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INFLUENCE OF MICROWAVE DRYING ON THE CONTENT OF PHOTOSYNTHETIC PIGMENTS IN SPINACH

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Abstract: *Drying is the process of removing the moisture in the product up to certain threshold value by evaporation. In this way, the product can be stored for a long period, since the activities of the microorganisms, enzymes or ferments in the material are suppressed via drying.Spinach leaves (Spinacia oleracea) were dried using two different methods: hot air and microware drying. The aim of this study was to determine the effects of the microwave output power on drying time, moisture content, moisture ratio and the dried product quality in terms of chlorophyll content. 10 g of leaf samples were dried in an oven at* 100^0C *to asses their initial moisture content. Six different microwave output powers (120, 280, 340, 460, 600 and 700 W) were investigated in drying experiments at constant sample loading. Microwave drying period lasted between 3 and 10 minutes. Increasing the microwave output power resulted in a considerable decrease in drying time. The content of chlorophylls was colorimetrically determined by measuring absorbance in the absorbance maximum for these pigments. The chlorophylls were extracted using acetone which was proven to be one of the most efficient solvents. Results showed that the optimum microwave power for drying in terms of chlorophyll content is 340W.*

Keywords: *microwave drying, chlorophyll content, drying rate*

1. Introduction

Spinach (*Spinacia oleracea L.*) is a cool season annual vegetable. Leaf vegetables, including spinach, compose an important group of plant foods. Spinach has a high content of vitamins, carotenoids, chlorophylls, organic acids and alkaline mineral constituents as well as antioxidants [1, 2].
It is a popular vegetable that is eaten raw, boiled or baked into various dishes. Spinach is low in calories and is a good source of ascorbic acid [3]. Spinach is a vegetable which rapidly perishes after harvest and which is consumed only in the product season. Drying is the one of the storage methods, which has the capability of extending the consumption period of spinach, yet maintaining its vitamin content.
Drying is one of the oldest methods of food preservation and represents a very important aspect of food processing. Food drying is a traditional method of food preservation which is also used for the production of special foods and food ingredients [4].
Drying not only affects the water content of the product, but also alters other

physical, biological and chemical properties such as enzymatic activity, microbial spoilage, viscosity, hardness, aroma, flavor and palatability of foods [5].

Natural drying (drying in the shade) and hot air drying are still most widely used methods to produce dried foodstuffs. Natural drying has many disadvantages due to the inability to handle the large quantities and to achieve consistent quality standards [6].

Hot-air drying leads to serious injuries such as the worsening of the taste, nutritional content and color of the product, decline in the water absorbance capacity, density and shifting of the solutes from the internal part of the drying material to the surface, due to the long drying period and high temperature [7-12].

Compared to hot air drying, microwave energy applications in the drying of vegetables have several advantages including the shortening of drying time, a homogenous energy distribution on the material and formation of suitable dry product characteristics due to the increase in temperature in the centre of the material. Among the other benefits of using microwave drying are inhibition of high surface temperatures, continuation of the product respiration, lowered product temperatures when combined with vacuum drying, reduction in the loss of water-soluble components and energy savings [13].

The aim of this study was to determine the microwave drying characteristics of spinach and to compare hot-air drying to microwave drying which reduces drying time considerably.

Also the effect of these drying techniques on the chlorophyll content of spinach was determined.

2. Experimental

2.1. Materials

Fresh spinach leaves were purchased from the local market. They were washed and stored at 4^0C in refrigerator for about one day for equilibration of moisture. Before drying experiments, the samples were taken out of the refrigerator and leaves were separated from stems and then weighed.

2.2. Methods

2.2.1. Microwave drying

A programmable domestic microwave oven with maximum output of 700W was used in the drying experiments. The oven was operated at microwave output powers of 120, 280, 340, 460, 600 and 700 W. Five grams of spinach leaves were spread evenly on a glass microwave oven plate and processed until the leaves were completely dried. The mass of the samples was measured every 1 minute during the drying procedure using a digital balance.

The following common semi-empirical equations (Eq. (1) and (2)) was used to describe the thin layer drying kinetics of spinach leaves [14, 15], where MR is the moisture ratio and DR is drying rate; M_t is the moisture content at a specific time (g water·g dry base^{-1}); M_e is the equilibrium moisture content was assumed to be zero for microwave drying; M_0 is the initial moisture content (g water·g dry base^{-1}); M_{t+dt} is the moisture content at t+dt (g water·g dry base^{-1}) and t is drying time (minutes). The equilibrium moisture content (Me) was assumed to be zero for microwave drying [16, 23].

$$MR = \frac{M_t - M_e}{M_0 - M_e} \qquad (1)$$

$$DR = \frac{M_{(t+d_t)} - M_t}{d_t} \qquad (2)$$

2.2.2. Quantification of photosynthetic pigments

Pigments were extracted from the dried materials using acetone, as extraction solvent. The ratio dried material: solvent was of 1:10. Quantification of photosynthetic pigments was performed on a ThermoSpectronic Genesys 20. The corrected equations for the quantitative evaluation of chlorophyll a and b in acetone were used as previously determined in other studies [17, 26, 30].

3. Results and Discussion

The moisture content versus time curves for microwave drying of spinach leaves as influenced by microwave output power are shown in Figure 1.

