Evaluation of Co-composting Methods Using Effective Microorganisms

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Abstract. Organic matter is indispensable for increasing crop yield, fertility and water holding capacity of the soil. Using organic fertilizer or compost promotes circular economy and resource recovery. Conversely, the method of composting is very important to enhance the quality of compost and simplify further complication on the final users. In this study the co-composting methods were evaluated by adding effective microorganisms with municipal solid waste i.e., food waste (31.2%), wet and dry grass (44.21%), soil (22.45%), sugarcane straw (0.09%) and urine separated excreta (44.21%). The composting methods was comparatively evaluated in terms of composting period, pH, temperature, moisture content and chemical parameters composted for 60 days. The experiment was performed for pit and heap composting methods with and without effective microorganisms. Both composting methods were turned periodically once in a week and to increase the reliability of the experiment, each treatments method was replicated two times for similar effective microorganism and composting matter. The analysis showed that using effective microorganism has significant change among the composting methods in moisture content, organic matter, temperature, total nitrogen, and exchangeable cations (Ca and Mg). In this regard, pit and heap aided with effective microorganism co-composting process matured on 39th and 45th day respectively.

Keywords: Co-composting · Pit · Heap · Effective microorganisms · Excreta · Municipal solid waste

1 Introduction

Compact eco-city is one of the national urban agenda currently adapted to promote urban agriculture through organized small business groups. Ethiopia is a member of this agenda of sustaining the agriculture and working toward waste recovery (NUA 2035). Rapid urbanization and population growth generates a huge organic waste. The shift to ecological sanitation opens an opportunity to recover the valuable nutrients and reduce the impacts on the global environment (Bong et al. 2019). Due to environmental

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compatibility and waste stabilization compositing have significant impact on quantity and quality of agricultural yield (Onwosi et al. 2017). The organized groups in Ethiopia particularly in Bahir Dar the case study doesn't have the proper skill to choose the effective and healthier composting methods, rather using the conventional composting methods. Moreover, the material used for co-composting were selected based on the preliminary research surveyed from the organized groups and own study.

Co-composting is a method used to enhance and counterbalance the degradation and nutrient recovery and produce safe and valuable quality compost (Camargo 2017; Olufunke et al. 2009). In addition to co-composting the use of microbial inoculums facilitate the maturation period, increase compost quality and reduces the impact on the environment due to its strong assimilative capacity (Laskowska et al. 2018). In Laskowska et al. 2018 and Shao et al. 2008 depicted the use of effective microorganisms controls and prevents secondary soil salinity. Effective microorganism (EM) is a mixture of groups of organisms that has a reviving action on humans, animals and the natural environment (Higa 1995; Balogun et al. 2016) and has also been described as a multiculture of coexisting anaerobic and aerobic beneficial microorganisms.

Co-composting of excreta and organic solid along with activated effective microorganism contributed towards producing good quality and large quantity of compost (Olufunke et al. 2009; Yousefi et al. 2012). More importantly the selection of appropriate composting methods is crucial for drawing the final decision. Thus, in this study an integrated evaluation of co-composting scenarios in line with composting methods is valuable for efficiently and effectively recover the waste in to wealth.

2 Materials and Methods

2.1 Raw Material

Organic solid waste consisted of food waste, municipal grass (wet and dry), and sugarcane straw collected from the city while urine separated excreta was collected from 14 ecosan-urine diverted dry toilets (UDDT) located in the City. Form the preliminary research conducted, the type of co-composting materials and compositions have been calculated and used for this study. In this regard, 81.2 kg (31.2%) food waste, 115.2 kg (44.21%) excreta, 2.4 kg (0.09%) dry grass, 58.5 kg (22.45%) soil, 0.9 kg (0.034%) sugarcane, and 2.4 kg (0.09%) wet grass were properly mixed to prepare mixed organic co-composting waste for four (two pits and heaps) experimental scenarios and two controls. The dimension of the composting pit and heaps were 1 m * 1 m * 1 m. The construction procedure adopted from Nzdl.org. 1992.

A widely used commercially available microbial inoculum (EM1) which contains lactic acid bacteria, yeast and phototrophic bacteria (Jusoh et al. 2013), was purchased from Woljjeji Industrial Plc. 2 kg of EM1 was activated with 20 L of water and 2 kg molasses and sprayed over the mixed waste after fermented for 8 to 10 days as per the experimental design.

