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Dependency of Flame Duration of Some Tropical Timbers on Their Oven Dry Densities

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Abstract Timber is an essential raw material needed in constructing one thing or the other in all fields of human endevour. It is combustible. In this research, fire characteristics of fifty-seven (57) tropical timbers were investigated. The characteristics studied are: flame duration (FD) and oven dry density (ODD). The tropical timbers with the highest FD are *C. nitida, P. carribean, A. bateri, A. indica, M. altissima,I. tomentosa, G. gnetoides, B. gracilipes* and a variety of *M. indica* respectively.The one with the highest ODD is *Manilkara*. The ones with the least of this fire characteristics (FD) were *B. bonopozense and S. campanulala* (1.4x10sec) . Although some tropical timbers with lower ODDs possess high FD, some of the timber with higher ODDs possess lower FD, it can be said that there is neither inverse nor direct relationship between the FD of the tropical timbers and their oven dry densities. Though density is an important factor, in determining the fire characteristics of timber, the cellular structure, molecular composition, orientation of fiber (direction of grain) and timber extractives (eg resins) deserve a special attention in explaining the results. The aim of this work is to identify the timbers that are fire resistant and those that are not and to compare the FD of these tropical timbers with their oven dry densities.

Keywords Tropical timbers, flame duration, oven dry densities, fire characteristics, fire resistant and non-fire resistant timbers.

Introduction

Fire or flame is a gaseous matter heated to such a degree as to be luminous, or it's a region of hot gases raised to incandescence. It is a chemical phenomenon that involves exothermic process of oxidation and combustion. Physically, flame is defined as rise in temperature of the ambient atmosphere and its pollution with gases. Fire triangle is represented as shown in Fig.1

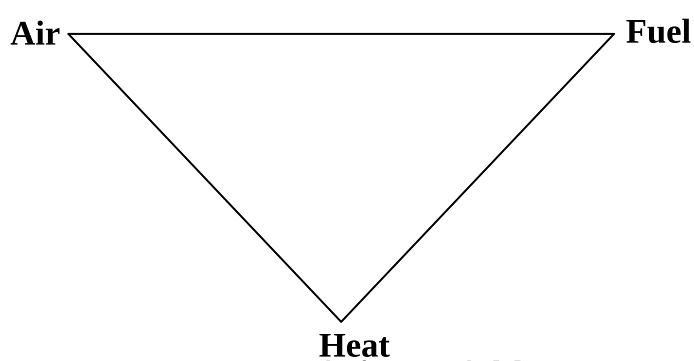

Figure 1: The fire triangle [1]

For fire to exist, air and fuel must be in equilibrium. The burning generates heat. Many strategies are used in the study of fire. These include, but not restricted to the following:

Ignition Time (IT), Flame Propagation Rate (FPR), Flame Duration (FD), Afterglow Time (AGT), Oven Dry Density (ODD), Moisture content, Water saturation capacity (porosity index), Ash content, Elemental Analysis, Thermal or heat conductivity,

Electrical conductivity, Smoke density Thermogravimetric, Analysis Limiting oxygen Index (LOI). A fire outbreak is an accidental disaster. Fire disaster is not a new misfortune in the world. Among the African nations, it is quite unfortunate that Nigeria is taking the lead on the constant fire calamities. The government and private institutions are not left out. Think of the Nigerian External Telecommunications Ltd (NET), Lagos and the Cocoa House Building, Ibadan. These national edifices were all successfully raped by the "undesirable element" called fire. On the other hand, only a few large markets within the country could be excluded from all these rampant undesirable occurrences. No State in Nigeria had not experienced fire problems once or twice in the past [2]. The most vulnerable places include markets, personal belongings and government establishments. Among the notable markets affected in the country are Aria (Ogbete), Gwombe, Sabongari, Diobu, Ariaria, Jos, Abakaliki and many others including the famous Onitsha. Although Onitsha markets had been encountering fire occurrences, the 1984 incidents in a year seemed to be more or less mysterious issues. The factor contributing to the attentiveness of the 1984 incidents was that none of the past fire occurrences gutted two giant markets possessed by the town in a day [1]. The conflagration of 17th December, 1984 that occurred at the Ochancha and Main-Markets brought the happiness and joy in the minds of the people of benedicted deportment to what could be described as dumb-founding darkness of the day in the field of the commercial undertaking-showing gigantic "sorry sights". A case where many people had earlier planned for their Christmass celebrations, though there were fair feelings of the banging austerity, while it remained only eight days before the merriment, the people of the "water city" and the nation at large experienced huge losses resulting from their commercial assets. Honestly speaking, this is a heavy slap to the channels of happiness and joy and management of life. Someone, for instance, who happened to be aware of the past fire incidents in Onitsha might have agreed with me that two huge markets burning down in a day might be more embarrassing and dishearting. This is so, because there were no physical or civil war, yet billions of Naira worth of valuables were lost.

