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Shea Butter (Vitellaria Paradoxa) Binder Addition to Okenya Sand in Kogi State Nigeria and Its Effects on Moulding Properties of The Sand

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***Abstract*—The study ''Shea Butter (vitellaria paradoxa) Binder Addition to Okenya Sand in Kogi State Nigeria and its Effects on Moulding Properties of the Sand'' has been extensively evaluated. The chemo-physical properties of shea butter, chemical analysis, clay content of Okenya sand, moulding properties of Okenya sand, and Okenya sand with shea butter were determined. In the same vein the mechanical properties of the aluminium samples cast from Okenya sand, and Okenya sand with shea butter moulds were determined. The addition of shea butter to Okenya sand relatively increased the green compression strength, dry shear strength, shatter index and compactibility of the sand. The green compression strength increased from 131.1 to 293.3kN/m^2, the dry shear strength increased from 69 to 134.5kN/m^2 and the shatter index from 45.1 to 97.6%. The addition of shea butter reduced the green shear strength and dry compression strength of Okenya sand. The mechanical test carried out on the test samples of aluminium cast from Okenya sand with shea butter moulds showed improvement with the impact strength. The impact strength improved from 4.2 joules to 15.2 joules while the hardness improved from 11.2 to 15.2 hardness number. The good surface finish of the cast component produced from these sand mixtures are indications that there was no metal mould reaction resulting from the use of the oil as binder. From the results, the work clearly showed that shea butter additive to Okenya sand had several effects on the moulding properties of Okenya sand. Some of these effects were positive as they improved the moulding properties while some were negative as they worsen the moulding properties.**

Keywords—Okenya sand, Addition, Vitellaria paradoxa, Binder, Moulding properties

INTRODUCTION

Sand moulding properties are determined by the nature of the sand, the binder(s) and other additives. The quality of a casting produced from a particular moulding mixture is determined by the properties of the moulding mixture. This informs why founders are so particular about moulding properties of moulding mixtures. Defects in castings can be controlled from this end by ensuring that moulding mixtures with good moulding properties are produced by mixing good foundry sand, binders and additives. The use of organic oils in foundry to improve moulding properties is not a new idea. It is however, a practice that have been in place for a long time (Nwajagu, 1994, Jain, 2003, Khanna, 2011)

Sand casting is still the most common casting technique used in Nigeria and that explains why so much research work has been done in trying to develop local raw materials for the process (Ihom, 2012). Sand casting is versatile and not so demanding in terms of tooling. The development of the foundry industry is a critical parameter towards the development of any country. The foundry industry is the 'mother of all industries' because machines which other industries must use in their factories have their origin in the foundry (Azodo et al, 2006). The eventual achievement of industrial emancipation and economic self reliance in Nigeria hinges on the success of the foundry industries. Foundry technology is however, at the developmental stage in Nigeria. This is partly due to the non-availability of important raw materials, and sometimes equipment for the processing of these raw materials in the foundry (Ihom et al, 2006a). Sand is one of the most important moulding materials used in the production of castings in the foundries. Nigeria is blessed with abundant sand deposits in different locations such as Okenya, Uwowo, and Anyigba in Kogi State, Darazo, Azare and Alkaleri in Bauchi State, Tudun Wada and Kwodon in Gombe state (Muhammed et al, 2003).

Foundry sand is high-quality silica sand that is used to form moulds for ferrous (iron and steel) and non-ferrous (copper, aluminium, brass etc) castings. Green sand consists of high quality silica sand with about 5- 10% bentonite clay as the binder, 2-5% water and about 5% sea coal (a carbonaceous mould additive to improve casting finish) Winkler and Bol'Shavov, (2000). The problem of raw materials particularly in sand casting is very serious. In the 1970's and early 80's in Nigeria, even moulding sands were imported by the few existing foundries. These were the Nigerian Railways Foundry in Lagos and the Defense Industries Corporation Foundry in Kaduna. It

was in the 70's that the Enugu sands were developed for casting. Today, several moulding sands have been developed across the country. However, much still need to be done in the area of sand and binders (Ihom et al, 2006b). The Okenya moulding sand deposit located in Idah, Kogi State- Nigeria has been used by local foundry men for years for casting various items and small scale industrial goods such as tripod pots, frying pans, pots and other household items. Unfortunately, this sand has not been technically characterized and documented for easy access by would be investors or future generations. This present work is informed by this lacuna.