2.2 Experimental Procedures

The co-composting of mixed waste was performed using three (one control) 1 m * 1 m * 1 m (1m3) unlined pits and three heaps (one control) composting methods.

The stick was provided in the middle of all composting scenarios for proper mixing and control. Moreover, simplify compost samplings which are collected from top, middle and bottom considering vertical - horizontal distribution and uniformly mixed before the sample has been measured.

For this set of experiments, two pits and two heaps experiments with two controls. Initially, sugarcane straw, wet and dry grass was chipped in to uniform sizes, food waste was added and all the waste thoroughly mixed layer by layer and the mixed waste was turned once in week. Moreover, effective microorganism was added in all the experimental scenarios as per the experimental design. Suitable site were selected for piloting the co-composting process and similar waste material were used for both methods shown in Fig. 1.

Fig. 1. (a) Brown dry grass, (b) Soil, (c) Green wet grass, (d) Effective microorganisms, (e) Urine separated feaces, (f) Mobil ecosan toilets, (g) Food waste

A 260.6 kg of mixed co-composting waste was subjected to compost in pit and heaps for 60 days. Before the compost become matured a total of well mixed and homogenous waste samples (228.57 gm) were withdrawn once in three days and at maturation for measuring various main physical and chemical parameters. While composting the waste in pits and heaps temperature, moisture content and pH were measured regularly at three days interval for the first 39 days. Moreover, for the remaining 45, 50, 55 and 60 days were also recorded. The samples were analyzed for checking the maturity and its quality.

2.3 Data Analysis

The experimental data were measured during composting process at site and laboratory. Temperature, moisture content and pH was measured during the composting period for 60 days at site. Using the standard procedure shown in Table 1, laboratory test was conducted for the selected physico-chemical parameters to determine; total nitrogen, Ca, K, Mg, Na, C:N and organic carbon in the laboratory. Analysis of variance (ANOVA) was used to identify whether there was significant difference between co-composting methods and with respect to measured parameters.

Table 1. Experimental methods and standards for the measured parameters (Ozores-Hampton 2017; Seal et al. 2012)

No.	Parameters	Experimental method	Standards
1.	Total nitrogen	Kjeldahl method	0.4–3.5%
2.	Phosphorous	Standard test	0.3–3.5%
3.	Temperature	Teramo meter	
4.	Moisture content	Standard test	35–40%
5.	pH	pH meter	7–8
6.	Exchangeable base (Ca, Mg)	Atomic absorption spectrophotometer	0.1–2 cmol (+)/kg, 1.2–8 cmol (+)/kg respectively
7.	Exchangeable K and Na	Flame -photometer	
8.	Organic carbon	Standard test	>19.4%
9.	C/N	Mathematical model	10:1 to 15:1

3 Results and Discussion

3.1 Temperature, Moisture Content and PH Profile of Co-composting Process

In this study the pH value while measured during co-composting process varied in the range of 5.4 to 7.75 for both methods. The optimum pH range is 7–8 and the microbial activity highly depends on the pH and the organic matter present in the waste (Seal et al. 2012). For pit and heap experiments pH starts increasing on 9th (6.75 & 5.75) to 21st (7.4 & 6.4) day respectively. From 22nd the pH value starts to decline until 27th day. Decrease in pH depicted that the formation of carbon dioxide gas and organic acid during the co-composting process (Kharrazi et al. 2014; Meng et al. 2017). The pH value slightly increase on 30th (7.5) to 39th (7.75) day for pit and extends till 45th (7) day for heap experiment. Even though, for pit and heap control no significant difference in pH values with in the interval, starts increasing on 27th (6.4 & 5.4) to 45th (7.15 & 6.8) day respectively shown in Fig. 2. The increase in pH for all scenarios indicated that the decomposition of organic matter was occurred and the formation of ammonia (Meng et al. 2017). These imply the compost becomes matured. The pit experiment in terms of pH attained maturity on day 39, while heap experiment, control and pit control reached maturity at the 45th and 50th days respectively. Hence, from the result of pH value obtained pit composting with effective microorganism method has attained the optimum pH value compared to all other scenarios.

