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Review

Functionality of liquid smoke as an all-natural antimicrobial in food preservation

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ABSTRACT

The smoking of foods, especially meats, has been used as a preservation technique for centuries. Today, smoking methods often involve the use of wood smoke condensates, commonly known as liquid smoke. Liquid smoke is produced by condensing wood smoke created by the pyrolysis of sawdust or wood chips followed by removal of the carcinogenic polyaromatic hydrocarbons. The main products of wood pyrolysis are phenols, carbonyls and organic acids which are responsible for the flavor, color and antimicrobial properties of liquid smoke. Several common food-borne pathogens such as *Listeria monocytogenes*, *Salmonella*, pathogenic *Escherichia coli* and *Staphylococcus* have shown sensitivity to liquid smoke in vitro and in food systems. Therefore liquid smoke has potential for use as an all-natural antimicrobial in commercial applications where smoke flavor is desired. This review will cover the application and effectiveness of liquid smoke and fractions of liquid smoke as an all-natural food preservative. This review will be valuable for the industrial and research communities in the food science and technology areas.

Contents

1. Introduction

Traditional smoking of foods, especially meats, has been used as a preservation technique for centuries. Wood smoke, in addition to

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preserving food quality with its antioxidant and antimicrobial properties, also imparts a desirable color, flavor and aroma to smoked foods. Application of liquid smoke requires less time than traditional smoking, is more environmentally friendly, and eliminates potentially toxic compounds while still imparting the desired flavors and aromas of traditional smoking. Use of condensates or "liquid smoke" allows the processor to control the concentration of smoke being applied more readily than generating smoke by burning of wood (Suñen, Fernandez-Galian, & Aristimuño, 2001). Liquid smoke is traditionally applied to meat, fish and poultry and it has also been used to impart flavor to non-meat items such as cheese, tofu and even pet food. Because the smoke flavor is concentrated, application of liquid smoke is best suited for use in marinades, sauces or brines or topically to processed meat items such as hot dogs, sausage, ham and bacon (Rozum, 2009).

According to an annual poll conducted by The Center for Food Integrity consumers have less confidence in the safety and quality of the food supply and are demanding more all-natural and minimally processed foods with less synthetic chemical additives (Andrews, 2012). Consumers also have increased interest in organic foods because they believe they are healthier, better tasting, or fresher than conventional products (Wier & Calverley, 2002). However, although free of synthetic chemicals, organic and all-natural foods are not exempt from bacterial contamination and may require the addition of an all-natural antimicrobial to insure their safety. All-natural antimicrobials including those derived from plants, animals and bacteria have been shown to be effective in increasing the safety of food products by destroying or limiting the growth of bacterial pathogens. Several reviews have been written on all-natural antimicrobials from bacterial, plant and animal origin (Davidson, Critzer, & Taylor, 2013; Juneja, Dwivedi, & Yan, 2012; Rai & Chikindas, 2011), as well as their use in organic poultry and meat production (Ricke, Van Loo, Johnson, & O'Bryan, 2012; Sirsat, Muthaiyan, & Ricke, 2009). However, these reviews contain little or no information on the use of liquid smoke as an effective all-natural antimicrobial. The review by Holley and Patel (2005) provides a nice overview on the use of liquid smoke as well as its antimicrobial properties in food systems, especially in fish. This review builds on the information presented in Holley and Patel (2005) as well as provides a more detailed and up to date discussion on the effectiveness of liquid smoke as an all-natural preservative in food products. We will examine the effectiveness of liquid smoke, including ranges of microbial susceptibility and factors affecting antimicrobial action and discuss currently understood mechanisms of action.

