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Processing of Rice and Wheat Husk for the Potential utilization of the Material for Pottery Products

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Abstract

In the past few decades, widespread adoption of green revolution technologies in agricultural practices has increased the crop yield. But this intensive mechanization of agriculture is generating wastes from the irrational applications like wastes produced from rice and wheat harvesting constitute about 81-90% residues as rice and wheat husk. These crop residuesare considered as waste but in actual these are natural and valuable resources reflected as potential black gold. However the management of these residuesis a great challenge and the forgoing disposal method of burning the husks has contributed adversely to the environment and causes greenhouse effect. In the present study we proposed a treatment method for rice and wheat crop residues which has no drawbacks as processing of rice and wheat husk for the potential utilization of the material for pottery products. Some physical properties were also measured both of husk paste and pots these include dry shrinkage rate, moisture content, porosity rate, plasticity, color comparison, drying time, absorption rate, wall strength and biodegradation rate. These properties were measured to assess the quality of product and to establish which husk material is more suitable for pottery. Wall strength of different samples was found out by Vickers hardness test which were in the range of 26.5-33.87HV and the values of biodegradation rate ranged from 15-33days. Due to excellent binding ability and appropriate wall strength both the rice and wheat husk material are applicable to form pots. They took very less time and biodegrade easily reducing pollution effects, loads on disposal sites and preserving the non-renewable petroleum resources.

Keywords: Agricultural practices, rice husk, wheat husk, pottery products, wall strength, biodegradation.

Introduction

Arising living standards, over population and high rates of resource consumption patterns contributed significantly to inadvertent and negative impacts on the urban and rural environment, generation of wastes far beyond the handling capacities of governments and agencies[1]. This rapid increase in population and resource exploitation induces the intensive mechanization of agriculture which results in production of billions of tons of agricultural waste per annum in the developed and developing countries[2]. Pakistan is a developing country which continuously expanding its agriculture and is rightly proclaimed as an agricultural country[3]. Furthermore Pakistan is one of the largest rice and wheat producing country where rice occupies about 10% of the total cultivated area, accounts for 6.1% of value added in agriculture and 1.3% in gross domestic product while wheat contributes 14.4% to the value added in agriculture and 3.0% in gross domestic product[4]. However, accompanying this development has been wastes from the irrational application of intensive farming methods, refining processes and the abuse of chemicals used in cultivation, remarkably affecting rural environments in particular and the global environment in general. Wastes produced particularly from rice and wheat harvesting constitute about 81-90% residues as rice and wheat husk[5].

Husk biomass waste is very much abundant, it is basically the outer shell or coating of a seed and represents global stores of fiber, energy, nutrients and has various applications both for the public as well as for the environment. We can see piles of husks at the back of the rice mills, flour mills etc where they are stacked for disposal or some are thrown and burned on road sides to reduce its volume however it becomes an issue of concern because the traditional practice to get rid of this waste has less advantages and more drawbacks[6].

Even though residue burning may give fields to the farmers that are more reliable to grow crops but this is an undesirable practice because burning these residues play pivotal role in the buildup of tropospheric methane, which is a greenhouse gas and is 60 times more effective than carbon dioxide in absorbing outgoing infrared radiations, also release nitrogen as both NOX (NO and NO_2) and carbon both as CO and CO_2 all of these emissions consequently increase the global warming and air pollution. Moreover seasonal burning of crop residues cause health problems most commonly respiratory diseases[7]. Therefore rather than burning mountains of husk that appears around rice and wheat mills, the husk which is an agricultural waste can be managed properly by different other methods.

The present study was conducted to treat the rice and wheat husk simply by processing them into environment friendly pottery products. As husk has potential to use as raw material in designing pottery products of different shapes those possess substantial physical properties. These pottery products are not only reduce the problem of agricultural waste but also diminish the dependence on non-renewable petroleum based, melanin products that are non-biodegradable and well existing for hundreds of years[8].

Material and Methods

Materials: Agricultural crop residues as rice husk and wheat husk, lemon juice and carboxymethylcellulose.

Sample Preparation: Husk material was first sieved and then thoroughly washed by water to remove all dirt materials and remaining unwanted bits. After washing, the samples were dried for 4-5hrs in heating oven at temperature 45^{o}C. The dried husk samples were then ground and crushed into powder form which was then further used for experimental procedures.