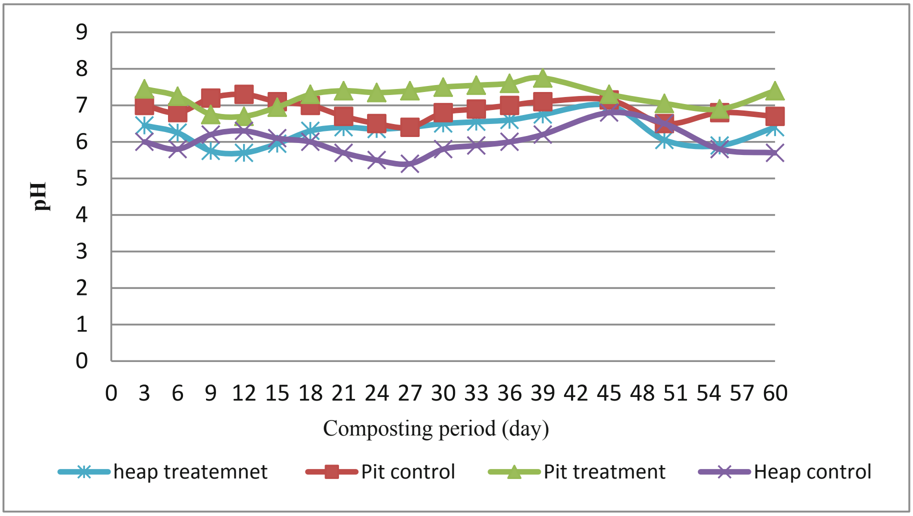

Fig. 2. pH profile in the co- composting process

The average temperature of the composting methods (pit and heap) was within the intervals (three days) showed no significant ($p > 0.05$) difference, but compared with control and experimental sample of both pits and heaps observed significant ($p < 0.05$) difference shown in Fig. 3.

The maximum temperature measured for pit and heap experiments were obtained on the 15th (40.25 °C) and 18th (37.5 °C) days respectively, have a significant difference ($p < 0.05$). While pit and heap control samples were reached a maximum temperature on the 27th day (40.6 °C & 38 °C respectively). From Fig. 3 showed that after 27th day the temperature for heap treatment is greater than pit treatment because in pit the compost reached maturation very fast while heap matures very late. The highest temperature represents thermophilic phase of the composts and influenced by the microbial activity which depend on the physico-chemical characteristics of the co-composted material (Van Fan et al. 2018). Conversely, the change in temperature also affected by the frequency of mixing (Hosseini et al. 2013).

The increase in temperature showed that highest microbial activity for the experiment treated with effective microorganism compared to the co-composting process without effective microorganism (control). The temperature for pit experiment from a maximum of 40.25 °C on day 15 declined to 32 °C on day 39. While heap experiment showed 37.5 °C on day 18 dropped to 32 °C on day 50. On the hand for pit and heap control the temperature from 40.6 °C and 38 °C on day 27 decreased to 33 °C on day 50 and 55 respectively. The decrease in temperature showed that the microbial activity become slow down and the organic matter present in the compost exhausted and the composting process reached cooling stage (Zakarya et al. 2019).

The maximum average moisture content for pit and heap experiments was recorded at 3rd day (52.5% & 47.5%) respectively. For pit experiment the moisture content declines to 45.6% on day 15 and slightly rises to 49% on day 21 and decline to 45.25% on day

