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Seasonal Effects on Growth and Bioenergetics of *Eudrilus eugeniae* (Kinb.) using Cane Sugar Pressmud (CSP) as Feed Substrate

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Abstract:

In India use of cane sugar pressmud(CSP) as nitrogenous feed for compost earthworms is a common occurrence for the commercialization of the product - vermicompost. Humus forming, epigeic compost earthworm *Eudrilus eugeniae* appears to thrive well when exposed to CSP throughout the year. However, it was observed that the expected vermicompost procurement dwindles under seasonal pattern of rainy, winter and summer; the effect of seasonal role-play was assumed to be the factor. To find out the reason, the present study was taken up under laboratory conditions to calculate the food budget of *E. eugeniae* when fed on ad libitum partially-aerobically decomposed CSP with the onset of rainy/winter/summer seasons from hatchlings to extended post reproductive periods. Data on growth period, growth, food consumption, daily food intake as a function of age group, total food intake as function of age group, feeding rate, feces defecation, food assimilation, assimilation rate (ASR), assimilation efficiency (ASE), conversion of assimilated food into body substance, conversion rate, gross conversion efficiency (K1), net conversion efficiency (K2), food oxidized as an expression of metabolism and metabolic rate were obtained and applied to statistical studies for the interpretations based on the fate of food eaten (CSP) under the influence of rainy, winter and summer seasons.

Keywords: cane sugar pressmud (CSP), cocoons, consumption, defecation, efficiencies, feces, growth, rates, seasonal role-play.

1.0 Introduction:

Cane sugar pressmud (CSP) an agro-industrial organic residue obtained in the sugar factories in India, commonly used as an organic amendment to improve soil texture and nutrient status in the fields of paddy and sugarcane cultivation. Availability of CSP annually is at the rate of 12 million tons (on the basis of every ton of cane crushing av. 35Kgs of pressumd). CSP has been successfully used as feed additive for the study of growth, biomoass and efficiencies of vermicompost recovery in compost earthworms under laboratory conditions (Kale et al, 1993; Kale, 1998a; 1998b; Lakshmi and Vizaylakshmi, 2000; Sunitha, 2001). As experienced by the author, the success of utilization of CSP for the continual production of vermicompost under commercialization processes, the recovery of vermicompost dwindle due to three main reasons namely - climatic factors, worm density and the availability of partially-aerobically decomposed CSP; although on trial and error basis the optimum levels of worm density and continual supply of partially-aerobically decomposed CSP were easily manageable and even the climatic factors like temperature, moisture can also be monitored under three agro-climatic seasons of rainy, winter and summer; even then, the dwindling factor of recovery of vermicompost as per the calculations are not procurable. Thus, gave way for the studies of growth and bioenergetics of the compost earthworm *Eudrilus eugeniae*, the most successful tool under open access large scale productions. A detailed laboratory data on the fate of eaten food, rates and efficiencies in terms of assimilation, conversion, metabolism were the most wanted records under the seasonal patterns of rainy, winter and summer and a mandatory option for macro-level production of vermicompost. As per the literature survey, it is understandable that the laboratory studies of growth and food utilization budget are a well-known documentation in the economically viable earthworms (Martin and Lavelle, 1992; Ndegwa and Thompson, 2000), insects (Naik and Delvi, 1997; Rath et al, 2006), fishes(Pandian, 1967; Mateo, 2007) and cows (Soest, 1982). In the current research the effect of seasons on *E. eugeniae* was taken up to make the most useful examination of fate of eaten feed substrate (CSP) in different growth stages from hatchlings to extended post reproductive periods. From the literature survey (Picci et al, 1978; Bhatt, 1991; Daniel, 1991; Rivet, 1991; Viljoen et al, 1991; Hallett et al, 1992; Reinecke et al, 1992; Reddy and Pasha, 1993; Holmstmp, 1994; Muyima et al, 1994; Edwards and Bohlen, 1996; DST Report, 1997; Ramesh et al, 1997; Fayole et al, 1997; Edwards, 1998; Uvarov and Scheu, 2004; Bisht et al, 2006; Sogbesan and Ugwumba, 2006) it is well known that temperature, moisture, pH, C:N ratio, quality and quantity of feed substrate, age of the worm, population density and worm survivability has greater influence on sum or whole of the feeding and defecation of compost earthworms that in turn influences the production target of vermicompost not only from the business grounds but also from the point of clearance of bulky organic pollutants of anthropogenic wastes for an act of sustainable zero pollution.

