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Comparative evaluation of physical properties and volatiles profile of cabbages subjected to hot air and freeze drying

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ABSTRACT

The aim of the present study was to evaluate the physical parameters, volatiles profile and sensory quality of the cabbage pieces subjected to hot air drying and freeze drying processes. Physical properties such as water activity, shrinkage, hardness, springiness, cohesiveness, chewiness, rehydration ratio and color measurements were measured using standard procedures while the volatile compounds were determined by the SPME-GC-MS method. The results showed that convective drying of cabbages lead to major adverse changes in physical and volatile compounds characteristics. Hot air and freeze drying of cabbages display different volatiles profile containing aldehydes, alcohols, terpenes, ketones and furans. Better retention of character impact cabbage green and pungent aroma compounds viz. allyl isothiocyanate, dimethyl sulfide, dimethyl disulfide, 1-octen-3-ol and (Z)-2-penten-1-ol was found in freeze dried cabbage. The presence of 3-(methylthio)-propyl isothiocyanate, methyl benzene isothiocyante and phenyl ethyl isothiocyanate is reported here for the first time in fresh cabbages. The flavor components of fresh cabbage were largely retained in the freeze dried product. Freeze drying also leads to positive sensory effects and better overall acceptability by consumers compared to the hot air dried product.

1. Introduction

The traditional hot air drying and low temperature vacuum freeze drying play vital roles in the dehydration process (Song, Cui, Jin & Mujumdar, 2015). Major quality parameters associated with dried food products are color, visual appeal, shape, flavor, microbial load, retention of nutrients, porosity, bulk density, texture, rehydration properties, water activity, freedom from off-odors (Chena & Opera, 2013).

Cabbage (*Brassica oleracea* L.) belongs to the family of Brassicaceae. It is widely cultivated and enjoys worldwide acceptance. It is economically a very important vegetable as it contains enriched amounts of phytochemicals and phytonutrients (Gong, Zhang, & Sun, 2007). Cabbage contains many flavor compounds; however, there are very few publications dealing with in-depth analytical study of cabbage volatiles. More than 16 compounds representing glucosinolates, sulfides, sugars, and some alcohols and aldehydes are reported to influence its flavor (Radovich, 2010). Lonchamp, Barry-Ryan, and Devereux (2009) reported the key volatile compounds of ready-to-use cabbages being 1, 4-dichlorobenzene, limonene, dimethyl sulfide, dimethyl disulfide and allyl isothiocyanate during different storage period. Hong and Kim (2013) analyzed hydrolysis products and other volatile constituents from Korean cabbages and its seeds which resulted in the identification of 16 and 12 volatile compounds, respectively. The primary volatile compound found in the cabbage was ethyl linoleolate, while 4,5-epithiovaleronitrile was the primary volatile component in the seed.

Although there are several techniques employed to extract the volatile compounds from food materials, solid-phase microextraction (SPME) has been considered to be a successful approach for volatiles capture in food analysis. It offers a simple and efficient sample preparation procedure that affords a versatile and sensitive

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detection method when the volatile compounds are analyzed in gas chromatography and mass spectrometry (GC-MS) system. All previous literature revealed the volatiles profile of the seeds of cabbages, cooked cabbages, cabbage powder and fresh cabbage (Hong & Kim, 2013; Radovich, 2010). To the best of author's knowledge there has not been any report on capturing and monitoring of volatiles in dehydrated cabbage by SPME technique.

The main objectives of the present study were to address this gap in knowledge and provide the quantitative results showing the changes in physical properties and a detailed volatiles profile on the composition, retention and changes which occur upon subjecting cabbages to dehydration employing hot air drying (HAD) and freeze drying (FD) processes utilizing the SPME technique and subsequently identifying the volatile compounds using GC-MS system.

2. Materials and methods

2.1. Raw material, sample preparation and moisture determination

Freshly harvested cabbages (*Brassica oleracea* L. variety Capitata L.) were procured from the local market in Aracaju, Brazil. The cabbage leaves were trimmed, peeled, washed and cut into slices of about 4.5 cm × 4.5 cm. The initial and the final moisture content of the samples were measured using a moisture analyzer (ML50; A&D Company, Japan) with a precision of 0.001%.

