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MICROWAVE ASSISTED DRYING OF FLAX STRAW AND FIBRE AT CONTROLLED TEMPERATURES

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ABSTRACT Flax fibre and stem were subjected to microwave drying at controlled temperatures. The rate of drying was then compared with conventional hot air drying. The product temperature was kept at 40, 60 and 80 °C for both microwave and hot air drying. The initial moisture content of flax fibre was about 60 % (wet basis); while for flax stem, it was about 70 % (wet basis). The microwave drying was conducted with a microwave apparatus which records the mass, product temperature, incident microwave power, reflected microwave power and inlet outlet air temperature. The final moisture content for both experiments was set to 9 % (dry basis). The microwave drying ensured about 60 % reduction of drying time for drying flax fibre and straw compared to hot air drying.

Keywords: Microwave, flax straw, flax fibre

1. Introduction

Flax is a crop which is used in various food and industrial products. The seeds are used in food industry for making oil, cattle feed etc. The stem is used for the production of fibre, bio composites, paper industry and many other industrial applications. Flax plant belongs to the *Linum usitatissimum* family. Flax seeds were consumed as a cereal in the past and were known for their medicinal values. The oil from the seed has been used as a medium for food frying, in lamp oil and as a preservative material in paints (Vaisey-Genser & Morris, 1997). Flax-seeds contain oil at 35% of its mass; out of that alpha-linolenic acid (omega-3 fatty acid) is 55% and linoleic acid is15–18%. Flax-seed is a rich source of omega-3-fatty acids and the richest source of plant lignans (Carter, 1993). The flax seeds are primarily used in the food industry, while the plant stems are used in fibre production. The stems of flax plants range from 20 cm to 150 cm (Hegi, 1925). The flax stem contains cellulose fibres (bast fibres) which have a number of mechanical and physio-chemical properties that are useful in textile and biocomposite industries. Flax fibres, which originates from renewable resources are used as an alternative to mineral fibres. Their low cost together with their lower density, higher specific stiffness and recyclability are the major incentives for their use in composite materials (Baley 2002).

Flax straw is used in the production of flax fibre for textile industry, production of bio composite materials and paper industry. Drying of flax straw is essential for maintaining its quality during storage. Commonly, natural fibres are dried under the sun light, but this process takes longer time and drying conditions are not easy to control. The quality of fibre by this drying is also not optimal. Drying is necessary for flax straw and fibre because the water contained inside the fibre forms bubbles during the mixing process involved in making biocomposite materials (Panigrahi et al., 2006). Hence, prior to the processing into a biocomposite material, the flax fibre must be dried properly. The main method of drying of flax straw is by passing hot air through the bales (Pereira et al. 2007). The hot air drying method is very inefficient since the major part of the energy will be wasted in forcing through the bale. Microwave drying is a faster way of drying as compared to other conventional methods (Raghavan et al. 2005). For that purpose, microwave drying of flax straw was tested and compared with hot air drying.

The flax fibre obtained after retting is of high moisture content. The moisture content of flax fibres should be very low for the production of biocomposite materials. Flax fibre is biodegradable, environmentally friendly, renewable, non-abrasive, economical, and easily available in Western Canada (Ghazanfari et al., 2006). In wet fibre, the water molecules behaves like a plasticizer, hence the cellulose molecules move freely, which causes low elastic modulus and tensile strength. The decrease in mechanical property of the flax fibre may also be due to the development of fungi in the presence of moisture in the internal structure of the fibre (Stamboulis et al., 2001). High temperature drying of flax fibre results in damage to its structure and colour. Microwave drying with hot air supply could offer uniform heating which retains the quality of the fibre. The objectives of this study were

i. To establish an optimum product temperature.
ii. To compare the microwave – convective drying with hot air drying at the same temperatures.

