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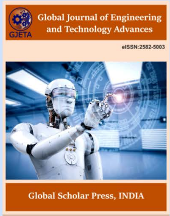

(Research Article)

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Improvement of aluminium alloy properties with aids of elements generated from cow horn additive

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Abstract

The researchers in the area of material science have employed various agricultural wastes to improve the properties of aluminium alloys. They took advantage of various elements present in these wastes to enhance the properties of aluminium alloy. The choice of materials should always depend on their capability in term of elements present in them. Inability to choose a material wisely may result into total failure of the components. Materials possess various properties ranging from mechanical properties such as tensile strength and impact strength to electrical properties such as thermal conductivity. Also, some materials have been identified to be deficient in certain areas such as low thermal conductivity, high wear rate, poor ductility, poor machinability, and weak strength, due to some elements present in them. In the present study, aluminium scraps (secondary aluminium) was used as base material and reinforced with locally available inexpensive cow horn particulate (agricultural wastes) of 3, 6, 9 and 12% by weight of aluminium to develop an improved material taking the advantage of the elements present in the reinforcing material. The spectrographic analysis was conducted to determine the chemical compositions of all the specimens, which shows various elements present in control sample and CHp reinforced aluminium alloy. Aluminium is in the range 91.3 - 93.0%, followed by silicon with 4.36 - 5.01%, other elements present include iron, copper, magnesium, manganese, chromium, nickel, zinc, titanium, lead and others. The elements present in each sample were studied and application areas of each sample were suggested.

Keywords: Aluminium Scraps; Aluminium Alloy; Cow Horn Particulate; Chemical Composition; Elements

1. Introduction

Several studies have been carried out in the field of material science with the aim of optimizing materials through the adoption of agricultural wastes as reinforcements which eventually brought about improved materials. Over time, agricultural wastes are being considered as suitable option for improving the aluminium alloys properties such as hardness, ductility and wear rate. Many researchers have employed various agricultural wastes such as rice husk ash (Gladston et al., 2015; Muni et al., 2019, Subrahmanyam et al., 2015), groundnut shell ash (Alaneme et al., 2018), Bean pod ash (Atuanya and Aigbodion, 2014), and cow horn particulate (Ochieze et al., 2018), to reinforce aluminium alloy and reported in the open literature the effects of these wastes on the mechanical properties of the reinforced aluminium alloy. Each type of agricultural wastes possesses various elements which make it fit as reinforcement.In an attempt to make a decision on the choice of material in the field of material engineering, there are always several factors needed to be considered such as ductility, hardness, wear rate, malleability, plasticity, fatigue, machinability, weldability, thermal conductivity, toughness and so on (Joseph and Babaremu, 2019). Inability to choose a material wisely can lead to failure of the components. Some materials have been identified to be deficient in certain areas such as low thermal conductivity, high wear rate, poor ductility, poor machinability, and weak strength (Joseph and Babaremu, 2019), due

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to elements present in them. According to Ochieze et al. (2018) CHp contains elements such as calcium, silicon, magnesium, aluminium, iron, manganese and sodium.

Fayomi et al. (2017) studied the influence of alloying elements on the integrity and functionality of aluminium alloy. They identified aluminium alloying approach as the principal method of producing various materials that can be used in different applications. Alloying elements such as iron, magnesium, manganese, zinc and silicon were added to pure aluminium with the aim of improving its properties. Stir casting method was employed for composite fabrication. The results show decrease in electrical and thermal conductivity when zinc was added to the pure aluminium. When the content of mg was increased there was decrease in electrical and thermal conductivity of the material. Aramide et al. (2012) investigated the influence of content of magnesium as well as cooling rates on the mechanical properties of Al-Mg alloys. The material used for the experiments were primary aluminium metal, magnesium metal and titanium boride. The content of Mg used in the preparation of samples range from 0% to 8%. The specimen was melt using electric furnace. Tensile and hardness tests were performed on the samples. Their results show that, increase in content of magnesium improves the tensile strength and reduces ductility and hardness of the resulting alloy.

