Drying and Quality Characteristics of Kale by Infrared Heating

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Abstract

Kale has high nutritive and dietetic value and is particularly rich in antioxidants. But it has a short shelf life as a fresh produce. To develop a drying method for kale using infrared (IR) heating, shredded kale samples (5 cm x 3 cm) were dried using IR radiation emitted by quartz tubular electric IR emitters and the quality attributes of dried kale samples were compared to those of hot air (HA) dried samples. The results showed that IR drying at product temperatures of 60℃, 65℃ and 70℃ required 70, 60 and 50 min, compared to 5, 4.5 and 4 h required by HA drying at 60℃, 65℃ and 70℃, respectively. IR drying at 70 ℃ reduced the drying time by 190 min or 79%. The infrared dried kale samples had a significantly higher quality attributes in terms of color, chlorophyll, carotenoids, and phenolic and vitamin C contents, and DPPH scavenging activity due to significant reduction in drying time. The IR dried samples also exhibited similar rehydration ratio and shrinkage degree with HA dried samples. These findings demonstrated that the IR drying is a very promising method for drying kale for use as dehydrated chips or rehydrated vegetable.

Introduction

Kale (*Brassica oleracea* L. var. *acephala* D.C.) is a leafy green vegetable that has high nutritive and dietetic values with cancer preventative properties. However, it has a short shelf life at ambient temperature and can be spoiled easily after harvest. HA drying of kale takes several hours and has low energy efficiency. The present demand for high-quality products in the snacks food market requires dehydrated foods produced with less environmental impact retaining the nutritional and organoleptic properties of the initial fresh product. IR drying has been investigated as a potential method to produce high quality dried foodstuffs, including fruits and vegetables, due to its potential advantages over conventional drying including high drying rate, high energy efficiency, high quality finished products, uniform temperature, and low footprints. IR drying was applied in this investigation to produce high quality dried kale.

Objectives

1. To study the drying characteristics of kale using IR heating
2. To evaluate the quality attributes of kale dried by IR and HA

Materials and Methods

Fresh kale samples purchased from the local market were washed, stemmed, and shredded into pieces of 3 cm × 5 cm. The kale pieces were dried using IR radiation emitted by three (480 watts) quartz tubular electric IR emitters and also by HA (2.0 m^3/min) by spreading in single layer. IR drying was performed at three product temperatures of 60ºC, 65ºC and 70ºC and 3 HA temperatures of 60ºC, 65ºC and 70ºC were used for HA drying. Initial moisture content (MC) of kale was determined by hot air oven drying method (105ºC for 24 h) and the MC during drying was calculated from the moisture loss by weighing the samples at 30 min intervals. Analytical grade chemicals were used in the determination of chlorophyll content, carotenoids, total phenolic, vitamin C contents, peroxidase and DPPH scavenging activities of kale samples dried by both IR and HA.

Results

1. Temperature profile and drying curves of kale

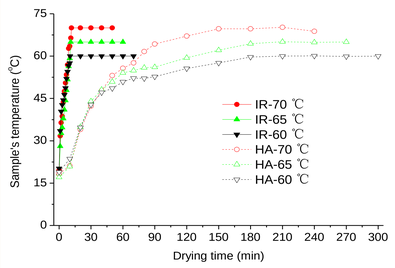


Fig.1. Temperature profile of kale during IR and hot air drying

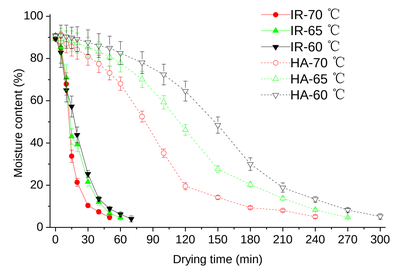


Fig.2. Effect of IR and hot air drying on moisture content of kale samples

IR drying at kale temperatures of 60ºC, 65ºC and 70ºC reduced the drying time by 190 min or 79%, 210 min or 78% and 230 min or 77%, compared to HA drying at 60ºC, 65ºC and 70ºC, respectively.