Shea butter is a solid fat obtained from the seeds of shea tree nuts. On a global scale, shea butter has made remarkable contributions in the food and cosmetic industries by reason of its bitter taste (Boffa, 2001). Shea butter has remained neglected with limited information in its application as binder in moulding sand for castings in the foundry industry.

The objective of this work is to investigate the effects of shea butter (vitellaria paradoxa) binder on the moulding properties of Okenya sand in Kogi State of Nigeria.

MATERIALS AND METHOD

Materials and Equipment

The materials used in this research work were sourced locally. The sand was sourced from Okenya in Idah Local Government Area of Kogi State. The shea butter was sourced from Bokkos in Bokkos Local Government Area of Plateau state. The aluminium scrap was sourced from Zaria in Zaria Local Government Area of Kaduna state. The equipment and materials used for the research work are shown in Table 1.

Table 1: List of Equipment and Materials

Description of Equipment	Location	Quantity	Remark
Laboratory sand mixer	ABU, Zaria	1No.	
Permeability meter	ABU, Zaria	1No.	
Compactability tester	ABU, Zaria	1No.	
Sieve shaker and sieve stack	ABU, Zaria	1No.	
Standard sand sample rammer	ABU, Zaria	1No.	
Universal sand strength tester	ABU, Zaria	1No.	
Electro-mech. permeability meter	ABU, Zaria	1No.	
Weighing scale	ABU, Zaria	1No.	
Metallurgical microscope	ABU, Zaria	1No. Nikon 73346 X27M	
Indentee univ. hardness tester	ABU, Zaria	1No. Model 8187.5LKY (B)	
Shovel	ABU, Zaria	1No.	
Crucibles	ABU, Zaria	1No.	
Glass ware	ABU, Zaria	1No.	
Hand trowel	ABU, Zaria	1No.	
Materials			
Sand	Okenya	150kg	
Shea butter	Bokkos	8 litres	
Aluminium scrap	Zaria	10 kg	

Method

The chemo-physical properties of *vitellaria paradoxa* (shea butter) oil were determined. This oil was used as binder on Okenya sand. The chemical and physical properties were determined to know its effect on the casting. The chemical composition, sieve analysis, clay content and refractoriness of Okenya sand were also determined. Sixteen (16) samples were prepared for the laboratory tests from various moulding sand mixtures to determine the mould mixture that gives the acceptable moisture content. The sand test samples were prepared in accordance with the standard specification for the preparation of moulding sand test samples using Ridsdale standard sand rammer conforming to imperial (2 diameter x 2 height) or DIN (5cm diameter x 5cm height) (Ihom,2012).

Each of the test samples from the mixtures were subjected to the relevant sand mould test parameters such as green compression, dry compression, green shear and dry shear strengths, shatter index, compactibility, bulk density, moisture content and permeability . All the tests were performed with the use of sand testing equipment of the Department of Metallurgical and Materials Engineering, Ahmadu Bello University, Zaria in Kaduna State. Nine (9) trial mouldings were carried out using sand mixtures from Okenya sand, Okenya sand with shea butter to produce moulds for the casting of aluminium samples. The physical and the mechanical properties of the aluminium samples were determined The moulding mixture that produced the optimum compression strength from the results was identified and used to produce the engine sitting of Peugeot 504 vehicle. Attempt was made to determine such properties as metal mould reaction at the metal casting temperature, collapsibility and surface finish. Tables 2

and 3 shows the various moulding mixtures that were prepared for the tests.