2. Materials and method

2.1 Flax straw: Flax grown in a McGill university green house under controlled conditions was used for the experiments. The flax seeds were sown in separate pots filled with soil and manure mix. The flax plants were harvested after 100 days and kept in the green house for 2 weeks for drying. Under natural conditions, these flax stems were used for the drying test. The moisture content of flax stem was 3.93 % (wet basis) which was calculated by oven dry method at 105 ° C for 72 hours. The flax straws were immersed in a container full of water for 48 hours before conducting the drying test to increase its moisture content to 68 -70 percent wet basis.

2.2 Flax fibre: The flax fibres used for microwave drying was ordered from a local market of Saskachewan, Canada. The fibre had a moisture content of 4.22 % (wet basis) which was established by oven dry method at 105 ° C for 72 hours. The flax fibre was immersed in a container full of water for 48 hours before conducting the drying test. The flax fibre was really hydrophilic and absorbed water very fast. This property is a drawback of flax fibre for the production of biocomposite materials (Wang, et al. 2007). The flax straws were immersed in a container full of water for 48 hours before conducting the drying test to increase its moisture content to 60 % wet basis.

2.3 Microwave Apparatus: The drying of flax fibre and flax straw was done using a microwave apparatus designed in the post harvest technology lab, Macdonald Campus, McGill University which is shown in figure 1. The microwave generator operated at 2450 MHz with a variable power from 0 to 750 kW. The temperature of the flax was measured with the help of an optical fibre probe (Nortech EMI-TS series, Quebec City, Canada). The temperature probes were connected to an Agilent 34970A data acquisition unit and that unit was connected to a computer (Dev et al, 2007). There was a hot air supply with adjustable temperature, attached to the microwave oven as hot air was passed through the microwave oven to remove the moisture from the samples.

