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The effects of drying parameters in the codfish (*Gadus Morhua*) drying rates

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Abstract: Drying of codfish (*Gadus Morhua*) has great importance in several regions of the world. The correct definition of drying procedures of a vast range of products is crucial in what concerns energy minimization and minimal time of kiln residence, without compromising the final product quality. The main goal of this study is to obtain the drying curves of codfish for temperatures of 15°C, 18°C and 20°C, relative humidities of 45%, 50%, 55%, 60% and 65% and air velocities of 1.5m/s and 2m/s. Secondly it is required to determine the influence of these parameters in the drying process. The following conclusions can be drawn from the study: Increasing the temperature of the drying air decreases the total drying time, while decreasing the relative humidity decreases it and the air velocity has a limited influence on the codfish drying process.

Keywords: Codfish; drying; relative humidity; temperature; air velocity.

1. Introduction

Drying of codfish (*Gadus Morhua*) has great importance in several regions of the world. As all fish, fresh codfish is susceptible to deterioration by fast destructive action of enzymes, oxidation of lipids, high pH, high water activity and accentuated contents of non-protein nitrogen substances. Accordingly, it is of critical importance to adopt measures ensuring perfect conservation immediately after capture and during storage, distribution and commercialization.

The correct definition of drying procedures of a vast range of products is crucial in what concerns energy minimization and minimal time of kiln residence, without compromising the final product quality. However, drying can change the sensory characteristics and nutritional value of foods, and the intensity of these changes depends upon the conditions used in the drying process and the specific characteristics of each product.

Simulation models of drying processes are used for designing new or improving existing drying systems or even for the control of the drying process. All external parameters (transfer coefficients, potential, etc.) used by the simulation models are directly related to the drying conditions, i.e. relative humidity, temperature and air velocity of the drying medium inside the mechanical dryer [1, 2]. Furthermore the drying conditions, affect the energy demands (ventilation, heating, dehumidification, residence time, etc.). As a consequence particular attention in studying how the drying-air parameters influence the drying process has been given [3]. Establishment of the drying conditions is needed to reduce the drying time and ensuring high quality. However, the selection of the drying condition is difficult to achieve, because many combinations of operating variables are present [4].

Several researchers have investigated the drying kinetics of different fishes in order to determine the influence of diverse drying parameters. Drying of lightly salted sardine (*Sardinella aurita*) was accomplished using three air temperatures (35°C, 40°C, 50°C) and three air velocities (0.5m/s, 1.5m/s, 2m/s) and the effects of drying conditions on drying kinetics were studied by Bellagha *et al.* [5]. From the drying kinetic studies of salted sardines it is observed that only the falling drying rate period exists. Also, air temperature is the main factor influencing the drying kinetics. The drying rate increases with air velocity but this effect may be inverted above certain air

conditions, due to hardening of the fish surface due to protein modification by the combined effects of heat and salt.

Djendoubi *et al.* [6] studied the effect of air drying process on the dehydration kinetics of sardine muscles (*Sardina pilchardus*). Experimental drying kinetics was measured at five air temperatures (40, 50, 60, 70 and 80°C), two relative humidity and at a constant air velocity of 1.5 m/s. The sardine drying kinetics was accelerated by increasing air temperature and was showed down when increasing air humidity. The drying time increased with increasing relative humidity at the same temperature. The drying rate decreased when moisture content or drying time decreased. No constant drying period was observed and the dehydration of the muscles occurred only in the falling rate period. These results indicated that diffusion is the most likely physical mechanism governing moisture removal from the muscles.

The effects of air temperature and fat on the drying kinetics of the fish muscles in a thin layer, were analyzed by drying curves of the dimensionless average moisture content versus time [7]. The air temperature had a greater effect during the first stage of the falling rate period, where the temperature of the material starts increasing to near the temperature of the drying air. The constant rate period took place in all samples because of the high initial moisture content of the fish fillets.

Vega-Gálvez *et al.* [8] analyzed the air drying kinetics of yellow squat lobster (*Cervimunida johni*) fishery waste. This study was carried out at temperatures from 50 to 90°C. A clear effect of temperature is observed on the drying process of yellow squat lobster waste, where increase in the drying temperature is accompanied by a decrease in the drying time.

