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Jobs in the circular bioeconomy under scrutiny: The challenging reality of compost production in Rwanda

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ABSTRACT

Today, most African countries have dysfunctional municipal waste management system, negatively impacting the environment and human health. However, as most of this waste is recyclable, informal actors are making their income out of the collection/sorting of waste. Accounting for the risks involved in waste manipulation, it is important to ensure decent working conditions for those recycling it. This study focuses on biowaste recycling in Rwanda, a Circular Economy leader in Africa, with the purpose of: (i) characterizing the working conditions of waste recyclers along the definition of 'decent work' and (ii) assessing workers' satisfaction and its determinants. We surveyed 63 workers employed in three compost production and three biowaste processing companies. Our results show that the work can be considered relatively decent compared to national references, except for insufficient social protections and occupational safety. Workers reported being rather satisfied with their jobs, although our analyses of covariance showed that workers employed in composting were significantly less satisfied than the others. These findings highlight the importance of household-level waste separation for improving not only worker safety, but also nutrient recovery. Further research should investigate how to push forward waste sorting at the household level and improve worker safety (SDG 8) without negatively affecting the women currently employed in waste sorting at the company level (SDG 5).

1. Introduction

The transition from a linear economy to a circular economy (CE) is a promising way to contribute to the United Nations' Sustainable Development Goals (SDG) [1,2]. In low- and middle-income countries (LMICs), CE practices are mainly performed daily, mostly by informal workers [3,4] driven by economic necessity [5]. This leads to informal waste-recycling activities assuming the bulk of urban recycling [6,7]. These informal jobs allow many economically vulnerable populations, composed largely of female workers, to survive [8]. In some developing countries, it is estimated that up to 2% of the population earns their income from waste [9]. Meanwhile, their informal employment conditions expose them to negative health impacts, occupational risks, and a lack of social security [2,10,11]. Further, informal employment prevents them from being considered CE's main actors, generating economic value from recovering material flows [4,12].

Managing solid waste sustainably is, and will continue to be, a challenging issue in many LMICs, given their rapid urbanization [13,14]. This means that solid waste management companies, which rely heavily on informal workers [4], will continue to employ them, since the sector is a main source of employment for the unskilled [15]. However, it is not sustainable to claim developing "sustainable" waste management in LMICs without ensuring the necessary working conditions for those involved [16]. Pla-Julián and Guevara (2019) [17] argue that it is critical to engender CE by understanding the roles performed by all workers in the food value-chain, from production to waste management. Indeed, in many countries, women perform most of the agricultural and household labor involving food and waste management, leading to

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gendered practices related to waste recycling [8,18–20]. For example, Dada et al. (2022) [10] showed that Nigerian women are mostly responsible for waste separation, whereas men dominate collection. In parallel, women perform the most financially precarious work in the informal sectors, while men hold more stable jobs with monthly wages [8].

The dominant CE literature ignores these critical social and gendered dimensions as a consequence of high-income countries' (HICs) conceptualization of CE [12] and CE's technical and engineering focus [20]. Though some scholars admit that the informal economy drives CE in LMICs, its conceptual foundations remain anchored in the reality of HICs' formalized and organized economies [5]. Some scholars have recognized the social blind spot of CE and proposed new definitions that account for social dimensions [1,12,20–22], meanwhile, even if scholars agree that the social dimension of CE is insufficiently discussed, no unified methodology has been adopted to assess social sustainability [23].

Taking into account Padilla-Rivera et al.'s (2020) [16] analysis, we use "decent work" (SDG 8) as the guiding framework for our study. They demonstrated that "labor practices and decent work" (41%) are the second-most represented thematic area in the literature on the social dimension of CE, after "society" (49%). The International Labor Organization (ILO) broadly defines decent work as "productive work for women and men in conditions of freedom, equity, security and human dignity" (ILO, 2015, p.1) [24]. Burchell et al. (2014) [25] criticize this as too vague for measuring and comparing across countries, because of the lack of universal consensus on what a "good job" encompasses. This is a consequence of the field's early developmental stage [26] and the multiple academic approaches/scales used concerning individual workers, the jobs themselves, the regulatory environment, or the labor market as a whole [27]. Current data on the provision of decent work is mostly collected at the national level via labor force surveys, which do not include workers' views on their working conditions [28,29]. Nonetheless, promoting decent work and social inclusion remain key recommendations that national governments should follow when developing CE practices [30].

Rwanda, a founding member of the African Circular Economy Alliance, is a driver of CE in Africa, along with Nigeria, South Africa, and Kenya [1]. In Rwanda, 70% of municipal solid waste is composed of biowaste [30], so there is a big opportunity to produce organic fertilizer locally, instead of importing synthetic products [31]. In addition to recovering nutrients, the circular bioeconomy can improve urban sanitation, decrease carbon emissions from waste (mitigating climate change), and create jobs [32]. The circular bioeconomy here refers to the transformation of renewable biological resources into value-added products such as food, feed, bio-based products, and bioenergy [33].

