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VALORISATION OF PLANT BIOMASS FOR KALAMKARI OF ANDHRA PRADESH: WASTE DISPOSAL ISSUES

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ABSTRACT

Indian crafts utilize indigenous materials known for their sustainability and biodegradability. A craft diagnostic survey conducted in 2023 at the Machilipatnam Kalamkari cluster in Andhra Pradesh revealed improper disposal of organic waste from production processes, posing environmental and health risks. Analysis of gross calorific value (GCV), ash content, moisture content, fixed carbon, and volatile matter showed that the GCV of bio-waste samples ranged from 3848 to 4143 Kcal/kg, surpassing that of cow dung and matching or exceeding Indian coal (4050 K. Cal/Kg) and lignite (3200 K. Cal/Kg). *T. chebula* had moisture content (8.95%), lower than Indian coal (16.5%).A strong correlation (0.8226) between GCV values of bio-waste and fossil fuels was observed, highlighting the dual opportunity to address waste disposal issues and mitigate energy crises. Implementing these solutions can tackle environmental concerns while promoting sustainable development, creating value-added opportunities for traditional craft industries.

Keywords: Biofuels, Bio-waste, Kalamkari, Recycling, Sustainability, Valorisation.

INTRODUCTION

The Machilipatnam Kalamkari craft cluster in Andhra Pradesh is renowned for natural dyeing and hand block printing using eco-friendly materials (Edwards, 2016). However, a survey revealed improper disposal of production waste, including plant-based mordants and dyes, into garbage bins or local canals. This practice poses environmental and health risks, such as pest infestations and water pollution, particularly during the rainy season. Solid waste mismanagement contributes to issues like eutrophication, impacting water quality and ecosystems (Handayani *et al.,* 2018).

Despite their biodegradability, the environmental impact of natural dyes remains underexplored. Moist or biodegradable waste decomposes over time, and recycling plays a crucial role in conserving resources, reducing pollution, and generating employment (Handayani *et al.,* 2018). The recycling process involves collection, sorting, and manufacturing, fostering environmental sustainability and community engagement.

Organic waste has diverse applications, including handmade paper production, composting, biogas and biofuel generation, and wastewater treatment (Waghmode, 2016). Biomass from red rose dye extraction, for

*Corresponding Author E-mail i.d: thadepalli.srivani@nift.ac.in; Part of Ph.D. thesis going to be submitted to Avinashilingam University, Coimbatore, Tamilnadu instance, can absorb chromium (VI) from water. Agricultural and food processing wastes are valuable resources, aiding in bioethanol and biomethane production (Rehman, 2015), enzyme synthesis (Nitin, 2017), and textile effluent treatment (Basu, 2016).

Biofuels, derived from biomass, offer renewable energy solutions. Traditional biofuels like wood provide heat and electricity, while ethanol, initially from plant starches, now includes non-edible fibrous materials (Selin, 2021). Biofuels also support transportation, with ethanol blends like E10 widely used (BETO, 2024).

The Gross Calorific Value (GCV) of various agricultural, forest, and animal residues in kilocalories per kilogram (K. Cal/Kg) represents the energy content of different biomass residues, which are potential sources for biofuel production. Coconut waste has the highest Gross Calorific Value (GCV) at 5200 K. Cal/Kg, making it highly energy-dense. Moderate GCV materials include Paper (4801), Babool stalk (4707), Groundnut shells (4661), and Sawdust (4654). Lower GCV biomass includes Bagasse (4300), Cotton stalks (4252), and Sugarcane (3966), while Bark (2675) has the lowest energy content, making it less efficient for biofuel production (Eco Stan, 2023). GCV, measured by a bomb calorimeter, determines the heat released during combustion, aiding in selecting biomass for energy applications and waste valorization. This data is crucial for selecting appropriate biomass materials for biofuel production and waste valorization. Higher GCV materials are more suitable for energy applications, while lower GCV materials may be better suited for composting or other uses.

Field surveys identified a research gap in vegetable dye waste valorization in Kalamkari production. This study explores waste generation, utilization, feasible technologies, and barriers to adoption. With limited literature on bio-waste management from dyeing plants, recycling into incense sticks presents a sustainable solution, addressing energy concerns and supporting handmade production.

