International Journal of Plant & Soil Science

26(3): 1-18, 2018; Article no.IJPSS.46554
ISSN: 2320-7035

Effect of Vermicompost and Tuber Size on Processing Quality of Potato during Ambient Storage Condition

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Authors' contributions

Authors MM and TSR both were involved in conception and designing the experiment. Author MM was conducted the study, interpretation of data, and critically wrote the manuscript. Author RC helped to review draft copy. Authors SM, PKK, MSZ, MR and MS were involved in data collection. All the authors were approved the manuscript finally to make a version for publishing.

Article Information

DOI: 10.9734/IJPSS/2018/46554
Editor(s):
(1) Dr. L. S Ayeni, Adeyemi College of Education, Ondo State, Nigeria.
Reviewers:
(1) Rahul Datta, Mendel University, Czech Republic.
(2) Md. Zulfikar Khan, Khulna University, Bangladesh.
(3) Jaime Cuauhtemoc Negrete, Autonomous Agrarian Antonio Narro University, Mexico.
Complete Peer review History: http://www.sdiarticle3.com/review-history/46554

Original Research Article

Received 07 November 2018
Accepted 16 January 2019
Published 01 February 2019

ABSTRACT

Aims: The experiment was conducted to assess the effect of vermicompost and tuber size on processing quality of potato during ambient storage condition.
Study Design: Experiment was conducted in a split-plot design, where vermicompost levels were assigned to main plots and tuber size to subplots.
Place and Duration of Study: The experiment was conducted at the agronomy research field of Sher-e-Bangla Agricultural University, during the period from November 1, 2014 to April 30, 2015 and November 1, 2015 to April 30, 2016 in Rabi season.

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Methodology: The experiment was consisted of two factors, i.e., factor A:- Vermicompost level (Vm-4): Vm_1: 0 t ha^{-1} (Control), Vm_2: 3 t ha^{-1}, Vm_3: 6 t ha^{-1} and Vm_4: 9 t ha^{-1}; factor B:- Tuber size (T-5): T_1: 5-10 g, T_2: 10-20 g, T_3: 20-30 g, T_4: 30-40 g and T_5: >40 g. After harvesting, the potato was collected and stored at ambient condition for laboratory analysis.
Results: The research showed that vermicompost had a significant effect on most of the storage parameters. Results also showed that storage quality parameters increased with increasing vermicompost level irrespective of tuber size. Among the twenty (20) treatment combinations, vermicompost at the rate of 9 t ha^{-1} with tuber size >40 g showed the highest firmness (44.349 N), specific gravity (1.084 g cm^{-3}), dry matter (22.77%), flesh color (L*- 75.60; a*- 11.76; b*- 24.96). In respect of ambient storage condition; weight loss increased with increasing storage time, while firmness, specific gravity, dry matter, flesh color decreased with increasing storage time. Quality parameters slowly decreased with increasing storage time up to 40 days after storage (DAS) and thereafter sharply decreased and finally became non-suitable both for table and processing purpose.
Conclusion: Therefore, the experiment showed that potato growers may use a higher dose of vermicompost for improving processing quality of potato and can store potato up to 40 DAS at ambient condition.

Keywords: Potato; weight loss; firmness; specific gravity; dry matter; flesh color; ambient storage.

1. INTRODUCTION

Potato (*Solanum tuberosum* L.) belonging to the Solanaceae family is cultivated in nearly 150 countries and is the world's single most vital tuberous crop with an important role in the global food network and food security [1]. It is the world's fourth largest crop after maize, wheat, and rice. In the world's top 10 potato producing countries, Bangladesh ranks 7th position [2]. Potato is one of the main vegetable crops in Bangladesh [3]. In Bangladesh, it positions 2nd after rice in production [2]. The total area, per ha yield and total production of potato in Bangladesh were 499725 ha, 22.53 t ha^{-1}, and 10,215,957 metric ton respectively in the fiscal year 2017-2018, which was 7.83% greater than the previous year 2016 [2,4]. The total production is increasing day by day because of a substitute food crop against rice and wheat and is a nutrient rich crop as such consumption also quickly increasing in Bangladesh [4].

Potato is unique compared to other vegetables in that they are exclusively consumed in processed forms. Approximately 60% of the fresh potato crop is used for industrial processing into products such as French fries and chips, whereas the remaining 40% is sold on the fresh market for home preparation and fresh food service applications [5]. Due to the increasing demand of consumers and foreign importers on this important crop, special attention should be given to increase its quality and storage time.

Potato tuber quality is one of the most important quality attributes for consumers and industrial demand [6]. Processing quality of potato tubers is determined by high dry matter [7,8]. High dry matter content increases chip yield, crispy-consistency, and reduces oil absorption during cooking [9,10].

Nowadays gradual deficiencies in soil organic matter, reduced yield of crop and quality are alarmingproblems in Bangladesh. The cost of inorganic fertilizers is very high. On the other hand, the organic manure is easily available to the farmers and its cost is low compared to that of inorganic fertilizers. Vermicompost is a good source of different macro and micronutrients particularly NPKS. The increased microbial activity improves the availability of soil Phosphorus and nitrogen. Vermiculture is the science of rearing of earthworms for mass propagation on organic wastes under semi-natural conditions and vermicomposting is the bioconversion of organic waste materials through earthwormic ways [11]. Senesi et al. [12] mentioned that vermicomposting is a controlled, aerobic, biological process and able to convert biodegradable humus-like organic substances and suitable for the application of soil amendment. Vermicompost contains 0.15-0.56% potassium [13]. Potassium extends storage life and improves processing quality of potato tuber [14,15]. Cold storage facility is limited in Bangladesh. The application of vermicompost may enhance the ambient storage quality and shelf life of a potato.