Table 2: Experimental Table for Okenya Sand Mixture

Mould mixture	A	B	(C)	D	E	F
Water (%)	2	4	5	6	8	10
Sand (%)	98	96	95	94	92	90

Table 3: Experimental Table for Okenya Sand with Shea Butter

Mould mixture	A	(B)	C	D	E
Sand (%)	94.5	94	93.5	93	92.5
Water (%)	5	5	5	5	5
Shea butter (%)	0.5	1.0	1.5	2.0	2.5

RESULTS AND DISCUSSION

Results

The results of the work are displayed in Tables 4- 11, Fig. 1, and Plate 1 below:

Table 4: Chemo- Physical Properties of Shea Butter

Parameters	Shea Butter
Colour	Milky-cream
Odour	Milky
Taste	Tasteless
Clarity	Fat
Viscosity (NSm^{-2})	0. 2
Flash point (^oC)	85
Specific gravity	0.88
Acid value (mg/KOH/g)	3.17
Free fatty acids (%)	1.87
Moisture (%)	0.32
Calorific value (Kcal/Kg)	9.00

Table 5: Chemical Analysis of Okenya Sand

Compound	Percentage (%)
Al_2O_3	10.90
SiO_2	80.6
P_2O_5	0.25
CaO	0.21
TiO_2	1.11
V_2O_5	0.07
Cr_2O_3	0.03
MnO	0.04
Fe_2O_3	6.02
NiO	0.03
CuO	0.03
ZnO	0.04
LOI	3.00

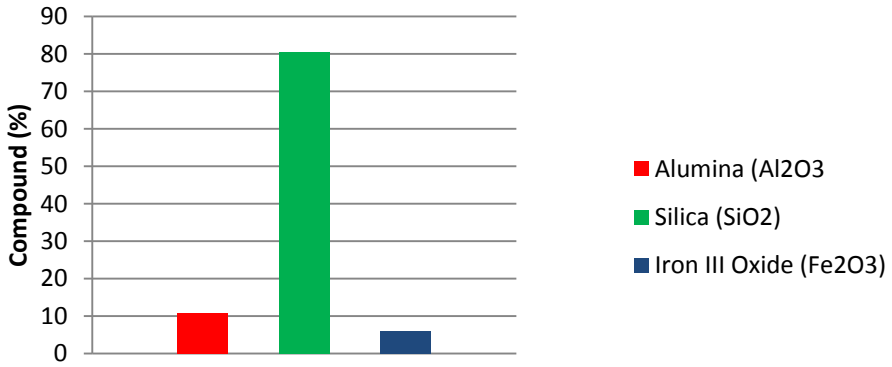

Figure 1 : Chemical Composition of Okenya Sand

Table 6: Sieve Analysis of Okenya Sand

S/No.	Sieve Aperture	BSS No.	Weight Retained	% Weight Retained	Product (% Weight Ret. X BSS No.)
1	1.400	10	-	-	-
2	1.000	16	2.97	3.03	48.64
3	0.710	22	11.11	11.35	249.92
4	0.500	30	19.55	19.98	600.00
5	0.355	44	24.55	25.09	1060.84
6	0.250	60	22.95	23.46	1408.20
7	0.180	100	7.03	7.18	719.00
8	0.125	150	4.52	4.62	693.00
9	0.090	200	2.67	2.72	546.00
10	0.063	300	1.17	1.19	360.00
11	-0.063	350	1.30	1.32	465.50
Total			97.82	99.94	6151.10

Clay content of Okenya Sand: 18.95%

Table 7: Physical Properties of the Representative Moulding Sand Samples

Sample	**Okenya sand**	**Okenya sand with shea butter**	**Standard value**
Parameters			
Green Compression Strength (KN/m^2)	131.1	293.2	31.03- 41.37
Green Shear Strength (KN/m^2)	26.9	22.0	-
Dry Compression Strength (KN/m^2)	1552.5	1000.5	137.8- 206.8
Dry Shear Strength (KN/m^2)	69.0	134.5	-
Shatter Index (%)	45.1	97.6	-
Compactibility (%)	30.0	40.0	38-40,45-52
Bulk Density (g/cm^3)	1.6	1.7	1.36- 1.44
Moisture Content (%)	5	5	5-7
Mass of Sample (g)	160	170	-
Permeability (mmWs)	190	190	8-30, 65- 200
Refractoriness (^oC)	1500	1500	1500