MATERIAL AND METHODS

The first phase of the study involved qualitative research through a field survey of fifteen skilled master craftsmen in the Machilipatnam Kalamkari craft cluster in Andhra Pradesh. Primary data was collected via an interview schedule, focusing on open-ended responses to capture insights from personal discussions. The sample included ten master block printers, two block makers, and three younger craftsmen from five villages: *Pedana, Machilipatnam, Polavaram, Kappa-ldoddi, and Guduru*. Anonymized responses highlighted diverse perspectives on waste generation, pollution, and disposal issues, forming the basis for experimental research. The second phase adopted a quantitative approach, incorporating secondary data for comparative analysis with the experimental findings.

Insights from Field Research - Materials disposed of during and after the craft activity: Materials discarded during and after the crafting activity include more predominantly the wet waste/pulp generated from the use of natural plant sources like *T. chebula*, *L. microcarpa, R. cardifolia, P. granatum, B. monosperma*etc., in Kalamkari production. The organic waste collected from the mentioned five plant sources as shown in Figure 1 are used in the present study to explore their potential for reuse/ recycling.

Materials:

The organic biomass disposed of after the extraction and boiling (dyeing) in the Kalamkari craft cluster used for the study is given in Table 1.

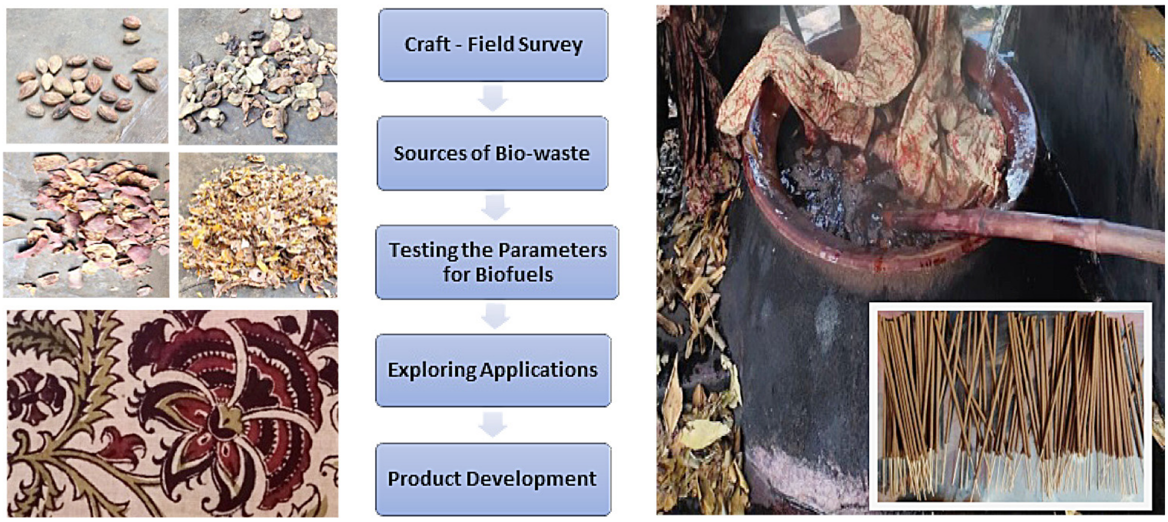

Fig. 1. The flowchart of processes for conversion of biomass into incense sticks

Preparation of Bio-waste for Testing

Solid organic waste is collected from job workers involved in boiling processes across the cluster. The wet waste is washed with distilled water, air-dried for 72 hours, and powdered to a uniform size as shown in Figure 2. For experimenting with the burning propagation of the dried solid waste (which is a residual waste after natural dyeing) the bio-waste is then tested for its biofuel efficiency. The coarse powders are further ball-milled for one hour using a Milling Machine (RSBM-1/060-718) to produce fine powders with an 80 mesh size, suitable for making various types

Table 1. Selected plant sources used in Kalamkari production

S. No.	Plant source	Purpose	Local name Telugu/Hindi/ English name	Scientific Name	Sample Code	Consumption per day at the cluster (Kg.)
1	Roots	Dye	***Manjistha***	***Rubia Cardifolia***	MJ	100 (approx.)
2	Flowers	Dye	*ModugaPuvvu /Palash*	*Butea monosperma*	MP	100 (approx.)
3	Fruit peel/ Rind	Dye	*Danimmaberadu/* Pomegranate rind/*Anar ka chilka*	*Punicagra-natum*	PP	100 (approx.)
4	Dried unripe fruit	Mordant	*Karakkaya/* Myrobalam/ *Haritaki/ harad*	*Terminalia Chebula*	KR	300 (approx.)
5	Leaves	Dying auxiliary	*Chennangiaaku/ Kasaundhi/Jajaku*	*Lagerstroemia microcarpa*	JJ	600 (approx.)

a) b) c)

Fig. 2. a). Coarsely ground powders b). Ball mill c). Ball-milled powders.

a) b) c) d)

Fig. 3. a). Bomb Calorimeter b). Combustion bomb c). Oven d). Muffle furnace

of incense sticks both by hand and machine processes in a systematic procedure using the recipes given in table 2.