Rana et al. (2012) reported the effects of some elements on the mechanical properties and microstructure views of aluminium alloys. In their review work, they considered the use of alloying approach in modifying microstructures of aluminium alloys and enhancing the mechanical properties of aluminium alloy. They studied the effects of major alloying elements such as Si, Cu, and Mg, minor elements such as Ni and Sn, microstructure modifier elements such as Ti and Sr and impurity elements such as Fe and Zn, on mechanical properties and microstructures of aluminium alloys. They stated some of the properties of each of the elements such as Nickel which improves the hardness of a material and silicon which reduces the melting point and improves the fluidity of aluminium. Stadler et al. (2013) investigated the influence of Si, Cu, and Ni on the thermal conductivity and thermal expansion coefficient of Al-Si cast alloys. The chemical composition was systematically varied and the thermal conductivity, thermal expansion coefficient and thermal shock resistance was evaluated. Experiments were performed on series of hypoeutectic and eutectic Al-Si foundry alloys. The results show decrease in thermal conductivity of the material when copper was added to the sample. There was formation of Fe- and Ni- rich metallic compounds when Ni was introduced. Ochieze et al. (2018) performed experiments on a primary aluminium alloy (A356) reinforced with cow horn particulates (CHp) so as to know the effects of CHp on the wear characteristics of the aluminium alloy. They observed that the reinforced A356 alloy exhibited a better sliding resistance to the wear comparing with unreinforced A356 alloy.

In the present study, cow horn particle is being used as reinforcing material. Some elements, as mentioned previously, present in cow horn have made it to be recognised as viable reinforcing material. It is known for its toughness, tensile strength, ductility and impact strength, with presence of reasonable amount of carbon (Kumar and Boopathy, 2014). Our focus is therefore to show the influence of elements generated from cow horn on the properties of secondary aluminium alloy.

2. Material and experimental procedure

Aluminium scraps consisting of automobile parts was used as base material in this work. Aluminium scraps was purchased from Aluminium scraps merchant in Ado-Ekiti. It is readily available and main advantage of using this material is to ensuring our environment is saved from the havocs of end-of-life materials (that is, environmental pollution).

2.1. Reinforcing Material

Cow horn particulates were procured locally in Ado-Ekiti, Nigeria. The bony core of the cow horns were gathered from the keratin sheath from the Abattoir as shown in Figure 1a. The bony core was washed thoroughly with water and detergent in order to remove all traces of marrow, blood and other substances that can hamper proper bonding between the aluminium alloy and the additives and dried in the sun for four weeks as shown in Figure1b. The bony core was then crushed with hammer in order to break into smaller pieces as shown in Figure1c, and later grinded with a grinding machine to have cow horn particulates (CHp) as shown in Figure1d. The weight proportions of CHp for reinforcement in the study were 3, 6, 9 and 12 % respectively. The mentioned percentages of the CHp were mixed differently with the aluminium alloy as the reinforcement for the preparation of cast specimens.

Figure 1(a) Raw cow horns (b) Thoroughly washed and sun-dried cow horns (c) Crushed cow horns (d) grinded cow horns (cow horn particulates)

Table 1 shows the chemical composition of cow horn particulates (CHp) as was presented by the Ochieze et al., 2018. The chemical composition of the cow horn was assumed to be of the same with the cow horn applied in the research work.

Table 1 Chemical composition of cow horn particulates (CHp)

Constituents	**CaO**	**SiO_2**	**MgO**	**K_2O**	**Al_2O_3**	**Fe_2O_3**	**MnO**	**Na_2O**
% Composition	76.09	11.79	3.54	0.52	0.10	0.09	0.06	0.003

2.2. Specimen Preparation

Mould cavity was prepared and labelled A to E. Then aluminium scraps was heated to 660^{0}C using furnace to have molten aluminium at foundry workshop, Obafemi Awolowo University, Ile-Ife. The specimen labelled A, which is the control sample, did not contain reinforcement, while the specimen B, C, D and E are reinforced with CHp. The CHp fractions considered were 3, 6, 9 and 12 % weights of aluminium respectively. The first fraction of CHp was added into molten aluminium and stirred. The molten metal with CHp was reheated to 750^{0}C for proper mixture of the specimen. It was then poured into the mould cavity for the casting purpose. The cast specimen was allowed to solidify in the mould as shown in Figure 2.

