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Decontamination of food products with superheated steam

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Abstract

Food products can often be contaminated with mycotoxins and spores, many of which are resistant to heat. To ensure the safety of our food supply they must be reduced or eliminated from the final product through processing procedures. The effects of superheated steam (SS) as a processing medium on grains contaminated with the Fusarium mycotoxin deoxynivalenol (DON) and with *Geobacillus stearothermophilus* spores are presented here. The processing temperature was between 110 and 185 °C with three steam velocities of 0.65, 1.3 and 1.5 m/s for DON contaminated wheat and between 105 and 175 °C at one steam velocity of 0.35 m/s for mixture of sand and spores. Reductions in DON concentration of up to 52% were achieved at 185 °C and 6 min processing time. This was due only to thermal degradation and not to solubilization and extraction. The effect of processing with SS on heat resistant spores was conducted for processing times of 0.5–480 min. The thermal resistance constant for *G. stearothermophilus* was determined to be 28.4 °C for the SS processing temperature of 130–175 °C. The first 5 min of SS processing were most effective in the reduction of spores. The use of SS has proven itself to be beneficial by reducing the contamination in foods in addition to any drying that may occur.

Keywords: Superheated steam; Processing; Drying; Oat groat; Wheat; Quality; Mycotoxins; Deoxynivalenol; *Geobacillus stearothermophilus* spores

1. Introduction

Superheated steam (SS) is steam that has been given additional sensible heat to raise its temperature above the saturation point at a given pressure. Unlike saturated steam, a drop in temperature will not result in condensation of the steam as long as the temperature is still greater than the saturation temperature at the processing pressure. Superheated steam provides advantages over air processing mediums including, increased heat transfer that may improve thermal degradation, an oxygen free environment, accelerated drying rate, and improved energy efficiency. In addition, the use of SS as a processing medium can reduce or eliminate microbial load on foods, can solubilise and extract contaminants such as spores, mycotoxins, and odors in addition to thermal degradation. Disadvantages of the SS processing technique include: high capital cost, complexity of the equipment, and high temperature of processed products (important when processing temperature-sensitive products). A number of products have processed with SS including: Asian noodles (Markowski, Cenkowski, Hatcher, Dexter, & Edwards, 2003), brewers' spent grain and distillers' spent grain (DSG) (Tang, Cenkowski, & Izydorczyk, 2005), sugar-beet pulp (Tang, Cenkowski, & Muir, 2000), potato (Tang & Cenkowski, 2000), potato chips (Caixeta, Moreira, & Castell-Perez, 2002), lumber (Woods, Husain, & Mujumdar, 1994), wood pulp and paper (Douglas, 1994), coal (Potter & Beeby, 1994), and sludge (Franics & Di Bella, 1996).

Experiments on drying DSG in SS showed major nutrient levels were not significantly affected by increased SS medium temperature and processing time although starch content was reduced in dried samples (Pronyk, Cenkowski, & Muir, 2004).

The rising cost of gasoline reached a point in North America that the cost of production of fuel from ethanol became feasible. Alcohol production concentrates the protein, fat, and fiber from the grain in the DSG but has the

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drawback of also concentrating any toxins from fungal growth, including mycotoxins from *Fusarium* species. *Fusarium* proliferates in the field during wet growing conditions and may cause yield reductions resulting from small and undeveloped kernels and can also produce mycotoxins, such as deoxynivalenol (DON) a trichothecene mycotoxin produced by *Fusarium graminearum*. When *Fusarium*-infected grain is used to produce alcohol, the level of DON can increase by roughly two fold in the dried DSG (Bennett & Richard, 1996; CAST, 2003). Canadian guidelines for DON levels are 5 ppm on a dry matter basis for total feed intake for beef cattle, sheep, and poultry but only 1 ppm for swine, dairy cattle, and horses (Manness, Nicholson, & Nicolaou, 2002). If grain with high levels of DON is utilized in the production of ethanol, and the DSG is used as animal feed, then a method for reducing DON levels must be employed before or after fermentation is complete.