Steps Involved in Experimental Design of Pottery Products: The complete steps involved in experimental design of pottery products was employed separately to both rice and wheat husk.

Preparation of Husk paste: Weighed 3.5g of carboxymethylcellulose and mixed it with 100ml of distilled water to make 3.5% edible glue. Then mixed thoroughly the husk powder with edible glue in the ratio of 96.5:3.5% and some lemon juice was also added. After that the mixture was saturated with steam in the autoclave for 20min at the temperature of 120^{o}C. As a result uniform husk paste material was formed which was then further sterilized with UV light for 15min by using UV lamp.

Rolling the husk paste: The sterilized husk paste was then rolled to form a pleated sheet by using rollers.

Primary shaping: The pleated husk paste was then moulded into different shapes by using different types ofmoulders. After that the moulded product was dried at a temperature of 80^{o}C in oven as a result primary product was formed. Primary product often broke at angulated portions therefore required secondary shaping operations to eliminate cracks.

Secondary shaping and drying: After the primary product was formed secondary shaping was done by filling all the cracks with the husk paste. The prepared product or pot was then dried at a temperature of 80^{o}C in oven.

Surface treating and secondary drying: After drying the surface of the pot was treated with sand paper to completely smooth the surface and thus coated with water resistant coat which was then again dried at room temperature. As a result final product was formed.

Evaluation of Physical Properties of Husk Paste and Pottery Products Plasticity (ASTM D4318-10): Plasticity of husk paste was determined by rolling a coilof husk paste first and then wrapped it around a finger. After wrapping checked in which husk paste most cracks appeared[9].

Dry shrinkage rate (ASTM C326-09): Dry shrinkage rate was determined by following ASTM standard procedure. First rolled out a coil of husk paste to about five inches and then dried the coil in heating oven until it reached to maturation temperature, after drying re-measured the coil by using ruler. Then calculate the dry shrinkage rate by employing following formula[10]:

$$\mathrm{D.S} = \frac{\mathrm{A} - \mathrm{B}}{\mathrm{A}} \times 100$$

Where: D.S = Dry Shrinkage Rate (%), A= length of husk coil before drying (inches), B= length of husk coil after drying (inches).

Moisture content (ASTM C324-01): With the reference of standard procedure firstly weighed the empty tray and then tray with almost 100g of husk paste, after that oven dried the sample for 24 hours at 80^{o}C. At the end of oven drying period the sample was re-weighed. Then calculate the moisture content by employing following formula[11]:

$$\mathrm{M.C} = \frac{\mathrm{A} - \mathrm{B}}{\mathrm{A}} \times 100$$

Where: M.C = Moisture Content (%). A = weight of husk paste before oven drying (g) B = weight of husk paste after oven drying (g)

Porosity rate (ASTM C378-88): In order to determine the porosity rate, firsttook a piece of maturated husk paste, weighed it. Put it in boiling water for 5min and left it in water until it cooled down. After that removed the piece from water, dried it off with a sponge and re-weighed. Then calculate the porosity rate by employing following formula[12]:

$$\varphi = \frac{\mathrm{A} - \mathrm{B}}{\mathrm{A}} \times 100$$

Where: φ = Porosity rate (%). A = weight of piece of husk paste after boiling (g) B = weight of piece of husk paste before boiling (g)

Color: Visually observed the color of matured pots and then compared with color chart.

Drying time (ASTM C326-09): To determine the drying time, first measured the time when the pot was wet, then placed it in oven at temperature of 80^{o}C till it reached to maturity after that rechecked the time. Then calculate the drying time by employing following formula[10]:

$$\mathrm{D} = \mathrm{A} - \mathrm{B}$$

Where: D = Drying time (hrs), A = time period of pot after drying (hrs), B = time period of pot before drying (hrs).

Absorption rate (ASTM C378-88): To determine the absorption rate, firstweighed the dry pot and then boiled it in water for one hour at 40-45°C. After that removed the pot from the water and re-weighed. Then calculate the absorption rate by employing following formula[12]:

$$A.R = \frac{A - B}{A} \times 100$$

Where: A.R = Absorption rate (%). A = saturated weight (g), B = dry weight (g)

Wall Strength (ASTM E384 - 11e1): Wall strength of pots was determined with the use of Vickers hardness testing machine. This test was performed as placed the sample potin machine then indenter was pressed into the pot by applying controlled test force which was then maintained for 10 – 15 seconds. After the completion of dwelling time the indenter was removed from the pot leaving asquare shaped indent in the surfaceof the pot, the area of sloping surface of indentation was then calculated. Then the Vickers hardness was calculated by employing following equation[13].

$$HV = \frac{L}{d^2}$$

Where: HV= Vicker's Hardness (HV), L = Applied load (kg), d= Diagonal length of square impression (mm).