Figure 2 The solidification process of the casted specimens

The specimens were ejected from the mould after they have been allowed to cool to room temperature. Similar procedure was repeated for each weight volume fraction of CHp reinforcements shown in Table 2.

Table 2 Labels of Samples Prepared

Sample Designation	Composition
A	Al (control sample)
B	Al+3%CHp
C	Al+6%CHp
D	Al+9%CHp
E	Al+12%CHp

Thereafter, the specimens were machined to specification on lathe machine for spectrographic analysis.

2.2.1. Spectrographic Analysis

Spectrographic analysis was carried out on the sample specimens shown in Figure 3. The samples were grinded to have flat and smooth surface. Silicon carbide papers of grit size 220µm (most coarse), 320µm, 400µm and 600µm (most fine) were placed on the grinding machine. The grinding process was done under running water to wash away the grits and also to avoid overheating. The samples were turned through 90^0 while changing from one grit size to another. This is to neutralize the scratching effect of the previous grinding of the former grit size. Thereafter, a polishing cloth was placed on the polisher for the initial polishing, swamped with solution of one micron of silicon carbide solution, and then, followed by the final polishing stage with polishing cloth swamped with solution of 0.5µm silicon carbide until the surface of the specimen became a mirror-like. Thereafter, spectrographic analysis was conducted on the samples with the aid of spectrographic metal analyzer. The data obtained were used to determine its chemical compositions.

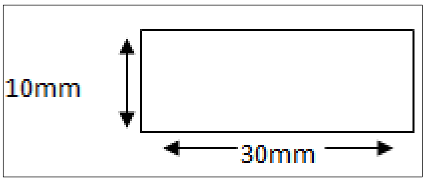

Figure 3 Spectrographic specimen

3. Results and discussions

3.1. Results of Spectrographic Analysis

The chemical composition obtained from the samples of the cast aluminium alloy with difference percentages of the cow horn particles added are presented in Table 3.

Table 3 Chemical composition of samples

Chemical composition	Al	Si	Zn	Cu	Fe	Mg	Mn	Ni	Pb	Ti	Cr
Al	93	4.42	0.59	0.66	0.77	0.36	0.09	0.02	0.02	0.03	0.02
Al+3%CHp	92.6	4.65	0.61	0.74	0.84	0.31	0.09	0.03	0.03	0.03	0.02
Al+6%CHp	91.4	5.01	1.23	1.04	0.86	0.16	0.14	0.04	0.03	0.03	0.01
Al+9%CHp	92	4.36	1.28	1.14	0.73	0.18	0.11	0.06	0.06	0.03	0.01
Al+12%CHp	91.3	4.88	1.69	1.03	0.68	0.21	0.09	0.03	0.03	0.02	0.01

The values of additional elements changed after the casting of the samples as presented in Table3. This is due to the fact that mechanical properties of the materials depend on the elements obtained from the additives (cow horn particles) added to it before casting. Therefore, the values of the major elements changed when they were observed after casting as presented and seriously discussed in this section.

3.1.1. Elements increases with the incresae of CHp Values

The major element (Al) at zero percentage of cow horn is 93% was suddenly decresed to 91.3% as the percentage of added cow horn particles increses from 0% to 12% respectively. The details of the Aluminium values with the percentages of the addedd cow horn particulates before and after is shown in Figure 4.

