1994), and in particular its usage to win Olympic medals (Beckett, 1992). Clenbuterol is categorised as a class 3 agent by the Association of Racing Commissioners International, and a competitor would be disqualified whose biologic samples was identified to contain clenbuterol after a race (Robinson, 2000). Chinese swimmer Ouyang Kunpeng and American swimmer Hadi were both suspended in the trials of the Beijing Olympic Games because of positive drug tests for clenbuterol (http://tinyurl.com/n5bdgtp).

The accumulation of clenbuterol residues in meat products intended for human consumption (Posyniak *et al.*, 2003) is associated with a potential risk to consumer health (Smith, 2000). Brambilla *et al.* (2000) highlights the possibility of β-agonist poisoning through a ingestion of contaminated meat, as the complement of previous researches in which liver and kidney, but not muscle meat, was considered to contain pharmacologically active residue levels of clenbuterol as the result of clenbuterol doses used as growth promoters (usually 10-20 μg/kg per day orally) (Rose *et al.*, 1995; Sauer *et al.*, 1995). Outbreaks of food poisoning due to clenbuterol contamination have been described in Spain (Garay *et al.*, 1997; Martinez-Navarro, 1990), France (Pulce *et al.*, 1991), Italy (Brambilla *et al.*, 1997, 2000; Maistro *et al.*, 1995;), Portugal (Barbosa *et al.*, 2005; Ramos *et al.*, 2009) and China (Shiu and Chong, 2001), drawing much public concern. In some cases, people were seriously injured with myalgia, tachycardia, cephalalgia, nervousness, dizziness and skeletal muscle tremors (Hahnau and Jülicher, 1996; Salleras *et al.*, 1995).

Side effects of clenbuterol have also been described in animals, including decreased aerobic performance in mice, rats, and horses (Duncan *et al.*, 2000; Ingalls *et al.*, 1996) (Kearns and McKeever, 2002), and sudden cardiac death in rats (Bakker *et al.*, 1998).

In 1998, clenbuterol was approved by FDA as a component of a prescription-only drug, Ventipulmin8 Syrup, for treating horses with airway obstruction. Following with the approval were several controls to make sure that this drug would not be misused in animal-oriented food (FDA, 2002). Because of its potential adverse effect on humans and its long history of illegal use at racetracks, the FDA approval process met serious obstructions and lasted for nearly two decades (Jones, 1998).

Although approved for horse therapy, clenbuterol is banned from use in food-producing animals by FDA (Lust *et al.*, 2011), and prescribing, purchasing, or distributing 'compounded' clenbuterol is in violation of federal law (FDA, 2002). In the European Union (EU) clenbuterol, to be precise Ventipulmin, used to be approved as a medicine for use in humans for asthma (Lust *et al.*, 2011). In July 1997, being aware of possible clenbuterol abuses, the public representatives of European Economic Community voted on a law to ban the use of β-agonists as well as clenbuterol in animals destined for human consumption and to pursue unfair practice in animal production (Directive 96/22/EC; EC, 1996). The maximum residue level (MRL) of clenbuterol was established as 50 ng/l in milk (Directive 00/60/EC; EC, 2000). Although having a long history, clenbuterol as a growth promoter did not become widespread in Europe until the forbidden of the use of hormones in animal production by European Directive in 1988 (Directive 88/146/EC; EC, 1988).

In 1997, addition of clenbuterol to feeds was banned in China. Ironically, in China the mass use of clenbuterol was initially because of promotion by the government. Study and promotion of clenbuterol was a key topic of the seventh five-year plan of the Ministry of Agriculture (MOA). During that time, many leading agricultural universities in China invested a lot of manpower and resources to conduct clenbuterol research. Unfortunately, most of the researchers focused on the increase of lean meat proportion, while taking little notice of the potential residue problem (Shi, 2011).

Food safety problems brought by the clenbuterol abuse are particularly serious in China. This is because of the serious extent of illegal use, and that since certain organs, such as the liver, contain high concentrations of clenbuterol residues (Gaillard *et al.*, 1997), and the consumption of internal organs is more common in China than in western countries because of custom and religious reasons, the outbreak of clenbuterol-derived food poisoning incidents is much more frequent in China.

3. Questions and the challenges we are facing

A long series of well-publicised foodborne illnesses has made food safety a major global concern. Clenbuterol's ability to stimulate a muscle-directed protein anabolic response (Kearns *et al.*, 2001; Kuiper *et al.*, 1998) and create a greater proportion of muscle to fat (MacLennan and Edwards, 1989) has given rise to its widespread and illegal use in the meat animal production industry.

