# ROTARY DRUM COMPOSTING OF URBAN SOLID FOOD WASTES GENERATED IN COMMERCIAL AND RESIDENTIAL COMPLEXES

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## ABSTRACT

*The production of Urban Solid Wastes (USW) is expected to increase in multifold in the coming years because of the rapid urbanization in towns and cities. The unscrupulous disposal of compostable Urban Solid Food Wastes (USFW) from large establishments like hotels, shopping malls, apartments, and restaurants mixed with USW in landfills, have necessitated decentralized system of onsite treatment for safe disposal. This study has been carried out in a laboratory scale Rotary drum in the aim of promoting onsite composting of USFW and to encourage the public participation in organic waste recycling and to have a greater consumer–led environmentalism. Optimum moisture, temperature, with optimum input feedstock ratio of organic waste and continuous supply of air maintained in the rotary drum, accelerates the composting process, the key requirements for rapid aerobic composting. Three combinations of trials were carried out to identify the best recipe in composting, using cooked wastes, uncooked wastes separately and with the mixed combination of cooked and uncooked wastes. Out of these three combinations of trials, the maximum C/N reduction was found out in the combination of cooked and uncooked wastes along with bulking agent rice husk and cow dung.*

***Keywords: Urban Solid Waste; Organic Waste; Food Waste; Bulking Agent; Compost; C/N Ratio;***

## I INTRODUCTION

The mixing of organic fraction of food and vegetable waste along with solid wastes and dumping them in landfills have caused undue hardships to the general health of public. Nationwide regions world over are setting ambitious goals for evading such menace and started for effective handling of USW. In some US cities, the goals have been set such that 70% of USW diversion is expected by 2015 in New York, about 75% diversion by 2013 and zero waste by 2025 in Los Angeles [7]. This provides the path to go for decentralization and onsite treatment of organic wastes and derive environmental benefits, like reduction in pollution of water, land, air and also the economic benefits that go to farmers with the end product. These, if propagated well, the understanding of nature together with the mandatory enforcement laws of compulsory recycling of organics, the costs of recycling can be brought down with the reduction in volume of waste. Pay–as–you–throw (PAYT) concept of waste charges when implemented would encourage much greater consumer–led environmentalism and consumers will demand less unnecessary packaging and demand for more recyclable materials from producers and retailers [9].

The main aspects in going for the decentralization in the present scenario is strongly validated with the following points (1) the frequent fire that happens at the landfills of main Indian cities like Delhi, Kolkatta, Bangalore, Chennai, Mumbai, Trivandrum, Coimbatore and Madurai have created a suffocating and unhygienic environment, (2) the high cost of collection and transportation through the busy streets, (3) the lack of manual labour, (4) the lack of space for disposal and the rising land cost, (5) the strong public opposition to large treatment facilities, (6) the high cost of machineries and technology required in collection and segregation, (7) the high treatment cost of wastes and the ineffective tariff collection from the communities for treatment and disposal, (8) the lack of a ban on disposal of wastes in landfills and (9) the lack of enforcement for recycling organics alone. Solid Waste Management (SWM) strategies used by several agencies all over the world have set their agenda of various strategies like (i) volume reduction at the source of generation (ii) recycling and reuse (iii) combustion with energy recovery (iv) combustion for volume reduction and (v) disposal in landfill facilities. Although waste stream managers view different strategies, the volume reduction at source by way of composting still remains a safe and best means to divert wastes [1].

### 1.1 Uncooked and cooked food waste

Multitudes of shopping malls, super markets, and tall high rise apartments which have sprung up in and around a city, are going to be the main challengers of solid waste management of raw and cooked food wastes. In US, nearly 40 percent of food today and the waste food ends rotting up in landfills which accounts for a large portion of U.S. methane emissions [8]. It has been estimated that up to one in seven truckloads of perishables delivered to US supermarkets are thrown away [5]. In restaurants, institution canteen and hostels, most of the food wastes that are generated are organic. The rising shopping malls, super markets, and posh apartments in India are also leading to the same situation. Besides from plate waste, other forms of waste in restaurants arises from the preparation of food like peelings, cut pieces, decayed vegetables, fruits etc., The pressure to maintain extensive menu choices at all times also leads to large wastage of food.

