Synergistic Effect of Acoustic and Vacuum Drying to Antioxidant Attributes of *Cordyceps militaris*

Minh Phuoc Nguyen¹

¹Faculty of Biotechnology, Ho Chi Minh City Open University, Ho Chi Minh City, Vietnam.

Author’s contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Acoustic drying allows the utilization of lower temperatures than conventional methodology in the drying process. Vacuum drying is one of the most energy demanding processes. Water evaporation also takes place at lower temperatures under vacuum and hence the product processing temperature can be significantly lower, offering higher product quality. *Cordyceps militaris* is a well-known entamophagus fungus with wonderful health benefits such as adaptogenic, aphrodisiac, anti-oxidant, anti-aging, neuroprotective, nootropic, immunomodulatory, anti-cancer and hepatoprotective role by its phytochemical constituents. This study focused on the synergistic effects of acoustic and vacuum drying on antioxidant properties of *Cordyceps militaris*. We noticed that acoustic drying at power 800 W in frequency 40kHz combined with vacuum drying at pressure -0.8 bar were suitable for dehydration of this valuable material. From this approach, a combination of acoustic and vacuum drying created a synergistic effect consuming less energy than single drying method because it can be performed at low temperature while maintaining the product quality and wholesomeness. Moisture content is partly removed by acoustic drying and further dehydration in a vacuum dryer to reduce moisture to a stable level.

Keywords: *Cordyceps militaris*; acoustic; vacuum; drying; antioxidant; synergistic.
1. INTRODUCTION

Acoustic drying has potentially great commercial importance. It was used as a pretreatment in many dehydration applications [1]. It creates microscopic pathway inside the sample and this permits the loose movement of moisture from core to surface [2]. The moisture removal from solids produced without any change in liquid phase. The effects of acoustic dehydration are more significant at low temperature which reduces the probability of food decomposition [3]. Heat sensitive components may be dried with the acoustic drying to avoid alterations of flavour, colour and nutritional values [4]. Improved energy efficiency, better quality products, decreased environmental impact and safety of system are considered as benefits reported for this emerging technology [5].

Vacuum drying is an important process for drying highly heat-sensitive materials. The use of vacuum drying lowers the solvent boiling temperature, permitting operation at lower temperatures, directly influencing final product quality [6]. Vacuum-dried materials are characterized by better quality retention of nutrients and volatile aroma [7]. Vacuum-drying consequently requires less drying time than conventional hot-air-drying and in most cases results in a higher quality dried product.

Mushrooms are popularly exploited for their excellent nutrients and therapeutic functions. Cordyceps militaris is highly valued as staple component of the traditional Chinese and Tibetan medicine [8]. Cordyceps militaris is a well-known entomaphagus fungus with wonderful health benefits by its adaptogenic, aphrodisiac, anti-oxidant, anti-aging, neuroprotective, nootropic, immunomodulatory, anti-cancer and hepatoprotective role [9-13]. C. militaris is a parasitic fungus on Lepidoptera larvae which has been used as a traditional medicine in China. Polysaccharides and cordycepin exist in C. militaris that make up the fruiting body, mycelium or spores responsible for the anti-inflammatory antioxidant, anti-tumor, anti-metastatic, immuno-modulatory [14], hypoglycaemic, steroidogenic and hypolipidaemic effects [15]. C. militaris inhibits cell proliferation in tumor cells in order to develop it as a new agent for the prevention and treatment of cancer [16]. Extract of C. militaris possessed anti-oxidative property dismutase and glutathione peroxide level [17]. Cordyceps has been associated with reduction in cholesterol and triglyceride and an increase in the ratio of high density lipoprotein to LDL cholesterol [18]. Extract of C. militaris included a component acting as an insulin sensitizer [19]. Cordycepin inhibited melanin synthesis related enzymes, such as tyrosinase, tyrosinase [20]. Some notable literatures mentioned to processing of C. militaris. One study determined the effect of drying methods including hot air drying and freeze drying on the quality of cordycepin production from Cordyceps militaris. The antioxidant activity and also total phenolic contents of C. militaris extract prepared from freeze drying had higher value than that of extracted from hot air drying [21]. The changes in moisture content and shrinkage ratio of Cordyceps militaris during mid-infrared-assisted convection drying were studied [22]. Not many reports mentioned to the dehydration of this valuable and sensitive source. Purpose of the present study focused on the synergistic effect of acoustic and vacuum drying on antioxidant characteristics of Cordyceps militaris.

2. MATERIALS AND METHODS

2.1 Materials

The fruiting bodies and mycelium of Cordyceps militaris were used as the raw material. They were obtained from Can Tho city, Vietnam. After collecting, they must be quickly conveyed to laboratory for acoustic drying. Chemical substrances and reagents such as Folin-Ciocalteu reagent, Na₂CO₃, Gallic acid, NaNO₂, AlCl₃·6H₂O, NaoH, catechin, ethanol, methanol, potassium persulfate, phosphate buffer, potassium hexacyanoferrate, trichloroacetic acid solution, ferric chloride, ascorbic acid, ferrous sulfate, FRAP reagent, acetate buffer were all analytical grade supplied from Rainbow Trading Co. Ltd., Vietnam.