On Saturday, October 17, 1998, the thirty-two (32) communities in Idejerhe were thrown into unprecedented mourning when a pipeline carrying fuel exploded and kill over five hundred (500) people. Then in October 20, 1998, it was reported that official negligence resulted in grave tragedy at Idejerhe, Niger Delta, Nigeria. It was pointed out that;

*Over 500 people were roasted to death; and that death toll may reach 1000.
*Thirty-two (32) communities mourn.
*Fire explosion was from a leaking fuel manifold.
*Persistent and paralyzing fuel scarcity caused disaster.
*Gloom and fear gripped communities; victims filled hospitals.
*Shell Helicopter hovered five minutes before explosion.

Fire disaster is not peculiar to Nigeria. It also occurs in other nations.Some notable fire disasters that claimed the lives of many students are highlighted as follows:-

- Lake Vie Grammer School in Collinwood, Ohio, (176 dead).
- The New London Consolidated School in Texas (294 dead).

Our Lady of the Angels School in Chicago (95 dead).

There were also a number of classic fires in public assembly that lead to upgrades in fire and life safety. Some of them are: [3]. 1903 - Iroquois Theater (602 dead).

. 1919 - Dance Hall, Via Platt, Theater in Paisley, Scotland (70 dead).
. 1929 – The Glen Motion Picture Theater in Paisley, Scotland (70 dead).
. 1940 – Rhythm Club, Natchez, Ms (198 dead).
. 1942 – The Cocoanut Grove, Boston (491 dead).
. 1977 – Beverly Hills Upper Club, Southgate, LA (164 dead).
. 1990 – Happy Land Social Club, Bronx, NY (87 dead).

The page of history told the stories of great cities that were destroyed by fire [3].

. London – 789, 982, 1212, 1666
. Venice – 1106, 1577
. Boston – 1631, 1653, 1676
. Moscow – 1752

. Rome – 1764
. Chicago – 1871
. Baltimore – 1904
. San Francisco -1906

The important lesson, learnt from American historic catastrophes was that after each fire disaster, they latter developed the firefighting force department. This was called a fire department. This was a reaction to a problem [2].

Having understood the usefulness of trees to mankind and brief historical account of fire incidents, it becomes very glaring that there is the need to study fire or thermal characteristics of timbers, since timbers are combustible and many materials used in diverse fields of human endeavor are made of timber.

Experimental procedures:

Sample collection and preparation: The fifty-seven (57) tree species samples were collected from eleven states in Nigeria. The states are: Anambra, Imo, Enugu, Sokoto, Katsina, Kano, Kebbi, Yobe, Edo, Zamfara and Gombe. The map showing the states in Nigeria are shown in **Fig. 2**.

Figure 2: Map showing the thirty-six (36) states in Nigeria[5]

Some of the tree species were living trees cut down . Some were the already felled trees. Dulmer machine was used to cut out part of the tree drunk. Thirty-two timbers were obtained from the timber sheds or saw mills at Onitsha, Nnewi and Awka. The states from where these timbers were collected were ascertained from the timber dealers. The tree species were authenticated by the Forest Officer in each of the State or the Local Government Area where the timbers were collected. The timber dealers or the saw millers were able to say the botanical names of few timbers collected from the timber shed. Most of the timbers collected there were taken to the Forest Officer in that Local Government Area where the tree species were got. By mentioning the local or common name of tree species and by having a look at the parts of tree species, the Forest Officers were able to say the botanical names of the tree or timber species.

