

Rapid Detection and Identification of Dioscorine Compounds in *Dioscorea hispida* Tuber Plants by LC-ESI-MS

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Studies have revealed that *Dioscorea hispida* tubers contain a poisonous substance called alkaloid dioscorine. The method for removing alkaloid dioscorine in *Dioscorea hispida* is explored in this research through a soaking process. The tubers were peeled, washed, sliced, and soaked for 5 days in either 1.0 M sodium chloride (NaCl) or distilled water. The aim of this study was to firstly identify the amount of toxic dioscorine remaining after soaking for 5 days, and then determine the best solution for removing dioscorine compounds in the tubers that were obtained from a tropical area in Peninsular Malaysia. The liquid chromatography electrospray ionization mass spectrometric (LC-ESI-MS) systems were used to identify the presence of alkaloid dioscorine compounds within *Dioscorea hispida* tubers. The analysis showed that no dioscorine compounds were present in day 5 for samples soaked in the NaCl solution. However, the relative abundance in the distilled water solution at day 5 was 281000, indicating a 95% decrease of the relative abundance value of the dioscorine compounds. This work aimed to determine the minimum days needed to remove the poisonous element before *Dioscorea hispida* tubers could be used for food consumption or for any other applications.

Keywords: *Dioscorea hispida*; Dioscorine compounds; Alkaloid; Foods; LC-ESI-MS

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INTRODUCTION

Dioscorea hispida, locally known as ubi gadong in Malaysia, is a seasonal plant found in tropical regions such as Malaysia, Indonesia, Vietnam, Thailand, and India. The plant can grow up to 20 m in height and has thorny stems. It is a wild plant with diverse shapes, such as round or oval, and with yellowish-brown skin (Sami and Fata 2019). Recent studies have shown that the *Dioscorea* species can be eaten after undergoing cooking methods such as baking, frying, and boiling (Kumoro *et al.* 2019). This plant belongs to the Dioscoreaceae family and is not frequently consumed by the public because it is a toxic species. It contains the dioscorine alkaloid compound, which can be harmful to health (Napisah and Rosma 2020).

The main challenge faced by researchers is the problem of detoxification. Mlingi *et al.* (1995) state that the safest amount of tubers that can be consumed should not exceed 10 mg of hydrogen cyanide (HCN) per kg of body weight. Dioscorine can be extremely

harmful to humans and may result in poisoning with symptoms ranging from vomiting, nausea, stomach pains, and health complications (Gunawan *et al.* 2019). Dioscorine is a water-soluble alkaloid compound within *Dioscorea hispida* and has the molecular formula of $C_{13}H_{19}O_2N$, which is exceptionally toxic. It is well established regarding the tuber's toxicity in the environment and is generally consumed after undergoing a toxic removal process of the dioscorine compound (Irmayadani *et al.* 2019).

In recent times, there has been growing attention in the agricultural sector for developing biodegradable plastics using *Dioscorea hispida* tubers, sugar palm (Ilyas *et al.* 2018, 2019a, 2019b), sago (Halimatul *et al.* 2019a, 2019b), bengkuang (Syafri *et al.* 2019), potato (Jumaidin *et al.* 2019a), cassava (Jumaidin *et al.* 2019b, 2020), and corn starch (Edhirej *et al.* 2017). The main form of carbohydrates in natural tubers is starch, which has a high percentage of energy contribution to the human diet (Sanyang *et al.* 2018; Ilyas and Sapuan 2020; Nazrin *et al.* 2020). However, plastics developed from *Dioscorea hispida* starch have definite drawbacks in their structural stability compared to conventional plastics, which are known for their stiffness (Navia and Villada 2005). The *Dioscorea hispida* tubers are natural fibers with an abundant source of starch and contain lignin, cellulose, hemicellulose, and fibers (Hamid *et al.* 2019). There are currently only a few published studies focusing on the toxicity removal in *Dioscorea hispida* tubers and their applications. However, there is no information on the specific duration for removing dioscorine from *Dioscorea hispida* tubers through a soaking method with sodium chloride or distilled water. It has been reported that sodium chloride solution for soaking process caused differences in osmosis pressure outside and inside the material. The osmosis diffusion occurred from the inner parts of soaked *Dioscorea hispida* tubers due to the different osmosis pressure after the material being soaked in the sodium chloride solution (Kresnadipayana and Waty 2019).

