Comparison of Mosquitoes Response to Different Diodes Wavelengths

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Abstract: ***Development of light-emitting diode (LED) trap for mosquitoes (Diptera: Culicidae) continues to be desirable over other types of electro-mechanical traps for the control of mosquito menace. It is a key menace to a large number of people and creatures around the world. This project furthers the development of mosquitoes LED-trap using recently developed low energy LED colours. Tests were conducted to determine most inviting wavelength to mosquitoes using available ten (10) different LED wavelengths. The project was done within the living area in Lagos State, Nigeria. The population density of attracted and captured mosquitoes was analysed. Six hundred and four (604) specimens were capture in the experiment and three species were discovered. Amidst this superset were19 male mosquitoes and the most prevalent species was female Culex mosquito followed by other insects. Male Culex mosquitoes and female Anopheles mosquitoes were the next respectively, while unidentified mosquitoes have the lowest count. The trap did not capture male Anopheles mosquito. The experiment shows that more Culex mosquitoes were attracted toward the purple LED than blue, green, pink and warm white while other light spectra such as white, red, yellow, green-yellow and orange were less attractive to mosquitoes. The low ratio of damage mosquitoes to identifiable mosquito's shows that this passive is desirable compared to the Communicable Disease Centre (CDC) traps.***

Keywords: Mosquito, Trap, Fanless, LED, Culex, Anopheles`

1. Introduction

A critical menace to millions of people and creatures around the world have been mosquitoes (Diptera: Culicidae) that act as vectors for malaria, yellow fever, Japanese encephalitis, filariasis, West Nile, dengue, zika, chikungunya and dangerous pathogens as well as parasites [1]. These mosquito-borne ailments weaken and genuinely cripple a great many individuals consistently and destroy incalculable lives. More lives are lost by mosquitoes transmitted diseases on a year premise than war, psychological warfare, weapon viciousness and other human diseases added together [2]. Mosquitoes produce irritation and can shatter open air actions, yet when disease pathogens are not involved [3]. Other infections may arise as a result of mosquito bite such as itching, pain, redness allergic reaction, irritation and so on. Besides, they can constitute genuine health issues to animals too. Weight loss in livestock, issues of reduction in milk produced by the dairy cow and in beef cattle are also connected to mosquito bites [4].

Different examining gadgets have been developed and utilised for mosquito surveillance and comprehension. Generally, utilisation of light or odour as attractants have been applied by the primary testing gadgets among different devices developed and utilised for observation including population dynamics of mosquito [5–7]. These inspecting gadgets can be divided into passive or active traps concerning the existence or non-existence, separately and suction parts that drag gnats into the trap [8]. Centres for Disease Control and Prevention (CDC) light trap maybe the most excellent illustration among the active trap category [9]. Centers for Disease Control and Prevention traps are being used most frequently all through the world to conduct observation for gnat and Vector-borne disease [10].

Continued advancements with the odour-baited or/and light traps functioning in capturing grown-up female anopheline mosquitoes seeking host have been worked on to support malaria observation and tracking. Moreover traps utilisation have their disadvantage, including impediment [11]. Other than expanding energy utilisation, the active fan-type device can harm anopheline mosquitoes to the extent that they are not identified easily and thereby making species separation impossible [12–14]. Also, the fan-type traps ordinarily require overwhelming power-bank in running electric fan, which must be energised after each utilisation. A few types of the gadgets (e.g., CDC, BGS) are equipped with nylon mesh-collecting bag that come up with massively marred mosquitoes amid stockpile.

