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Feasibility study on water reclamation from the sorting/grading operation in mandarin orange canning production

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ABSTRACT

The mandarin orange canning industry consumes a large quantity of fresh water, and discharges a similarly high volume of wastewater. If insufficiently treated, this effluent can seriously impact the environment. Water conservation and wastewater minimization can facilitate wastewater treatment. In this study, four filtration treatments were investigated to improve effluent quality from the sorting/grading operation at two mandarin canning factories for the purpose of water reclamation. The combined treatment consisting of a bag filter, activated carbon filter and precision filter yielded the best water quality improvement. The resulting elimination ratios for Chroma, turbidity, total sugars, pectin, and chemical oxygen demand were individually 27.64%, 55.56%, 22.55%, 21.35% and 42.22%. The treated water was clear and free of odor, and the pH was 6.7 ± 0.2. When the residual chlorine concentration was greater than 0.5 mg/L, the total bacterial count in the treated effluent was less than 10 CFU/mL and the coliform group was not detected. Further, the physicochemical and microbial parameters of the treated water conformed to the Chinese Standard of Drinking Water Quality except for chemical oxygen demand (38.60 ± 7.00 mg/L), which was mainly due to the saccharides in oranges. The results for the combined treatment of chlorination, bag filter and activated carbon filter at pilot scale indicated the feasibility of water reclamation during the sorting/grading step of full scale mandarin orange processing. At an average usage of 3500 t/d fresh water for a mandarin canning production line having a daily output of 100 metric tons, the water saving efficiency achieved with this combined treatment could reach 34.28%. A factory of this capacity can pay back the required investment for the treatment technology in the third production season, and will simultaneously save 373,840 Yuan. The cost-effective approach to water reclamation identified in this study minimized wastewater generation and facilitated clean production in a mandarin orange canning factory. The results indicate that a recycling process to enable water re-use can be implemented in food processing industries if it will not affect food safety. Such an approach to water management is beneficial to the coordinated and sustained development of economy, society, resources and environment.

1. Introduction

Mandarin orange canning is the dominant form of production in the Chinese citrus industry, and yields one of the most competitive products in the international market, accounting for 70% of the international trade for China (Shan, 2008). A great deal of fresh water is consumed during mandarin canning. The production of one metric ton of canned mandarin oranges requires 30–50 kL of fresh water in the current canning process in China, and results in a similarly large volume of effluent containing large amounts of organic components (Wang et al., 2006). This wastewater will pollute the environment if not properly treated. But, because the wastewater is rich in pectin and difficult to treat, the cost of treatment is high. Ways by which to reduce water consumption and improve water utilization in the mandarin canning industry has become an urgent issue in China.

Two decades ago, Wang and Smith (1994) pointed out that water re-use and recycling were two methods by which to

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minimize wastewater in process industries. Because large water consumption and wastewater emissions characterize most food production processes, many studies about wastewater treatment in the food industry have been carried out, including cases of process optimization to minimize water use in food processing (Bohdziewicz and Sroka, 2005; Klemeš and Perry, 2007; Matsumoto et al., 2012; Pavón-Silva et al., 2009). Some researchers have studied the feasibility of reusing low-polluted wastewater in food factories (de Koning et al., 2008; Noronha et al., 2002; Chavalparit and Ongwandee, 2009). However, so far, due to legislative restrictions and health concerns, reusing water in the food industry is rare (Casani et al., 2005; Kirby et al., 2003). Europe's rules on the hygiene of foodstuffs embody a more open attitude to recycling water or water reuse (EC, 2004); the recycling or reuse of water can be incorporated into food production processes if regulatory authorities believe the water will not adversely affect food safety.

To reduce the impact of wastewater pollution from citrus canning industries on the environment, several wastewater treatment technologies and methods in canned citrus processing industries have been investigated (Cai and Song, 2006; Tanabe et al., 1986, 1987), but there are few reported studies about water conservation and reuse. Thevendiraraj et al. (2003) carried out a water and wastewater minimization study at a citrus plant. Other studies have shown that reusing water for processing in food industries is feasible in practice (Abd El-Salam and El-Naggar, 2010; Andrade et al., 2014; Cristóvaõ, et al., 2015).