### 1.2 Onsite treatment of wastes-using a rotary in-vessel drum

More than 80% of the wastes from restaurants, canteens, hotels, theatres, wedding halls and community centers are found to be organic and contains recyclable plastics. To compost the food waste and vegetable matter, it requires minimizing its unique property of high moisture content and low physical structure. It is important to mix fresh food waste with a bulking agent that will absorb the excess moisture as well as to add structure to the mix. Bulking agents with a high C:N ratio, such as sawdust, rice husk and yard waste, are good choices. Food waste is highly susceptible to odor production -- mainly ammonia -- and large quantities of leachate. The best prevention for odor is by composting them in an enclosed and well-aerated In-vessel so that remains aerobic and free of standing water. Leachate can be reduced through aeration and with sufficient amounts of high carbon bulking agent. It is easy to capture leachate and the captured leachate can be reapplied to the compost. Onsite treatment of USFW is the better option of source reduction of wastes; it not only reduces the volume of wastes but also reduces the cost of transportation, and derives some return of revenue from the composted wastes in addition to the aesthetic environment it provides to the city in promoting the greenery.

In-vessel compost technology is promoted for managing food scraps in areas with limited space. The rotary drum composting studied world over and with trials conducted at our laboratory it has been concluded further with many research findings that It (1) has short composting period, (2) reduces unnecessary odours during composting, (3) reduces leachate and the captured leachate can be recirculated, (4) requires less space, (5) ease in operation, and (6) gives uniform end product. The refinement required in the rotary motion inclination is given and the combination of food wastes for effective composting is studied here in this work [9]. The composting of food scraps and vegetable wastes does require enough carbon source, for which a bulking agent is added to increase the carbon content as well as to reduce the moisture content and thereby to provide integrity and porosity [2,12]. The microorganisms feed with enough oxygen content in the In-vessel in controlled conditions with air supply provided by an air compressor steadily supplying oxygen in varying quantities to meet their requirement of composting the wastes food wastes. The accelerated composting is executed by rotary motion which further inhibits anaerobic conditions. Food wastes generally consists of both uncooked waste generated during preparation of food due to peeling, cutting and rejection of decayed portion of vegetables (Pre-consumer waste) and cooked waste (Post consumer waste) [5].

In this work, it is decided to compost wastes separately initially as the uncooked waste does not have much moisture, whereas the cooked waste boiled and ground form have to be blended with proper quantity of bulking agents because of the high moisture content [6]. Therefore three tests of trials carried out. The First Trial tests are conducted initially for treating uncooked waste (pre-consumer waste) The second trial tests are carried out separately with cooked foods which are wasted (Post consumer waste) by the consumer. The third trials are carried out combined with both cooked waste and uncooked waste. The main objectives of these trials are: (1) to determine the optimal input feed stock C/N ratio acceptable for microbial composting of the organic food waste both in the uncooked form or in its cooked form and with the combination of both cooked and uncooked varieties of waste in the laboratory scale rotary reactor and (2) to determine the maximum reduction of C/N ratio of wastes in the uncooked form or in its cooked form and with the combination of both cooked and uncooked varieties of waste in the laboratory scale rotary reactor.

