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Original Research Article

Effect of Storage Period and Conditions on Essential Oil Yield and Properties of Lemon Grass (*Cymbopogon citratus*)

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ABSTRACT

In this study, fresh lemon grass was harvested and stored in the sun and shade for a period of four weeks followed by extraction of essential oil using steam distillation technology on weekly basis. The effect of storage period and conditions on the oil yield, properties and extraction pattern was investigated. The results show that there was significant decrease in the oil yield from 0.21% in the 1st week to 0.16% in the 4th week for sun storage. However, a slight decrease was observed from 0.38% in the 1st week to 0.21% in the 4th week for shade storage. Two mathematical model equations were developed for the prediction of oil yield as a function of storage time for both conditions. The model equations predicted that for lemon grass stored for 5 weeks under shade and sun, the expected oil yield would be 0.16% and 0.14% respectively. The results further revealed that properties and extraction pattern of the oil were not significantly affected by both period and storage condition. Based on these findings, lemon grass should best be stored in the shade before utilization.

1. INTRODUCTION

Essential oil is made up of important phytochemicals and various bioactive compounds. Essential oil can be referred to as any concentrated, hydrophobic and lipophilic liquid of plants that having high volatile aroma compounds carrying a distinctive scent, flavor, or essence of the plant (Hossain et al., 2012).

Lemon grass, a perennial *Cymbopogon* grass, belongs to the *Poaceae* family rich in lemon-scented smell. The oil from Lemon grass is regarded as one of the most important essential oils for its various applications as flavor and fragrance ingredients in perfumery, cosmetics, food additives, herbicides, pharmaceutical and medicinal applications (Dayan et al, 2009). Some of the specific medicinal and bioactive applications include: antimicrobial (Liakos et al., 2016; Bŏzik et al., 2017), antibacterial (Balakrishnan et al., 2014), antifungal (Sarma et al., 2004), detoxifying activities (Tak et al., 2017) and even in anti-cancer therapy

(Thangam et al., 2014). Lemon grass oil has also been proven to treat a wide spectrum of health conditions physiologically such as excessive perspiration, flatulence, muscle aches, and scabies (Schaneberg and Khan, 2002). It is also applied in the treatment of orthopedics, muscular and skin problems (Schaneberg and Khan, 2002) and as anticonvulsive agent (Blanco et al., 2009). Due to these important uses, *Cymbopogon* grasses are cultivated on large scale, especially in tropics and sub-tropics (Akhila, 2010). An estimated annual production of about 1000 tons is achieved from an area of 16000 ha worldwide (Skaria et al., 2012; Abdulazeez et al., 2016). The *citral* fraction of lemon grass essential oil is regarded as the most important compound whose yield is influenced by many factors such as temperature, light intensity, fertilizer, and maturity stage of the plant (Miyazaki, 1965). Moreover, the oil content and yield of aromatic plants are often altered during harvesting, post harvesting processes and storage condition (Motsa, 2006). Despite availability of literatures on the influence of these factors on oil yield, there still exist gaps of information on the effects of storage period and condition of storage of lemon grass on its oil yield.

Thus, this work investigates the effect of these factors and establishes the best storage period and condition for lemon grass in order to maximize oil yield during extraction. The study will also serve as an important source of information to the commercial producers of lemon grass essential oil particularly regarding the best period and condition to store the lemon grass before extraction.

2. MATERIALS AND METHODS

2.1. Materials

The fresh lemon grass used in this study was obtained from National Research Institute for Chemical Technology (NARICT) plantation in Zaria, Nigeria. The grass was prepared by removing all foreign materials found in it. One hundred and sixty kilograms of the grass was divided into 8 (portions) for eight batches of operation. Four (4) portions were kept under shade (27 ^{o}C) and the remaining four (4) portions in the sun (31^{o}C) as shown in Figures 1 and 2 respectively. Essential oil extraction plant using steam distillation was designed and fabricated in NARICT, Zaria as shown in Plate 1.

Figure 1: Lemon grass kept under shade

Figure 2: Lemon grass kept in the sun

2.2. Description of the Essential Oil Extraction Plant

The extraction of essential oil was done using water as solvent in the form of steam in a steam distillation pilot plant. The pilot plant is mainly made up of oil extractor, steam boiler, condenser, gas-fired burner and oil separator as shown in Plate 1. The oil extractor and condenser were fabricated using grade 304 stainless steel while the oil separator was transparent glass. The boiler section is located at the bottom of the oil extraction chamber and separated by a stainless steel weir mesh. A detail of these equipment specifications is shown in Table 1.