The use of TPS for potato production has increased recently in Europe, North America and Asia, especially in the developing countries

[16,17,18]. This is due to low transmission of disease, high multiplication rate and good tuber yield [19]. In Bangladesh, this technology has been highly promising [19,20,21].

Sometimes potato produced in Bangladesh is not good quality enough in respect of dry matter content, which is not present at optimum level in produced product [22]. So, using different amount of vermicompost materials may put contribution for improving the quality of potato in Bangladesh condition. Effect of vermicompost and tuber size on yield and processing quality of potato derived from TPS are still unknown, especially in Bangladesh condition.

2 MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the agronomy research field of Sher-e-Bangla Agricultural University, during the period from November 1, 2014 to April 30, 2015 and November 1, 2015 to April 30, 2016 in Rabi season. The experimental area was located at 23° 77' N latitude and 90° 38' E longitudes and at an altitude of 8.6 m from the sea level.

2.2 Soil Condition and Weather

The soil of the experimental area was to the general soil type series of shallow red brown terrace soils under Tejgaon series. Upper level soils were clay loam in texture, olive-gray through common fine to medium distinct dark yellowish-brown mottles under the Agro-ecological Zone (AEZ-28) and belonged to the Madhupur Tract [23]. Soil pH was 5.6 and had organic carbon 0.45%. Weather and soil condition presented in Table 1.

2.3 Experimental Treatment

The experiment consisted of two factors viz., factor (a): vermicompost level (Vm_1: 0 t ha^{-1} (control); Vm_2: 3 t ha^{-1}; Vm_3: 6 t ha^{-1}; Vm_4: 9 t ha^{-1}) and factor (b): seedling tuber size (S_1: 5-10 g; S_2: 10-20 g; S_3: 20-30 g; S_4: 30-40 g; S_5: >40 g). The seedling tuber of BARI TPS-1 was used for the study.

2.4 Experimental Design and Layout

The experiment was laid out in a split-plot design with 3 replications. The vermicompost was assigned to main plots and seedling tuber size to subplots. The distance between row to row was 50 cm and plant to plant distance was 25 cm. Distance between plot to plot was 75 cm. The size of the unit plot was 2 m × 1.5 m. So, the total number of plots were 60.

2.5 Crop Management

Collected seed tubers were graded according to the size 5-10 g, 10-20 g, 20-30 g, 30-40 g, >40 g and kept in room temperature to facilitate good sprouting. Finally, sprouted potato tubers were used as planting material. The allocated plots were fertilized by recommended doses of urea 250 kg ha^{-1}, Triple Super Phosphate (TSP) 150 kg ha^{-1}, Muriate of Potash (MoP) 250 kg ha^{-1}, gypsum 120 kg ha^{-1}, Zinc sulfate 10 kg ha^{-1} and boric acid 10 kg ha^{-1} [25] except treatment. All the intercultural operations and plant protection measures were taken as per when needed. After haulm cutting the tubers were kept under the soil for 7 days for skin hardening.

2.6 Parameters Determined

Data on different storage parameters were determined. The same study was conducted under the same treatment under same field condition in both year and finally, the means were taken from these two experiments.

2.6.1 Weight loss (%)

At the end of the experiment, remaining good tubers were recorded and their percentage was calculated on the basis of the initial weight of tuber. Weight loss was calculated using the following formula:

$$\% \text{ WL} = \frac{\text{IW}-\text{FW}}{\text{IW}} x\ 100$$

Where,

% WL = Percent total weight loss, IW = Initial weight of tubers (kg), FW = Final weight of tubers (kg).

2.6.2 Firmness (N)

The fresh potato tubers were cut into several slices to take the firmness reading by a Texture Analyzer, Sun Rheometer Compac 100 (Sun scientific co. Ltd, Japan). The reading seems thathow much pressure is taken by the potato tuber slice to make it chips. Each measurement was conducted on 10 potato slices as described by Van et al. [26].

Table 1. Monthly meteorological information during the period from November, 2014 to April, 2015 and November, 2015 to April, 2016

Year	Month	Air temperature (℃)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2014-2015	November	29	12	62	3.2
	December	25	10	56	5
	January	24	11	49	0.9
	February	26	15	45	15.3
	March	30	18	46	46
	April	36	28	60	103
2015-2016	November	33	15	61	3.6
	December	30	12	54	5.3
	January	25	10	48	0.8
	February	27	15	46	15.2
	March	34	19	46	48
	April	38	29	63	212.5

Source: [24]

2.6.3 Specific gravity (g cm^{-3})

Specific gravity was measured by using the following formula [27]-

$$\text{Specific gravity} = \frac{\text{Weight of tuber in air}}{\text{Weight of tuber in fresh water at } 4\,^{\circ}\text{C}}$$

2.6.4 Dry matter content (%)

The samples of tuber were collected from each treatment. After peeling off the tubers, the samples were dried in an oven at 72ºC for 72 hours. Dry matter content was calculated as the ratio between dry and fresh weight and expressed as a percentage [28]. Dry matter percentage of tuber was calculated with the following formula [29]-

$$\text{Dry matter content (\%)} = \frac{Dryweight}{\text{Fresh weight}}\, x\ 100$$

2.6.5 Color measurements

Color is an important quality attribute which influences the acceptability of fried products [30]. The color was measured with a color spectrophotometer NF333 (Nippon Denshoku, Japan) using the CIE Lab L*, a* and b* color scale. The 'L*' value is the lightness parameter indicating the degree of lightness of the sample; it varies from 0 = black (dark) to 100 = white (light). The 'a*' which is the chromatic redness parameter, whose value means tending to red color when positive (+) and green color when negative (–). The 'b*' is yellowness chromatic parameter corresponding to yellow color when it is positive (+) and blue color when it is negative (–). Each sample consisted of 10 slices, each of which was measured thrice.