The main goal of this study is to obtain the drying curves of codfish for temperatures of 15°C, 18°C and 20°C, relative humidities of 45%, 50%, 55%, 60% and 65% and air velocities of 1.5m/s and 2m/s. Secondly it is required to determine the influence of these parameters in the drying process.

2. Materials and methods

2.1. Raw materials and drying conditions.

The experiments were carried out using salted codfish samples of 100g (average), with an average initial moisture content of approximately 60.73%. The weight of the material was measured in fixed time intervals and recorded as a function of drying time [9]. At the end of each drying experiment, dry matter of the dried codfish was determined by leaving it for 48h in an oven at $105\pm 2^{\circ}\text{C}$. Tests to determine the equilibrium moisture content were performed in a hygrothermal chamber, where the desired values of relative humidity and temperature were controlled.

The investigation of the drying characteristics has been conducted for a temperature range of 15°C , 18°C and 20°C , relative humidities varying between 40% and 65% and air velocity of 1.5m/s and 2m/s.

The drying data from the different drying tests were then expressed as moisture ratio (MR) versus drying time and drying rate (DR) versus moisture content.

2.2. Drying experimental installation

Figure 1 shows the drying machine's mechanical apparatus and instrumentation. The dryer using ambient heated air and working in closed loop was equipped with a continuous monitoring system. This system includes a centrifugal blower, driven by a variable velocity AC motor which determines the air velocity control within the drying chamber. The air is forced through electric heating resistances allowing the air temperature control to be raised. Steam at atmospheric pressure is used for humidification and a dehumidifier is used for cooling and dehumidifying the air. The air velocity is measured by an air velocity transmitter (Omega, model FMA 1000). The air temperature and the relative humidity are acquired through a digital thermo-hygrometer (Omega, model RH411). The weight of the dried sample was measured using a precision balance with an accuracy of 0.01 g, having a maximum capacity of 2000 g.

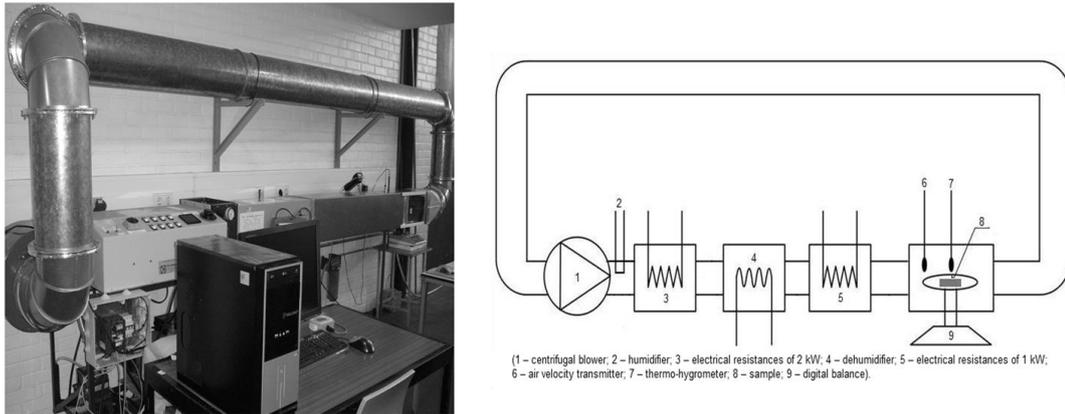


Figure 1: Drying experimental installation

The control and operation of the drying process are accomplished by the use of the computer card in conjunction with the Matlab/Simulink® platform. Data acquisition of the dryer is handled by a PCI-6025E card, from National Instruments. The control of the air conditions (relative humidity, temperature and air velocity) was achieved via software, specially developed for the purpose, with a Fuzzy Logic control (Figure 2).

