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Review

Water reconditioning and reuse in the food processing industry: Current situation and challenges

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ABSTRACT

Background: While the demand for food and water is growing, water shortages are already occurring in many of the world's major food production areas. Irrigation is unarguably the most water demanding operation among the food supply chain, however, efforts from different sectors will collectively secure food for the world's population. Food processing is a key component of the food supply chain and its water footprint is of great consideration, not only because of the high-quality water used in the manufacturing of products but also for the significant volumes of pollutant wastewater generated. Different food sectors produce wastewater of different qualities, but for all cases water reconditioning and reuse offer opportunities to reduce water consumption and to contribute to a better water management in the food processing industry.

Scope and approach: The factors converging to implement such initiatives including, regulations in place, available technologies, food safety considerations, risk perceptions, water quality, environmental impacts and research needs are discussed herein. The goal of this review paper was to bring to the forefront of the debate the challenges and opportunities that water conservation initiatives offer, in order to produce more food with less water.

Key findings: Water reconditioning and reuse are technologically-feasible alternatives for the food processing industry to incorporate better water management and sustainability in food processing operations that are lacking. Successful implementation of conservation strategies is associated with the holistic evaluation of the intervention, providing information related to cost, risk, and environmental performance.

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1. Introduction

A renewable resource is defined as an element that after exploitation, can return to its previous stock level by natural processes of growth or replenishment (OECD, 2001). Water used to be considered a renewable natural resource, but that assumption is not adequate anymore within the reality the world is facing today. Water scarcity is already limiting the economic growth of China and India and the current serious drought in California forced the state to limit its agricultural water withdrawals (Morrison, Morikawa, Murphy & Schulte, 2009). But, why is water becoming scarce in the first place? Climate change is a significant contributor, however, population growth and economic development play an important role as well by increasing domestic water demand and driving dietary shifts into higher animal protein consumption.

A meat-based diet has a larger water footprint (36% larger) than a vegetarian diet (Hoekstra, 2012). For example, the volume of 29, 31, 112 L of water are required to produce 1 g of animal protein from egg, milk, and meat, respectively; while for the production of 1 g of cereal protein, 21 L of water are used (Mekonnen & Hoekstra, 2010). Due to the imminent changes in population and eating preferences, FAO projections indicate that between 2000 and 2050, global meat and milk production should increase by 102% and 82%, respectively (Boland et al., 2013), which indicate a higher demand in the water use to meet the increasing need for agricultural commodities.

The challenge of feeding a growing population is clearly defined. The question is, how can food production reach those levels with limited water, an essential component in agriculture and food processing? Water reconditioning and recycling, in all sectors of the food supply chain, offer potential opportunities to overcome this

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challenge. Nevertheless, the food industry, especially at the food processing stage, is highly sensitive to this concept due to the negative non-science based perceptions about the characteristics of this water and potential risks for contamination (Casani, Rouhany, & Knøchel, 2005). If more scientific information can be made available, this risk perception could be less biased. Unfortunately, there are limited publications about the implications of using reconditioned water in food processing settings.

To bring water conservation practices in the food processing industry to the forefront of the discussion, the current situation of water reconditioning and reuse in the food processing sector, technologies available for wastewater treatment, opportunities for the recovery of valuable by-products, regulation constraints, tools to evaluate the implications from a holistic approach and opportunities for future research are reviewed.

Before expanding on the discussion, some definitions of the terminology used for water reuse are included in Table 1 for clarification.

2. Water, its use and importance in food processing

Water is used throughout the food production chain at different stages including irrigation, processing, cooling, heating, and cleaning. Irrigation represents 37% of the total U.S. freshwater withdrawal, while the manufacturing industry accounts for an additional 5–10% of freshwater consumption (EPA, 2013). The food processing industry itself accounts for over 30% of the water used in manufacturing as a whole (Australian Food Statistics, 2007). Though the proportion of water usage in the food processing industry is relatively small, it is important to highlight that food processing facilities use high-quality water and are frequently located in close proximity to urban areas. Therefore, they not only compete with the community for natural resources but in addition food companies produce a significant amount of effluents, which if not properly handled can cause significant environmental impacts. Together with the fact of water scarcity, stricter environmental regulations and the increasing cost of municipal water and wastewater treatments, all become determining factors that motivate food businesses to look for alternative ways to produce food efficiently and in a sustainable framework (Maguire, 2015).