2.7 Statistical Package

The data obtained for different characters were statistically analyzed following the analysis of variance (ANOVA) techniques by using Statistix 10 [31] computer package program. The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% level of probability [32].

3. RESULTS AND DISCUSSION

3.1 Weight Loss

Significant variation was found among different levels of vermicompost on tuber weight loss at different storage time. The maximum weight loss was shown by Vm_1 (4.27%, 8.03%, 12.22%) and minimum weight loss was shown by Vm_4 (1.57%, 3.09%, 6.33%); at 20, 40 and 60 DAS respectively (Fig. 1).

A remarkable difference was shown among different tuber sizes on tuber weight loss at different storage time. The maximum weight loss was shown by T_1 (3.15%, 5.85%) and minimum weight loss was shown by T_5 (2.62%, 5.04%); at 20 and 40 DAS respectively. At 60 DAS maximum weight loss (9.35 %) was shown by T_2 which was statistically similar to T_1 and T_3; and minimum weight loss (8.26 %) was shown by T_4 which was statistically similar to T_5 (Fig. 2).

Among different interaction of vermicompost levels and tuber sizes, significant dissimilarity was shown on tuber weight loss at different storage time. At 20 DAS maximum weight loss (4.41 %) was shown by Vm_1T_1 which was statistically similar to Vm_1T_2, $Vm_1T_3$and Vm_1T_5; and minimum weight loss (1.35 %) was shown by Vm_4T_4 which was statistically similar to Vm_3T_5 and Vm_3T_4. At 40 DAS maximum weight loss (8.25 %) was shown by Vm_1T_1 which was statistically similar to Vm_1T_2; and minimum weight loss (2.80 %) was shown by Vm_4T_5 which was statistically similar to Vm_4T_4 and Vm_3T_5. At 60 DAS maximum weight loss (13.20 %) was shown by Vm_1T_2 which was statistically similar to Vm_1T_3, $Vm_1T_1$and Vm_1T_5; and minimum weight loss (5.95 %) was shown by Vm_4T_2 which was statistically similar to Vm_4T_1, Vm_4T_5, Vm_4T_3, Vm_3T_5, Vm_3T_4 and Vm_4T_4 (Table 2).

Weight loss of tuber was initially attributed to the water loss that happened through the outermost skin tissues during the processes of respiration and sprouting. It was increased according to increasing storage time, but higher level vermicompost showed minimum weight loss compared to lower level vermicompost [33].

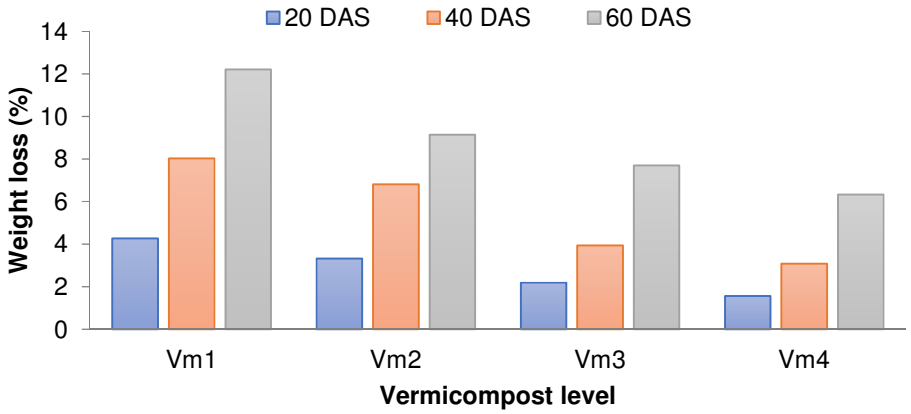

Fig. 1. Response to vermicompost on weight loss (%) of potato tuber at different days after storage

LSD values 0.1012, 0.0978 and 0.4109 for 20 DAS, 40 DAS, and 60 DAS, respectively).Vm_1 – Control, Vm_2 – 3 t ha^{-1}, Vm_3 – 6 t ha^{-1}, Vm_4 – 9 t ha^{-1}

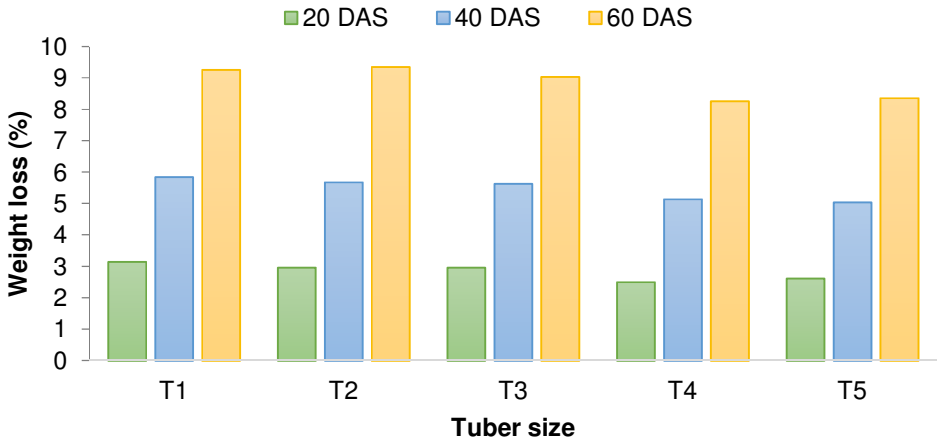

Fig. 2. Effect of tuber size on weight loss (%) of potato tuber at different days after storage