Table 8: Physical Properties of Aluminium Samples from Okenya, and Okenya with shea Butter Sand Moulds

Property	Appearance
Lustre	Dull
Colour	Thin white
Density	$2.71g/cm^3$
Visual Inspection	No external defect
Surface view	Smooth

Table 9: Tensile Strength Test for Aluminium Samples

Binder	Ultimate Tensile Strength MPa	Elongation (%)	Reduction in area (%)
Nil	56.6	5.3	4.3
Shea butter	56.4	0	0

Table 10: Impact Strength Test for Aluminium Samples

Binder	Energy Joule
Nil	4.20
Shea butter	4.88

Table 11: Rockwell Hardness Test for Aluminium Samples

Test Sample	Hardness Number
Okenya sand mould (1)	11.2
Okenya with shea butter mould (3)	15.2

Plate 1:Aluminium casting of engine sittings for Peugeot 504 cars from Okenya (1), and Okenya with Shea Butter (3)

DISCUSSION

Chemo-Physical Properties of Shea Butter

Table 4 showed shea butter has milky-cream colour, milky odour and fatty in clarity. shea butter is tasteless. The Table also shows the flash point, viscosity, specific gravity, acid value, moisture and calorific values of shea butter. The flash point which determines the flammability of shea butter is 85^{o}C. The viscosity provides lubrication for the mould. It eases the removal of the pattern from the mould cavity. The viscosity of 0.20 NSm^{-2} is for shea butter at 25^{o}C. Shea butter has a high viscosity and a specific gravity of 0.88. Acid value of shea butter is 3.71(mg/KOH/g), and the percentage free fatty acids composition is 1.87. The acid value measures the free fatty acids present in the oils. The presence of high free fatty acids in the mould can lead to corrosion of parts. Shea butter has a lower acid value and it can be suitable for aluminium castings. shea butter has a moisture content of 0.32%; the higher the moisture content, the easier the removal of the pattern from the mould. shea butter has 9.0Kcal/kg as the calorific value; this implies that when shea butter is subjected to heat, the same amount of energy will be produced.

Characterization of Okenya Sand

Table 5 and Figure 1 showed the chemical composition of Okenya sand. Okenya sand has alumina (Al_2O_3) content of 10.9%. The sand has high alumina content as the value is higher than 3.94-8.84% and silica content of 80.6% which is within the range of 81.40-92.4% for a typical moulding sand composition (Agarwal et al, 2006). The oxides of Iron (FeO, Fe_2O_3) present in Okenya sand is 6.02%. The value is higher than 0.50-2.91% for a typical moulding sand composition. The high value of the oxide of the oxide of Iron (FeO, Fe_2O_3) accounts for the reddish appearance of Okenya sand sample. The loss on Ignition of Okenya sand has a value of 3%. This value is within the range of 0.90-5.0% for a standard moulding sand (Agarwal et al, 2006).

The sieve analysis showed that the particles are distributed over a wide size range from size fractions of +1400microns to 63microns. From Table 6, sieves apertures of 500microns, 355microns and 250microns corresponding to British Standard Sieve Number (BSS No.) 30, 44 and 60 respectively retained 79% of the total bulk of the sand. The particle size distribution can be said to have also met the American Foundrymen's Society (AFS) specification of moulding sand. The bulk of retained sand is on three consecutive sieves corresponding to 500microns, 355microns and 250microns size fraction. The grain finess number (GFN) of 61.54 also indicates that Okenya sand falls within the range of American Foundrymen's Society finess number of 45-100 (Serve and Beadle, 2000) noting that grain finess number in the range of 61-80 are suitable for heavy grey iron casting (Burns,1986). This shows that the sand can be used as moulding sand for heavy grey iron casting both in green and dry state.

The sand is a four-sieve sand.
The percentage weight of clay present in Okenya sand is 19%. This value is higher than 8% of a typical composition of moulding sand by http://en.wikipedia.org/wiki/sandcasting. Okenya sand is therefore natural sand and not synthetic sand. This shows that Okenya sand has a high binding property considering the high percentage of clay. The clay content of moulding sands used for casting of Aluminium alloys is in the range of 12-18% (Burns, 1986). Based on this fact, the clay content in Okenya moulding sand makes it suitable for aluminium alloys moulding sand.