Methods

Tests for Biofuel Applications: The Gross Calorific Value (GCV -ASTM 5865 – 10a) of the dried and powdered samples of plant waste is tested using a Bomb calorimeter as shown in Figure 3.

The Ash Content (ASTM D 3174 – 04), Moisture content (ASTM 3302M-17), Fixed Carbon (ASTM D 3172-13) and Volatile Matter (ASTM D 3175-17) are determined with respect to ASTM standards and formulas.

Description of Ingredients and Procedure Followed for Making Incense Sticks:

The incense stick formula comprises 30-40 parts bamboo core, 30-40 parts herbal powder, 15-40 parts sticky powder, and 1-5 parts potassium nitrate by weight. In this study, the traditional carbon/charcoal or mango wood sawdust was replaced with bio-waste powder. *Raal* powder, derived from the Sal tree (*Shorearobusta*), and *jigat/makko* powder, made from the bark of *Litseaglutinosa*, served as natural binders. Potassium nitrate (KNO_3), a naturally occurring mineral, enhances combustion performance and reduces carbon monoxide emissions, while also producing smoke and maintaining stable conditions.

The base mixture for unscented incense sticks was prepared by combining these ingredients with water to achieve the desired dough consistency. Bamboo sticks were coated under compression using an incense stick-making machine, then dried for 24-48 hours. Finally, the sticks were dipped in essential oils for 30 minutes, dried, and stored in the form of

Table 2. Composition of ingredients used in making incense sticks

Ingredients	T. c	P. g	B. m	L. m	R. c	Function	Price in Rs. /Kg.
Powder (gr.) (Bio-waste)	100	100	40	32	50	Bio-fuel used for generation of heat	Grinding Charges
Raal (gr.)	50	20	30	30	20	Generates smoke	55
Binder (gr.)	50	40	30	15	15	A medium to bind all the ingredients used	55
Potassium Nitrate/PN (gr.) (Saltpetre)	15	15	15	15	15	Accelerates burning of combustible materials	128
Water (ml.) / Rose water	100	100	25	13	40	For making dough in the required consistency	-
Essential oils (Cintronella)	For dipping of non-incensed sticks in oil-based fragrance					For fragrance in general or special purpose	Rs.1500/- -5000/ lt.
Bamboo skewers or sticksmade of sandal are used as core that gets burned along with the incense1.3mm						For rolling of incense and handling for use	9 inches 80-100

Note: *T. c (Terminalia chebula), P.g (Punicagranatum), B. m (Butea monosperma), L. m (Lagerstroemia microcarpa)* and *R. c (Rubiacardifolia).*

bundles in airtight containers to prevent bending and to retain incense property to enhance scent. Notably, it was observed that *Terminalia chebula* fruit powder has oil holding capacity of 4.93±0.01 mL/g and a water holding capacity of 6.28±0.06 mL/g (Amina, 2023) which might have contributed to the successful performance of incense sticks made from *T.chebula*, that received high ratings from a prominent *agarbatti* manufacturer involved in the exploration of new materials.

