Effect of Storage Duration and Media of Storage on Proximate Composition of Cassava Tubers (*Manihot esculenta*)

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***Abstract*—Cassava tubers are highly perishable than other major root and tuber crop thus leading to high postharvest losses; there is need to design storage structures to store the tubers for a period of time. The main objective of this study was to design different storage media and their effect on proximate composition of cassava tubers. A wooden rectangular cabinet was constructed to store the tuber in cold and moist environment also, the tubers were stored underground while some were stored in open platform at room temperature (control). Freshly harvested cassava tubers were stored for five weeks and samples were taken at one week interval for proximate analysis (moisture content, carbohydrate and starch content). Results were analyzed using Duncan Multiple Range Test at 5% level of probability. There was a significant different in the storage duration and storage media on starch and carbohydrate content; underground pit and control (open platform) both retained the highest % moisture content at the 5th week of storage also at 5% level of probability. There was an increase in %moisture content with duration of storage for underground and open platform which causes rapid microbial infestation and deterioration. Cold storage and moist saw dust media retained the highest starch and carbohydrate content at the fifth week of storage at 5% level of probability. The cassava stored in the constructed cold storage and moist saw dust were proved most effective storage media in retaining nutritive value at the end of five weeks.**

Keywords—cassava tubers; storage duration; storage media; proximate composition.

I. INTRODUCTION

Cassava, (*Manihot esculenta)* is a tuberous root crop of the family *euphorbiaceare*. It is a popular crop worldwide. It is known to be drought-tolerance and thrives well on marginal soils, it is a cheap source of calorie intake in human diet and a main source of carbohydrate in animal feed [1]. It is believed to be originally native of South America. It grows well in areas with annual rainfall of 500-5000mm and full sun, but it is susceptible to cold weather and frost [2]. Cassava is commonly grown in all tropical countries of the world, mostly in Brazil, Indonesia, Nigeria, Zaire, Congo, Uganda, Ghana, and the Democratic Republic of Congo. A very wide range of cassava varieties are grown worldwide depending on the locality, but they are broadly classified into the sweet and the bitter varieties based on the level of the poisonous hydrogen cyanide (HCN) present in the tuber. They are also classified based on time to maturity. Most of the traditional varieties mature in eighteen months and beyond but, some new improved cassava varieties have been developed by International Institute for Tropical Agriculture (IITA) which matures as early as six months after planting; they are high yielding, more resistance to pest diseases, with cyanide contents as low as 3.1mg/100g [3].

Nigeria is by far the highest producer of the crop in the world with production level estimated at 49million tons per year [4]. Cassava production in Nigeria is far more the production rate in Brazil and almost double the production of Indonesia and Thailand. It is presently the most important food crop in Nigeria from the point of view of both the area under cultivation and the tonnage produced due to the fact that it has transformed greatly into high yielding cash crop; a foreign exchange earner; as well as a crop for world food security and industrialization. As a result of this, there has been an unprecedented rise in the demand for cassava and its numerous products worldwide for both domestic and industrial applications [5]. Until recently, cassava was primarily produced for food as it is consumed on daily basis in different forms and often times more than once daily. Surplus production of cassava products enters international trade in different forms, such as chips, flour, broken dried roots, meal, tapioca starch, raw material for compound animal feed among other uses. Cassava tubers are rich source of carbohydrate. Most of the carbohydrate is present as starch (31% of fresh weight) with smaller amount of free sugars (less than 1% of fresh weight). Cassava tubers are low in protein (0.53%), although higher concentrations of 1.5% have been reported [6]. Protein from other source is therefore needed if cassava is to be part of a balanced diet. Cassava is generally considered to have a high content of dietary fibre, magnesium, sodium, riboflavin, thiamin, nicotinic acid and citrate [7], iron and vitamin A are considered to be low.

A. Background of the Study

Cassava roots are much more perishable than other major root and tuber crops. This has been attributed to the fact that cassava tuber has no function in propagation and possesses no bud from which re-growth can occur [8], [9], [10].The problem of storing fresh cassava roots has led to the traditional practice amongst subsistence farmers of leaving the roots in the ground until they are needed. This practice does have a number of disadvantages. The most important being that large areas of land are occupied by a crop that is already mature and is not available for further cropping. The longer roots remain in the ground the more they become fibrous and woody and their starch content decreases. It is also considered that their susceptibility to loss is increased while the mature roots are still in the ground.