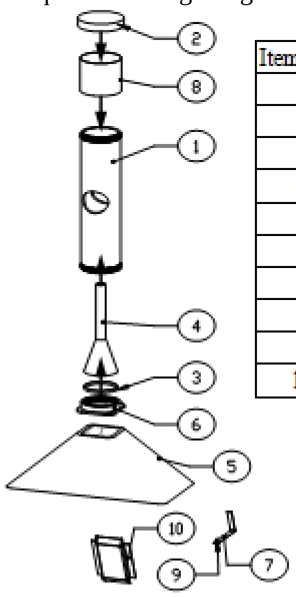
Silva et al., (2019) worked on Silva trap (a passive trap), and this was juxtaposed with the mini light trap from Centres for Disease Control and Prevention (CDC) in an animal zone in north-eastern Brazil. The finding indicated that the Silva trap has a satisfactory outcome and proficient device for examining anopheline mosquitoes. A few ongoing investigations have tried LED wavelength to as certain if a LED can perform as a powerful replacement for incandescent lights in mosquito observation snares [15]. Diptera feeding on blood, for example, mosquitoes, biting midges and sand flies regularly are fascinated to specific wavelength such as UV, blue and green [16].Nevertheless, most of these studies are conducted outside West Africa, and no account of a secondary colour (purple, orange, pink) LED light that is now available in the market. Subsequently, the main aim of this investigation was to assess on the field the attraction of mosquitoes to more LED colours in Nigeria. Nigeria is the most populous nation in West Africa and has similar climatic, environmental and socio-economic conditions with her neighbouring countries such as Ghana, Guinea, Senegal, Cote d'Ivoire, Togo, Benin, Mali, Niger, Cameroon and the rest.

ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2019): 7.583

2. Material and method

2.1 Material Adopted for the Mosquito Trap

The light trap is developed to further improve on the passive mosquito trap.It is the make-up of two fundamental parts (Figure 1 and 2): a round and hollow collecting body (part 1) and a rectangular capturing hood (part 5). The round and hollow body have two horizontal openings to supply fresh air. The apertures are secured with a synthetic net to screen off the caught mosquitoes from exiting the trap. Crest end of the round and hollow body incorporates a screw-detachable cover (Figure1, part 2) to collect trapped mosquitoes for analysis. A translucent funnel (Figure 1, part 4) is joined to the foot opening of the round and hollow body to convey mosquitoes into the trap (Figure 1, part 4) and a transparent tube is connected to the tip of the funnel to put a stop to mosquitoes from flying back. The rectangle capturing hood is screwed to the base of the round and hollow body (Figure 1, part 5) and the broad aspect facing down. LED (Figure 1, part 9) are utilised to lure mosquitoes into the equipment. This is attached to the inner part of the rectangular capturing hood and held in position by a holder shown in Figure 1, part 7. The rectangular capturing hood encompasses a reflective finishing at which LED wavelength is directed. The LED is installed facing up in such a way that the bulbs waves are centred into the round and hollow body along the funnel centre. The holder for the battery is fixed into the inner side of the rectangular capturing hood (Figure 1, part 10), which is replaceable after each utilisation. This gadget is used uprightly (Figure 2) permitting creepy crawlies to enter the round and hollow part from underneath. Following fascination by light bulbs, mosquitoes fly through the light-up inward hood surface of the rectangular capturing hood and after that wing straight up through the clear funnel into the collecting round and hollow component [8]. The rectangular capturing hood can be segregated from the round and hollow body after each operation for smooth movement and management. Preparatory to the transportation of the captured creepy crawlies, the pipe inlet of the round and hollow body is capped to prevent mosquitoes from getting away.



Item No.	Description
1	Cylindrical Collection Body
2	UPVC Cap
3	PVC Gasket
4	Tube & Funnel
5	Hood
6	Adaptor
7	LED holder
8	Net
9	5mm LED
10	Power pack

Figure 1: Trap exploded diagram

Figure 2: Trap assembly drawing.

2.2 Method of Trapping

Test which is to show preference or attraction of mosquitoes to different light wavelength was conducted at No. 14 Kolawole street, off Liasu Road, Council bus-stop, Alimosho Local Government Area, Lagos State, Nigeria (Latitude: 6.567528100907991; Longitude: 3.309801332652569). It is a living area with surrounding bungalow and story buildings as shown in the Google map in Figure 3.

