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Review

Ultrasound in the meat industry: General applications and decontamination efficiency

Fulya Turantaş [a,*,1], Gülden Başyiğit Kılıç [b], Birol Kılıç [c]

[a] Ege University, Ege Vocational School, Food Microbiology Dep., Bornova, İzmir, Turkey
[b] Mehmet Akif Ersoy University, Engineering-Architecture Faculty, Food Engineering Dep., Burdur, Turkey
[c] Süleyman Demirel University, Engineering Faculty, Food Engineering Dep., Isparta, Turkey

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ABSTRACT

This review summarizes the findings of research focused on ultrasound as a "green", nonchemical technology in the meat industry to improve meat quality and safety. An overview of the importance of the decontamination in meat processing and microbial inactivation using ultrasound combined with some other applications is provided along with results of high power ultrasound studies which have been applied and adapted in the meat industry. The research results revealed that ultrasound by itself or in combination with other processing and/or preservation methods has a potential for improving the general quality, marination and tenderness of meat, preventing microbial growth and recontamination in meat and meat products as well as for the determination of defects in carcasses and cleaning process equipment. This review will provide an interpretation of ultrasound applications, an up-to-date summary of published articles, and an overview of the microbial inactivation in meat and poultry and their products by ultrasound. Since there is a need for not only a pathogen-free product but also a quality product; this review also can be accepted as a report on the results of research in the field of meat quality improvements with ultrasound applications.

Contents

1. Introduction

Meat and poultry have traditionally been viewed as a vehicle for a significant proportion of human food-borne diseases. The related literature identifies microbiological hazards carried primarily by healthy animals as causing the majority of food-borne risks to human health, e.g. *Salmonella enteritidis*, *Campylobacter jejuni*, *Escherichia coli*, *Shigella*, *Cryptosporidium*, *Clostridium perfringens*, *Yersinia enterocolitica*, and *Listeria monocytogenes* (Aymerich et al., 2008; FDA/FSIS, 2003; Jutzi, 2004; Linscott, 2011; Lynch et al., 2009; Mor-Mur and Yuste, 2009; Venuto et al., 2010). The published Foodborne Diseases Active Surveillance Network (FoodNet) reports showed that these pathogens continue to be the leading causes of foodborne infections in the United States (Henao et al., 2010; Mccabe-Sellers and Beattie, 2004; Nyachuba, 2010). In spite of extensive food safety regulations and excellent monitoring systems on the food industry, one of the greatest challenges for authorities is the control of food-borne diseases. The number of foodborne outbreaks associated with eating meat and poultry products is still high and elicits intense consumer concern about meat safety (Aymerich et al., 2008; Newell et al., 2010). The continuation of meat-

* Corresponding author at: Ege University, Ege Vocational School, Food Microbiology Dep., 35100 Bornova, İzmir, Turkey. Tel.: +90 232 3112556.
[1] http://www.fulyaturantas.com.

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borne diseases of public health importance has also been well illustrated by human surveillance studies (CDC, 2011, 2013; EFSA, 2009).

Meat is a highly perishable food product and becomes hazardous due to microbial growth, however, microbial contamination is unavoidable under industrial processing conditions. The sources of contamination are usually untreated waste water, animal or human feces and poor hygienic working surfaces during processing. So, the manufacturing of meat and meat products can be a constant struggle to provide desirable quality characteristics and suppress or minimize the influence of undesirable microorganisms at different stages of the process. In addition, the hygienic and healthy production of meat and meat products does not only deal with the processing line in slaughter and meat plants, it also covers the prevention of microbial adhesion, physical removal and, destruction of microorganisms on meat during the production steps (Sofos, 2008, 2009; Sofos and Geornaras, 2010).

