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Sustainable Conversion of Stubble in to Compost: Spectral & Physico-Chemical Study

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***Abstract:*-Open-field burning of stubble is a major contributor to air pollution and soil degradation in northern India. This study explores a sustainable alternative by converting stubble into compost through co-composting with cow dung and vegetable peels. The objective was to evaluate compost maturity and quality using spectral and physicochemical parameters. The composting process was carried out over a 40-day period, during which samples were regularly analyzed. Key physicochemical properties such as pH, organic carbon, nitrogen, phosphorus, potassium, and moisture content were measured, along with spectral observations related to color and texture changes. Results showed that the addition of cow dung and vegetable peels accelerated decomposition, leading to a nutrient-rich compost. Organic matter increased steadily, pH stabilized within a favorable range, and NPK values improved significantly. Spectral observations also confirmed progressive maturity of the compost. The findings indicate that combining stubble with cow dung and vegetable waste offers an eco-friendly solution to residue management. The process not only reduces environmental pollution but also produces high-quality compost that can enhance soil fertility and support sustainable agriculture.**

1. INTRODUCTION

Crop residue management has emerged as a major challenge in modern agriculture. Large quantities of stubble are generated after the harvesting of paddy and wheat, and farmers often burn these residues to quickly prepare fields for the next crop. Although burning is a simple and low-cost option, it causes serious environmental damage in the form of air pollution, greenhouse gas emissions, and loss of valuable soil nutrients. This widespread practice highlights the urgent need for sustainable alternatives. Composting is one of the most effective eco-friendly solutions for managing crop residues. It transforms stubble into nutrient-rich organic matter that improves soil health and reduces the dependency on chemical fertilizers. The addition of organic materials such as cow dung and vegetable peels accelerates the decomposition process. These inputs provide microorganisms and essential nutrients that enhance compost quality, making it suitable for sustainable farming practices. The evaluation of compost quality requires both visual and scientific indicators. Spectral observations such as changes in color and texture indicate the progress of decomposition, while physicochemical parameters including pH, organic carbon, nitrogen, phosphorus, potassium, and moisture content give precise measurements of compost maturity. This study focuses on the sustainable conversion of stubble into compost by assessing both spectral and physicochemical characteristics. The research aims to demonstrate that agricultural residues can be effectively transformed into valuable organic fertilizer instead of being wasted or burnt. By incorporating cow dung and vegetable waste, the decomposition process is accelerated, resulting in compost with higher nutrient content and better stability.

The significance of this approach lies not only in providing a solution to the stubble burning problem but also in promoting resource recycling. Materials like stubble, cow dung, and vegetable peels are often regarded as waste, yet when combined, they produce compost that can enrich soil and support crop growth. This reduces reliance on synthetic fertilizers, lowers cultivation costs, and contributes to sustainable agriculture. Furthermore, the process helps in mitigating environmental pollution and advancing eco-friendly farming practices.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in District Gurdaspur, an area with extensive paddy and wheat cultivation. The region was selected for the availability of crop residues and suitable conditions for controlled composting experiments.

2.2 Raw Materials

The composting materials included:

- Crop Residues (Stubble): paddy stubble collected immediately after harvesting.
- Cow Dung: Freshly obtained from local dairy farms, serving as a microbial inoculant and nitrogen source.
- Vegetable Waste: Kitchen scraps, including potato and onion peels, used to provide easily degradable organic matter and accelerate decomposition.

2.3 Composting Procedure

A pit measuring 3.5 feet in depth was prepared in an open area to allow proper aeration and drainage. Stubble, cow dung, and vegetable waste were layered alternately. Water was added regularly to maintain moisture at 50–60%, optimal for microbial activity. The pile was manually turned every 10–12 days to enhance aeration and ensure uniform decomposition. The total composting period was 40 days.

2.4 Spectral Analysis

Decomposition progress was monitored using visual observations such as changes in color, texture, and odor. Additionally, advanced techniques were employed to evaluate structural changes:

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- X-ray Diffraction (XRD): Used to detect changes in the crystalline structure of organic matter during composting.
- Scanning Electron Microscopy (SEM): Provided high-resolution images of the surface morphology, confirming the breakdown of stubble fibers and microbial activity.