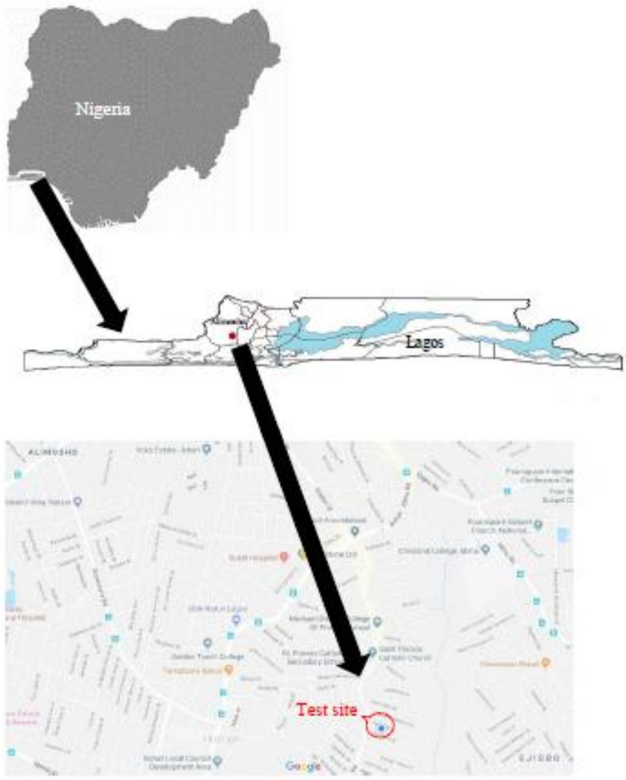


Figure 3: Map showing study site in Alimosho, Lagos State, Nigeria (Google map, 22/07/2019)

Tentraps were equipped with one 5mm round type high intensity LED as follows: blue trap with blue LEDs (450-455nm, 7, 000-8, 000 milicandella, 30°, 20 mA, 3.2 V), purple trap with purple LEDs (395-400 nm, 300-400 milicandella, 30°, 20 mA, 3.4 V), pink trap with pink LEDs (- nm, 7, 000-8, 000 milicandella, 30°, 20 mA, 3.2 V), red trap with red LEDs (620-625 nm, 2, 000-3, 000 milicandella, 30°, 20 mA, 2.2 V), orange trap with orange LEDs (602-610 nm, 1, 500-2, 000 milicandella, 30°, 20 mA, 2.2 V), yellow trap with yellow LEDs (588-592 nm, 1, 500-2, 000 milicandella, 30°, 20 mA, 2.2 V), green yellow trap with green yellow LEDs (570-575 nm, 500-700 milicandella, 30°, 20 mA, 2.2 V), green trap with green LEDs (515-525 nm, 15, 000-18, 000 milicandella, 30°, 20 mA, 3.2 V), warm white trap with warm white LEDs (2800-3000 k, 14, 000-16, 000 milicandella, 30°, 20 mA, 3.2 V) and white trap with white LEDs (6000-9000k, 12, 000-14, 000 milicandella, 30°, 20 mA, 3.2 V). They are energised by rechargeable 3.7V Li-ion standard batteries (a battery per trap). The capacity of the batteries is 1150 mAh, and this may take about ± 57.5hs (1150/20) or ± 4 12h-nights of work), all the ten batteries are fully charged before being deployed to the position in the experiments and recharge every third day of the experiment before redeployment for collection. The ten mosquito traps were then set outside a living environment with space of3m from one and the other in an L-setting, as shown in Figure 4. These traps were operated between 18:00 to 06:00 in May and June 2019. They were hung randomly and rotated each night on the fence wall at approximately 1.5m above ground level.