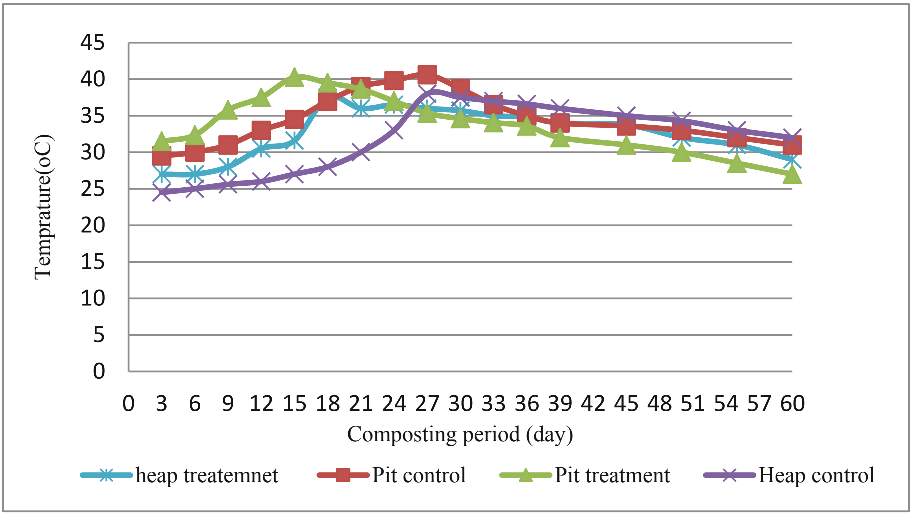

Fig. 3. Temperature profile in the co-composting process

30, rises to 47% on day 36 and finally decline for the reaming composting periods. Hence, the maximum and final moisture content decline was 43.9% recorded on day 39. While heap experiment also experienced the moisture content fluctuation over the co-composting period. The final maximum decline was obtained 38.9% on day 39. For pit and heap control samples there was a fluctuation in moisture content and the final maximum decline reading on day 39 was 42% & 37% shown in Fig. 4.

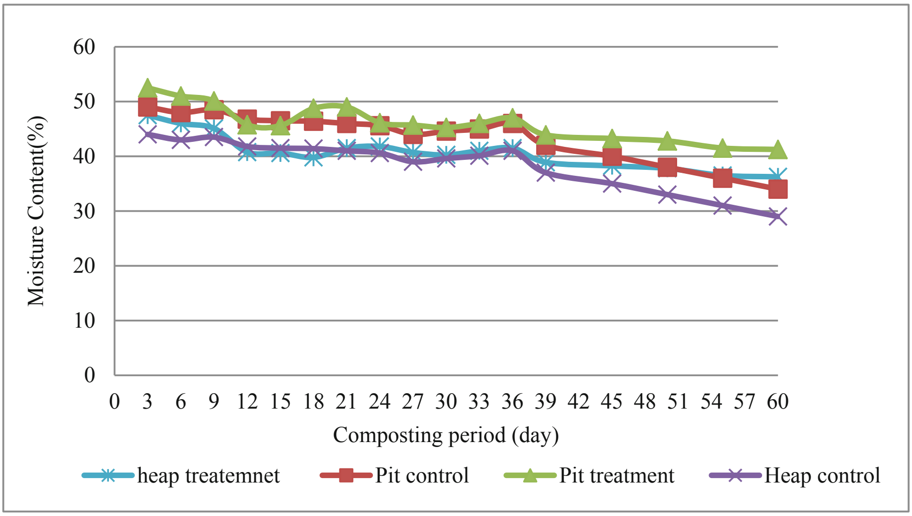

Fig. 4. Moisture content profile in the co-composting process

The moisture content fluctuation happened due to temperature variation over the composting period (Zakarya et al. 2019). In this regard, the moisture losses when the temperature rises in the composting process. Conversely, the co-composting materials used play an important role by increasing the moisture content. From this study the experiment performed with the addition of effective microorganisms attained relatively higher moisture content than controls.

3.2 Physico-Chemical Properties of the Compost

The organic carbon content and C:N of pit experiment (14:1) compared to other scenarios has a significant ($p < 0.05$) difference. For pit experiment the organic carbon is 33.5% on day 39, however heap control showed the smallest organic carbon content 18.5%. As shown in Fig. 5 pit and heap experiments treated with effective microorganism ranked first and second respectively compared to other scenarios. Compared to the standard value pit and heap control have the smallest C:N (8.7:1 & 8.4:1 respectively) than others. The C:N showed that the uptake of carbon content for the decomposition of organic matter by the microorganisms.