In the last decade, fierce competition in the meat production industry has further intensified the illegal use of clenbuterol. With the price inflation of food, water, electricity and logistics, the production costs of the meat industry have risen sharply. Under tight profit margins and the threat of bankruptcy, some farmers are pushed to take a risk to pursue illegal profit (Chen *et al.*, 2011).

The profit brought by clenbuterol is appealing. Pigs fed with clenbuterol can be sold at a price of 0.4 yuan higher per kilogram than for normal pork. To assume each pig as 100 kg, the additional profit brought by clenbuterol addition can be 40 yuan (about US$ 8) per pig. Typically, there are 100 pigs in a small farm, then the additional profit can reach 4,000 yuan, a considerable sum to a small farmer (Chen *et al.*, 2011).

With the temptation of handsome profits, the banning of clenbuterol proves to be very difficult. Although the use of clenbuterol to increase weight gain in food-producing animals has been prohibited by the health authorities in many countries (EC, 1996; Hahnau and Jülicher, 1996; Kuiper *et al.*, 1998; Li and Zhang, 2011), the incidence in meat animals still ranges from 0 to 7% (Brambilla *et al.*, 2000; Kuiper *et al.*, 1998), and it is the most illegally used β-agonist in cattle farming (Ramos *et al.*, 2009).

The existing problems in clenbuterol management are complicated and diverse. These problems are discussed in the next paragraphs.

Imperfect administration system

To establish a strict and complete management system for food safety supervision, as well as for clenbuterol control, China still has a long way to go. The current administration system in China is deficient, with relevant departments claiming responsibility only for their directly related functions, and announcing only directly related information. Without a unified network for risk communication, risk information obtained by each department cannot be shared effectively, leading to potential monitoring loopholes (Wang *et al.*, 2009).

Deficient food chemical residue standards

The present food chemical residue standards are deficient (Wang *et al.*, 2009). There exist legal gaps of clenbuterol detection in the slaughter links. According to the 'Animal Epidemic Prevention', the quarantine objective for animal and animal products is zoonosis and parasitosis, so clenbuterol is not included; according to the State Department 'Pig Slaughtering Regulations', the Commercial

Department is responsible for the quality inspection of the meat producing plant, but the current meat quality inspection procedures do not include the clenbuterol test. According to the Food Safety Law, the health departments are in charge of the health inspection and supervision of pig slaughter, but clenbuterol detection is outside the scope of health inspection and supervision.

Weak government capacity at local levels

In China, many food processors operate at local levels, while new regulations and dictates from Beijing are often ignored by local officials. On one hand, some local governments often lack sufficient resources and proper means to carry out directives and enforce safety regulations (Thompson and Hu, 2007). On the other hand, since rural food processing is encouraged by local authorities as an essential means to increase rural incomes and local employment, local officials are reluctant to close businesses even when they are in violation of regulations or standards. Last but not least, some local officials collude with local companies to hinder directives from higher-level authorities to enforce safety regulations. Corruption in China poses a particular challenge, as corruption sometimes extends from grass-roots cadres to the highest levels, such as the scandal in the State Food and Drug Administration (SFDA), which was reported by China Daily (2007) and caused great concern.

A lack of sound risk alert system

Only proactive measures can prevent a risk from turning into a real crisis, so the risk alert system is of great importance. Since a sound risk alert system has not been established in China, in most of the cases, the administrative departments start to take action only when the large-scale outbreaks of food poisoning incidents have already taken place, not being able to respond to potential food security threats (Wang *et al.*, 2009).

Weak safety awareness

In meat processing enterprises, food safety awareness of the people in charge is relatively weak, and the general level of food safety management is low (Wang *et al.*, 2009). In most cases, productivity and profit are emphasised, while quality and detection are neglected.

Decentralised manufacturing and distribution systems

The meat industry is not scaled-up, integrated and standardised (Editorial Department, 2011). Large numbers of small businesses are spread over all aspects of breeding, purchasing, slaughtering and marketing, making it hard to control the safety of meat products and control risk in the food chain. Also the distribution of meat, poultry and egg products is highly fragmented, with low market share in the transaction process, so the wholesale market is unable to play its full potential role in quality control.

Among the 21,000 meat producing plants in China, the three biggest enterprises, Shuanghui, Yurun and Jinluo share less than 5% of the total slaughter capacity, namely 30 million. While in the US, the top four pork processing plants account for over 50% of the total capacity, the top three pork processing plants in Netherlands account for 74% of the national processing capacity, and Denmark's biggest pork processing enterprise accounts for 8% of the total capacity.