2.0 Materials and Methods:

Hatchlings of *E. eugeniae* were taken for the estimation of food utilization budget in different seasons of rainy, winter and summer. Details of the experimental design is shown in **Table 1.** The experiments were terminated when the worms' active stage would end up in erratic behavior like disturbed feeding and defecation, sluggishness with aeging factors and/or death of some of the worms in the replicates. Details of the method applied for calculations of the obtained data prior to statistical analyses are shown in **Table 2.** The calculated data of food utilization budget from hatchlings to extended post reproductive periods were subjected to simple central measures such as mean and dispersion measures such as standard deviations. To understand the energy allocation of food intake T-diagram is shown to enumerate the bioenergetics between the age groups and in different seasons.

3.0 Results and Discussion:

Works of earlier bioenergeticists (Brody, 1945; Fry, 1947) provide framework for the influential relation between environment and animal activity. Consumption = metabolism, waste and growth. The effect of season on growth of *E. eugeniae* from hatchlings to post reproductive periods is depicted in **Table: 3.** During rainy and summer season worms took only 80 days as their active period of activity; however there was differences of growth attainment seen based on the cocoon production (**Table: 4**). In rainy season worms produced cocoons from 21st to 60th day and in summer season cocoon productions were initiated in the 60th day to 80th day. During winter season worms took 100 days as their active period of activity and produced cocoons from 60th to 100th day period. It can be summarized that a favorable and steady growth and reproduction was attained during winter season and that the other two seasonal impact on the worms were seen as early and extended reproductive stages (in rainy season) and extended growth stages of large immatures (in summer season) with only last 20 days were reproductively active days.

Table 1: Details of the experimental design

Details of partitioning of worm age for the study period	Small immature (from hatchlings to 20th day) - 1 to 3 weeks Large immature (from 21st day to 40th day) – 3 to 6 weeks Adult(1) (from 41st day to 60th day) - 6 to 9 weeks Adult(2) (from 61st day to 80th day) – 9 to 12 weeks Adult(3) (from 81st day to 100th day) – 12 to 15 weeks
No of replicates	3
Details of the feed substrate	Partially-aerobically decomposed CSP given ad libitum
Details of moisture maintenance	Av. 60% moisture in the feed substrate (irrespective of the atmospheric temperature and the season. A sample of the feed was kept in triplicate as control (without earthworms) to record the percent moisture of the feed prior to the start of the experiment and on completion of the every 20th day of the experiment.

Details of seasonal study	The experiment began with the onset of respective season of rainy/winter /summer. The recorded temperatures in the three seasons: Rainy season : 28 degree C + 2 degree Winter season : 26 degree C + 2 degree Summer season : 32 degree C + 2 degree
details of the weighing record	The worms, their feces, given feed as well as left over feed were weighted in a single pan balance to an accuracy of 0.1mg. Feces were collected and oven dried. The uneaten feed was collected at the termination of each set of experiments (at the end of 20th day) and oven dried. The worms' weights on fresh and dry weight basis were recorded at the beginning and at the end of the experiment.
Details of the termination of the experiment	The experiments were terminated at the end of every 20th day and study parameters were recorded accordingly.
Data on growth	To record the growth attainment, few worms from each replicate were freeze killed and then placed in hot air oven at av.85 degree C. until the constant weights were obtained.
Method followed for the gut clearance	Worms were allowed in submerged water for a period of 18 – 20hrs for gut clearance to start the next set of 20-day period studies. When the worms were bulged due to immersion in water during gut clearance, were then put on layers of dry filter paper for 15 – 20mts to lose excess water until the original body consistency were obtained.
Experiment study details in three seasons	Rainy season : upto 80days Winter season : upto 100days Summer season : upto 80days

Table2: Details of the method applied for calculations for the data prior to statistical analyses

Conversion of feed into body substance	- : estimated by subtracting the dry weight of the experimental individuals at the beginning of the experiment and from that at the termination of the experiment
Food intake	- : was determined by subtracting the dry weight of uneaten food from the dry weight of the feed provided.
Food untilization budgets	- :were studied using IBP formula and terminology(Petrusewiez and Macfadyen, 1970) **I = B + M + F** (where, **I** = food consumed(ingested); **F** = undigested food; **B** = food consumed – undigested food; **I – F** = assimilated food; **M** = assimilated food used for growth (gain in biomass, growth and conversion)
values	- : expressed in mg dry weight per age group
rates	- : expressed in mg dry food per mg live individual per day
Efficiencies	- : expressed in percentage
Growth	- : considered in mg live weight as function of age group
Applied calculations	
Rates of : **(a) Feeding** **(b) Assimilation** **(c) Conversion** **(d) Metabolic**	Each value (of feeding / assimilation / conversion / metabolic) of each individual age group (of small immature / large immature / adult(1) / adult(2) / adult(3) multiplied by worm period of activity (20 days for each age group) divided by total number of worm period from small immature to adult(2) / adult(3).
Assimilation efficiency (ASE):	Based on insect physiologists, Muthukrishnan and Pandian, 1987.
Conversion Efficiency: **(a) Gross conversion efficiency – K1** **(b) Net conversion efficiency – K2**	Based on insect physiologists, Pandian, 1967 and Delvi, and Pandian, 1972
Metabolism	Difference between assimilation (AS) and Production (P), calculations based on insect physiologists, Muthukrishnan and Pandian, 1987