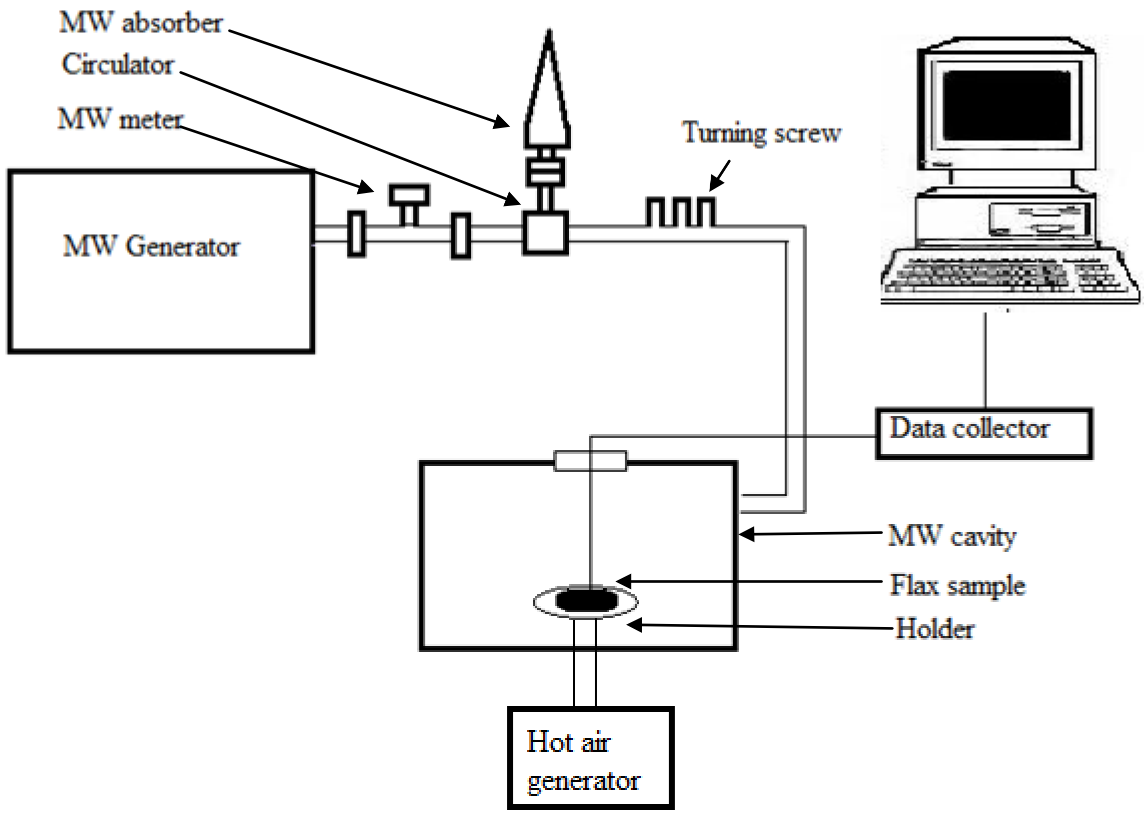

Figure 1 Diagram of microwave drying apparatus (Adopted from Dev et al, 2007)

2.4 Microwave drying of flax straw: The flax straws were cut into 15 cm length in the middle part of the plant to ensure uniformity for carrying out drying tests. 25 g of flax straws were taken and kept in a jar full of water for 48 hours at the room temperature to ensure fully wet conditions. The samples were taken from the water after 48 hours and the surface water was removed by using a centrifugal rotator operated manually. The samples were then weighed, and transferred to the microwave apparatus. The microwave drying was done at three different temperatures of 40°C, 60°C and 80°C. While drying, the reflectance was controlled throughout the experiment by controlling the tuners manually. The temperature, reflectance and mass were recorded by the computer at intervals of 30 seconds. The drying was conducted till it reached a final moisture content of 9 % (wet basis). Three replicates of each test were done.

2.5 Microwave drying of flax fibre: 25 g samples of initial moisture content 4.2 % (wet basis) were kept in a glass jar filled with water at room temperature for 48 hours. The samples were taken out and the excess water was removed by using a manual centrifugal rotator. Initial moisture content was 60% (wet basis). The drying temperatures were set at 40°C, 60°C and 80°C. Air flow of 40°C, 60°C and 80°C was ensured in the microwave oven for the removal of moisture from the samples for the experiments.

2.6 Hot air drying of flax straw and flax fibre: The same procedure for the sample preparation as per the microwave drying was followed. The experiments were done with different temperatures of convective air at 40°C, 60°C and 80°C without microwave incidence. The mass and product temperature were noted at 30 second intervals.

3 Results and discussion

3.1 Flax straw: The drying of flax straw with microwave energy and with hot air alone were compared. The temporal variation of moisture content during microwave drying of flax straw at different temperatures of 40°C, 60°C and 80°C is shown in Figure 2.