## II MATERIALS AND METHODS

Figure 1 shows the laboratory scale rotary drum fitted with a compressor for providing airflow to the waste for composting. The fabrication of the closed drum is carried out with a 4 feet long 8” diameter stainless steel pipe and with two end flanges of steel sheet of same thickness and are fixed with stainless steel bolts and nuts. The capacity of the vessel has been worked out to be about 37.7 litres in volume so that an amount of 30 litres of wastes can be tested for its compost ability. The internal surface of the drum is fitted with eight numbers of fins fixed longitudinally and bends in the radial direction. The fins are provided in order to facilitate the proper mixing of the wastes as well as to prevent lump formation during the rotation of the drum. There is a central pipe provided in the drum which is supported by beveled edge taper bearings at the ends, specially provided to prevent any leakage of air and temperature. Air is supplied through a compressor and the supply is regulated through a valve and measured with the help of a rotometer. The air inlet pipe is perforated for fifty percent of its length to let air inside to provide enough amount of oxygen during the aerobic process and the remaining fifty percent perforated portion of the pipe is to bring the exhaust gases to the outlet end. The entire surface of the drum is covered by 15mm thick polyurethane foam to prevent the escape of temperature through the steel drum. An inlet of 6” x 6’is provided for feeding the wastes into the drum and also an outlet provided for same size for collecting the processed end product. The doors are with insulation and provided with a brass control outlet to drain any leachate that is collected in the drum. If leachate is present in the drum, it will hinder the aerobic process and may lead the waste to anaerobic condition. The entire drum is run by a 1 HP motor driven by a chain with a toothed gear fixed at the centre run of the drum peripherally. A reduction gear of 1:20 ratio is fitted along with the motor in order to reduce the speed of the drum. The rotational speed of the drum is further reduced and the rpm can be varied by using a variable transformer fitted to the supply. The entire 4 feet length of the drum is further supported at two points with guide vanes fitted at the periphery of the drum which accommodates well with the guide wheels fixed on the supporting frame. This helps to prevent the drum from slipping during the long continuous run.

**Fig. 1 Laboratory scale rotary drum with compressor**

### 2.1 Analysis of the waste

Investigation was carried out during the conversion process for every two days, to determine the physical and chemical parameters, to find its degree of maturity and also biological parameters by taking a sample of 100 gm of waste. The direct measurement of chemical parameters like Total Organic Carbon (TOC) and Total Kjeldhal Nitrogen (TKN) were found to be useful in better prediction of the rate of degradation and the samples were tested for it. The Volatile Solids (VS) was measured after igniting the sample at 550º C for 2 h in a muffle furnace [3], TOC was calculated using the formula (100 - % ash)/1.8 and Total Kjeldahl Nitrogen (TKN) was measured using semi-micro Kjeldahl method [4].

### 2.1 First set of trials with uncooked waste, bulking agent (saw dust) and cow dung

The wastes were sorted manually to ensure that it contained no oversized and undesirable materials and then was shredded manually to a size of 20-30 mm to give a better exposure for microbial treatment and to expedite the ensuing metabolic process. The moisture content of the waste collected was relatively high due to vegetables and to prevent excess moisture, bulking agents are to be added. The main function of the bulking agents is to increase the proportion of free airspace and to assist in providing optimum moisture content, besides providing stability and satisfying the energy requirements, before composting. For optimal composting performance, a C/ N range of 25 to 35 is often recommended in the literature. This study primarily investigated the effect of C/N ratio initially along with the performance of laboratory scale reactor, treating food waste (USFW). Three sets of trials were run with the initial Mix C/N ratios within the range of 25-35 as per the literature studies have shown. If C/N ratio is less than 25-30, it will cause Nitrogen loss and if the ratio is found excess in the range more than 30-35 will cause slowing of the process [6]. Three test trials were conducted. The first set of trials was carried out with first test as control with mere uncooked waste(Pre-consumer waste ) alone(MIX A).The second test was carried out with uncooked waste and bulking agent (Saw dust ) and cow dung (MIX B).The third test was carried out with uncooked waste, bulking agent ( Rice husk) and cow dung [2]. The mix ratios for first set of trials are given in Table 1.