Table 3: The effect of season on *E. eugeniae* from hatchlings to post reproductive periods

Agro-climatic seasons	Study observations	Effect of season on the growth factor of *E. eugeniae*
Rainy season	Required 80 days for the completion of growth period later showed weight loss, non-cocoon production stage and diminished feeding activity. The small immature period (pre-reproductive stage) lasted for 20 days from the hatchling stage. The next 21st day to 40th day were large immature period (extended pre-reproductive stage) but cannot be called as immature because worms at this stage produced cocoons; can be said as initiated reproductive period.	During rainy season, the growth period from 21st day to 60th day can be considered as active reproductive period and the 61st day to 80th day as post reproductive or extended reproductive period.
Winter season	Required 100 days for the completion of growth period, later on showed weight loss, reduced cocoon production and diminished feeding activity. The pre-reproductive period/small immature period lasted for 20 days from the date of hatchling. The large immature period lasted for 21st day to 40th day which can be noted as extended pre-reproductive period because at this stage the worms did not produce any cocoons. Later the worms produced cocoons during the 60th, 80th and 100th day period.	During winter season, the growth period from 21st to 40th day can be considered as the pre-reproductive or small immature period. 41st to 60th day as extended pre-reproductive period or large immature stage. 61st to 100th day a period of 40days can be considered as the active reproductive periods.
Summer season	Required 80 days for the completion of growth period, later showed weight loss, negligible and/or without cocoons and diminished feeding activity. The pre-reproductive period/small immature period lasted for 20days from the date of hatchling. The large immature period lasted for 21st day to 40th day and further extended to 41st to 60th day as extended pre-reproductive stage without any cocoon production even though the worms had developed clitellum.	During summer season, the growth period from 21st to 60th day can be considered as large immature stage or extended pre-reproductive period. Only 61st to 80th day of 20days period was cocoon production stage.

Table 4: Mean cocoon production in E. eugeniae fed ad libitum on CSP in different seasons

Season	Reproductive age (in days)	Cocoons/age	Total Cocoons/worm	Inference based on season
Rainy season	Large immature Adult(1) Adult(2)	3.46 8.25 16.11	27.82	Although large immature stage but initiation of cocoons seen, the influence of the season.
Winter season	Adult(1) Adult(2) Adult(3)	17.75 8.14 15.27	41.16	A perfect worm age group according to the biology of the worm, perfect seasonal role.
Summer season	Large immature to Adult(2) age	nil	nil	A perfect growth pattern seen but no cocoons, showing impact of the season

Table 5: Food intake, assimilation, conversion, metabolism, feces defecation and growth in *E. eugeniae* from hatchlings to post reproductive periods in different seasons fed on ad libitum CSP