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Key:
A=Oil extractor
B=Boiler
C=Condenser
D=Cooling water tank
E=Oil collector
F=Steam and oil line
G=Cooling water line

Plate 1: Steam distillation pilot plant for extracting essential oil from lemon grass

Table 1: Process unit specifications of essential oil extraction plant

Process unit	Specification
Extractor	
Material of construction	Stainless steel
Height	1.65 m
Diameter	0.45 m
Thickness	0.003 m
Boiler	
Capacity	0.0075 m^3/hour
Condenser	
Type of condenser	shell and tube
Material of construction of shell	mild steel
Material of construction of tube	stainless steel
Number of passes in the tube	2
Number of pass in the shell	1
Tube length	1.2 m
Tube outside diameter	0.02 m
Tube inside diameter	0.016 m
Number of tubes	16
Number of tubes per pass	8
Shell internal diameter	0.385 m
Number of baffles	3
Baffles spacing	0.3 m
Baffles cut	15%
Baffle pitch	Square
Tube side fluid	Steam and oil
Shell side fluid	Cooling water
Oil Separator	
Capacity	0.0005 m^3
Shape	Conical
Flow rate	0.00025 m^3/min

Every component of the steam distillation pilot plant was coupled together as shown in Plate 1 for the extraction of essential oil from lemon grass. The gas-fired burner was connected to a 12.5 kg gas cylinder with a rubber hose and placed directly under the oil extractor. The connections were adequately checked to avoid gas leakages. The cooling water from the overhead tank was allowed to run into the condenser at the rate of 1.67×10^{-3} m^3/min. This was done to aid easy condensation of the steam and oil mixture vapour to liquid.

2.3. Methods

The method employed in the extraction of the essential oil from lemon grass was steam distillation method and the block diagram for the extraction process is shown in Figure 3.

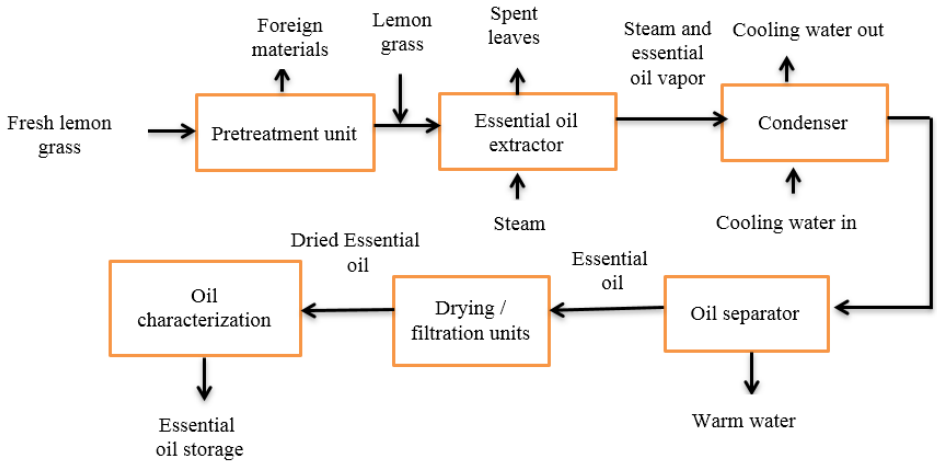

Figure 3: Block diagram for the steam extraction of essential oil from Lemon grass

2.3.1. Extraction of essential oil

The extraction was first carried out using fresh lemon grass which served as control before using stored lemon grass. Twenty five (25) liters of water and 20 kg (W_1) of fresh lemon grass were charged into the essential oil extractor (A) shown in Plate 1. The gas line was opened and the burner was ignited and recorded the time of ignition. The burner fuel- to- air ratio was adjusted until blue flame was obtained implying steady energy supply. After about 26 minutes of igniting the burner (induction period), steam and oil mixture began to drop in the oil separator (E) as condensate. The oil was then separated from the warm water and measured using measuring cylinder after every 10 minutes for a period of 70 minutes. The oil was dried using anhydrous Sodium Sulphate (Na_2SO_4) and allowed to stand overnight followed by filtration to remove moisture and suspended impurities.

After the 1st week of storage, the same extraction procedure mentioned above was repeated using lemon grass kept under sun and shade separately. In each case, the cumulative oil collected, extraction time, steam requirement and energy consumption were recorded. Similar procedures were repeated for the 2nd, 3rd and 4th week of storage for both sun and shade storage of the lemon grass. In each case the weight of the dried oil was recorded (W_2) and oil yield was calculated using Equation (1).

$$\% \, Yield = \frac{W_2}{W_1} \times 100 \quad (1)$$

2.3.2. Determination of properties

The extracted lemon grass oil was analyzed for its properties using standard method as shown in Table 2 (Giannelos et al., 2002; Galadima, 2004).