Detection difficulties

The detection of clenbuterol faces the problems of high cost, heavy workload and low sampling ratio (Li and Zhang, 2011). For the Shuanghui Group, considering the cost of a clenbuterol test strip is 5-6 yuan, and the number of pigs in Shuanghui is about 1.2 million, if every pig was tested (assuming non-pooled samples) the test strip cost alone will reach 60-70 million (over US$ 1 million). Most companies are not able to afford the high cost of clenbuterol detection, leading to relatively low self-check rate compared with what is required (Li and Zhang, 2011). Besides, standards for clenbuterol detection are not uniform and effective, (Li and Zhang, 2011) further contributing to the difficulty of testing. For example, the urine test that is currently the most convenient clenbuterol test has been proved to be not so reliable. Discontinuing the treatment several days before the animal is slaughtered (the time at which urine is taken) is sufficient to produce a negative result in urine tests (Gaillard *et al.*, 1997).

Emerging alternatives turn out to be another hurdle to the control of contaminant residues. Since the use of clenbuterol has been limited and severely punished, some pharmacies provide the farmer with alternatives, such as ractopamine, salbutamol, terbutaline and cimaterol, for which effective detection methods have not been established, to evade the clenbuterol issue. Although these alternatives are undetectable in meat and liver, they may still cause food poisoning after ingestion of contaminated products, making a real challenge to the supervision and control of clenbuterol abuse.

4. Management

The food safety statute system in China is composed of laws, administrative regulations, and standards, with laws established by the National People's Congress and its standing committee, administrative regulations established by Local People's Congress and its standing committee or primary government unit, and standards established by the Standardization Administration of the People's Republic of China (Wang *et al.*, 2009).

The food safety law system in China comprises of 'Food Hygiene Law of the People's Republic of China', 'Product Quality Law of the People's Republic of China', 'Standardization Law of the People's Republic of China', 'Agriculture Law of the People's Republic of China' and 'Law of the People's Republic of China on Import and Export Commodity Inspection', with a number of administrative regulations including 'Special Regulations of the State Council on Strengthening Safety Supervision and Administration of Food and Other Products', 'Administrative Regulations of the People's Republic of China on Pesticides', 'Measures for the Hygiene Administration of Food Additives' and various food safety regulations of local governments (Wang *et al.*, 2009).

The supervision of food safety is controlled by the government, especially eight food safety relevant governmental ministries/departments: SFDA, MOA, the Ministry of Commerce (MOC), the Ministry of Health (MOH), the Administration for Industry and Commerce, the General Administration for Quality Supervision Inspection and Quarantine (AQSIQ), National Development and Reform Commission, and the Environment Protection Administration (Ren *et al.*, 2006).

These governmental ministries/departments are reinforced by relevant agencies. Among which, the Chinese Center for Disease Control undertakes a large amount of food inspection work. 10 reference laboratories and 63 approved laboratories for residue detection also proved to be great reinforcement to the inspection network of food safety (Wang *et al.*, 2009).

Frequent outbreaks of food poisoning incidents resulting from the residue of harmful chemicals in recent years impelled Chinese government to take a set of remedial measures. A series of chemical residue standards, certification, as well as management and monitoring system have been established in China to control the food safety risk, improve the food quality, rebuild consumer confidence and improve competition of export agricultural production (Song *et al.*, 2010).

The Chinese standards system for food is comprised of four levels of standards, including: national standards, industry standards, provincial standards, and corporate standards (Wang *et al.*, 2009). Among the standards, 28 examination method standards are for the detection of veterinary drugs. These standards, all of which achieve the MRL standards of the Codex Alimentarius Commission, Japan, and the EU (Yuan, 2006), provide the test methods for 18 species and 131 kinds of veterinary drugs and 7 kinds of biotoxins, providing technical support for the detection of over 786 kinds of chemical residue (Wang *et al.*, 2009).

Measures specially aimed at the control and management of clenbuterol abuse have been taken by the Chinese government. According to the Drug Administration Law and related regulations, production and sales of clenbuterol to non-medical institutions and individuals by any organisation or individual is forbidden. Prescribing, purchasing, or distributing clenbuterol is in violation of national law (Li and Zhang, 2011). In 1997, MOA seriously forbade the addition of clenbuterol to feeds. In 2001, MOA, the Ministry of Health and State Drug Administration issued together the 'Prohibited list of drugs to add to animal feeds and drinking water', clenbuterol as well as six other β-agonists. In 2004, MOA, the Ministry of Public Security, MOH, MOC, the State Economic and Trade Commission(SETC), the State Administration of Industry and Commerce (SAIC), AQSIQ and SFDA jointly issued a document to ban the use of forbidden additives in the breeding industry, enhancing the control of the clenbuterol abuse (Li and Zhang, 2011).