During the last twenty years there have been some developments in improving storage methods capable of extending the shelf life of fresh cassava roots by at least two weeks. These amongst other advantages, make it possible to market the crop further on the field and given an increased margin to the opportunity of holding stocks of fresh cassava, even for few days, at a processing plant. A joint project between Natural Resources Institute (NRI) and Centro International de Agriculture Tropical (CIAT), studied alternative storage methods to traditional reburial procedures [11], [12], [13]. These included storage in pits, in field clamps and in boxes with moist sawdust. All the storage methods investigated favoured curing conditions in a high humidity and high temperature environment in order to slow down the rates of physiological and microbiological deterioration. However, to be successful they all require careful harvesting and selection of the roots prior to storage, since curing is not effective if root damage is extensive. Some modern methods, such as refrigeration, deep freezing, waxing, controlled atmosphere and chemical treatments, have been suggested for the storage of fresh cassava. Freezing and waxing have been used primarily for export markets in Europe and America, where the customers of African and Latin American origin are prepared to pay high prices. These techniques required specialized equipment and skills and are very capital intensive [14].

B. *Justification*

Fresh cassava tubers start to deteriorate almost immediately after harvest and can only last for a maximum of three days before they deteriorate. Reduction in traditional ways of storing cassava tubers (underground storage) will protect and prolong the shield life for a long period with less in loosing nutrient. There is the urgent need for modernized storage for cassava tubers to reduce post-harvest losses and maintain the quality attributes of cassava tubers for a longer period of time after harvest thus, the main objective of this research was to construct different storage media for cassava tubers, evaluate the level of effectiveness of the storage structures and determine the effects of the storage structures on quality attributes of cassava (starch, moisture content and carbohydrate content).

II. METHODLOGY

Four different storage media were evaluated for the cassava tubers; they include: cold storage, moist wood storage, underground pit storage and room temperature (control). A wooden rectangular cabinet (900 x 500 x 400 mm; Figure 1) was constructed for the cold storage and moist wood shavings storage medium. The materials used for the construction were locally sourced to reduce the overall cost of construction. Other factors considered in the choice of materials include strength, durability and availability. An underground pit of the same dimension as the wooden rectangular cabinet was dug and protected from soil movement, erosion and water intrusion using protective insulative covers like nylon, vegetative materials and stones.

The wooden rectangular cabinet contains three layers; the first layer designed to serve as the cold storage medium (refrigeration compartment with the inner part lined with aluminum sheet/foil to protect the wood from decay and conserve the cooling temperature), the second layer serve as the medium of moist wood shaving (filled with moist wood shaving) and the third layer is a very small compartment of the whole structure housing the compressor and other refrigerating components.

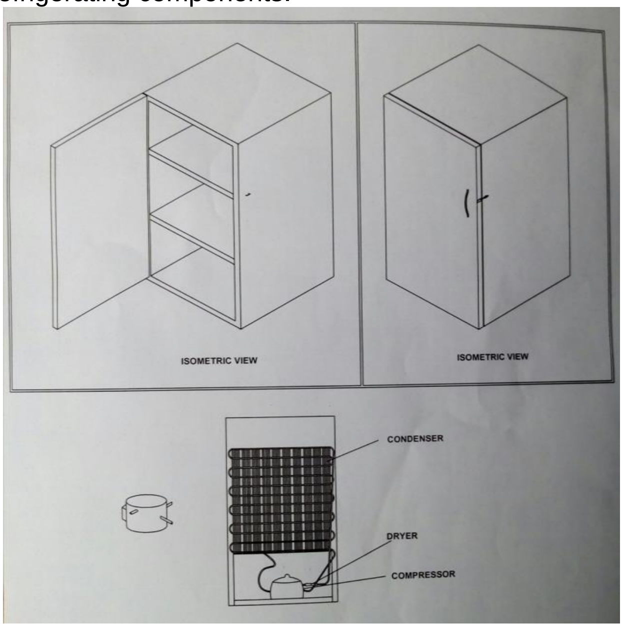

Figure 1: Wooden Rectangular Cabinet

A. *Functional Parts of the Wooden Rectangular Cabinet*

i. ***Wall:* -** this comprises door and the three inner sides. The inner sides including the roof are made of aluminum foil. Aluminum helps in conserving the cooling air in the medium. The outer parts of the wall are made of the wall of plywood. The cooling chamber is also lagged with foam (insulating materials) at the tip of the opening (Fig 3)
ii. ***Condenser:* -** this is the part that condenses the hot Freon 12 into liquid air during heat exchange cycle.