Liquid chromatography-mass spectrometry is commonly used in many research fields such as in food and safety, environmental, pharmaceuticals, and industrial material purposes (Lee *et al.* 2019). Studies explain liquid chromatography as the separation of compound elements of a sample according to their retention strength for immobile or mobile phases by identifying the separated elements using electrical conductivity followed by LC-MS specifications (Su *et al.* 2019). Recent research has been largely exploratory in nature for the detection of primary substances as references, using time retention and peak intensity (Barbieri and Heard 2019). An early example of chromatography research includes determining the best resolution of qualifying and quantifying substances. However, the chromatography process can be tough for simultaneous multiple analyses (Vinale *et al.* 2020). Twenty cohort study analyses examined the relationship between mass spectrometry (MS), which uses strongly sensitive identification techniques, and the ionization of sample components using multiple methods (Jalal *et al.* 2018). It was found that the separation of resulting ions in a vacuum was according to the mass charge ratios as well as the intensity of each ion (Brown and Carmical 2019).

The role of the mass spectra provided by MS is to specify the concentration position of ions and has shown that mass is the precise information for certain molecules, together with the ability of MS to obtain direct information for identifying a single component. However, it is different for multiple components to analyze the spectra (Naz *et al.* 2019). Although some previous research has been carried out on the method to identify dioscorine compounds such as ultraviolet-visible spectrometry (Kresnadipayana and Waty 2019), TLC densitometry, and TLC image analysis (Sasiwatpaisit *et al.* 2014), no studies have been found which used LC-MS technique. Hence, the combination of LC-MS systems can

be used to identify the alkaloid dioscorine compounds in *Dioscorea hispida* tubers (Hajšlová *et al.* 2018). This is important for determining the amount of dioscorine compounds in *Dioscorea hispida* tubers that can be used for food consumption or any other applications (Leete and Michelson 1988). To date, little reliable evidence is present on the types of solutions that can be used for removing dioscorine in *Dioscorea hispida*. This study aimed to determine the dioscorine toxic compound present in *Dioscorea hispida* tubers after 5 days of soaking through an LC-MS analysis. The *Dioscorea hispida* tubers were obtained from tropical areas in Peninsular Malaysia and their potential use in the development of biocomposites was investigated.

EXPERIMENTAL

Materials

Dioscorea hispida was obtained from fresh tubers from Kuala Terengganu, Malaysia. For the experiment, these tubers went through a process for removing the poisonous element, alkaloid dioscorine. The *Dioscorea hispida* tubers were extracted following the method employed by Mohd. Hori *et al.* (2016). Two different types of solutions were prepared: 1.0 M sodium chloride (NaCl) and distilled water. The tuber pieces were soaked for 5 days in each solution. The NaCl was supplied by Evergreen Engineering and Resources in Sdn Bhd., Malaysia and was used as the solution for removing the toxic elements in *Dioscorea hispida*.

Sample Preparation

The *Dioscorea hispida* (Fig. 1a,b) was cleaned (Fig. 1c) and cut into pieces using a slicer blade having 3 mm thickness, as shown in Fig. 1d. The pieces were weighed using a digital weighing scale into 25 g portions, and 5 samples were prepared for the 1.0 M NaCl and distilled water solutions. The samples were then soaked for 5 days in 500 mL of the selected solutions (Fig. 1e). After the soaking process, the samples of *Dioscorea hispida* tubers went through a blending process (Philips NL 9206AD) to produce a solution mixture as preparation for LC-MS (Agilent 6520 Accurate-Mass Q-TOF) alkaloid dioscorine detection.