In October 2010, 'Views on further strengthening clenbuterol supervision' was issued by the Office of Central Institutional Organization Commission to further implement the division of responsibilities of the clenbuterol supervision department, improve the institutional mechanism, and to achieve the overall process monitoring coverage (The State Commission Office for Public Sector Reform, 2010).

In 2011, MOA, SETC, SAIC, AQSIQ and SFDA jointly issued a document to launch a nationwide movement to severely punish the illegal production, marketing and use of clenbuterol (Li and Zhang, 2011).

In 2011, Guangzhou Bureau of Agriculture, together with Bureau of Food Safety Office, Bureau of Industry and Commerce and Municipal Bureau for Public Security, carried out four continuous enforcement actions by spot check to ban the residues of clenbuterol in pigs. In these actions, 809 pigs were destroyed, arousing a strong reaction in society (http://tinyurl.com/mxqwrgv).

China is not short of food safety regulations, standards, certifications, and assurance systems, but many of them are just at initial stage in implementation and practice at both national and local level. Frequent food safety incidents generated by clenbuterol and other chemical residues hastened the application and promotion of relevant food safety assurance approaches throughout the nation.

The food traceability system (FTS) was described by the International Organization for Standardization (ISO, 1994) to have 'the ability to trace and follow a food, feed, food producing animal or ingredients, through all stages of production and distribution'. With considerable outbreaks of foodborne diseases, governments are urged to construct such a system to maintain the safety and quality of food.

The EU (Directive 02/178/EC; EC, 2002; Giraud and Halawany, 2006), USA (Pouliot and Sumner, 2008), Australia (MLA, 2004) and Japan (Nanseki, 2007) have all adopted FTS. The Chinese government is also promoting a series of food traceability programmes throughout the country (Ministry of Commerce of China, 2006), but is still facing the lack of mandatory uniform data standards and limited application across regions. Since pork accounts for 65% of Chinese meat consumption, taking up 50% of world production (National Bureau of Statistics of China, 2007), the establishment of FTS in the pork market is considered to be of special significance. Song *et al.* (2008) surveyed the development of traceability system in China and the attitudes of consumers toward it, finding that though 93% of consumers questioned considered FTS to be necessary, only 63% of them had confidence in it.

Good agricultural practices (GAP) is a collection of principles to maintain the safety and health of food from on-farm production to post-production processes. It encourages reduced use of agricultural chemicals and pharmaceuticals, environmental protection, animal welfare guarantee, as well as protection of worker health, safety and welfare. GAP is an effective way of reducing food safety risk in the upstream of the food supply chain, and is expected to be an effective measure to help control clenbuterol residue problem. It has been adopted by the Chinese government as a remedial measure to deal with food safety scares. The first good agricultural practice national standards in China (ChinaGAP), GB/T20014.1-11-2005, was based on the EUREPGAP, and proclaimed in 2005. Up to now, 24 ChinaGAP national standards and 603 ChinaGAP certifications have been established, covering 31 provinces, municipalities and autonomous regions, and including contents of combinable crops, fruit and vegetable, cattle and sheep, pig, poultry and aquaculture (Song *et al.*, 2010).

The application of GAP is expected to maintain food safety, increase profits and restore consumer confidence, but it still has some problems, such as the rise in final price of food products brought by the certification fee. Some consumers think the extra cost of food brought by GAP should be borne by the government.

5. Suggestions

Although former President Hu Jintao and Premier Wen Jiabao publicly and repeatedly pledged to solve food safety problems and improve food quality, the Chinese government is still facing many complex challenges. There is no shortcut to solve the current food safety issues, including the clenbuterol abuse problem. The Chinese government and food producing industry should be prepared to fight a protracted war aimed at progressive improvement.

Improve supervision and management system

The harsh reality of clenbuterol abuse and public health risk underlines the necessity of strengthening the legal system, reform of managerial system, and establishment of proper standards and technical code systems (Wang *et al.*, 2009; Pleadin *et al.*, 2010). Systematic monitoring and control of contaminant residues throughout the manufacture of animal-derived food, coordinated with a sound risk alert system and validated analytical methods of detection are of great necessity. Besides, the respective departments in the management system should work on their clearly defined functions and responsibilities, and on close cooperation with each other (Wang *et al.*, 2009).

Strengthen publicity, education and training

Veterinarians and farmers take great responsibility to control the use of clenbuterol. They should be aware that the unapproved clenbuterol products have not been shown to be safe, and may have potential hazards to the public. The government should take some measures to enhance veterinarians and farmers' capability by means of publicity, education and training, to make them more disciplined, responsible and professional. With lean meat usually considered to be healthier than fat meat, some consumers pursue lean meat blindly. This trend can be the real source of illegal use of clenbuterol in meat producing animals. Consumers should be guided to have a proper attitude towards meat products, and abandon their excessive enthusiasm for lean meat, then the meat market may resume its healthy operation (FDA, 2002).