iii. ***Compressor: -*** this part compressed the gas to release energy needed for the cycle. The size used is 95watts.

iv. ***Cooling fins :-*** serve as the passage of the cooling gas (Freon 12)

B. Mode of operation of Wooden Rectangular cabinet

The vapour compression refrigeration system uses a circulating liquid refrigerant (freon12) as a medium to absorb and move heat from the space to be cooled to another space and subsequently dump the absorbed heat out of the system. Such system has four components; a compressor, a condenser, an expansion valve (throttle valve) and an evaporator. Circulating refrigerant enter the compressor in the thermodynamic state known as a saturated vapour and is compressed to higher pressure: higher temperature vapour. It is at this stage, that energy is dumped out of the system. That hot vapour is routed through a condenser where it is cooled and condensed into a liquid flowing through a coil or tube. The heat energy of the circulating refrigerant is dumped into the environment.

C. Sample Preparation and Labeling

6kg of freshly harvested cassava tubers were measured and stored in each of the four media after cleaning and sorting. Samples used for quality evaluation were labeled according to week of storage as presented in Table 1.

TABLE 1: LABELING OF STORED CASSAVA SAMPLES

Storage duration (weeks)	Cold storage	Moist wood shavings	Underground	Control
1	T1CLA	T2SA	T3GA	T4CA
2	T1CLB	T2SB	T3GB	T4CB
3	T1CLC	T2SC	T3GC	T4CC
4	T1CLD	T2SD	T3GD	T4CD
5	T1CLE	T2SE	T3GE	T4CE

D. Sampling Method

The proximate tests of fresh samples of cassava tubers were determined before storage; three cassava tubers were randomly selected and labeled TO1, TO2 and TO3 for initial proximate analysis. Each treatment was replicated three times. One sample from each of the four treatments (storage media) were taken and analyzed at the end of every week (7days interval) for a storage period of 5 weeks for proximate test. 3 gram of each sample was grinded before taken to the Laboratory for proximate analysis. The parameters analyzed include moisture content, carbohydrate and starch all determined in accordance with AOAC Official Methods of Analytical Chemists.

E. Moisture content Determination

2g of the sample was weighed into a previously weighed crucible. The crucible plus sample taken was transferred into the oven which was set at 100°C to dry to a constant weight of 24hours overnight. At the end other 24hours, the crucible plus sample was removed from the oven and transferred to desiccators, cooled for ten minutes and weighed. Equations 1 -3 were used to calculate the percentage dry matter (%DM) and percent moisture

F. Selecting a Template (Heading 2)

$$\text{(\%DM) of Dry matter} = \frac{W3}{W1} - \frac{Wo}{Wo} \times \frac{100}{1} \quad (1)$$

$$\text{\% Moisture} = \frac{W1}{W1} - \frac{Wo}{Wo} \times \frac{100}{1} \quad (2)$$

Where: W_o is the weight of the empty can, W_1 is the weight of the empty plus sample and W_3 is the weight of crucible plus oven dried sample

G. Starch Determination

Sample of 20mg (0.02g) was weighed, 1ml of the ethanol was added (100%); 2mls of distilled H_2O was also added and 1ml to the blank. 10ml of hot ethanol and vortex was added to mix on vortex mixer centrifuge at 2000rpm for 10mins. Supernatant (sugar) was separated from the deposit (starch).7.5ml of per chloric acid as added to the residue and leave for 1hour, make up to 25mls with distilled H_2O and filter with filter paper, 0.05ml was taken from the filtrate, 0.95ml of distilled water was added and 0.5ml of 5% phenol. 2.5ml of conc. $H_2SO_4$was added and vortex to mix and leave to cool and develop, then read at 490nM wavelength.

