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Interaction Effect of Operating Parameters of Blade on Vermicompost Quality under Drum Condition

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The curve blade, operational parameters and vermicompost physical properties are the key parameters come to pronouncement for breaking, churning and mixing clods condition. C, L and J curve blades was tested in the churning machine under drum condition for large, medium and small textured clods at vermicompost physical properties namely moisture content (15.24-35.48 % db.), bulk density (646 -732kg m^{-3}) and crushing force (30 N). The performance results were analyzed in terms of mean mass diameter of vermicompost with the effects of three operating parameters namely moisture content % db, blade speed m s^{-1} and blade type. Experiments were designed by opstate software and statistically analyzed and evaluated by RBD method. The average values of vermicompost mean mass diameter were found to be minimum 4.31 mm with their optimum moisture content % db, blade speed m s^{-1} were found to be 25.42 %, 5.34 m s^{-1} and C-curve blade respectively.

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Keywords: C-curve blade; moisture content; bulk density; operating parameters; mean mass diameter; opstate software RBD three factor methodology.

1. INTRODUCTION

Vermicomposting of organic wastes is gaining popularity these days since it adds value to waste and reduces volume, making it easier to use [1]. Vermicomposting is a biological process involving associations between earthworms and microorganisms that effectively transforms various types of organic waste into manure full of nutrients [2]. Breaking and mixing is the most important unit operation in churnig of vermicompost. It is done mainly to braked the clods of vermicompost, to mix the composted and uncomposed clods with minimum losses. As a result of this processing the dry state, semisolid and moderate wet of the vermicompost to improve the quality and fine particles through the design and development of different type use blade [3]. Churning operation breaks and mixes the vermicompost clods; resulting in a good fine size distribution of vermicompost. The churning operation required to achieve an acceptable quality of vermicompost, using curve lades and it is also significantly reduced in comparison to the series of operations that would result in the same quality with the use of passive (local) tools but that was very time consuming and low efficiency. Also conducted research on the different-blades interaction of a churning operation performance under churning drum condition [4,5]. Churning drum is a generic term for a test facility for studying vermicompost dynamics, especially on the churning machine interaction research in production of vermicompost sector in agriculture. Generally, a churning drum facility consists of drum, shaft, rotary cutting unit and flange etc. The application of churning drum for churning operation through machine the interaction research was developed and fabricated for research work with the reference of several research institutes, such as the National Tillage and Machinery Laboratory (NTML) in the United States of America [6]. Ideally, in the field of production area, the moisture content varies throughout the entire field as it is not under controlled condition. The water content of the vermicompost is an important property that the churning operation [7]. Looking to the present practice of vermicompost preparation among the farmers and the implements used to perform different operations as a creaking crushing of clods, there is a need to find out the suitable alternative either operation wise or equipment wise by which cost of operation can be reduced and efficiency of the vermicompost quality can be improved. In this research, performance of churning operation with C, L and J curve blades has been evaluated and compared based on vermicompost sizes quality at different operating parameters by maintained vermicompost physical properties under churning drum condition for large, medium and small textured of vermicompost. The work quality of churning operation, under drum conditions, also depends on design parameters like churning blade layout, speed of rotor, type of blades and moisture content of vermicompost. The design theory of the Japanese C- curve blade was studied by Sakai [8]. Design process gave satisfactory results in studying the effect of edge curve angle of blade on churning resistance. Bukhari et al. [9] found that the degree of vermicompost pulverization attained by a churning operation was comparable with the use of a different physical condition of vermicompost. Ram et al. [10] reported that the churning pulverized the vermicompost quiet effectively than local tools and traditional practises by farmer.

2. MATERIALS AND METHODS

Laboratory experiments were conducted in the College of SVCEAT & RS IGKV raipur, Chhattisgarh state India. All laboratory tests were carried out as per the recommendation of the Regional Network for Agricultural Machinery [6].