Some processing wastewater streams are particularly interesting for reuse due to low microbial or chemical contamination, the need for minimal treatment, or low risk perception; examples of streams that present one or more of these conditions include, but are not limited to, cheese whey (Rektor & Vatai, 2004), condensed water from evaporation processes (Vourch, Balannec, Chaufer, & Dorange, 2008), rinse water from operations start up and final produce rinse water (Balannec, Gésan-Guiziou, Chaufer, Rabiller-Baudry, & Daufin, 2002), and fresh-cut vegetables processing (Selma, Allende, López-Gálvez, Conesa, & Gil, 2008). However, a detailed analysis based on the potential microbial, chemical and physical hazards should be considered to determine the safety of water reuse. Water from these streams can be recovered and treated (reconditioned) to reach any quality level, for reuse in the same or other processes. In order to achieve a significant reduction in water usage, it seems logical that recovered water be reused in high water demanding operations identified throughout the processing flow. Yet, information about water usage during specific process operations is not openly available from the U.S. food industries. This fact is a significant hindrance in conducting studies on water conservation alternatives since the knowledge about potential streams for water recovery and water quality requirements for different operations is limited and therefore does not allow for improvements in the most significant water consuming operations. The California League of Food Processors (2015) has made a significant contribution in this area, by conducting and publishing the results from a survey that compiles information on current water usage and management practices on different food processing sectors. Their findings support the need for baseline information on water use by individual operations within a given manufacturing process. Cooperation among industry, academia and regulatory agencies is fundamental to strengthen the culture of water conservation and sustainable production in the food processing industry.

3. Regulations

The U.S. Environmental Protection Agency (EPA) has published some guidelines for water reuse (EPA, 2012a), although official federal regulations are not in place. In the U.S., standards regarding water reuse is the responsibility of each state and their local agencies.

The idea of reusing processing water in food plants in not new, in fact, the United States with the assistance of Australia, Netherlands, India, Germany, France and the International Dairy Federation prepared and proposed a revised Draft Guidelines at the 31st session of the Codex Alimentarius Commission (Codex Alimentarius, 1999). Even though all delegates agreed on the importance of water conservation initiatives for the food processing industry, the decision about the inclusion of these guidelines was deferred on several consecutive sessions, until the 34th session when the decision to discontinue the consideration of the Proposed Draft Guidelines was made (Codex Alimentatius, 2004). One lesson learned from these sessions is a general guidance for all operations may not be available. Instead, guidelines for water reuse should be developed for specific commodities due to the fact that the practice of water reuse varies widely depending on the type of industry (Codex Alimentatius, 1998).

Currently, regulations require that potable water or equivalent must be used for food contact applications, but other water qualities are acceptable for non-food contact applications (Casani et al., 2005). Both situations open the door for water reconditioning and reuse practices, as long as the water quality requirements are satisfied and the safety and quality of the final products are not

Table 1
Definitions of selected water reuse terminologies.

Reclaimed water	Water that was originally a constituent of a food, has been removed from the food by a process step and has been subsequently reconditioned when necessary such that it may be reused in a subsequent manufacturing operation
Reconditioning	The treatment of water intended for reuse by means designed to reduce or eliminate microbiological, chemical and physical contaminants, according to its intended use
Recycled water	Water, other than first use or reclaimed water, that has been obtained from a food manufacturing operation and has been reconditioned when necessary such that it may be reused in a subsequent manufacturing operation
Reuse	The recovery of water from a processing step, including from the food component itself, its reconditioning treatment, if applicable; and its subsequent use in a food manufacturing operation

Source: Taken from the proposed draft guidelines for the hygienic reuse of processing water in food plants. Presented to the Codex Alimentarius Commission (Codex Alimentarius, 1999).

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