H. Carbohydrate Determination

2g of sample was weighed into a boiling tube with analytical balance. 25ml of hot 80% ethanol was added into the boiling tube and shake on a vortex mixer. The materials were allowed to settle for 30 minutes and then filtered through a Whatman No 41 filter paper into a baker. The above steps were repeated thrice for complete extraction of glucose. The extract was evaporated until the ethanol was evaporated. 10ml water was added to dissolve the contents and transferred into 100ml volumetric flask. The beaker's content was washed 3 times and added to the volumetric flask also, 1ml of the liquor was pipetted into a test tube and 1ml water as blank was pipetted into another test tube. 6ml of anthrone-sulphuric acid reagent (which was prepared by dissolving 1g of anthrone in 760ml of conc. H_2SO_4plus 40ml of distilled water) was added and shaken vigorously on a shaker for 2 minutes and cooled. Standard glucose solution of range 10-15µg/ml was treated with anthrone-sulphuric acid reagent as above. The absorbance of the bluish colour solution of sample and glucose standard were read on a Spectrophotometer at a wavelength of 490nm against the blank. Equaitions 3 and 4 were used to determine the percentage glucose and carbohydrate of the samples [15].

$$\%\,Glucose = \frac{Absorbance\ x\ Av.Gradient\ x\ Dilution\ of\ sample\ factor}{Weight\ of\ Sample\ x\ 10{,}000}$$

$$\%\,Carbohydrate = \%\,Glucose\ x\ 9.06$$

I. Statistical methods for Analysis

Analysis of variance (ANOVA) of two factors Completely Randomized Design (CRD) was used to evaluate the effect and significance of each level of storage duration from each storage media on % Starch, % moisture content and % Carbohydrate content of the cassava at alpha (α) = 0.05. The effect of duration of storage, effect of storage media and interaction effect between duration and storage media on % moisture content, % starch and % carbohydrate of the tubers stored were statically analyzed using Duncan's Multiple Range Test (P<0.05.)

III. Results And Discussion

Cassava tubers were stored in four different storage media [cold, moist, underground and room temperature (control)]. Proximate analysis of the fresh samples were determined before storage, the result obtained is presented in Table 2 while the result of the proximate test carried out after storing the tubers for five (5) weeks is presented in Table 3.

TABLE 2: PROXIMATE ANALYSIS OF CASSAVA TUBERS BEFORE STORAGE

Sample	Starch (%)	Moisture content (%)	Carbohydrate (%)
1	32.7	66.20	55.4
2	32.9	67.24	55.0
3	32.6	66.17	55.7
Average	32.75	66.71	55.35
S. D.	0.212	0.757	0.495

TABLE 3: PROXIMATE ANALYSIS OF CASSAVA TUBERS FOR 5 WEEKS STORAGE TIME

Storage duration	Storage medium	Starch content (%)	Moisture content (%)	Carbohydrate content (%)
Week 1	T1CLA	31.91 (0.2)	53.09 (5.1)	40.12 (1.1)
	T2SA	31.02 (0.5)	60.86 (2.8)	46.6 (1.5)
	T3GA	30.13 (0.9)	45.93 (8.3)	49.35 (0.3)
	T4CA	31.27 (0.4)	53.05 (10.9)	47.23 (1.6)
Week 2	T1CLB	30.71 (0.4)	64.07 (1.4)	37.87 (2.6)
	T2SB	30.25 (0.7)	65.5 (4.9)	38.1 (1.6)
	T3GB	28.87 (0.3)	62.52 (3.9)	42.2 (2.7)
	T4CB	30.17 (0.5)	66.07 (7.5)	43.23 (1.9)
Week 3	T1CLC	29.51 (0.5)	72.56 (0.8)	35.62 (1.8)
	T2SC	29.48 (0.6)	74.26 (0.7)	30.7 (1.8)
	T3GC	27.62 (0.4)	78.9 (0.9)	35.05 (1.0)
	T4CC	29.07 (0.6)	77.56 (1.8)	38.1 (0.8)
Week 4	T1CLD	28.31 (0.5)	83.34 (1.2)	33.52 (1.1)
	T2SD	28.18 (0.3)	86.58 (1.3)	27.51 (1.8)
	T3GD	25.11 (0.08)	89.42 (0.5)	26.64 (1.0)
	T4CD	27.76 (0.4)	89.67 (1.1)	27.34 (1.5)
Week 5	T1CLE	27.11 (0.2)	94.06 (1.1)	31.54 (0.9)
	T2SE	26.86 (0.1)	96.67 (1.6)	24.71 (1.7)
	T3GE	22.60 (0.3)	98.27 (0.6)	18.51 (0.5)
	T4CE	26.54 (0.4)	98.87 (1.0)	16.54 (1.7)