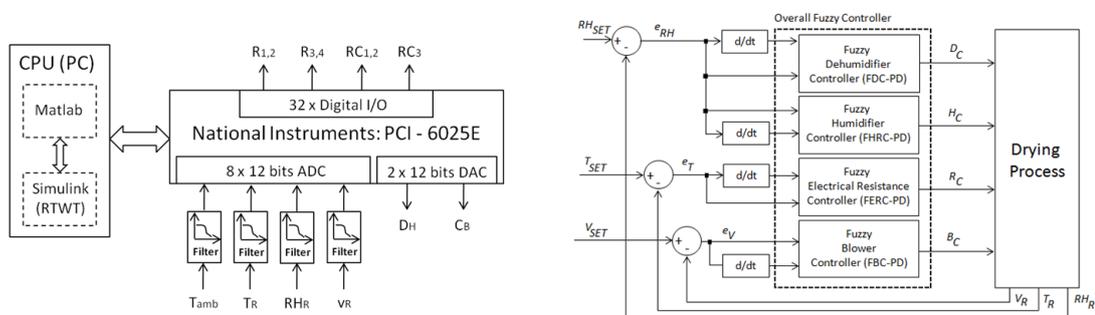


Figure 2: Hardware and software platforms

2.3. Moisture ratio and drying rate

The measures of mass were made using a digital analytical balance with precision 10^{-3} . The moisture ratio (MR) is given by equation 1:

$$MR = \frac{M_t - M_g}{M_0 - M_g} \quad (1)$$

where M_0 is the initial moisture content (w.b.), M_e is the equilibrium moisture content (w.b.) and M_t is the moisture content (w.b.) in the time t .

The drying rate (DR) of the codfish during drying experiments was calculated using the following equations:

$$DR = \left| \frac{m_{t+\Delta t} - m_t}{\Delta t} \right| \quad (2)$$

where m is the mass (g).

3. Results and discussion

The drying curves of all drying tests conducted are plotted in figures 3 - 11. In these figures the moisture ratio was plotted versus time, for different values of relative humidity, temperature and air velocity, as well as the drying rate was plotted versus moisture content.

3.1. Effect of temperature

The effect of different temperatures on the drying kinetics of salted codfish was studied (Figures 3 to 5). The drying curves were plotted for different values of temperature and for the relative humidities and air velocities values kept constant.

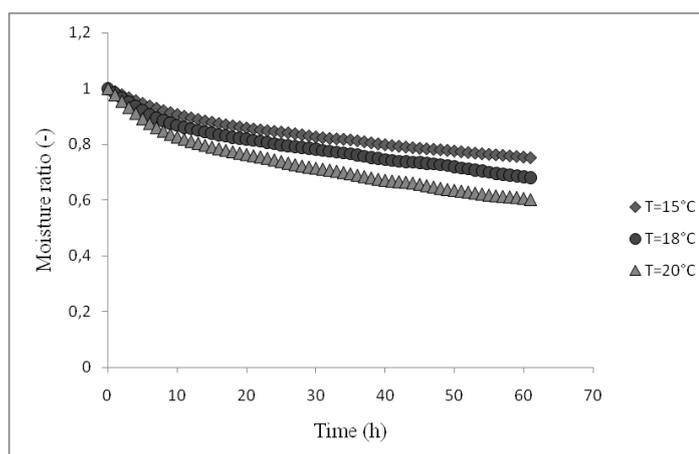


Figure 3. Temperature effect on the drying curves for relative humidity 50% and air velocity 2m/s.

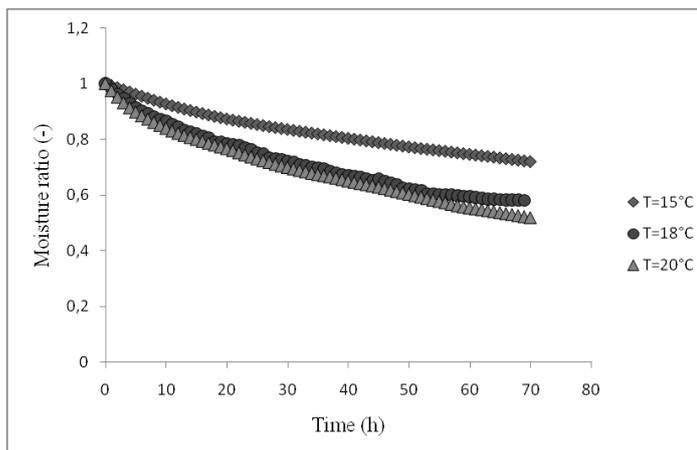


Figure 4. Temperature effect on the drying curves for relative humidity 50% and air velocity 1.5m/s.