**Table 1 Mix ratios of feedstock (first set of trials)**

| Mix ratios | Materials and composition | | |
|---|---|---|---|
| | Materials | Ratio | Quantum of wastes |
| MIX-A (Input C/N ratio 30-35)(Control) | Uncooked food and vegetable wastes | 10 parts waste alone | 20 litres of Uncooked food and vegetable wastes |
| MIX-B (Input C/N ratio 30-35) | Uncooked food and vegetable wastes: bulking agent (Saw dust): Cow dung | 10:5:2 | 20 litres of waste, 10 litres of bulking agent (Saw dust) and 2 litre of Cow dung |
| MIX-C (Input C/N ratio 30-35) | Uncooked food and vegetable wastes: bulking agent (Rice husk):Cow dung | 10 :5:2 | 20 litres of waste, 10 litres of bulking agent (Rice husk) and 2 litre of Cow dung |

### 2. 2 Trials using cooked wastes, bulking agent and cow dung (second set of trials)

The wastes were sorted manually to a size well below 10-15 mm and it has moisture relatively high due to the cooking of the vegetables and to prevent this excess moisture, bulking agents were added. The bulking agents increases the proportion of free airspace and largely assists in providing optimum moisture content, other than providing stability and satisfying the energy requirements, before composting. Rice husk is used as bulking agent. For optimal composting performance, as usual a C/ N range of 25 to 35 is provided [10, 11]. Different mix ratios were tried maintaining the C/N ratio within the range of 25-35 as per the literature studies. Three sets of test trials were conducted. The first test was carried out as control with cooked waste alone (MIX A1).

The second test was carried out with cooked waste, bulking agent, saw dust and cow dung (MIX B1).The third test was carried out with cooked waste, bulking agent of rice husk and cow dung (MIX C1). The tests are conducted as per the mix ratios provided in Table 2.

**Table 2 Mix ratios of feedstock (second set of trials)**

| Mix ratios | Materials and composition | | |
|---|---|---|---|
| | Materials | Ratio | Quantum of wastes |
| MIX-A1<br>(Input C/N ratio 30-35) | Cooked Food and Vegetable Wastes | 10 parts of Wastes alone | 20 litres of waste alone |
| MIX-B1<br>(Input C/N ratio 30-35) | Cooked Food and Vegetable Wastes with: bulking agent (Saw dust):cow dung | 10 :6:2 | 20 litres waste with 10 litres of bulking agent (Saw dust) and 1 litre of cow dung |
| MIX-C1<br>(Input C/N ratio 30-35) | Cooked Food and Vegetable Wastes with: bulking agent (Rice husk) :cow dung | 10:6 :2 | 20 litres of Wastes and 12 litres of bulking agent (Rice husk) and 2 litres of cow dung |

### 2.3 Trials using combination of cooked and uncooked vegetable wastes, using rice husk as bulking agent and cow dung as starter (third set of trials)

The third set of trials was carried out using a combination of cooked and uncooked vegetable wastes. The moisture content of the waste collected was relatively high due to the cooking of the vegetables and to prevent this excess moisture, bulking agents were added. The bulking agents increase the proportion of free airspace and largely assist in providing optimum moisture content, other than providing stability and satisfying the energy requirements, before composting.

**Table 3 Mix Ratios of Feedstock (Third Set of Trials)**

| Mix ratios | Materials and composition | | |
|---|---|---|---|
| | Materials | Ratio | Quantum of wastes |
| MIX-A2<br>(Input C/N ratio 30-35) | Cooked and uncooked Vegetable and food Wastes | 10 parts of wastes alone | 20 litres of Wastes |
| MIX-B2<br>(Input C/N ratio 30-35) | Cooked and uncooked Vegetable and food Wastes : bulking agent (Saw dust) :Cow dung | 10 :5.5:2 | 20 litres Wastes and 10 litres of bulking agent (saw dust) and 2 litres of cow dung |
| MIX-C2<br>(Input C/N ratio 30-35) | Cooked and uncooked Vegetable and food Wastes : bulking agent (Rice husk): Cow dung | 10:5.5:2 | 20 litres of Wastes, 10 litres of bulking agent (Rice husk) and 2 litres of cow dung |

For optimal composting performance, as usual an initial C/N range of 25 to 35 was provided. This study investigated for the effect of reduction of C/N ratio with the cooked food and uncooked vegetable wastes in the drum. Three test trials were conducted. The first test was carried out as control with cooked and uncooked wastes alone (MIX A2).The second test was carried out with cooked and uncooked wastes, bulking agent (saw dust) and cow dung (MIX B2). The third test was carried out with cooked and uncooked wastes, bulking agent of rice husk and cow dung (MIX C2). Therefore, the tests were conducted as per the mix ratios provided in Table 3.