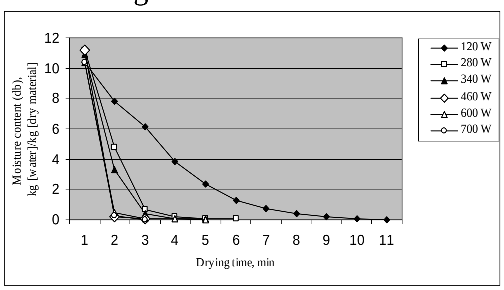

Figure 1. Drying curves of spinach leaves under various microwave output powers

The time required from the lowering of moisture content of spinach levels to 0,1 level varied between 3 and 11 minutes depending on the microwave power level.

As the microwave output power was increased, the drying time of leaves was significantly reduced. Similar findings were reported by several authors [18-21]. By working at 700W instead of 120W, the drying time is shortened by 75%. The drying rate was calculated as the quantity of moisture removed per unit time, per dry matter. The drying rate curves for spinach dried at different microwave output powers are given in Figure 2. The moisture content of the material was very high during the initial phase of the drying which resulted in a higher absorption of microwave power and higher drying rates due to the higher moisture diffusion. As the drying progressed, the loss of moisture in the product caused a decrease in the absorption of microwave power and resulted in a fall in the drying rate. Higher drying rates were obtained at higher microwave output powers. Thus, the microwave output power had a crucial effect on the drying rate. Similar findings were reported in previous studies [16, 21, 22].

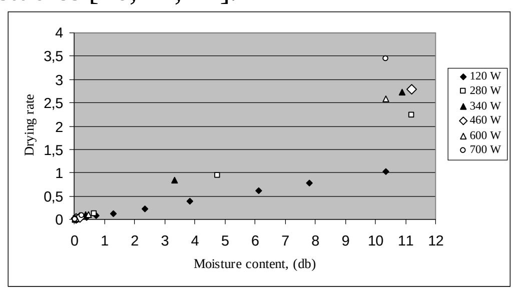

Figure 2. Drying rate curves for spinach leaves under various microwave output powers

The drying rate decreased continuously throughout the drying period. It is obvious from Figure 2 that the constant rate period was absent; all drying process of spinach took place in falling rate period. These results are in good agreement as compared to the earlier studies of various vegetables [23-25].

Figure 3 shows the moisture ratio versus the drying time through the semi-empirical equations (1).

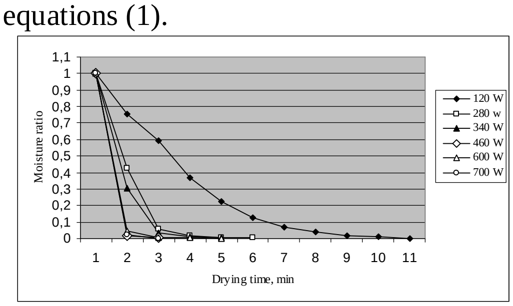

Figure 3. Moisture ration versus time curves for spinach leaves under various microwave output powers

Ultraviolet-visible spectroscopy was used for the quantification of photosynthetic pigments from dried material depending on the microwave output power.

Figure 4 shows the dependence between the microwave output power and the content of chlorophylls of the dried material. The highest concentration of chlorophylls is obtained for the samples dried at 336W.

Results showed that a prolonged application of microwave radiation determined a decrease in chlorophyll content. Also the content of chlorophylls is also diminished when a high microwave radiation is applied to samples.

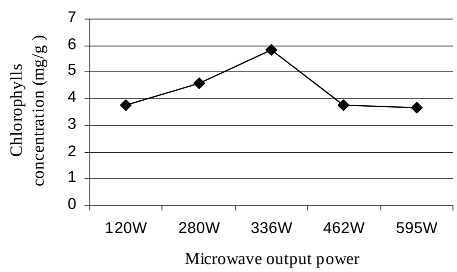

Figure 4. Chlorophyll content dried spinach leaves under various microwave output powers

The values for chlorophyll content in the samples dried using microwave radiation varied from 3,75mg/g dried material.

The chlorophyll content in the samples dried using hot-air was 2,48mg/g dried material. This value can be explained by the fact that photosynthetic pigments are highly susceptible to degradation during thermal treatment. The hot-air drying of spinach involved a 2 hours thermal treatment which determined a much pronounced degradation of chlorophylls.

4. Conclusion

Microwave drying techniques can greatly reduce the drying time of biological materials without quality degradation [13, 16, 21, 27-29].

Compared with hot-air drying microwave drying offers opportunities as energy saving, precise process control, uniform energy and high thermal conductivity to the inner sides of the material, space utilization, sanitation, and high quality of the finish product. It also reduces the drying time and prevents food from decomposing [31, 32].

In the present study the microwave drying period of spinach varied from 3 to 10 minutes depending on the microwave powers. Drying time decreased considerably with increased microwave output power. Therefore microwave output power had a crucial effect on the drying rate.

The chlorophyll contents varied from 3,76 to 5,84mg/g dried material. The highest value was obtained for the sample dried at 340W. Also the lowest values for chlorophyll content, 2,48mg/g dried material, was obtained for hot-air dried material.

As an overall conclusion, compared to hot-air drying, the use of microwave rays in the drying of products has become widespread because it minimizes the decline in quality and provides a reduced drying time.

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