Biodegradation rate: In order to calculate the biodegradation rate, first weighed the pot and then buried it in soil. After 2 week the buried pot was dug out from the soil then was cleaned, dried and re-weighed. Then calculate the biodegradation rate by employing following formula[14].

$$B.R = A - B$$

Where: B.R = Biodegradation rate (days), A = weight of the pot before burying (g), B = weight of the pot after burying (g).

Results and Discussion

Figure-1 shows the experimental synthesis of pottery products from both the rice husk, wheat husk and the mixture of these two by the action of edible binder carboxymethylcellulose and UV sterilization. The physical properties of husk paste and pottery products were determined to evaluate the quality of products and have been reported in table- 1 and table-2 respectively.

Results of table-1 reveal the values variation between different physical properties of husk paste which are then further described in detail. Plasticity is important to determine because it indicates the ability of husk material to being moulded in different shapes. According to experimental results the wheat husk paste had very plastic nature while the lowest plasticity was of mixture of rice and wheat husk paste, as shown in figure-2. The drying shrinkage indicates to some degree the plasticity of the husk material. A large drying shrinkage means that husk material could absorb much water, which in turn indicates fine ground husk particles. These fine ground husk particles are responsible for high plasticity[15].

Dry shrinkage rate is an important factor for quality assessment of husk paste. Test results indicated that the highest dry shrinkage rate was 7.15% of wheat husk paste. Basically dry shrinkage rate is based on the drying time, temperature and moisture content. As temperature increases shrinkage also increases. Similarly direct relationship exists between moisture content and dry shrinkage rate. Wheat husk has the highest moisture content of 10 -15% while the moisture content of rice husk is 8.68 – 10.44%[16]. As the wheat husk has the highest moisture content therefore its dry shrinkage rate is higher than other samples.

Table-1
Comparison of minimum and maximum mean values between different physical properties of rice husk, wheat husk and mixture of rice and wheat husk paste

Physical properties	Rice husk paste	Wheat husk paste	Mixture of rice and wheat husk paste
Plasticity	Intermediate	High	Low
Dry shrinkage rate (%)	1.35-1.82	6.7-7.15	0.75-0.97
Moisture content (%)	40.21-43.12	43.44-46.37	34.48-40.25
Porosity rate (%)	47.75-48.25	45.37-47.12	53.25-53.87

Table-2
Comparison of minimum and maximum mean values between different physical properties of rice husk, wheat husk and mixture of rice and wheat husk pottery products

Physical properties	Rice husk pottery products	Wheat husk pottery products	Mixture of rice and wheat pottery products
Color	Light brown	Dark brown	Yellowish brown
Drying time (hrs)	21:13-21:36	22:02-22:13	19:59-22:56
Absorption rate (%)	50.75-52.25	53.25-54.13	46.82-48.2
Wall strength (HV)	26.5-29.25	27.5-30.37	31.5-33.87
Biodegradation rate (days)	15-19.5	23-25.5	28.5-33

Figure-1
a) Husk pottery products before water resistant coating, b) husk pottery products after water resistant coating as final products

The values of moisture content were determined by following ASTM standard procedures. Test results indicated that the highest value of moisture content was 46.37% of wheat husk paste because naturally wheat husk has higher moisture content than rice husk[17]. Moreover wheat husk has pores of larger sizes which trap water and results in higher moisture content than that of rice husk which has pores of smaller size. Additionally, the husk paste had higher moisture content than the natural moisture content of wheat and rice husk because extra water was added during the formation of paste[18].