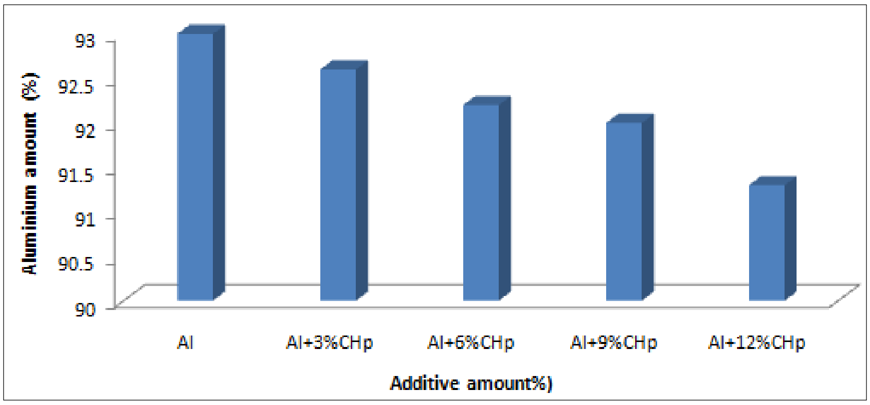

Figure 4 Aluminium Values against Cow horn percentages

From the Figure 4, the percentage values of the aluminium were founded decreasing as the additives values increased, this may due to the replacement and substitution of the addition of the elemets of the cow horn additives added to it during the casting process.

Also, Figures 5 to 7, show the values of the Si, Zn and Cu elements obtained after the testing for the chemical compostion from the cast samples respectively. As indicate in the Figure 5, increase in the percentages values of the cow horn additves increases the values of the silicon from 4.42% to 5.1% and the values dropped to 4.36 and 4.88% at 9 and 12 of cow horn percentages added respectively.

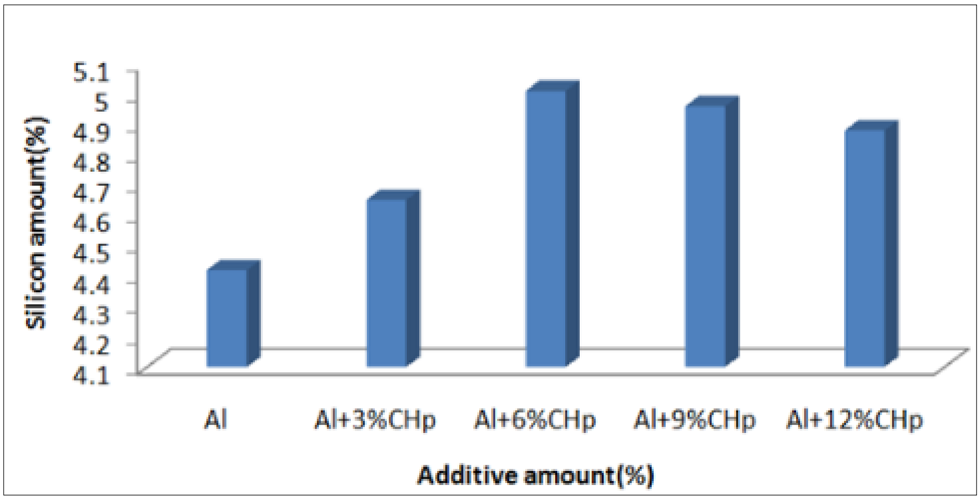

Figure 5 Silicon values against Cow horn values

While sudden increase in values of zinc content rise from 0.59 to 1.69 pecentages along with increase of cow horn additives from 0 to 12 percentages as indicated in Figure 6.