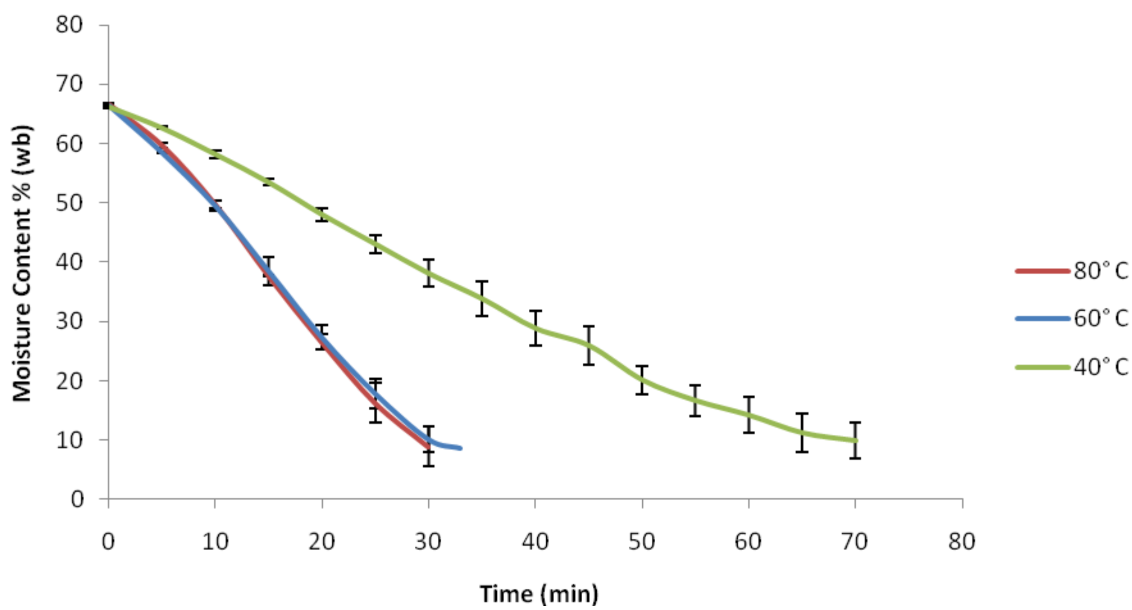

Figure2. The temporal variation of moisture content during microwave drying of flax straw at temperatures of 40°C, 60°C and 80°C

The microwave drying of flax straw at 40°C took 92 minutes to reach a moisture content of 9 % (wet basis) from 70% (wet basis) while 80°C microwave drying took 29 minutes to reach the final moisture content of 9% (wet basis). The moisture removal is faster with the increase in temperature.

Hot air drying was conducted on flax straw samples at three temperatures of 40°C, 60°C and 80°C and the drying was compared with microwave drying for each temperatures as shown in figures 3,4 and 5

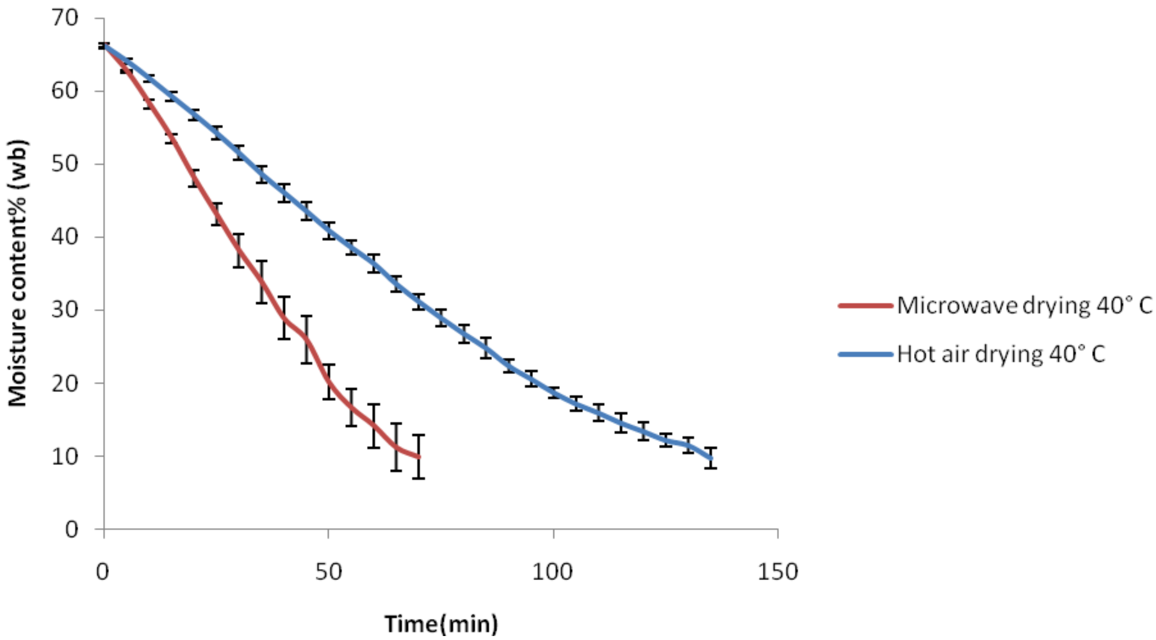

Figure3. Comparison of microwave and hot air drying at 40° C

Figure 3 shows that the hot air drying of flax straw from an initial moisture content of 70% (wet basis) to the final moisture content of 9% (wet basis) took 131.5 minutes while the microwave drying at the same temperature took only 91 minutes. The microwave drying of flax straw showed 30.8% reduction of time when compared to the hot air drying at the same temperature of 40°C.

