GREEN MANUFACTURING TECHNOLOGY: A CHALLENGE AND OPPORTUNITY FOR THE MEAT INDUSTRY

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Abstract – This article reviewed the development of green chemistry and green manufacturing internationally. The risk of the hazardous chemicals like PAHs, HAAs, TFAs, nitrite, formaldehyde, oil oxydates and PM2.5 to human body and the environment produced by traditional meat processing technologies such as grilling, frying, smoking and boiling, was discussed here. In view of modern science and technology as well as the sustainable development of food industry, the concept of meat green manufacturing technology was defined and, the opportunity and challenges facing meat industry were summarized.

Key Words –green chemistry, hazardous chemicals, traditional meat processing technologies

I. INTRODUCTION OF GREEN CHEMISTRY

Chemistry could inevitably brought harms to human beings and environment despite its positive aspect of creating social wealth [1]. This severe reality compelled countries all over the world to seek sustainable development regarding environmental protection and human health. So far, many efforts had been made to minimize the negative impacts derived from chemistry or inappropriate use of chemicals.

The concept of "green chemistry" was initially proposed by American Chemistry Association (ACS) and was echoed by many other countries soon after. Anastas et al [2] gave the definition that *green chemistry is an approach to the synthesis, processing and use of chemicals that reduces risks to humans and environment.* So far, green chemistry and green engineering were highlighted by governments in USA, Germany, Australia, England, and other developed countries. Although green chemistry was mostly applied in chemical industries or manufacturing industries, it was really a challenge and opportunity for its application in food industry, especially in traditional meat products, which was often processed by frying, grilling, roasting, barbecuing, smoking and boiling under high temperatures.

II. HAZARDOUS SUBSTANCES IN TRADITIONAL MEAT PRODUCTS

Traditional meat products could be traced back to 3000 years ago, originated in ancient Babylon and China. Nowadays, a variety of meat products had been developed due to the differences of geographical environment, climate, economy, ethics, religion and dietary in different countries and regions. The most famous processing technology were frying, grilling, smoking and boiling, which confer the meat pleasant flavor, color and good texture, but on the other hand, generate hazardous chemicals that pose threats to both the environment and human health.

Polycyclic Aromatic Hydrocarbon (PAHs)

PAHs were a large group of diverse organic compounds that contain two or more fused aromatic rings. More than 100 PAHs had been characterized so far, some of which were shown to be mutagenic and carcinogenic. Food could be contaminated by PAHs through polluted soil, water and air, and the contamination often occurred in meat products due to pyrolysis of lipid when heated at high temperature above 200℃[3]. 3,4-benzopyrene (BaP) is the most typical one since it could cause lung cancer, skin cancer, gastric cancer. A study showed that Peking duck prepared by hung oven process could produce BaP and PAHs at 8.7 and 54.7μg/kg repectively [4]. Another study focused on various grilled meat revealed that total PAHs contents ranged from 6.3 to 238.8ng/g in poultry meat, 0.1 to 547.5 ng/g in red meat, and 6.6 to 249.7ng/g in seafood products [5]. The range of BaP content found in direct smoked meat products was 0.38-3.21μg/kg [6].

Trans Fatty Acids (TFAs)

After high temperature treatment of oils, the spatial configuration of the unsaturated fatty acids molecule changes, transfatty acids were formed [7]. A large number of epidemiological survey showed that TFA was one of the key factors leading to central obesity, type II diabetes mellitus and cardiovascular disease [8]. Therefore, special attention should be paid to the safety of hydrogenated of food and fried food. In addition, a large number of studies showed that repeated high temperature grease would produce more trans fats [9]. Wang et al [10] found that the amount of TFA reached 0.23mg/g after frying at 170℃; Chen et al [11] found the content of 9t12c C18:2 in chicken fillets changed from 0.71 to 1.76 mg/g when frying temperature changed from 150 ℃ to 250℃.