(LSD values 0.1067, 0.0887 and 0.6598 for 20 DAS, 40 DAS, and 60 DAS, respectively).T_1 5-10 g, T_2 – 10-20g, T_3 – 20-30 g, T_4 – 30-40 g, T_5 - >40 g

Table 2. Combined effect of vermicompost and tuber size on percent of weight loss at different days after storage of potato tuber

Combinations	Weight loss (%) at		
	20 DAS	40 DAS	60 DAS
Vm_1T_1	4.41 a	8.25 a	12.27 ab
Vm_1T_2	4.37 a	8.07 ab	13.20 a
Vm_1T_3	4.29 a	8.05 bc	12.28 ab
Vm_1T_4	4.06 b	7.93 bc	11.28 bc
Vm_1T_5	4.22 ab	7.88 c	12.10 ab
Vm_2T_1	3.79 c	7.14 d	10.53 c-d
Vm_2T_2	3.29 d	6.86 e	9.84 de
Vm_2T_3	3.23 d	6.80 e	9.21 ef
Vm_2T_4	3.09 d	6.73 e	7.58 g-i
Vm_2T_5	3.19 d	6.50 f	8.61 e-g
Vm_3T_1	2.70 ef	4.61 g	8.21 f-h
Vm_3T_2	2.49 f	4.57 g	8.42 fg
Vm_3T_3	2.75 e	4.47 g	8.23 f-h
Vm_3T_4	1.51 gh	3.07 ij	7.05 h-j
Vm_3T_5	1.50 gh	2.96 jk	6.58 ij
Vm_4T_1	1.68 g	3.41 h	6.02 j
Vm_4T_2	1.69 g	3.20 i	5.95 j
Vm_4T_3	1.57 g	3.19 i	6.43 ij
Vm_4T_4	1.35 h	2.84 k	7.12 h-j
Vm_4T_5	1.58 g	2.80 k	6.15 j
CV (%)	4.52	1.95	8.96
$LSD_{0.05}$	0.2155	0.1858	1.2479
Level of significance	**	**	*

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

*** = Significant at 1% level of probability, * = Significant at 5% level of probability; Vm_1 – Control, Vm_2 – 3 t ha^{-1}, Vm_3 – 6 t ha^{-1}, Vm_4 – 9 t ha^{-1};T_1 5-10 g, T_2 – 10-20g, T_3 – 20-30 g, T_4 – 30-40 g, T_5 - >40 g*

3.2 Firmness

Among different levels of vermicompost, profound dissimilarity was observed on the firmness of tuber flesh at different storage time. The maximum firmness of tuber flesh was taken by Vm_4 (40.967 N, 37.501 N, 34.845 N, 26.579 N), and minimum firmness was taken by Vm_1 (33.285 N, 29.287 N, 27.219 N, 22.943 N); at 0, 20, 40 and 60 DAS respectively (Fig. 3).

A significant difference was observed among different tuber sizes on the firmness of tuber flesh at different storage time. At 0 DAS the maximum firmness (39.136 N) of tuber flesh was taken by T_5 and minimum (36.144 N) was taken by T_1 which was statistically similar to T_2. At 20 DAS maximum firmness (34.700 N) of tuber flesh was taken by T_5 and minimum firmness (32.013 N) was taken by T_1. At 40 DAS maximum firmness (31.991 N) of tuber flesh was taken by T_5 and minimum (29.340 N) was taken by T_1. At 60 DAS maximum firmness (25.779 N) of tuber flesh was taken by T_5 and minimum firmness (23.969 N) was taken by T_1 (Fig. 4).

Significant dissimilarity was found among different interaction of vermicompost levels and tuber sizes on the firmness of tuber flesh at different storage time. At 0 DAS the maximum firmness (44.349 N) of tuber flesh gotten by Vm_4T_5 and minimum (32.066 N) was gotten by Vm_1T_1 which was statistically similar to Vm_1T_2. At 20 DAS maximum firmness (40.033 N) of tuber flesh gotten by Vm_4T_5 and the minimum (28.052 N) was gotten by Vm_1T_1. At 40 DAS maximum firmness (36.078 N) of tuber flesh gotten by Vm_4T_5 and minimum (25.239 N) was gotten by Vm_1T_1. At 60 DAS maximum firmness (27.157 N) of tuber flesh gotten by Vm_4T_5 and minimum (21.310 N) was gotten by Vm_1T_1 (Table 3).

Firmness was significantly maximum with a higher level of vermicompost than control. Higher

firmed tuber does not lose too much water, as a result, potato tuber loses less water during storage time [34,35,36,37].

3.3 Specific Gravity

Significant variation was obtained among different levels of vermicompost on the specific gravity of tuber at different storage time. The highest specific gravity of tuber was exhibited by Vm_4 (1.0785 g cm^{-3}, 1.0726 g cm^{-3}, 1.0689 g cm^{-3}, 1.0637 g cm^{-3}), and lowest was exhibited by Vm_1 (1.0469 g cm^{-3}, 1.0433 g cm^{-3}, 1.0367 g cm^{-3}, 1.0285 g cm^{-3}); at 0, 20, 40 and 60 DAS respectively (Fig. 5).

Remarkable variation was obtained among different tuber sizes on the specific gravity of tuber at different storage time. At 0 DAS the highest specific gravity (1.0688 g cm^{-3}) of tuber was exhibited by T_5 which was statistically similar to T_4, and lowest (1.0573 g cm^{-3}) was exhibited by T_1. At 20 DAS highest specific gravity (1.0655 g cm^{-3}) of tuber was exhibited by T_5 and lowest (1.0517 g cm^{-3}) was exhibited by T_1. At 40 DAS highest specific gravity (1.0627 g cm^{-3}) of tuber was exhibited by T_5 and lowest (1.0441 g cm^{-3}) was exhibited by T_1. At 60 DAS highest specific gravity (1.0578 g cm^{-3}) of tuber was exhibited by T_5 which was statistically similar to T_4 and lowest (1.0379 g cm^{-3}) was exhibited by T_1 (Fig. 6).