2. Generation of liquid smoke from wood pyrolysis

Liquid smoke is produced by condensing wood smoke created by the controlled, minimal oxygen pyrolysis of sawdust or wood chips. The wood is placed in large retorts where intense heat is applied, causing the wood to smolder (not burn), releasing the gases seen in ordinary smoke. These gases are quickly chilled in condensers, which liquefies the smoke. The liquid smoke is then forced through refining vats, and then filtered to remove toxic and carcinogenic impurities. Finally, the liquid is aged for mellowness. Fig. 1 shows a schematic of a typical liquid smoke production facility. Factors influencing the flavor and antimicrobial properties of liquid smoke include the temperature of smoke generation, moisture content of the wood as well as the type of wood used to generate the smoke (Simko, 2005). Common woods include hickory and mesquite, but liquid smoke has also been prepared from rice hulls (Kim et al., 2011, 2012), coconut shells (Zuraida, Sukarno, & Budijanto, 2011) and pecan shells (Van Loo, Babu, Crandall, & Ricke, 2012). In general, woods used to generate liquid smoke are roughly comprised of 25% hemicellulose, 50% cellulose, and 25% lignins (Simko, 2005). See Table 1 for information about composition of specific woods. Pyrolysis occurs in four stages starting with water evaporation, followed by decomposition of hemicelluloses, cellulose decomposition and finally decomposition of lignins. Pyrolysis of hemicellulose and cellulose occurs between 180 °C and 350 °C and produces carboxylic acids and carbonyl compounds while lignins are pyrolyzed between 300 °C and 500 °C and generate phenols (Ramakrishnan & Moeller, 2002; Simko, 2005). Smoke flavor compounds, including phenols, are responsible for the smoke flavor and smoky aroma while carbonyl compounds impart a sweet aroma and color to smoked meat products.

In addition to carbonyls, acids, and phenols, pyrolysis of wood often generates unfavorable compounds such as polycyclic aromatic hydrocarbons (PAH). Polycyclic aromatic hydrocarbons are families of compounds, some which are naturally occurring, others are the result of incomplete burning and are typically formed at pyrolysis temperatures between 500 °C and 900 °C (Simko, 2005). The level of PAH formation is also influenced by the wood source (Guillén, Sopelana, & Partearroyo, 2000). Some PAH compounds such as benzo(a)pyrene (B(a)P), have

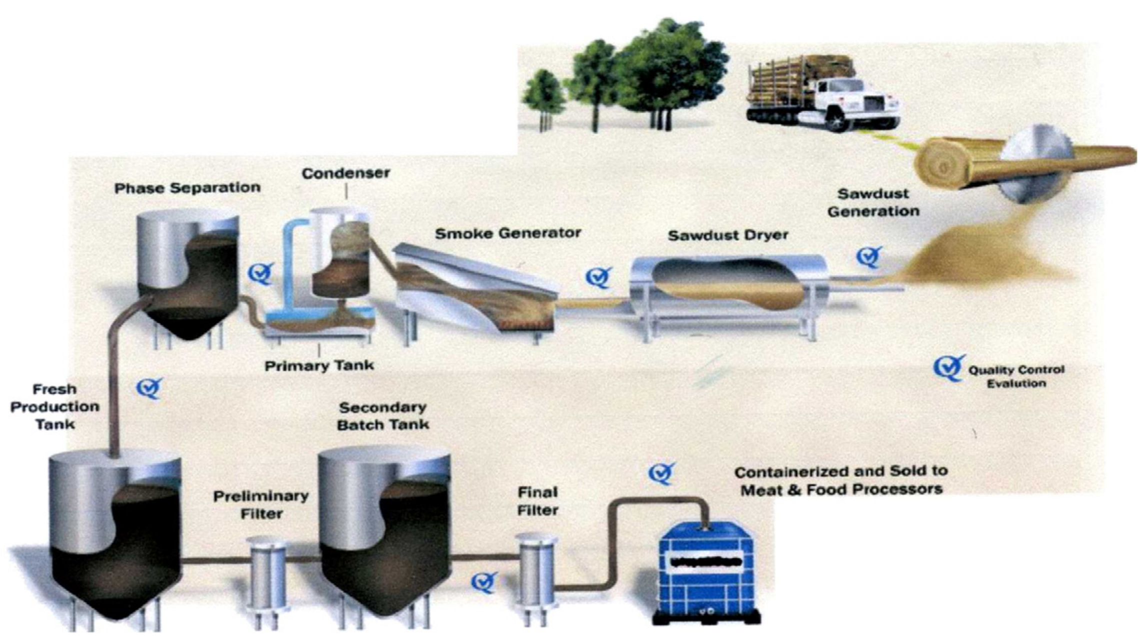

Fig. 1. Flow diagram of typical liquid smoke production.