Heterocyclic Aromatic Amines (HAAs)

HAAs mainly formed via maillard reaction with the natural components such as creati(ni)ne, amino acids and sugars in muscle foods at high temperatures. Some of the HAAs were strongly carcinogenic, causing breast cancer, gastric cancer, colon cancer, lung tumor [12-13]. MeIQ and PhIP are identified as strong mutagenic and Trp-P-1, Trp-P-2, Glu-P-1, Glu-P-2, AaC,MeAaC, IQ, MeIQx and PhIP were characterized by strong cancerogenic properties against mammal cells. The generation of HAAs depended greatly on heating temperature and time as well as other factors including water activity, precursors, antioxidants. Szterk et al [14] discovered that the time of cold storage of raw meat before processing also affected the formation of HAAs, that is, the longer the raw meat was stored, the more HAAs was formed during grilling. They also showed that there was a strong correlation between the formation of HAAs and substrates of free purine bases, pyrimidine bases and their nucleosides [15]. Gibis et al [16] investigated the concentrations of HAAs in pan-frying bacon slices, with MeIQx ranging from 1.5-5.6ng/g, PhIP 0.1-2.6ng/g, Norharman 5.0-19.9ng/g and Harman 0.3-1.7ng/g. Yao et al [17] detected both IQ-type and non-IQ type HAAs in braised suace beef, the amount of which ranging from 4.33-27.15ng/g

Formaldehyde

Traditional smoked meat products were favored by people due to their smoky flavor. However, formaldehyde was inevitably absorbed on the surface of meat products during the smoking process. Epidemiologic studies had showed that formaldehyde causes nasopharyngeal cancer, leukemia and sinonasal cancer [18]. It also received great attention due to its recognized toxic activity associated with eyes and the upper respiratory tract [19-20]. The US Environmental Protection Agency (EPA) had established a maximum daily dose reference (RfD) of 0.2mg/kg body weight per day for formaldehyde. Zhu et al [21] optimized a procedure for formaldehyde detection and found the smoked meat products contained high formaldehyde concentrations up to 125mg/kg per weight.

Nitrites/Nitrates

Nitrates and nitrites were food additives for better color and flavor, longer shelf life and antioxidation [22]. Human consumption of food products that contain a high concentration of these chemicals might resulted in nausea and vomiting, dizziness, confusion, cyanosis, and methemoglo-binemia [23-24]. Additionally, nitritesand nitrates could be metabolized in the organism and produce nitrosamines, a potential carcinogenic compound. Recent study focuses on the nitrite substitute by use of vegetables, which naturally contained nitrite.

PM2.5

PM2.5 was air-borne particles with diameters no more than 2.5μm, containing large amount of toxic and harmful materials such as PAHs, HAAs, formaldehyde. It was characterized by long retaining time in the air and long transformation distance, which posed great threat to human health and the atmospheric environment. PM2.5 could be generated from traditional food processing. For example, frying of chicken generated 2440 ug/m^3 PM2.5, containing 56.25ng/m^3 BaP, 54.27-291.05ng/m^3 HAAs and 0.27mg/m^3 formaldehyde, while grilling of duck generated 1800 ug/m^3 [25].

III. MEAT GREEN MANUFACTURING

In 1996, the Society of Manufacturing Engineers proposed the concept of “Green Manufacturing”, also called “Manufacturing for Environment”, and published the development trend of it in 1998[26]. Since then, institutes of green manufacturing were established in many other developed countries, such as Canada, Japan, British[27-28]. However, moste studies focused on machinery building, electricity, textile, dyes, paper making, suicide [29]. Little attention had been attached to food industry. The problem of food safety was gaining increasing concern along with the development of society and technology as well as people’s pursuit of health. It was almost a common sense that 70%-90% of human cancer was caused by environmental factors, among which dietary factor could not be ignored. Hence, it was necessary to reform traditional food technology based on the principle of green chemistry and green engineering. Meat green manufacturing technology was defined as a modern manufacturing pattern that employ the concepts and principles of green chemistry and green engineering, turning high-quality raw meat into healthy meat products by green formula design, green processing, green packaging, green transport and green distribution so as to minimize the risks of hazardous chemicals to human body health and the environment, through which both economic and social benefits can be obtained and coordinated.

With use of the meat green manufacture, a series of healthy meat products had been developed below 120℃, by Professsor Peng and colleagues, such as fish, chicken, roasted duck, smoked pork and beef. Green manufactured meat products were characterized by attractive color, pleasant flavor and favorable texture, along with the remarkable decreased amounts of PHAs, HAAs, TFA, formaldehyde and PM2.5 in comparison with that produced by traditional processing.

IV. CONCLUSION

As the progress of society and economy and the rapid development of science and technology, the emerging discipline of food green chemistry would gain great popularity whether in theory or in practice. The demand of green manufacturing food products would be urgent along with the enhancement of public awareness in health and safety.

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