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Chemical Compositions and Food Preservation Ability of White Turmeric Rhizomes Essential Oil

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Abstract

White turmeric (*Curcuma aromatica* Salisb.) has been widely used as a traditional herbal drug both in Vietnam and other Asian countries. In this study, the essential oil of white turmeric rhizomes (collected from Dien Bien province) was extracted and evaluated for its chemical composition and antibacterial potential against *E. coli* and *S. aureus*. The raw material was 82.48% in moisture and was steam distilled within 3 days from collection at a 0.4 kg L^{-1} ratio of raw material/equipment volume for 180 minutes. Under these conditions, the essential oil accounted for about 0.3% of the raw material. The GC-MS analysis showed that the composition of the essential oil consisted of more than 46 substances including α-zingiberene, 17.85%; β-sesquiphellandrene, 13.28%; and *ar*-curcumene, 9.45%. The white turmeric essential oil exhibited antibacterial activity against gram-positive strains of *S. aureus* with an inhibition zone diameter of 8.0mm but did not inhibit gram-negative strains of *E. coli*. Importantly, white turmeric essential oil at a concentration of 0.25% could extend the shelf life of mangoes by at least 5 days more than the control samples.

Keywords

Chemical composition, essential oil, food preservation, white turmeric rhizome

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Introduction

White turmeric, or *Curcuma aromatica* Salisb., belongs to the ginger family and has vigorous yellowish rhizomes that grow around the roots. The plant grows naturally and is distributed in most forests in Vietnam and can be found in Dien Bien, a North West province

(Wikipedia, 2017). *Curcuma aromatica* has been shown to improve health by capturing free radicals (Al-reza *et al.*, 2010) and has an immunomodulatory effect (Ahmed *et al.*, 2008). It has long been used as a tonic, and a treatment for bruises, sprains, and snake bites (Rajkumari & Sanatombi, 2018). It is also used to treat skin infections and improve skin color (Ahmad *et al*., 2011). White turmeric has been proven to promote blood circulation and treat cancer (Lee *et al.*, 2007; Li *et al*., 2009; Xiang *et al*., 2017). In India, white turmeric is widely used as a cosmetic and aroma, and is used as a medicine for various diseases related to the skin, heart, and respiratory system (Sikha *et al.*, 2015). White turmeric and its extracts have many different pharmacological effects including anti-inflammatory, wound healing, antioxidant and free radical scavenging, anti-tumor, anti-cough, and kidney detox (Sinoriya *et al.*, 2018).

The chemical compositions of the white turmeric parts have been well studied. White turmeric essential oil accounts for 0.7% of dry leaf weight and has 23 main components. This essential oil is highly resistant to oxidants and free radicals (Al-reza *et al.*, 2010). The qualitative composition of white turmeric essential oil is relatively similar to yellow turmeric oil and *C. sichuanensis* essential oil. However, the ratio of ingredients in the three essential oils is different. In particular, the main components of white turmeric essential oil are curcumol (35.77%) and 1.8-cineole (12.22%) (Snu-Yao *et al.*, 2011). The essential oils extracted from white turmeric leaves have exhibited activity against various bacterial strains such as *Staphylococcus aureus, Listeria monocytogenes* ATCC 19166, *Bacillus subtilis* ATCC 6633, *Pseudomonas aeruginosa* KCTC 2004, *Salmonella typhimurium* KCTC 2515, and *Escherichia coli* ATCC 8739 (Al-Reza *et al.*, 2011).

In 2007, Le *et al.* reported that white turmeric rhizomes grown in Tuyen Quang province contained groups of sterols, alkaloids, flavonoids, curmarins, saponins, and glucosides but did not contain tannins. The extracts of the rhizomes in different solvents had the ability to inhibit some bacteria and fungi at concentrations of 50-200 µg mL^{-1} (Le *et al.*, 2007). Another study on white turmeric grown in Champasak Province, Laos revealed that essential oil accounted for about 0.25% of the dry rhizome with many constituents. The three components making up the largest portion of the composition were 1,3-cyclohexadiene, 5-(1,5-dimethyl-4-hexenyl) -2-methyl-, [S- (R*, S*)] (10.72 %); β-myrcene (10.70%), and eucalyptol (9.71%) (Sythongbay, 2015). A review paper summarized that Japanese *C. aromatica* oil had curdione (32.2-44.0%), 1,8-cineole (7.5-25.3%), and germacrone (4.6-9.6%), while a sample from Thailand contained camphor (26.9%), ar-curcumene (23.2%), and xanthorrhizol (18.7%) as the main components. Camphor (18.2-48.3%), β-curcumene (28.4-31.4%), ar-curcumene (22.1-24.1%), xanthorrhizol (4.8-16.2%), 1,8-cineole (5.5-15.9%), isoborneol (8.2-12.2%), curzerenone (5.5-11.0%), germacrone (4.9-10.6%), camphene (7.4-10.2%), curdione (4.8-8.0%), borneol (4.9-8.2%), β-elemene (7.5%), curzerene (4.6-6.0%), α-pinene (5.7-5.9%), and terpinolene (5.2%) were the components of oil extracted from Indian samples of *C. aromatica* (Dosoky *et al.*, 2019).