After the collection and authentification, they were occasionally conveyed to the saw mill where each timber was cut into two different shapes and sizes; They are:

(i) Splints of dimensions of 30cm x 2.5cm x 0.6cm

(ii) Cubes of dimensions of 2.5cm x2.5cm x2.5cm i.e. 15.625 cubic centimeter. The splints of timber were dried in an oven at 105^0C for 48hours before the experiment. American Standard for Testing and Materials (ASTM) was employed in the analysis. The picture of the saw mill used is in Figure 3.

Figure 3: Photograph of saw mill at Ihiala

Determination of the Flame Duration (FD) of the timbers

Three splints of each tree species were selected. The samples were vertically clamped. Cigarette lighter was used to supply a steady flame. After the ignition of the splint sample, it starts burning. The time interval from the time it started burning to the time the flame went off on its own was recorded as flame duration. It was observed that few splints of tree species would continue burning till the whole length of the splint was burnt. In this case flame duration was recorded as infinity. The tree species that were observed to exhibit this characteristic were: *P. carribean, I. tomentosa, M. altissima, C. nitida, G. gnetoides, M. indica var. opiolo mango, A. indica, B. gracilipes, and A. bateri*. In this work, flame duration is recorded in seconds.

Determination of Oven Dry Density (ODD)

Three 2.5cm cubes of each timber were randomly selected from one hundred and eighty cubes of the tree species. Each was weighed with Top loading balance, Model: PL 203, Make: Mettler Toledo. After recording the initial weight, the sample was transferred into the drying oven at the temperature of 105^oC. The sample was left in the oven for three hours. After the heating, the oven was switched off, and the sample left overnight to cool. The sample was re-weighed after twelve hours. Care was taken to ensure that sample did not absorb moisture before and during weighing. After recording the second weight for each, the samples were taken back into the oven for another 3 hrs at that same temperature. This was repeated until any two subsequent weights were equal i.e. constant weight attained. Three cubes of each tree species were tied together with a copper wire and weighed as a single entity. Cu wire was removed and the three samples re-weighed. The weight of a cube was obtained by calculating the average of the three samples of each tree species. The dimensions of the three 2.5cm cubes were measured and the volume of each was calculated. The average volume of the three samples was recorded as the volume of each sample of the timbers. Finally the oven dry density of each tree species was determined by dividing the average dry weight of the three sample by the average volume of three samples.

$$\text{ODD} = \frac{\text{Average dry wt of samples g/dm}^3}{\text{Average volume of samples}}$$

Results and Discussion

The results of the investigations carried out in this work are given in Tables 1 and 2, and Figures 1, 2,3, 4 and 5. The thermal characteristics of tropical timbers investigated in this research include; flame duration (FD) and oven dry density (ODD).