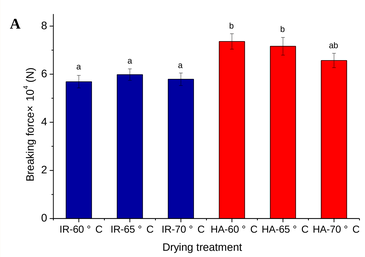
2. Quality of dried kale samples

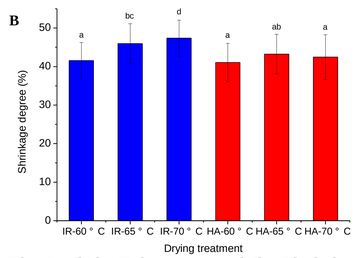
a. Color

Fig.2. Color of dried and fresh kale samples

IR dried kale samples had an attractive green color than hot air dried samples.

b. Crispness, shrinkage degree and rehydration ratio





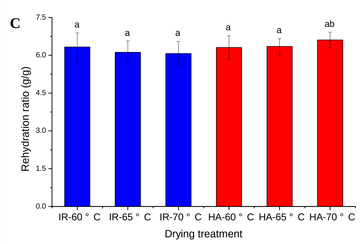


Fig.3. (A) Crispness, (B) Shrinkage degree, and (C) Rehydration ratio of IR and hot air dried kale samples

HA dried kale had slightly better crispness than IR dried samples. HA and IR dried kale samples had similar shrinkage degree and rehydration ratio.

Results (Continued)

c. Chlorophyll contents

Table 1. Chlorophyll contents of IR and HA dried kale samples

Drying treatment	Chlorophyll a (mg/100g DW)	Chlorophyll b (mg/100g DW)	Total Chlorophyll (mg/100g DW)	Chl a : Chl b
IR, 60 ℃	109.96±9.13^{cd}	51.47±4.67^{bc}	161.43±12.82^{c}	2.14±0.18^{b}
IR, 65 ℃	105.74±9.54^{c}	48.34±4.01^{b}	154.08±13.19^{b}	2.19±0.17^{b}
IR, 70 ℃	119.76±8.79^{e}	52.85±5.03^{c}	172.61±14.14^{c}	2.27±0.20^{bc}
HA, 60 ℃	96.48±9.75^{b}	56.09±5.39^{c}	152.57±14.67^{b}	1.72±0.15^{a}
HA, 65 ℃	77.93±6.87^{a}	36.23±3.65^{a}	114.16±10.78^{a}	1.69±0.15^{a}
HA, 70 ℃	76.86±6.98^{a}	45.52±3.96^{b}	122.38±19.47^{a}	2.15±0.18^{b}

d. Carotenoids, total phenolic and vitamin C contents

Table 2. Carotenoids, total phenolic, and vitamin C contents of IR and HA dried kale samples

Drying treatment	Carotenoids (mg/100g DW)	Total phenolics (mg GAE/100g DW)	Vitamin C (mg/100g DW)
IR, 60 ℃	15.96±0.72^{cd}	895.96±60.16^{c}	153.87±12.35^{d}
IR, 65 ℃	14.17±0.68^{c}	834.15±36.66^{c}	145.16±12.44^{d}
IR, 70 ℃	12.43±0.61^{c}	794.93±18.80^{b}	120.67±10.61^{c}
HA, 60 ℃	8.32±0.37^{b}	693.24±70.13^{a}	73.11±6.29^{b}
HA, 65 ℃	7.84±0.35^{b}	832.82±36.30^{bc}	69.98±6.11^{b}
HA, 70 ℃	6.06±0.31^{a}	702.61±26.32^{a}	54.52±4.97^{a}

e. Peroxidase and DPPH scavenging activities

Table 3. Peroxidase and DPPH scavenging activities of IR and HA dried kale samples

Drying treatment	Peroxidase activity (U/mg protein)	DPPH scavenging activity/IC_{50} (mg/ml)
IR, 60 ℃	17.35±1.41^{e}	3.13±0.15^{a}
IR, 65 ℃	14.69±1.63^{d}	3.29±0.16^{a}
IR, 70 ℃	10.87±1.02^{bc}	3.95±0.21^{bc}
HA, 60 ℃	9.05±0.67^{b}	5.07±0.32^{e}
HA, 65 ℃	8.92±.074^{b}	3.78±0.19^{b}
HA, 70 ℃	7.29±0.69^{a}	4.62±0.35^{d}

IR dried kale samples had a better quality attributes in terms of chlorophyll, carotenoids, phenolic and vitamin C contents, and DPPH scavenging activity due to significant reduction in the drying time by IR drying than HA drying.

Conclusions

1. IR drying of kale at the product temperatures of 60ºC to 70ºC resulted in significant drying time reduction of 77-79%, compared to HA drying at 60ºC to 70ºC.
2. The infrared dried kale samples had a significantly higher quality attributes in terms of attractive dark green color, chlorophyll, carotenoids, phenolic and vitamin C contents, and DPPH scavenging activity compared to HA dried samples.

Acknowledgements

Authors acknowledge the California Energy Commission (CEC) for funding this research project (# PIR 13-007).

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