Porosity is the volume occupied by air in relation to the volume of husk itself. The highest porosity rate was 53.87% of mixture of rice and wheat husk paste while the least porosity rate was 45.37% of wheat husk paste. This is due to the reason that porosity depends upon the bulk density and pore sizes. Inverse relationship exists between these factors and porosity rate. As bulk density and pore sizes increases porosity rate decreases and vice versa. Wheat husk has the highest bulk density of 750kg/cm^3 and has pores of larger size while the rice husk has the bulk density of 564 kg/cm^3 and has pores of smaller size. Therefore the porosity rate of wheat husk paste was low as compared to other samples[19].

Results of table-2 indicate the values variation between different physical properties of husk pottery products. Color comparison is used to characterize the pottery products on their appearances. Rice husk pottery products were of light brown in color, wheat husk pottery products were of dark brown in color while the mixture of rice and wheat husk pottery products were yellowish brown in color, as shown in figure- 3. Variations in color were occurred either due to the difference in nutrient, chemical composition and complex biochemical process of different husk samples or in maintaining temperature conditions during autoclaving and oven drying[20].

The drying time is used to determine how much time is required in drying the pots. According to the test results the highest drying time was 22hrs and 4min of wheat husk pottery products while the least drying time was 19hrs and 59 min of mixture of rice and wheat husk pottery products. Drying time is basically depends upon many factors like moisture content, thermal conductivity and particle size. There is direct relationship between moisture content and drying time as moisture content increases the drying time also increases because with the increase in moisture content the resistance to airflow increases. The particle size of ground husk also effects the drying time as resistance pressure increases with an increase in the percentage of fine particles while the resistance pressure decreases with coarse particles[21]. Moreover the wheat husk has poor thermal conductivity than rice husk[16]. As the wheat husk has the highest moisture content fine ground particles than that of ground rice husk and poor thermal conductivity therefore it took more time in drying than other husk pottery products[22].

Absorption rate is the amount of water that can leach through a dried pottery product. Thus the highest water absorption value was 54.13% of wheat husk pottery products. Chemical conformation and amounts play a vibrant role in the water absorption pattern of husk. Husk fibers as well as natural fibers are three dimensional, polymeric composites made up primarily of lignin, cellulose, hemi cellulose, and small amount of protein, fat, starch, and ash. The hemicelluloses are chiefly responsible for moisture absorption[23]. The hemi cellulose content of wheat husk is 26.4 while of rice husk is 25.9 therefore wheat husk has higher ability to absorb water than other samples. Moreover the large pore sizes in wheat husk are also responsible for higher water absorption than other samples[24].

Wall strength test was conducted to find out the values of wall strength of pottery products. Test results revealed thatthe highest wall strength was 33.87HV of mixture of rice and wheat husk pottery products, as shown in figure-4. The ultimate strength of any composite is based on numerous factors, most significant of which are the properties of the components and the volume fraction of natural fiber composites. As fiber weight fraction increases the tensile strength also increases. Mixture of rice and wheat husk has the highest volume fraction of natural fibers therefore its wall strength rate was highest[25].

Biodegradation rate was determined to confirm that pottery products formed from husk are biodegradable. According to the results all the husk pottery products were completely biodegraded however the variations were seen in the days required to degrade them completely. The minimum days required to degrade were 15 days of rice husk pottery products while the maximum days required to degrade were 33 days of mixture of rice and wheat husk pottery products, as shown in figure- 5. The variations in decomposition pattern are likely due to the difference in the pottery product composition. Those made of high cellulose material and nitrogen content decompose easily because nitrogen may have stimulated the activity of microorganisms and subsequent decomposition rates therefore require fewer days such as rice husk has 38% cellulose content and 0.47% nitrogen content higher than the cellulose and nitrogen content of wheat husk, 36% and 0.41% respectively[26]. Therefore rice husk pottery products degrade easily in fewer days than others while the mixture of rice and wheat husk pottery products required highest days to degrade because of complex structure and bonding between molecules[14].

Conclusion

The present study concluded that the crop residues such as rice and wheat husk have enough potential to process them into biodegradable pottery products. Because of excellent binding ability both the rice and wheat husk material is applicable to form pots. The physical properties were measured to assess their quality and the values of wall strength, fast biodegradation rate and plastic nature of husk material are acceptable in range to form pottery products. But the results revealed that rice husk material is more suitable than others because it has the best binding ability which in turn reduces the formation of cracks in them, take less time to dry and biodegrade easily in few days than others. Accordingly both rice and wheat husk can act as a sustainable resource for the industrial manufacture of low cost commodity products like pots, decoration pieces which in turn reduce the loads of agricultural wastes, generate income and eliminate the pollution induced by the burning of such crop residues.