Although there have been many studies on the composition, and the antibacterial and antioxidant activities of white turmeric (Choudhury & Ghosh, 1996; Lee *et al.*, 2007; Ahmad *et al.*, 2011), applied research using this plant is relatively limited. As far as we are concerned, white turmeric essential oil has only been studied for the prevention of zebra mosquitoes (*Aedes aegypti*). The results suggest that this could be a potential natural material to replace chemicals for the prevention of zoonotic diseases (Choochote *et al.*, 2005). From the mentioned references, it could be inferred that white turmeric grown in different places has varied chemical compositions that in turn lead to different bioactivities. Therefore, it is a requirement to understand the chemical composition of an investigated plant before using it.

In addition, an increasing number of investigations have been carried out involving food preservatives of natural origins, especially from plants, to replace synthetic food additives in

order to implement a sustainable approach in food technology. Among the various natural substances, plant essential oils have received special attention from researchers around the world because they are potential natural agents for preserving foods with antioxidant, antibacterial, and antifungal properties (Barberis *et al*., 2018). However, studies on the ability of Vietnamese plant oils to preserve food have not yet been popular. In the literature, we found only one research team at Thai Nguyen University of Agriculture and Forestry that has carried out an experiment using *Curcuma longa* essential oils for food preservation. The results showed that a 0.5% concentration of yellow turmeric essential oil allows good preservation of mangoes for 10 days (Tran & Hoang, 2015). In this study, we aimed to extract the essential oil of white turmeric rhizomes collected in Dien Bien province and evaluate its composition and antibacterial activity as well as its ability to preserve mangoes.

Materials and Methods

Materials

White turmeric rhizomes were collected in Dien Bien province in August 2019 and brought to the laboratory within 2 days. The rhizomes were 2-2.5cm in diameter, light brown, and internally pale yellow with a camphoraceous odor. Distilled water was used throughout the experiment. The distillation process of the rhizomes is described in **Figure 1**.

Methods

Determining the moisture and essential oil content

After collecting the white turmeric, the broken roots were removed, cleaned with water, and sliced with a knife. The moisture contents of the sliced rhizomes were then determined by drying the roots to a constant weight at the temperature of 105^{o}C. In brief, 40g of white turmeric rhizomes were weighed accurately in a dry dish. The dish with the rhizomes was dried at 105^{o}C for about 6 hours. After drying, the dish was covered with a lid and cooled down to room temperature in a desiccator. The dish was reweighed. The process was repeated until the difference between the 2 weights did not exceed 0.5mg. Three samples were used to calculate the average value of the moisture content. The moisture content was calculated by:

$$W = (m_1 - m_2)/m_1 \times 100\%$$

in which W is the moisture content (%), m_1 is the weight of the original sample (g), and m_2 is the completely dried sample weight (g).