Regarding women, in 2003, the Rwandan government adopted a socially progressive constitution that seeks to give equal chances for all across all sectoral policies [34]. Rwanda is the best performer in Sub-Saharan Africa, in terms of closing the gender gap, and the country is in the global top four in terms of women's political empowerment; they hold more than 50% parliamentary and ministerial positions [35]. However, the livelihoods of a majority of rural women are precarious [34], and female casual agriculture laborers earn 23% less than their male counterparts [36]. When it comes to youth, 37.7% in 2021 were not in education, employment or training [37]. The Rwandan Ministry of Agriculture sees this as an opportunity for agricultural development, as young Rwandans can use agricultural technologies to create agribusinesses [35]. Currently, 90% of Rwandans are employed informally, with 40% in agriculture; women and youth are the most affected by unemployment [38]. In that sense, developing the circular bioeconomy could contribute to create potentially decent jobs for them [24].

This study has three objectives: (i) characterizing the working conditions of those recycling organic waste in Rwanda's micro, small, and medium enterprises (MSMEs) following the decent work guidelines, (ii) assessing workers' satisfaction levels, and (iii) understanding which factors determine worker satisfaction. We focus on MSMEs, as they constitute 98% of Rwanda's [39] and promote social sustainability by creating decent jobs (SDG 8) and ensuring gender equality (SDG 5) [40]. More specifically, we aim to address these two research questions (RQs):

RQ1: To what extent can the jobs created by the circular bioeconomy be considered "decent work"?
RQ2: How satisfied are the workers employed in the circular bioeconomy, and what are the determinants of their satisfaction?

For RQ1, we hypothesized that jobs within circular bioeconomy might show shortcomings to be called "decent work" concerning gender [8,18,41] and social security [37,42,43]. For RQ2, we hypothesized that worker satisfaction is influenced by age, gender, parent and marital status, and the type of work being done (innovation type), based on previous works on the determinants of worker satisfaction in Africa [27,29,44,45].

2. Materials and Methods

2.1. Questionnaire

The survey consisted of 44 questions covering the worker's profile, working conditions, and satisfaction (see Appendix A for the detailed questionnaire). The first 17 questions characterized the worker's sociodemographics (age, gender, marital status, education, income). The following 20 evaluated their working conditions along the five indicators from the ILO's decent work guidelines [24]: 1) fair income; 2) security in the workplace and social protection for families; 3) better prospects for personal development and social integration; 4) freedom to express their concerns, organize, and participate in the decisions that affect their lives; and 5) equal opportunities and treatment for all.

To understand the working conditions and answer RQ2, we asked four questions about satisfaction (with the job, wages, social security, and relationship to their supervisor). We used a five-point Likert scale from 1 (very dissatisfied) to 5 (very satisfied) to evaluate satisfaction. We also included two open-ended questions: the first concerned workers' role in the company, while the second addressed workers' ideal employment. Finally, we asked about workers' perceived agency using a standardized four-point ladder of power to make decisions for themselves [46].

A literature review identified which factors might affect workers' satisfaction, acknowledging that the topic has been far less studied in LMICs compared to HICs [29]. We found that worker satisfaction in the primary sector in Africa is influenced by job attributes [29], gender [21], age [44], educational background, and marital status [27]. Therefore, we considered these independent variables for identifying the determinants of worker satisfaction and answering RQ2.

2.2. Sample

This study is embedded in a larger research project, RUNRES (Rural Urban Nexus RESilience), supported by the Swiss Agency for Development and Cooperation. RUNRES seeks to improve the resilience and sustainability of regional food systems by recovering nutrients from biowaste to produce compost/animal feed/fertilizer. This research focuses on three companies that collaborate with RUNRES in Rwanda (A, D, E), and on three others (B, C, F) selected with the support from YALTA (Youth in Agroecology and Business Learning Track Africa). Three of these produce compost (A, B, C); the others valorize crop residues/peels into products (D, E, F). More specifically, Company D processes cassava peels into animal feed. Company E uses fruit waste from a juice company and local household food waste to feed black soldier fly larvae. Once grown, these larvae are sold for animal feed, and the remaining organic fraction (frass) is sold as compost. Company F uses crop residues from local farmers (e.g., beans, sorghum, rice) that are mixed and used as a

Table 1
Description of workers' and companies' characteristics

Criteria	Companies A	B	C	D	E	F	Total
Company size[*]	Small	Small	Small	Small	Micro	Micro	
Company location (province)	Southern	Southern	Northern	Southern	Southern	Southern	
Raw material processed	Municipal solid waste	Municipal solid waste	Municipal solid waste	Cassava peels	Fruit waste	Crop residues	
Output product	Compost	Compost	Compost	Animal feed	Animal feed	Oyster mushrooms	
# of workers interviewed	16	12	12	11	4	8	**63**
% of total workforce	64%	46%	75%	65%	80%	100%	
% of total sample (N = 63)	25%	19%	19%	17%	6%	13%	**100%**
Average age of workers	38.2 SD=9.10	27.8 SD=7	42.8 SD=18.2	24.8 SD=5.7	26.3 SD=6.2	21.5 SD=1.8	**31.9 SD=12.5**
% male workers	69%	67%	0%	64%	50%	100%	**57%**
% of workers who have completed primary school or above	69%	58%	50%	64%	25%	63%	**59%**
% of workers with one or more children	100%	42%	67%	18%	75%	0%	**54%**

[*] Company size: Micro < 10 employees, Small 10 ≤ 50 employees.

substrate to grow oyster mushrooms. The six companies are heterogeneous, concerning the waste they recycle, as shown in Table 1, but they have in common their workforces, employing below 10 employees (micro) and between 10 and 50 employees (small).

