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COMPARATIVE STUDY OF DISSIPATION FACTOR OF YOUNG AND MATURE BITTER LEAF (VERNONIA AMYGDALINA) BASED ON LOCATION

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Abstract. The use of Schering Bridge arrangement in combination with function generator and oscilloscope allows for precise measurement of heat dissipation in plant materials. This study aims to determine and compare the heat dissipation properties of young bitter leaf (YBL) and mature bitter leaf (MBL) samples obtained from two different locations. Measurements were conducted on ten fresh leaf samples per category from each location. Results indicated that for samples from the first location, the dissipation factors for YBL and MBL were (2.076 ± 0.010) and (3.231 ± 0.013) respectively, while from the second location, the values were (3.231 ± 0.013) and (3.233 ± 0.015) respectively. The data suggest that while the geographical location does not significantly influence the heat dissipation of bitter leaf (Vernonia amygdalina), the age of the leaves does, with YBL exhibiting a higher capacity to withstand elevated temperatures compared to MBL under identical storage conditions. This study provides insight into the thermal properties of bitter leaf, contributing to broader research on plant thermoregulation. The novelty of this work lies in its demonstration that leaf age, rather than location, is a determinant factor in heat dissipation.

Keywords: Age of growth, Analysis of variance, Dielectric, Schering Bridge, Temperature.

1. Introduction

Dissipation is one of the fundamental properties of dielectric materials. In recent years, knowledge of dielectric properties has been greatly applied in agricultural sector. Of particular note is their application to the study of plant materials, especially the leaves. By such attempt, it is possible to exploit the use of remote sensing, microwave heating/drying, water stress in plants [1, 2] and also characterize vegetation leaves [3]. In this regard, some of the plant leaves reported on are those of banana [4], sweet and sour cherry [2], monster [6], bamboo and canna plants [7]. Findings from the mentioned researches have revealed that insight could be gained on quality of agricultural products as well as plant dynamic change due to water content. These observations are in line with the submission of Van Emmerik [8] that leaves dielectric properties influence microwave scattering from a vegetation canopy and are a function of leaf water content

Interestingly, our vegetation is dominated by various kinds of plants among which bitter leaf (Vernonia amygdalina) is a typical example. In tropical regions of West Africa, Vernonia amygdalina is predominantly cultivated [9]. It is a rapid regenerating soft woody perennial shrub that can grow perpetually to a height of about 1 m to 6 m and withstand a broad range of weather conditions. Its leaves are 6 mm in diameter and 20 cm long [10]. Vernonia amygdalina belongs to Asteraceae family, the largest of flowering plants [11]. In the languages of different regions like Bini, Tiv, Ibibio, Yoruba, Igbo, and Hausa, this plant is referred to by several local names such as Oriwu, Ityuna, Etidot, Ewuro, Onugbu, and Chusardoki respectively. Vernonia amygdalina has several biological and medicinal uses. For instance, it can be used as food, anti-cancer, anti-oxidant [12, 13]. It can as well be applied to cure typhoid fever [14], induce fertility [15], enhance breastmilk [16], treat malaria, diabetes, constipation, and high blood pressure [17, 18] among others. Not only that, the leaf extract is an effective corrosion inhibitor metals protection [19].

The essence of this study is to determine and compare heat dissipation factor of young and mature Vernonia amygdalina from two different locations. To the best of the authors' knowledge, this paper is the first to report such findings. Plant leaves do absorb energy and excess energy absorbed by them is dissipated as fluorescence and heat. Since heating phenomenon is of fundamental importance in its application to industrial processing of food and agricultural materials [20]. Giannakourou and Tsironi [21] noted that desired shelf-life improvement of vegetables can be obtained by mild heat treatment and low-temperature preservation. Ifesan et al. [22] found that a significant amount of mineral content of leaf appeared stable after being subjected to spontaneous fermentation for five days at room temperature. Xiao et al. [23] noticed that thermal blanching is an essential operation for many fruits and vegetables processing because it inactivates enzymes, enhances drying rate and product quality, removes pesticide residues and toxic constituents, and decreases microbial load. It is hoped that the information from this research would be useful in devising adequate storage and industrial processing techniques for the vegetable materials. Additionally, the study may give information about the relative differences in the structurally behaviors at molecular levels of the leaves.