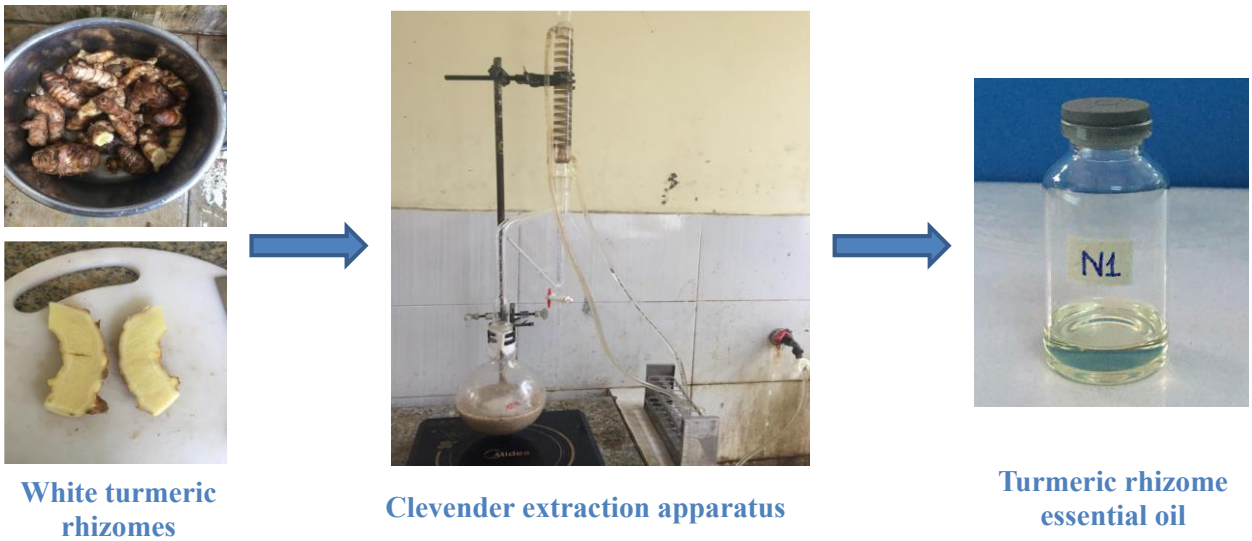

Figure 1. White turmeric rhizome essential oil extraction procedure

White turmeric essential oil was extracted by steam distillation. The pretreated rhizomes were introduced into the steam distillation system. To determine the essential oil content in the white turmeric rhizomes, 250g of pretreated rhizomes were accurately weighed, 400mL of distilled water was added, and then they were ground together to obtain a mixture. The resulting mixture was put in a heat-resistant 1000mL flask and the essential oil distilled by a Clevender light essential oil extractor. The distillation ended when the amount of essential oil in the intake tube did not increase. In order to ensure the essential oils in the material were thoroughly extracted, the distillation process was maintained for 4 hours. Water remaining in the crude oil was removed by anhydrous Na_2SO_4. The content of the essential oil in the dry raw materials was determined by the formula:

$$X = m_3/[m_1*(100-W)/100] *100$$

in which X is the content of the essential oil in the dried raw material (%), m_3 is the weight of the essential oil obtained (g), and m_1 is the weight of the raw materials (g).

Studying the influence of technical parameters on the distillation yield

The material storage time, material weight/equipment volume ratio, and distillation time were investigated for their influence on distillation yield as well as essential oil quality and economic efficiency.

The yield of the essential oil extraction was calculated by the formula:

$$Y = \frac{m_4}{m_1.X} .100 \ (\%)$$

in which X is the content of the essential oil in the dried raw material (%), m_4 is the weight of the essential oil obtained in each experiment (g), and m_1 is the weight of the raw materials (g).

Sensory evaluation of the essential oils (according to the National standard number 8640: 2010)

The clarity and color of the essential oil samples were determined by observing 20mL of each sample placed in a clean, dry, transparent test tube. About 1g of the essential oil was put in a clean, dry test cup. A few drops of water were added into the cup, mixed well, and we used our tongues to determine the taste of the mixture. To identify its smell, a few drops of the essential oil were put on a clean, dry, absorbent paper and we used our noses to determine the smell of the essential oil every 15 minutes for 4-5 times.

Composition analysis

The composition of the white turmeric essential oil was determined by the gas chromatographic-mass spectroscopy (GCMS) method on an Agilent 7890A Gas Chromatograph with an Agilent MS5975C detector and helium carrier gas. The GC column was a ZB-5 fused silica capillary column with a (5% phenyl)-polymethylsiloxane stationary phase and a film thickness of 0.25µm, a length of 60m, and an internal diameter of 0.25mm (Phenomenex, Torrance, CA, USA). The injector temperature was 250^{o}C and the ion source temperature was 200^{o}C. The GC oven temperature was programmed for an initial temperature of 60^{o}C, then the temperature was increased at a rate of 4^{o}C min^{-1} to 240^{o}C. Identification of the oil components was based on their retention indices determined by reference to a homologous series of n-alkanes, and by comparison of their mass spectral fragmentation patterns with those in our own in-house library.

Antibacterial activity

The antibacterial activity of the white turmeric rhizome essential oil was determined by the diffusion method on agar plates in a Mueller-Hilton agar (MHA) environment (Balouiri *et al.*, 2016). The MHA environment composition consisted of meat extract 2 g L^{-1}, casein 17.5 g L^{-1}, NaCl 1.5 g L^{-1}, and agar 17 g L^{-1}, at pH (25 ^{o}C) = 7.3 ± 0.2. The TSB (Trypticase soy broth) consisted of trypticase peptone 17 g L^{-1}, phytone peptone 3 g L^{-1}, NaCl 5 g L^{-1}, K_2HPO_4 2.5 g L^{-1}, and glucose 2.5 g L^{-1}, at pH (25^{o}C) = 7.3 ± 0.2, and was used as the growth medium for the test bacteria.

Pre-used strains of *Staphylococcus aureus* and *Escherichia coli* were enriched on TSB medium for 12 hours at 37°C and 100rpm shaking. The bacterial suspensions were then centrifuged to separate the biomass, and diluted

with sterile distilled water to a turbidity equivalent to 0.5 MC Farland. Each bacterial suspension was then diluted 100 times with sterile distilled water to achieve a density of 1.5 x 10^6 CFU mL^{-1} for use in the antibacterial activity investigation.