Values in brackets are Standard Deviations from the mean

Cold storage retained the highest percentage of starch content 31.91%, underground pit retained the highest percentage of carbohydrate content 49.35% while moist saw dust retained the highest percentage of moisture content 60.86% at the end of first week of storage. It was observed that moisture content increased at the end of second week of storage. Open platform (control) retained the highest percentage of moisture content 66.07%; this was due to the activities of fungi and microbial agents.

Moreover, moisture content increased as duration of storage increased; at the end of third week of storage, underground pit retained the highest percentage moisture content 78.90%, cold storage retained highest percentage of starch content 29.51% and open platform retained the highest percentage of carbohydrate content 38.10% at the end of three weeks of storage.

Rapid increase in moisture content was observed at the end of the fourth week of storage after which cold storage retained the highest percentage of starch content 28.31% and carbohydrate content 33.52%. Open platform retained the highest percentage of moisture content 89%. It was observed that storage media and duration of storage have a great impact on cassava tubers stored for five weeks. Cold storage retained the highest percentage of starch content 27.11% and highest percentage of carbohydrate content 31.54% while control retained the highest percentage of moisture content 98.87%.

A. *Percentage Starch content of Stored Cassava Tubers*

There was a high significant difference at 5% level of probability by Duncan Multiple Range Test (DMRT) at each level of duration of storage and storage media on percentage of starch content. The result of Duncan's test as shown in Table 8 indicated that the cassava stored for one week retained the highest percentage of starch content 31.1a while cassava stored for five weeks retained the least starch content 25.8e. Cold storage medium produced the highest percentage of starch content 29.5a followed by moist saw dust storage 29.2b. Underground pit and control retained the least starch content 26.9c and 28.9b. The lower temperature (15^0C) in the cold storage media reduced the activities of rapid microbial infestation and deterioration. The analysis of the percentage starch content of the samples is presented in Table 4.

TABLE 4: ANALYSIS OF VARIANCE (% STARCH CONTENT)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Samples	63.86	3.00	21.29	111.76	0.00**
Duration	212.83	4.00	53.21	279.35	0.00**
Samples * Duration	14.92	12.00	1.24	6.53	0.00**
Error	7.62	40.00	0.19		
Corrected Total	299.23	59.00			

** highly significant

B. *Percentage Moisture content of the Stored Cassava Tubers*

There was high significant difference in each level of duration of storage and no significant difference in each level of storage media on % moisture content. Table 8 shows that cassava stored for five weeks produced the highest moisture content 97.0a. This effect was due to enzymatic reactions in the tissue of cassava tubers and table 4.10 shows that control retained highest percentage of moisture content 77.1, while cold storage retained the least 73.4. Table 5 shows the analysis of variance of the percent moisture content.

TABLE 5: ANALYSIS OF VARIANCE (% MOISTURE CONTENT)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Samples	136.67	3.00	45.56	2.74	0.06ns
Duration	14583.61	4.00	3645.90	219.58	0.00**
Samples * Duration	408.76	12.00	34.06	2.05	0.04*
Error	664.17	40.00	16.60		
Corrected Total	15793.22	59.00			

ns; not significant; **; highly significant; *; significant

C. *Percent Carbohydrate Content of Cassava Tubers after 5 Weeks Storage Duration*

Tables 6 and 7 shows high significant difference at 5% level of probability by Duncan Multiple Range Test (DMRT) for each level of storage duration and media on %carbohydrate content. The result of Duncan's test as shown in Table 8 indicated that the cassava stored for one week retained the highest percentage of carbohydrate content 45.8a while cassava stored for five weeks retained the least 22.8e. Cold storage medium produced the highest percentage of carbohydrate content 35.7a (Table 9)

The lower temperature (15^0C) in the cold storage media was not conducive habitat for insect and fungi infestation. These infestations could lead to deterioration in carbohydrate content and nutritive value of the stored cassava tubers. The mean effect of storage media, storage duration and the interaction effect between duration and storage media on percentage starch content, moisture content and carbohydrate content is presented in Tables 7-9 respectively