The microwave drying of flax straw at 60° C took 28 minutes to reach the final moisture content of 9% (dry basis) from an initial moisture content of 67% (wet basis). The hot air drying at the same temperature of 60° C took 62 minutes (Figure 4). So there is a 54.8 % reduction in time with microwave drying.

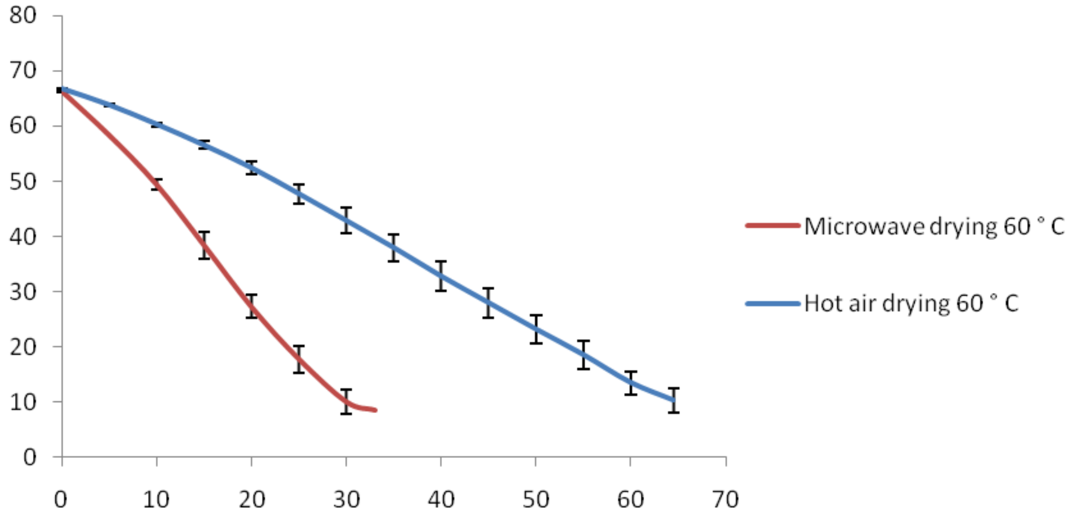

Figure 4. Comparison of microwave and hot air drying at 60° C

The comparison of microwave drying and hot air drying at 80° C is shown in Figure 5. Hot air drying was completed in 50.5 minutes from the initial moisture content of 67% (wet basis) to the moisture content of 9% (wet basis) while the microwave drying took only 30 minutes to reach the same final moisture content. It shows a 48.5 % reduction of time with microwave drying.