## III RESULTS AND DISCUSSION

### 3.1 Temperature

The three sets of trials are tried in the laboratory scale rotary drum with an input C/N ratio of 30-35 provided for effective degradation of the substrate. The temperatures of the substrate at the beginning of the composting process in all the mixes are in the range 32ºC to 34.5ºC.

In the first set of trials, the highest temperature of 52.5ºC (Fig. 2) was attained only on the 3rd day in Mix C, which indicates a growth of microorganisms to a certain extent and in all the other mixes slowing down of the process can be seen due to the improper mix of substrate provided in the feed stock [8]. The temperature rose to a maximum of 55 ºC on 3rd day itself which showed some improvement for Mix C. Mix A did not show any improvement from the beginning to the end of the trial period. The rise of temperature was slightly seen in the second trial of Mix B. The optimum mix of C/N ratio of 30-35 with uncooked waste, with a bulking agent of rice husk and cow dung as a starter has been found to be a ideal combination as found to be suitable as the compost maturity has been indicated by the rise of the temperature of 55° C for nearly three days which is maximum of all the mixes.

In the second set of trials, the highest temperature of 59ºC was attained only on the 3rd day in Mix C1 (Fig. 4), which indicates a growth of microorganisms to a certain extent and in all the other mixes have slowed down. Mix A1 does not show any improvement from the beginning to the end of the trial period. The rise of temperature was slightly higher in the second set of trial of Mix B1. The optimum mix of C/N ratio of 30-35 with uncooked waste, with a bulking agent of rice husk and cow dung as a starter has been found to be a ideal combination as found to be suitable as the compost maturity has been indicated by the rise of the temperature of 59° C for nearly three days which is maximum of all the mixes in the second set of trials.

In the third set of trials, The highest temperature of 65ºC (Fig. 6) was attained on the 3rd day in Mix C2, which indicates enormous growth of microorganisms to a certain extent and in all the other mixes have slowed down of the process. The temperature rose to a maximum of 49º C on 5th day which shows slight improvement for Mix B2. Mix A2 does not show any improvement from the beginning to the end of the trial period.

### 3.2 Reduction of C/N ratio

In all the three sets of trials, the rate of reduction in C/N ratio is indicative of the rate of decomposition of the waste.

In the first set of trials, it is found to be maximum in Mix-C having an input feedstock C/N ratio of 30-35, as the C/N ratio is well brought down from 31.41 to 15.85 as shown in Fig. 3. But, the variation in the rate of reduction in

C/N ratio between the other two mixes, Mix-A and Mix-B, is not as much and that they can be considered insufficient to have been composted as the C/N ratios are only brought down to 34.21 and 26.73 respectively [13]. The ranking of mixes in terms of rate of reduction of C/N ratio by the linear fit indicated by the R-squared value and the equation is in the order of Mix-C < Mix-B < Mix-A. Hence, it is concluded that the initial feedstock C/N ratio of 30-35 of Mix C is found to be the best combination in composting of uncooked vegetable wastes with rice husk and cow dung.

In the second set of trials, the rate of reduction in C/N ratio is found to be maximum for Mix-C1 having an input feedstock C/N ratio of 30-35 as it is well brought down from 31.31 to 14.46 as shown in Fig. 5. The ranking of mixes in terms of rate of reduction of C/N ratio indicated by the R-squared value and the equation is in the order: Mix-C1 < Mix-B1 < Mix-A1 [14]. Hence, it is concluded that the initial feedstock C/N ratio of 30-35 of Mix C1 is found to be the best combination in composting of uncooked vegetable wastes with rice husk and cow dung.