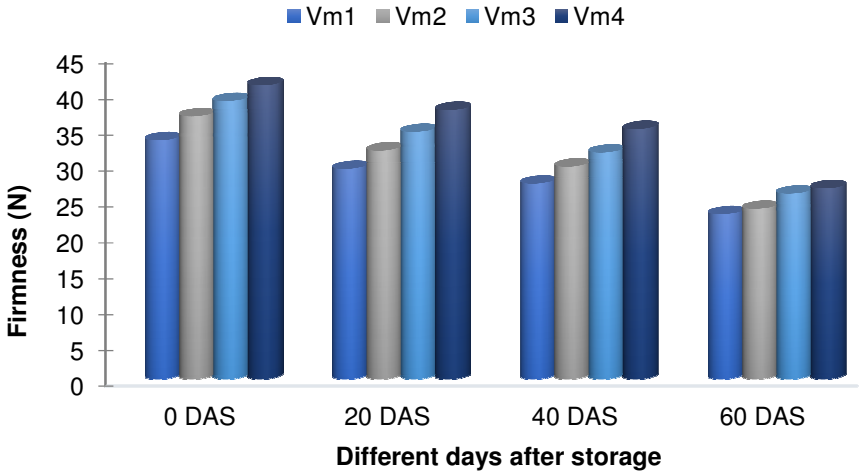

Fig. 3. Response to vermicompost on firmness (N) of potato tuber at different days after storage

(LSD values 1.2717, 0.5051, 0.3037 and 0.2633 for 0 DAS, 20 DAS, 40 DAS, and 60 DAS, respectively). Vm_1 – Control, Vm_2 – 3 t ha^{-1}, Vm_3 – 6 t ha^{-1}, Vm_4 – 9 t ha^{-1}

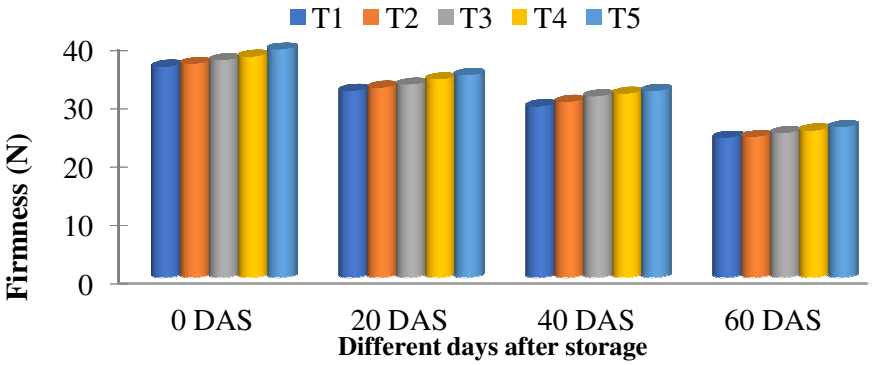

Fig. 4. Effect of tuber size on firmness (N) of potato tuber at different days after storage

(LSD values 0.6104, 0.3246, 0.2213 and 0.0908 for 0 DAS, 20 DAS, 40 DAS, and 60 DAS, respectively). T_1 5-10 g, T_2 – 10-20g, T_3 – 20-30 g, T_4 – 30-40 g, T_5 - >40 g

Table 3. Combined effect of vermicompost and tuber size on firmness of tuber flesh at different days after storage of potato

Combinations	Firmness (N) at			
	0 DAS	20 DAS	40 DAS	60 DAS
Vm_1T_1	32.066 k	28.052 o	25.239 p	21.310 n
Vm_1T_2	32.541 jk	28.868 n	26.717 o	22.260 m
Vm_1T_3	33.341 j	29.420 mn	27.857 n	22.840 l
Vm_1T_4	33.614 j	29.863 lm	28.074 mn	23.707 jk
Vm_1T_5	34.862 i	30.234 kl	28.207 mn	24.600 h
Vm_2T_1	36.104 hi	30.917 jk	28.384 m	23.513 k
Vm_2T_2	36.241 hi	31.261 j	28.853 l	22.510 m
Vm_2T_3	36.450 hi	31.956 i	29.597 k	23.720 j
Vm_2T_4	37.006 gh	32.321 hi	30.244 j	24.097 i
Vm_2T_5	37.391 f-h	32.736 gh	30.946 i	24.723 h
Vm_3T_1	37.605 f-h	33.168 g	30.311 j	25.147 g
Vm_3T_2	38.330 e-g	33.892 f	30.933 i	25.360 f
Vm_3T_3	38.643 e-g	34.035 f	31.678 h	25.780 e
Vm_3T_4	39.306 c-e	35.431 e	32.153 g	26.287 d
Vm_3T_5	39.941 cd	35.797 de	32.732 f	26.637 bc
Vm_4T_1	38.799 d-f	35.915 de	33.426 e	25.907 e
Vm_4T_2	39.489 c-e	36.260 d	33.913 d	26.377 cd
Vm_4T_3	40.538 bc	36.929 c	35.178 c	26.653 b
Vm_4T_4	41.662 b	38.369 b	35.631 b	26.803 b
Vm_4T_5	44.349 a	40.033 a	36.078 a	27.157 a
CV (%)	1.96	1.17	0.86	0.44
$LSD_{0.05}$	1.6691	0.7665	0.4971	0.3082
Level of significance	*	**	*	**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