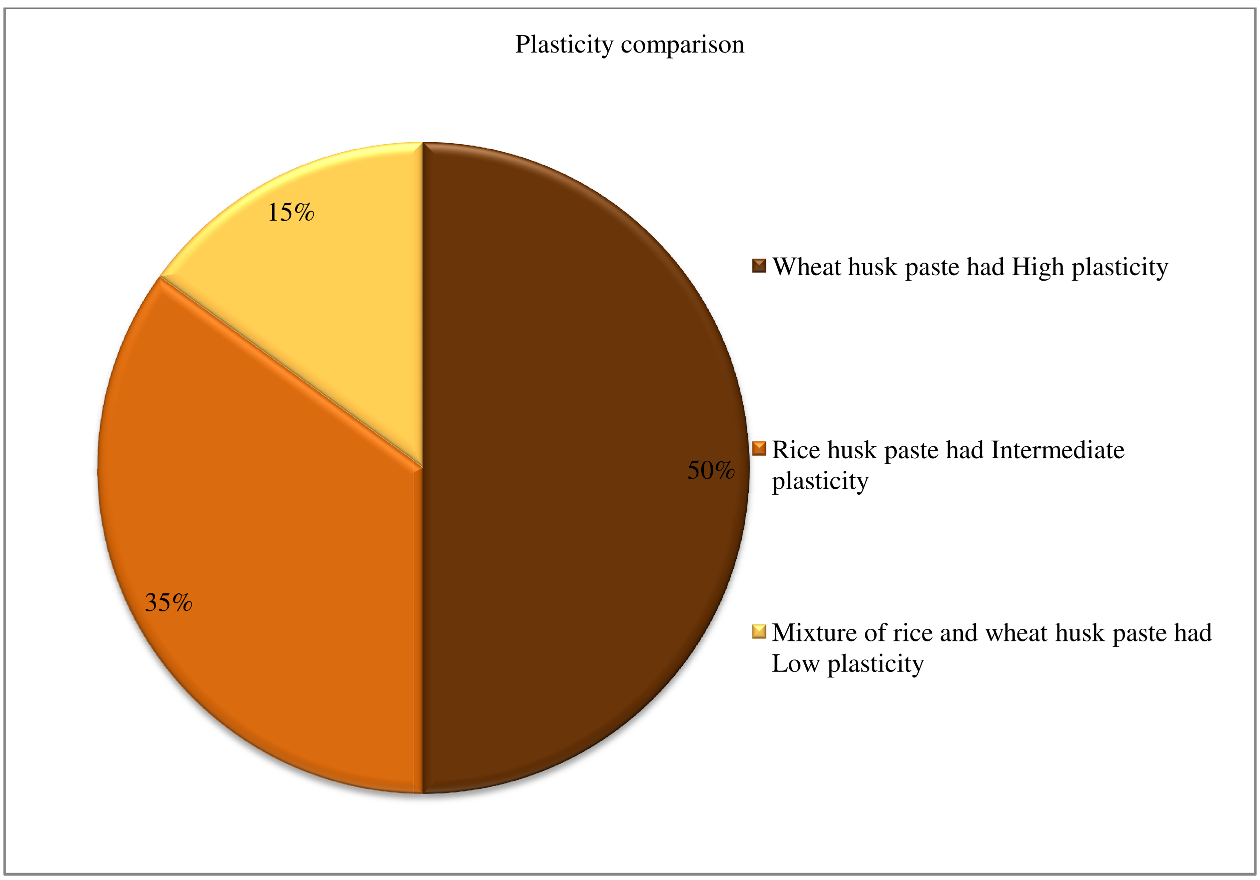

Figure-2
Plasticity comparison between rice husk paste, wheat husk paste and mixture of rice and wheat husk paste