The typical operations at mandarin orange canning factories include raw material selection, washing, peeling/preparation, blanching, sorting/grading, filling, sealing, retorting, cooling, and labeling or storage (Ramaswamy and Marcotte, 2006). The discharged wastewater from the sorting/grading operation has been shown to be less polluted than wastewater from other processing steps, but it accounts for approximately 55% of the total water usage (Wang et al., 2006).

To reduce the water consumption of canned citrus production and improve the water utilization ratio, this study examined effluent from sorting/grading processing steps of two mandarin orange canning factories. This effluent was not heavily polluted, but did have relatively high chemical oxygen demand. The effluent therefore seemed to be a good candidate for investigation of four filtration treatments to improve effluent quality for the purpose of reclamation and reuse. The reason for the high chemical oxygen demand was examined. The combined treatment of chlorination, bag filtration and activated carbon filtration at pilot scale was evaluated. The research lays the foundation for water reuse in the mandarin orange canning industry.

2. Materials and methods

The effluent quality from the sorting/grading operation at two mandarin canning factories was examined. It was collected in a tank and then treated using the water treatment equipment shown in Fig. 1. This water treatment equipment was supplied by Hangzhou Huaqi Water Treatment Technology Co. Ltd. The equipment mainly consisted of a water pump, dosing pump, pressure device, bag filter, activated carbon filter, and precision filter; each of which could be used alone or in combination. The equipment design and operating parameters for water treatment are shown in Table 1.

2.1. Analytical methods

Water samples were collected, preserved and analyzed for chemical and physical parameters according to the Chinese Standard Methods for the Examination of Water and Wastewater (Chinese Environmental Protection Administration, 2002).

The microbial status of samples was determined using the Petrifilm™ method, as described in Publication GB/T4789 from the Chinese Ministry of Public Health (Ministry of Health of China, 2008).

The total sugar content in the water samples was determined using the method described by Dubois, et al. (1956). The pectin content in samples was determined using the method of Filisetti-Cozzi and Carpita (1991).

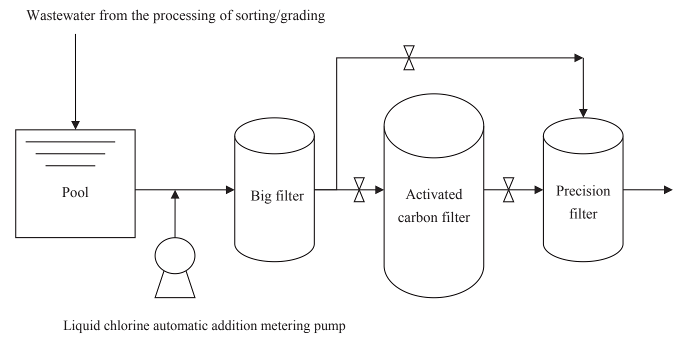

Fig. 1. Water treatment equipment improves effluent quality for the purpose of water reclamation.

2.2. Experimental treatment

Four filtration treatments and disinfection with chlorine were investigated to improve effluent quality for the purpose of water reclamation.

2.2.1. Treatment of the effluent

Four treatments were investigated in this study: (Treatment 1) bag filtration combined with activated carbon filtration and precision filtration, (Treatment 2) bag filtration combined with activated carbon filtration, (Treatment 3) bag filtration combined with precision filtration, and (Treatment 4) bag filtration.

Each treatment lasted for two consecutive days with continuous operation at a treated water flow rate of 15 t/h. Four water samples were collected every 12 h. The water quality was analyzed immediately after sample collection. The results were reported as means with standard deviations.

2.2.2. Disinfection with chlorine before treatment of effluent

The untreated effluent from the sorting/grading operation was disinfected using varying dosages of chlorine, which resulted

Table 1
Information for the parameters of water treatment equipment or facilities was represented.

Equipment or facilities	Characteristics
Collecting pool	Volume: 30 m^3
Liquid chlorine automatic addition metering pump	Flow in max: 4.7 L/h
Bag filter	Dimension: D500*1200; Flow in max: 15 t/h; filter-bag: 150 μm (pore diameter); pressure: <3–5 kg
Activated carbon filter	Dimension: D500*1200; Flow in max: 50 t/h
Precision filter	Dimension: D500*1200; Flow in max: 15 t/h; PP filter core: 5um; pressure: <3–5 kg