ABSTRACT

This study aimed to develop an infrared dryer and to evaluate the quality of ultrasound assisted infrared dried samples of moringa leaves and beetroot slices. A semi-continuous infrared dryer was developed comprising of a drying chamber, a conveyor belt, six ceramic infrared heaters, a blower and a control panel. The quality attributes of the ultrasound pretreated infrared dried samples were compared with conventional drying methods such as heat pump dryers and cabinet dryers.

Ultrasonic pretreatment was carried out using an ultrasound bath with a chiller having a capacity of 10L operating at a frequency of 33 kHz and having an output power of 250W. The ultrasound pretreatments were performed according to the central composite design (CCD) with three levels of sonication temperature (10℃, 20℃ and 30℃) and five levels of treatment time (5, 10, 15, 20 and 25 min). Moisture content, water activity, vitamin C, antioxidant activity, betalain content and colour were selected as the response variables. The ultrasound pretreated samples showed an increase in moisture content, enhanced extraction of vitamin C and betalain content and improved antioxidant activity. The optimized process parameters for ultrasound pretreatment viz. temperature (22.65°C) and exposure time (25 minutes), resulted in moringa leaves with 83% moisture content, 0.98 water activity, 287.48 mg/100 ml vitamin C, 73.99% antioxidant activity inhibition, and color values of 36.56 L*, -12.08 a*, and 23.19 b*. The process achieved a desirability score of 0.893. The methodology of the desired function yielded optimal parameters of 25.55°C for 25 minutes, resulting in beetroot with 91.6% moisture content, 0.99 water activity, 37.61 mg/100 g betalain, 85% antioxidant activity inhibition, and color values of 25.75 L*, 31.38 a*, and 9.09 b*. The process achieved a desirability score of 0.880.

The drying experiments were conducted using a Box-Behnken Design (BBD). For moringa leaves, three levels of temperature: 40°C, 50°C, and 60°C, three levels of heater speed (20, 30, and 40 rpm) and three levels of airflow rate (0.5, 1.0, and 1.5

m/s) were selected for optimization. The response variables measured included drying time, water activity, rehydration ratio, shrinkage, color, and energy consumption. Infrared drying of moringa leaves resulted in a reduction in moisture content as a function of drying time, achieving a drying efficiency of 56.74%, with specific energy consumption of 9.17 kWh/kg and a capacity of 6 kg per batch.. The desirability function methodology indicated that optimal drying conditions were achieved at 60°C, 0.94 m/s airflow rate and 39 rpm heater speed, resulting in a drying time of 13.83 minutes, water activity of 0.381, rehydration ratio of 5.68 with an energy consumption of 0.74 kWh and an overall desirability score of 0.910. Response surface methodology applied to beetroot demonstrated a reduction in drying time with an increase in temperature. The desirability function methodology identified optimal drying conditions at 69.4°C, 1.5 m/s airflow rate, and 20 rpm heater speed. Under these conditions, the drying time, water activity and rehydration ratio were 0.87 hours, 0.313 and 8.37, respectively, with an energy consumption of 3.52 kWh and an overall desirability score of 0.910. Infrared drying technique is associated with an enhanced moisture diffusivity and reduced activation energy. Hence the drying time of infrared samples were reduced by 50% compared to the other conventional dryers.

Moringa leaves and beetroot were subjected to dry under optimal temperature in the infrared dryer, heat pump dryer and cabinet dryer to select the best drying techniques. Various biochemical and proximate analysis revealed that the ultrasound pretreated infrared dried samples had a greater acceptance limit with reduced energy consumption and drying time. Microstructural analysis of the dried product indicated enhanced pore size for infrared dried samples, resulting in an elevated rehydration ratio. Compared to the other conventional dryers the colour was more preserved in infrared dryer which indicated consumer acceptance and enhanced market value. The benefit cost ratio of ultrasound assisted infrared drying of moringa leaves was 1.03:1 with a payback period of 1.38 years, whereas the benefit cost ratio of ultrasound assisted infrared drying of beetroot samples was 1.28:1 with a payback period of 1.28 years. Ultrasound pretreated infrared drying technology presents a promising solution for small and medium-scale growers and entrepreneurs, enabling them to efficiently process agricultural produce while maintaining high-quality standards.