Physical Properties of the Representative Moulding Sand Samples

Green compression strength of Okenya sand mould mixture is 131.10KN/m^2 as shown in Table 7. The high clay content of 19% and a moisture content of 5% contributed greatly to the relatively high green compression strength. The green compression strength is above the range of 31.31 KN/m^2 to 41.37 KN/m^2, which is acceptable as the standard value (Burns, 1986). This implies that the sand will withstand the withdrawal of pattern from the sand mould without breakage. It can also resist the turbulent reaction of the liquid metal in the mould, prevents erosion of the mould cavity walls and also reduce metal penetration into the mould walls (FOSECO, 1968).
The green compression strength of Okenya sand with shea butter reached the peak value of 293.2KN/m^2 at ratio 1.0% composition of shea butter. The high clay content of 19% and a moisture content of 5% contributed greatly to the relatively very high green compression strength. The green compression strength is above the range of 31.31KN/m^2 to 41.37KN/m^2 which is acceptable as the standard value (Burns, 1986).

The green compression strength of Okenya sand with shea butter has high value of 293.2 KN/m^2. This implies that shea butter has imparted good compression strength to the moulding mixture. The green shear strength of Okenya sand mould mixture is 26.91KN/m^2 as shown in Table 7. The green shear strength of Okenya sand with shea butter reached the peak of 22.08KN/m^2 at 1.0% shea butter content.

This strength may prevent shearing of the mould as molten metal is being poured into the mould. However, shear strength of 20KN/m^2 is acceptable as standard for sand casting (Middleton, 1976).
The green shear strength of 26.9KN/m^2 for Okenya moulding sand is higher than that of Okenya sand with shea butter.
Table 7 showed that Okenya sand has dry compression strength of 1552KN/m^2. As the water content is increased, so the strength increases to the maximum level of above 3294.7KN/m^2 at ratio 10:90 of water to sand. The dry compression strength of Okenya sand using shea butter as a binder increases with increase in the percentage of oil from 621 KN/m^2 for 0.5% shea butter to 2346 KN/m^2 for 2.5%. A ratio of 1.0:5 of shea butter to water has dry compression strength of 1000.5KN/m^2. As the water content is increased, so the strength increases. These values are relatively above the standard value of 137.8KN/m^2 to 206.8KN/m^2 (Burns, 1986).
The dry compression strength of Okenya sand is the highest with the value of 1552.5 KN/m^2 when compared to 1000.5 KN/m^2 for shea butter moulding sand mixtures.
The dry shear strength of Okenya sand mixture is 69KN/m^2. There is increase in the dry shear strength value of the sand from 55.2KN/m^2 at 5% moisture content to 476.1KN/m^2 at 10% moisture content. The dry shear strength of Okenya sand with shea butter increased from 84.18 KN/m^2 for 0.5% shea butter to 239.3 KN/m^2 for 2.0% and finally dropped to 217.35KN/m^2 for 2.5% shea butter. The shear strength value for 1.0% shea butter content in the mixture is 134.5KN/m^2 as shown in Table 7. There is increase in the dry shear strength value of the sand as the water content increases. The dry shear strength value of 134.5 KN/m^2 for Okenya sand with shea butter is higher compared to 69KN/m^2 for Okenya sand.
Table 7 showed that Okenya sand mixture has a shatter index value of 45.1% and this increased to 97.6% when shea butter was added to Okenya sand mixture at 5% moisture content. The shatter index acceptable in foundry practice is 50% to 85% as the mouldable range. The value of 45.1% is close to the minimum value. The high clay content of 19% with the corresponding moisture content of 5% can be attributed to the relatively low value of the shatter index. The result also showed that higher value of shatter index in range of 63% - 89.5% could be achieved with higher moisture content. The shatter index acceptable in foundry practice is from 50% to 85% (Beeley, 1972). The value of 97.6% is slightly above the acceptable value.
Table 7 showed the compactibility values of Okenya moulding sand as 30%, and 40.0% for Okenya sand

with shea butter. These values fall within the standard value for the moulding sand (Burns, 1986).

