Applied Thermal Engineering 47 (2012) 63–72

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Wood consumption and analysis of the bread baking process in wood-fired bakery ovens

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A R T I C L E I N F O

Article history:
Received 13 October 2011
Accepted 5 March 2012
Available online 24 April 2012

Keywords:
Wood consumption
Measurement
Efficiency
Wood-fired bakery oven
Bread quality

A B S T R A C T

Combustion of biomass in small-scale furnaces is used widely in different applications. The technology used is often "fixed grate" combustion in small batch furnaces. The efficiency of such a furnace is often low, which results in a high environmental impact. The aim of this work was to analyse the performance of the existing wood-fired bakery ovens that can be used to improve the efficiency. The data collected from 15 semi-direct and 3 indirect bakeries consisted of: the dimensions of the oven, the temperature profiles of the combustion chamber and the baking oven, the baking time and the bread quality. It was found that as much as 60 tons/day of green wood are consumed in the bread baking process in the area investigated. Two types of bakery ovens are used most commonly: indirect and semi-direct. The specific consumption was found to be 0.55 and 0.90 kg of wood per kg of wheat flour baked for the indirect and the semi-direct respectively. The analyses of the bread baked show that the variation of the temperature profile during the baking process influences the quality of the bread produced.

1. Introduction

Bread is a staple food for many people. The bread making process consists of several different stages, of which baking is the key step: under the influence of heat, raw dough is transformed into a light, porous, readily digestible and tasty product [1]. The control of parameters such as temperature and time during baking is basically an engineering problem that is critical to the successful implementation of commercial composite flour-baking technology [2]. Despite of technological advances and process automation bread making is a traditional food process that still depends on skilled workers. Knowledge about the process time as a function of operating conditions is one of the main interests of design engineers and equipment user. To better understand and therefore to predict, optimise and control baking, it is essential to consider both transport phenomena and quality changes taking place in bread during the process [3]. Industrial baking oven conditions are usually estimated from the tree modes of heat transfer: convection, radiation and conduction. The proportion of each individual mode of heat transfer in baking process depends on oven design, configuration and operation. Air and oven-wall temperature profiles as well as air velocity can affect the convection/radiation heat transfer and hence the quality of the baked products [4]. Due to the relation between the heat transfer rate, investment cost and lost exergy, all of them must be considered for a realistic optimization [5].

In ovens where the necessary heat is generated from combusting wood, the thermodynamic efficiency of the combustion of wood in fixed grate technology depends upon a large number of factors, such as the design of the furnace, composition of fuel, design of the cooking chamber, cooking practice employed and meteorological conditions. The combustion process is the key to the total efficiency of wood-burning bakery ovens. Fixed grate combustion in small batch furnaces is largely used in developing countries; it is also the technology used most often in Mozambique which is a country with considerable forest resources; the main source of energy for different activities is based on biomass. A recent estimation by GRNB [6] showed that the demand for wood fuel has continually increased over the last two decades. At present, 80% of the energy used comes from biomass which represents an annual average consumption of wood fuel per capita in urban areas estimated at 1.2 m^3 and 1.0 m^3 in rural areas [6].

In recent years, wood fuels have been used increasingly for industrial applications, mainly in the bread baking process.

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doi:10.1016/j.applthermaleng.2012.03.007

However, the technology and the energy conversion devices employed are generally poor as well as inefficient, so the scope for improving them both is large.

Two kinds of furnaces are used in bread baking process in Mozambique: indirect and semi-direct. The indirect bakery oven is characterized by two independent chambers: the combustion chamber and the baking chamber. Air is circulated in the combustion chamber by force in indirect ovens, in contrast to the natural circulation of air used in semi-direct ovens (Fig. 1A). The baking chamber, which is composed of three shelves each with three or four drawers, is designed to transfer heat mainly via natural convection and radiation from coil to bread in the baking process (conductive heat transfer also occurs but only to a minor extent). Inside of the coil there is a circulating fluid, which is heated from the combustion chamber. A study performed by Krist-Spit and Sluimer [7] indicates that the contribution made by radiated heat to the top of the dough ranged from 61 to 76%, depending on the use of forced circulation. The heat transferred via convection associated with the water vapour sprayed in the atmosphere of the oven influences the colour of the bread's surface (i.e. the crust): the continuous injection of steam during the baking process resulted in the crust being browner [8]. The high cost of electricity and maintenance, however, mean that this is not cost-effective for the majority of enterprises interested in, or even considering, increasing the efficiency compared of traditional wood-fired bakery ovens.