Table 1: Names of the selected fifty-seven (57) tropical timbers from Nigeria

Tree species No	Botanical name	Common name	Vernacular names
1.	*Cola nitida*	Colanut	Ibo - oji, Hausa – goro Yoruba - obi gbanja, Nupe – Chigban'bi
2.	*Newboldia levis*		Ibo – Ogilisi, Hausa – aduruku, Yoruba – akoko,Benin – Ikhimi
3.	*Crysophyllum albidium*	White Star apple	Ibo – udala Yoruba-Agbalumo,Edo-Otien
4.	*Treculia Africana*	African bread fruit	Ibo – ukwa
5.	*Psidium guajava*	Guava	**Ibo – gova**
6.	*Citrus sinensis*	Sweet orange	Ibo – oloma
7.	*Dacroydes edulis*	Native pear	Ibo – ube
8.	*Chlorophoro exelsa*	Iroko	Ibo – orji, Hausa – loko, Yoruba – iroko, Benin – uloko Nupe – rook,Ijwa – olokpata
9.	*Gaeis guineensis*	Oil palm tree	Ibo – nkwu
10.	*Cocus nucifera*	Coconut tree	Ibo – aku oyibo
11.	*Persea Americana*	Avocado pear	Ibo – ube oyibo
12.	*Irvingia smithii*		Ibo – ogbono
13.	*Irvingia gabanensis*		Ibo – ugiri, Yoruba – Oro, Benin – Ogwe, Efik – Oyo Nupe – pekpeara,Ijaw – ogboin
14.	*Caesalpina pulcherima*	Pride of Barbadose	
15.	*Terminalia catappa*	Umbrella tree or Indian Almond	
16.	*Spathodea campanulala*		Ibo – echichii
17.	*Ricinovenvron heudenocii*		Ibo – okwe
18.	*Ficu natalensis*		Ibo – ogbu
19.	*Banbax bonopozense*		Ibo – Akpu ,Yoruba – Puopola,Benin – oboidia Ijaw – idoundu
20.	*Ceiba petandra*	Silk cotton plant	Ibo – akpu ogwu,Yoruba – araba,Benin – okha, Efik – ukem Ijaw – afalafase
21.	*Cola gigantia*		Ibo – ebenebe, Hausa – bokoko, Yorubo – ogugu, Benin – ukpokpo, Efik – dikir, Ishan – abolo
22.	*Acacia nilotica*	Cacia	Hausa – bagaruwa, Kanuri – kangari,Fulani – gaudi
23.	*Nauclea diderrichii*		Ibo – uburu mmiri, Yoruba – opepe, Benin – obiakhe, Ijaw – owoso,Urhobo – urherekor
24.	*Gmelina arborea*	Bushbeech or Meligna	Ibo – malina,
25.	*Pteracarpus soyauxi*		Ibo – oha
26.	*Annoa senegalensis*		Ibo – oghulu, uburu ocha, Yoruba – abo,Hausa – Swandar daji,
27.	*Canarium schwanfurthii*		Ibo – ube okpoko

28.	*Pinus carribean*	Whispering pine	
29.	*Albizia ferruginea*	Albizia	Ibo- Ngwu or ngu Yoruba – Ayinre oga, Benin – uwowe
30.	*Brachystegia Nigeria*		Ibo – ufi, Yoruba – akolodo,Benin – okwen, Ishan – eku Ijaw – akpakpa, Efik – ukung,Boki – kpeunik, Ekoi – etare
31.	*Dialuim guineensis*		Ibo – icheku
32.	*Napoliana vogelii*		Ibo – nkpodu
33.	*Accio bateri*		Ibo – araba
34.	*Brachystigia eurecomya*		Ibo – achi mkpuru,Yoruba – akolodo,Benin – okwen Ijaw – akpakpa,Ishan – eku,Ekoi – etare, Boki – kepuruk Efik – ukung
35.	*Pluneria Africana*		
36.	*Walteria Americana*		
37.	*Azadirachta indica*	Neem plant	Hausa – dogonyaro
38.	*Khaya senegalensis*	Mahogany	Hausa – madacu
39.	*Manilkara*		Ibo – ukpi
40.	*Alstonia congensis*		Ibo – egbu
41.	*Tectona grandis*	Teak	
42.	*Mansonia altissima*	Mansonia Iron tree	Yoruba-ofun
43.	*Isoberlinia tomentosa*	Berlinia	Ibo – uboba, Hausa – faradoka (white doka) Nupe – baba
44.	*Isoberlinia doka*	Berlinia	Ibo – ububra ibu, Hausa – doka Nupe – babarochii bokun, Tiv – mkovol
45.	*Garcinia kola*	Bitter kola	Ibo – ugolo/adi, Yoruba – orogbo Benin –edun, Efik – efiari, Ijaw – okan Ibibio – efiat
46.	*Garcinia gnetoides*	Wild ugolo	Ibo – ugolo agho
47.	*Baphia nitida*		Ibo – aboshi ojii, Yoruba – irosun,Benin – otun, Efik – ubara Ijaw – abodi, Itsekiri – orosun, Urhobo – arhua
48.	*Baphia gracilipes*		Ibo – aboshi ocha
49.	*Terminalia brownie*	Congo afara	Ibo – edo, Hausa – baushe,Yoruba – idiodan
50.	*Terminalia superb*	Akmond tree (white afara)	Ibo – edo, Yoruba – afara,Benin – egboin nofua, Efik – afia eto,Ijaw – gbarada, Nupe –eji,Urhobo – unwonron
51.	*Terminalia glaucescens*	Black afara	Ibo –edo, Hausa – baushe,Yoruba – idiodan
52.	*Mangifera callina*	Kerosene mango	
53.	*Mangifera banganpalli*	Ordinary mango	Ibo – mango nkiti
54.	*Mangifera indica*	Mango with fibre	Ibo – opiolo mango
55.	*Mangifera indica*	Gernan mango	
56.	*Pentaclethra macrophyllum*	Oil bean tree	Ibo – ukpaka
57.	*Nauclea popeguinii*		Yoruba – opepe