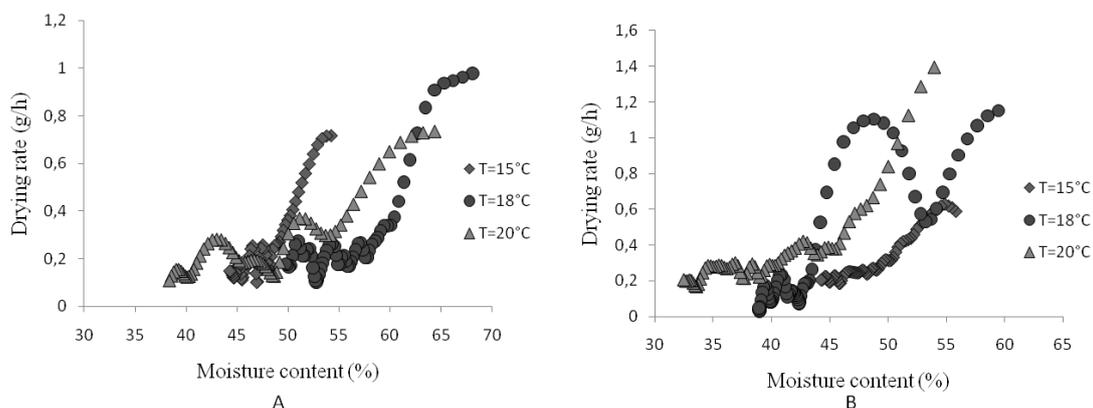


Figure 5. Temperature effect on the drying rates for: A) relative humidity 50% and air velocity 2m/s and B) relative humidity 50% and air velocity 1.5m/s.

All drying curves show a clear exponential tendency, and as expected, it was observed that drying occurs faster when there is an increase in temperature. The value of moisture ratio decreases rapidly, with consequent increase of the drying rate, when air temperature increased.

The experimental results are consistent with those reported in the literature for other fishes in which the air temperature is considered the salient factor affecting drying rate. The drying rate is considerably increased if higher temperatures were used as reported by several investigators [5, 6, 7, 8].

3.2. Effect of relative humidity

Figures 6 to 9 show the influence of relative humidity on the codfish drying curves. It is observed that for lower relative humidities, drying occurs quickly, and this behavior is more evident when combined with higher temperatures. It can be found that the drying rates decreased as relative humidity increased at a constant temperature.

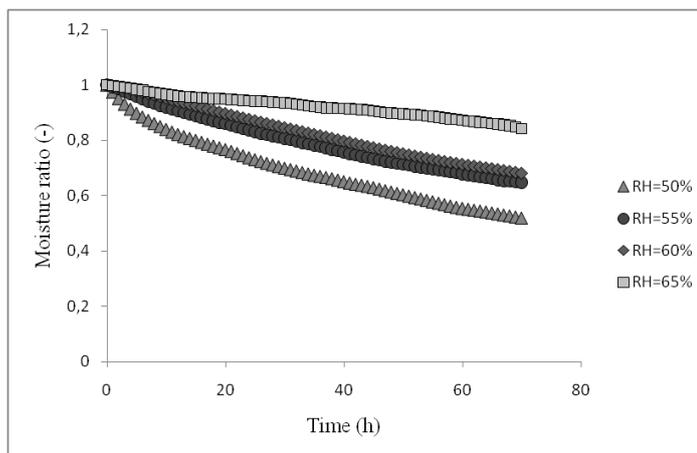


Figure 6. Relative humidity effect on the drying curves for temperature 20°C and air velocity 1.5m/s.

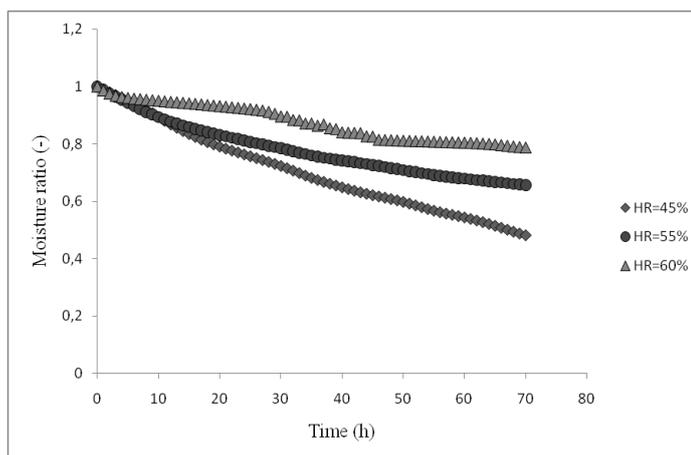


Figure 7. Relative humidity effect on the drying curves for temperature 18°C and air velocity 2m/s.