The semi-direct bakery oven consists of two chambers: one combustion chamber and one baking chamber (Fig. 1B). The oven,

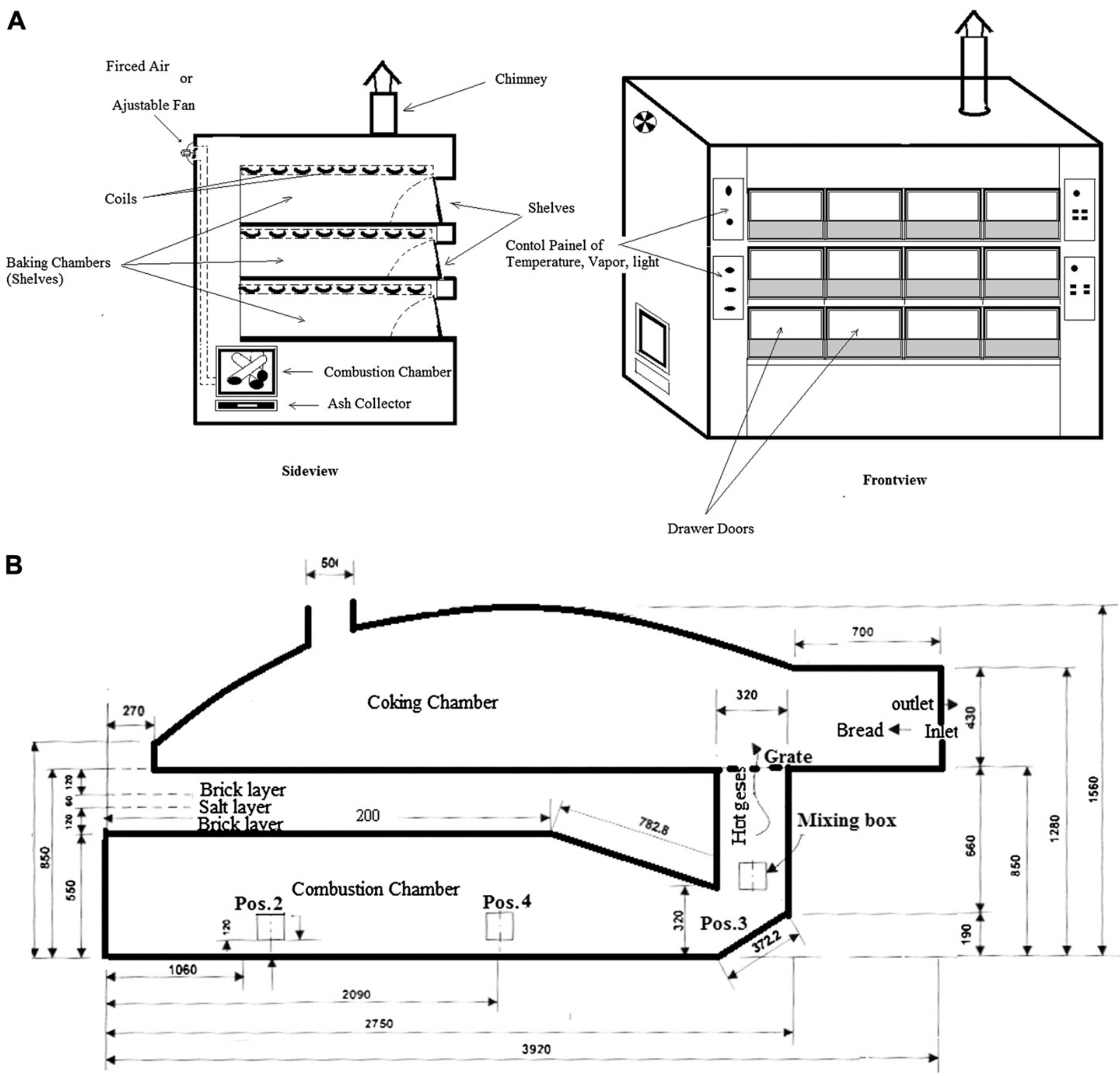

Fig. 1. A. Schematic representation of the indirect wood fired bakery oven. B. The technical design of the semi-direct wood fired bakery oven.