Internet Journal of Food Safety, Vol.13, 2011, p.339-341

Water Chemistry and Antimicrobial Treatment in Poultry Processing

Ronald Alan Holser[1]*

[1]*Russell Research Center, United States Department of Agriculture, Athens, GA USA*

Abstract

This study examined the influence of calcium and magnesium ions in process water on the solubility of trisodium phosphate. Water used in poultry processing operations may be treated with sanitizers such as trisodium phosphate to reduce microbial activity and the risk of contamination. This occurs when process water directly contacts bird carcasses, e. g., chilling or washing. The interactions between hard water ions and trisodium phosphate were evaluated with the speciation program Visual Minteq. Saturation index values were calculated for process water containing 0, 0.09, 0.18, or 0.9 mmol/kg calcium (0, 10, 20, 100 ppm) and the equivalent amount of magnesium at treatment levels of 0, 1, 5, or 10 wt% trisodium phosphate. The results showed the formation of phosphates and hydroxides in the presence of trisodium phosphate. The formation of calcium phosphate decreased with increasing temperature while magnesium hydroxide showed the opposite behavior between 0℃ and 60℃. The conversion of trisodium phosphate to calcium or magnesium phosphate with subsequent precipitation would reduce the concentration of sanitizer in the process water.

Key words: antimicrobial, chiller, process water, sanitizer, trisodium phosphate

Introduction

Poultry processing facilities require large volumes of water to prepare poultry products for the marketplace. The quantity of process water used has a direct impact on the environment and on operating costs (Yang et al., 2001). In addition to the amount of water used in poultry processing the composition of the water also has an impact on product quality and safety. Bird washing and chilling operations are two process operations that require the largest volumes of process water and may be influenced by process water chemistry. Recent studies reported that process water containing 200 ppm total calcium and magnesium ions was less effective in the removal of bacteria from poultry skin which has implications for poultry washing operations (Hinton and Holser, 2009). This is a significant result because the removal of bacteria is essential to maintain product quality and safety (Hinton and Ingram, 2005; Hinton and Cason, 2008). Immersion chilling also requires the direct contact of process water with the bird carcass in order to reduce its temperature and thereby inhibit bacterial growth. The risk of contamination of the chiller water exists due to bacteria from one carcass inoculating the water and spreading to other carcasses. The detailed mechanism of this cross-contamination was investigated and attributed to transfer of organic material from the carcasses and the bacteria that are trapped within fluid films on surfaces and in crevices (Thomas and McMeekin, 1980; Kim et al., 1996). In the United States chemical sanitizers such as chlorine are approved for use as antimicrobial treatments and shown to effectively reduce the number of microbes when used above 30 ppm (Tsai et al., 1995; Tamblyn et al., 1997). However, earlier studies also recognized that the amount of chlorine needed was dependent on the composition of the water due to reaction with organic material (Mead and Thomas, 1973; Morrison and Fleet, 1985; Lillard, 1989; Tsai et al., 1992).

The present study was undertaken to examine the behavior of dissolved minerals that occur in process water, particularly the hard water ions of calcium and magnesium, and characterize their interaction with the chemical sanitizer trisodium phosphate commonly used to treat process water. The results of this investigation may be used to improve process efficiency in poultry processing facilities and develop more effective process water management strategies.

Material and Methods

Saturation index values were calculated for process water containing 0, 0.09, 0.18, or 0.9 mmol/kg calcium (0, 10, 20,

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*Corresponding author. Mailing address: USDA-ARS-RRC, 950 College Station Road, Athens, GA 30605 USA, Tel: +1 706 546 3520, Fax: +1 706 546 3607, E-mail: Ronald.Holser@ars.usda.gov

100 ppm) and the equivalent amount of magnesium at treatment levels of 0, 1, 5, or 10 wt% trisodium phosphate. The pH was calculated from mass and charge balances. No excluded species were defined. Calculations were performed using the computer program Visual Minteq 3.0 (J.P. Gustafsson, Department of Land and Water Resources Engineering, Stockholm, Sweden). The program ran under the Windows XP operating system and typically converged to a solution with 20 iterations.