Table 2: Determination of properties of the oil using standard methods

Physical and chemical properties	Standard method
Specific gravity	ASTM D1429-13(2013)
Solubility in ethanol	ASTM D1107-96 (2013)
Iodine value	AOAC CDI-25 (1993)
Refractive index	ASTM C1648-12 (2018)

3. RESULTS AND DISCUSSION

3.1. Effect of Extraction Time on Oil Extracted

The effect of extraction time on the quantity of essential oil extracted from lemon grass kept under both shade and sun are presented in Figures 4 and 5 respectively. As seen in Figure 4, there was similarity in the extraction pattern throughout the storage period (1-4 weeks).

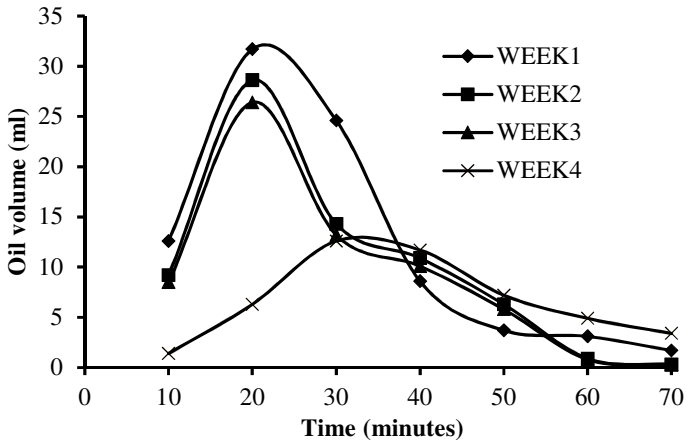

Figure 4: Extraction pattern of essential oil as a function of time for lemon grass stored under the shade

This pattern shows that the quantity of essential oil extracted increased with increase in extraction time until it reached extraction time of 20 minutes before declining for 1st, 2nd and 3rd weeks of storage and 30 minutes for the 4th week. The highest quantity of oil extracted at this time (20 minutes) were 32 ml, 29 ml and 26 ml for 1st, 2nd and 3rd week of storage respectively. The decrease in the oil yield on weekly basis was due to evaporation of both the oil and the moisture associated with the oil during storage. In the case of storage period of 4 weeks, the highest quantity extracted was 13 ml in 30 minutes before declining. In all cases (1-4 weeks), the average cumulative oil extracted was about 80 ml higher than 45 ml obtained from Vietnam lemongrass essential oil (Nguyen et al., 2017).

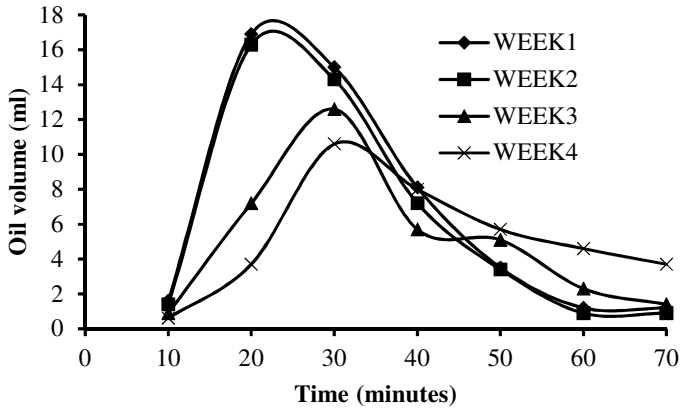

Figure 5: Extraction pattern of essential oil as a function of time for lemon grass kept in the sun

In Figure 5, similar pattern of extraction was observed as in the case of storage under shade with maximum oil of 17 ml and 16 ml extracted in 20 minutes for 1st and 2nd weeks respectively. However, maximum oil of 11 ml and 7 ml were obtained in 30 minutes for 3rd and 4th week respectively. The decrease in oil yield on weekly basis was due to the evaporation of the oil because of its high volatility and is more significant for storage under sun due to expose to high temperature compared to shade. The longer the storage period the more oil is evaporated.

3.2. Effect of Storage Period and Storage Condition on Oil Yield

There was significant reduction in the weight of the lemon grass from 20 kg of fresh leaves to 3.8 kg for storage under shade and 2.6 kg under sun in the 4th week as shown in Table 3.