2. Experimental Consideration

2.1. Materials collection

Fresh bitter leaves were gathered from two locations within a plantation where the plants were of same age of growth in Uyo metropolis, Akwa Ibom State, Nigeria. This was necessary to ensure that leaves were under the same site conditions and in turn, minimize the environmental effects on them.

From each stand considered for the study per location, several young and mature leaves were plucked. The age classification for the bitter leaves followed the method used by Damayanti et al [24], whereby the developmental stages of the leaves were considered such that those at the top and bottom were categorized as young and mature bitter leaves respectively. The leaves were kept in separate cellophane bags and labeled for ease of identification.

2.2. Methods

The surfaces of the bitter leaves were carefully cleaned to remove any impurity from them. Since leaf size is an important morphological character that has been frequently observed in numerous papers reporting comparative analysis [25], the average length, width, and other descriptive parameters were determined and used to further categorize them. The leaves were also weighed. Young ones of same mass were selected for the study. Similarly, mature leaves of same mass were chosen. The selected leaves were then used for analysis in this work as described below:

2.2.1. Measurement of chlorophyll content

The chlorophyll content of the bitter leaves was determined to gain more insights into the changes in their make-up due to age differences. In this research, 50 leaf samples of each age category and per location were utilized for this purpose. The leaves were washed with distilled water, air-dried for 120 hours at 45°C, covered with aluminium foil, put separately in black polystyrene bags, and kept in dark conditions at room temperature until use. Prior to use, the leaves were grinded to powdery form in each case using a coffee grinder such that 80% by volume of the particle size was about 240 µm as measured by means of a particle size analyzer (Malvern Mastersizer 2000). Extraction of chlorophyll pigment from each of the pulverized materials was done using acetone as solvent. Adopting the technique used by Ngeobo et al. [26], 0.5 g of the material was added to 50 cm^3 of the solvent and mixed using a laboratory magnetic stirrer until a uniform solution was formed. After mixing, the chlorophyll pigment was extracted using a water bath at 25°C for 30 minutes. This was followed by centrifugation of the extract at 2000 rpm for 5 minutes after which the supernatant was finally collected. The centrifugation was necessary to obtain pure chlorophyll. The supernatant was then subjected to spectrophotometric analysis at 663 nm and 645 nm for chlorophyll *a* and chlorophyll *b* absorbance measurements, respectively, using UV-VIS spectrophotometer (Genesys 10 S, Thermo Scientific) and the chlorophyll contents were calculated using the following relations [27]

$$C_a = 11.75A_{663} - 2.50A_{645} \quad (1)$$

while $$C_b = 18.61A_{645} - 3.96A_{663} \quad (2)$$

and $$T = C_a + C_b \quad (3)$$

where A = absorption at 663 nm and 645 nm, C_a = concentration of chlorophyll *a*, C_b = concentration of chlorophyll *b,* and T = total chlorophyll concentration.

The total chlorophyll content of the bitter leaves was similarly determined two more times, resulting to three trials after which the mean and associated error values were calculated on the basis of the age and location of the leaves.

2.2.2. Determination of dissipation factor

In this case, ten leaves were considered per age and from each location and they were coded. Then after, two identical copper plates measuring 27 mm x 10 mm x 4 mm were prepared and used to form a parallel-plate capacitor with copper lead terminals attached at convenient points. A section of each leaf was used as a dielectric in the capacitor formed. The cutting of the leaf was carefully done to ensure that the midribs were excluded from the section to be utilized as the dielectric. Also, after sandwiching of the dielectric (leaf) between the plates, the entire assembly was uniformly pressed with a load of 16 N such that no air gap existed within it. With the aid of a Schering Bridge arrangement (Figure 1), the dissipation factor was determined as detailed elsewhere [28 - 30]. In this research, a function generator (MFG -8219A) was used to supply the required ac signal at 1 kHz while a dual trace oscilloscope (CA 620) was employed as a monitoring device. From the measured capacitance, C_t obtained thus

$$C_t = \frac{RC_s}{R_s} \tag{4}$$

the leakage resistance, r of the capacitor arrangement under test was obtained by employing the mathematical formula [31]

$$r = \frac{CR_s}{C_s} \tag{5}$$

Then after, the dissipation factor, D in each case was determined using the relation

$$D = \omega r C_t \tag{6}$$

where R_s and R are select resistance values from decade resistance boxes, C_s and C are select capacitance values from decade capacitance boxes, $\omega = 2\pi f$ (where f is the frequency of the applied ac signal from the generator).