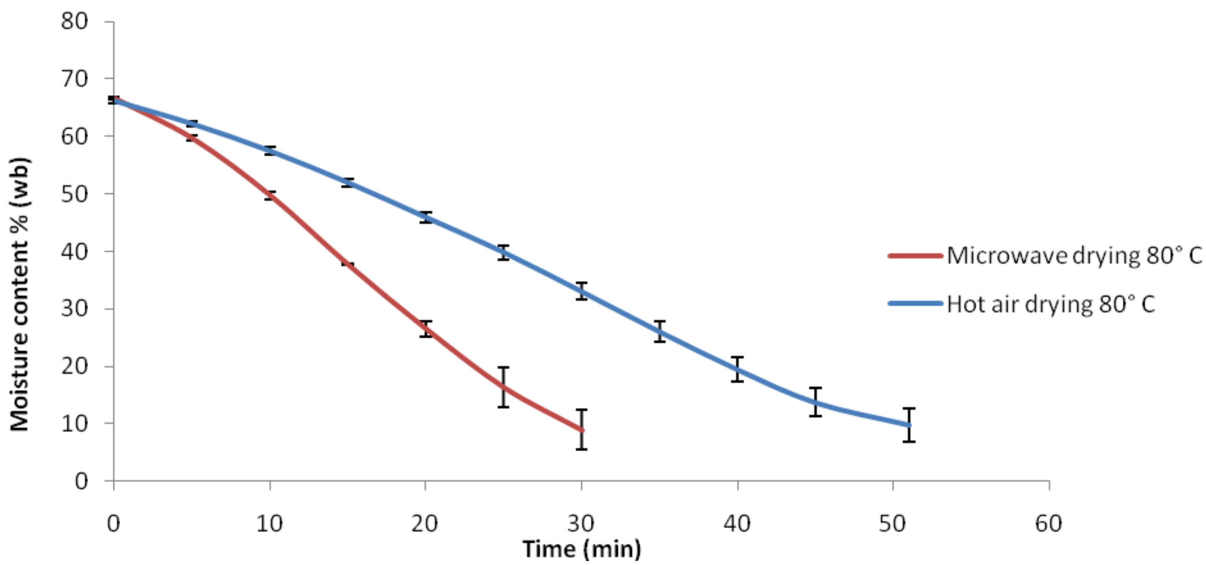

Figure 5. Comparison of microwave and hot air drying at 80° C

Considering both drying methods at three different temperatures of 40° C, 60° C and 80° C, it is observed that the percentage reduction of drying time was 30.8%, 54.8% and 48.5 % respectively.

3.2 Flax fibre: The microwave drying of flax fibre was done at temperatures of 40° C, 60° C and 80° C. The initial moisture content was 60% (wet basis) till it reached the final moisture content of 9% (wet basis). The results were compared with hot air drying at 40° C, 60° C and 80° C.

The microwave drying of flax fibre at different temperatures 40° C, 60° C and 80° C are shown in Figure 6.

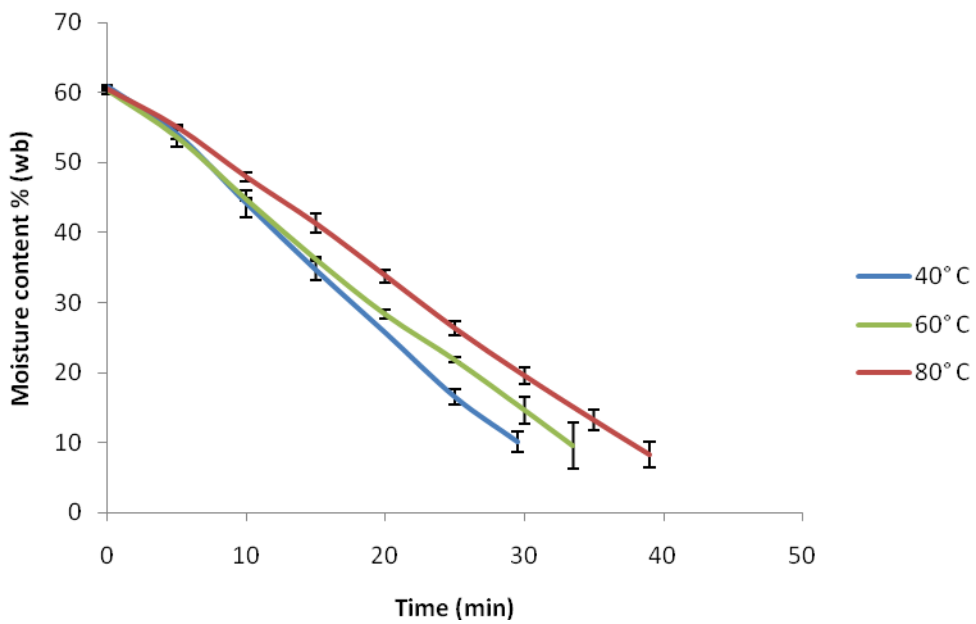

Figure 6 Microwave drying of flax fibre at 40° C, 60° C and 80° C

The microwave drying of flax straw at 80° C took 28.5 minutes to reach a final moisture content of 9% (wet basis) from 60% (wet basis) while 40° C microwave drying took 37 minutes to reach the final moisture content of 9% (wet basis). The microwave drying at 60° C took 34 minutes to reach the final moisture content of 9% (wet basis).