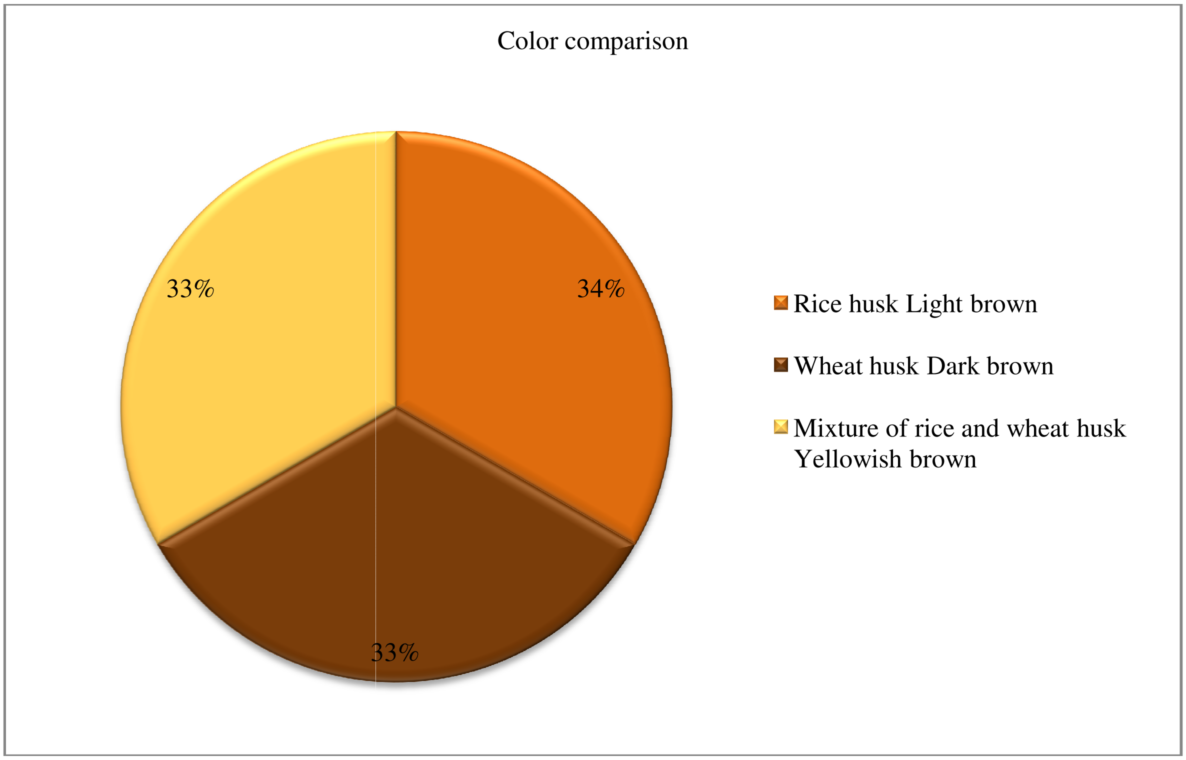

Figure-3
Color comparison between rice husk pottery products, wheat husk pottery products and mixture of rice and wheat husk pottery products