2.5 Physicochemical Analysis

To evaluate the quality and maturity of the compost, samples were collected at 10-day intervals during the 40-day composting period. The following parameters were measured:

- pH: Determined using a digital pH meter in a compost-water mixture to monitor acidity or alkalinity, which affects microbial activity.
- Organic Carbon: Measured to assess the decomposition of organic matter and formation of humus in the compost.
- Nitrogen, Phosphorus, and Potassium (NPK): Monitored using standard laboratory procedures to evaluate nutrient content.
- Moisture Content: Determined by oven-drying samples to maintain optimal microbial activity and ensure proper decomposition

6. Data Analysis

The spectral and physicochemical data were analyzed over time to assess compost maturity, nutrient enrichment, and stability. Changes in these parameters were used to determine the suitability of the final compost for agricultural application.

3 .RESULTS AND DISCUSSIONS

Compost was prepared using cow dung, stubble, and vegetable peels and analyzed through XRD, SEM–EDS, physicochemical tests, fertility and clean indices, and heavy metal content.

- XRD Analysis: Detected montmorillonite, kaolinite, illite, feldspar, and quartz, showing the presence of nutrient-rich clays and soil-structuring minerals.
- SEM Analysis: High proportion of carbon (34.11%) and oxygen (49.97%) confirmed the organic-rich nature, with silicon, aluminium, and trace nutrients (Na, Mg, K, Ca) present in smaller amounts.
- Physicochemical Properties (40th day):
- pH: 7.5 (within FCO standard 6.5–7.5)
- EC: 0.40 dS/m (safe, below 4 dS/m limit)
- Phosphorus: 1.12% (above 0.5% minimum)
- Potassium: 1.68% (above 1% minimum)
- Organic Carbon: 17.3% (above 16% minimum)
- Quality Indices (40th day): Fertility Index: 4.7 (very good) Clean Index: 4.9 (safe)
- Heavy Metals: Zn (0.4 mg/kg), Cu (0.6 mg/kg), Mn (2.6 mg/kg), and Fe (5.3 mg/kg) were far below FCO permissible limits, confirming environmental safety. The compost is nutrient-rich, structurally stable, free from harmful contaminants, and qualifies as good quality organic manure suitable for sustainable agriculture.

Table1 Physico-chemical, Mineralogical and Elemental Analysis of Compost

Analysis Type	**Parameter / Compound**	**Result / Value**	**Standard / Reference**
XRD	Montmorillonite, Kaolinite, Illite, Quartz, Feldspar	Detected	PDF (ICDD) database
SEM–EDS	C (34.11%), O (49.97%), Si (9.10%), Al (4.10%), Others (Mg, Na, K, Ca: 0.3–1.4%)	Elemental composition	-
Physico-chemical (40th day	pH: 7.5; EC: 0.40 dS/m; P: 1.12%; K: 1.68%; OC: 17.3%	FCO standards: pH 6.5–7.5; EC <4; P ≥0.5%; K ≥1%; C ≥16%	FCO standards
Indices (40th day)	Fertility Index: 4.7; Clean Index: 4.9	Very good & safe range	Standard scale (0–5)
Heavy Metals	Zn: 0.4 mg/kg; Cu: 0.6 mg/kg; Mn: 2.6 mg/kg; Fe: 5.3 mg/kg	FCO permissible limits: Zn ≤1000; Cu ≤500	FCO standards

CONCLUSION

This study demonstrates that composting a mixture of vegetable peels, cow dung, and stubble provides an effective and sustainable method for converting organic waste into nutrient-rich soil amendments. Proper management of key factors such as temperature, moisture, and pH produced a mature and stable compost, enhancing its suitability for agricultural use. Incorporating stubble into composting is particularly significant, as it offers an environmentally friendly alternative to stubble burning, reducing air pollution and associated health risks.

Ultimately, this research underscores the role of organic waste recycling in promoting resilient agroecosystems, reducing chemical input reliance, and creating a positive environmental impact. By combining practical waste management strategies with scientific validation, the study provides a scalable and environmentally responsible framework for enhancing soil health and supporting sustainable agricultural development. The resulting compost improves soil fertility, water retention, and microbial activity, thereby reducing the dependence on chemical

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fertilizers. By promoting awareness among farmers about the advantages of composting stubble and organic residues, this approach supports sustainable agriculture while simultaneously mitigating environmental harm. Overall, this research highlights composting as a practical, eco-friendly, and impactful solution for waste management, soil health, and environmental protection

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