Liquid Chromatography

Liquid chromatography-mass spectrometry (LC-MS) was applied to identify the alkaloid dioscorine compound in the solution mixture of *Dioscorea hispida* tubers after soaking completion based on days 1, 2, 3, 4, and 5. An Agilent 1290 Infinity LC system (Santa Clara, CA, USA) coupled with an Agilent 6520 Accurate-Mass Q-TOF mass spectrometer with dual ESI source was used, and the concentration samples were spun at 15000 rpm for 15 min.

The chromatography process was a compound separation method in which two or more elements were separated and optionally spread between two unmixable stages. Liquid chromatography (LC) was performed on an Agilent Zorbax Eclipse XDB-C18 column (narrow-bore 2.1 x 150 mm, 3.5-micron particle size) at 25 °C. The combination of ultra-purified water (H₂O) and acetonitrile (CH₃CN) was employed as the mobile phase. The chromatography was conducted using an isocratic mixture and a linear gradient of ACN, which were 5% at 0 to 5 min, 5 to 100% at 5 to 20 min, and 5 to 100% at 20 to 25 min. The column was flushed with acetonitrile at the end of the chromatographic process and re-

equilibrated for 5 min between individual runs. The flow rate was 0.5 mL/min and the injection volume was 1.0 μ L.

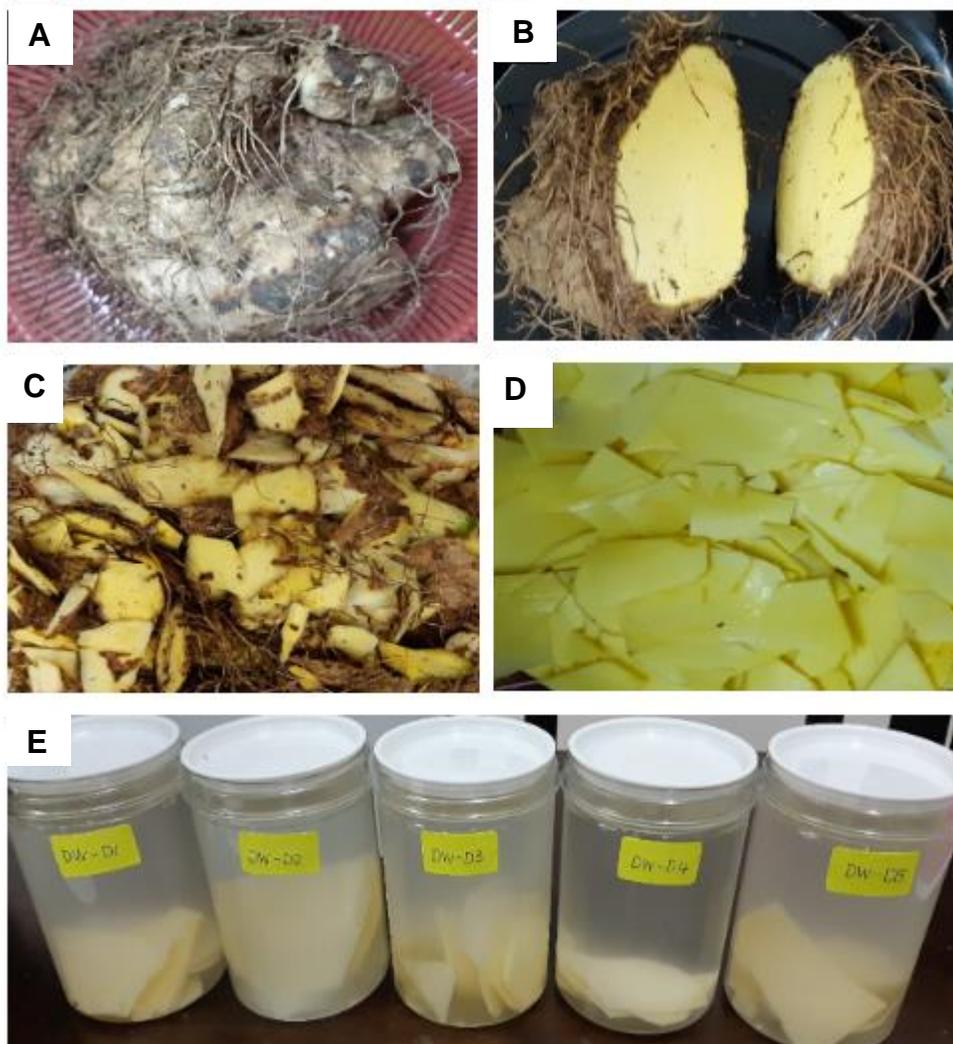


Fig. 1. (A) Irregular-shaped tubers, (B) yellowish-brown *Dioscorea hispida*, (C) peels of *Dioscorea hispida* tubers, (D) slices of *Dioscorea hispida* tubers, (E) soaking process of tubers in 1.0 M NaCl and distilled water solutions

Mass Spectrometry

The positive and negative ion LC-MS spectra were obtained on an ion trap Agilent MassHunter Qualitative Analysis B.07.00 using electrospray ionization (ESI). The analysis identified the polarity after optimizing the instrument settings on the ion charge condition and scanning speed. Nitrogen was applied as a drying gas with a flow rate of 10 L/min, as well as a nebulizer gas at a pressure of 412 kPa. The nebulizer temperature was fixed at 300 °C. The mass spectrometer was recorded in the range between 100 to 3200 m/z, the fragmentor voltage was set at 125 V, and the skimmer voltage was at 65 V.

Compound Identification

In the compound database structure, the MS data of the original compounds were kept in a library as storage data to be used in the Agilent software. Every sample of the