It has been shown that *Fusarium* mycotoxins are stable during most processing operations including fermentation (Bennett & Richard, 1996), although it does not affect the process even at concentrations approaching 20 ppm (Whitehead & Flannigan, 1989). Several methods have been investigated to reduce levels of DON in grain and products manufactured from contaminated grain including: physical methods such as milling or sieving (Hart & Braselton, 1983; Lee et al., 1987; Nowicki, Gaba, Dexter, Matsuo, & Clear, 1988; Seitz & Betchtel, 1985; Young, Fulcher, Hayhoe, Scott, & Dexter, 1984); washing or soaking (Accerbi, Rinaldi, & Ng, 1999; Trenholm, Charmley, Prelusky, & Warner, 1992); by the use of chemicals (Accerbi et al., 1999; Lauren & Smith, 2001; Wolf & Bullerman, 1998); or by thermal treatment in hot air above 140 °C (Yumbe-Guevara, Imoto, & Yoshizawa, 2003). These methods have provided varying levels of success, none of which are truly satisfactory for reducing DON levels.

Geobacillus stearothermophilus (former *Bacillus stearothermophilus*) is a Gram-positive, thermophilic, spore-forming bacterium often present on or within plant food products. The spores of this bacterium are very heat resistant and usually survive canning and sterilization operations, where saturated steam (moist heat) is used. Flat-sour spoilage of properly processed low acid canned foods may occur if the products are stored at elevated temperatures (Ng & Schaffner, 1997). The spores of *G. stearothermophilus* are used as a biological indicator to validate moist heat sterilization because of their exceptional resistance to this type of heat (Brown, 1994; Carlberg, 2005; Spicher, Peters, & Borchers, 1999).

The thermal resistance of spores depends on the type of heat used. Two forms of heat (moist and dry) are continually used to reduce microbial load during decontamination or sterilization processes. Moist heat usually refers to saturated steam and dry heat usually refers to hot air. Moist heat is much more efficient in elimination of microorganisms than dry heat (Carlberg, 2005).

There is a limited amount of data published on the effect of superheated steam processing on heat resistant *G. stearothermophilus* spores. Spicher et al. (1999) observed that the spores of *G. stearothermophilus* NCIB 8923 were 4.1 times more resistant to superheated steam than they were to saturated steam. Collier and Townsend (1956) also compared spores of three bacterial species (including *G. stearothermophilus* 1518 spores) resistance to superheated and saturated steam. They found that the spores' resistance was higher in the case of superheated steam treatment than it was in the case of saturated steam treatment.

The objectives of this research were: (i) to investigate the application of SS to reduce the level of DON from *Fusarium*-infected wheat; and (ii) to determine the thermal resistance of *G. stearothermophilus* spores treated with SS.

2. Materials and methods

Naturally contaminated *Fusarium*-infected Hard Red Spring wheat with an initial DON concentration of 15.8 ± 1.5 ppm was obtained at a Manitoba farm from the 2003 crop year. The initial moisture content was determined to be 6.6% wet mass basis (wb) (ASAE, 2002). To obtain a representative sample for processing, the initial 7 kg sample was reduced by coning and quartering until the sample was small enough to fit in a seed splitter (Burrows Equipment Company, Evanston, IL, USA). Coning and quartering was repeated until the sample size reached approximately 1 kg and was able to pass through a seed splitter. Samples were divided until a representative 4.5–8.5 g sample was obtained for SS steam processing.

2.1. Superheated steam processing conditions

Samples were dried in a single layer in a SS processing system developed in the Department of Biosystems Engineering at the University of Manitoba, Canada (Pronyk et al., 2004) (Fig. 1). Saturated steam was generated by

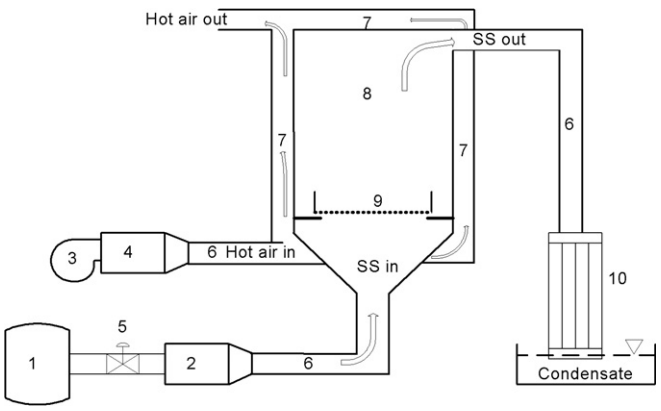

Fig. 1. Schematic diagram of the superheated steam (SS) processing system: (1) steam generator; (2) superheater; (3) fan; (4) air heating chamber; (5) steam flow control valve; (6) SS or hot air conveying pipes; (7) Hot air jacket; (8) SS processing chamber; (9) sample tray; (10) condenser.