Twenty-five mL of sterile MHA medium (about 40-50^{o}C) was added to each Petri dish and allowed to stand for 45 minutes for medium solidification. The activated microbial solutions were spread evenly on the surface of the agar. When the agar on the Petri dish solidified, a well in the agar surface was made and filled with 50µL of essential oil solution. The dish was then kept at room temperature for 2h, until the essential oil from the wells diffused into the bacterial culture medium. Afterward, the plates were placed in a 32^{o}C incubator for 16-20h. Every step proceeded immediately around the light of an alcohol lamp. The inhibition zone (sterile ring diameter) was measured in mm (if any).

Mango reservation test

Evenly sized mangoes were bought from a local garden. The fruits were washed thoroughly with clean water, avoiding substantial impacts on the fruit surface, air dried, and then separated into 3 groups (5 mangoes each).

Group 1: no treatment (control)

Group 2: mangoes were treated with white turmeric essential oil (0.25%)

Group 3: mangoes were treated with white turmeric essential oil (0.5%)

Each group of mangoes was then put in a carton box at room temperature and humidity of 80-85% (during storage, the humidity was checked daily to ensure it was between 80-85%). After the given time period, the status of the mangoes was checked.

Data analysis

The experiments to determine the influence of the technical parameters on the distillation yield and antibacterial activity were repeated three times to calculate the mean values and standard derivations. Duncan-Anova analysis was performed in Microsoft Excel (2010) to compare samples for significant differences at $P< 0.05$.

The Results and Discussion

Raw materials properties

The determined moisture and essential oil content of the raw materials were 82.48% and 0.3%, respectively. These results showed that the water content in fresh turmeric rhizomes was quite large so they could easily be decomposed by bacteria and molds, therefore it is essential to dry the rhizomes if long-term storage is required. The content of essential oil in the dry rhizomes was 0.3% and higher than that in turmeric from Laos (0.25%) (Sythongbay, 2015). The difference could be attributed to differences in soil or climate between the two regions.

The influence of storage time, material weight/equipment volume, and distillation time on the distillation yield

Steam distillation to extract essential oils is a common method used to separate an unmixed mixture like water and essential oils when they are in direct contact with each other. In order to establish an effective distillation process of essential oils, the parameters that influence the distillation yield were investigated. The best time for sample storage (or the time for wilting) was determined at the fixed raw material weight of 400g and fixed distillation time of 150 minutes. The obtained results are listed in **Table 1**. The table shows that the essential oil extraction yield of the raw materials stored for the first 3 days slightly decreased from 80.86% to 73.01% and then declined significantly for samples stored more than 3 days (from 73.01% to 57.92%). This can be the result of evaporation of the essential oil along with water removal when the sample moisture content was significantly reduced.

Essential oils of all the samples with storage times of fewer than 3 days were not different in color or taste (transparent, pale yellow, slightly spicy, and typical turmeric flavor). Therefore, white turmeric rhizomes should be distilled within 3 days of research, or 5 days from harvest.

Determining the appropriate amount of material for the distillation equipment is essential to ensure that the maximum volume of the device can be used without affecting the essential oil extraction efficiency. Different proportions of material weight and equipment volume were

tested and the results are shown in **Table 2**. In can be seen from **Table 2** that the smaller the proportion of material weight/equipment volume, the higher the yield of oil extraction (from 71.05% to 86.69%). This is due to the fact that at a smaller ratio, the raw materials could come into contact with water more easily and then the essential oil molecules could collect in the steam in a larger amount. However, at the proportion of 0.4 kg L^{-1} and lower, the extraction yield increased non-significantly. Therefore, the proportion of 0.4 kg L^{-1} was selected for further investigation.

According to the literature, the longer the distillation time is, the more oil is extracted. However, when the distillation time reaches a certain level, the amount of essential oil will not increase anymore and may adversely affect the quality of the product (Sikha *et al.*, 2015). Therefore, in actual production, the determination of the appropriate distillation time is an important step to achieve the highest economic efficiency.

In this study, the distillation time varied from 90 to 240min, while the ratio of raw materials/equipment volume was kept constant at 0.4 kg L^{-1}. The research results are shown in **Table 3**. The essential oil extraction yield increased with time from 71.90% to 95.10%. Though, at the distillation times of 180, 210, and 240 m, the essential oil yield did not increase significantly and the essential oil performance did not differ statistically at the significance level of $\alpha = 5\%$. To assure economic efficiency, the

Table 1. Effects of the storage time on essential oil extraction yield

Storage time (days)	Turmeric moisture (%)	Essential oil weight (g)	Essential oil extraction yield (%) (calculated based on the oil content of dry substance)
0	82.48	0.172 ± 0.008	80.86^{a} ± 3.97
1	80.26	0.186 ± 0.004	76.68^{ab} ± 1.72
2	79.16	0.195 ± 0.008	76.44^{ab} ± 3,13
3	75.96	0.213 ± 0.003	73.01^{b} ± 1.03
4	69.73	0.229 ± 0.005	63.47^{c} ± 1.39
5	62.26	0.264 ± 0.006	57.92^{d} ± 1.32

Note: Values followed by the same letter in each column are not significantly different at the 5% signigicance level.

