International Journal of Scientific Research and Engineering Development-– Volume 9 Issue 1, Jan-Feb 2026
Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Design and Development of Cost-Effective Die Machine for Biodegradable Container Production

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Abstract:

This research investigates a novel solution to sustainable product design through the use of rice bran, a large-scale agricultural by-product, as the major raw material for the production of biodegradable bowls. With escalating concern for environmental issues caused by plastic waste and the pressing need to create environmentally friendly replacements, this research examines the potential for converting rice bran, typically waste or utilized at minimal levels as animal feed, into a viable biodegradable product. The project highlights the viability and advantages of this solution for small farmers, especially in rice-growing areas, providing them with an alternative source of income and waste reduction. The study includes the development of rice bran composite tableware through the combination of rice bran with plant-based binders and additives, followed by low- cost, small-scale moulding techniques. The resulting bowls underwent extensive testing for determination of mechanical strength, water resistance, thermal stability, and biodegradability. Through the process of turning waste into wealth, this method not only helps in environmental sustainability but also supports circular economy tenets and rural development objectives. We assessed the effects of the RH to starch ratio (w/w %), pressing temperature (°C), and duration (minutes) on the hardness, colour variation, and density of the bowls, with the goal of optimizing the manufacturing process. A cost-effective manual die machine has been designed to process agricultural residues, enabling rural smallholders and women entrepreneurs to produce valuable products, thereby fostering circular economies and sustainable income. This research presents an innovative approach to addressing plastic waste while simultaneously enhancing the livelihoods of individuals in rural communities through the introduction of biodegradable rice bran bowls.

Keywords: Rice bran, Wheat starch, Finger millet flour, Corn starch, Glycerol, Areca leaf, Die machine, and Heating element.

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I. INTRODUCTION

Theescalatingissueofenvironmentalpollutiondueto plasticwastehasintensified thesearch forsustainable alternatives, particularly within the food packaging sector. The plentiful rice husk (RH), a by-product of rice farming, offers a promising avenue for the production of biodegradable containers that could replacesingle-useplastics.Thisresearchaimstoexplorethedevelopmentand feasibility of biodegradable bowls made from rice bran, an agricultural waste material. The focus of this study is to creating of biodegradable containers from Rice husk through thermo-pressing techniques. We assessed the effects of the RH to starch ratio (w/w %), pressing temperature (°C), and duration (minutes)onthehardness,colourvariation,anddensity ofthebowls,withthe goal of optimizing the manufacturing process. A cost-effective manual die machine has been designed to process agricultural residues, enabling rural smallholders and women entrepreneurs toproducevaluableproducts, thereby fosteringcirculareconomiesandsustainableincome.Thisresearchpresentsan innovative approach to addressing plastic waste while simultaneously enhancing the livelihoods of individuals in rural communities through the introduction of biodegradable rice bran bowls.

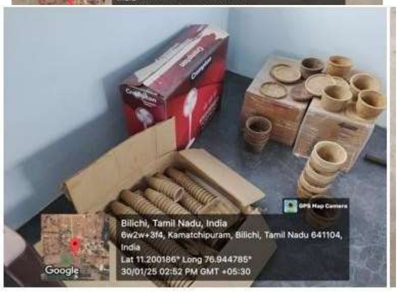
- DevelopmentofanAffordableManualDieMachine
- UtilizationofAgriculturalWasteforSustainablePackaging
- Small-ScaleBusinessModelforFarmersandWomenempowerment
- TestingandQualityAssurance
- EnvironmentalandEconomicImpactAssessment

Thisresearchfocusesonconvertingitintovalue-addedmaterialslikebio- composites, absorbents, and polymer-based products. The study outlines chemicaltreatmentmethodstoenhanceitspropertiesforindustrialuse.Utilizing ricestrawnotonlysupportswastereductionandenvironmentalconservationbut also contributes to sustainable material development by promoting the reuse of agricultural residues. This early research set a foundation for later innovations in biodegradable packaging and sustainable material alternatives,especiallyinruralandcottageindustries.Theirfindingsencouraged resource utilization from plantation waste, reducing environmental impact and promoting local economic development through value-added applications of areca biomass.