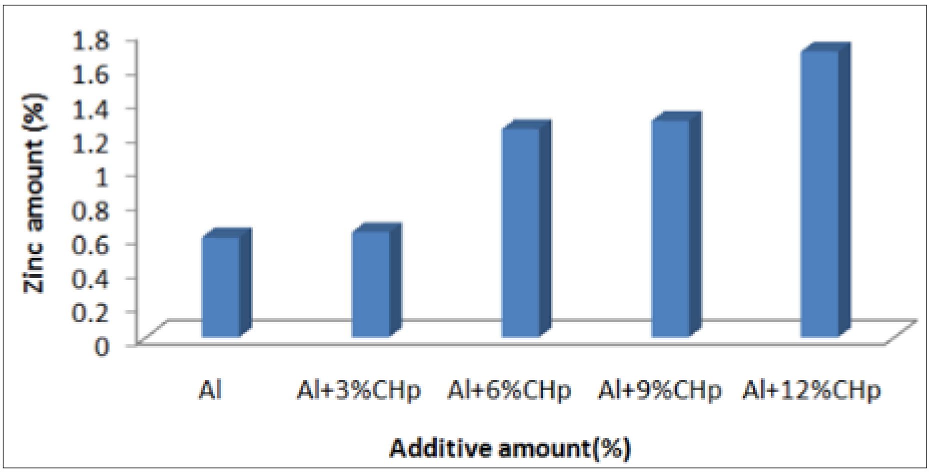

Figure 6 Zinc values against Cow horn values

Reponses of copper element in relation with the percentages of cow horn additives added were observed and tabulated in Figure 7repectively after the chemical compostion of cast specimens. It shows that the values of the copper increased from 0.66 at 0% to 1.14 at 9% of the cow horn additives before its value dropped to 1.03 at 12% added of cow horn.

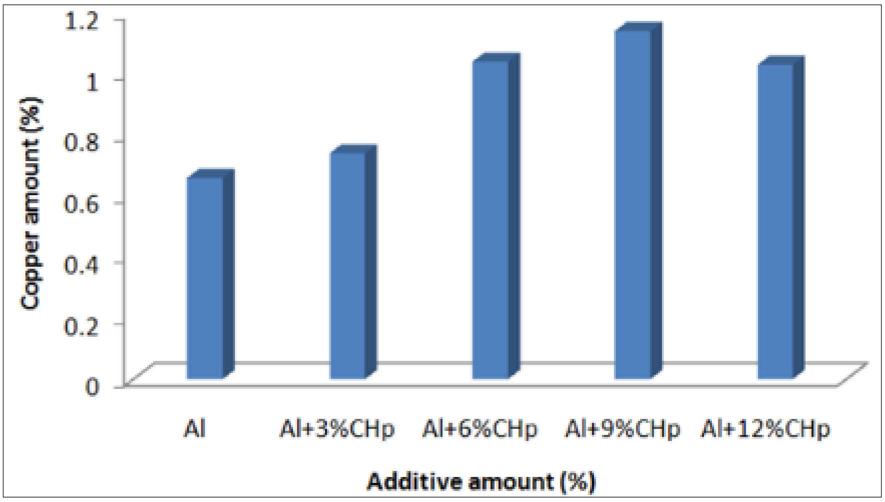

Figure 7 Copper values against Cow horn values

Figure 8 shows the relationship between the iron and cow horn values after the casting processes. The values of the iron is 0.77% at zero percentage of cow horn which jumped to 0.84 and 0.86 at 3% and 6% of added additives and suddenly decresed to 0.73 and 0.68 at 9 and 12 percentages of cow horn added as shown in Figure 8.

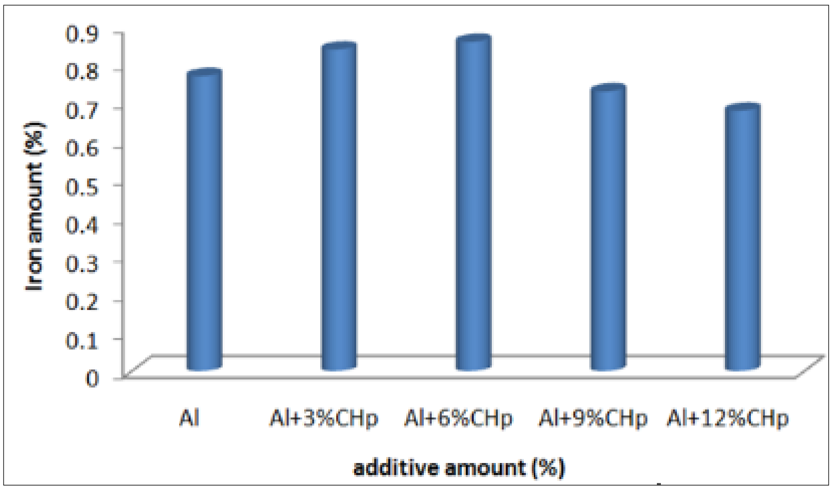

Figure 8 Iron values against Cow horn values

Figure 9 presents the values of Magnesium with decrease in values from 0.36 to 0.16% at 0 to 6 percentage of cow horn addictive but later increases to 0.18 and 0.21% at 9 and 12 percentage of cow horn addictive respectively.