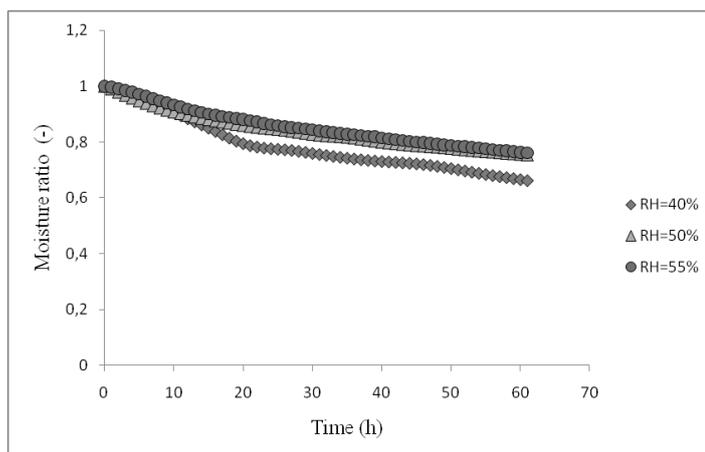


Figure 8. Relative humidity effect on the drying curves for temperature 15°C and air velocity 2m/s.

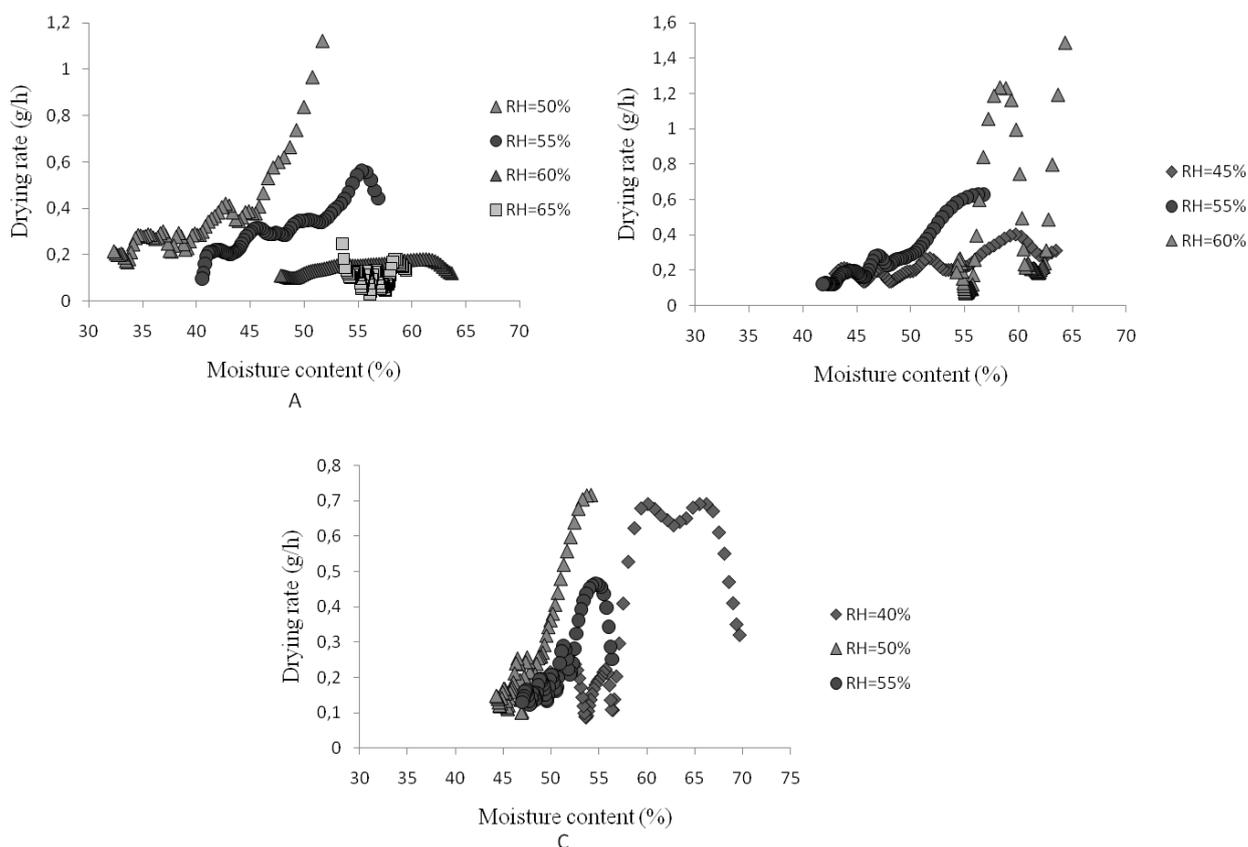


Figure 9. Relative humidity effect on the drying rates for: A) temperature 20°C and air velocity 1.5m/s; B) temperature 18°C and air velocity 2m/s and C) temperature 15°C and air velocity 2m/s

According to Kaya, Aydin and Demirtas [10], due to the increasing mass transfer, decreasing the value for relative humidity decreased the total drying time.

Decreasing the value for relative humidity increased the difference between the concentrations of water in the drying air and the product.

3.3. Effect of air velocity

The air velocities investigated were 1.5m/s and 2m/s. Figures 10 and 11 show the drying curves for the air velocity influence.

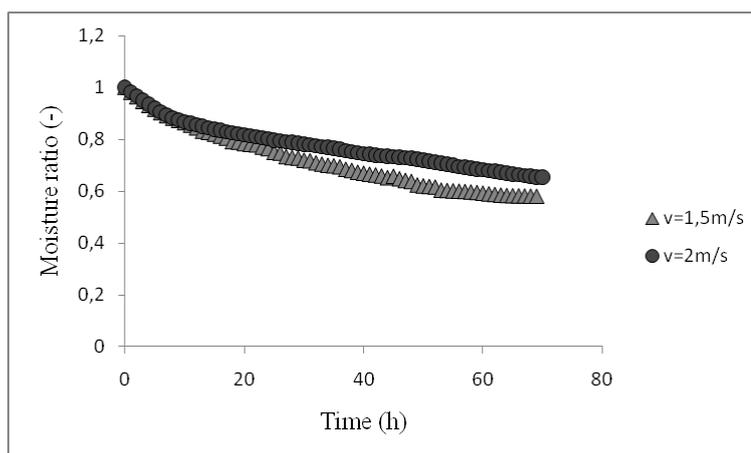


Figure 10. Air velocity effect on the drying curves for relative humidity 50% and temperature 18°C

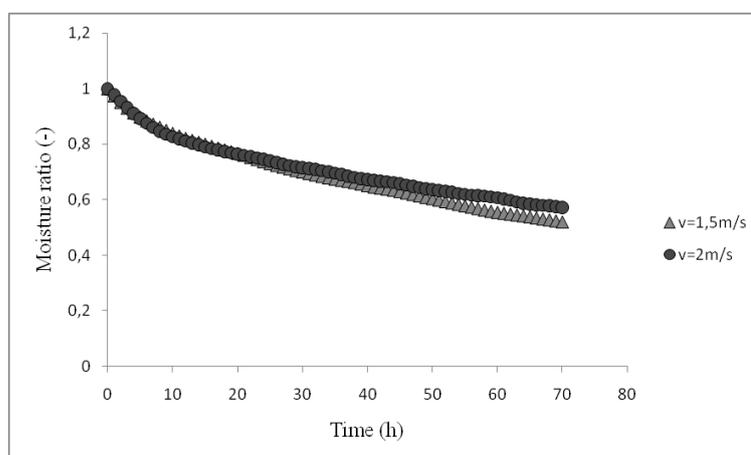


Figure 11. Air velocity effect on the drying curves for relative humidity 50% and temperature 20°C

According to Madamba et al. [11], some researchers chose to neglect the effect of the air velocity concluding that the resistance to moisture movement from the surface to the drying medium is less important if compared to the internal resistance.

In this work, it was observed that the increase in air velocity causes the drying to occur more slowly and that the effect of the air velocity magnitude is not pronounced at the initial time period of drying. This result is in accordance with what was found by others researches [5, 12].

4. Conclusion

The influence of drying air temperature in the range of 15°C-20°C, relative humidity in the range of 40%-65% and of the air velocity of 1.5 and 2m/s for salted codfish was studied.

The following conclusions can be drawn from the study:

- Increasing the temperature of the drying air decreases the total drying time, while decreasing the relative humidity decreases it.
- The air velocity has a limited influence on the codfish drying process.

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