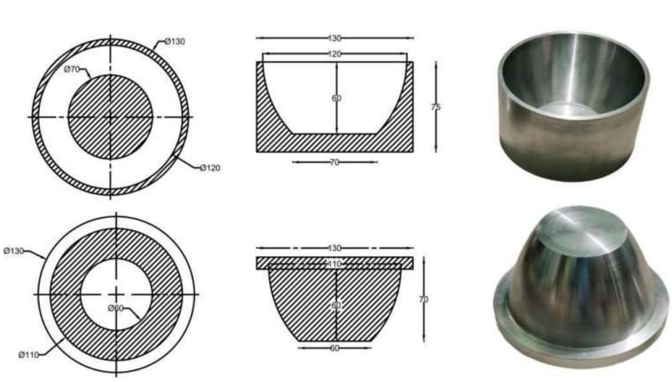
The study evaluated available biodegradable cup-making machines and found that most are expensive, require advanced technical knowledge, and are designed for industrial-scaleoperations.Throughsurveysandcompetitoranalysisincluding firmslikeSPSKalyanMachineDesignerinCoimbatore.Furthermore,demand analysisamongfoodvendorsandeco-consciousbusinessesindicatedagrowing market for sustainable packaging, confirming the economic viability of introducingamanual,low-costalternative.Theseinsightsguidedthedirection and scope of the design process.

The currently existing product is known as Bio degradable cups making machinewhichutilizedbyagriculturalresiduesasraw materials.Themachines are highly expensive and mainly used for business models and new startup ideas.

The process underwent in the machine are; the raw materials (agricultural residues)aremixedwithfoodgradebinderswhichwaspressedusingadiemold at80-90degreeCelsiusfor2-3minsforproducing10-20biodegradablecups.



The fabrication process began with the computer-aided design (CAD) of the male and female parts of the mold, ensuring dimensional accuracy and uniformcompression.Thedesignincorporatedfeaturesforefficientdemolding andconsistent shaping.Heat-resistantmaterialssuchasaluminumwereselected to ensure durability under repeated thermal cycles. Precision manufacturing methodssuchasCNCmachiningwereusedtofabricatethemoldparts.Proper tolerances and surface finishes were maintained to ensure product quality and operational efficiency. The dimension of the bowl is: height of 60mm and the upper diameter of 120mm and bottom of the bowl having 60mm diameter.



DIEMOLDComputer-AidedDesign

In mold fabrication, the machine frame and structural components were designed.Thegoalwastocreateacompact,portable,anddurablemachinethat couldbefabricatedatlowcostusinglocallyavailablematerials.Mildsteelwas selectedfor itsstrengthandaffordability.Theframewasdesignedtosupportthe die mold, heating components, and press mechanism securely. A manually operated lever or screw press was incorporated to apply uniform pressure, allowing users with minimal technical knowledge to operate the machine efficiently. The design also emphasized easy maintenance and component replacement.

The final stage of the methodology involved rigorous testing and evaluation of both the machine and the products it generated. The biodegradable cups were tested for structural integrity, food safety, and environmental degradability. The machine itself was subjected to durability tests under repeated operation. Key performance metrics such as production rate, energy consumption, and raw material efficiency were recorded and analysed. Field testing was conducted with real users in a rural setting to validatethemachine'spracticalityandgatheruserfeedback.Theseevaluations confirmed the machine's potential to serve as an accessible, sustainable, and economically beneficial tool for its target users

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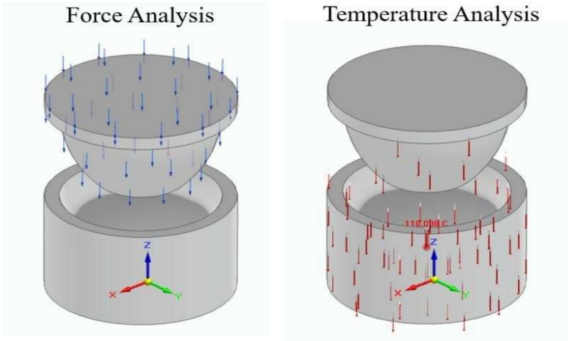
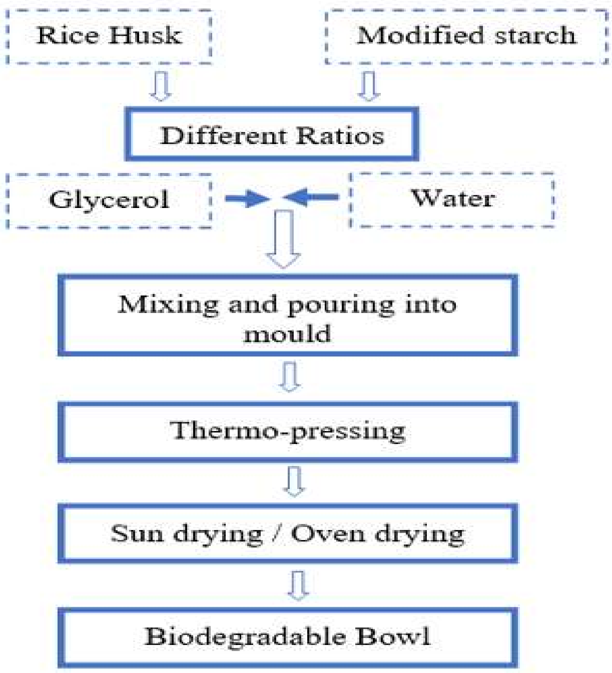


