Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 146 (2016) 481 – 493

Procedia Engineering

www.elsevier.com/locate/procedia

8th International Cold Climate HVAC 2015 Conference, CCHVAC 2015

Thermal and Moisture Analysis For Tobacco Leaf Flue-curing with Heat Pump Technology

Yafeng Bao[a,b], Yong Wang[a.b]*

[a]*Key Laboratory of the Three Gorges Reservoir Region's Eco-Environment, Chongqing University, Chongqing 400045, China*
[b]*National Centre for International Research of Low-carbon and Green Buildings, Chongqing University, Chongqing 400045, China*

Abstract

The drying process control of porous medium is one of the important factors affecting the quality of dry object. Unlike traditional coal burning barn, an alternative better approach using the heat pump technology for tobacco drying process is proposed in this study. Based on the theory of heat and mass transfer in porous medium, a numerical model is established using a widely accepted computational fluid dynamics (CFD) package, Ansys-Fluent, and different drying process boundary conditions and physical properties are considered. Numerical results such as the distribution of the temperature, humidity and velocity field in the curing barn are provided. Besides, on-site measurements are conducted based on an actual curing barn in Chongqing. Through comparing the distribution of the key parameters in the tobacco leaf flue-curing process with our numerical simulation, good agreements are found. Since the numerical simulation can enrich our understanding of thermal and moisture environment within the curing barn, the approach prosed in this study can be applied in future engineering projects for better drying process control of porous medium, such as tobacco leaf curing.

Peer-review under responsibility of the organizing committee of CCHVAC 2015

Keywords: Porous medium; Heat and mass transfer; CFD; Tobacco leaf flue-curing; Heat pump technology;

* Corresponding author. Tel.: +86-23-65120750; fax: +86-23-65120773.
E-mail address: cqwangyong@cqu.edu.cn

Peer-review under responsibility of the organizing committee of CCHVAC 2015
doi:10.1016/j.proeng.2016.06.377

1. INTRODUCTION

With the adjustment of agricultural structure and the implementation of the strategy of sustainable development, flue-cured tobacco production industry has experienced a big change. Previously, general heating source for curing barn was coal heating, which heat utilization rate is relatively low with a high coal consumption [1,2]. Moderate scale planting has become the new alternative flue-cured tobacco production direction in China. Heat pump drying technology was first patented in the United States in 1950. Due to its significant advantages such as energy-saving and reduced emissions, heat pump drying gained rapid industry application [3-5], especially in tobacco baking.

Bryan, et al. performed tobacco baking experiments for tobacco K326 in 1999 for the first time and both the heat pump dehumidification curing barn and conventional fuel curing barn were used [6]. Changrong and Jianbin found heat pump heating and thermal wind circulation can make full use of heat energy for flue-cured tobacco [7]. Xiaojun et al. also put research efforts on designing of heat curing barn and tobacco baking test [8,9]. Yu et al. investigated the baking energy saving way using solar heat pump [10].

Recently, numerical simulation technology has been applied in the field of thermal and mass transfer in porous medium, including tobacco drying field. Majority of them are focused on the drying process of cut tobacco [11-15]. Overall, numerical studies focusing on the flow field distribution inside the tobacco baking barn are limited.

In this paper, the thermal and mass transfer is numerically simulated during curing barn baking process. The flow field distribution and the influence of different conditions on the heat and mass transfer are studied. This research can improve the performance of curing barn internal airflow, the flue-cured tobacco quality, and contribute valuable suggestions for engineering application.

Nomenclature

u_b	total value
u_v	volume of void space
K_{eff}	coefficient of thermal conductivity
K_f	coefficient of thermal conductivity of fluid phase which consider the influence of turbulence
K_s	coefficient of thermal conductivity of the solid skeleton
d	size dimension which take the equivalent diameter for non-pipe flow
C_2	coefficient of inertial resistance
D_p	equivalent volume diameter
S_m	quality of the source term
E_f	fluid total energy
E_s	solid total energy
S_f^h	fluid enthalpy source term
r_l, r_v	relaxation factors
T_{sat}	liquid saturation temperature
D_H	hydraulic diameter
A	sectional area
P_w	wet circumference
l	turbulence length scale
k	turbulent energy
C_u	0.09
DBT	dry-bulb temperature
WBT	wet-bulb temperature

Greek letters

γ	porosity
v	velocity of infiltration
υ	kinematic viscosity of the fluid
$1/\alpha$	viscous resistance coefficient