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Recent developments in the application of nuclear technology in agro-food quality and safety control in China

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ABSTRACT

Having effective control on quality and safety of Chinese agro-food is of global significance due to the massive volume of production and export. Because of the technical advantages, as well as advocation of peaceful use of such technique by international community, nuclear techniques have been widely applied in China for food control purpose. This paper reviewed the recent developments of nuclear technique applications for food traceability (stable isotope analysis on beef, wheat, lamb, tea) and authentication (stable isotope analysis on organic food, apicultural products, camellia oil, orange juice), food contaminant analysis (radio-immunoassay and stable-isotope dilution for drug residues and microbial toxins) and food quality assurance (gamma ray and electron beam irradiation) in China, specifically with an intense discussion upon the first application as the authors believe it will be the most promising nuclear based technique for food quality and safety control. In conclusion, current situation of application was outlined and defects of discussed technologies were identified for future development.

1. Introduction

China is the world's largest agricultural country in terms of agriculture's share in the country's GDP composition as well as agro-food production. And due to its unique culture, dietary habit and industrial development phase, majority of daily food consumption are fresh produced in agriculture. For a long period, top priority has been given by the government to increase the agricultural output and secure the food supply. Nuclear technologies have been introduced in agriculture in China since 1956 for this purpose originally. And after the research development plan was launched by the first national congress of nuclear agriculture in China in 1960, nuclear related technologies have been widely applied in many fields of agriculture, such as plant genetics and breeding, agro-product irradiation, soil and water management, plant nutrition and metabolism as well as insect pest control (SIT) (Wen & Wang, 2004). However, over the past decades, with the rapid globalization and the increasing complexity of trade in food, the food safety was facing more challenges. This is especially notable in developing countries like China where the economic development is booming, whereas the level of quality and safety of food lags behind the consumers' requirement. Consumers, particularly in China and the rest of the world importing Chinese agro-food products are currently showing special concerns on the control of quality and safety of food after notorious food scandals were exposed such as melamine in infant formula, adulterated organic meat products and so on. Driven by the huge demand on food quality and safety, nuclear technology has also been steered to be applied to meet the emerging need. Currently, major applications of such techniques for the purpose of food quality and safety control in China are stable isotope analysis for agro-food provenance verification as well as counterfeited products discrimination, irradiation for food quality control and radio-immunoassay and stable isotope dilution technique for determination of contaminants. In this paper, the authors illustrated the developments in above mentioned fields in China and also assessed the capability and potential of such techniques in the control of the quality and safety of agro-food for this country. This review is mainly based on

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published English and Chinese language articles, including some work published by authors of this paper. The Chinese language papers were selected from the CNKI (China National Knowledge Infrastructure) database. CNKI is the biggest Chinese literature database, including Chinese academic journal articles, doctoral and master's dissertations, conference articles and other types of documents. The English language papers were mainly selected from the ISI Web of Knowledge and Google Scholar.

2. Stable isotope analysis for agro-food provenance verification and authenticity discrimination

Traceability systems play a key role in assuring food quality and safety. The traceability system of agro-product and food is required to be established in accordance with the *Law on Quality and Safety of Agricultural Products* (2006) and the *Law on Food Safety* (2009) in China. Current food labelling system cannot always guarantee that the food is authentic, good quality and safe, and it becomes particularly vulnerable in the case of unconscious or deliberate misoperation (http://en.wikipedia.org/wiki/2008_United_States_salmonellosis_outbreak). Analytical techniques that enable the provenance of food to be determined provide an independent means of verifying "paper" traceability systems and also help to prove authenticity, to combat fraudulent practices, and to control adulteration, which are important issues for health, economic, religious or cultural reasons (Fragni, Trifirò, & Nucci, 2015; Kelly, Heaton, & Hoogewerff, 2005; Pillonel et al., 2003). Therefore, stable isotopic fingerprinting techniques have recently attracted attention and gradually become a reliable and useful tool for food traceability and authenticity discrimination in China due to the independent property of this technique built upon the natural isotopic signals that will not be interfered with intentional or unintentional man actions.