Table 2: Flame duration and ODD of fifty-seven (57) tropical timbers

Tree species No	Botanical name	FD Flame Duration x 10^1 cm/Sec	ODD Oven dry density x 10^{-2} g/cm^3
1.	*Cola nitida*	∞	66.6
2.	*Newboldia levis*	3.9	68.1
3.	*Crysophyllum albidium*	11.8	62.7
4.	*Treculia Africana*	4.2	58.8
5.	*Psidium guajava*	10.8	**85.5**
6.	*Citrus sinensis*	13.4	86.5
7	*Dacroydes edulis*	6.4	51.1
8.	*Chlorophoro exelsa*	6.4	58.4
9.	*Gaeis guineensis*	9.7	59.9
10.	*Cocus nucifera*	5.6	60.1
11.	*Persea Americana*	8.4	43.4
12.	*Irvingia smithii*	36.5	81.7
13.	*Irvingia gabanensis*	6.2	87.8
14.	*Caesalpina pulcherima*	10.4	46.5
15.	*Terminalia catappa*	19.7	65.4
16.	*Spathodea campanulala*	1.4	32.0
17.	*Ricinovenvron heudenocii*	6.2	34.2
18.	*Ficu natalensis*	8.2	48.5
19.	*Banbax bonopozense*	1.4	24.0
20.	*Ceiba petandra*	2.9	35.5
21.	*Cola gigantia*	3.9	54.0
22.	*Acacia nilotica*	2.2	64.6
23.	*Nauclea diderrichii*	10.1	54.1
24.	*Gmelina arborea*	14.1	58.6
25.	*Pteracarpus soyauxi*	10.4	47,5
26.	*Annoa senegalensis*	7.1	37.0
27.	*Canarium schwanfurthii*	1.9	41.3
28.	*Pinus carribean*	∞	40.7
29.	*Albizia ferruginea*	16.0	66.8
30.	*Brachystegia Nigeria*	20.0	72.1
31.	*Dialuim guineensis*	15.0	73.1
32.	*Napoliana vogelii*	11.6	74.3
33.	*Accio bateri*	∞	97.5
34.	*Brachystigia eurecomya*	3.6	77.2
35.	*Pluneria Africana*	7.0	60.3
36.	*Walteria Americana*	4.5	50.1
37.	*Azadirachta indica*	∞	79.0
38.	*Khaya senegalensis*	9.8	77.5
39.	*Manilkara*	8.5	109.7
40.	*Alstonia congensis*	14.4	40.1
41.	*Tectona grandis*	19.5	55.1
42.	*Mansonia altissima*	∞	59.6
43.	*Isoberlinia tomentosa*	∞	49.6
44.	*Isoberlinia doka*	22.0	45.1
45.	*Garcinia kola*	30.8	92.1
46.	*Garcinia gnetoides*	∞	68.3
47.	*Baphia nitida*	28.4	88.6
48.	*Baphia gracilipes*	∞	79.2
49.	*Terminalia brownie*	11.3	69.3
50.	*Terminalia superb*	4.6	55.6
51.	*Terminalia glaucescens*	3.8	56.2

