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Influence of air dehumidification on water evaporation in a food plant

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ABSTRACT

To reduce the proliferation of bacteria inside food plants, cleaning and disinfection are performed daily following production. These operations are followed by drying during which the drying rate should be as high as possible. This study shows the influence of a dehumidifier on the water mass evolution on surfaces during the drying of a food plant. The temperature, relative humidity and water mass evolution were monitored under two conditions: with and without a dehumidifier. Comparison of the results shows that the drying rate is about 1.5 times higher when a dehumidifier is used. These data were used to develop a simplified heat and mass transfer model allowing the prediction of the temperature and drying rate at different locations. The results can help the manufacturer to evaluate the benefits of a dehumidifier and consider the use of other devices to achieve better airflow distribution or greater heat supply for certain surfaces.

Influence de la déshumidification de l'air sur l'évaporation de l'eau dans une usine agroalimentaire

Mots-clés : Déshumidificateur ; Usine agroalimentaire ; Transfert de masse ; Humidité relative ; Évaporation d'eau

1. Introduction

Listeria monocytogenes is a serious foodborne pathogen that can cause severe infection called listeriosis and above all occurs in ready-to-eat food products. Product contamination is initially caused by contamination inside the premises of the food processing plant (Autio et al., 1999; Vogel et al., 2001; Wulff et al., 2006). Thereafter, contamination can increase throughout the cold chain and depends on the temperature and residence time of product in the refrigerating equipment (Duret et al., 2014). The product temperature can be determined using heat transfer models where the input parameters such as the product characteristics are known (Flick et al., 2012; Hoang et al., 2012). Legislation requires the absence of *L. monocytogenes* in five 25 g samples of a product before the latter leaves the food plant, and for products placed on the market allows a maximum of 100 CFU g^{-1} during their shelf-life (EC, 2005). This implies that many products must be destroyed if contamination occurs in the food plant. Inside the production room, equipment with

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Nomenclature

Cp_a	specific heat capacity of air [J.kg^{-1}.K^{-1}]
C	water vapor concentration in the air [kg.m^{-3}]
h	heat transfer coefficient [W.m^{-2}.K^{-1}]
k	mass transfer coefficient [m.s^{-1}]
Le	Lewis number [dimensionless]
m	mass of water [kg]
$m_{w,evap1}$	mass of water condensed on one evaporator [kg]
mC	heat capacity of materials [J.K^{-1}]
$\dot{m}$	air mass flow rate [kg.s^{-1}]
RH	relative humidity [dimensionless]
S	total surface area [m^2]
T	temperature [°C or K]
V	volume of the room [m^3]
x	water content [kg$_{water}$.kg$_{dry\ air}$$^{-1}$]
α	air distribution coefficient [dimensionless]
β	percentage of wet surface over total surface [%]
ρ	air density [kg.m^{-3}]
γ	air renewal rate [dimensionless]

Subscripts

a	air
f	floor
0	initial time
e	equipment
w	wall

complex shapes can be difficult to clean, thus enabling bacterial growth to take place. In damaged equipment, cracks on the floor etc., the presence of water and nutrients provide environments in which bacteria can develop (Carpentier and Cerf, 2011) and prevent bacteria from being affected by lethal concentrations of chemical products. This in turn enables bacteria to adapt to the disinfectants used, making eradication of bacteria more difficult (Muhterem-Uyar et al., 2015). Residual water and humidity in the premises are determining factors in microbial development, and can be reduced using a dehumidifier.

2. Literature review

There are many types of dehumidifier (La et al., 2010) for different applications. For human comfort, the use of a dehumidifier makes it possible to slightly reduce and to homogenize the relative humidity inside a building in order to reduce moisture levels and ensure human well-being (Cunningham, 2007; Teodosiu et al., 2003; Teodosiu, 2013). Kim et al. (2008) carried out an experimental and numerical (3D CFD) study and demonstrated the influence of a dehumidifier in a greenhouse on the relative humidity: a reduction of about 10% (from ~70% to ~60%) was achieved. In a food production plant, the use of a dehumidifier makes it possible to raise the drying rate. However, from our literature review, there have been no studies reporting the influence of dehumidification on the relative humidity in air and on the rate of water evaporation on the surfaces of a food plant. Also, to our knowledge, there are no published data on the water load inside a food processing plant after cleaning and during drying. In most food processing plants, there is no dehumidifier, and when one is used, it is in most cases designed in an empirical manner. In a previous study (Lecoq et al., 2016), an experiment was performed in a food production plant without a dehumidifier in order to study water evaporation on the surfaces (walls, floor and equipment). The relative humidity was rather high (~85%), thus inducing a low evaporation rate during the 2-hour drying period, and water still remained on certain surfaces. A simplified heat and mass transfer model was developed to predict the evaporation rate on these surfaces and a part of the present study is based on this model.

The main objectives of this study are to present an estimation of the water load after cleaning and to analyze the influence of a dehumidifier on the air humidity and the water evaporation rate at different locations in an industrial food plant. The simplified model developed by Lecoq et al. (2016) was adapted to predict the drying rate in the food processing plant under two operating conditions (with and without a dehumidifier).

3. Experiment in a food plant

The experiments were carried out in a chilled food production plant during the drying period (Fig. 1). The ambient conditions (temperature, relative humidity, air velocity) and the water mass on several surfaces were measured in two cases: with and without a dehumidifier operating in the room.

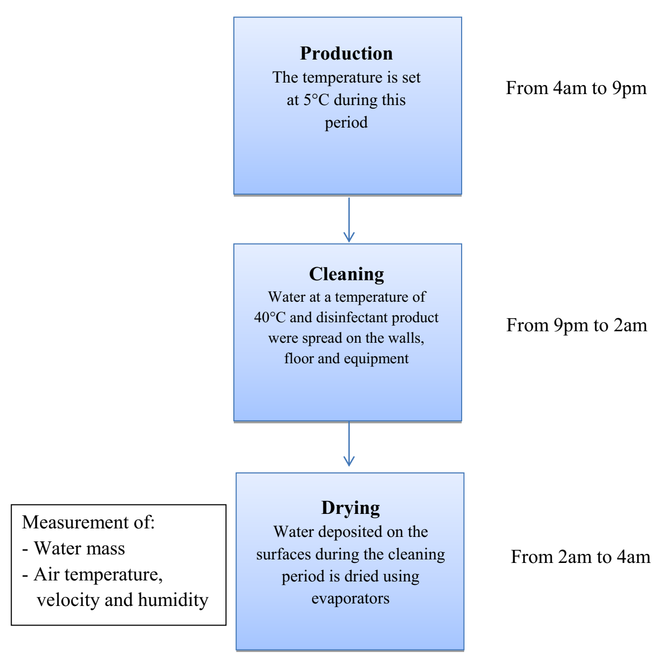

Fig. 1 – Different daily operations in the production plant investigated.