Table 7 showed that the bulk density of Okenya sand test sample is 1.6 g/cm^3. It increases with increasing water content. The bulk density of 5% moisture content is 1.56g/cm^3. The value is adequate for casting especially for non-ferrous metals (Middleton, 1976). The adequate bulk density is as a result of good compression strength. This will minimize metal penetration from the mould cavity into the mould wall. The bulk density of Okenya sand with shea butter is 1.70g/cm^3 . The bulk density of the sand mixture increased with increase in shea butter content. It increased from 1.70g/cm^3 for 0.5% and 1.0%, 1.80g/cm^3 for 1.5%, 1.83g/cm^3 for 1.5% and 2.5% of shea butter. These values are adequate for casting especially for non- ferrous metals (Middleton, 1976). The adequate bulk density is as a result of good compression strength. This will minimize metal penetration from the mould cavity into the mould wall.
The moisture content of the moulding sand mixture for the test analysis was varied within the range of 2% water addition up to a maximum of 10%. The moulding mixture containing 2% moisture content was not mouldable. This amount of water could possibly be too low for the high clay content (19%) in the sand to make any significant impact on the binding effect. The moulding sand mixtures containing 4%, 5%, 6%, 8% and 10% moisture contents were mouldable and the standard test samples were produced for the required tests.
The moisture content of 5% in the mixture of Okenya sand, and Okenya sand with shea butter as shown in Table 7 has the highest value of green compression strength. The 5% moisture content is within the standard value of 5-8 % for moulding sand (Burns, 1986). The moisture content and the high clay content of 19% will impart to the mass of the sand, a high green strength and sufficient permeability.
Table 7 showed that permeability of Okenya sand with 5% moisture content is 190mmWs. This permeability value of the sand mould mixture composition of ratio 5:95 is higher than that of Okenya sand and shea butter mixture. The results obtained showed that the mixture with 5% moisture content yield highest value for green compression strength, green shear strength and permeability. Most of the other results increased with increase in moisture content. For this reason, 5% moisture content was chosen as constant in the mixtures for the binder (shea butter).
Permeability of Okenya sand with shea butter was 190mmWs. This value fall within the range of 65 to 200 for ferrous castings (Burns, 1986).
The permeability of Okenya sand and Okenya sand with shea butter has values of 190mmWsl. This implies that Okenya sand and Okenya sand with shea butter moulds has high capacity to allow the out flow of air through the compacted sand mould than Okenya sand mould.

The investigation of refractory properties shown in Table 7 revealed that the refractoriness of Okenya sand sample was 1500^{o}C. From the result, the refractoriness maintains the same value at varying proportions of water content. The high refractoriness could be due to the high clay content of the Okenya sand.

Physical Properties of Aluminium Samples from Okenya, and Okenya with Shea Butter Sand Moulds

The aluminium sample from the two moulds showed that the lustre is dull and it has a thin white colour. The samples have densities of 2.71g/cm^3 each. From the visual inspection, no external defect was noticed and it showed a smooth surface appearance as shown in Table 8.

Table 9 showed the result of tensile strength test of aluminium samples. The aluminium sample from the Okenya sand has the highest ultimate tensile strength of 56.6MPa, and the highest percentage reduction in area of 4.3%. The test sample from Okenya sand mould and shea butter has an ultimate tensile strength of 56.5MPa with no reduction in area.

The aluminium samples from the Okenya sand and shea butter moulds has the highest notch impact of 4.88, and 4.20 joules for Okenya sand mould as shown in Table 10.

Table 11 showed the result of the Rockwell hardness test on the Aluminium samples. The hardness number of aluminium samples from Okenya sand with shea butter has the highest hardness number of 15.2, and 11.2 for Okenya sand mould.