2.1 Moisture Content

Moisture content of vermicompost was determined by oven drying method. The different depth of heap of vermicompost sample was weighed with crucible and placed in the oven at 105°C for 24 hours [11]. After taking out from the oven, the samples were cooled in a desiccator and weighed. The average moisture content on dry basis of these samples was calculated using the following equation 1 [12].

$$M_c = \frac{W_2 - W_3}{W_3 - W_1} \times 100 \quad \ldots \qquad (1)$$

Where,

M_c= Moisture content, % db;
W_1= Weight of crucible, g;
W_2= Weight of crucible + wet sample, g; and
W_3= Weight of crucible + oven dried sample, g.

2.2 Bulk Density

Bulk density affects handling of vermicompost in the machine. The bulk density of a vermicompost like tea powder is the ratio of the mass of an untapped powder sample and its volume including inter particulate void volume. A 500 ml empty cylinder is weighed and measure the volume of the cylinder. Carefully scrape the excess powder from the top of the cylinder. The cylinder and the sample are then weighed. The bulk density of the sample is calculated from the following equation 2 [13].

$$\rho_b = \frac{W_2 - W_1}{V} \quad ... \qquad (2)$$

Where,

ρ_b = Bulk Density**,** kg m^{-3};
W_1 = The weight of the cylinder, kg;
W_2 = The weight of the cylinder and sample, kg; and
V = The volume of the cylinder, m^3.

$$V = \frac{\pi}{4} \times d^2 \times h$$

Where,

d = Diameter of cylinder, m;
h = Height of cylinder, m.

2.3 Mean Mass Diameters

The vermicompost breaks into small aggregates resulting from the action of rotary blade forces. The mean mass diameter (MMD) of the vermicompost aggregated considered as pulverization. The amount of vermicompost pulverization (Pulverization Index) was measured by determining the mean mass diameter of vermicompost clod (MMD) by using sieve analysis method. Sieves of appropriate mesh sizes were selected to carry out the sieve analysis to assess the degree of pulverization. During experiment, sieve set containing 6 sieves in the range of 11.2 - 0.425 mm and pan were used. The three samples of treated vermicompost churned were collected randomly after used of from different independent parameters viz., blade speed, moisture content and blade type thereafter taken sampler (500 gram). The sample of vermicompost was first dried for 24 hours and then passed through the set of sieves and vermicompost mass retained on each sieve was weighed. The following expression was used to calculate Mean Mass Diameter (MMD). Mehta et al. [14].

$$\text{MMD} = \frac{1}{W}\,(A + 2.4B + 3.4C + 4.8D + 6.8E + 11.85F) \quad ... \qquad (3)$$

Where,

MMD = Mean mass diameter, mm;
W = Total weight of sample, kg;

2.4 Statistical Analysis

The observation data were statistically analyzed by opstate software using RBD design model. Analysis of variance (ANOVA) was used to evaluate the significance of each parameter and the interactions between parameters on mean mass diameter as a dependent parameter. Comparisons among treatment means independent parameter as moisture content % db, blade speed m s^{-1} and blade type respectively, were conducted using F-test at p = 0.05 level.

3. RESULTS AND DISCUSSION

3.1 Effect of Moisture Content, Blade Speed and Blade Type on Mean Mass Diameter

It is one of the most important parameters that defines the performance of the blades. The data obtained from the experiment conducted was analysed statistically and ANOVA Table 1 for the effect of moisture content, blade speed and blade type on mean mass diameter is depicted in Table 1. The detailed data of effect of independent parameters on mean mass diameter of vermicompost clod is presented in Table 3. The result obtained from the test were discussed in the following sub sections.