We surveyed 63 workers, 36 men and 27 women, at six sites. The sampling strategy was biased in favor of surveying as many women as available, as they were less numerous than men at all sites except Company C. Inducing their artificial over-representation gave us a balanced female/male sample. When selecting male participants, we tried to interview as many as possible at each site, simultaneously respecting the time boundaries the company leaders requested. The workers were, on average, 31.9 years old with the youngest worker being 19 and the oldest being 69 years old (SD=12.5, Range=50). Overall, the workers had rather low education levels: 11% had no primary schooling, 30% had some primary schooling, 35% completed primary schooling, and 24% had some secondary or vocational schooling. In terms of marital status, 67% of females were unmarried (30% had children), while 33% were married. For the males, 47% were married and 47% were unmarried. Company F employs only men, whereas Company C employs only women. Workers were mostly local residents, with 59/63 who reached work by foot and 4/63 by bike. Commuting time fluctuated from 5 minutes to 120 minutes one-way (mean = 30 min SD=28min). On most sites, workers spent six days out of seven on the worksite, starting from 7:00 until 17:00 with one hour for lunch. Company C, employing only female workers, was the only site where workers came for half-days (7:00-13:00). This was appreciated by the female workers who could better combine their unpaid responsibilities with their paid job.

2.3. Data collection

As the respondents did not speak English, we hired Rwandan interviewers (two women, one man), whom we trained prior to the data collection. During this training, we validated that each survey question was culturally acceptable, paying special attention to potential gender issues in the workplace and uncomfortable work-related topics. We ensured that each interviewer would interview a worker of the same gender (especially for female workers) and that they would find or create a private space for the discussion. These conditions could potentially facilitate the sharing of gendered experiences, as the needs and roles of female and male workers are not identical (e.g., menstruation, hierarchical relationships, social pressure for gendered roles).

Once the interviewers were trained, we collected the data in November 2021 across Rwanda's Southern and Northern Provinces. We visited one company per day and surveyed as many workers as possible at each site. Before starting the survey, the enumerators distributed a written paper in Kinyarwanda stating that the information shared would be confidential and anonymous, and that participants could end the interview at will. Interviews began once participants provided their consent.

Table 2
Value labels of the ANCOVAs' independent and dependent variables

Binary categorical independent variables	*Value label*		*N*
Gender	0	Male	36
	1	Female	27
Marital status	0	Single	28
	1	Partnered	35
Company innovation type	0	Non-compost	23
	1	Compost	40
Parent status	0	No children	29
	1	One child or more	34
Independent covariate variable (continuous)			
Age (years)			63
Dependent variables (satisfaction)	*Numerical rating scales*[*]		
Overall job	1–5	Very low to very high	63
Wages	1–5	Very low to very high	63
Social security	1–5	Very low to very high	63

[*] 1 = Very dissatisfied, 2 = Somewhat dissatisfied, 3 = Neither dissatisfied nor satisfied, 4 = Satisfied, 5 = Very satisfied

2.4. Data analysis

We analyzed the 63 workers' data using descriptive statistics structured around the five categories of decent work [47]. To understand which independent variables explain overall job, wage, and social security satisfaction, we conducted three ANCOVAs [48]. Each included four dichotomous independent factors: gender (male/female), innovation type (non-compost/compost innovation), marital status (single/-partnered), and parent status (no/yes), and the covariate variable age. Accounting for the very small subsample sizes in more specific categories, our data on marital status was simplified into the binary option noted above.

Interactions among the independent variables were not included in the model, to limit the degree of freedom to 5, thereby ensuring analytical robustness [49]. Table 2 shows the frequency distribution of the binary independent variables and the numerical coding of all variables. Quantitative statistical analyses were conducted using SPSS version 26.

3. Results

3.1. Description of the working conditions according to the Decent Work agenda

RQ1 addressed the extent to which the jobs created by the circular bioeconomy could be considered decent work according to the five ILO dimensions [47]. Regarding a fair income, workers earned a median wage of 31,000 Rwandan francs (RWF) per month (SD=11,907), the equivalent of 29.16 USD (calculated October 11, 2022). This wage is low compared to the current international poverty line of 2.15 USD per person per day, or 64.50 USD per month [50]. Meanwhile, the wage is higher than 50% of Rwandan workers, who earn a median of RWF 18, 175 per month (17 USD) or less [51]. The Rwandan National Labor Force estimates the mean monthly salary in the agricultural sector is 20, 813 RWF (19.50 USD) (Danish Trade Union Development Agency, 2021, p. 20) [38]. In our case, the mean monthly salary of a bioeconomy worker is 33,643 RWF, 61.86% higher.