In the third set of trials, the rate of reduction in C/N ratio is found to be maximum for Mix-C2 having an input feedstock C/N ratio of 30-35, as it is well brought down from 30.57 to 13.85 as shown in Fig. 7. But, the variation in the rate of reduction in C/N ratio between the two mixes, Mix-A2 and Mix-B2, was not as much and that they can be considered insufficient to have been composted as the C/N ratios are only brought down from 31.84 to 20.37 respectively. The ranking of mixes in terms of rate of reduction of C/N ratio indicated by the R-squared value and the equation is in the order: Mix-C2 < Mix-B2 < Mix-A2. Hence, it is concluded that the initial feedstock C/N ratio of 30-35 of Mix C2 is found to be the best combination in composting of combining both uncooked vegetable wastes and cooked vegetable wastes with rice husk and cow dung.

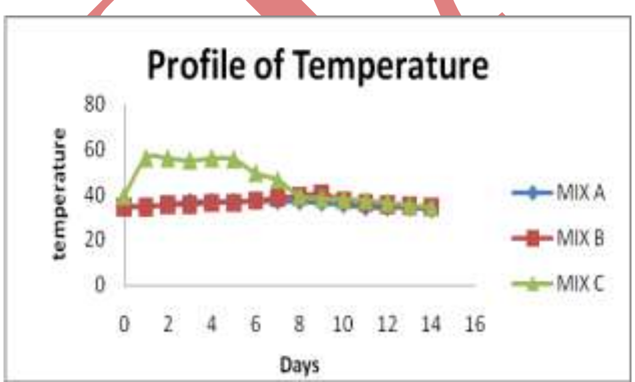



**Fig. 2 Temperature profile of all Mixes from A-C (First Set of trials)**

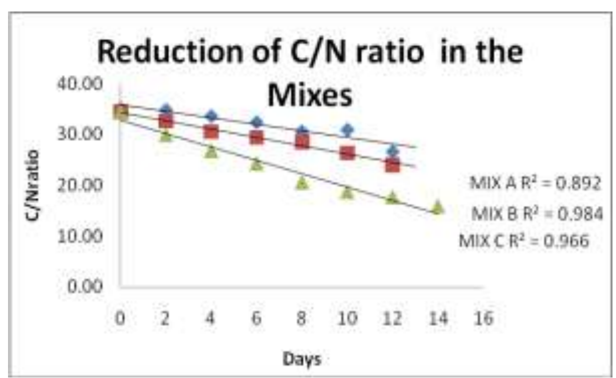
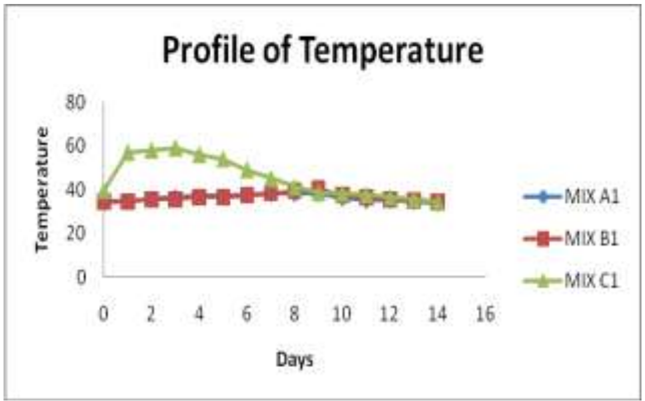