52.	*Mangifera callina*	8.3	60.9
53.	*Mangifera banganpalli*	14.0	65.3
54.	*Mangifera indica*	∞	74.8
55.	*Mangifera indica*	8.0	44.4
56.	*Pentaclethra macrophyllum*	8.5	78.8
57.	*Nauclea popeguinii*	14.5	63.2

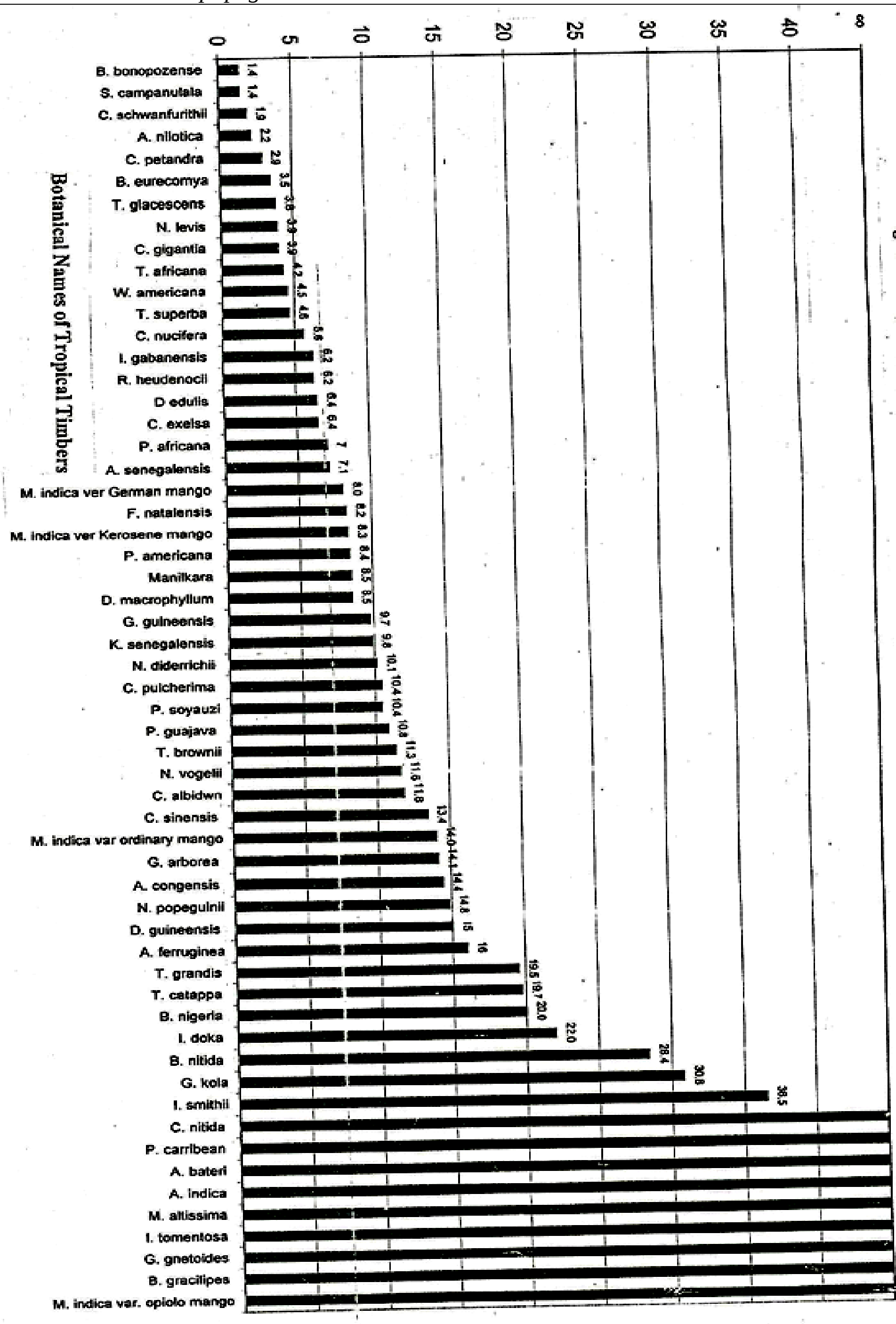

Figure 4: Graph of (FD) flame duration of 57 tropical timbers

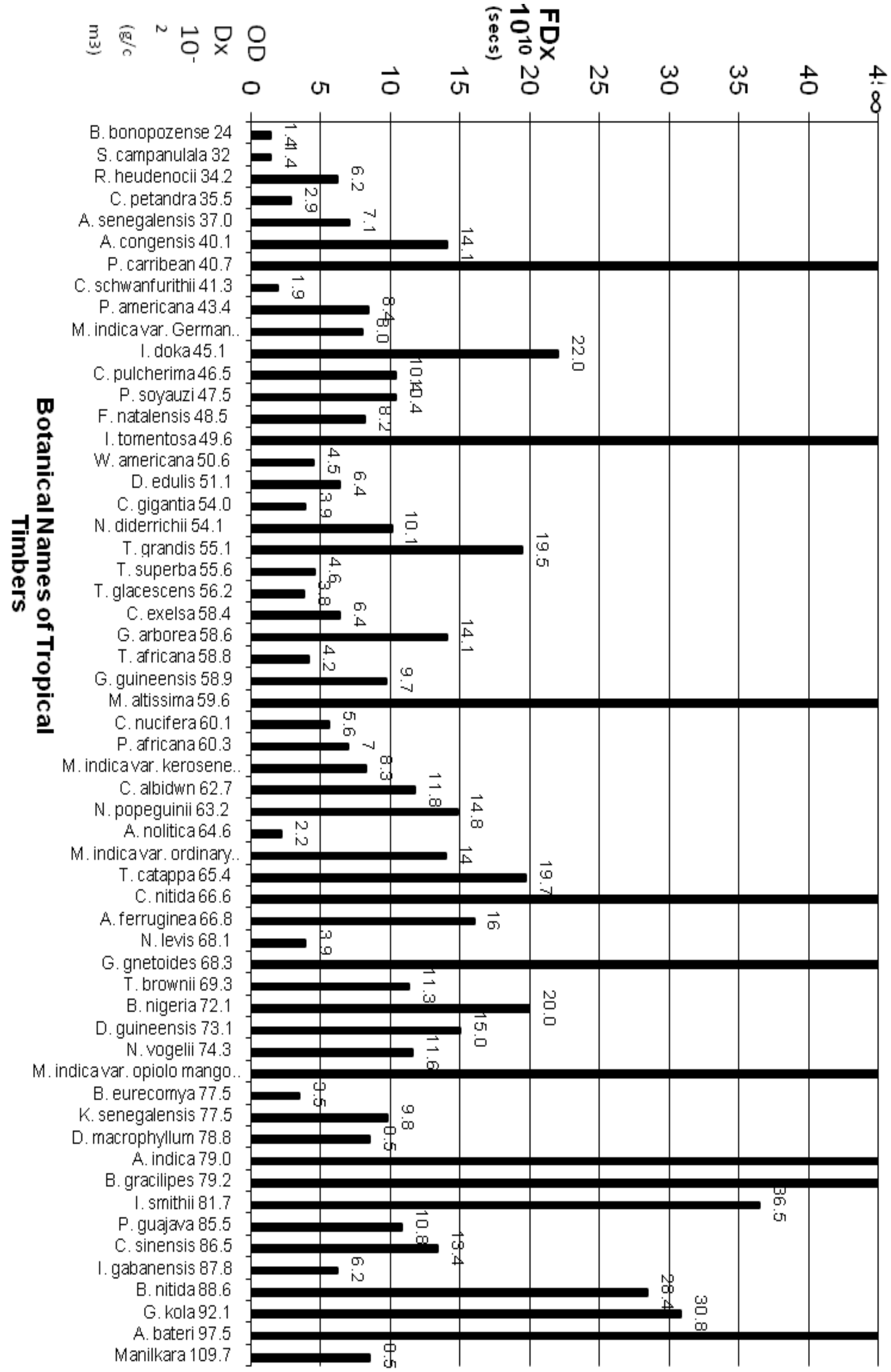

Figure 5: Graph of flame duration vs oven dry density

Discussion

Figure 4 signifies the bar graph of flame duration of fifty-seven tropical timbers. The flame duration of these tropical timbers were represented in their ascending order of magnitude. The Figure indicates that the two timbers with the least flame duration are *B. bonopozense* and *S. campanulala* (1.4x10 sec). It is also seen that the nine timbers with the highest flame duration are: *C. nitida, P. carribean, A. bateri, A. indica, M. altissima, I. tomentosa, G. gnetoides, B. gracilipes* and a variety of *M. indica* called opiolo mango by the Ibos. Their flame duration is infinity (∞). This means that the nine tropical timbers can self-sustain their combustion till the whole length of the splints of timbers (woods) are burnt. Other timbers with equal flame duration are: *N. levis and C. gigantia (3.9x10sec), I. gabanensis and R. heudenochii (6.2x10sec), D. edulis and C. excelsa (6.4x10sec), Manilkara and D. macrophyllum (8.5x10sec), C. pulcherima and P. soyauxi (10.4x10 sec).