Results and Discussion

An aqueous solution of trisodium phosphate in the presence of calcium and magnesium ions may form several phosphate and hydroxide compounds. The most common compounds include Ca3(PO4)2 , Ca5(PO4)3OH, Mg3(PO4), and Mg(OH)2. The solubility of these compounds varies with temperature and as the solution becomes saturated the dissolved species may precipitate as solids. Process water that contains a high concentration of calcium and magnesium ions is more susceptible to the formation of solid precipitates or scale. In a processing facility this may be addressed by treating the water to remove the dissolved ions and prevent the formation of scale or by accepting the formation of scale and mechanically removing it as part of routine maintenance.

Figure 1 displays saturation index values for water containing 0.9 mmol/kg Ca++ and Mg++ treated with 10 wt% trisodium phosphate. This represents the extreme case of high sanitizer concentration in very hard water. These results clearly show the influence of temperature on saturation index value. For example, the calcium phosphate compounds hydroxyapatite or Ca5(PO4)3OH and β-Ca3(PO4)2 exhibit the highest saturation index values at the lowest temperatures. Precipitation of these compounds is most likely to be problematic at the low temperatures associated with chiller operation. This trend is also observed with Mg3(PO4). In contrast, brucite or Mg(OH)2 and Ca3(PO4)2 (amorphous) exhibit the opposite behavior and occur at higher temperatures. Similar results were obtained for the other conditions examined. Figure 2 presents saturation index values calculated for process water with 0.09 mmol/kg of each ion at 1 wt% and 10 wt% sanitizer.

Hard water ions are known to reduce the efficiency of liquid cleansers by forming insoluble salts which removes the cleanser from the soluble phase (Kovach, 2007). In a similar manner the interaction between process water minerals and a sanitizer such as trisodium phosphate forms precipitates that reduce its concentration and the desired antimicrobial activity. In the poultry processing facility this poses a risk of increased contamination and decreased product quality. Integrating results of these solubility calculations on the process water supply with data collected by commercial processing facilities for environmental regulatory compliance would promote the development of a comprehensive process water management strategy.

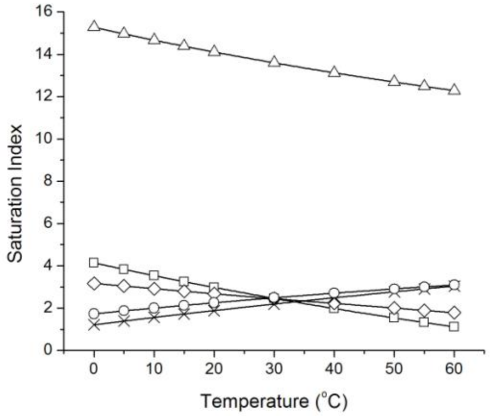

Figure 1. Saturation index values of process water containing 0.9 mmol/kg (100 ppm) of calcium and magnesium ions treated with 10 wt% trisodium phosphate. Δ, Ca5(PO4)3OH; x, amorphous Ca3(PO4)2; □, β-Ca3(PO4)2; ○, Mg(OH)2; ◊, Mg3(PO4)2.

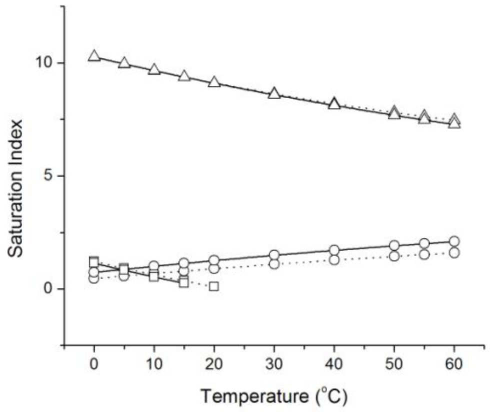

Figure 2. Saturation index values of process water containing 0.09 mmol/kg (10 ppm) of calcium and magnesium ions treated with 1 wt% trisodium phosphate (dash lines) or 10 wt% trisodium phosphate (solid lines). Δ, Ca5(PO4)3OH; □, β-Ca3(PO4)2; ○, Mg(OH)2.

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