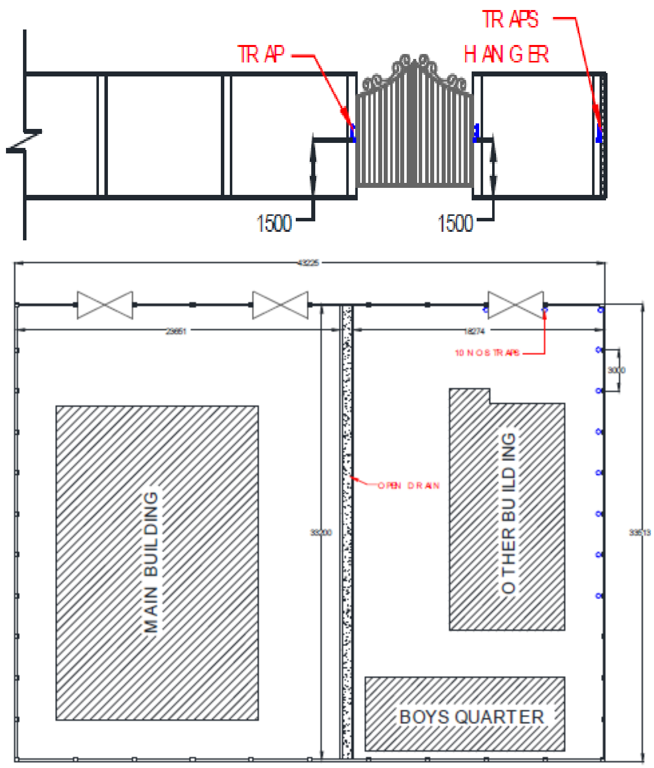


Figure 4: Study site layout and trap locations

2.3 Species Identification

After collection, gnats were placed in a bucket and sprayed with Baygon insecticide and cover for 30mins to be killed. The dead mosquitoes are collected into a plastic collector and transported to the Mechatronic Laboratory, Covenant University, Ota, Ogun State, Nigeria for identification, counts and separation to species. The traps were then washed with Magikmulti purpose detergent powder soak in the water to remove insecticide odour from the trap. The Kruskal-Wallis test thereafter by Dunn´s multiple comparison test was done to examine the data. The Shapiro-Wilk test was used to evaluate the assumption of the normality of the data. The differences were statistically significant when $p < 0.05$. All tests were performed utilising GraphPad Crystal program (GrahpPad Program Inc, San Diego, USA).

3. Results and Discussion

3.1 Responses of adult mosquitoes to different light wavelengths

Test, which is to show preference or attraction of mosquitoes to different light wavelengths was conducted over a 15-night span of investigations. Six hundred and four (604) specimens and three species were established. 19 male mosquitoes were captured, making 3.2% (Table 1). Most prevalent species was female Culex mosquitoes with a mean number of 34.67 ± 3.98 per night, followed by other insects with a mean number of 3.93 ± 0.85, male Culex mosquitoes with a mean number of 1.27 ± 0.42, female Anopheles mosquitoes with a mean number of 0.2 ± 0.14, unidentified mosquitoes with a mean number of 0.2 ± 0.11and zero male Anopheles mosquito.

Using 2-way ANOVA Tukey's multiple comparisons test (Table 2): when alpha = 0.05;Purple LED shows the highest level of significant attaining four stars compared with yellow LED (adjusted P<0.0001). When Purple LED is separately compared with Red LED and Orange LED, P = 0.0001 for each. P = 0.0004 for Purple LED compared with Green Yellow LED, Purple LED compared with White LED gives P=0.0047 and Purple LED compared with Pink LED, Green LED and Warm White LED did not show any statistically significant value. Blue LED compared with Red LED, Orange, Yellow and Green Yellow LED had adjusted P range between 0.0015 – 0.0055, while White LED compared with Blue LED had P=0.0423 and Pink LED, Green LED and Warm White LED compared with Blue LED data are not significant. Green LED compared with Red LED, Orange and Yellow LED had adjusted P range between 0.0063 – 0.0074, while Green Yellow LED compared with Green LED had P=0.0197. Green LED compared with Pink LED, White LED and Warm White LED has no statistically significant value. At 95% Confidence Intervals purple LED peaked at 2.219 versus Yellow higher than any other comparison in Table 2.

The total figure of female Culex mosquitoes captured by the purple LED trap was more than the number trapped by the other individual colour LED traps, but no significant difference among purple, green, blue, pink and warm white LED traps. Using multiple comparisons Tukey method, which compares column means (main column effect) test indicated that the adjusted P value range from 0.0604-0.9999. But purple, green, blue, pink and warm white LED traps were significantly different from the other five colours. All these outcomes illustrated that this trap is an effective device in capturing Culex mosquitoes than anopheles mosquitoes based on the result of the light trap. 2way ANOVA Tukey's multiple comparisons tests indicated that purple LED shows the highest level of significance, attaining four stars.