Promote public supervision

The strength of public opinion should not be underestimated. Various forms of public supervision platform, such as a public oversight board, should be set up to maintain the exchange of food safety information, as well as exposure of illegal behavior of companies and individuals. The public supervision pathway can be a great support and complement to the legal supervision and government actions.

Standardisation and scale

There are about 240,000,000 small-scale farmers in China, many of them are not able to afford the fees of clenbuterol detection and certifications, which is the key hurdle to the systematic control of clenbuterol usage. To achieve the standardisation and scale in the meat producing industry, some cooperative models can be used to organise the farmers, such as 'company + small-scale farmers' or farmers' cooperative organisation. Once organised, the small-scale farmers can be better disciplined, and the overall management of meat industry can be more effective (Song *et al.*, 2010).

Maintain continuity and stability of policies

In China, due to special historical reasons and long-term impact of the planned economy, the government intervenes a lot in economic activities and market operation, and the policies alter frequently. Without continuity and stability of policies, companies are more likely to seek immediate interest, rather than pursuing relatively uncertain long-term interest (Editorial Department, 2011).

6. Conclusions

Clenbuterol has a long history of illegal use globally, and poses clear hazards to human health. In recent years, frequent outbreaks of food-poisoning scares caused by the consumption of clenbuterol containing food brought this traditional veterinary drug back to public concern. In China, where the abuse of clenbuterol is severe, the livestock industry was disgraced because of the 'Shuanghui' clenbuterol scandal. Since the meat products of 'Shuanghui' were found to contain clenbuterol, the pig industry in Henan province as well as in the whole country suffered a tremendous impact. Pork farms directly involved were on the verge of bankruptcy, and law-abiding pork farms also experienced a poor market. In some regions, price of pigs dropped by 0.9-1.0 RMB, with the fall in consumer trust (Li and Zhang, 2011). To recover from the current industry recession, Chinese livestock production needs special measures to deal with the clenbuterol problems. The Chinese government will indubitably play a critical role in management and supervision of clenbuterol abuse. Until now, a series of regulatory authorities, legal systems, monitoring networks and standards and regulations had been established in China, and intensified efforts and greater commitment have been shown by the Chinese government to handle the current tough reality. Without package solutions, the future challenges are not difficult to imagine. For China, the task is heavy and the road is long.

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References

Bakker, A.J., Head, S.I., Wareham, A.C. and Stephenson, D.G., 1998. Effect of clenbuterol on sarcoplasmic reticulum function in single skinned mammalian skeletal muscle fibers. American Journal of Physiology-Cell Physiology 274: C1718-C1726.

Barbosa, J., Cruz, C., Martins, J., Silva, J.M., Neves, C., Alves, C., Ramos, F. and Da Silveira, M.I.N., 2005. Food poisoning by clenbuterol in Portugal. Food Additives & Contaminants: Part A 22: 563-566.

Beckett, A.H., 1992. Clenbuterol and sport. The Lancet 340: 1165.

Beekley, M.D., Ideus, J.M., Brechue, W.F., Kearns, C.F. and McKeever, K.H., 2003. Chronic clenbuterol administration alters myosin heavy chain composition in Standardbred mares. The Veterinary Journal 165: 234-239.

Brambilla, G., Loizzo, A., Fontana, L., Strozzi, M., Guarino, A. and Soprano V., 1997. Food poisoning following consumption of clenbuterol-treated veal in Italy. The Journal of the American Medical Association 278: 635.

Brambilla, G., Cenci, T., Franconi, F., Galarini, R., Macrě, A., Rondoni, F., Strozzi, M. and Loizzo, A., 2000. Clinical and pharmacological profile in a clenbuterol epidemic poisoning of contaminated beef meat in Italy. Toxicology Letters 114: 47-53.

Buttery, P.J. and Dawson, J.M., 1987. The mode of action of beta-agonists as manipulators of carcass composition. In: Hanrahan, J.P. (ed.) Beta-agonists and their effects on animal growth and carcass quality. Elsevier, London, UK, pp. 29-43.

Castle, A. and Yaspelkis, B.B., 2001. Attenuation of insulin resistance by chronic β2-adrenergic agonist treatment: possible muscle specific contributions. Life Sciences 69: 599-611.

Chen, F., Liu, M. and Li, P., 2011. Difficulty of banning clenbuterol for ten years. Country Agriculture Farmers 4: 32-34.