Table 3: Effect of storage period on the weight of lemon grass

Storage period (week)	Weight (kg)	
	Shade	Sun
0	20	20
1	8.6	5.1
2	6.6	4.0
3	4.6	3.4
4	3.8	2.6

The reduction in lemon grass weight increases with increase in the storage period and is primarily due to evaporation of both moisture and oil from the lemon grass which was more significant for the case of storage under sun compared to storage in the shade. Among advantages of storage is the reduction in moisture content which allows a larger-quantity of grass to be processed, thus economising the fuel use (Kabiru, 2018).

Yellow colour lemongrass oil was extracted from the fresh lemongrass (control) with a yield of 0.39% on fresh weight basis. This result agrees with those of previous researchers who reported that oil content should on average be in the range 0.25-0.5% but with good management and selected strain could yield up to 0.66-0.90% (Hanaa et al., 2012).

The effect of storage time (weeks) and conditions (shade and sun) on oil yield were investigated as shown in Figure 6. Slight significant changes in the oil yield were observed for storage in the shade from 1st week (0.38%) through the 4th week (0.21%). This might be due to exposure of lemon grass sample in very low temperature during shade storage (Debashis et al., 2014).

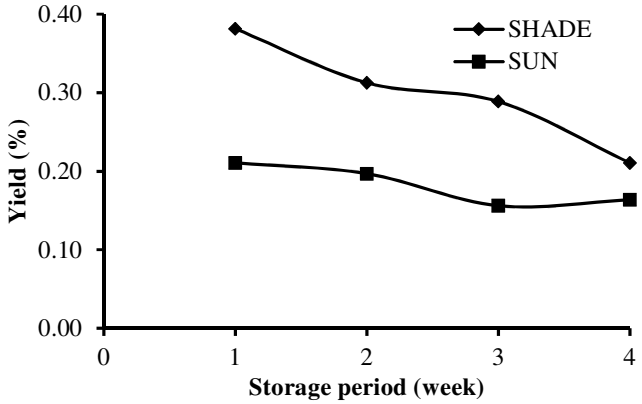

Figure 6: Effect of storage period and condition on oil yield

However, significant reduction in oil yield was observed for storage in the sun from 0.21% in the 1st week to 0.16% in the 4th week as also shown in Figure 6. Comparison of oil yield obtained in the 4th week (0.21%) for shade and 0.16% for sun with fresh lemon grass (0.39%), shows that there was reduction of 46.2% or for shade and 59% for sun. This implies that storage in the shade preserves more oil than storage in the sun and thus is recommended as the best storage method. The reported oil yield for one week storage in the sun and shade were 0.25% and 0.27% respectively (Mu'azu et al., 2018). The oil yield for one week storage in this study was 0.21% and 0.38% for sun and shade respectively. These results were in agreement with the reported values of 0.25% for sun and 0.27% for shade (Debashis et al., 2014). The slight difference could be due to time of harvesting, maturity, tree age, leaf age and fertilizer application (Maffeis et al., 2000).

3.3. Prediction of Oil Yield Due to Storage Period and Condition

To predict oil yield due to storage period and condition beyond four weeks, Figure 6 was linearized to obtain Figure 7.

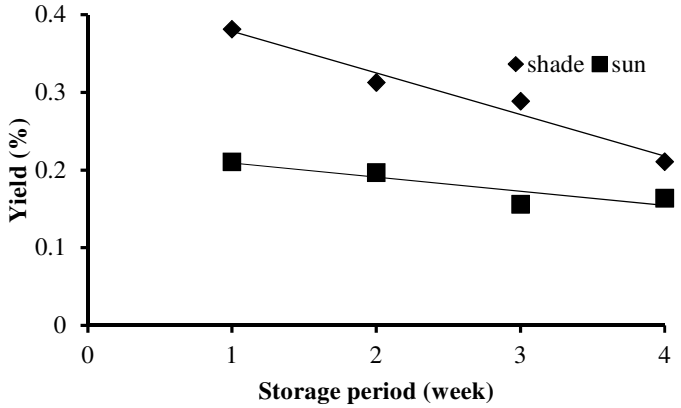

Figure 7: Linearization of effect of storage period and condition on oil yield

Two mathematical model equations were obtained for prediction of oil yield as a function of time of storage of lemon grass in the sun and shade as presented in Equations (2) and (3) respectively.

$$Y = -0.0182X + 0.2273 \quad (2)$$

$$Y = -0.0536X + 0.4324 \quad (3)$$

In Equations (2) and (3), Y represents oil yield and X storage period. The equations allow prediction of oil yield at any given time in any storage condition (sun and shade). For instance, if X=5 in Equation (2), then Y = -0.0182(5) + 0.2273 = 0.136%. Similarly. for X=5 in Equation (3), then Y = -0.0536(5) + 0.4324 = 0.164%. In other words, when the lemon grass is separately kept under both sun and shade for a period of 5 weeks, the expected oil yield would be 0.136% and 0.164% respectively.