The measurements in this work were performed at (25 ± 1)ºC. Statistical Package for the Social Sciences (SPSS) Software was employed for statistical analyses in this research. Such analyses included computation of the mean and corresponding standard error values of the data obtained for each of the parameters (like the length, width, and chlorophyll content) of the bitter leaves as well as the use of one-way analysis of variance (ANOVA) to assess the differences in the dissipation factors at 0.05 level of significance based on age and also location of the bitter leaves.

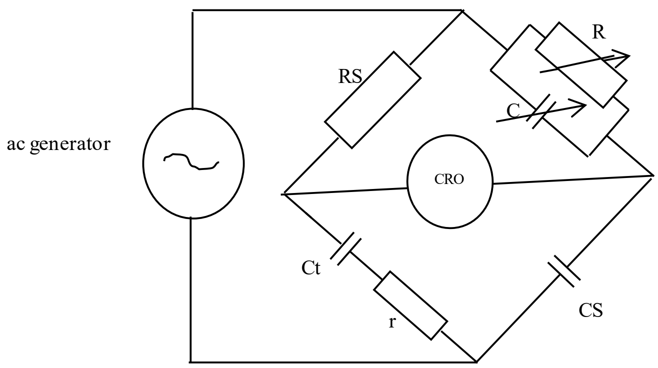

Fig. 1: Schematic diagram of the Schering bridge setup used in the study

3. Results and Discussion

Table1 shows the particulars describing the leaves for their categorization. The mature leaves are found to be longer and wider than the young ones. In the column for total chlorophyll contents, the non-bracketed data are for the bitter leaves from location A while the values in parenthesis are for the bitter leaves gathered from location B. For either the young bitter leaf (YBL) or mature bitter leaf (MBL) category, the mean chlorophyll contents are the same for the bitter leaves from the two locations. However, the MBL is higher than the YBL in total chlorophyll content by about 13.01% both at location A and location B. Due to fact that more quantities of chlorophyll are present in the MBL, a greener coloration is observed compared to the YBL. All these simply indicate that, physically and structurally, the age of the leaves has influence on their characteristics.

Table 1. Description of criteria for the leaves categorization

Category	Parameters			
	Length (mm)	Width (mm)	Total chlorophyll content (mg g^{-1})	Green coloration
YBL	115.0 ± 1.0	63.0 ± 2.0	1.161 ± 0.002 (1.161 ± 0.001)	Not deep
MBL	160.0 ± 2.0	80.0 ± 1.0	1.312 ± 0.001 (1.312 ± 0.002)	Deeper

Values in the parenthesis are for bitter leaves at location B

It is important to note that a vegetable leaf has its internal structure mainly made up of the epidermis (upper and lower), mesophyll, and vascular bundle. Also, the leaf is a photosynthetic organ responsible for manufacturing food for plants and its distinct internal parts include stomata, chloroplasts and guard cells. Interestingly, leaf acts as a site for photosynthesis, transpiration and gas exchange. Bielczynski et al [32] observed that older (mature) leaves are more prone to photo-damage than younger ones.

The values of dissipation factor obtained for the studied leaf samples are recorded in Table 2. Irrespective of the location, the MBL shows a greater tendency for heat dissipation in comparison to the YBL. This observation may be attributed to differences in the anatomy of the leaves. As reported by Oguchi et al [33], leaf anatomy influences photosynthetic capacity by changing the mesophyll thickness and increasing the space for chloroplasts at the cell surface necessary for the gas exchange. Thus, since MBL does not have the same cell wall and organelles configuration, it can be expected that structural differences between the MBL and YBL could at least be partially responsible for their varied dissipation tendencies. The implication in this case is that, in a dissipative system, the loss rate of energy by MBL would exceed that associated with the YBL even from the same stock if both are subjected to the same conditions of oscillation.