China Daily, 2007. Former SFDA chief executed for corruption. China Daily, Beijing, China P.R. Available at: http://www.chinadaily.com.cn/china/2007-07/10/content_5424937.htm.

Chodorowski, Z. and Sein, A.J., 1997. Acute poisoning with clenbuterol – a case report. Przeglad Lekarski 54: 763-764.

Claeys, M.C., Mulvaney, D.R., McCarthy, F.D., Gore, M.T., Marple, D.N. and Sartin, J.L., 1989. Skeletal muscle protein synthesis and growth hormone secretion in young lambs treated with clenbuterol. Journal of Animal Science 67: 2245-2254.

Cristino, A., Ramos, F. and Da Silveira, M.I.N., 2003. Control of the illegal use of clenbuterol in bovine production. Journal of Pharmaceutical and Biomedical Analysis 32: 311-316.

Dalrymple, R.H., Baker, P.K., Gingher, P.E., Ingle, D.L., Pensack, J.M. and Ricks, C.A., 1984. A repartitioning agent to improve performance and carcass composition of broilers. Poultry Science 63: 2376-2383.

Daubert, G.P., Mabasa, V.H., Leung, V.W.Y. and Aaron, C., 2007. Acute clenbuterol overdose resulting in supraventricular tachycardia and atrial fibrillation. Journal of Medical Toxicology 3: 56-60.

Delbeke, F.T., Desmet, N. and Debackere, M., 1995. The abuse of doping agents in competing body builders in Flanders (1988-1993). International Journal of Sports Medicine 16: 66-70.

European Commission (EC), 1988. Directive 88/146/EC. Official Journal of the European Union L70: 16.

European Commission (EC), 1996. Directive 96/22/EC. Official Journal of the European Union L125: 3-9.

European Commission (EC), 2000. Directive 00/60/EC. Official Journal of the European Union L327: 1-73.

European Commission (EC), 2002. Directive 02/178/EC. European Parliament and Council, 2002. Official Journal of the European Union L31: 1-24.

Dumestre-Toulet, V., Cirimele, V., Ludes, B., Gromb, S. and Kintz, P., 2002. Hair analysis of seven bodybuilders for anabolic steroids, ephedrine and clenbuterol. Journal of Forensic Sciences 47: 211-214.

Duncan, N.D., Williams, D.A. and Lynch, G.S., 2000. Deleterious effects of chronic clenbuterol treatment on endurance and sprint exercise performance in rats. Clinical Science 98: 339-347.

Editorial Department, 2011. To see the predicament of Chinese meat processing enterprises from the 'lean events'. China Food Safety 4: 20-22.

Erichsen, D.F., Aviad, A.D., Schultz, R.H. and Kennedy, T.J., 1994. Clinical efficacy and safety of clenbuterol HCl when administered to effect in horses with chronic obstructive pulmonary disease (COPD). Equine Veterinary Journal 26: 331-336.

Ferraz, G.C., Teixeira-Neto, A.R., D'Angelis, F.H.F., Lacerda-Neto, J.C. and Queiroz-Neto, A., 2007. Effect of acute administration of clenbuterol on athletic performance in horses. Journal of Equine Veterinary Science 27: 446-449.

Food and Drug Administration (FDA), 1998. Freedom of information summary of NADA, 140-973. FDA, Silver Spring, MD, USA. Available at: http://tinyurl.com/olcbudb.

Food and Drug Administration (FDA), 2002. Illegal compounding of clenbuterol. FDA Veterinarian Newsletter 17: 2. Available at: http://www.fda.gov/AnimalVeterinary/NewsEvents/FDAVeterinarianNewsletter/ucm110396.htm.

Gaillard, Y., Balland, A., Doucet, F. and Pépin, G., 1997. Detection of illegal clenbuterol use in calves using hair analysis: Application in meat quality control. Journal of Chromatography B: Biomedical Sciences and Applications 703: 85-95.

Garay, J.B., Jiménez, J., Jiménez, M.L., Sebastian, M.V., Matesanz, J.P., Moreno, P.M. and Galiana, J.R., 1997. Intoxicación por clenbuterol: datos clínicos y analíticos de un brote epidémico en Mostóles, Madrid. Revista Clinica Espanoca 197: 92-95.

Giraud, G. and Halawany, R., 2006. Consumers perception of food traceability in Europe. In: the 98th EAAE Seminar Marketing Dynamics within the Global Trading System: New Perspectives, 29 June-2 July, 2006, Chania, Crete, Greece, pp. 1-9. Available at: http://ageconsearch.umn.edu/bitstream/10047/1/sp06gi04.pdf.