2.2 Researching Procedure

Cordyceps militarisss were dried at different acoustic drying power (200, 400, 600, 800, 1000 W) and vacuum drying pressure (-0.2, -0.4, -0.6, -0.8, -1.0 bar) in the same drying temperature (40°C) to the final moisture content 6.0%. All treated samples were then stored in dry cool place before evaluating total phenolic (mg GAE/100 g), total flavonoid (mg GE/100 g), DPPH (%) and FRAP (mmol Fe²⁺/g).
2.3 Antioxidant Capacity and Statistical Analysis

Total phenolic (mg GAE/100 g) was estimated spectrophotometrically using Folin-Ciocalteu reagent [23]. Total flavonoid (mg GE/100 g) was estimated spectrophotometrically [24]. DPPH (%) radical-scavenging activity was determined using reducing power assays [25]. The FRAP (mmol Fe²⁺/g) was determined as described by Chung et al. [26]. The experiments were run in triplicate with three different lots of samples. Statistical analysis was performed by the Statgraphics Centurion XVI.

3. RESULTS AND DISCUSSION

3.1 Effect of Acoustic Drying Power to Antioxidant Capacity of Cordyceps militaris

Ultrasonic waves can cause alternating compressions and expansions resulting in microscopic channels in the porous materials [27]. They intensify the mobility of water molecules and facilitate the evaporation process. In the present research, Cordyceps militaris were dried at different acoustic drying power (200, 400, 600, 800, 1000 W) at the same frequency 40 kHz. Present finding results showed that 800 W of acoustic drying was appropriate for semi-dehydration (see Table 1). The acoustic dehydration was applied in some notable studies. Dehydration of onion slices using sound waves was evaluated. Drying rates were increased by acoustic vibrations and the increase depended on the sound frequency [28]. The effects of ultrasonic power, radiation distance, hot air velocity and temperature on drying characteristics were studied on carrots [29]. It also be used to develop the drying process of such vegetables as apple and mushroom [30].

Table 1. Effect of acoustic drying power (W) to antioxidant capacity of Cordyceps militaris

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Acoustic drying power (W)</th>
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<tbody>
<tr>
<td></td>
<td>200</td>
</tr>
<tr>
<td>Total phenolic (mg GAE/100 g)</td>
<td>42.23±0.03&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total flavonoid (mg GE/100 g)</td>
<td>17.65±0.01&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>DPPH (%)</td>
<td>51.64±0.02&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>FRAP (mmol Fe²⁺/g)</td>
<td>0.41±0.00&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
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</table>

Note: Data are means of three determinations (n = 3) ± SD. Means with different superscripts in each row indicate significant differences at p ≤ 0.05 based on Duncan multiple range test

3.2 Effect of Acoustic Drying Combined with Vacuum Drying Pressure to Antioxidant Capacity in Cordyceps militaris

Vacuum drying technology is an important process for drying highly heat-sensitive materials. The water evaporation proceeds more rapidly at low pressures [31]. To shorten the drying time, ultrasonic treatment and vacuum drying are combined. Mechanical waves produced by the ultrasonic treatment facilitate the transfer of heat and water from inside to the surface of the food. The vacuum dehydration, by disrupting the cell walls of the food, accelerates moisture transfer, which speed up the drying rate [32].

Table 2. Effect of vacuum drying pressure (bar) to antioxidant capacity in Cordyceps militaris

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Vacuum drying pressure (bar)</th>
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<tbody>
<tr>
<td></td>
<td>-0.2</td>
</tr>
<tr>
<td>Total phenolic (mg GAE/100 g)</td>
<td>54.71±0.00&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total flavonoid (mg GE/100 g)</td>
<td>25.78±0.00&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>DPPH (%)</td>
<td>58.65±0.02&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>FRAP (mmol Fe²⁺/g)</td>
<td>0.58±0.01&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Note: Data are means of three determinations (n = 3) ± SD. Means with different superscripts in each row indicate significant differences at p ≤ 0.05 based on Duncan multiple range test
In the present research, the semi-acoustic dried samples were subjected to different vacuum drying pressure (-0.2, -0.4, -0.6, -0.8, -1.0 bar). Present finding results revealed that the most antioxidant characteristics still maintained in maximum level by acoustic drying at -0.8 bar (see Table 2). The combined drying techniques can shorten drying time and improve drying efficiency and the quality of products. In another report, ultrasound-assisted vacuum drying could be used as an alternative drying method for minced meat drying due to lower drying times and higher quality parameters [32].

4. CONCLUSION

Acoustic drying based on the operation of the ultrasonic vibration in direct contact with the product. It represented an emergent, ideal and promising technology because the effects of power ultrasound were more significant at low temperature which reduced the probability of food degradation. We have successfully found the synergistic effect of acoustic and vacuum drying greatly affected to antioxidant capacity and stability of *Cordyceps militaris*. From this combination, the most valuable cordycepin and adenosine inside this precious natural species.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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