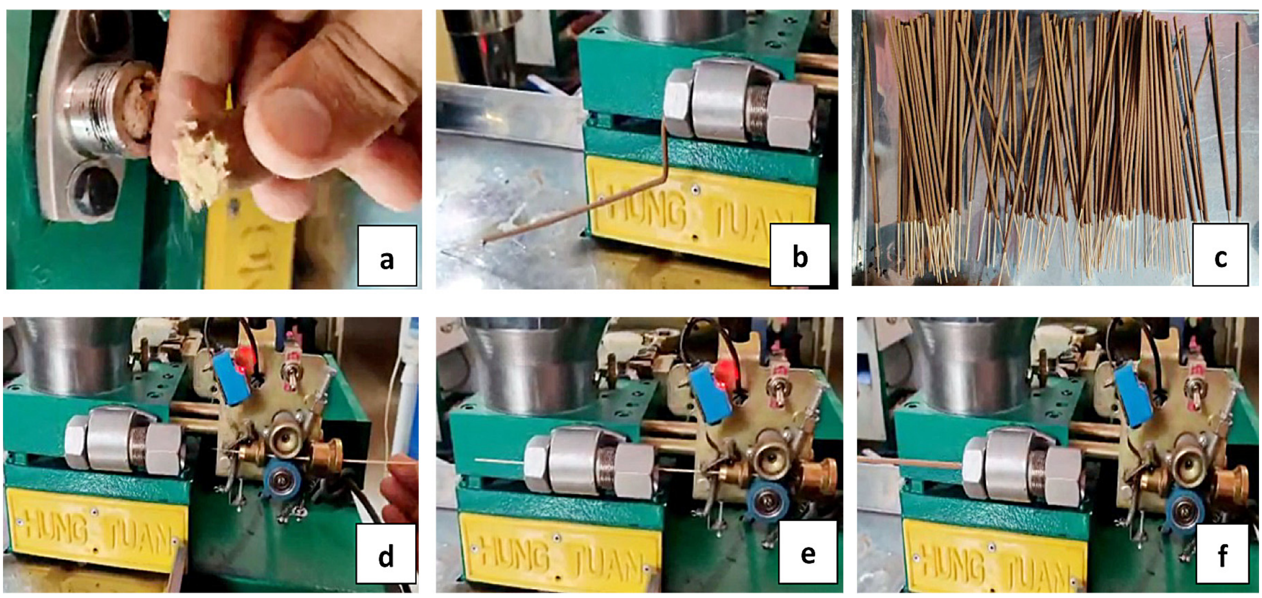

Figure 4. a) - b). Hard and sticky mass resulting in broken incense sticks; c). Incense sticks produced out of *T. chebula*waste; d) - f). Making of incense sticks

As the hand-made sticks are thick and uneven, taking more time to dry, further production was carried out only by machine as shown in Figure 4.

The hand-made incense sticks failed to burn continuously till the end. It was observed that the burning propagation of machine-made sticks was continuous, which is supported by the inherent calorific value of ***T. chebula*** (4007 K. Cal/Kg) and *L. microcarpa* (4143K. Cal/Kg). Hence the incense sticks are entirely made by machine. *T. chebula* showed excellent performance when ignited, similar to carbon powder. It proved easy to handle, taking a drying time of 2.5 hours. *P. granatum* was found to produce dough that gets hard and sticky causing machine jam. With *B. m, L. m* and *R. c.*, as bio-waste powder, moderate performance of ignition and non-uniform liberation of smoke was observed. The material might be suitable for use as *dhoop* cups and coils.

RESULTS AND DISCUSSION

Assessment of parameters for biofuel applications:

The gross calorific values (GCVs) of agricultural, forest, and animal residues typically range from 2675 to 5200 Kcal/Kg. Bio-waste collected from the Kalamkari cluster was tested and showed GCVs ranging from 3848 to 4143 Kcal/Kg. These results indicate that the GCVs of the bio-waste tested are higher compared to several other bio-wastes such as paddy straw, cow dung, rice husk, wood waste, tobacco waste and barks. They are also comparable to biofuels derived from maize stalks and sugarcane. Furthermore, other parameters like ash content, moisture content, volatile matter, and fixed carbon of the bio-wastes from the cluster were tested and compared with those of fossil fuels, as detailed in Table 3.

Table 3. GCV and other parameters of some Bio-fuels

Bio-fuels	GCV (K.Cal/Kg)	AC (%)	MC(%)	VM (%)	FC (%)
***Animal residues**					
Cow dung	3240	20.35	7.34	35.25	12.66
***Fossil fuels**					
Indian coal	4050	21.00	16.50	41.50	30.00
S. African coal	6018	16.72	8.06	31.53	48.94
Indonesian coal	5611	3.86	33.72	41.48	41.00
Lignite	3200	20.35	7.34	35.25	15.25
****Bio-waste from Kalamkari production**					
R. cardifolia	3848	6.20	12.56	34.20	16.14
B. monosperma	3924	7.84	12.56	35.15	17.64
T. chebula	4007	8.20	8.95	32.10	24.94
L. microcarpa	4143	4.75	9.22	30.37	15.45
P. granatum	3916	6.32	20.40	40.12	20.00

Source*: www.ces.iisc.ernet.in; note**: Test results of the study

Gross Calorific Value (GCV): The GCV is a key for assessing biofuels. All tested materials exceeded cow dung's GCV (3240 K. Cal/Kg), with *L. microcarpa*(4143K.Cal/Kg) surpassing both Indian coal (4050 K. Cal/Kg) and lignite (3200 K. Cal/Kg). However, traditional fossil fuels like South African coal (6018 K. Cal/Kg) and Indonesian coal (5611 K. Cal/Kg) had higher values.