Table 1: Mean capture per night per trap and total number of gnats and rate of mosquitoes taken with blue, purple, pink, red, orange, yellow, green yellow, green, warm white and white LEDs outlets in Lagos, southwest of Nigeria.

Mosquitoes	Traps LED Colour																														Total	%
	Blue			Purple			Pink			Red			Orange			Yellow			GreenYellow			Green			Warm White			White				
	Mean	SEM	N	Mean	SEM	N	Mean	SEM	N	Mean	SEM	N	Mean	SEM	N	Mean	SEM	N	Mean	SEM	N	Mean	SEM	N	Mean	SEM	N	Mean	SEM	N		
Female Anopheles	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.07	0.07	1	0.00	0.00	0	0.00	0.00	0	0.13	0.13	2	0.00	0.00	0	0.00	0.00	0	3	0.50
Male Anopheles	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0	0.00
Female Culex	6.20	1.89	93	7.47	1.65	112	5.53	1.19	83	0.67	0.46	10	0.60	0.19	9	0.67	0.19	10	0.67	0.30	10	6.47	1.89	97	4.40	1.26	66	2.00	0.62	30	520	86.10
Male Culex	0.20	0.11	3	0.13	0.13	2	0.13	0.13	2	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.27	0.21	4	0.13	0.09	2	0.27	0.12	4	0.13	0.13	2	19	3.20
Other Mosquitoes	0.07	0.07	1	0.07	0.07	1	0.07	0.07	1	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	3	0.50
Other insect	1.20	0.38	18	1.07	0.38	16	0.20	0.11	3	0.13	0.09	2	0.13	0.09	2	0.07	0.07	1	0.33	0.13	5	0.33	0.21	5	0.33	0.21	5	0.13	0.09	2	59	9.80
Total number of individuals	115			131			89			12			12			11			19			106			75			34			604	
Mean of individuals per night/trap	19.17 ±15.03			21.83 ±18.21			14.83 ±13.64			2.00 ±1.63			2.00 ±1.44			1.83 ±1.64			3.17 ±1.64			17.67 ±15.88			12.50 ±10.74			5.667 ±4.883				
Total number of males	3			2			2			0			0			0			4			2			4			2			19	3.20