BOWLUSINGRICEHUSK

The Bowl having dimension of 120 mm (12cm) of upper diameter, 60 mm (6cm) of bottom diameter, height of 60 mm (6cm) and thickness of 5mm. The Die and Mold is made up of Aluminium material which gives more efficiency in conduction of heat. The Die is heated by using cotton candy Heating element.The process begins with gathering the necessary materials: rice husk powder, straw powder, corn starch, 2 to 3 tablespoons of glycerol, water, and coconut oil, which will be used as a Mold release agent



The initial step involves the careful collection and selection of suitable areca leaves.Onlymature,large,andunbrokenleavesarechosentoensurethe finalproducthassufficientsurfaceareaandstrength.Theseleavesaregenerally collected after they have naturally fallen from the areca palm, making the process highly sustainable and non-invasive to the plant itself.

Shaping Through Molding

The softened leaves are then shaped into the desired bowl form using a metal mold, typically made from aluminum due to its heat conductivity, light weight, and resistance to corrosion. The mold consists of two parts: a male (upper) and female (lower) die, designed to press the leaf into a standardized bowl shape. During this stage, the leaf is placed between the two halves of the mold, and moderate pressure is applied.

Drying and Final Hardening

Once the bowl is shaped, it undergoes a drying process to remove residual moisture and harden the material. This step is essential to ensure structural integrity and increase the bowl's resistance to liquids and mechanical stress

Once collected, the leaves undergo thorough cleaning to remove dirt, debris, insects, and any microbial contaminants. Washing is typically done using clean water, and in some cases, mild organic disinfectants may be used. This cleaning process is critical not only for hygiene but also for improving the aesthetic appeal and quality of the final product

- To study need of bio degradable container.
- To design Die machine using servaral materials.
- Materials like, aluminium, heating elements, iron, inslulation materials, bolt and nuts.
- Using different types of materials for making bio degradable containers.
- Development of die machines methodology

RESULT AND DISCUSSION

POWER CONSUMPTION CALCULATION

Specifications of the Heating Element:

- Rated Voltage (V): 220 V
- Power Rating (P): 1000 W (1 kW)
- Operating Time per Cycle: 10 minutes = 0.167 hours

Energy Consumed per Cycle (in kWh):

Energy = Power (kW) × Time (h) = 1 × 0.167
= 0.167 kWh
Daily Energy Consumption (for 30 bowls/day):
Daily Energy = 0.167 × 30 = 5.01 kWh/day
Cost of Electricity:
Assuming cost per unit = ₹7
Daily Cost = 5.01 × 7
= ₹35.07
EFFICIENCY CALCULATION
Step 1: Total Energy Supplied
Input Energy (E) = 1000 W × 600 seconds
= 600,000 Joules
Step 2: Useful Heat Required by Mold and Material
Mass (m): 1.5 kg (including aluminum mold and rice husk mixture)
Specific Heat Capacity (c): Average estimated = 1200 J/kg·°C
Temperature Rise (ΔT): 25°C to 120°C = 95°C
$Q = m \times c \times \Delta T = 1.5 \times 1200 \times 95 = 171,000$ J
Step 3: Efficiency (η):
$\eta = (Q / E) \times 100$
$= (171,000 / 600,000) \times 100$
$\approx 28.5\%$

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