3.2 Effect of Moisture Content and Blade Speed on Mean Mass Diameter

The mean Table 3 for the effect of different moisture content of vermicompost and different blade speed on mean mass diameter is presented in Table 3. The data revealed that moisture content of the vermicompost affect the mean mass diameter significantly at 5 % level of significance. It was observed that the mean mass

Table 1. Mean mass diameter calculation method

Size of aperture (mm)	Diameter of clod passing the upper sieve and retained on the nest small aperture sieve (mm)	Representative diameter of clod (mm)	Weight of clod (kg)
2.0	<2	1	A
2.8	2-2.8	2.4	B
4.0	2.8-4.0	3.4	C
5.6	4.0-5.6	4.8	D
8.0	5.6-8.0	6.8	E
11.2	11>	11.85	F

Table 2. ANOVA table for effect by moisture content, blade speed and blade type on mean mass diameter of vermicompost

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F-Tabulated
Replication	2	0.05			3.18
Factor M	2	9,451.45	4,725.73	64,419.99	3.18
Factor S	2	903.04	451.5	6,155.02	3.18
Int M X S	4	61.75	15.43	210.44	2.55
Factor B	2	142.16	71.08	968.97	3.18
Int M X B	4	16.40	4.10	55.91	2.55
Int S X B	4	2.36	0.59	8.06	2.55
Int M X S X B	8	10.54	1.31	17.96	2.12
Error	52	3.81	0.07		
Total	80	10,591.59			

M: moisture content, S: Blade speed and B: Type of blade diameter increased with increase in moisture content from 15.23% to 35.24%. Due to different moisture content lowest mean mass diameter 4.98 mm was observed at 15.23% moisture content (M1), whereas highest mean mass diameter (5.24 mm) was found at 35.24% moisture content (M3).

The effect of blade speed on mean mass diameter was found significantly different (α= 0.05). It was noted that the mean mass diameter decreased with increase in blade speed from 4.45 m s^{-1} to 6.23 m s^{-1}. Due to different blade speed the lowest mean mass diameter (4.42 mm) was observed at blade speed 6.23 m s^{-1} (S2), and the highest mean mass diameter of about 5.78 mm observed at blade speed of 4.45 m s^{-1} (S3). The decrease in mean mass diameter at low blade speed (S1) may be due to at lower speed the vermicompost particle less churned than the higher blade speed (S3).

The interactive effect of moisture content and blade speed on the mean mass diameter was observed and represented in Table 4. The data showed that there is difference found (CD=0.057) due to M×S at 5% level of significance. Due to interactive effect (M×S) minimum mean mass diameter of 4.31 mm was observed at 4.45 m s^{-1} blade speed (S1) at 15.23% moisture content (M1) of vermicast.

3.3 Effect of Moisture Content and Blade Type on Mean Mass Diameter

The ANOVA Table 4 and mean Table 4 for the effect of different moisture content of vermicompost and different blade type on mean mass diameter of vermicompost after churning is shows in Table 4. The data revealed that moisture content of the vermicompost affect the mean mass diameter significantly at 5 % level of significance it was already discussed in previous section. The effect of different type of churning blade (B1), (B2) and (B3) on mean mass diameter of the machine was also found to significantly different (α= 0.05). Due to different type of blade the mean mass diameter was observed 2.41 mm, 5.43 mm and 7.47 mm for C-curve (B1), L-curve (B2) and J-curve (B3) blade respectively. It was noted that the mean mass diameter decreased with increase in blade of C-curve (B1) then it started increasing by increasing the blade curve. The increase in mean mass diameter at J-curve (B3) may be due to lower contact with vermicast during churning than the C-curve blade (B1).

The interactive effect of moisture content and blade type on the mean mass diameter was also observed and presented in Table 4. The data showed that there is difference found (CD = 0.057) due to M×B at 5% level of significance. Due to interactive effect (M×B) minimum mean mass diameter of about 2.26 mm was observed with C-curve blade (B1) at 15.23% db of moisture content (M1) of vermicompost.

The graphical representation was also made between moisture content and blade type on the mean mass diameter in the Fig. 2. It was also found that the effect of moisture content and type of blade on mean mass diameter followed the polynomial trend. The regression equation for the trendline is presented in Table 5.

3.4 The Effect of Blade Type and Blade Speed on Mean Mass Diameter

The mean Table 6 for the effect of different blade type and different blade speed on mean mass diameter of vermi compost after churning is depicted in Table 6. The mean mass diameter decreased with increase in speed of blade from 4.45 m s^{-1} to 6.23 m s^{-1} in churning unit. As discussed in section 2.3 minimum mean mass diameter of vermicompost observed with C-curve blade due to its high curvature.