Food budget	Worm period	Rainy season	Winter season	Summer season
Food intake	Small immature	146.82 +/- 9.68	94.38 +/- 16.70	173.33 +/- 21.69
	Large immature	430.00 +/- 80.00	389.22 +/- 18.95	216.25 +/- 13.52
	Adult(1)	1118.21 +/- 117.84	427.81 +/- 31.68	283.33 +/- 480.87
	Adult(2)	1302.72 +/- 90.74	418.33 +/- 26.95	688.89 +/- 300.62
	Adult(3)	nil	557.61 +/- 46.57	nil
Food Assimilation	Small immature	71.82 +/- 11.27	50.22 +/- 19.03	33.33 +/- 23.30
	Large immature	10.00 +/- 0.00	78.11 +/- 5.93	157.92 +/- 14.19
	Adult(1)	297.38 +/- 42.03	56.98 +/- 39.03	1083.33 +/- 510.13
	Adult(2)	141.61 +/- 72.11	77.86 +/- 70.12	1344.44 +/- 280.05
	Adult(3)	nil	49.28	nil
Conversion of assimilated food	Small immature	1.52 +/- 0.09	2.04 +/- 0.51	3.29 +/- 0.45
	Large immature	13.73 +/- 0.73	10.73 +/- 0.29	7.14 +/- 1.33
	Adult(1)	4.32 +/- 0.82	4.50 +/- 0.63	7.17 +/- 0.41
	Adult(2)	4.40 +/- 0.62	4.46 +/- 0.78	3.00 +/- 1.88
	Adult(3)	nil	3.81 +/- 1.49	nil
Metabolism (food oxidized)	Small immature	70.29 +/- 11.19	48.18 +/- 18.64	30.05 +/- 23.75
	Large immature	83.73 +/- 30.73	67.38 +/- 5.67	150.78 +/- 15.87
	Adult(1)	293.05 +/- 42.59	52.48 +/- 39.31	1076.16 +/- 510.42
	Adult(2)	137.21 +/- 72.38	73.40 +/- 70.08	1341.44
	Adult(3)	nil	45.47 +/- 60.60	nil
Feces defecation	Small immature	75.00 +/- 8.66	44.17 +/- 10.10	140.00 +/- 44.44
	Large immature	420.00 +/- 80.00	311.11 +/- 19.24	58.33 +/- 7.64
	Adult(1)	820.83 +/- 76.38	370.83 +/- 66.83	200.00 +/- 50.00
	Adult(2)	1161.11 +/- 158.41	340.48 +/- 96.98	344.44
	Adult(3)	nil	508.33 +/- 79.49	nil
Growth	Small immature	112.25 +/- 11.91	123.75 +/- 26.44	240.95 +/- 47.84
	Large immature	878.87 +/- 13.32	782.13 +/- 54.78	486.77 +/- 75.37
	Adult(1)	1802.92 +/- 30.15	1561.44 +/- 41.66	953.37 +/- 45.02
	Adult(2)	2116.06 +/- 47.60	2183.12 +/- 37.24	1480.11 +/- 125.16
	Adult(3)	nil	2717.64 +/- 137.11	nil

*food intake = mg dry wt/day/worm
*assimilation = mg dry wt/day/worm
*conversion = mg dry wt/mg dry worm/day
*metabolism = mg dry wt/mg dry worm/day
*feces defecation = mg dry wt/day/worm
*growth = mg wet wt/worm

Table 6: Rates of feeding, food assimilation and conversion in E. eugeniae from hatchlings to post reproductive periods in different seasons fed on ad libitum food CSP

Rates	Worm period	Rainy season	Winter season	Summer season
Feeding rate	Small immature	1.320 +/- 0.191	0.777 +/- 0.153	0.726 +/- 0.052
	Large immature	0.490 +/- 0.097	0.498 +/- 0.018	0.454 +/- 0.097
	Adult(1)	0.621 +/- 0.075	0.274 +/- 0.026	1347 +/- 0.490
	Adult(2)	0.616 +/- 0.043	0.192 +/- 0.016	1.149 +/- 235
	Adult(3)	nil	0.260 +/- 0.027	nil
Food assimilation rate	Small immature	0.641 +/- 0.082	0.399 +/- 0.111	0.154 +/-0.115
	Large immature	0.011 +/- 0.000	0.100 +/- 0.007	0.332 +/- 0.073
	Adult(1)	0.165 +/- 0.026	0.036 +/- 0.024	1.135 +/- 0.515
	Adult(2)	0.067 +/- 0.035	0.035 +/- 0.032	0.914 +/- 0.203
	Adult(3)	nil	0.018 +/- 0.023	nil
Conversion rate	Small immature	0.014 +/- 0.001	0.016 +/- 0.001	0.014 +/- 0.001
	Large immature	0.016 +/- 0.001	0.014 +/- 0.001	0.015 +/- 0.001
	Adult(1)	0.002 +/- 0.000	0.003 +/- 0.001	0.008 +/- 0.000
	Adult(2)	0.002 +/- 0.000	0.002 +/- 0.000	0.002 +/- 0.002
	Adult(3)	nil	0.001 +/- 0.001	nil