Regarding workplace security, 79% wear protective gloves, hats, boots, and jumpsuits. In most cases, the workers were given these on their first working day. However, those employed by compost companies (A, B, C) need more frequent gear replacement, as the sharp objects in raw waste rapidly damage them. Social protection was nonexistent for the vast majority of workers, who neither receive health insurance nor pensions from their employers. This situation is characteristic for the active population in Rwanda who works in informality [52]. Only some workers from Company B had health insurance (12/63) covered by their employers and 8/63 also had a pension. Meanwhile, the latter is deducted monthly from the workers' wage. This explains why most of them prioritize meeting their needs in the present rather than planning for an uncertain future [53]. Employers explained that covering workers' social insurance is too expensive for low-revenue businesses like theirs [54]. Some employers try to compensate with other non-monetary benefits, such as daily on-site meals (Companies D–F). Therefore, some improvements are needed to secure working conditions and ensure social protection, but we must recognize that these findings are not specific to the bioeconomy, but rather indicative of Rwanda's developing economy. As the ILO stated in its report on Decent Work for Rwanda: "the absence of an informal sector pension scheme in Rwanda is a critical issue" (2018, p. 7) [43]. The same goes for workplace safety, where the Occupational Safety and Health National Policy adopted in 2014 is not well implemented because of the low institutional capacity of Rwanda's economic actors (ILO, 2018, p. 7–8) [43].

Regarding prospects for personal development and social integration, while 33% of workers had no savings, the rest reported some minor savings (50%), or even sufficient savings (16%). Those who saved mentioned they use this money to buy – in order of priority – livestock (37%), better clothes or shoes (19%), more food (16%), and health insurance (13%) (Table 3). It seems that recycling biowaste is preferred over other jobs, as 29% (5F, 13M) of workers had a previous job that they had quit, or they migrated to secure this employment. Indeed, workers mentioned having a higher and more stable income in the waste sector, compared to casual or seasonal construction or farming work. However, in an ideal world, workers reported to an open-ended question that their ideal employment would be 'business' for 32/63, 'farming' for 9/63, 'being a driver' (6/63), 'being a soldier' (3/63), 'being a tailor (3/63), and for the last 10/63, worker mentioned a diversity of ideal jobs or being satisfied with their current job.

Regarding the freedom to express concerns and participate in decisions affecting their lives, the findings are rather positive; 55% feel empowered in the workplace and that their needs/ideas are considered (15F, 20M), while 21% feel comfortable at work, but cannot necessarily participate in decision-making (4F, 9M). When asked about personal agency, 90% reported having input in some or most decisions in their lives.

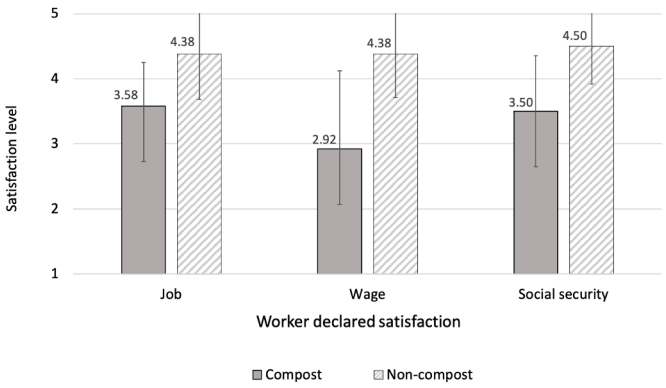

Fig. 1. Compost versus non-compost workers' job, wage, and social security satisfaction.
Variables were measured on a 5-point Likert scale: 1=very dissatisfied to 5=very satisfied, N=63.

Regarding the equality of treatment and opportunity for all, we analyzed two elements at each innovation site: horizontal and the vertical segregation. Horizontal segregation is the concentration of women and men in different sectors and occupations, whereas vertical segregation is the concentration of women and men in different grades, levels of responsibility, or positions [55]. Across the six companies, female and male workers reported responsibility for many different roles. Female workers mentioned being responsible either for sorting, cleaning, or feeding BSF larvae. Male workers mentioned a higher diversity of roles compared to women, namely: sorting, using machinery, making bricks from plastic waste, technician, security guard, mushroom inoculation and sterilization, all processes for BSF, all processes for mushroom farming, and drying and chopping cassava. Surprisingly, we found no gender wage gap, even amid horizontal segregation in terms of occupation. For example, men producing compost heaps earned the same as women sorting inorganic from organic waste at compost sites.

Regarding vertical segregation, both females and males worked as innovation site supervisors and company leaders. During the workshop with company leaders, they explained how they choose site supervisors based on higher education (e.g., completed secondary school), and at Company A, the supervisor was elected by his/her fellow workers [54]. However, when considering overall wages across all positions, we observed that those with higher monthly salaries (70,000 RWF, or 66 USD) are dominated by men (e.g., guards, technicians, managers). Positions with the lowest pay and those paid daily per task are typically female jobs, such as peeling cassava (10 RWF per kilogram, approximately 1500 RWF per day, or 1.41 USD).

Considering the above, the answer to RQ1 is that working conditions can be considered relatively decent, compared to what individuals from similar socioeconomic backgrounds in rural Rwanda can expect. Table 3 in Appendix B summarizes the elements described above.

3.2. Worker satisfaction and its determinants

One part of the questionnaire focused on workers' satisfaction with their job, wages, social security, and relationships with superiors, using a 5-point Likert scale. Overall, most variables scored higher than 3.00/5.00 (job satisfaction mean=3.79, SD=0.92; wage satisfaction mean=3.44, SD=1.10; social security satisfaction mean=3.52, SD=1.11). We inferred that the workers are rather satisfied with their jobs in the bioeconomy.