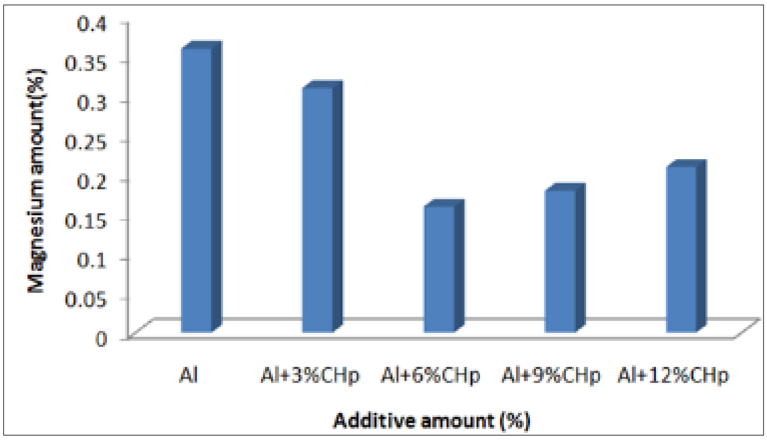

Figure 9 Magnesium values against Cow horn values

Figure 10shows values of Manganese having 0.09% and increased to 0.14% at zero percentage to six percentage of cow horn and dropped to 0.11% and 0.09% at 9 and 12 percentage of cow horn addictive respectively.

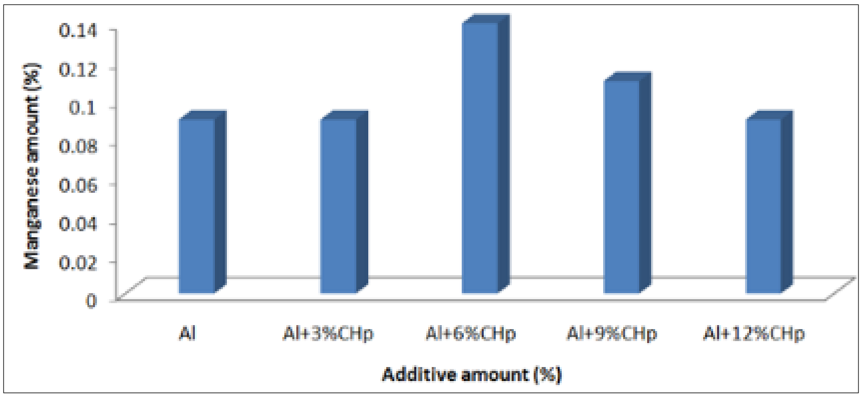

Figure 10 Manganese values against Cow horn values

Both Nickel and Lead increased from zero to nine percentage of cow horn addictives but later dropped at 12 percentage of cow horn addictive as presented in Figures 11 to 12.

Nickel has values 0.02, 0.03, 0.04, 0.06% at zero to nine percentages of cow horn addictives and decreased to 0.03% at twelve percentages of cow horn addictives as shown in Figure 11.