Table 2. Effects of material weight/equipment volume on essential oil extraction yield

Raw material/equipment volume (kg L^{-1})	Net weight of obtained oil (g)	Essential oil extraction yield (%)
0.2	0.179 ± 0.005	86.69^{a} ± 2.33
0.3	0.174 ± 0.010	81.64^{a} ± 4.85
0.4	0.172 ± 0.008	80.86^{a} ± 3.97

Table 3. Effects of distillation time on essential oil extraction yield

Distillation time (minutes)	Essential oils obtained (g)	Essential oil extraction yield (%)
90	0.152 ± 0.005	71.90^{c} ± 2.36
120	0.164 ± 0.003	77.19^{b} ± 1.41
150	0.174 ± 0.006	80.86^{b} ± 2.78
180	0.202 ± 0.004	93.92^{a} ± 2.08
210	0.206 ± 0.005	94.02^{a} ± 2.38
240	0.208 ± 0.007	95.10^{a} ± 3.13

Note: Values followed by the same letter in each column are not significantly different at the 5% level.

ideal time required for distillation of white turmeric rhizome essential oil was 180 minutes. Cannon *et al.* (2013) reported that the distillation of lemongrass essential oil reached its maximum efficiency at 160 minutes, after which time, the yield of the essential oil extraction decreased from 25 to 40% due to the longer the distillation time, which resulted in the decomposition of the essential oils.

Chemical composition of white turmeric essential oil

The chemical compositions of Dien Bien white turmeric essential oil determined by GCMS are listed in **Table 4** and **Figure 2**. The study revealed that the essential oil consisted of more than 46 substances that accounted for about 90% of the sample content. Among the substances, the three main compounds were α-zingiberene (17.85%), β-sesquiphellandrene (13.28%), and *ar*-curcumene (9.45%). Zingiberene and sesquiphellandrene are two terpenes that are also present in ginger essential oil and show many bioactivities (Mao *et al.*, 2019). *Ar*-curcumene and the two compounds are present in the essential oils of many plants belonging to the genus *Curcuma* and are the main components of *Curcuma aromatica* grown in Thailand and India (Dosoky *et al.*, 2019). In general, essential oils extracted from plants in different places have some similar constituents, but with different climatic conditions, soils, and collection times, their chemical compositions vary (Al-reza *et al.*, 2010; M. Al-Reza *et al.*, 2011; Promod, 2018). In some cases, if the constituents of an essential oil are markedly different, genetic and morphology differences of the plants should be considered (Kojima *et al.*, 1998).

Antibacterial activity of white turmeric essential oil

The antibacterial activity of turmeric essential oil against the bacterial strains *Staphylococcus aureus* and *Escherichia coli* was investigated. The results are shown in **Figure 3**. The essential oil showed antibacterial activity against *S. aureus* with an inhibition zone diameter of 8.0 mm while it did not affect the growth of *E. coli*. A previous study reported that white turmeric essential oil inhibited gram-positive bacteria and did not inhibit gram-negative bacteria (M. Al-Reza *et al.*, 2011). Our results are in agreement with a study on *Curcuma aromatica* hexane extract that was found to be active against all gram-positive strains tested, but not for gram-negative strains. This was explained by the different cell walls of gram-negative and gram-positive bacteria. The gram-positive cell wall consists of a thick layer of peptidoglycan covering the plasma membrane, while the gram-negative cell wall is more complex with a thin layer of peptidoglycan, a periplasmic space, and an outer membrane made of a lipoprotein and lipopolysaccharide complex. It is this multi-layered structure that protects gram-negative bacteria cells from the effects of essential oils and the periplasmic space containing toxins and enzymes suppresses the effects of essential oils before they come into contact with the plasma membrane (Revathi & Malathy, 2013). In another study, the essential oils of *Mentha arvensis* L. (0.625 mL mL^{-1}) and *M. piperita* L. (1.25 mL mL^{-1}) were introduced directly into pineapple and mango juice and their effect on some bacteria was evaluated. The results showed that the essential oils inactivated *E. coli*, *Listeria monocytogenes*, and *Salmonella enterica* by disrupting the cytoplasmic membranes and increasing permeability and potential depolarization, as well as inhibiting efflux pump and respiratory activities (de Sousa Guedes & de Souza, 2018).