To understand which of the independent variables might determine satisfaction (job, wage, social security), we carried out three ANCOVAs for each dependent variable. The "innovation type" was the only statistically significant factor for determining job (p-value=0.025) and wage satisfaction (p-value=0.006). This is likely a consequence of the

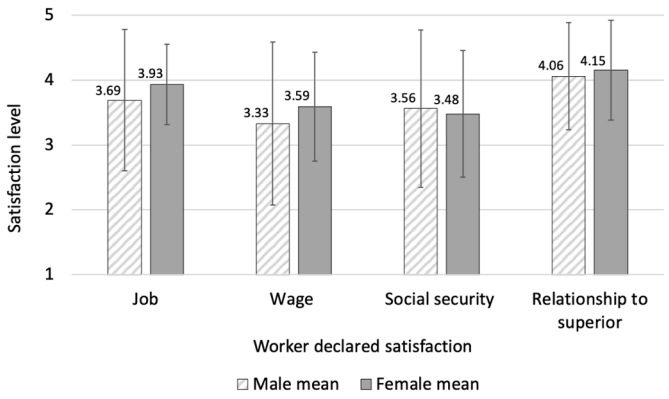

Fig. 2. A gendered lens on worker satisfaction.
Variables were measured on a 5-point Likert scale: 1=very dissatisfied to 5=very satisfied, N=63.

nature of the raw materials being handled in the different company types. In compost companies, workers manipulate many types of inorganic waste (glass, metal, plastic, carton), which exposes them to sharp, potentially harmful objects. Fig. 1 highlights the lower satisfaction of compost-production workers. It is important to note that the relationship between social security satisfaction and "innovation type" was not statistically significant (p-value=0.191).

Even though the literature review seemed to show that gender might be an important predictor of worker satisfaction, it was not statistically significant in our study. Fig. 2 presents the values for job, wage, social security, and relationship with superiors' satisfaction through a gendered lens. The lowest satisfaction value comes from males' wage satisfaction (3.33, SD=1.26), whereas the lowest female satisfaction concerns social security (3.48, SD=0.98). Interestingly, women and men are similarly satisfied with their relationship with their work superior, which scored the highest for both men (4.06, SD=0.83) and women (4.15, SD=0.77).

4. Discussion

4.1. Recycling waste and decent work

This study aimed to understand the working conditions of informal biowaste workers in Rwanda. The 63 workers we surveyed received a monthly wage of 31,000 RWF, equivalent to 29.16 USD (calculated October 11, 2022), giving 67% of them the ability to make some savings. This wage is higher than that of most agriculture workers and 12 times higher than the minimum Rwandan wage of 100 RWF/day, or 2400 RWF/month [56]. CWG & GIZ (2011) [6] similarly found that informal waste workers' wages were 110%–240% above the legal minimum wage in the six cities they studied (Cairo, Egypt; Cluj, Romania; Lima, Peru; Lusaka, Zambia; Pune, India; Quezon, the Philippines). These higher waste sector wages seem to compensate for the difficult working conditions and make the job somewhat attractive. These jobs are also essential the urban poor's survival [57]. In the rural Rwandan context, Bigler et al. (2017) [58] showed how difficult it is, especially for women, to access paid employment. In our case, 71% of workers lacked cash-generating employment before joining their waste recycling firms. This emphasizes the importance of the waste sector for creating new wage employment that can secure the livelihoods of the urban and rural poor.

Our results on insufficient worker safety and social security are aligned with the literature. CWG & GIZ (2011) [6], who conducted a case study on waste management in six LMICs' cities, concluded that health and safety conditions need improvement. Similarly, Noel (2010) [57], working in Haiti, highlighted that workers reported multiple symptoms and illnesses, with some gender specificities; special care should be given to female workers, as the gendered division of labor leads to different exposures to specific health risks [14]. Women are often the ones most closely manipulating the waste in their roles as pickers and sorters [8]. We also observed some women bringing their children to the worksite, thus exposing their children to similar health risks. This reinforces the importance of improving waste workers' working environments [14].

Regarding equal treatment and opportunity, we found interesting details that contrast with the literature. First, regarding the gender wage gap, our study's full-time workers earned equivalent wages. This contrasts with Bigler et al. (2017) [58], who found women earn 19% less than men in Rwanda, even when performing the same tasks (women=730 RWF/day; men=900 RWF/day). Second, when it comes to women in higher-level positions, in our sample, two out of six company founders were female (Companies C and D). This contrasts with the literature, which emphasizes men's tendency to dominate upper managerial positions [8,18,57]. We think this might be a consequence of Rwanda's push for gender equality since its new constitution of 2003 [59]. Also, since the Rwandan genocide of 1994, women have historically played an important role in the economy, leading to 86% female labor participation, which is higher than elsewhere in Africa (Danish Trade Union Development Agency, 2021, p. 28) [38]. In that sense, the results of our study are likely to mirror Rwanda's outstanding situation, in terms of gender equality, and are likely not generalizable to other African countries. Finally, our results on gender-differentiated roles are aligned with the literature on waste management in LMICs [8,14,57]. These reports show that women are employed to collect and sort waste, while men are assigned more physically demanding tasks. However, in Rwanda, it seems the gender differentiation of work is based on a complementary approach, rather than a hierarchical one [54].