TABLE 6: ANALYSIS OF VARIANCE (% CARBOHYDRATE)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Samples	37.52	3.00	12.51	2.25	0.00**
Duration	3980.93	4.00	995.23	417.58	0.00**
Samples * Duration	763.54	12.00	63.63	26.70	0.00**
Error	95.33	40.00	2.38		
Corrected Total	4877.32	59.00			

**; highly significant

TABLE 7: MEAN EFFECT OF STORAGE ON % STARCH CONTENT, % MOISTURE CONTENT AND % CARBOHYDRATE

Storages	Starch	MC	COH
Cold storage	29.5a	73.4	35.7a
Moist sawdust	29.2b	76.8	33.5b
Underground	26.9c	74.8	34.3b
Control	28.9b	77.1	34.5b
		Ns	

ns; not significant. Means with same letter (s) in a column are not significantly different at 5 % level of probability by Duncan Multiple Range Test (DMRT)

TABLE 8: MEAN EFFECT OF DURATION ON % STARCH CONTENT, % MOISTURE CONTENT AND % CARBOHYDRATE

Duration	Starch	MC	COH
7	31.1a	53.2e	45.8a
14	30.0b	64.5d	40.3b
21	28.9c	75.7c	34.9c
28	27.3d	87.3b	28.8d
35	25.8e	97.0a	22.8e

Means with same letter (s) in a column are not significantly different at 5 % level of probability by Duncan Multiple Range Test (DMRT)

TABLE 9: MEAN OF INTERACTION EFFECT BETWEEN DURATION AND STORAGE MEDIA ON % STARCH, % MOISTURE CONTENT% CARBOHYDRATE.

Storage	Period	Starch	MC	COH
Cold storage	7	31.9a	53.1h	40.1de
Moist sawdust	7	31.0b	60.9g	46.6b
Underground	7	30.1cd	45.9i	49.4a
Control	7	31.3ab	53.1h	47.2ab
Cold storage	14	30.7bc	64.1g	37.9ef
Moist sawdust	14	30.2cd	65.5fg	38.1ef
Underground	14	28.9ef	62.5g	42.1cd
Control	14	30.2cd	66.1fg	43.2c
Cold storage	21	29.5de	72.6ef	35.6fg
Moist sawdust	21	29.5de	74.3e	30.7i
Underground	21	27.6ghi	77.9de	35.1g
Control	21	28.9ef	78.1de	38.1ef
Cold storage	28	28.3fg	83.3cd	33.5gh
Moist sawdust	28	28.2fg	86.6c	27.5j
Underground	28	25.1k	89.4bc	26.6jk
Control	28	27.8gh	89.7bc	27.3jk
Cold storage	35	27.1hij	94.1ab	31.5hi
Moist sawdust	35	26.9ij	96.7ab	24.7k
Underground	35	22.6l	98.3a	18.5l
Control	35	26.5j	98.9a	16.5l

Means with same letter (s) in a column are not significantly different at 5 % level of probability by Duncan Multiple Range Test (DMRT)

IV. CONCLUSIONS

The effect of storage duration (1 – 5 weeks) and storage media [cold storage, moist storage, underground and room temperature (control)] on the proximate composition of cassava tubers was investigated. Storage duration and media plays a vital role on the proximate composition of cassava tubers. Cassava stored for one week retained the highest percentage of starch content (31.1) and highest percentage of carbohydrate content (45.8). At the end of the five weeks of storage, cold storage media retained the highest percentage of starch content (27.1) and carbohydrate content (31.5). The moisture content of the tubers increased from an initial value 66.71% to a final moisture content of 94.1, 96.7, 98.38 and 98.9% for cold storage, moist saw dust, control and underground pit storage respectively at the end of five weeks of storage signifying high rate of decay. The storage at room temperature (Open platform) retained the highest moisture content at the end of five weeks of storage; this may be due to the uncontrolled actions of the activities of bacteria and fungi. After the text edit has been completed, the paper is ready for the template. Duplicate the template file by using the Save As command, and use the naming convention prescribed by your conference for the name of your paper. In this newly created file, highlight all of the contents and import your prepared text file. You are now ready to style your paper; use the scroll down window on the left of the MS Word Formatting toolbar.

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