*** = Significant at 1% level of probability, * = Significant at 5% level of probability; Vm_1 – Control, Vm_2 – 3 t ha^{-1}, Vm_3 – 6 t ha^{-1}, Vm_4 – 9 t ha^{-1}; T_1 5-10 g, T_2 – 10-20g, T_3 – 20-30 g, T_4 – 30-40 g, T_5 - >40 g*

A significant difference was found among different combination of vermicompost levels and tuber sizes on the specific gravity of tuber at different storage time. At 0 DAS the maximum specific gravity (1.0853 g cm^{-3}) of tuber showed by Vm_4T_4 which was statistically similar to Vm_4T_5 and Vm_3T_5, and minimum specific gravity (1.0460 g cm^{-3}) was shown by Vm_1T_5 which was statistically similar to Vm_1T_4, Vm_1T_2, Vm_1T_1 and Vm_1T_3. At 20 DAS maximum specific gravity (1.0817 g cm^{-3}) of tuber showed by Vm_4T_5 which was statistically similar to Vm_3T_5 and Vm_4T_4, and minimum (1.0410 g cm^{-3}) was shown by Vm_1T_5 which was statistically similar to Vm_1T_4 and Vm_1T_1. At 40 DAS maximum specific gravity (1.0780 g cm^{-3}) of tuber showed by Vm_4T_5 which was statistically similar to Vm_4T_4 and Vm_3T_5, and minimum (1.0300 g cm^{-3}) was shown by Vm_1T_1 which was statistically similar to Vm_1T_2. At 60 DAS maximum specific gravity of tuber (1.0733 g cm^{-3}) was shown by Vm_4T_5 which was statistically similar to Vm_4T_4, $Vm_3T_5$and Vm_3T_4, and minimum specific gravity (1.0220 g cm^{-3}) of tuber was shown by Vm_1T_1 which was statistically similar to Vm_1T_2 (Table 4).

High specific gravity is an essential processing quality factor for potato and increased with increasing vermicompost level. It ensures high dry matter content in the tuber. During ambient storage condition; specific gravity of potato tuber decreased with increasing ambient storage time, however higher level of vermicompost and bigger tuber size exhibited gradually decreased of specific gravity compared to control with sharply decreased of specific gravity [38].

3.4 Dry Matter Content

Significant variation was found among different levels of vermicompost on tuber dry matter content at different storage time. The maximum dry matter was obtained by Vm_4 (20.93%, 20.42%, 19.97%, 16.53%), and the minimum dry matter was obtained by Vm_1 (17.35%, 16.39%, 15.45%, 11.47%); at 0, 20, 40 and 60 DAS respectively (Fig. 7).

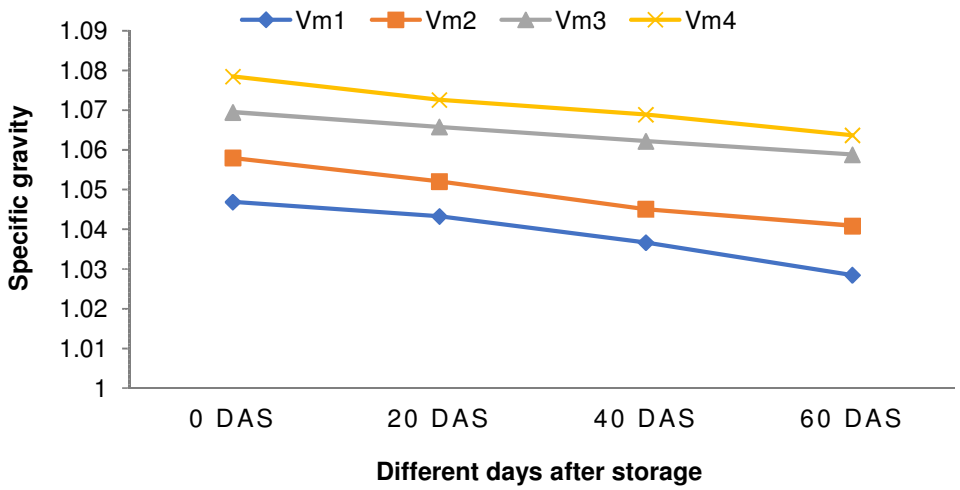

Fig. 5. Response to vermicompost on specific gravity (g cm^{-3}) of potato tuber at different days after storage

(LSD values 0.0007, 0.0008, 0.0007 and 0.0008 for 0 DAS, 20 DAS, 40 DAS and 60 DAS, respectively). Vm_1 – Control, Vm_2 – 3 t ha^{-1}, Vm_3 – 6 t ha^{-1}, Vm_4 – 9 t ha^{-1}

Table 4. Combined effect of vermicompost and tuber size on specific gravity at different days after storage of potato tuber