2.2. Drying experiments

The cabbage leaves were subjected to drying by employing a conventional hot air dryer and a freeze dryer. HAD in a shelf dryer (Marconi MA 035/5, Piracicaba, Brazil) was performed at air temperature of 45 °C and air flow rate of 1 m/s. The samples (100 g) were spread uniformly in a single layer in the dryer. At frequent intervals, a small portion of sample was taken out and its moisture content determined. Drying was continued until constant moisture content was achieved in the samples. In FD (Christ Alpha 1-2 LD plus Lyophilizer Shropshire, UK), the samples (100 g) were frozen at −21 °C at an absolute pressure of 85–90 Pa until constant moisture content was achieved in the samples. The dried samples were kept in polythene bags and stored in a desiccator at room temperature (28 ± 2 °C) until further analysis.

2.3. Physico-chemical analysis

2.3.1. Water activity

The water activity (a_w) of the samples was determined at 25 °C using an Aqualab water activity meter (Series 4TEV, Pullman, USA).

2.3.2. Shrinkage ratio

The volume changes of the dried sample were estimated in terms of the shrinkage ratio (SR) measured using a digital vernier caliper (Mitutoyo, Series 500, Japan) and length shrinkage (S_l) and diameter shrinkage (S_d) are calculated as follows:

$$S_l = l_o - l_t/l_o \times 100\%$$

$$S_d = d_o - d_t/d_o \times 100\%$$

where, l_o (mm) and d_o (mm) are length and diameter of fresh sample, l_t (mm) and d_t (mm) are length and diameter of dried sample, respectively. Taking, both these values, the shrinkage ratio was calculated as follows:

$$S_l = L_l - L_x/L_l \times 100\%$$

where, L_l (cm) is the average of length and intermediate diameter of fresh sample, L_x (cm) is the average of length and intermediate diameter of sample after drying.

2.3.3. Texture analysis

The mechanical properties of fresh and dried cabbages were evaluated using a Texture Analyzer (Brookfield C 3, Middleboro, USA). The determinations were made using a single pointed aluminum probe (TA3/100), fixture TA-RT-KI and 2.5 kg load cell. The compression distance was 5 mm and the test parameters were as follows: pre-test speed - 2 mm/s, test speed − 0.5 mm/s, post-test speed − 0.5 mm/s, time lag between two compressions − 0 s and data rate − 10 points/s and the following attributes were determined: hardness, springiness, cohesiveness and chewiness from the force-displacement graph of two compression-decompression cycles.

2.3.4. Color measurement

Color analysis was performed by using a color reader (Konica Minolta CR-10, Osaka, Japan). The instrument was calibrated against a ceramic reference and the parameters such as L* (brightness), a* (redness), b* (blueness), h° (hue angle) and C* (chroma) were obtained. Color difference (ÄE) was also calculated in order to evaluate the change in color of dried samples from those of their respective fresh ones using the following formula:

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$$

where ΔL = L-L_0, Δa = a-a_0 and Δb = b-b_0. L_0, a_0, b_0 and L, a, b are the color values of dried and fresh samples, respectively.

2.3.5. Rehydration ratio

The rehydration ratio (RR) of the dried cabbage samples was determined by immersing the samples at 25 °C and 100 °C. A 2.5 g of sample was immersed in boiling water for 10 min and then transferred to a funnel covered with Whatman no. 1 filter paper. Water was drained using a gentle suction until no drop oozes out from the sample. The sample was then removed, weighed and the RR was calculated as follows:

$$RR\ (\%) = \frac{R_2}{R_1}$$

where, R_2 and R_1 are constant masses reached after water absorption (g) and initial weight (g) of the sample, respectively.

2.4. Volatile capture and analysis

2.4.1. HS-SPME technique

Headspace (HS) volatile compounds were collected using a SPME fiber coated with 50/30 μm DVB/CAR/PDMS (Divinylbenzene/Carboxen/Polydimethylsiloxane; Supelco, Bellefonte, USA). The fiber was conditioned by heating (270 °C) in the injection port of GC, following the manufacturer's recommendation prior to the use. The SPME extraction of volatiles was performed following the method of Cheong et al. (2011) with modifications. For HS-SPME extraction, a sample of ground fresh or dehydrated cabbage (2 g) was placed in a 10 mL vial with 2 mL of saturated NaCl and subjected to incubation at 40 °C for 10 min under agitation at 500 rpm. The suitability of the headspace SPME technique for the extraction of compounds depends on the transfer of the analyte from sample to the gaseous phase and consequently on to the fibre (Câmara, Alves,