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A Comparative Study of Properties of Linseed Oil and Rubber Seed-Shea Butter Hybrid Oil Bonded Cores

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ABSTRACT

This study was carried out to compare the functional properties of cores produced using linseed oil (LO) and rubber seed- Shea butter hybrid oil (RSSBHO) as binders. Hybrid core oil made of 50% of rubber seed oil and 50% of Shea butter oil was prepared. Core sand mixtures containing oil content of 0.5, 1, 1.5, 2, 2.5 and 3% were prepared using linseed oil and the hybrid oil, separately. Various specimens were then prepared from the core sand mixtures and tested for green and dry compression strengths, green and dry tensile strengths, green permeability and collapsibility. Maximum strengths of the cores were obtained for both oils at 3% oil content. For cores bonded with hybrid oil, 40 kN/m^2, 625 kN/m^2, 36.33 kN/m^2, 591 kN/m^2, 410.67 and 166.67 s were obtained for green compression strength, dry compression strength, green tensile strength, dry tensile strength, permeability number and collapsibility, respectively while for those bonded with linseed oil the values were 38 kN/m^2, 634 kN/m^2, 35 kN/m^2, 604.67 kN/m^2, 421.67 and 170 s, respectively. T-test analysis showed that the properties of the cores produced from hybrid oil are statistically equal to those of cores produced from linseed oil at $p>0.05$ and are within the acceptable standard values. Therefore, hybrid RSSBHO can be used to replace linseed oil in the production of cores for aluminium alloys, copper bronzes, copper brasses and iron and steel castings.

Keywords: *Binder, Core, Linseed Oil, Rubber Seed - Shea Butter Hybrid Oil, Strength*

1. INTRODUCTION

A core is a device used in castings and moulding processes to produce internal cavities and re-entrant angles. The core is normally a disposable item that is destroyed to get it out of the casting [1]. It is also used in castings to make undercuts [2]. They are most commonly used in sand casting, but are also used in die casting.

Foundry cores may be made from sands and metals with essential additives added in the case of the former. In sand core making a suitable binding agent is required. According to Wilson and Faraday [3], the main purpose of the core binder is to hold the sand grain together, give strength and ascertain a sufficient degree of collapsibility. In addition, the binder should be such that it produces minimum amount of gas when the molten metal is poured in the mould.

There are numerous binders used in core sands to add strength to the core; the oldest binder being vegetable oil, but some synthetic oils are now used, in conjunction with cereal or clay. Generally, the binder is introduced into the green core sand which is then baked in an oven between 200 and 250ºC. Baking drives away the moisture in the core and hardens the binder by forming a coherent solid film which holds the sand grains together thereby giving strength to the core [4, 5].

According to [1], core oils are those oils that are used to produce cores in foundry practice for casting purpose. They further stated that as a result of the increased demand for environmentally friendly core oils, there is a growing interest in binders that would offer substantial advantages in terms of cost, occupational safety, health and other environmental issues.

Majority of organic binders used presently are mainly based on phenol formaldehyde resins which, though provide exceptional performance in terms of process robustness, easy breakdown and removal of the core sand after casting, are however environmentally not friendly. They are composed of corrosive acids or volatile organic compounds whose thermal breakdown products give out very foul and pungent odours and waste streams that are hazardous to health of users [6, 7].

In their work, [8] had earlier shown that there is a need for development of environmentally friendly binder systems based around organic, inorganic or hybrid derivatives that would give significant advantages in terms of cost, occupational health, safety and other environmental issues. Such systems could be produced from clean, non-toxic and environmentally friendly vegetable material obtained from plant trees. In addition, [9] observed that production of efficient sand cores for castings entails distinct consumption of resources and significant manufacturing costs. Therefore, an efficient core binder, developed locally in a developing economy such as Nigeria, represents a major advancement in obtaining sand core of desirable performance and high strength thus reducing cost of production of castings. But unfortunately, according to [10], Nigerian foundries rely on imported core binders such as linseed oil due to inadequate research on potentials of local materials.

There is need, therefore to source for other alternative binders that are environmentally friendly as well as non corrosive in nature. Towards this end, some studies [9, 11 12, 13 and 14] have been carried out on various fatty based oil binders such as rubber, beniseed, melon, groundnut, Shea butter, palm and cotton seed oils with varying degrees of success and some technical limitations. The present work is aimed at further research on locally available oils for the purpose of reducing reliance on the importation of linseed oil through the use of rubber (*Hevea brasiliensis*) seed - Shea butter (*Vitellaria paradoxa*) hybrid oil.