4.2. Innovation type as a predictor of work satisfaction

Our ANCOVA highlighted that the workers employed in compost production were significantly less satisfied than others. The effect of the innovation type (compost/non-compost) was so strongly linked to satisfaction that all other independent variables were deemed non-significant (gender, age, marital status, parent status). We found no other studies focused on biowaste workers' satisfaction in a similar context that allowed for comparisons; therefore, we assume this lower satisfaction might be linked to the type of raw material processed. Indeed, as there is no household-level waste separation in Rwanda [60], compost producers need to manipulate sometimes dangerous inorganic waste (e.g., broken glass, metal, sharp objects, medical waste) to obtain exclusive biowaste. As for biowaste-processing companies, their workers are not required to manipulate inorganic waste, as they valorize crop residues to breed black soldier flies and produce oyster mushrooms. In addition, as Noel (2010) [57] showed, there is a "garbage man" stigma that could influence the lower satisfaction of compost producers who must manipulate "people's trash," leading to attracting only the most desperate workers. Other assumptions might include the fact that biowaste processing may be perceived as more technical and, therefore, requiring more skills and machinery expertise, or simply that selling an end-product (animal feed, oyster mushrooms) is more gratifying than selling compost and recyclables.

4.3. Waste separation at household level is essential, but might exclude female paid labor

The literature shows that the priority of improving nutrient recovery and working conditions for waste workers (air quality/smell) is on implementing household-level waste separation prior to waste collection [14,31]. Further, managing household garbage is mostly handled by women as part of their unpaid social reproductive work [8,18,19,61], and that across cultures [19]. Meanwhile, what differs between HICs and LMICs is the nature of the waste management system, from a highly

mechanized and male dominated one to a more low-tech manual one [5]. The latter creating many female and male labor opportunities. Therefore, pushing forward waste segregation at the household level in a LMIC context might lead to tensions between achieving gender equality (SDG 5) and decent work (SDG 8) [51]. Indeed, while worker safety might improve if they receive sorted waste, female workers who are hired to sort waste might lose their paid jobs, inducing a shift from a paid to unpaid work as women are the ones managing household waste [10,19,62]. Many scholars have described how the transition from informal to formal waste management tends to exclude female workers [12,63,64] and how reproductive work mostly performed by women is not recognized in gross domestic product [61]. For this reason, Otoo and Drechsel (2018) [65] argue that there are multiple social equity-related risks in solid waste management, as women have gender-specific needs as workers in the waste valorization process and challenges, as they do not equally access the paid employment opportunities created.

4.4. Limitations

First, as there is no recognized measurement tool for assessing "decent work," we built our own questionnaire containing 37 multiple-choice questions, four worker satisfaction questions using a five-point Likert scale, and one personal agency question. This mixed questionnaire made it difficult to answer RQ1 in an aggregated way. Indeed, due to the plurality of scales, we were obliged to answer the five dimensions of the decent job agenda separately. Second, we did not ask specifically about illnesses, having assumed that the manipulation of non-hazardous and mostly organic waste should not represent major health risks; however, we did not take into account the mixed nature of the waste workers handle at compost-production sites. Hence, there might be some related health impacts that we were unable to capture. Finally, the goal of this study was explorative, as we found no previous literature on Rwandan biowaste workers. Due to the limited sample size, further research is needed to validate our results. We also recommend further research to use qualitative methods to bring nuance and potentially uncover additional dimensions of work satisfaction that were not made visible by our restrictive survey.

5. Conclusions

By focusing on six waste-recycling companies in Rwanda and surveying 63 workers, this study shows that the jobs created by these companies can be considered relatively decent work according to the ILO's definition, except for worker safety and social security, which need improvement. Meanwhile, the workers report being rather satisfied with their working conditions. Our statistical analyses show that those employed at compost-production sites are significantly less satisfied with their jobs than those employed at biowaste-processing sites. Surprisingly, we found no gender wage gap for full-time workers, even though they are employed in different activities. These findings differ from the previous literature on gender dynamics and waste practices and seem to be specific to Rwanda, a leading country in terms of gender equality. Theoretically, this study contributes to the literature on CE examples in LMICs that create inclusive and decent jobs, with the strength of merging a description of working conditions with workers' perspectives on the same.

The implications of our findings highlight the importance of household-level waste separation for improving worker safety, the working environment (air quality, smell), and nutrient recovery. However, by pushing forward household waste separation, sorting will likely become an unpaid task assigned to women (who often handle household garbage management), instead of being a paid female job. Therefore, practitioners should be aware, whilst developing or formalizing municipal waste management, that their interventions might affect women and men differently, as the sector is characterized by gender-segregated roles.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendices

Appendix A. Survey questionnaire

Part A Worker profile		
1	Year of birth of the respondent	
2	Gender of the respondent	Male Female
3	Marital status	Legally married Not legally married Single mother Polygamous relationship Unmarried Widowed Engaged Other
4	Education attainment	No primary schooling Some primary schooling (p1 to p5) Completed primary schooling (p6) Some secondary schooling Some vocational schooling University No response
5	Number of children	
6	Religion	Christian Muslim Traditional religion

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(*continued*)