The ability to preserve mangoes

Images of the mangoes in the control group and the two experimental groups treated with white turmeric essential oil are shown in **Figure 4**. Under room temperature conditions, after 5 days, the mangoes in the control group began to show signs of spoilage. After 10 days, the control group mangoes were almost no longer usable and the experimental group with the 0.5% essential oil concentration began to show dark spots. Meanwhile, mangoes in the experimental group with the essential oil concentration of 0.25% were more mature than at day 0 but not rotten. It can be noted from these results that the white

turmeric essential oil was able to prevent the rotting process of mangoes. This result may be due to the fact that the essential oil prevented gram-positive bacteria such as *S. aureus*. However, the experimental group with the essential oil concentration of 0.5% was not as good as the 0.25% concentration group because high concentrations of essential oils can damage the surface of the treated mangos due to its hydrophobic nature (Sánchez-González et al., 2011). These results are in agreement with the published results relating to citronella and cajeput essential oils that inhibited *Aspergillus niger* fungi isolated from mangoes. The authors confirmed that high concentrations of the essential oils could adversely affect the mango preservation process (Lieu *et al*., 2018).

Conclusions

In conclusion, the white turmeric raw material had a moisture content of 82.48% and the dry material contained 0.3% essential oil. To obtain a high essential oil extraction yield, raw materials should be stored for no more than 3 days and distilled at the raw material/equipment

Table 4. Composition of Dien Bien white turmeric rhizome essential oil

No.	Compound	Time (min)	RI	%	No.	Compound	Time (min)	RI	%
1	Pinene <a->	10.13	939	0.14	24	β -Bisabolene	29.37	1518	3.76
2	Camphene	10.63	955	0.12	25	δ-Cadinene	29.74	1531	2.06
3	β-Pinen	11.50	984	0.65	26	β -Sesquiphellandrene	29.89	1536	13.28
4	Cineole 1,8	13.27	1038	0.37	27	δ-Cadinene	29.94	1538	2.06
5	Camphor	17.36	1155	2.11	28	Selina-3,7(11)-diene	30.27	1548	0.20
6	Camphene hydrate	17.55	1161	0.17	29	Germacrene B	31.15	1578	0.92
7	Isoborneol	17.82	1169	1.14	30	Turmerol<ar->	31.55	1591	0.17
8	Borneol (= Endo-Borneol)	18.13	1178	0.46	31	Caryophyllene oxide	31.96	1605	1.01
9	α-Terpineol	18.93	1200	0.17	32	4bH, 5aH-cis–Eudesm-6-en-11-ol	32.17	1613	0.40
10	δ-Elemene	13.95	1348	0.27	33	Curzerenone	32.40	1621	3.03
11	*Cis* β-Elemene	25.80	1404	2.78	34	Zingiberenol	32.56	1626	1.48
12	Sesquithujene	26.07	1413	0.34	35	Humulene Epoxide II	32.73	1632	0.34
13	Caryophylene(E-)(= β-caryophylene	26.85	1437	1.74	36	Bisacumol (Isomer 1)	32.92	1639	0.27
14	γ-Elemene	27.11	1445	0.49	37	α-Acorenol	33.04	1643	0.62
15	β-Farnesene (Z)	27.59	1461	0.44	38	Cubenol<1-epi>	33.17	1648	1.41
16	Aromadendrene	27.71	1465	0.39	3	Cadinol <epi-a-> (= Tau – Cadinol)	33.62	1660	1.00
17	α-Humulene	27.93	1472	0.74	40	Muurolol <epi-a-> (= T-Muurolol)	33.56	1662	0.92
18	Caryophyllephyllene	28.17	1479	0.23	41	α-Cadinol	33.93	1675	1.69
19	*ar*-Curcumene	28.59	1493	9.45	42	3(15)- Cedren-4-ol	34.94	1711	1.92
20	Germacrene D	28.77	1498	1.48	43	Germacrone	35.18	1720	3.11
21	α-Zingiberene	28.97	1505	17.85	44	Curcumenol	36.13	1755	1.14
22	Curzerene	29.17	1512	3.58	45	α-Oxibisabolene	36.30	1762	0.63
23	Selina-4(15),7-diene	29.25	1514	1.06	46	Furanegermenone	37.76	1817	1.35

Note: RI = retention time index.