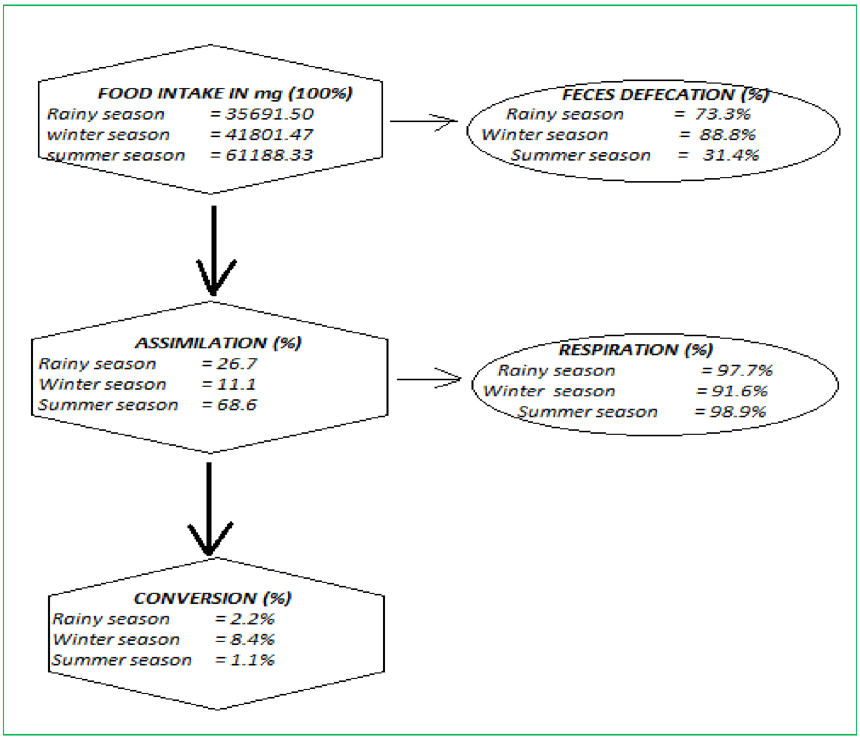
***feeding rate = mg dry food/mg live worm/day**
***assimilation rate = mg dry wt/day/worm**
***conversion rate = mg dry wt/mg live worm/day**

Table 7: Assimilation efficiency and conversion efficiency (as K1 and K2) shown in different season from hatchlings to post reproductive periods

Efficiencies	Worm period	Rainy season	Winter season	Summer season
Assimilation Efficiency	Small immature	48.837 +/- 5.805	52.155 +/- 14.769	20.458 +/- 15.072
	Large immature	2.381 +/- 0.451	20.097 +/- 1.739	72.963 +/- 3.784
	Adult(1)	26.524 +/- 1.121	13.740 +/- 10.384	82.394 +/- 8.247
	Adult(2)	11.139 +/- 6.233	19.370 +/- 17.811	79.357 +/- 2.833
	Adult(3)	nil	8.899 +/- 11.004	nil
Gross Conversion Efficiency (K1)	Small immature	1.04 +/- 0.09	2.17 +/- 0.53	1.89 +/- 0.04
	Large immature	3.27 +/- 0.16	2.76 +/- 0.17	3.33 +/- 0.82
	Adult(1)	0.39 +/- 0.10	1.05 +/- 0.08	0.62 +/- 0.27
	Adult(2)	0.33 +/- 0.03	1.06 +/- 0.20	0.17 +/- 0.11
	Adult(3)	nil	0.70 +/- 0.32	nil
Net Conversion Efficiency (K2)	Small immature	2.14 +/- 0.22	4.33 +/- 1.22	23.80 +/- 29.95
	Large immature	137.33 +/- 7.26	13.77 +/- 0.73	4.58 +/- 1.25
	Adult(1)	1.49 +/- 0.45	10.796 +/- 6.41	0.78 +/- 0.41
	Adult(2)	4.07 +/- 2.84	31.52 +/- 46.74	0.22 +/- 0.14
	Adult(3)	nil	18.81 +/- 17.57	nil

***assimilation efficiency = % of food intake**
***gross conversion efficiency (K2) = % of food intake**
***net conversion efficiency (K1) = % of food assimilated**

T diagram 1: Showing energy allocations of consumed food in E. eugeniae fed ad libitum on CSP in different seasons



3.1 Food intake, assimilation, conversion, metabolism, feces defecation and growth in *E. eugeniae* from hatchlings to post reproductive periods in different seasons are shown in the **Table: 5.** The data can be summerised as:

3.1a Food intake is the digestive capacity of an organism depending on the climatic and physiological factors (Lavelle, 1983; Satchell, 1967; Neuhauser et al, 1979; Dash, 1987). It appears that summer season has enhanced consumption of feed in all age groups followed by rainy season. Daily food intake as a function of age group, compared to small immatures, other age groups have shown consumption at higher rate irrespective of the season. Total food intake as a function of age group reveals that maximum consumption is in winter season as is the fact the worm activity has been for 100 days. Food consumption as a factor and winter season as a favourable factor shown reproductively active periods and survivability of the worms.