Table 3. Interaction effect of moisture content and blade speed on mean mass diameter, mm

Blade speed, m s^{-1} ⇒ Moisture content, % (db)⇓	**S1=4.45 m s^{-1}**	**S2=5.34 m s^{-1}**	**S3=6.23 m s^{-1}**	**Mean**
M1=15.23 % (db)	5.67	4.95	4.31	4.98
M2=25.42 % (db)	5.77	5.08	4.42	5.09
M3=35.24 % (db)	5.89	5.29	4.53	5.24
Mean	5.78	5.11	4.42	
Factors		C.D.	SE(d)	SE(m)
Factor(M)		0.033	0.016	0.012
Factor(S)		0.033	0.016	0.012
Interaction M X S		0.057	0.028	0.02

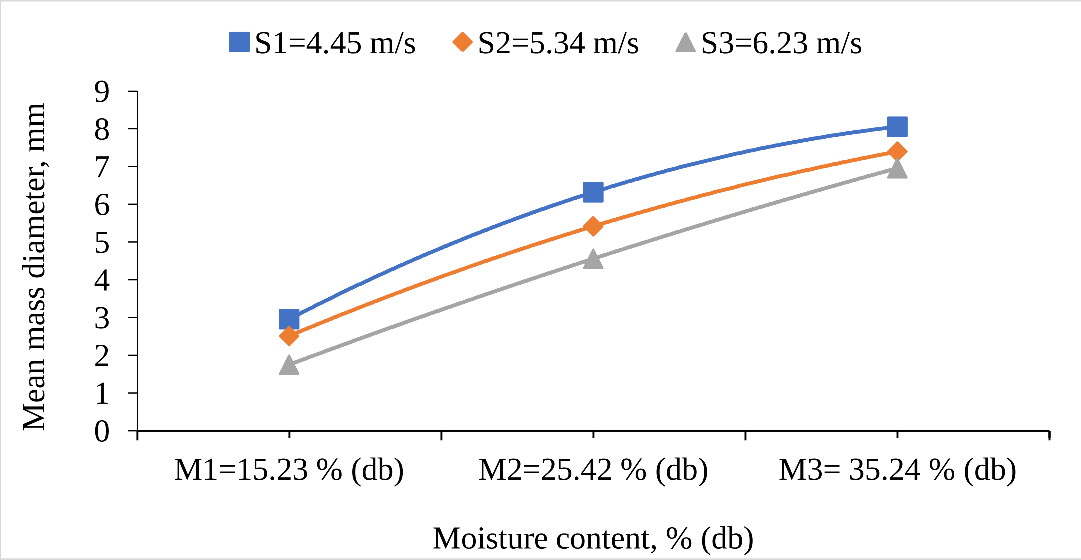

Fig. 1. Interactive effect of moisture content and blade speed (M×S) on mean mass diameter

Table 4. Interaction effect of moisture content and blade type on mean mass diameter, mm

Blade type, ⇒ **Moisture content, % (db) ⇓**	**B1= C-curve**	**B2=L-curve**	**B3=J-curve**	**Mean**
M1=15.23	2.263	5.31	7.37	4.98
M2=25.42	2.427	5.39	7.46	5.09
M3=35.24	2.537	5.603	7.587	5.24
Mean	2.41	5.43	7.47	
Factors		C.D.	SE(d)	SE(m)
Factor(M)		0.033	0.016	0.012
Factor(B)		0.033	0.016	0.012
Interaction M X B		0.057	0.028	0.02