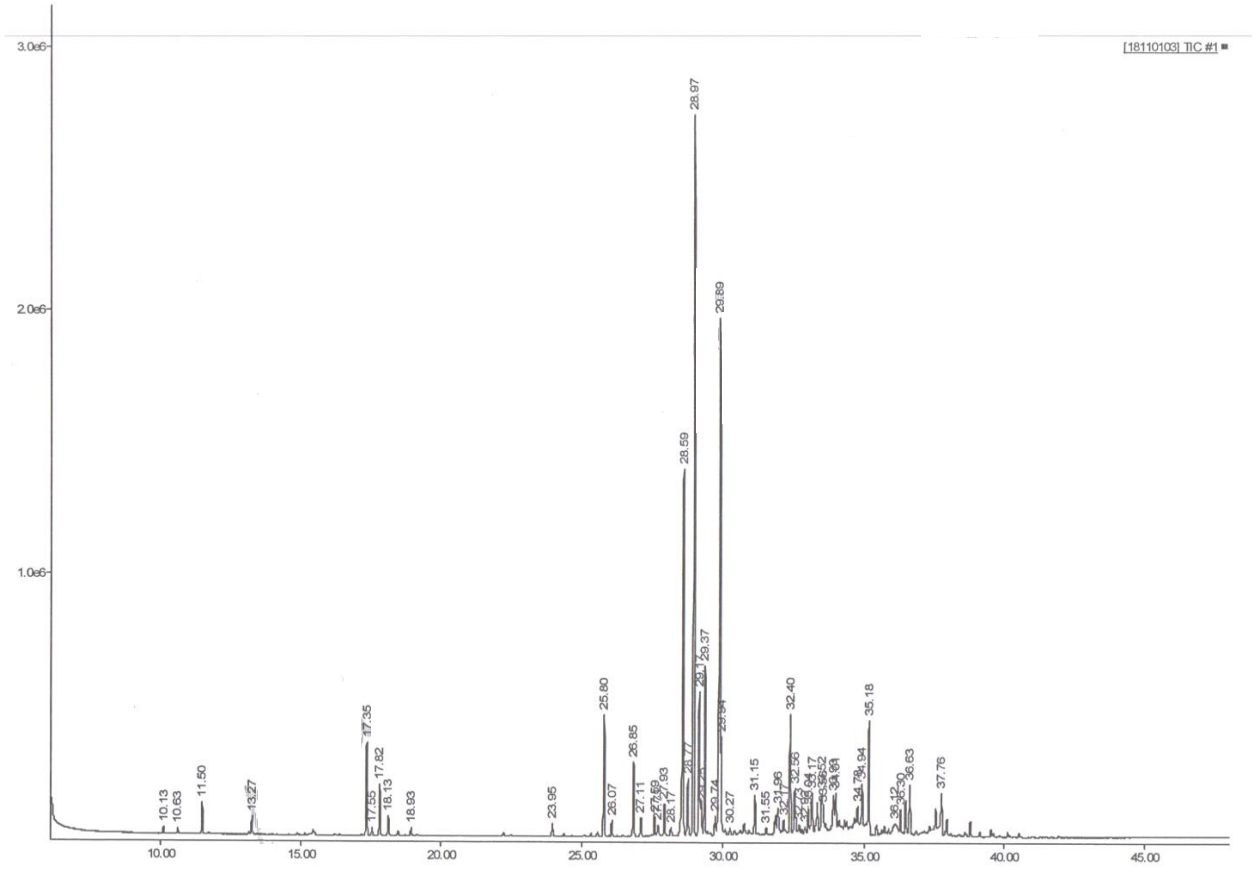

Figure 2. GC spectrum of Dien Bien white turmeric essential oil

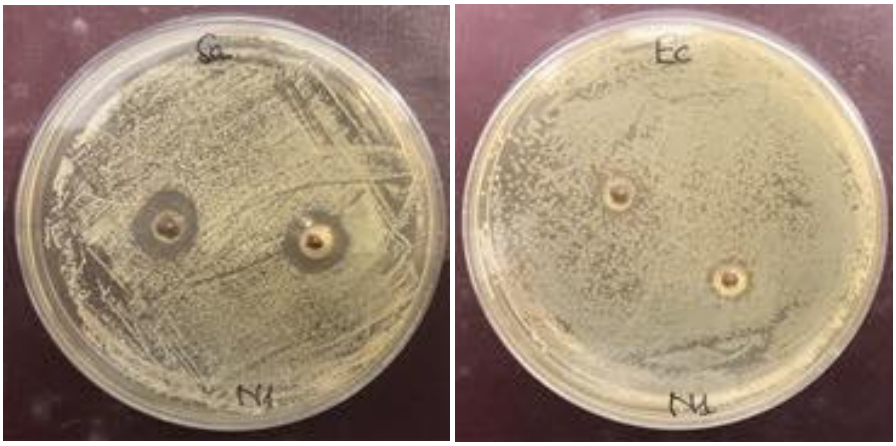

Figure 3. Antimicrobial activity of white turmeric essential oil against *S. aureus* and *E. coli*

volume ratio of 0.4 kg L^{-1} for 180 minutes. There were more than 46 components accounting for more than 90% of the white turmeric rhizome essential oil. Among them, the three main substances were α-zingiberene (17.85%), β-sesquiphellandrene (13.28%), and *ar*-curcumene (9.45%). The essential oil exhibited antibacterial activity against gram-positive strains of *S. aureus* with an inhibition zone diameter of 8.0mm but did not inhibit gram-negative strains of *E. coli*. Importantly, white turmeric essential oil at a concentration of 0.25% could extend the shelf life of mangoes by at least 5 days more than the control samples. However, the activity of the