3.1b Assimilation is directly dependent on the digestive capabilities. Assimilated energy is utilized for growth, metabolism and reproduction. Earthworms are said to waste large portion of ingested energy as egesta predicting inefficiency of assimilation. In the present research large portion of assimilated energy was spent for metabolism during summer season thus this effect was seen in less production of egesta (as vermicompost) and steady production of egesta in rainy and winter season. Assimilation trend higher in adult(1) in all seasons.

3.1c Conversion is the assimilated food into body substance usually higher in the early growth. In the present study, conversion of assimilated food higher in large immature period in rainy season; in adult(1) in winter and summer seasons.

3.1d Metabolism generally considered as food oxidized that is utilizable energy converted into chemical transformations as respiration, production of coelomic fluid, locomotion and reproduction. It is analyzed that adult(1) has highest metabolic rate in rainy and summer season; adult(2) in winter season.

3.1e Feces defecation is the unwanted waste material voided by the worms but of high value as vermicompost from the angle of soil fertility and as business venture. Research have shown that the temperature, pH value, C/N ratio and organic wastes used in vermicomposting are important factors influencing the growth and survival of compost earthworms (Lie et al, 2000; Qiao et al, 2003 and Hou et al, 2005). It can be analysed that the effect of season on feces defecation considering its importance as vermicompost. Adult(1) has shown maximum defecation in rainy season; there is a steady defecation in all the age groups in winter and summer season. The trend of defecation is minimized to maximum from small immature to adults. Feces defecation is in correlation with the age of the worms.

3.1f Growth is the conversion of food material into tissue through the process of feeding, digestion, assimilation and synthesis. It is the achievement of left over of assimilated energy divided by the remained energy after the expenditure for maintenance and metabolism (respiration). It can be analyzed that prevalence to growth is seen in rainy season than in summer. Growth tendency is steady state in winter season.

3.2 Rates of feeding, assimilation and conversion are shown **in Table: 6.** Temperature and moisture affect the feeding rate (Barlet, 1959; Mitchell, 1978; Lavelle et al, 1980; Dash et al, 1986). The present study reveals that worm size is not a function of feeding but age. Assimilation rate shows direct proportion to the assimilation, which in turn is proportional to the food intake. The fluctuation trend is dependent on the worms' feeding capability in season and in age groups. Conversion rate show same patterns among age groups and between seasons. Conversion rate decrease as the worm period increase.

3.3 Efficiencies of assimilation and conversion (as gross conversion - K1 and net conversion - K2) are shown in **Table: 7. In** the present study assimilation efficiency were maximal during the initial periods and shown a steady fall with age advancement. K1 is shown as variable in different seasons. Large immatures have shown maximum gross conversion efficiency in summer season. In winter and rainy season it is variable from one age group to the other. K2 is shown a variable tendency in all seasons. Maximum for large immature in rainy season; variable in winter and negligible in all age groups in summer. It was found that compared to the eaten food, the metabolic state of *E. eugeniae* and the energy demands of their maintenance determined the fates of the food consumption and the growth with seasonal influential role. Bioenergetics of compost earthworm is a tool to understand the fate of eaten food. Consumption and metabolism (respiration) is seasonal dependant and that has a prime role to play on the feces defecation.

4.0 Conclusion:

Effect of seasons from the point of utilization of cane surgar pressmud (CSP) for commercialization and continual production of vermicompost the following points can be putforth:

1) Food intake increase several time in comparison to growth and is age dependant. Rate of food consumption decrease with increase in body wt. Thus adult(2) and adult(3) worms are inefficient workers in the production of vermicompost, they are better harvested and taken for protein meal production.
2) Rainy season and winter seasons are best suited for vermicomposting with lower energy spent on metabolism. It is advisable to discontinue to do vermiprocesses in summer season, except for maintenance of vermeries to make use of the populations for productions with the onset of rains.
3) **T diagram:** 1 showing energy allocations of consumed food in different seasons is self explanatory in understanding the production of vermicompost.

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References:

1) Bisht R, Pandey H, Bisht S.P.S. and Kaushal, B.R. (2006). Feeding and casting activities of the earthworm Octolasion tyrtaeum and their effects on crop growth under laboratory conditions. Tropical Ecology, 47(2): 291-294. ISSN 0564-3295
2) Barley, K.P. (1959). The influence of earthworms on soil fertility. II Consumption of soil and organic matter by the earthworm Allolobophora