**Fig. 3 C/N ratio of all Mixes from A-C (First set of trials)**



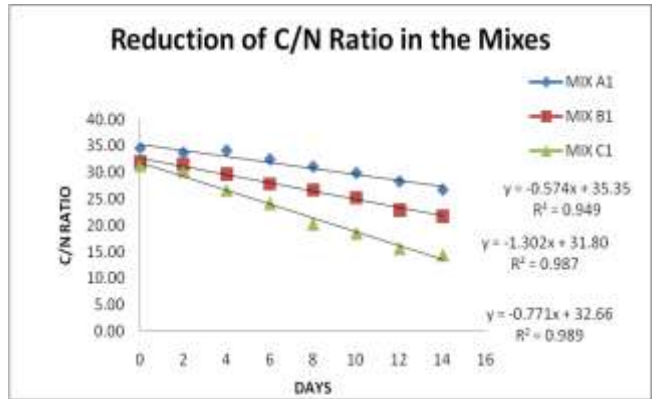
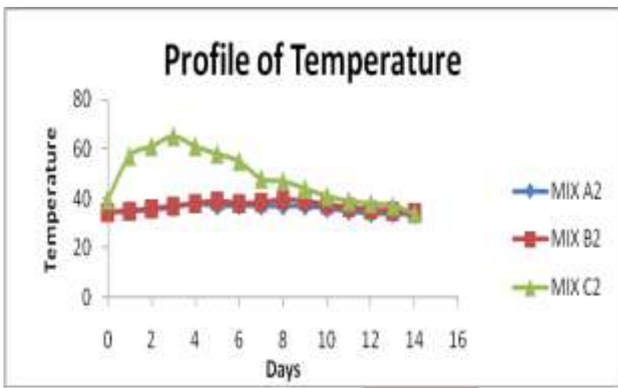




**Fig. 5 C/N ratio of all Mixes from A1-C1 from A1-C1( Second set of trials)**

**Fig. 4 Temperature profile of all Mixes ( Second set of trials)**



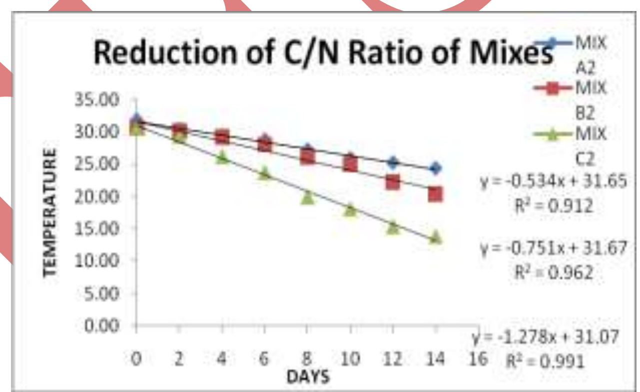




**Fig. 6 Temperature profile of all Mixes from A2-C2 (Third set of trials)**

**Fig. 7 C/N ratio of all Mixes from A2-C2 (third set of trials)**

## IV. SUMMARY AND CONCLUSIONS

- From the First set of trials conducted in the laboratory scale in-vessel on uncooked food and vegetable waste, it was found that the optimal feed stock ratio with a single bulking agent of rice husk and cow dung as inoculum was found favored better than with the bulking agent of saw dust in Mix B as the C/N ratio have got reduced to 15.90 in Mix C.

- From the second set of trials carried out in the laboratory scale in-vessel with cooked food and vegetable waste with a bulking agent of Rice husk and cow dung showed that the combination is better than that of uncooked vegetable food waste as the results of C/N Ratio have shown to be reduced to 14.36 in Mix C1

- The third set of trials carried out to determine the with both cooked and uncooked food and vegetable waste with bulking agents and cow dung showed that this final combination provided better combination than uncooked vegetable food waste as the results of C/N Ratio have shown to be reduced to 13.85 of Mix C2 with a bulking agent of Rice husk.

- The final Mix ratio of all the three stages of trials have produced the best results and are in the order of MIX C2< MIX C1 <MIX C. which particularly have the bulking agent of Rice husk. The bulking agent of Saw dust combination may not have worked out well because of having high lignin content.

## V. RECOMMENDATIONS

- Further work is needed to investigate the reduction of the high C: N ratio feedstock on the final product quality, with specific emphasis on reduction of time period lesser than 5 days.
- The thermophilically treated waste in a drum fared comparatively better than the Windrow or heap or static composting from literature studies and also suitable for onsite composting and for also mobile composting, as volume reduction occurs in short span of time and also effective in transforming a greater proportion of the food and vegetable waste material.
- The exhaust gases of Carbon dioxide and other gases should be taken care of, by way of providing a bio-filter.

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