The microwave drying at 40° C was compared with the hot air drying at 40° C in Figure 7. From the graph, it is seen that the microwave drying of flax fibre took 37 minutes to reach a final moisture content of 9% (wet basis) from the initial level of 60% (wet basis) while the hot air drying took 125 minutes to reach a final moisture content of 9% (wet basis). Microwave drying achieved a percentage reduction of 70.4% of hot air drying time.

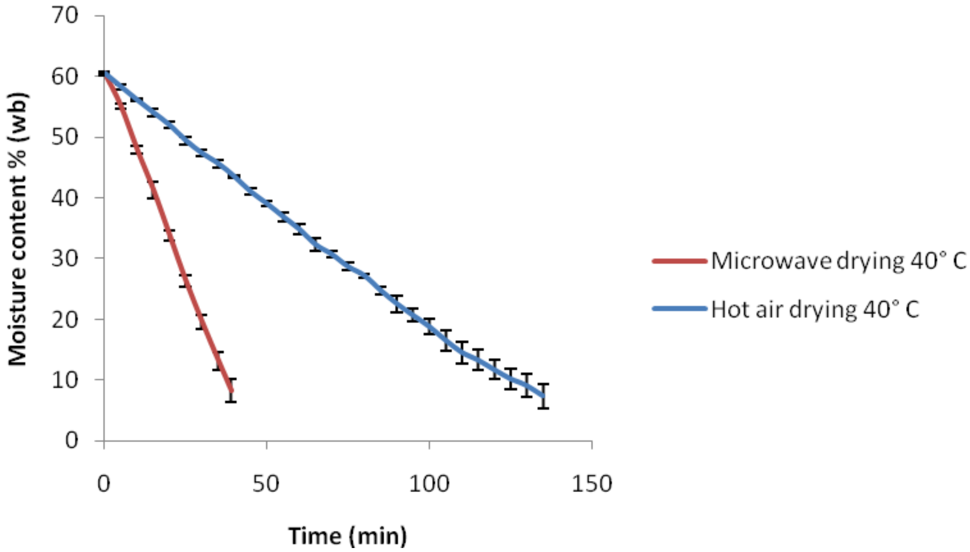

Figure 7. Comparison of microwave and hot air drying at 40° C

The drying of flax fibre at 60° C with microwave and hot air is shown in Figure 8. The hot air drying of flax fibre took 76.5 minutes to reach the final moisture content of 9 % (wet basis) from the moisture content of 60% (wet basis) while microwave drying took only 34 minutes to reach the same level. So the microwave drying of flax fibre at 60° C showed a percentage reduction of drying time of 55.6% compared to hot air drying.