specimen was analyzed by MS and the process data were recorded. The fragmentation patterns from the LC-MS results of the unknown compound were cross-checked against those in the library for positive compound identification. Figure 2 presents the compound structure of dioscorine in the *Dioscorea hispida* tubers.

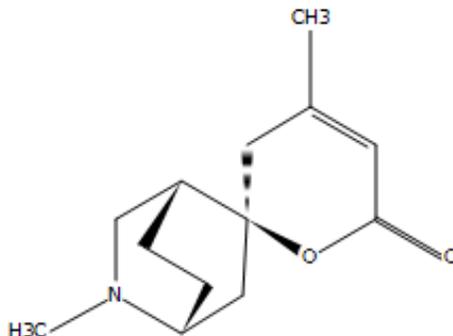


Fig. 2. Dioscorine compound structure (Abiodun *et al.* 2009)

RESULTS AND DISCUSSION

Dioscorine Identification by LC-ESI-MS Analysis

Table 1 provides the experimental data of the *Dioscorea hispida* soaked in distilled water for 5 days. The results indicate that the dioscorine compound composition clearly showed a decreasing trend of relative abundance values. The dioscorine compound screening used a positive polarity mode from day 1 until day 5. However, there was a 95% significant difference between the amount of relative abundance of dioscorine compound for the sample DW-D1 (5373789) to DW-D5 (280835.53). Strong evidence of retention time (R_t) was shown in Table 1, resulting in the positive correlation that the number of days for the soaking process should be increased to remove the toxic elements.

Table 2 provides the experimental data of the soaking process for the *Dioscorea hispida* samples in the NaCl solution. A substantial difference can be seen at SC-D1 (375851.63) and SC-D4 (7141.75). However, the sample SC-D5 detected no dioscorine compound on day 5. The result of soaking *Dioscorea hispida* tubers in the NaCl solution presented more successful findings compared to the distilled water solution. The NaCl solution removed the alkaloid dioscorine more rapidly (approximately 98% amount of relative abundance) compared to distilled water (Kresnadipayana and Waty 2019). The correlation factor is related to different pH of the solutions. Sodium chloride was more neutral with a pH 7, while distilled water was slightly acidic with a pH of 5.8 (Hudzari *et al.* 2012). The abundance amount of dioscorine from these findings specifically supports the hypothesis that the NaCl solution is a better medium for the soaking process and can efficiently remove the poisonous element in *Dioscorea hispida* tubers (Biswal and Bozormer 1991).