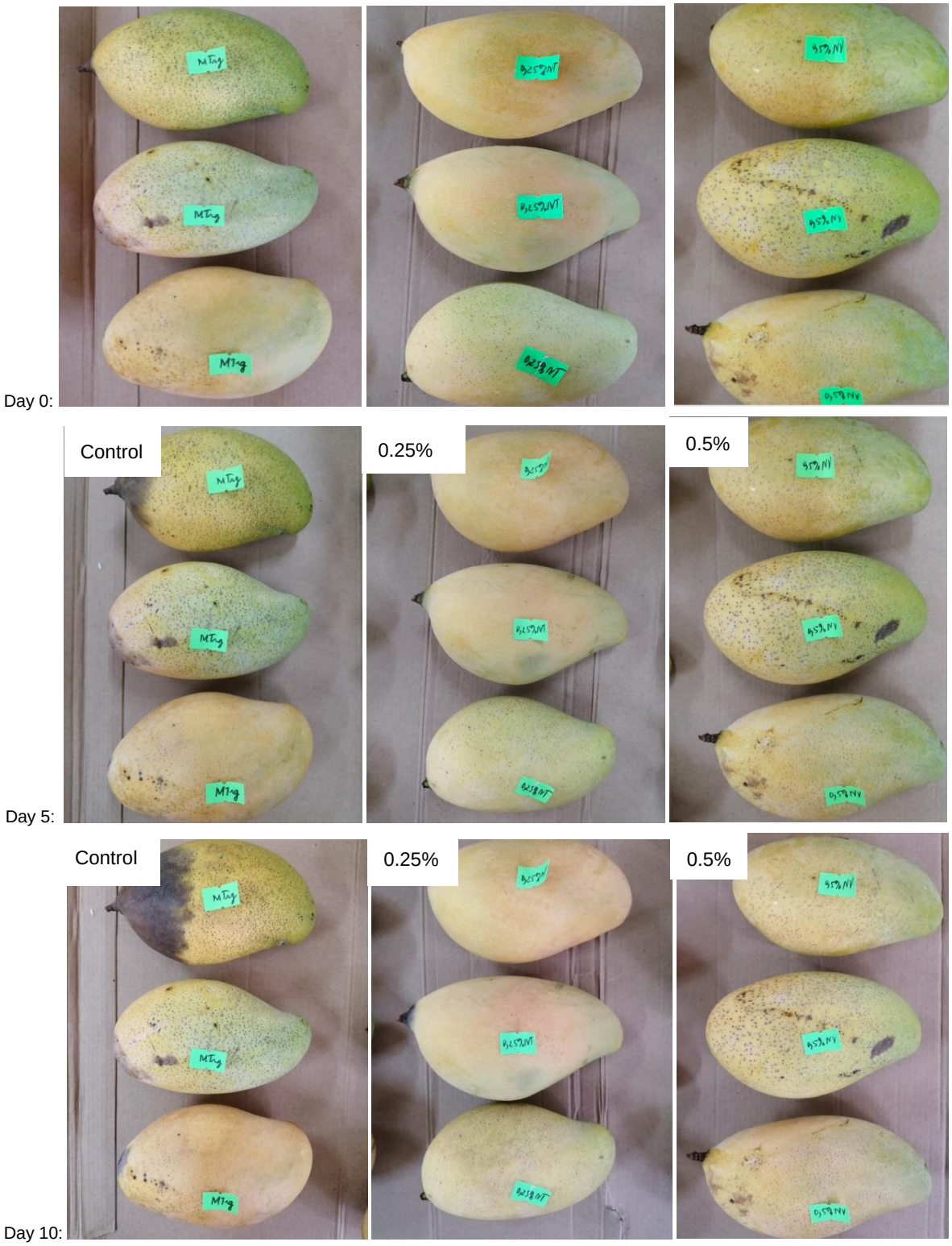

Figure 4. Preservation test of mangoes with no essential oil (control group – left), 0.25% essential oil concentration (center), and 0.5% essential oil concentration (right)

essential oil against fungi such as *Aspergillus niger* or *Fusarium oxysporum*, and quantitative research on mango quality when preserved with white turmeric essential oil should be carried out in further studies.

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