Table 2. Measured dissipation factor of the leaves

Location code	Leaf code	Value of dissipation factor per leaf category	
		YBL	MBL
A	A01	2.081	3.240
	A02	2.031	3.302
	A03	2.063	3.258
	A04	2.080	3.171
	A05	2.092	3.202
	A06	2.060	3.270
	A07	2.081	3.182
	A08	2.053	3.239
	A09	2.131	3.254
	A10	2.092	3.194
	Mean ± std. error	2.076 ± 0.010	3.231 ± 0.013
B	B01	2.080	3.301
	B02	2.081	3.194
	B03	2.042	3.288
	B04	2.053	3.222
	B05	2.104	3.179
	B06	2.062	3.258
	B07	2.092	3.210
	B08	2.042	3.320
	B09	2.131	3.170
	B10	2.053	3.191
	Mean ± std. error	2.074 ± 0.009	3.233 ± 0.015

As a matter of fact, dissipation is a term that is often used to describe ways in which heat energy is wasted. Factors that affect the magnitude of heat dissipation include heat capacity, and temperature difference between the material under test and the ambient temperature of its surroundings. Because no system is perfect, whenever there is a change in a system, energy is transferred to useful energy stores and some of it is dissipated into the surroundings. As temperature increases, the fraction of heat dissipation decreases. From the results, as recorded, it can be adjudged that the location has no influence on heat dissipating ability of bitter leaves but the age does. This is obvious from Figure 2 in which case the mean values for YBL or MBL differ very slightly notwithstanding the locations but reasonable different if compared on the basis of age. Since YBL has lower thermal dissipation, it means that it could withstand higher temperatures than MBL if both are under same heat stress during storage.

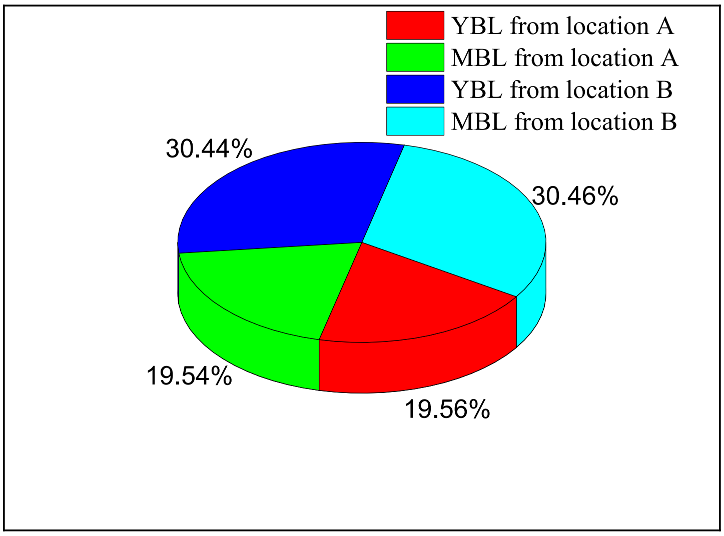

Fig. 2: Chart illustrating the proportions of dissipation factor for the bitter leaf samples

Table 3 shows the calculated F-values obtained by statistically analyzing the dissipation factors of the leaves samples (as reported in Table 2 above) using the ANOVA at 0.05 level of significance. It can be seen that the calculated value exceeds the critical value when comparing YBL with MBL samples obtained from either location, thus indicating a significant difference. On the contrary, insignificant difference is revealed when comparing on the basis of leaf age between the two locations.

Table 3. Results of the ANOVA test

Paired parameters	Calculated F-value	Critical F-value
YBL and MBL	5274[a]	4.414
	3527[b]	
Locations A and B	0.0365[c]	
	0.0093[d]	

a: samples obtained from location A;
b: samples obtained from location B;
c: young bitter leaf samples
d: mature bitter leaf samples.

4. Conclusion

The results of the experimental investigation carried out in this study showed that young bitter leaf (YBL) and mature bitter leaf (MBL) differ in their heat dissipation tendencies. Irrespective of their locations, the MBL samples exhibited greater dissipating ability compared to the YBL samples. However, it was observed that, on the basis of location, YBL samples compared very well in their thermal dissipation factors and a similar observation was possible in the case of MBL samples from the two different locations considered in this study. Under same conditions of storage, it could be adjudged from the results that YBL samples would withstand higher temperature compared to the MBL samples.

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