As shown in Tables 1 and 2, the retention time (R_t) increased for samples DW-D1 (1.648) to DW-D5 (1.715) in distilled water and SC-D1 (1.693) to SC-D4 (1.718) in the NaCl solution. These results are consistent with the data obtained from the time measurements taken when the solute passed through the column during the LC-MS analysis. Figure 3 presents a graph comparison regarding the amount of relative abundance in *Dioscorea hispida* tubers and the different days and solutions used.

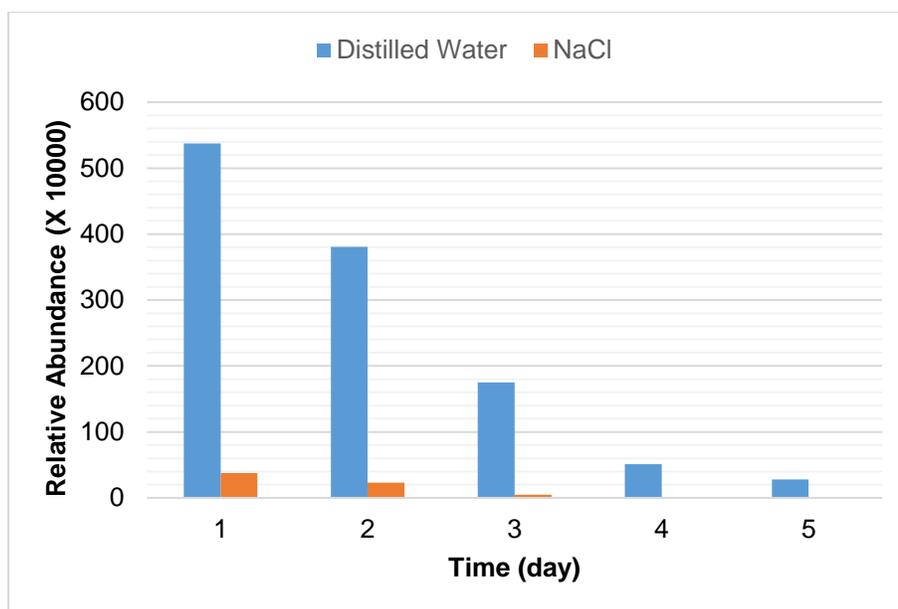


Fig. 3. Relative abundance values in *Dioscorea hispida* for different days and solutions

Table 1. Distilled Water Samples: Polarity, Relative Abundance, Retention Time at MS Obtained with Dual ESI Sources of Dioscorine Compound

Samples	Compound	Polarity	Relative Abundance	Retention Time (R _t)
DW-D1	Dioscorine	Positive	5373789	1.648
DW-D2	Dioscorine	Positive	3806964.25	1.661
DW-D3	Dioscorine	Positive	1751439.63	1.679
DW-D4	Dioscorine	Positive	511627.91	1.707
DW-D5	Dioscorine	Positive	280835.53	1.715

Table 2. Sodium Chloride Samples: Polarity, Relative Abundance, Retention Time at MS Obtained with Dual ESI Sources of Dioscorine Compound

Samples	Compound	Polarity	Relative Abundance	Retention Time (R _t)
SC-D1	Dioscorine	Positive	375851.63	1.693
SC-D2	Dioscorine	Positive	231581.36	1.705
SC-D3	Dioscorine	Positive	46796.39	1.713
SC-D4	Dioscorine	Positive	7141.75	1.718
SC-D5	Dioscorine	Positive	-	-

LC-ESI-MS Spectrum and Fragmentation Pathways for Dioscorine

The LC-MS analysis using ESI is the most popular for identifying the dioscorine compound (Della-Flora *et al.* 2019). Following the present results, these studies have demonstrated that the dioscorine compound had been protonated to the positive mode. It is possible that the mobile phase of 0.1% formic acid enhanced the sensitivity and protonation. The soft ionization techniques produced very little fragmentation, which provides evidence on the molecular mass of the compound (Naz *et al.* 2019).