2.1. Verification of the geographical origin of food

Geographical origin is an important factor influencing consumer purchasing decisions for food (Liu, Guo, Wei, Shi, & Sun, ; Luo, et al., 2015; Pillonel et al., 2003; Trincherini, Baffi, Barbero, Pizzoglio, & Spalla, 2014). Stable isotopic fingerprinting technique provides a robust tool to determine the origin of food (Nietner, Haughey, Ogle, Fauhl-Hassek, & Elliott, 2014; Silva et al., 2014; Zhao et al., 2014). Generally, the isotopic compositions of plant materials reflect various factors such as isotopic compositions of source materials and their assimilation processes as well as growth environments (Luo et al., 2015). The principle behind is that the slight changes in some of these isotope fractionations (measurable changes in the ratio of the 'heavy' to 'light' isotope of a given element) are usually geographically specific. For instance, stable isotope ratios of hydrogen and oxygen are applicable to the characterization of geographical origin because they are strongly latitude dependent (Kelly et al., 2005). Other typical stable isotopes used for provenancing purpose are carbon and nitrogen, as their fractionations are to be influenced by agricultural practices and animal diet, and specialties of such information contains clues that lead to geographical origin of food (Kelly et al., 2005). When these isotopic signals are reflected somehow in the food under investigation, then the link between the food and the geographical location can be established. Although the technique is still in its early stage in China, a number of research papers have been published in recent years on tracing geographical origins of beef, lamb, wheat, and tea by analyzing stable isotopes and multi-elements combined with statistics, which demonstrated the unique merits of this technique.

2.1.1. Beef

Beef is one of the most important meat products for Chinese people and therefore its safety has become a major concern for responsible government agencies as well as ordinary consumers. In China, development of a traceability system for agro-products still lags behind the demands for beef even with the existing system mainly based on ear tags and life numbers and ultimately depends on paper records, which can be easily fabricated or mislabeled by illegal dealers (Zhao, Guo, et al., 2013; Zhao, Zhang, et al., 2013). Therefore, a reliable and scientific system to identify the beef geographic origin is urgently needed. For this purpose of research, variation in carbon and nitrogen stable isotope ratios has been investigated for the samples of different cattle tissues (defatted beef, crude fat and tail hair) and from different provinces(Jilin, Ningxia, Guizhou and Hebei) in China by Guo (Guo, Wei, Pan, & Li, 2010). The results implied that these three tissues responded to the diet in a similar pattern. From the data of discriminate analysis, $d^{13}C$ was a better indicator for tracing the origin of cattle than $d^{15}N$. Furthermore, correct classification rate could be improved to 85% by a combination of C and N stable isotope ratio, as compared to 73% and 47% of beef samples correctly classified by only C and N analysis, respectively. Later, based on the preliminary results found in the previous study, the same group of scientists has also explored further trying to prove the potential to verify the geographical origin of cattle by just looking at the stable isotope signals in cattle tail hair. In their study, the $d^{13}C$, $d^{15}N$ and $d^{2}H$ values in 167 cattle tail hair samples from 7 sampling sub-regions belonging to four beef production regions were measured by Isotope Ratio Mass Spectrometer (IRMS). Variance analysis and linear discriminant analysis (LDA) results showed that significant differences existed in $d^{13}C$, $d^{15}N$ and $d^{2}H$ values of tail hair among different sampling regions. An overall correct classification rate of 82.6% and cross-validation rate of 79.6% were obtained for the four beef production regions based on $d^{13}C$, $d^{15}N$ and $d^{2}H$ values, compared to 70.7% and 70.1% for the seven sampling sub-regions (Liu et al.). Later, Yan Zhao (Zhao, Guo, et al., 2013; Zhao, Zhang, et al., 2013) has combined the analysis of stable isotopes and multi-elements signals to trace the geographical origins of beef from four different provinces (Shandong, Heilongjiang, Yunnan and Tibet) in China. Chemometric results indicated that eight key variables, including $\delta^{13}C$, $\delta^{15}N$, Mg, K, Mn, Zn, Se and Zr, were identified as providing maximum discrimination between among samples and an overall correct classification rate of 100% and cross-validation rate of 100% has been obtained. This result indicated the accuracy of differentiation can be improved by multiple isotope composition and multi-element information method, which was in agreement with research findings in beef and other meat products internationally (Camin et al., 2007; Heaton, Kelly, Hoogewerff, & Woolfe, 2008; Horacek & Min, 2010; Kelly et al., 2005).

2.1.2. Wheat

China is a large wheat production country with an approximate yield of 122 million tons in 2013(FAO. FAOSTAT, vol. 2013. Food and Agriculture Organization of The United Nations. http://faostat3.fao.org/browse/Q/QC/E). Meanwhile, the import of wheat was also considerable reaching 3.42 million tons in 2012 (Luo et al., 2015). In this case, it is an imperative to develop a simple and fast analytical method that can verify the production origin to further monitor the quality variations and to distinguish inferior ones from those with premium quality. In order to develop such a tool to discriminate the geographical origin of wheat, Chinese scientists (Luo et al., 2015; Wu et al., 2015) investigated $d^{13}C$ and $d^{15}N$ values of wheat samples originated from different regions (Australia, Canada, USA, Jiangsu province of China and Shandong province of China) using the method of element analyzer–stable isotope ratio mass