* The rates of flame propagation of these tropical timbers (with equal flame duration) differ but in terms of combustion, they can self-sustain themselves till the whole length of wood is burnt. Flame duration is the time of self-sustained combustion of materials. For a flame to exist, there must be heat and fuel (burnable material). Since combustion proper entails self –sustained exothermicity, its lifetime (or flame duration) must depend on fuel source; its quantity and availability.

Figure 5 indicates the graph of flame duration vs oven dry density. It is noted that the two timbers with the least flame duration (1.4x10 sec) possess the least ODD. They are *B. bonopozense and S. campanulala ($24x10^{-2}g/cm^3$) and ($23x10^{-2}g/cm^3$)* respectively. The timber *Manilkara* with the highest ODD ($109.7x10^{-2}g/cm^3$) was observed to possess only the flame duration of (8.5x10 sec). Again, it is very surprising to note that the already mentioned nine tropical timbers with the highest flame duration rate have great disparity in the ODD. Their ODDs are written in their increasing order of magnitude as follows:

$40.7x10^{-2}g/cm^3$, $41.6x10^{-2}g/cm^3$, $56.6x10^{-2}g/cm^3$, $66.6x10^{-2}g/cm^3$, $68.3x10^{-2}g/cm^3$, $74.8x10^{-2}g/cm^3$, $79.0x10^{-2}g/cm^3$, $79.2x10^{-2}g/cm^3$ and $97.5x10^{-2}g/cm^3$. These anomalies or disparities cannot be successfully explained by the author. *It has been said that, "Comparison of relative fuel values of different timber species presents considerable difficulty, partly because subsidiary merits, such as even, regular burning qualities and low ash content, are not easily assessed and partly because the volumetric unit of measurement of fire wood- the cord-is capable of wide fluctuations in the actual amount of contained timber or in effect of combustible material,"[4].*

Figure 5 brings before the sight again that greater majority of the tropical timbers with higher ODDs have higher flame duration while the lesser number of tropical timbers with lower ODD have lower flame duration. From this table, one can assert that in absence of varied chemical composition of these tropical timbers and absence of personal error that tropical timbers with higher ODDs possess higher flame duration. Although, the figure conclusively portrayed that there is no direct or inverse relationship between the flame duration and oven dry density of various species of fifty-seven tropical timbers.

Conclusion

Flame duration of tropical timbers is an important factor to be considered for one to make wise choice of timbers.

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