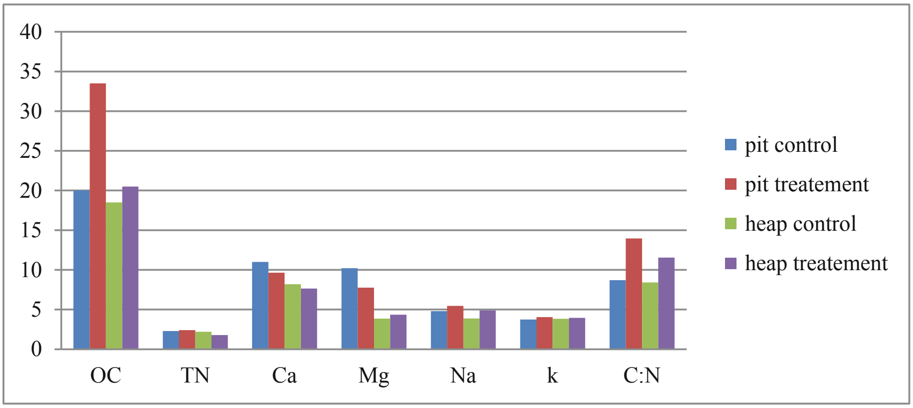

Fig. 5. The physico-chemical properties of the compost measured at 39 day

The increase in carbon indicated that in the co-composting process there was reduced the release of carbon (Ameen et al. 2016; Varma and Kalamdhad 2014a, b). Hence, the presence of microbial activity in the composting process would lead to the increase of organic carbon and reduce the emission of ammonia and volatilization of ammonia. Since pit experiment attained the highest organic carbon contributed to better quality and maturity of the final compost.

In pit and heap experiment at day 39 recorded the total nitrogen 2.4% and 1.75% respectively, in which pit experiment was significantly ($p < 0.05$) higher than heap experiment and control shown in Fig. 5 and Table 2. The calcium (Ca) and magnesium (Mg) content of pit experiment (9.64 & 7.75 cmolc/kg) and control (11 & 10.2 cmolc/kg) has significant ($p < 0.05$) difference compared to heap experiment (7.65 & 4.35 cmolc/kg) and control (8.2 & 3.86 cmolc/kg) respectively.

Table 2. The mean result for physico-chemical properties at 39 day and maturity date

Composting methods	pH	OC	TN	Ca	Mg	Na	K	C:N	Moisture content (%)	Temperature (°C)	Maturity date
Pit treatment	7.75	33.5	2.4	9.64	7.75	5.45	4.05	14.0	43.9	32.0	39.0
Heap treatment	6.75	20.5	1.77	7.65	4.35	4.9	3.95	11.5	38.9	34.0	45.0
Pit control	7.1	20	2.3	11	10.2	4.8	3.75	8.7	42.0	34.0	50.0
Heap control	6.2	18.5	2.2	8.2	3.86	3.87	3.83	8.4	37.0	36.0	50.0

The decline in Ca indicated that the reduction of ash content in the final compost. But potassium (K) has no significant ($p > 0.05$) difference compared to all scenarios. Highly stabilized and decomposed compost has high potassium content (Varma and Kalamdhad 2014a, b). In this regard, pit experiment (4.05 cmolc/kg) has better composting capability compared to others.

3.3 Co-composting Maturity

The maturity of compost measured primarily using ammonia to nitrogen and carbon to nitrogen (C:N) ratio (Guo et al. 2012). The carbon to nitrogen ratio for pit treatment has significant ($p < 0.05$) difference compared to heap experiment and controls. This is the critical indicator to measure the maturity of the compost. But the controls have carbon to nitrogen ratio out of the standard value and this implies the compost need more decomposition period for better maturation. The compost maturity varies from 39 to 60 days depending on the co-composting methods and experiments. Pit and heap control doesn't show any significant difference between each other. However, pit experiment aided with effective microorganism attained maturation on 39 days has significant difference compared to heap experiment (45 days) shown in Table 2.

4 Conclusion

Co-composting using excreta from mobile ecosan toilets and municipal solid waste (food waste, grass and sugarcane straw) with the help of microbial inoculum (EM1) achieved the maturity of compost in 39 days for pit, while 45 days for heap experiments and 50 days for controls.

In this research, the co-composting of excreta and municipal solid waste (food waste, sugarcane straw, municipal grass) using effective microorganism was evaluated for pits and heaps composting methods. The compost quality, maturation period and physico-chemical properties of the final compost were evaluated and from this result pit method performs better than heap. Hence the usage of effective microorganism and co-composting of organic waste in pit is the most appropriate composting method than heap and conventional methods.