Guldner, N.W. and Klapproth, P., 2000. Clenbuterol-supported dynamic training of skeletal muscle ventricles against systemic load: a key for powerful circulatory assist? Circulation 101: 2213-2219.

Hahnau, S. and Jülicher, B., 1996. Evaluation of commercially available ELISA test kits for the detection of clenbuterol and other β2-agonists. Food Additives & Contaminants Part A 13: 259-274.

Ingalls, C.P., Barnes, W.S. and Smith, S.B., 1996. Interaction between clenbuterol and run training: effects on exercise performance and MLC isoform content. Journal of Applied Physiology 80: 795-801.

International Organization for Standardization (ISO), 1994. ISO standard 8402:1994. ISO, Geneva, Switzerland.

Jones, W.E., 1998. Clenbuterol approved by FDA. Journal of Equine Veterinary Science (USA) 18: 426-427.

Kallings, P., Ingvast Larsso, C., Persson, S. and Appelgren, L. 1991. Clenbuterol plasma concentrations after repeated oral administration and its effects on cardio-respiratory and blood lactate responses to exercise in healthy Standardbred horses. Journal of Veterinary Pharmacology and Therapeutics 14: 243-249.

Kearns, C.F. and McKeever, K.H., 2002. Clenbuterol diminishes aerobic performance in horses. Medicine & Science in Sports & Exercise 34: 1976-1985.

Kearns, C.F. and McKeever, K.H., 2009. Clenbuterol and the horse revisited. The Veterinary Journal 182: 384-391.

Kearns, C.F., McKeever, K.H., Malinowski, K., Struck, M.B. and Abe, T., 2001. Chronic administration of therapeutic levels of clenbuterol acts as a repartitioning agent. Journal of Applied Physiology 91: 2064-2070.

Kuiper, H.A., Noordam, M.Y., Van Dooren-Flipsen, M.M., Schilt, R. and Roos, A.H., 1998. Illegal use of beta-adrenergic agonists: European Community. Journal of Animal Science 76: 195-207.

Li, P. and Zhang X.J., 2011. Perspective on the Shuanghui 'lean events'. Outlook Weekly 14: 8-10.

Lust, E.B., Barthold, C., Malesker, M.A. and Wichman, T.O., 2011. Human health hazards of veterinary medications: information for emergency departments. The Journal of Emergency Medicine 40: 198-207.

MacLennan, P.A. and Edwards, R.H., 1989. Effects of clenbuterol and propranolol on muscle mass. Evidence that clenbuterol stimulates muscle beta-adrenoceptors to induce hypertrophy. Biochemical Journal 264: 573-579.

Maistro, S., Chiesa, E., Angeletti, R. and Brambilla, G., 1995. Beta blockers to prevent clenbuterol poisoning. The Lancet 346: 180.

Martinez-Navarro, J.F., 1990. Food poisoning related to consumption of illicit β-agonist in liver. The Lancet 336:1311.

Meat and Livestock Australia (MLA), 2004. Australia's system for livestock identification and traceability. MLA, North Sydney, Australia. Available at: http://www.mla.com.au/Meat-safety-and-traceability.

Ministry of Commerce of China, 2006. Report on the food safety in market. Ministry of Commerce of China, Beijing, China P.R. Available at: http://news.foodmate.net/2011/11/193911.html.

Montrade, M.P., Le Bizec, B., Monteau, F., Siliart, B. and Andre, F., 1993. Multi-residue analysis for β-agonistic drugs in urine of meat-producing animals by gas chromatography-mass spectrometry. Analytica Chimica Acta 275: 253-268.

Nanseki, T., 2007. A risk management system for agrochemical use: design, development and applications. CD-ROM of the 6th Biennial Conference of European Federation of IT in Agriculture and the World Congress on Computers in Agriculture.

Palmer, J., Shepherd, G.L., Cifelli, A.T., Myles, P.S. and Weeks, A.M., 1992. Muscling in on salbutamol. The Lancet 340: 1407.

Pleadin, J., Vulic, A., Persi, N. and Vahcic, N., 2010. Clenbuterol residues in pig muscle after repeat administration in a growth-promoting dose. Meat Science 86: 733-737.

Posyniak, A., Zmudzki, J. and Niedzielska, J., 2003. Screening procedures for clenbuterol residue determination in bovine urine and liver matrices using enzyme-linked immunosorbent assay and liquid chromatography. Analytica Chimica Acta 483: 61-67.

Pouliot, S. and Sumner, D.A., 2008. Traceability, liability and incentives for food safety and quality. American Journal of Agricultural Economics 90: 11-26.