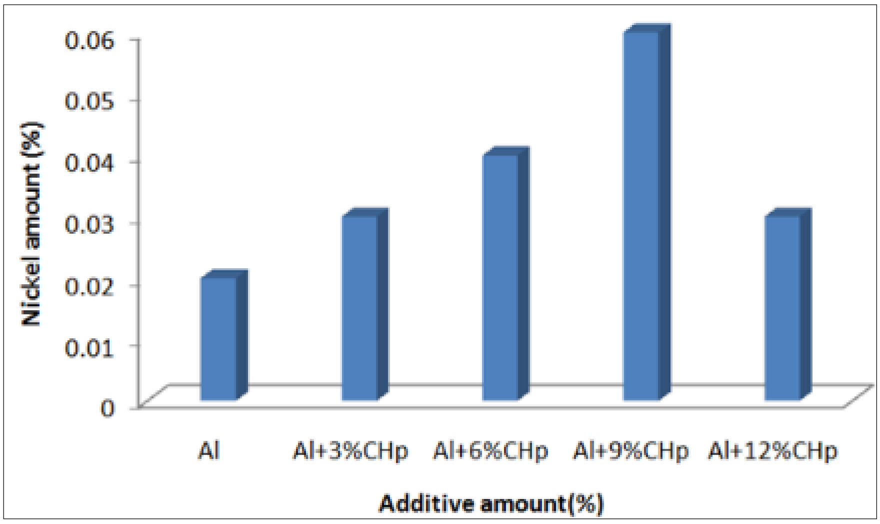

Figure 11 Nickel values against Cow horn values

Figure 12presents the values of Lead with increase in values from 0.02 to 0.06% at 0 to 9 percentage of cow horn addictive but later dropped to 0.03% at 12 percentage of cow horn addictive.

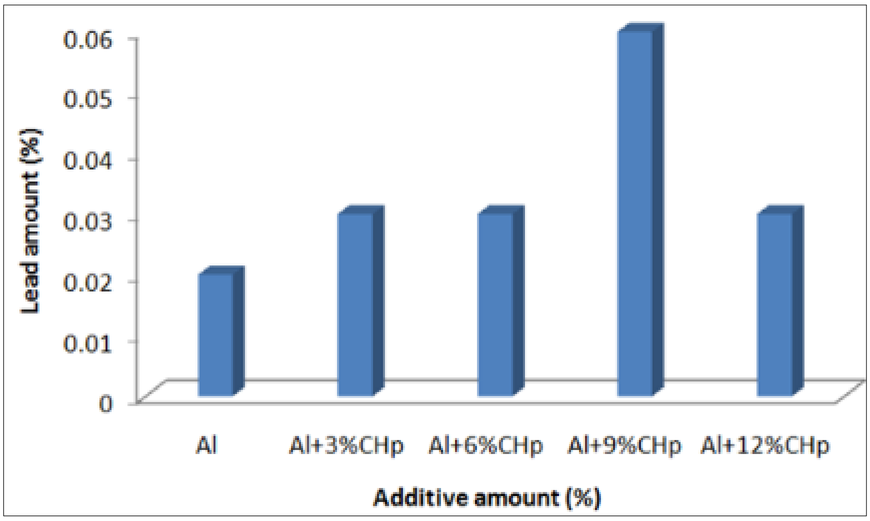

Figure 12 Lead values against Cow horn values

Some elements like Ti and Cr are minorly decreasing along with the increase of CHp as shown in Figure 3.

Figure 13shows that the values of Titanium remains constant having 0.3% at 0 to 9 percentages and slightly dropped to 0.2% at 12. While Figure 14 presents the values of Chromium with 0.2% at both 0 and 3 percentages of addictive and dropped to 0.1% thereafter.