Part A Worker profile		
		Agnostic Atheist No religion Other
7	Household situation (conditional question if respondent is <18 years old)	Living with mother Living with father Living with both parents Living on his/her own
8	Household structure	I am the household head. I am not the household head.
9	Number of women living in the household (including the interviewee) during the last 6 months	
10	Number of men living in the household (including the interviewee) during the last 6 months	
11	Unpaid care activities: Which additional care responsibilities do you carry-out at home?	None Taking care of the children Breast-feeding Taking care of the livestock Subsistence agriculture Cooking for the family Cleaning the house Taking care of the household garbage Taking care of the elders Taking care of the sick Fetching the water Fetching the wood Other
12	How much time (in minutes) do you spend on are activities (described above) every day?	
13	How were you made aware that this job exists?	A personal contact told me about the job. I was waiting in the village with other unemployed people, and I was called in to work. I heard there was a new business starting here and I spontaneously decided to come and ask for a job. Other.
14	Please indicate the number of cows that you own:	
15	Please indicate the number of goats/chicken/pig that you own:	
16	Please indicate the number of square meters of land that your household owns:	
17	Please select the type of phone that you own:	No phone Cell phone (normal) Smartphone
Part B: Work satisfaction		
18	What is your main employment?	Here (worker in the biowaste innovation) Casual agricultural work on others' farms Subsistence farmer Trainer/advisor Charcoal burner/seller Brewing/selling beer Handicraft Selling phone credit Driver Trader Other
19	Do you have a secondary employment?	No, I do not have a secondary employment. Here (worker in the biowaste innovation) Casual agricultural work on others' farms Subsistence farmer Trainer/advisor Charcoal burner/seller Brewing/selling beer Handicraft Selling phone credit Driver Trader Other
20	Is this job permanent or are you working on a seasonal or irregular/casual basis?	Permanent (full-time) Permanent (part-time) Seasonal Casual work/irregular (when needed)
21	What type of contract do you have with your employer?	Written contract Oral contract (regular) Oral contract (irregular) No contract, but regular. No contract, on call only
22	How do you come to work (most of the time)?	Walking Biking

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Part B: Work satisfaction		
		Bus
		Moto
23	How much time (in minutes) do you need to come to work (transport time)?	
24	What is your role in the innovation where you work? (what do you do)	(open answer)
25	On what frequency do you get paid?	Per hour
		Per day
		Per week
		Per month
		Other
26	How much do you get paid (RWF)?	
27	What frequency do you prefer for getting paid?	Payment per hour of work
		Payment per day of work
		Payment per week
		Monthly payment
		Other
28	Have you ever considered migrating to a larger city to increase chances of getting a job?	Yes, I am considering to migrate to a larger city to get a job.
		I am somewhat hesitant.
		No, I do not want to migrate to the city.
29	If you could, would you prefer to live in a larger city like Kigali?	Yes, I would largely prefer.
		Rather yes, I think living in Kigali would open many perspectives for me.
		Rather not, I think living here has some advantages.
		Not at all.
30	Are you able to save money at the end of the month?	No, not at all.
		Yes, but it is minor.
		Yes, sufficiently
31	If you did save some money, what did you spend it for?	I did not save some money
		I was able to buy a cell phone
		I was able to buy better clothes and shoes
		I was able to buy a bicycle
		I was able to improve the quantity of my diet
		I was able to eat more diverse (quality of food)
		I was able to buy a goat/chicken/pig
		I was able to buy a cow
		I was able to save money to get married
		I was able to improve my house (build a roof, renovation…)
		I was able to pay the "mutuelle de santé"
		Other
32	Do you decide alone on how to spend your salary?	Yes, I decide alone.
		Not really, I share the decision-making with my partner.
		No, my husband is in charge when it comes to deciding how to spend the earnings.
		No, my wife is in charge when it comes to deciding how to spend the earnings.
		No, my parent(s) are deciding how my earnings can be spent.
		Other
33	Who usually makes decisions about major household purchases? (for example livestock, bicycle)	Man
		Woman
		Both
		Someone else
34	Who usually makes decisions about purchases for daily household needs? (for example daily purchases, small assets, clothes, food)	Man
		Woman
		Both
		Someone else
35	Do you feel that your opinion is taken into consideration by your superior on the work-site?	Yes, I feel empowered on the worksite, and my needs/ideas are taken into account.
		Somewhat yes. I feel comfortable at work, but this does not necessarily mean I can participate in the decision-making.
		No, I do not feel like my needs or ideas are taken into account on the workplace.
		I don't know.
36	Are you overall satisfied with your job?	1 = Very dissatisfied
		2 = Somewhat dissatisfied
		3 = Neither dissatisfied nor satisfied
		4 = Satisfied
		5 = Very satisfied
37	Are you satisfied the wage you earn for this job?	1 = Very dissatisfied
		2 = Somewhat dissatisfied
		3 = Neither dissatisfied nor satisfied
		4 = Satisfied
		5 = Very satisfied
38	Are you satisfied with your social security conditions? Think about what happens if you are sick or if as a woman, you are pregnant…	1 = Very dissatisfied
		2 = Somewhat dissatisfied
		3 = Neither dissatisfied nor satisfied
		4 = Satisfied
		5 = Very satisfied