2. MATERIALS AND METHODS

2.1. Materials

The materials for this study were rubber seed oil (RSO), Shea butter oil (SBO), clay, sand, cereal binder (wheat flour starch) and water, all sourced from Nigeria. Raw rubber seed oil was obtained from Rubber Seed Research Institute, Benin, Edo state. The Shea butter oil was obtained from a local vendor in Idumuje Unor, Delta state while imported linseed oil (LO) was obtained from a local vendor in Lagos. The fatty acids of the oils determined by trans-esterification method in accordance with procedure in [15] are given in Table 1.

The clay was collected from clay deposit in Ebu in Delta state while the silica sand was obtained from Federal Institute of Industrial Research, Oshodi, Lagos state.

2.2. Equipment and Tools

The main equipment and tools for the study were digital balance, sieves, oven, core sand mixture rammer, universal sand strength machine, tensile core strength accessory. Others included permeability testing machine (permmeter), collapsibility testing machine with in-built furnace and core boxes.

Table 1: Fatty Acid Profile of Oils

Oil	Saturated Acid, %			Unsaturated Acid, %		
	Palmitic	Stearic	Arachidic	Oleic	Linoleic	Linolenic
Rubber seed	10.6	8.4	-	24.6	39.4	17.0
Shea butter	2.0	30.0	0.4	60.0	0.6	7.0
Linseed	6.4	3.5	0.5	19.6	20.4	49.6

2. METHODS

2.3.1 Core Oil and Core Sand Mixture Preparation

Rubber seed- Shea butter hybrid oil (RSSBHO) consisting of 50% of RSO and 50% SBO was prepared from the raw RSO and SBO by mixing vigorously in a container.

A sample of silica sand was washed and oven dried at 110ºC to remove moisture. The silica sand was classified with BS sieve of size range of 40-72 mesh. The sand core mixtures were made with 6% clay, 5% water and 3% cereal binder (wheat flour starch). The oil content in the mixtures was varied between 0.5 and 3.0% with an interval of 0.5% while the sand was varied between 85.5 to 83% with an interval of 0.5% as adopted from a previous study [14].

2.3.2 Test Specimen Preparation

Using a digital weighing balance, measured quantities of silica sand, clay, cereal binder and water were poured and mixed in a roller mill for 10 min and moulded into test cores by subjecting the mixture to three blows each weighing 6.5 kg from a height of 50 mm in a standard rammer adjusted to produce close tolerance specimens in accordance with [16]. The tensile test specimens were made in shape of figure eight (8) in accordance with standard foundry practice as given in literature [17]. While specimens for compression strength, permeability and collapsibility tests were made in cylindrical form with 50 mm diameter by 50 mm height. Specimens for dry tests were then oven baked at a temperature of 200ºC for a period of 1 hour and then oven cooled to room temperature before the tests.

2.3.3 Tests

Tensile and compressive tests were conducted for both green (unbaked) and dry (baked) specimens using the universal sand strength machine in accordance with the method in [14]. The results of the tensile test were then compared with the standard data in Table 2 [17, 18].

The permeability specimens were made and tested in green state with the permmeter as described in [14] after which the permeability was calculated using 1 [19]:

$$P = \frac{3007}{T} \qquad (1)$$

Where, *P* – Permeability, number; *T*- Time, sec
The collapsibility was determined by loading baked standard AFS specimens into the collapsibility testing machine with an

in-built furnace heated to 600°C and soaking at this temperature for about eight minutes [16]. Thereafter, time taken for the specimen to rupture was then recorded.

Table 2: Desired Tensile Strength Property Ranges of Sand Cores [17, 18]

Type of Alloy Casting Applications	Baked Tensile Strength (kN/m^2)
Class I iron/steel cores	700 – 1000
Class II iron/steel cores	500 – 700
Class III iron/steel cores	350 – 600
Class IV iron/steel cores	200 – 300
Class V iron/steel cores	80 – 150
Copper bronzes cores	400 – 600
Copper brasses cores	500 – 700
Intricate Aluminium cores	500 – 700
Non-intricate Aluminium cores	400 – 600
Magnesium cores	300 - 500

3. RESULTS AND DISCUSSION

The results of the mechanical tests of cores made from the hybrid oil and the linseed oil are shown in Figs. 1-3.