caliginosa (Savigny). Aust. J. Agric. Res. 10: 179-185.
3) Butt, K.R., 1991. The effects of temperature on the intensive production of *Lumbricus terrestris* (Oligochaeta: Lumbricidae). *Pedobiologia,* 35 : 257-264.
4) Brody, S. (1945). Bioenergetics and Growth. New York, Reinhold. 1,023pp.
5) Daniel, 0 (1991). Leaf-litter consumption and assimilation by juveniles of *Lunbricus terrestris* L. (Oligochaeta, Lumbricidae) under different environmental conditions. Biol Fertil Soils, 12 : 202-208.
6) Dash H.K, Beura, B.N and Dash, M.C. (1986). Gut load, transit time, gut microflora and turnover of soil, plant and fungal material by some tropical earhworms. Pedobiologia, 29, 13-20.
7) Dash, M.C. (1987). The other annelids. In Animal Energetics. Vol. I Academic Press, Inc.
8) Department of Science and Technology Research Project Report. (1997).Biodiversify of soil organisms and bioenergetics of earthworm population in natural and interfered ecosystems. Institute of Research in Soil Biology and Biotechnology, Chennai, India. 98 pp.
9) Dominguez, J, Briones M.J.I, and Mato, S. (1997). Effect of the diet on growth and reproduction of *Eisenia Andrei* (Olegochaeta, Lumbricidae). Pedobiologia 41, 566-576, Gustav Fischer Verlag Jena.
10) Edwards, C.A. and P.J. Bohlen (1996). Biology and Ecology of Earthworms (3rd Ed.), Chapman and Hall, London, U.K.
11) Edwards C.A. (1998). The use of earthworms in the breakdown and management of organic wastes. In: Edwards, C.A. (Ed.), Earthworm Ecology. CRC Press, Boca Raton, FL, pp. 327±354.
12) Fayolle, L, Michaud, H, Cluzeau, D, Stawiecki, J. (1997). Influence of temperature and food source on the life cycle of the earthworm *Dendrobaena veneta* (Oligochaeta). Soil Biol. Biochem. 29, 747–750.
13) Fry, F.E. (1947). Effects of the environment on animal activity. Univ. Toronto Stud. Boil. Ser., 55 Publ. Ontario Res. Lab. No. 68, pp. 5-62.
14) Hallett. L., Viljoen, S.A. and Reinecke, A.J. (1992). Moisture requirements in the life cycle of *Perionyx excavatus* (Oligochaeta). Soil Biol Biochem**,** 24 : 1333-1340.
15) Holmstmp, M. (1994). Physiology of cold hardiness in cocoons of five earthworm taxa (Lumbricidae: Oligochaeta). J Comp Physiol *B,* 164 : 222-228.
16) Hou, J. Y, Qian, G. L and Dong, R. (2005). The Influence of Temperature, pH and C/N Ratio on the Growth and Survival of Earthworms in Municipal Solid Waste" Agricultural Engineering International: the CIGR Ejournal. Manuscript FP 04 014. Vol. VII. November, 2005.
17) Kale, R.D. S.N. Seenappa and J. Rao. (1993). Sugar factory refuse for the production of vermicompost and worm biomass. V International Symposium on Earthworms; Ohio University, USA.
18) Kale, R.D. (1998a). Earthworm Cinderella of Organic Farming. Prism Book Pvt Ltd, Bangalore, India.
19) Kale, R.D. (1998b). Earthworms: Nature's Gift for Utilization of Organic Wastes. In C.A. Edward (Ed.).
20) 'Earthworm Ecology'; St. Lucie Press, NY, ISBN 1-884015-74-376.
21) Lakshmi, B.L. and G.S. Vizaylakshmi, 2000. Vermicomposting of Sugar Factory Filter Pressmud Using
22) African Earthworms Species (Eudrillus eugeniae). Journal of Pollution Research, 19 (3): 481-483.
23) Lavelle P, Sow B and Schaefer, R. (1980). The geophagous earthworms community in the Lamto savanna (Ivory Coast): Niche Partitioning and utilization of soil nutritive resources. Soil Biology as related to land use practices. (ed. D.L. Dindal), Proc. 7th Natl. Soil. Zoo. Coo., Syracuse, Environmental Prot. Agen. Washington D.C. pp 653-672.
24) Lavelle P. (1983). The structure of earthworm communities. In Earthworm Ecology from Darwin to Vermiculture. (ed. J.E. Satchell), Chapman and Hall, London, pp. 449-466.
25) Liu, Y.L. (2000). The technology and condition of indoor earthworm cultivating. Microbiology Journal. 20(3): 63-64.
26) Martin A and Lavelle, P (1992). Effect of soil organic matter quality on its assimilation by Millsonia anomala, a tropical geophagous earthworm. Soil Bio. Biochem, Vol. 24, No.12, pp. 1535-1538.
27) Mateo, I. (2007). A bioenergetics based comparison of growth conversion efficiency of Atlantic Cod on Georges Bank and in the Gulf of Maine. J. Northw. Atl. Fish. Sci. Vol. 38: 23-35.