Combinations	Specific gravity (g cm^{-3}) at			
	0 DAS	20 DAS	40 DAS	60 DAS
Vm_1T_1	1.0463 j	1.0433 k-m	1.0300 i	1.0220 j
Vm_1T_2	1.0463 j	1.0443 j-l	1.0317 i	1.0240 ij
Vm_1T_3	1.0497 ij	1.0463 i-k	1.0367 h	1.0280 hi
Vm_1T_4	1.0460 j	1.0417 lm	1.0407 gh	1.0330 fg
Vm_1T_5	1.0460 j	1.0410 m	1.0447 fg	1.0353 f
Vm_2T_1	1.0550 h	1.0480 h-j	1.0370 h	1.0293 gh
Vm_2T_2	1.0577 gh	1.0507 gh	1.0373 h	1.0343 f
Vm_2T_3	1.0540 hi	1.0490 hi	1.0457 f	1.0420 e
Vm_2T_4	1.0600 fg	1.0543 ef	1.0510 e	1.0473 d
Vm_2T_5	1.0633 ef	1.0583 d	1.0543 de	1.0513 cd
Vm_3T_1	1.0583 gh	1.0543 fg	1.0513 e	1.0473 d
Vm_3T_2	1.0620 fg	1.0580 de	1.0553 de	1.0510 cd
Vm_3T_3	1.0667 de	1.0607 d	1.0587 cd	1.0541 c
Vm_3T_4	1.0787 bc	1.0750 b	1.0717 b	1.0700 ab
Vm_3T_5	1.0820 ab	1.0810 a	1.0740 ab	1.0713 a
Vm_4T_1	1.0697 d	1.0613 d	1.0580 cd	1.0530 c
Vm_4T_2	1.0757 c	1.0674 c	1.0604 c	1.0554 c
Vm_4T_3	1.0780 bc	1.0730 b	1.0717 b	1.0653 b
Vm_4T_4	1.0853 a	1.0797 a	1.0763 a	1.0717 a
Vm_4T_5	1.0840 a	1.0817 a	1.0780 a	1.0733 a
CV (%)	0.23	0.18	0.24	0.27
$LSD_{0.05}$	0.0013	0.0011	0.0013	0.0015
Level of significance	**	**	*	**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

*** = Significant at 1% level of probability, * = Significant at 5% level of probability; Vm_1 – Control, Vm_2 – 3 t ha^{-1}, Vm_3 – 6 t ha^{-1}, Vm_4 – 9 t ha^{-1}; T_1 5-10 g, T_2 – 10-20g, T_3 – 20-30 g, T_4 – 30-40 g, T_5 - >40 g*

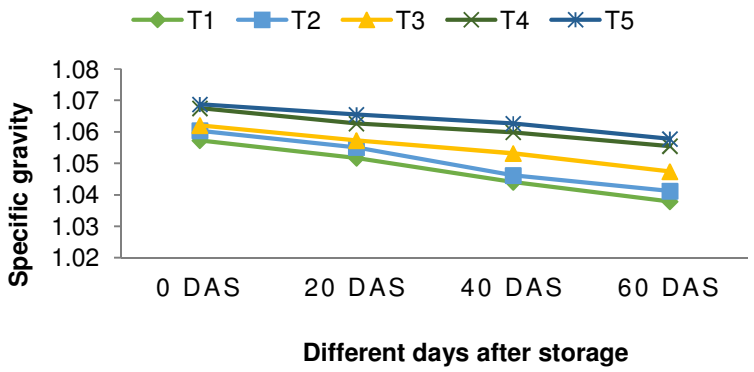

Fig. 6. Effect of tuber size on specific gravity (g cm^{-3}) of potato tuber at different days after storage

(LSD values 0.0006, 0.0005, 0.0006 and 0.0007 for 0 DAS, 20 DAS, 40 DAS and 60 DAS, respectively). T_1 5-10 g, T_2 – 10-20g, T_3 – 20-30 g, T_4 – 30-40 g, T_5 - >40 g

Profound dissimilarity was found among different tuber sizes to dry matter content at different storage time. At 0 DAS the maximum dry matter (20.70 %) was obtained by T_5 and minimum dry matter (18.04 %) was obtained by T_1. At 20 DAS maximum dry matter (19.99 %) was obtained by T_5 and minimum dry matter (17.33 %) was obtained by T_1. At 40 DAS maximum dry matter (19.14 %) was obtained by T_5 and minimum (16.65 %) was obtained by T_1. At 60 DAS maximum dry matter (15.32 %) was obtained by T_5 and minimum dry matter (13.01 %) was obtained by T_1 (Fig. 8).

Significant variation was found among different combination of vermicompost levels and tuber sizes on tuber dry matter content at different storage time. At 0 DAS the maximum dry matter (22.87 %) was obtained by Vm_3T_5 which was statistically similar to Vm_3T_4 and Vm_4T_5, and minimum dry matter (17.11 %) was obtained by Vm_1T_1 which was statistically similar to Vm_1T_2. At 20 DAS maximum dry matter (22.29 %) was obtained by Vm_3T_5 which was statistically similar to Vm_4T_5, and minimum dry matter content (16.16 %) was obtained by Vm_1T_1 which was statistically similar to Vm_1T_2. At 40 DAS maximum dry matter (21.52 %) was obtained by Vm_4T_5 which was statistically similar to Vm_4T_4, and minimum (15.21 %) was obtained by Vm_1T_1. At 60 DAS maximum dry matter (17.95 %) was obtained by Vm_4T_5 which was statistically similar to Vm_4T_4, and the minimum dry matter content (11.29 %) was obtained by Vm_1T_1 which was statistically similar to Vm_1T_2 (Table 5).

High dry matter content is an important processing quality factor, however during storage condition, it reduces gradually. High dry matter content (%) was observed which might be due to the application of high rate of vermicompost which played an important role in affecting the dry matter of tubers [38,39,40,41]. Loss of dry matter of tuber during storage period may be due to respiration [42]. Sprouting is a physiological process at which resting buds break their dormancy and resume growth by utilizing stored food [43].

3.5 Flesh Color

Significant dissimilarity was obtained among different levels of vermicompost on lightness (L*), green-red chromaticity (a*) and blue-yellow chromaticity (b*) of potato flesh at different storage time. The highest L* value (74.49, 73.06, 68.90) was taken by Vm_4, highest a* value (11.13, 2.73, 2.30) was taken by Vm_4, highest b* value (23.91, 22.97, 21.13) was taken by Vm_4; the lowest L* value (69.39, 63.25, 54.28) was taken by Vm_1, lowest a* value (2.50, 0.486, 0.280) was taken by Vm_1, lowest b* value (13.94, 10.68, 8.88) was taken by Vm_1; at 20, 40 and 60 DAS respectively (Table 6).