The results of the strength characteristics tests show that green and dry strength of the cores made using LO and RSSBHO increased with increase in the oil content in the sand mix. The green compressive strength (GCS) of LO and RSSBHO bonded cores increased from 21.67 and 22 kN/m^2, respectively in 0.5% core oil in sand to 38 and 40 kN/m^2, respectively in 3.0% core oil in sand mix while the dry compressive strength (DCS) increased from 579 and 573.67 kN/m^2, respectively to 634 and 625 kN/m^2, respectively. Similarly, the green tensile strength (GTS) of LO and RSSBHO bonded cores increased from 20.33 and 20.33 kN/m^2, respectively to 35 and 36.33 kN/m^2, respectively while the dry tensile strength (DTS) increased from 541.33 and 528.33 kN/m^2, respectively to 604.67 and 591 kN/m^2, respectively.

The increase in strength with increase in oil content in sand mix is evidently due to effective bonding mechanism of binders which promotes formation of binder film surrounding core sand particles such that inter-particle distance between neighbouring particles is reduced leading to strong bonds within the matrix of the core sand [20]. This is achieved by absorption of oxygen which causes core oils in sand to be polymerized and form high strength sand core [21]. The obtained strength values are within ranges required for casting aluminium alloys, copper bronzes, copper brasses, class II iron/steel and class III iron/steel [17, 18].

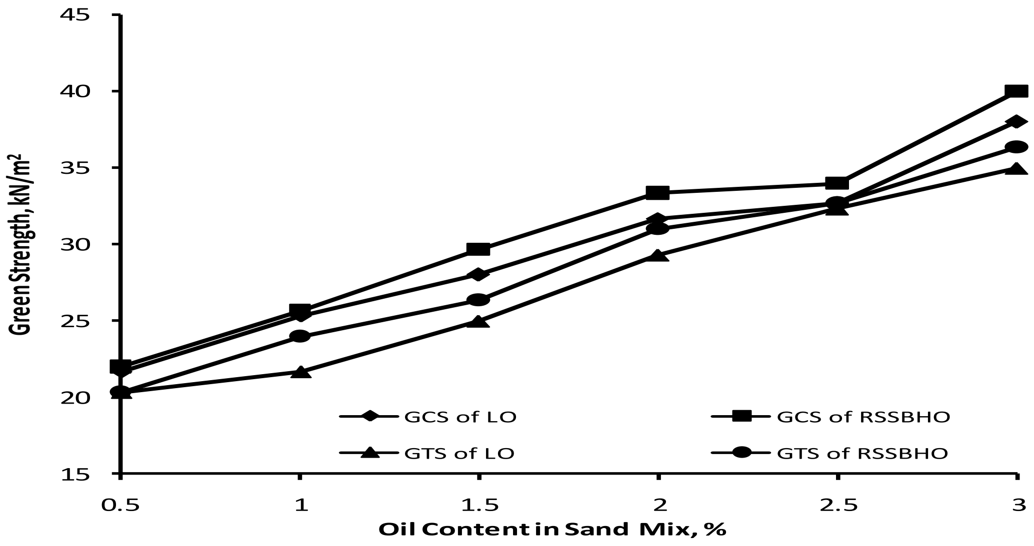

Figure 1: relationship between green strength of the core and oil content in sand mix