CONCLUSION

The work titled ''Shea Butter (*Vitellaria Paradoxa*) Binder addition to Okenya Sand In Kogi State Nigeria and Its Effects on Moulding Properties of the Sand'' has been investigated and the following conclusions have been drawn from the study:

1. The addition of shea butter binder to Okenya sand which is a natural moulding sand has shown that moulding properties like green compression strength improved from 131.1 to 293.2 kN/m^2 , dry shear strength improved from 69 KN/m^2 to 134.5 kN/m^2, shatter index improved from 54.1% to 97.6% and compactability improved from 30.1% to 40%, whereas properties like green shear strength dropped from 26.9 kN/m^2 to 22 kN/m^2, and dry compression strength dropped from 1552.5kN/m^2 to 1000.5kN/m^2.
2. The effects of shea butter on the moulding properties of Okenya sand has been both negative and positive with the positive been overwhelming leading to improvement of the moulding mixture.

Sample castings from aluminium alloy using moulds prepared from a mixture of Okenya sand and shea butter were sound.

REFERENCES

Argarwal, R.L., Banga, T. R. and Tahil, M. (2006) Foundry Engineering,

Khanna Publishers. 2B Nath Market, NAI Sarak, Delhi 110006.

Asuquo, L.O. and Bobo-jama, S. A. (1991), Foundry Technology, Lagos;

Abic Publisher.

Azodo,U. C., Abia-Bassey,N., and Onyi, B. I., (2006) Machine

Components Manufacture for Small and Medium Scale Enterprises- The Proda Foundry Experience. Proceedings of the 23rd Annual Conference of the Nigerian Metallurgical Society.

Boffa, J. M. (2001) Agroforestry Parkland systems in Sub-Saharan African:FAO conservation guide 34.

Rome: Food and Agriculture Organisation of the United Nations. Agroforestry system

52(2):169-170.

Burns, T.A. (1986) Foseco Foundry Man's Handbook, 9th Edition Pergamon Press, London.

FOSECO, (1968) Casting Defects and their cure, Foundrt Practice Issue

165, pp2-6.

Idenyi, N.E. and Ani, N.M. (2006) Characterization of Abakaliki and Ugbawka rice husks.Technical Proceedings of the 22nd Annual Conference of the Nigerian Metallurgical Society.

Ihom, A.P., Jatau, J.S. and Muhammad, M.H. (2006a) Assessment of Honey as a Binder for Core Making in Foundry. Proceedings of the 23rd Annual Conference of the Nigerian Metallurgical Society pp 40-44.

Ihom, A.P., Anbua, E.E., onche, E. and Aigbodion, V.S. (2006b) Assessment of the Core Properties of a newly Developed Core Binder with respect to Urea Formaldehyde Furfuryl Alcohol (UFFA)-Benzene Sulphonic Acid (BSA) Binder System, Journal of Scientific Industrial Studies 20:50-59.

Ihom, A.P. (2012) Foundry Raw Materials and Testing Procedures, 1st Edition, A^2P^2 Transcedent Publishers, Jos, pp1-70.

Jain, P. L. (2003) Principles of Foundry Technology 4th Edition, McGraw Hill Publishing Co. Ltd. New Delhi, India.

Khanna, O. P. (2011) Foundry Technology, 14th Reprint, Dhanpat Rai Publications (P)

Middleton, J. M., (1970) Steel Moulding Materials, Institute of the British Foundry Men, London. Vol LXIII, PP 207-223.

Middleton, J.M. Scrata (1976) Alternatives to Silica for mould production. Chemical Binder Foundries, Birmingham- England, pp5-7.

Muhammed, M. H., Bawa, M. A. and Akuchi, N. T. (2003) Characterization of Alkeleri and Gombe foundry sand sample, Proceedings of the Nigerian Metallurgical Society.

Nwajagu, C. O. (1994) Foundry Theory and Practice, First Edition ABC Publishing, Enugu pp 68-70.

Serve, F.L. and Beadle, J.D. (2000) Sands and Preparation. Castings production Engineering series, Macmillan Press Ltd Norwich, UK.

Winkler, E.and Bol'shavov, A. A. (2000) Characterization of Foundry Sand Waste, Chelsea Centre for Recycling and Economic Development, University of Massachusetts, Nr 31

en.wikipedia.org/wiki/sandcasting