Table 2: 2way ANOVA Tukey's multiple comparisons test

Compare column means (main column effect)					
Number of families	1				
Number of comparisons per family	45				
Alpha	0.05				
Tukey's multiple comparisons test	**Mean Diff.**	**95.00% CI of diff.**	**Significant?**	**Summary**	**Adjusted P Value**
Blue vs. Purple	-0.1778	-1.062 to 0.7068	No	ns	0.9998
Blue vs. Pink	0.2889	-0.5957 to 1.174	No	ns	0.9900
Blue vs. Red	1.144	0.2598 to 2.029	Yes	**	0.0018
Blue vs. Orange	1.144	0.2598 to 2.029	Yes	**	0.0018
Blue vs. Yellow	1.156	0.2709 to 2.040	Yes	**	0.0015
Blue vs. GreenYellow	1.067	0.1820 to 1.951	Yes	**	0.0055
Blue vs. Green	0.1000	-0.7846 to 0.9846	No	ns	>0.9999
Blue vs. Warm White	0.4444	-0.4402 to 1.329	No	ns	0.8509
Blue vs. White	0.9000	0.01538 to 1.785	Yes	*	0.0423
Purple vs. Pink	0.4667	-0.4180 to 1.351	No	ns	0.8100
Purple vs. Red	1.322	0.4376 to 2.207	Yes	***	0.0001
Purple vs. Orange	1.322	0.4376 to 2.207	Yes	***	0.0001
Purple vs. Yellow	1.333	0.4487 to 2.218	Yes	****	<0.0001
Purple vs. GreenYellow	1.244	0.3598 to 2.129	Yes	***	0.0004
Purple vs. Green	0.2778	-0.6068 to 1.162	No	ns	0.9924
Purple vs. Warm White	0.6222	-0.2624 to 1.507	No	ns	0.4356
Purple vs. White	1.078	0.1932 to 1.962	Yes	**	0.0047
Pink vs. Red	0.8556	-0.02906 to 1.740	No	ns	0.0677
Pink vs. Orange	0.8556	-0.02906 to 1.740	No	ns	0.0677
Pink vs. Yellow	0.8667	-0.01795 to 1.751	No	ns	0.0604
Pink vs. GreenYellow	0.7778	-0.1068 to 1.662	No	ns	0.1416
Pink vs. Green	-0.1889	-1.074 to 0.6957	No	ns	0.9996
Pink vs. Warm White	0.1556	-0.7291 to 1.040	No	ns	>0.9999
Pink vs. White	0.6111	-0.2735 to 1.496	No	ns	0.4631
Red vs. Orange	0.000	-0.8846 to 0.8846	No	ns	>0.9999
Red vs. Yellow	0.01111	-0.8735 to 0.8957	No	ns	>0.9999
Red vs. GreenYellow	-0.07778	-0.9624 to 0.8068	No	ns	>0.9999
Red vs. Green	-1.044	-1.929 to -0.1598	Yes	**	0.0074
Red vs. Warm White	-0.7000	-1.585 to 0.1846	No	ns	0.2641
Red vs. White	-0.2444	-1.129 to 0.6402	No	ns	0.9971
Orange vs. Yellow	0.01111	-0.8735 to 0.8957	No	ns	>0.9999
Orange vs. GreenYellow	-0.07778	-0.9624 to 0.8068	No	ns	>0.9999
Orange vs. Green	-1.044	-1.929 to -0.1598	Yes	**	0.0074
Orange vs. Warm White	-0.7000	-1.585 to 0.1846	No	ns	0.2641
Orange vs. White	-0.2444	-1.129 to 0.6402	No	ns	0.9971
Yellow vs. GreenYellow	-0.08889	-0.9735 to 0.7957	No	ns	>0.9999
Yellow vs. Green	-1.056	-1.940 to -0.1709	Yes	**	0.0063
Yellow vs. Warm White	-0.7111	-1.596 to 0.1735	No	ns	0.2434
Yellow vs. White	-0.2556	-1.140 to 0.6291	No	ns	0.9959
GreenYellow vs. Green	-0.9667	-1.851 to -0.08205	Yes	*	0.0197

GreenYellow vs. Warm White	-0.6222	-1.507 to 0.2624	No	ns	0.4356
GreenYellow vs. White	-0.1667	-1.051 to 0.7180	No	ns	0.9999
Green vs. Warm White	0.3444	-0.5402 to 1.229	No	ns	0.9665
Green vs. White	0.8000	-0.08462 to 1.685	No	ns	0.1160
Warm White vs. White	0.4556	-0.4291 to 1.340	No	ns	0.8311

4. Conclusion and Recommendation

The low ratio of damage to identifiable mosquitoes shows that the trap can be compared to Silva trap, with the additional bit of leeway for its lower power consumption and usage outdoor. Since it does not require odour bait, CO_2or dragging fan, it is more suitable for outdoor use. When hung outside an exploratory house, the passage of mosquitoes is intercepted at this level making the setup a useful instrument for controlling transmission of malaria in and around the domesticated environment in the living area in sub-Saharan Africa and Nigeria in particular. The trap had not been able to attract significant anopheles' mosquitoes for a reason unknown. However, this work is a pointer to the fact that the area is heavily populated with Culex mosquitoes that transmit malaria and committing most mosquito nuisance.

Further work needed to be done on the developed trap to compare it with the CDC light trap and other commercially available mosquito traps to ascertain its capture rate also and predominance of Culex mosquitoes in the region. It is of importance to work on the trap to adapt it for domestic use. Further examinations are required with an attention on the utilisation of multiple high-intensity LEDs (more than one number), but of the same colour to ascertain their impact on mosquitoes in like manner, LEDs of different colours that are controlled by a microcontroller to be ON and OFF alternatively between the promising colours as observed in this work. This trap may be further tested with bait such as human-bait, chemical-bait and animal bait, for a general upgrade of mosquito light-trap. Collections may be extended to other regions in Nigeria and other neighbouring countries.

5. Conflict of interest

The authors have no conflicts of interest to disclose.

6. Acknowledgements

The authors acknowledge Covenant University Ota, Ogun State, Nigeria, for the sponsorship and provision of research facilities for this project.

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