28) Mitchell M.J. (1978). Role of invertebrates and microorganisms in sludge decomposition. Conf. Proc. Util. Soil organisms sludge management, State Univ. N.Y. pp.35-50.
29) Muyima, N.Y.O, Reinecke, A.J and Viljoen S.A. (1994. Moisture requirements of Dendrobaena veneta (Oligochaeta), a candidate for vermicomposting. Soil Biol. Biochem. 26: 973-976.
30) Naik, P.R. and Delvi, M.R. (1997). Effect of permethrin on nutritional behaviour of mulberry silkworm Bombyx mori and Eri silk worm Philosamia ricini. Bull. Of Pure and Appl. Sci. 16A No.1-2, pp45-55.
31) Neuhauser, F, Kaplan D.L, and Hartenstein, R. (1979). Life history of earthworm Eudrilus eugeniae. Rev. Ecol. Biol. Soil 16: 525-534.
32) Ndegwa S.A. and Thompson K.C. (2000). Effects of stocking density and feeding rate on vermicomposting of biosolids. Bioresource Technology, 71, (2000)5± 12.
33) Pandian, T.J. (1967). Intake, digestion, absorption and conversion in the fishes, *Megalops cypronoides* and *Ophiocephalus striatus*. Mar. Biol. 1: 16-32.
34) Picci et al (1978) in Ferrari, G. (1986): Oxygen, water and temperature in the decomposition process of an organic substance during composting in compost: production, quality and use. In: Bertoldi, M. De, Ferranti, M.P., L'Hermite, P. & Zucconi, F. (eds). Proceedings of a symposium organized by the commission of the European communities, Directorate General Science, Research and Development, 17-19 April 1986.Udine Italy.
35) Qiao Y.Y, Li W, Peng, G.J, and Dong R.J. (2003). Effect of earthworm in environment protection. *Innovation and Development of Pasturage Engineering*. China Agriculture Science Press. 205-211.
36) Ramesh P.T, Sagaya A andGunathilagraj K (1997). Population Density of Earthworms Under Different Crop Ecosystem. In Proceeding of Training Program on Vermiculture at ICAR, New Delhi.
37) Rath S.S, Singh, M.K and Suryanarayana. (2006). Change in rate of feeding and assimilation in Antheraea mylitta fed on two major food plants and its effect on silk production and reproduction. Agrl. Journal 1(1): 24-27. ©Medwell Online, 2006.
38) Reddy, M.V. and Pasha, M., (1993). Influence of rainfall, temperature and some soil physicochemical variables on seasonal population structure and vertical distribution of earthworms in two semi-and tropical grassland soils. Inr JBiotech, 37 : 19-26.
39) Reinecke, A.J., S.A. Viljioen and R.J. Saayman (1992). The suitability of Eudrilus eugeniae, Perionyx excavatus and Eisenia fetida (Oligochaete) for vermicomposting in Southern Africa in terms of their temperature requirements. J. of Soil Biology and Biochemistry, 24: 1295-1307.
40) Rivet-o-Hernandez. R., (1991). Influence of pH on the production of *Eisenia foetida.* AvancAlitnr~ltA tlim, 31 : 215-217.
41) Satchell J.E. (1967). Lumbricidae. Soil Biology. A. Burges and F. Raw, eds., pp.259-322. Academic Press, N.Y.
42) Soest Van, P.J. (1982). Nutritional ecology of the ruminants. O and B, Corvallis, Oregon.
43) Sogbesan and Ugwumba (2006). Effect of different substrates on growth and productiviy of Negeria Semi-Arid Zone earthworm Hyperiodrilus euryaulos. (Oligochaeta: Eudrilinae). World J. Zoology 1(2): 103-112.
44) Sunitha, N.S. (2001). Bioenergetics of tropical earthworm on exposure to domestic and industrial sludge. Thesis submitted and awarded from Jnana Bharathi, Bangalore University,Bangalore. India. Thesis awarded for Ph.D.degree.
45) Uvarov, A.V and Scheu, S. 2004. Effects of temperature regime on the respiratory activity of developmental stages of *Lumbricus rubellus* (Lumbricidae). Pedobiologia 48, 365–371.
46) Viljoen S.A, Reinecke A.J and Hartman, L. (1992). The temperature requirements of the epigeic earthworm species Dendrobaena veneta (Oligochaeta) – a laboratory study. Soil Biol. Biochem, 24: 1341-1344.