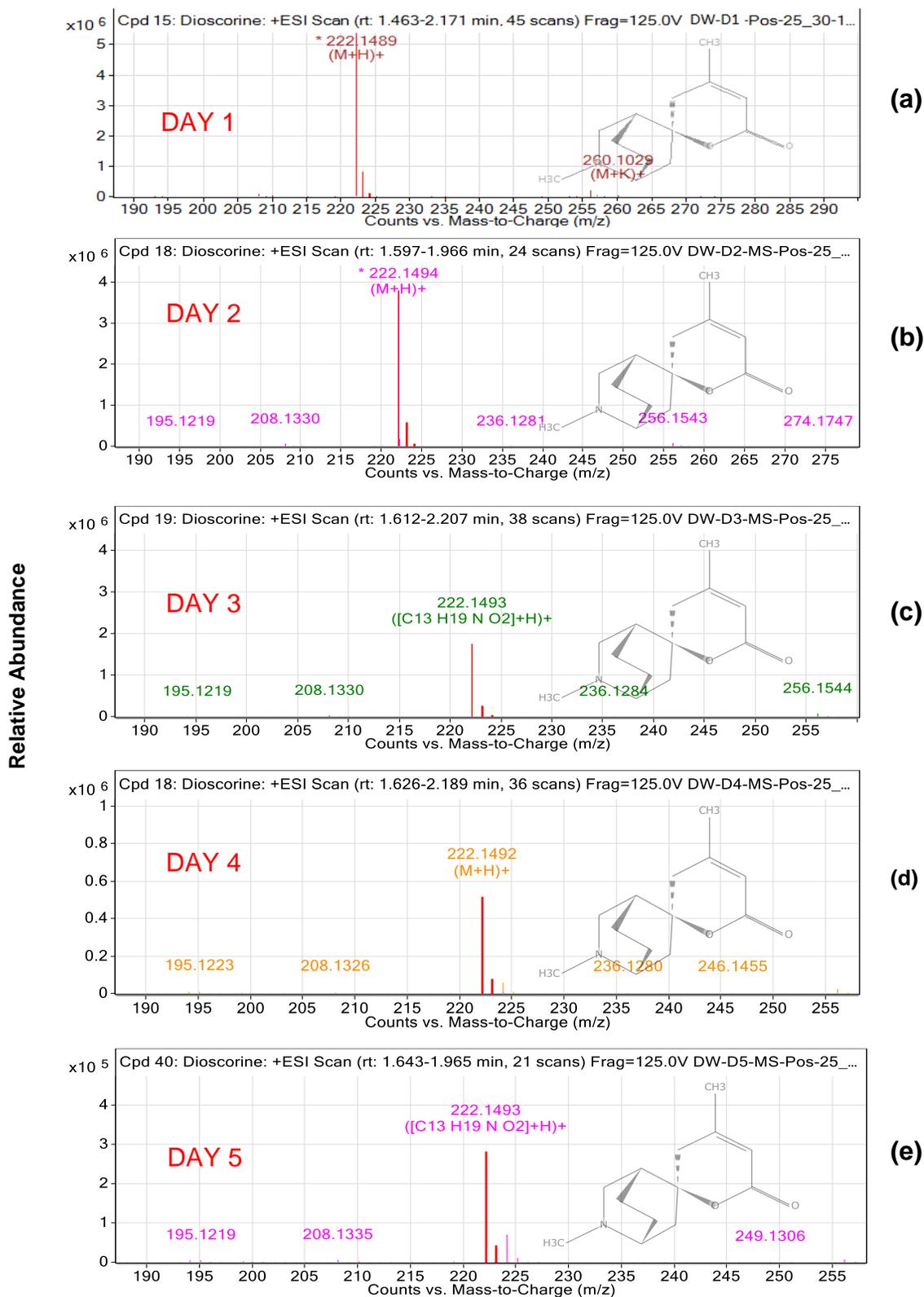


Fig. 4. Fragment ion spectra in MS analysis of dioscorine compound for distilled water: (a) DW-D1, (b) DW-D2, (c) DW-D3, (d) DW-D4, and (e) DW-D5