References

Ameen, A., Ahmad, J., Munir, N., et al.: Physical and chemical analysis of compost to check its maturity and stability. Eur. J. Pharm. Med. Res. **3**, 84–87 (2016)

Balogun, R.B., Ogbu, J.U., Umeokechukwu, E.C., Kalejaiye-Matti, R.B.: Effective microorganisms (EM) as sustainable components in organic farming: principles, applications and validity. In: Nandwani, D. (ed.) Organic Farming for Sustainable Agriculture. SDB, vol. 9, pp. 259–291. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-26803-3_12

Bong, C.P.: Towards low carbon society in Iskandar Malaysia: Implementation and feasibility of community organic waste composting. https://www.ncbi.nlm.nih.gov/pubmed/27267145. Accessed 8 Feb 2019

Camargo Millán, G.: Co-composting of solid waste organic urban with sludge. J. Int. Area Stud. **21**(2), 23–36 (2017)

Guo, R., et al.: Effect of aeration rate, C/N ratio and moisture content on the stability and maturity of compost. Bioresour. Technol. **112**, 171–178 (2012)

Higa, T.: What is EM Technology, College of Agriculture, University of Ryukyus, Okinawa, Japan (1995)

Hosseini, S., Aziz, H.: Evaluation of thermochemical pretreatment and continuous thermophilic condition in rice straw composting process enhancement. Bioresour. Technol. **133**, 240–247 (2013)

Jusoh, M., Manaf, L., Latiff, P.: Composting of rice straw with effective microorganisms (EM) and its influence on compost quality. Iran. J. Environ. Health Sci. Eng. **10**(1), 17 (2013)

Laskowska, E., Jarosz, Ł.S., Grądzki, Z.: Effect of the EM Bokashi® multimicrobial probiotic preparation on the non-specific immune response in pigs. Probiotics Antimicrob. Proteins **11**(4), 1264–1277 (2018). https://doi.org/10.1007/s12602-018-9460-5

Meng, L., Li, W., Zhang, S., Wu, C., Lv, L.: Feasibility of co-composting of sewage sludge, spent mushroom substrate and wheat straw. Bioresour. Technol. **226**, 39–45 (2017)

National Urban Agenda (2035) United Nations Development Programme. Plan 2018–2035

Nzdl.org: Learn how to Make and Use Compost Manure in Farming (Friends-of-the-book Foundation, 1992, 54 p.): (introduction…) (2019). http://www.nzdl.org/gsdlmod. Accessed 8 Feb 2019

Olufunke, C., Doulaye, K., Silke, R., Daya, M., Chri, Z.: Co-composting of faecal sludge and organic solid waste for agriculture: process dynamics. Water Res. **43**, 4665–4675 (2009)

Onwosi, C., et al.: Composting technology in waste stabilization: on the methods, challenges and future prospects. J. Environ. Manage. **190**, 140–157 (2017)

Ozores-Hampton, M.: Guidelines for assessing compost quality for safe and effective utilization in vegetable production. HortTechnology **27**(2), 162–165 (2017)

Seal, A., Bera, R., Chatterjee, A.K., Dolui, A.K.: Evaluation of a new composting method in terms of its biodegradation pathway and assessment of compost quality, maturity and stability. Arch. Agron. Soil Sci. **58**(9), 995–1012 (2012)

Shao, X., Tan, M., Jiang, P., Cao, W.: Effect of EM Bokashi application on control of secondary soil salinization. Water Sci. Eng. **1**(4), 99–106 (2008)

Varma, V.S., Kalamdhad, A.S.: Evolution of chemical and biological characterization during thermophilic composting of vegetable waste using rotary drum composter. Int. J. Environ. Sci. Technol. **12**(6), 2015–2024 (2014a)

Varma, V.S., Kalamdhad, A.S.: Stability and microbial community analysis during rotary drum composting of vegetable waste. Int. J. Recycl. Org. Waste Agric. **3**(2), 52 (2014b)

Yousefi, J., Younesi, H., Ghasempoury, S.M.: Co-composting of municipal solid waste with sawdust: improving compost quality. CLEAN Soil Air Water **41**(2), 185–194 (2012)

Zakarya, I., Khalib, S., Mohd Ramzi, N.: Effect of pH, temperature and moisture content during composting of rice straw burning at different temperature with food waste and effective microorganisms. In: E3S Web of Conferences, vol. 34, p. 02019 (2019)