

Performance of Centralized Municipal Biodegradable Waste Composting: The Case of Kutaisi Composting Centre, Georgia

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Municipal solid waste systems increasingly prioritize biological treatment of the organic fraction to reduce landfill reliance and recover nutrients in line with circular bioeconomy objectives (European Environment Agency, 2013; World Bank, 2018). However, the operational performance of full-scale centralized composting remains strongly context-dependent, with outcomes shaped by feedstock variability, contamination, aeration and moisture management, and process monitoring capacity (Haug, 1993; Barrena et al., 2006). This study evaluates the real-scale performance of the Kutaisi Composting Center (Georgia), focusing on process dynamics, stabilization/maturity development, and final compost quality indicators under routine municipal operating conditions.

The facility processes source-separated municipal biowaste using windrow composting with periodic turning. Performance evaluation was conducted during the 2024–2025 operating period using a combination of operational monitoring (windrow temperature evolution, turning frequency, composting duration, and moisture management) and product assessment. Compost stabilization and maturity were assessed using physico-chemical indicators (pH, electrical conductivity, organic matter, and C/N ratio) and biological indices, with emphasis on respiration activity as a robust descriptor of biological stability in full-scale settings (Adani et al., 2004; Evangelou et al., 2016; Cesaro et al., 2019). Quality interpretation was aligned with internationally used approaches that rely on multi-parameter indices rather than single thresholds, supporting comparability and quality assurance in compost markets (Borisova et al., 2022; Siles-Castellano et al., 2021).

The composting process exhibited rapid temperature increase, reaching thermophilic conditions within the first week and maintaining temperatures above 55 °C for more than 30 days (Figure 1), consistent with effective sanitation requirements reported for full-scale municipal composting systems (Cesaro et al., 2019; Borisova et al., 2022). Peak temperatures of approximately 65–70 °C were observed during the active phase, followed by a gradual decline during the maturation stage, indicating stable aerobic degradation and effective process control. The composting process consistently achieved a thermophilic phase, indicating effective biodegradation and sanitation potential, while the cooling/maturation phase length varied with season and feedstock composition. Observed variability was primarily attributed to fluctuations in biodegradable fraction composition and contamination by non-compostable materials—an issue widely reported as a critical constraint to stable operation and product quality in municipal composting systems (Huynh et al., 2023; Jalalipour et al., 2020). Gas- and odor-related risks were managed operationally through turning and moisture control; nonetheless, spatial and temporal heterogeneity in bioprocess conditions is expected in municipal windrows and can influence stability trajectories and emissions, reinforcing the need for process-informed monitoring (Stegenta et al., 2019; Raul et al., 2023). Overall, the resulting compost exhibited stabilization and maturity trends consistent with evidence from other full-scale and industrial-scale studies where respiration indices and multi-parameter quality control reliably distinguish mature from insufficiently stabilized material (Bazrafshan et al., 2016; Cesaro et al., 2019; Miguel et al., 2022).

The findings demonstrate that, even under routine municipal conditions, centralized composting can produce a stable, agronomically suitable compost when supported by (i) systematic control of moisture and aeration, (ii) feedstock quality management at collection and reception, and (iii) routine stability testing using respiration-based indices (Barrena et al., 2006; Evangelou et al., 2016; Adani et al., 2004). For Kutaisi, the most leverageable improvements include strengthened source-separation behavior, enhanced pre-sorting to reduce contamination, and formalized quality assurance aligned with recognized compost evaluation frameworks (Borisova et al., 2022; Siles-Castellano et al., 2021). This case study contributes empirical evidence from a transitioning municipal system and supports scaling of biological treatment as a practical landfill-diversion pathway in the region (European Environment Agency, 2013; World Bank, 2018).

Table 1. Summary of operational and compost quality indicators for windrow composting at the Kutaisi Composting Center (2024–2025).

| Day | Phase (indicative) | Temperature (°C) |
|-----|----------------------------|------------------|
| 0 | Start (feedstock mixing) | 24 |
| 1 | Early mesophilic | 32 |
| 2 | Mesophilic | 43 |
| 3 | Transition to thermophilic | 55 |
| 4 | Thermophilic | 62 |
| 6 | Thermophilic peak zone | 67 |
| 8 | Thermophilic | 64 |
| 10 | Thermophilic | 61 |
| 14 | Late thermophilic | 57 |
| 18 | Cooling | 50 |
| 24 | Cooling | 43 |
| 30 | Early maturation | 38 |
| 40 | Maturation | 33 |
| 50 | Late maturation (stable) | 29 |

Notes: Turning events commonly occur every 3–7 days in early stages; turning typically causes short-term temperature dips followed by recovery.

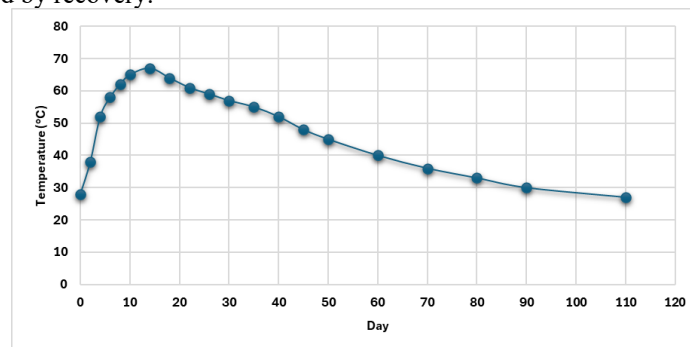


Figure 1. Representative temperature profile of a windrow during composting at the Kutaisi Composting Center, showing mesophilic, thermophilic, and maturation phases.

Figure 1. Representative temperature evolution during windrow composting of source-separated municipal biodegradable waste at the Kutaisi Composting Center, illustrating rapid mesophilic heating, a sustained thermophilic phase ($\approx 55\text{--}70\text{ }^{\circ}\text{C}$), and gradual cooling during maturation, in agreement with full-scale composting performance reported in the literature (Cesaro et al., 2019; Borisova et al., 2022; Miguel et al., 2022).

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