Another possible explanation for the results obtained from the MS analysis (Tables 1 and 2), could be that the liquid-liquid protocols coupled with the LC-ESI-MS based on the selected particle size column for the toxic compounds. The dioscorine compound was identified in the positive ion mode ESI-MS/MS spectra and transferred into the library by using the matches fit score from the dioscorine compound value. The chromatographic separation process in the *Dioscorea hispida* tuber samples was set by the mass spectrometer to scan the mass range with the upper mass limit. It was identified by the highest molecular weight of the subject compound analysis and the smaller limit by the background of ions. The final scanning process of the samples was stored, and the total ion intensities was produced. The total ion current was stored and computed for the result analysis (Badoud *et al.* 2010). These are important findings for the retention times of the longest retained component, which were scanned by the mass spectrometer to obtain the data for processing. This is particularly useful for subsequent spectral analyses, which were based on the total ion (TIC) trace obtained from the *Dioscorea hispida* tuber mixtures. These are due to the appropriate time by retaining the longest retention time and producing the data available for processing. Figure 4 presents the mass spectrometer analysis obtained from the investigation of *Dioscorea hispida* tubers in the distilled water solution. The first set of analyses examined the identification of the alkaloid dioscorine after 5 days of soaking. The relative abundance amount remarkably decreased from DW-D1 to DW-D5.

Interestingly, the *Dioscorea hispida* in the NaCl solution also presented a more rapid decrease of relative abundance from SC-D1 to SC-D4. These results are likely to be related to the osmosis diffusion action when the immersion of *Dioscorea hispida* tubers using sodium chloride (NaCl) solution is carried out. The osmosis reaction is influenced by the concentration gradient. The higher concentration gradient of sodium chloride, the faster the osmosis reaction will occur (Kresnadipayana and Waty 2019). Table 2 shows that the dioscorine alkaloid content was not detected in sample SC-D5, indicating that the *Dioscorea hispida* tubers are safe for consumption or to be used for other purposes. The m/z ratios coverage of the mass spectrum was produced, whereby the single mass spectrum was provided with complete analytical information for each *Dioscorea hispida* tuber sample (Müller *et al.* 2000). These results are consistent with the research and suggest that the use of the sodium chloride solution is quicker in removing the alkaloid in *Dioscorea hispida* tubers compared to distilled water solution, as shown in Fig. 5 (Oellig and Schmid 2019), which is crucial because the compound may cause food poisoning depending on the toxicity content of the tuber.

The availability of toxic dioscorine was a concern, but the usage of sodium chloride made it easier and faster to remove. This method can effectively minimize the time of preparing *Dioscorea hispida* compared to soaking in a flowing river water for 7 days, which was demonstrated as a technique for removing the dioscorine compound (Roslan *et al.* 2012). Recent studies have been accomplished regarding the application of pesticides, which can benefit from the soaked water technique for *Dioscorea hispida*. The advancements of food products from *Dioscorea hispida* will produce a safer outcome for human consumption (Hudzari *et al.* 2012).