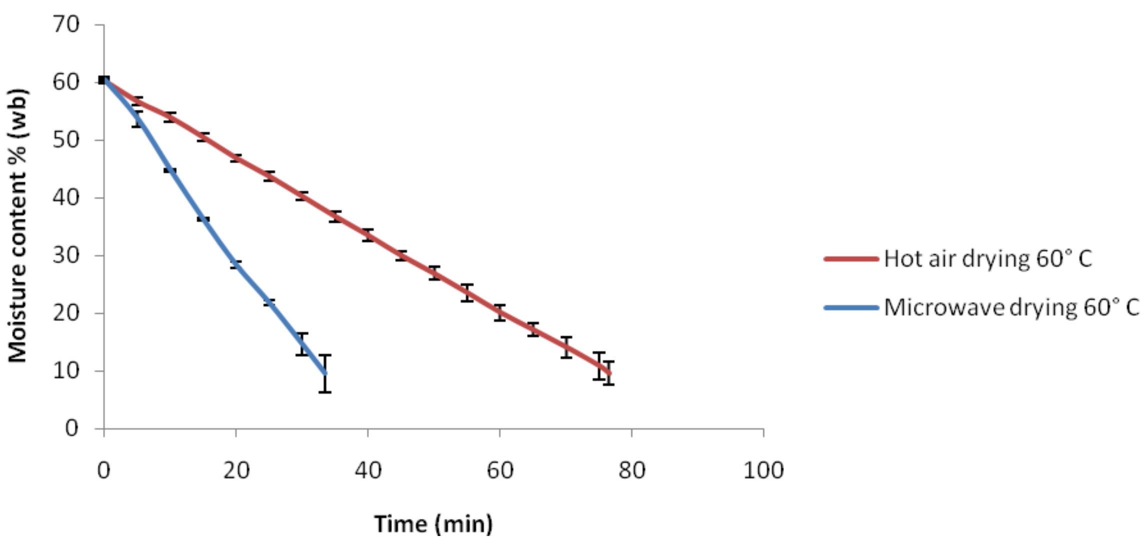

Figure 8. Comparison of microwave and hot air drying at 60° C

The comparison of microwave drying with hot air drying at 80° C is shown in Figure 9.

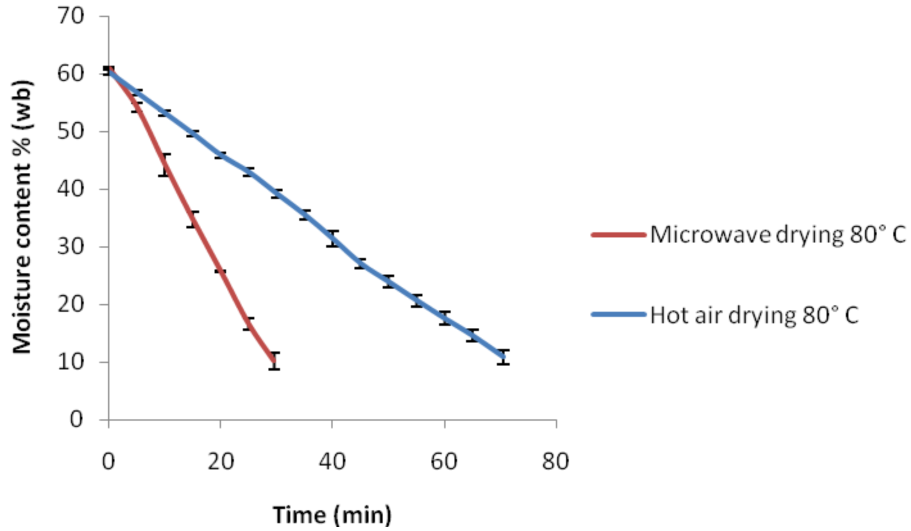

Figure 9. Comparison of microwave and hot air drying at 80° C

The hot air drying took 70.5 minutes to reach the final moisture content of 9% (wet basis) from the moisture content of 60% (wet basis) while microwave drying took only 28.5 minutes to reach the same level of 9% (wet basis). So the microwave drying of flax fibre at 60° C showed a percentage reduction of time of 59.6% compared to hot air drying.

Discussion

The microwave drying of flax straw and fibre at controlled temperatures of 40° C, 60° C and 80° C showed considerable reduction in drying time as compared to the hot air drying at the same temperature ranges. But in microwave drying, the difference of drying time with initial and final phase was very less. The microwave – convective drying and hot air drying were compared, and the microwave- convective drying at 60° C is the suitable method for flax fibre and straw in terms of reducing drying time and in terms of quality.

Acknowledgement

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