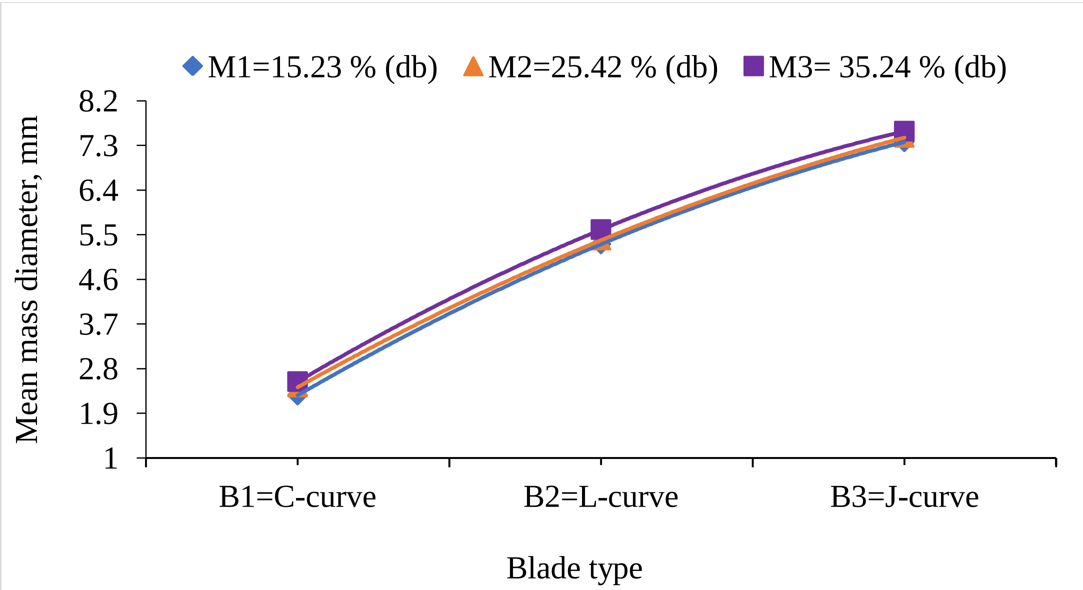

Fig. 2. Interactive effect of moisture content and type of blade (M×B) on mean mass diameter

Table 5. Regression equation for the trendline of mean mass diameter, mm

Parameters	Blade type	Regression equation
Mean mass diameter (MMD), mm	C-curve	$MMD=-0.32M^2+0.005M +43.54$
	L-curve	$MMD= -1.14M^2+ 6.77M +22.19$
	J-curve	$MMD= - 0.29M^2+ 2.47M+15.08$

The interactive effect of different types of blades (B1), (B2) and (B3) and different speeds of blade (S1), (S2) and (S3) on the mean mass diameter was also found significant (CD=0.057) at 5% level of significance. Due to interactive effect (S×B) minimum mean mass diameter of 1.75 mm was observed with C-curve blade (B1) at 6.23 m s^{-1} speed of blade (S3) in churning unit similar result also observe by Bhambota et al. [15].

The graphical representation due to different type of blade (B) and speed of blade (S) was also made and presented in the Fig. 2. It was also found that the effect of speed of blade and type of blade on mean mass diameter followed the polynomial trend. The regression equation for the trendline is presented in Table 6 [16,17].

The interactive effect of moisture content (M), blade type (B) and blade speed(S) on mean mass diameter are show in Table 8 and it was resulted significant (CD=0.098). As a result of interactive effect moisture content (M), blade type (B) and blade speed(S). Highest mean mass diameter was obtained 8.06, mm at J-curve blade (B1), blade speed 4.45 m s^{-1} (S2) and 35.24 % of moisture content (M2). thereafter, obtained the lowest mean mass diameter was obtained 1.73 at C-curve blade (B3), blade speed 6.23 m s^{-1} (S3) and 15.23 % of moisture content (M1).

Table 6. Interaction effect of blade speed and blade type on mean mass diameter, mm

Blade type, ⇒ Blade speed, m s^{-1}⇓	B1= C-curve	B2=L-curve	B3=J-curve	Mean
S1=4.45	2.96	6.32	8.05	5.78
S2=5.34	2.51	5.42	7.4	5.11
S3=6.23	1.75	4.56	6.96	4.42
Mean	2.409	5.434	7.472	
Factors		C.D.	SE(d)	SE(m)
Factor(S)		0.033	0.016	0.012
Factor(B)		0.033	0.016	0.012
Interaction S X B		0.057	0.028	0.02