Pulce, C., Lamaison, D., Keck, G., Bostvironnois, C., Nicolas, J. and Descotes, J., 1991. Collective human food poisonings by clenbuterol residues in veal liver. Veterinary and Human Toxicology 33: 480-481.

Ramos, F., Cristino, A., Carrola, P., Eloy, T., Silva, J.M., Castilho, M.C. and Noronha Da Silveira, M.I., 2003. Clenbuterol food poisoning diagnosis by gas chromatography-mass spectrometric serum analysis. Analytica Chimica Acta 483: 207-213.

Ramos, F., Baeta, M.L., Reis, J. and Silveira, M., 2009. Evaluation of the illegal use of clenbuterol in Portuguese cattle farms from drinking water, urine, hair and feed samples. Food Additives & Contaminants Part A 26: 814-820.

Ren, D.P., Pan, S.Y., Xue, S.J. and He, H., 2006. The perfection of food safety legal system in China. Food Science 5: 270-275.

Ricks, C.A., Dalrymple, R.H., Baker, P.K. and Ingle, D.L. 1984. Use of a β-agonist to alter fat and muscle deposition in steers. Journal of Animal Science 59: 1247-1255.

Robinson, N.E., 2000. Clenbuterol and the horse. Proceedings of the Annual Convention of the American Association of Equine Practitioners 46: 229-233.

Rose, M.D., Shearer, G. and Farrington, W.H.H., 1995. The effect of cooking on veterinary drug residues in food, I: clenbuterol. Food Additives & Contaminants Part A 12: 67-76.

Salleras, L., Dominguez, A., Mata, E., Taberner, J.L., Moro, I. and Salvà, P., 1995. Epidemiologic study of an outbreak of clenbuterol poisoning in Catalonia, Spain. Public Health Reports 110: 338-342.

Sasse, I.I.L. and Hajer, R., 1978. NAB 365, a β-2 receptor sympathomimetic agent: clinical experience in horses with lung disease. Journal of Veterinary Pharmacology and Therapeutics 1: 241-244.

Sauer, M.J., Pickett, R., Limer, S. and Dixon, S.N., 1995. Distribution and elimination of clenbuterol in tissues and fluids of calves following prolonged oral administration at a growth-promoting dose. Journal of Veterinary Pharmacology and Therapeutics 18: 81-86.

Shi, P., 2011. To see chaos in academic research from the 'lean events'. South Wind Window 9: 45-46.

Shiu, T.C. and Chong, Y.H., 2001. A cluster of clenbuterol poisoning associated with pork and pig offal in Hong Kong. Public Health Epidemiology Bulletin (Hong Kong) 10: 14-17.

Slocombe, R.F., Covelli, G. and Bayly, W.M. 1992. Respiratory mechanics of horses during stepwise treadmill exercise tests, and the effect of clenbuterol pretreatment on them. Australian Veterinary Journal 69: 221-225.

Smith, D.J., 2000. Total radioactive residues and clenbuterol residues in swine after dietary administration of [14C] clenbuterol for seven days and preslaughter withdrawal periods of zero, three, or seven days. Journal of Animal Science 78: 2903-2912.

Song, M., Liu, L.J., Wang, Z. and Nanseki, T., 2008. Consumers' attitudes to food traceability system in China: evidences from the pork market in Beijing. Journal of the Faculty of Agriculture, Kyushu University 53: 569-574.

Song, M., Gao, X.O., Liu, L.J. and Nanseki, T., 2010. Reducing food safety risk: experiences from the adoption of good agricultural practices in China. Journal of the Faculty of Agriculture, Kyushu University 55: 379-385.

The State Commission Office for Public Sector Reform, 2010. Suggestions on further strengthening the supervision of clenbuterol. The State Commission Office for Public Sector Reform, Beijing, China P.R. Available at: http://tinyurl.com/pqp5vax.

Thompson, D. and Hu, Y. 2007. Food safety in China: new strategies. Global Health Governance 1: 1-19.

Wadler, G.I., 1994. Drug use update. The Medical Clinics of North America 78: 439-455.

Wang, S., Zhu, H.P., Ge, Y. and Qiao, H., 2009. Current status and management of chemical residues in food and ingredients in China. Trends in Food Science & Technology 20: 425-434.

Wang, Z., Mao, Y. and Gale, F., 2008. Chinese consumer demand for food safety attributes in milk products. Food Policy 33: 27-36.

National Bureau of Statistics of China, 2007. China statistical yearbook. National Bureau of Statistics of China, Beijing, China P.R.

Yuan, Y.H., 2006. Status of food safety and measure of strengthen food safety supervision. Journal of Community Medicine 12: 54-57.