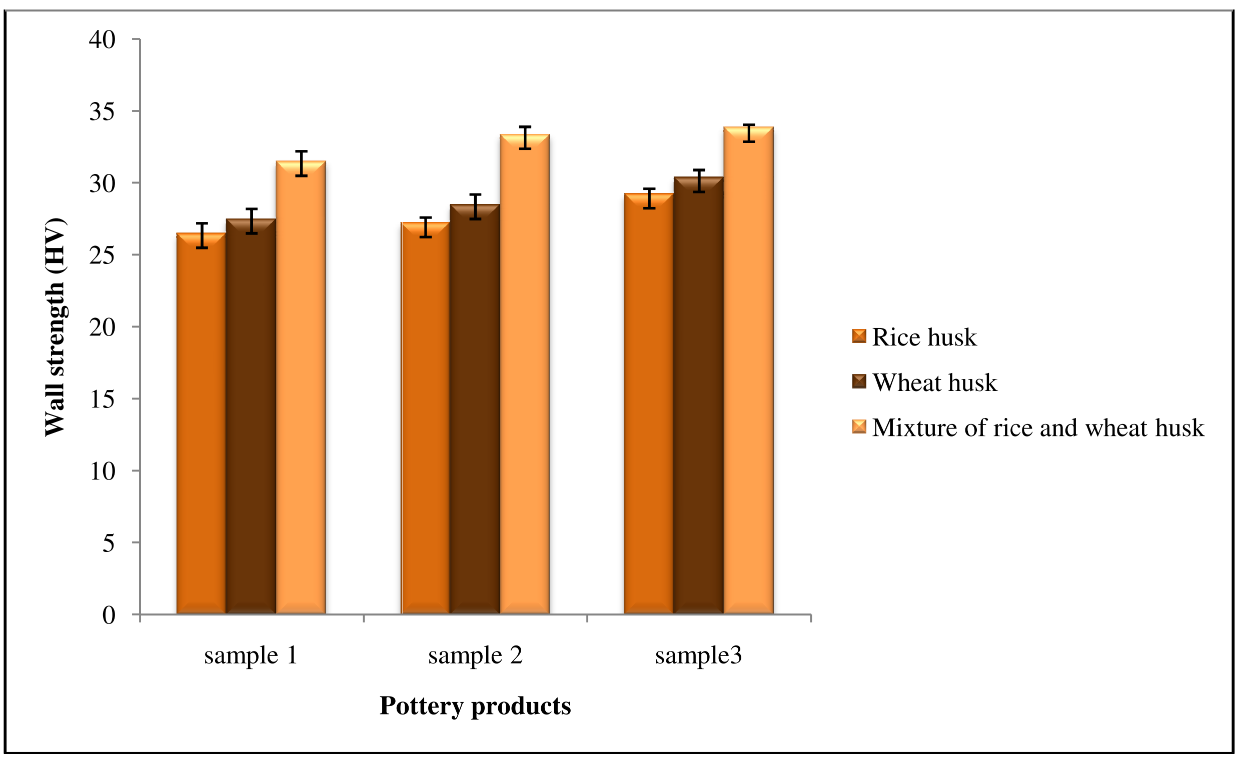

Figure- 4
Wall strength (HV) comparison between different pottery products samples of rice husk, wheat husk and mixture of rice and wheat husk

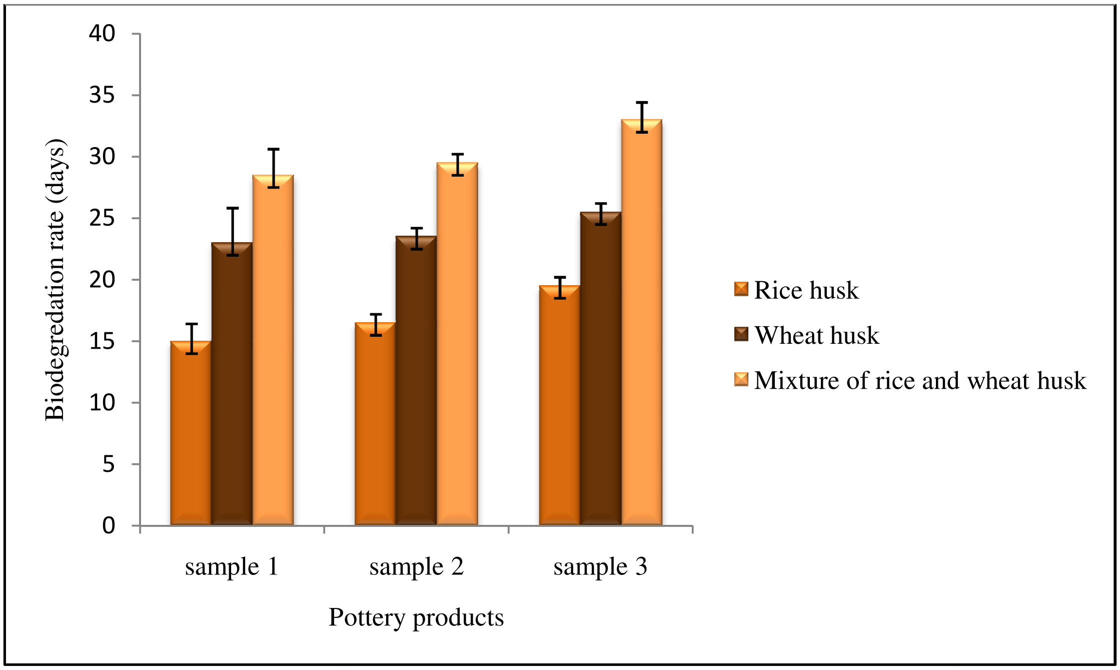

Figure- 5
Biodegradation rate (days) comparison between different pottery products samples of rice husk, wheat husk and mixture of rice and wheat husk

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