Ash Content (AC): Ash content indicates combustion residue. All samples had lower AC than cow dung (20.35%), Indian coal (21%), and lignite (20.35%), with *T. chebula* showing an AC of 8.20%. Indonesian coal had a notably low AC of 3.86%.

Moisture Content (MC): Low moisture is crucial for biofuel efficiency. All bio-wastes had higher MC than cow dung (7.34%) and lignite (7.34%) but were lower than Indonesian coal (33.72%). *T. chebula* had a MC of 8.95%, which is lower than Indian coal (16.5%).

Volatile Matter (VM): Generally, a lower volatile matter content is preferable for biofuels because a high volatile matter can lead to inefficient combustion. *T. chebula* (32.1%), *B. monosperma* (35.15%), and *L. microcarpa* (30.37%) had VM values lower than cow dung (35.25%).*P. granatum* (40.12%) was comparable to Indian and Indonesian coals.

Fixed Carbon (FC): Higher fixed carbon is desirable. All bio-wastes surpassed cow dung (12.66%) and lignite (15.25%) but were below fossil fuels. *T. chebula* had the highest FC at 24.94%, suggesting strong potential for biofuel use.

Limitations of the study: This study focuses on biomass collected from copper dyeing vessels, where fabrics dyed with *T. chebula* and fermented iron acetate mordants are treated with vegetable dyes. Comparing these results to existing literature is challenging due to variations in factors such as growth and storage conditions, environmental variables like temperature and humidity and different auxiliaries used in the dye bath.

Burning Performance of Incense Sticks: *T. chebula* showed excellent performance when ignited, similar to carbon powder. It proved easy to handle, taking a drying time of 2.5 hours. *P. granatum* was found to produce dough that gets hard and sticky causing machine jam. With *B. m, L. m* and *R.c.,*as bio-waste powder, moderate performance of ignition and non-uniform liberation of smoke were observed. The material might be suitable for use as *dhoop/* smoke cups and coils.

Analysis of Emission of Incense:

The study explored three methods of applying essential oils to incense sticks, using five plant-based essential oils that are rarely used in incense: Camphor, Camel grass, Benjoin resin, Marjoram, and Fragrant screw pine. The process followed small-scale agarbatti manufacturing practices, where *T. chebula* based blank incense sticks were soaked in essential oil for 30 minutes or rolled in an aluminum tin with a 1:2 fragrance-to-stick ratio, followed by a 24-hour drying period. Commercial manufacturers typically soak sticks for 24 hours to three days for better absorption, while aroma therapists apply twelve drops of essential oil per stick for more controlled aroma release. Among the oils tested, marjoram and camphor were most perceptible in terms of consistent aroma emission during the first minute of ignition, based on a qualitative analysis by a panel of five female evaluators.

Statistical Analysis: The statistical analysis was performed using IBM SPSS software version 22 for assessing all the values done in triplicate. GCV values of bio-wastes and fossil fuels are highly correlated (0.8226) and other parameters showed reasonable correlation (0.6234). The calculated chi-square value(7.30) is less than the tabulated chi-square value (24.996) at the significance level (á=0.05), with the associated p-value (0.948). Hence, there is no significant association between the variables of fossil fuels and bio-wastes.

CONCLUSIONS

Results from the study indicated that the Kalamkari residual wastes possess significant energy potential, with GCV values (3848 to 4143 Kcal/kg) surpassing several agricultural, forest and animal residues such as bark, tobacco waste, rice husk, cow dung, paddy straw (2675 to 3800 Kcal/Kg), and also lignite, the fossil fuel(3200 Kcal/Kg). All samples exhibited lower ash content (4.75% to 8.2%) than animal residue cow dung (20.35%) and fossil fuels such as Indian coal and lignite (20.35% to 21%). The moisture content of all bio-waste samples was lower than that of Indonesian coal (33.72%), with *T. chebula* having moisture levels (8.95%) comparable to S. African coal (8.06%). The volatile matter of *B. monosperma* (35.15%) was similar to that of cow dung (35.25%) and lignite (35.25%) whereas *P. granatum* showed VM values (40.12%) akin to Indian and Indonesian coal (41.48% and 41.5% respectively). Notably, *T. chebula* had the highest fixed carbon content (24.94%) among the tested bio-wastes, highlighting its suitability for use in incense sticks and other biofuel applications. Among the selected essential oils tested in combination with the blank sticks of *T. chebula*, marjoram and camphor were most perceptible in terms of consistent aroma emission during the first minute of ignition.

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