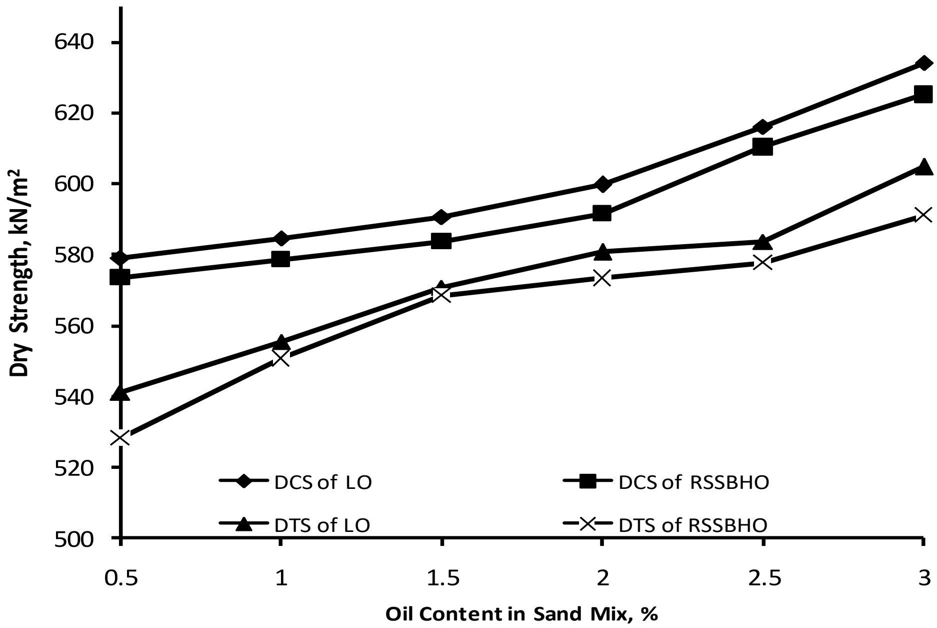

Figure 2: variation in dry strength of the core versus oil content in sand mix

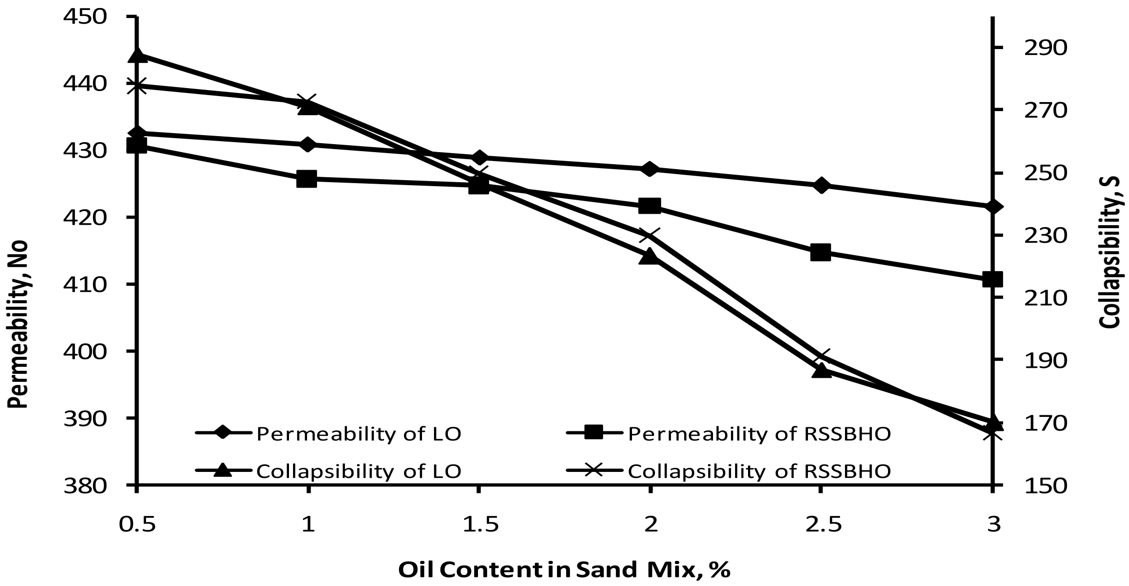

Figure 3: effect of oil content in sand mix on the permeability and collapsibility of the core

The permeability of the core decreased with increase in the oil content in sand mixture from 432.65 to 421.67 for cores made with LO and from 430.67 to 410.67 for cores made with RSSBHO. The trend is similar to that obtained in a previous study on the addition of linseed oil to foundry sand cores with Nigeria gum Arabic grade 2 and 4 [11]. The reduction in permeability with increase in oil content could be attributed to decrease in the pores in sand mix with increase in oil content and hence the inability of gases to permeate or pass through.

The time required to collapse the cores decreased with increase in the oil content in sand mixture from 288 to 170 seconds for cores made using LO while for cores bonded with RSSBHO, it decreased from 277.67 to 166.67 seconds. Hence, the collapsibility of the cores increased with increase in the oil content in sand mixture. The behaviour occurred possibly because at experimental temperature of 600°C at which collapsibility was measured, core oil and cereal binders (starch) were burnt off, thereby making it easier for the cores with more oil contents to collapse more readily after they had solidified.

The results of t-test analysis of the values of the mechanical properties show that there is no significant difference between the cores bonded with LO and those bonded with RSSBHO ($p>0.05$). Consequently, hybrid RSSBHO can be used to produce cores for traditional areas such as in aluminium alloys, copper bronzes, copper brasses, class II iron/steel and class III iron/steel castings where linseed oil is used to make cores.

4. CONCLUSIONS

Based on the study, the following conclusions were made:

1. The strength characteristics and collapsibility of cores separately bonded with LO and RSSBHO, containing 50%RSO-50%SBO increase with increase in oil content in sand mixture.
2. The permeability of cores separately bonded with LO and RSSBHO, containing 50%RSO-50%SBO decrease with increase in oil content in sand mixture.
3. The properties of cores made using RSSBHO, containing 50%RSO-50%SBO are statistically equal to those made using LO.
4. RSSBHO, containing 50%RSO-50%SBO is a suitable substitute for imported LO for the production of cores for aluminium alloys, copper bronzes, copper brasses, class II iron/steel and class III iron/steel castings.

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