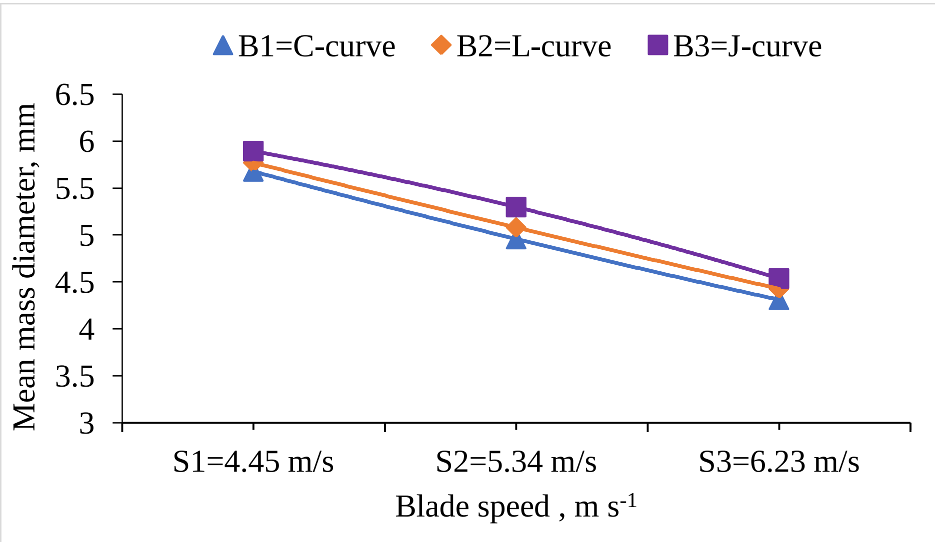

Fig. 3. Interactive effect of blade speed and blade type (S×B) on mean mass diameter

Table 7. Regression equation for the trendline of mean mass diameter

Parameters	Blade type	Regression equation
Mean mass diameter, MMD	C-curve	$MMD = -0.51S^2 + 3.91S + 30.10$
	L- curve	$MMD= -0.40S^2 + 3.21S + 26.75$
	J- curve	$MMD =-0.18S^2 + 2.11S + 23.97$

Table 8. Interaction effect by moisture content, blade speed and type of blade on mean mass diameter, mm

Blade Type, ⇒	**B1= C-curve**			**B2=L-curve**			**B3=J-curve**		
Blade speed, m s^{-1}⇒ **Moisture content, % db ⇓**	**S1=4.45**	**S2=5.34**	**S3=6.23**	**S1=4.45**	**S2=5.34**	**S3=6.23**	**S1=4.45**	**S2=5.34**	**S3=6.23**
M1=15.23 % (db)	2.83	2.70	1.73	6.23	5.23	4.47	7.97	7.33	6.47
M1=25.42 % (db)	2.87	2.74	1.77	6.27	5.28	4.53	8.01	7.38	6.53
M1=35.24 % (db)	2.91	2.78	1.81	6.31	5.32	4.58	8.06	7.42	6.56
Factors		C.D.		SE(d)			SE(m)		
Interaction B X S X M		0.098		0.049			0.035		

M: moisture content (M1=15.23 %, M2= 25.42 %, M3= 35.24 %) B: blade Type (B1=C-curve, B2=L-curve, B3=J-curve)
S: Blade speed (S1=4.45 m s^{-1}, S2=5.34 m s^{-1}, S3= 6.23 m s^{-1})

4. CONCLUSION

From the study it is concluded that. C curve blade interaction on operating parameters in a controlled physical property of vermicompost under enclose drum condition for fine textured vermicompost was observed and analyzed in terms of compost quality. It has been found out that, to get better performance, C curve blade should be operated at about 6.23 m/s blade speed, 15.42 % db. moisture content with minimum size of mean mass diameter of vermicompost was obtained 1.73 mm. Among the operating parameters, there was considerable significant difference in vermicompost quality, rotary speed was significantly (Table 4), therefore to attain the desirable vermicompost quality it required to increase fertilizer uniform distribution in field as well as all agricultural farming sector.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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