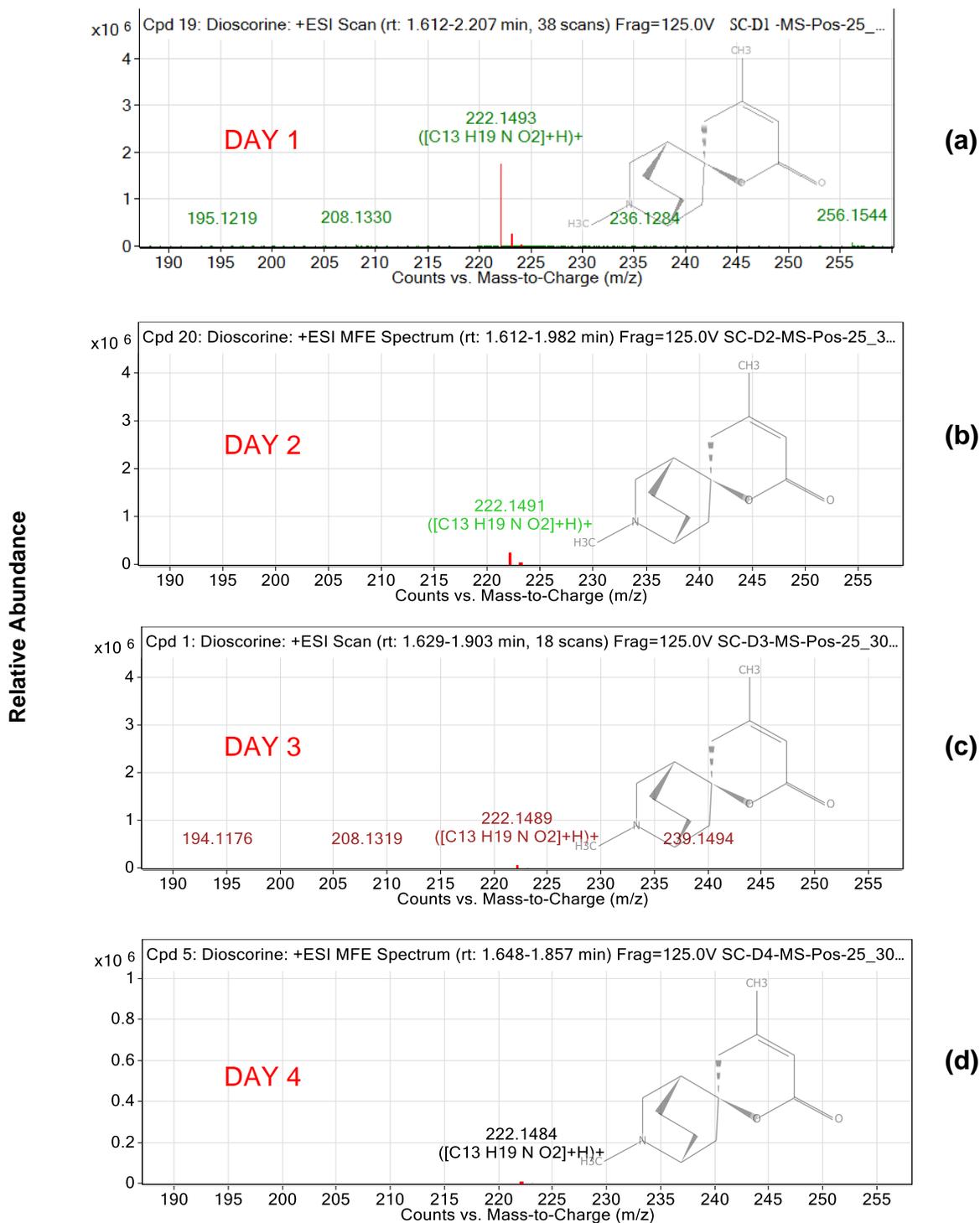


Fig. 5. Spectra of fragment ions in MS analysis of dioscorine compound for NaCl: (a) SC-D1, (b) SC-D2, (c) SC-D3, (d) SC-D4

CONCLUSIONS

1. The present study was designed to determine the minimum days for removing alkaloid dioscorine in *Dioscorea hispida* tubers. It was found that the dioscorine compound was removed faster by using the sodium chloride 1.0 M NaCl solution compared to distilled water.
2. The results from the LC-ESI-MS analysis showed that on day 5, there was no dioscorine detected for soaking in 1.0 M NaCl compared to 281000 of relative abundance amount in the distilled water solution.
3. This study established a qualitative LC-MS framework for detecting the dioscorine compound, and this approach has proven useful in expanding the understanding of toxic removal in *Dioscorea hispida* tubers.

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