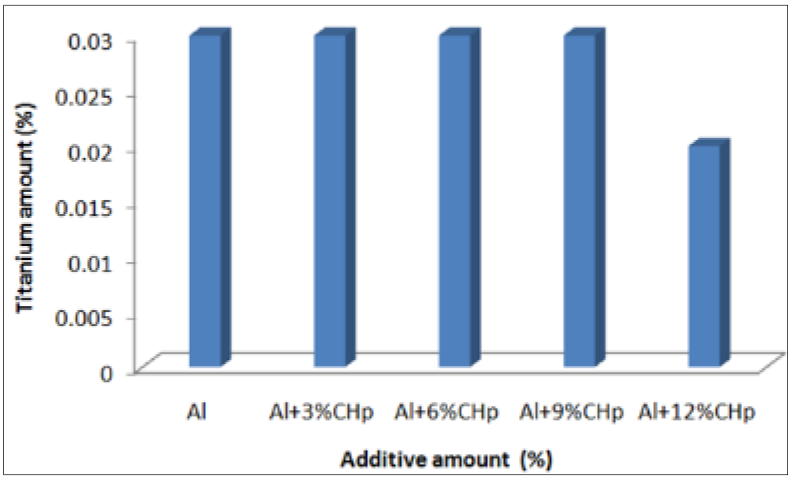

Figure 13 Titanium values against Cow horn values

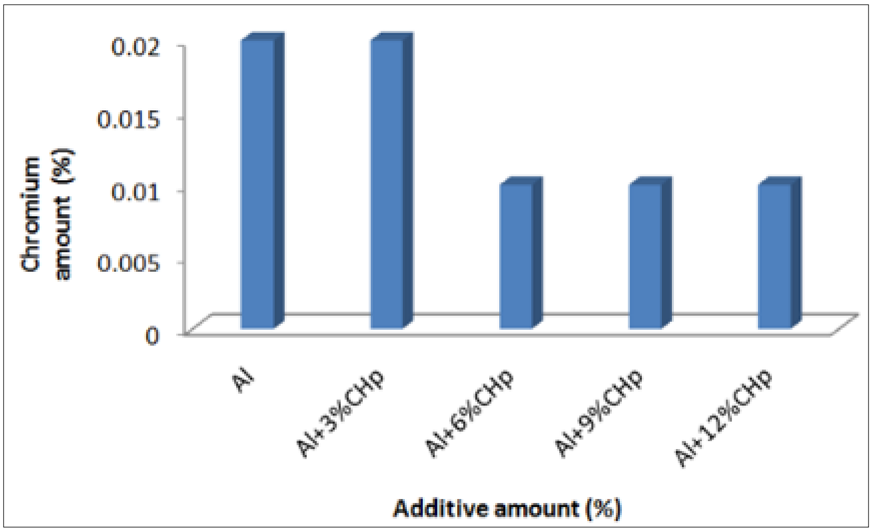

Figure 14 Chromium values against Cow horn values

Some elements such as Fe and Mn minorly increase from zero to six percentage of cow horn addictive before dropped at 9 percentage while Ni and Pb values increases from zero to nine percentage of cow horn additive before dropped at 12 percentage after the cast specimens chemical composition analysis (Table 3).

The differences in the percentages values of the elements present in the chemical compostion of reinforced aluminum alloy in vary percentage (i.e. 3, 6, 9, 12%) of cow horn addictive compared with the as –cast alloy (i.e at 0%) may due to the substitution of the cow horn elements mixed with the alloy before they were finally cast. The effects of these on mechanical properties of the alloy are properly dicussed in the Table 4.

Table 4 Elements and Recommended CHp(%) for various Mechachanical Properties

Element	Mechanical Properties	Recommended CHp (%)
Si	Silicon improves fluidity and increases resistance to hot cracking,	6
Zn	Zinc increases strength and permit precipation hardening	12
Cu	Copper decreases enlongation	9

Fe	Iron slighlty increases yield strength	6
Mg	Magnesium increases strength	0
Mn	Manganese improves the corrosion resistance of alumium	6
Ni	When Nickel is added to aluminium alloys it enhances hardness and strength of evaluated temperature.	9
Pb	Lead increases machinability of alumium alloy.	9
Ti	Titanium increases corrosion resistance, tensile strength and toughness.	0, 3, 6, 9
Cr	Chromium prevents grain growth in aluminium- magnesium alloy	3

4. Conclusion

This study has shown that end-of-life material; aluminium scraps and CHp; the agricultural waste littering the abattoirs can be successfully used as raw material and reinforcing material respectively in producing reinforced aluminium alloy. This can replace conventional aluminium intensive material and the following conclusions were drawn:

Cow horn particles, for reinforcement of aluminium alloy can turn agricultural waste into industrial benefits and reduces the environmental pollution.

The spectrographic analysis reveals that the elements present in the unreinforced sample remains almost intact.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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