In the industry, decontamination has traditionally been achieved using some chemical and physical methods. Current decontamination technologies include animal cleaning, chemical dehairing at slaughter, carcass washing, spraying, or rinsing with some antimicrobials or with water of mild temperatures/pressures, or use of combinations of these technologies (Huffman, 2002). The decontamination process is a very critical step and the chosen method must be low-cost, have no adverse effects on the quality characteristics of the product, human health, and the environment. Moreover, most decontamination techniques result in a relative reduction, not elimination of pathogens, depending directly on the type and the extent of the initial contamination (Hugas and Tsigarida, 2008; Koutsoumanis et al., 2004; Thakur et al., 2000). For this purpose, the multiple hurdle concept is an integrated basic approach in food preservation and the hurdle technology is generally defined as using the simultaneous or the sequential application of factors and/or treatments affecting microbial growth. The principle of this concept can be explained as; two or more inhibition and inactivation methods at suboptimal levels are more effective than one (Leistner, 2000; Leistner and Gould, 2002; McClements, 1995). Therefore, the wash water decontamination process is accepted as an initial step of hurdle-food preservation steps in the food industry and, in this manner, the necessity for an effective washing decontamination process in the meat industry is incontestable. The microorganisms can be physically removed from the carcass by using properly applied washing and rinsing methods significantly reducing the microbial level and contributing to the effectiveness of other preservation methods that follow (Arce-Garcia et al., 2002; Guerrero et al., 2005; Hugas and Tsigarida, 2008; López-Malo et al., 2005). The washing process should not be considered as a substitute for those good hygienic manufacturing practices; it must absolutely be accepted as an additional measure, following the applications in the production steps of meat and meat products. Chemical decontamination of carcasses has been used in different countries for several years. Some of the most commonly used antimicrobial substances are chlorine, chlorine dioxide, acidified sodium chloride, trisodium phosphate, ozone, cetylpyridinium chloride and peroxyacetic acid (Hugas and Tsigarida, 2008; Oyarzabal et al., 2004; Oyarzabal, 2005). These chemicals have generally some disadvantages such as constituting a health hazard or ecological menace, reducing antimicrobial activity in the presence of organic matter, requiring special handling, storage and transportation (Loretz et al., 2010). Especially, chlorinated compounds are still the most widely used sanitizers in the food industry in these decontamination methods (Al-Zenki et al., 2012; Behrsing et al., 2000; Beuchat et al., 2004; Hua and Reckhow, 2007; Sapers, 2001). It is mentioned in various literature studies that excessive use of chlorine compounds can be harmful due to the formation of toxic chlorine by-products such as trihalomethanes, chloramines, haloketones, chloropicrins, and haloacetic acids (Akbaş and Ölmez, 2007; Cao et al., 2010; Cho et al., 2010; Gil et al., 2009; Hernandez et al., 2010; Ukuku and Fett, 2006; Ölmez and Kretzschmar, 2009). Thus, the use of chlorine and chlorinated compounds is forbidden in Europe (Issa-Zacharia et al., 2010; Ölmez and Kretzschmar, 2009; Rico et al., 2007) and there is an effort to eliminate chlorinated compounds from the decontamination and the disinfection steps (Cao et al., 2010; Ersus Bilek and Turantaş, 2013; Hernandez et al., 2010; Ölmez and Akbaş, 2009; Sillanpää et al., 2011). Therefore the current European Union legislation (Regulation-EC No. 853/2004) does not ban chemical decontamination of foods of animal origin, but approval is tied to strict prescriptions and can only be authorized after the European Food Safety Authority (EFSA) and European Commission (EC) have provided risk assessments (EFSA, 2009; Hugas and Tsigarida, 2008).

The food industry is constantly challenged to meet demands for healthy, safe, high quality, nutritious, and natural food products with an extended shelf-life. In addition, consumers have become particularly aware of health concerns regarding food chemicals and antimicrobial substances (Feng and Yang, 2011; Winter and Davis, 2006). Thus, novel and complementary food preservation technologies are continuously being investigated, particular attention has been paid to the physical methods and biopreservation to extend the shelf-life and inhibit undesirable microorganisms, minimizing the impact on the nutritional and organoleptic properties of food products. Therefore, these alternative and innovative food preservation technologies can provide new opportunities to develop consumer-driven integrated strategies for the development of healthy, safe and high quality foods.

One of these methods used to process foods is high power ultrasound (Arroyo et al., 2011; Barbosa-Cănovas et al., 2011; Bates and Patist, 2010; Ersus Bilek and Turantaş, 2013; Patist and Bates, 2010; Rastogi, 2010). Ultrasound is a form of energy generated by a sound pressure wave with a frequency greater (above 20 kHz) than the upper limit of the human hearing range. Based on frequency range, ultrasound is divided into two categories as low (low intensity) and high power energy (high-intensity) (Awad et al., 2012; Jayasooriya et al., 2004). High power ultrasound can be applied to a large number of industrial processing applications including food processing and food safety related areas. Especially in the last decade, some researchers have reviewed the potential of ultrasound, by itself or when combined with other methods for applications ranging from improving the quality criteria such as tenderness, modifying the functional properties of proteins, enhancement of shelf life, restructuring of meat products, reducing salt and increasing the cooking yield to determining carcass characteristics and meat composition as well as for inactivation of microorganisms in meat and meat products (Brewer, 2012; Carcel et al., 2007; Chanona-Pérez et al., 2010; Dikeman, 2013; Dolatowski and Twarda, 2004; Dolatowski et al., 2007; Fortin et al., 2003, 2004; Got et al., 1999; James and James, 2010; Mason et al., 2011; Mullen, 2002; Niñoles et al., 2007; Pathak et al., 2011; Reynolds et al., 1978; Salazar et al., 2010; Vimini et al., 1983; Warriss, 2000; Zhou et al., 2012). Although commercial applications of ultrasound have been used in some industries (chemical, cosmetic, textile, polymer, and petrochemical) it has recently started to be used in the food industry for items such as ketchup, mayonnaise, and fruit juice production (Patist and Bates, 2010; Soria and Villamiel, 2010). Therefore, it can be emphasized that ultrasound has been the subject of interest for the meat industry. However, very limited information is available on the effects of ultrasound on the quality characteristics of meats and on the pathogens in red meat and poultry (Condon et al., 2011; Haughton et al., 2012; Jiranek et al., 2008; Piyasena et al., 2003).

This study will summarize basic knowledge and current applications of ultrasound technology as an alternative and innovative method to other decontamination applications. In this review, simulation of the existing literature data was also accomplished for an estimation of a single ultrasonic application in wash water, and of an antimicrobial effect of this technology which can be adapted in the washing decontamination of meats. In addition, the use of ultrasound in meat processing for improving meat quality criteria such as tenderness, enhancement of marination, increasing cooking yield, and determination of meat composition and carcass characteristics will be pointed out.