3.4. Properties of the Essential Oil

The properties of the lemon grass essential oil extracted was determined and compared with the standard specifications as provided by Galadima, (2004). The properties determined were colour, appearance, odour, taste, refractive index, specific gravity, iodine value and solubility in ethanol as shown in Table 4 and 5 for sun and shade storage respectively.

The colour of the oil extracted from fresh lemon grass which served as control was golden yellow and remained unchanged throughout the storage period. The odour and taste of the oil were lemon type and also remained unaffected by both condition and period of storage. The values obtained for other parameters such as refractive index, specific gravity, iodine value and solubility in ethanol in both cases are discussed in the following sections:

Table 4: Effect of storage period on properties of the oil stored in the sun

Parameter	Storage period (week)					
	Fresh	1	2	3	4	Literature value
Colour	Golden yellow	Golden yellow	Golden yellow	Golden yellow	Golden yellow	Golden yellow
Appearance	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Odour	Lemon-type	Lemon-type	Lemon-type	Lemon-type	Lemon-type	Lemon-type
Taste	Lemon-type	Lemon-type	Lemon-type	Lemon-type	Lemon-type	Lemon-type
Refractive index @ 25 °C	1.486	1.4854	1.4932	1.4858	1.4924	1.485-1.4936
Specific gravity @ 25 °C	0.8812	0.8911	0.8902	0.8891	0.8925	0.8725-0.8965
Solubility in 70% ethanol (v/v)	1:4	1:5	1:5	1:4	1:5	1:5
Iodine value (Centigram I/ gram oil)	113	114	113	115	114	115.85±0.57

Table 5: Effect of storage period on properties of the oil stored in the shade

Parameter	Storage period (week)					
	Fresh	1	2	3	4	Literature value
Colour	Golden yellow	Golden yellow	Golden yellow	Golden yellow	Golden yellow	Golden yellow
Appearance	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Odour	Lemon-type	Lemon-type	Lemon-type	Lemon-type	Lemon-type	Lemon-type
Taste	Lemon-type	Lemon-type	Lemon-type	Lemon-type	Lemon-type	Lemon-type
Refractive index @ 25 °C	1.488	1.487	1.492	1.491	1.489	1.485-1.4936
Specific gravity @ 25 °C	0.8912	0.8891	0.8909	0.8812	0.8943	0.8725-0.8965
Solubility in 70% ethanol (v/v)	1:5	1:4	1:4	1:5	1:5	1:5
Iodine value (Centigram I/ gram oil)	114	115	113	113	114	115.85±0.57

3.4.1. Specific gravity

Specific gravity of the essential oil after characterization at room temperature (25 °C) for sun storage ranged from 0.8812 – 0.8925 while for shade storage was 0.8812 – 0.8943 which were both within the ASTM specified values of 0.8725 – 0.8965 (Galadima, 2004). The agreement in the values obtained may be due to the fact that both lemon grasses were from the same region.

3.4.2. Iodine value

The Iodine value obtained ranged from 113-115 centigrams I/ gram oil for both storage conditions which show that the oil belongs to the class of non-drying oils. These values were in agreement with the literature values of 115.85 centigrams I/ gram oil ±0.57 and indicate that the lemongrass oil is predominantly polyunsaturated fatty acids consists mainly oleic and linoleic fatty acid (Kochhar, 1998). This class of oils whose iodine value is between 100-150 centigrams I/ gram oil possesses the property of absorbing oxygen on exposure to the atmosphere (Debashis et al., 2014).

3.4.3. Refractive index

The refractive index measured at room temperature (25 °C) for the essential oil for both sun and shade storages ranged from 1.4854 – 1.4932. These values were in agreement with the literature values of 1.4850 – 1.4936 as reported (Galadima, 2004).

3.4.4. Solubility in alcohol

The solubility of the extracted essential oils in 70% ethanol was 1:5 (v/v) for both storage conditions and 1:5 (v/v) was the reported literature value (Galadima, 2004).

4. CONCLUSION

Shade storage preserved more oil compared to sun with reduction in oil yield by about 59% for sun and 46.2% for shade in the 4th week. The properties of the oil were not significantly affected by both the storage period and condition. The developed mathematical models could be used to predict oil yield from lemon grass as a function of storage time under any of the stated conditions of storage (sun and shade). This will certainly help essential oil producers to known the optimum period and best condition to store the lemon grass before extraction.

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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