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Part B: Work satisfaction		
39	Please select which of these other benefits are covered by your employer:	Daily meals on-site Over-night stay during the week "Mutuelle de santé" for yourself (health insurance) "Mutuelle de santé" for yourself and other family members (health insurance) Protection gloves/masks/boots/clothes Social security ("pansiyo" or pension fund) Taking a break for breastfeeding during worktime Maternity leave is covered Other
40	Are you satisfied with your relationship with your superior? For example, do you feel free enough to take a toilet break or a lunch break during the workday?	1 = Very dissatisfied 2 = Somewhat dissatisfied 3 = Neither dissatisfied nor satisfied 4 = Satisfied 5 = Very satisfied
41	Do you feel that you have the power to make important decisions that change the course of your life? Rate yourself on a scale from 1 to 5.	1 = No input on decisions in my life 2 = Input into very few decisions in my life 3 = Input into some decisions in my life 4 = Input into most decisions in my life 5 = Input into all decisions in my life
42	Would you recommend this job to your friends or a member from your family?	Not at all. Only if my friend would be desperate for a job Maybe I would recommend this job. I would definitely recommend this job.
43	Do you think that small enterprises like this one have the potential to create employment opportunities in rural Rwanda?	Yes, I fully agree. Yes, I somewhat agree. No, I somewhat disagree. No, I totally disagree.
44	Let's imagine that you could choose your ideal employment: what would it be?	(open answer)

Appendix B

Table 3

Table 3
Characterization the biowaste work along five dimensions from the International Labour Organization framework on Decent Work [40]

Decent work dimension	Indicator	Survey result
1. Fair income	Wage[1]	Median = 31'000 RWF/month (SD = 11'907)
2. Safety at the workplace and social protection for families	Protection material	79% receive protection gloves/masks/boots/clothes from their employers (50/60)
	Social protection	Workers from Company B receive the worker health insurance for themselves and for family members (19% or 12/63). 17% of the workers have their pension fund covered (11/63).
	Other	Workers from companies D and F receive daily meals on site (16/63).
3. Better prospects for personal development and social integration	Saving capacity	33% did not save money (21/63) (11 F, 10 M) 51% did minor savings (32/63) (14F, 18M) 16% did sufficient savings. (10/63) (2F, 8M)
	Investment choices	• 37% bought a goat/chicken pig (23/63) (8F, 15M) • 19% bought better clothes or shoes (12/63) (4F, 8M) • 16% increased the quantity of their diet (10/63) (4F, 6M) • 13% paid their health insurance (8/63) (2F, 6M) Followed by 7 workers who "improved the quality of their food", 7 workers who "bought a cow", 6 workers who "paid the school fees for their children", 5 workers who "saved money to get married", 4 workers who "improved their house", 2 workers who "bought a cell phone", and 2 workers who "bought a bicycle".
	Worker situation prior to employment	• 71% of the workers did not have a cash-generating employment before working here. (45/63) • 29% of workers had a cash generating employment before working here. (18/63) (5F and 13M)
	Recommendation of the job to family/friend	• 16% "Not at all" (10/63) • 1% "Maybe" (1/63) • 30% "Only if family member or friend would be desperate for a job." (19/63) • 32% "I would recommend this job." (20/63) • 21% "I would definitely recommend this job." (13/63)
	Economic decision-making	• 56% "Yes I decide alone on how I spend my income". (35/63) (18 F, 17 M) • 32% "Not really, I share the decision-making". (20/63) (6F, 14M) • 13% "No my parents are deciding". (8/63) (3F, 8M)
4. Freedom for people to express their concerns, organize and participate in the decisions that affect their lives	Empowerment on the worksite	• 55% "Yes I feel empowered on the worksite and my needs/ideas are taken into account." (35/63)

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Table 3 (*continued*)

Decent work dimension	Indicator	Survey result
	Personal agency[2]	• 21% "Somewhat yes. I feel comfortable at work, but this does not necessarily mean I can participate in the decision-making." (13/63) • 16% "No, I don't feel empowered on the worksite, and my needs/ideas are not taken into account." (10/63) • 8% "I don't know." (5/63) Total mean = 3.32/4 (SD = 0.86) Female mean= 3.33/4 (SD = 0.88) Male mean = 3.31/4 (SD = 0.86) • 5/63 (8%) "1 = No input on decisions in my life." (F=2, M=3) • 1/63 (1%) "2 = Input into very few decisions in my life." (F=1, M=0) • 26/63 (41%) "3 = Input into some decisions in my life." (F=10, M=16) • 31/63 (49%) "4 = Input into most decisions in my life." (F=14, M=17)
5. Equality of opportunity and treatment for all women and men	Gender wage gap Worker status	Within a job position (same level of hierarchy for a full-time job): no gender wage gap. The jobs requiring a higher level of training and that are paid better (security guard, technician) are mostly occupied by men. The lowest paid and casual work (such as cassava peeling) are mostly occupied by women. In our sample, four of our innovation leaders are men and two are women.

[1] To calculate the median wage we excluded the three interviewed cassava peelers who are paid on a casual basis and per kg of cassava peeled. We only took into account the salaries of the workers on a full-time basis.

[2] To measure the sense of personal agency, we used the scale recommended by Petesch & Bullock (2018) [46].

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