Profound dissimilarity was got among different tuber sizes on lightness (L*), green-red chromaticity (a*) and blue-yellow chromaticity (b*) of potato flesh at different storage time. At 20 DAS the highest L* value (72.83) was taken by T_5 which was statistically similar to T_4, and lowest (70.91) was taken by T_1; highest a* value (7.48) was taken by T_5 and lowest (5.35) was taken by T_1; highest b* value (20.49) was taken by T_5 and lowest (18.19) was taken by T_1. At 40 DAS

highest L* value (69.31) was taken by T_5 which was statistically similar to T_4, and lowest (67.98) was taken by T_1 which was statistically similar to T_2; highest a* value (1.77) was taken by T_5 and lowest (1.27) was taken by T_1; highest b* value (18.65) was taken by T_5 and the lowest (17.83) was taken by T_1. At 60 DAS highest L* value (63.74) was taken by T_5 and lowest (62.50) was taken by T_1 which was statistically similar to T_2; highest a* value (1.44) was taken by T_5 and lowest (1.06) was taken by T_1; highest b* value (16.78) was taken by T_5 which was statistically similar to T_4 and lowest (16.09) was taken by T_1 which was statistically similar to T_2 (Table 7).

Significant variation was obtained among different interaction of vermicompost level and tuber size on lightness (L*), green-red chromaticity (a*) and blue-yellow chromaticity (b*) of potato flesh at different storage time. At 20 DAS the highest L* value (75.60) was taken by Vm_4T_5 which was statistically similar to Vm_4T_4 and lowest (66.98) was taken by Vm_1T_1; highest a* value (11.76) was taken by Vm_4T_5 which was statistically similar to Vm_4T_4, and lowest (1.91) was taken by Vm_1T_1 which was statistically similar to Vm_1T_2; highest b* value (24.96) was taken by Vm_4T_5 which was statistically similar to Vm_4T_4 and lowest (12.31) was taken by Vm_1T_1. At 40 DAS highest L* value (73.75) of tuber flesh was taken by Vm_4T_4 which was statistically similar to Vm_4T_5 and the lowest (62.55) was taken by Vm_1T_1 which was statistically similar to Vm_1T_2; highest a* value (3.19) was taken by Vm_4T_5 and the lowest (0.390) was taken by Vm_1T_1 which was statistically similar to Vm_1T_2; highest b* value (23.50) was taken by Vm_4T_5 and lowest (10.44) was taken by Vm_1T_1 which was statistically similar to Vm_1T_2. At 60 DAS highest L* value (69.64) of tuber flesh was taken by Vm_4T_5 and the lowest (53.77) was taken by Vm_1T_1 which was statistically similar to Vm_1T_2 and Vm_1T_4; highest a* value (2.57) was taken by Vm_4T_5 and the lowest (0.136) was taken

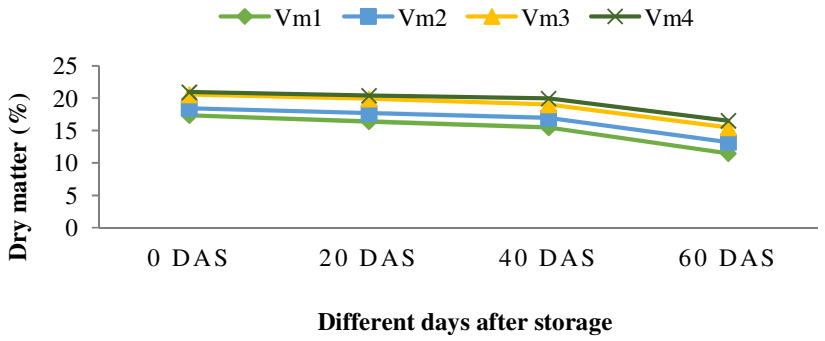

Fig. 7. Response to vermicompost on dry matter (%) of potato tuber at different days after storage

(LSD values 0.0676, 0.0331, 0.0322 and 0.0981 for 0 DAS, 20 DAS, 40 DAS and 60 DAS, respectively).Vm_1 – Control, Vm_2 – 3 t ha^{-1}, Vm_3 – 6 t ha^{-1}, Vm_4 – 9 t ha^{-1}

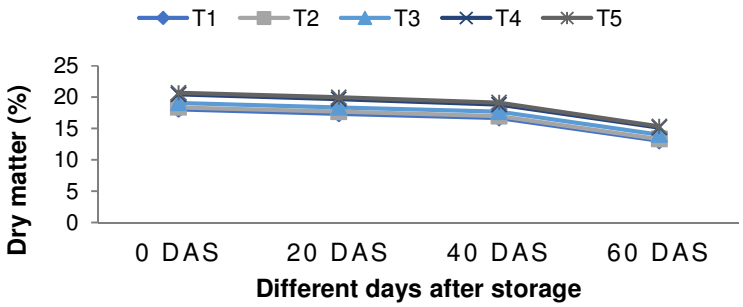

Fig. 8. Effect of tuber size on dry matter (%) of potato tuber at different days after storage

(LSD values 0.0684, 0.0285, 0.0211 and 0.1015 for 0 DAS, 20 DAS, 40 DAS and 60 DAS, respectively).T_1 5-10 g, T_2 – 10-20g, T_3 – 20-30 g, T_4 – 30-40 g, T_5 - >40 g

by Vm_1T_1. In respect of blue-yellow chromaticity (b*) of potato flesh was obtained numerically non-significant at 60 DAS (Table 8).

Table 5. Combined effect of vermicompost and tuber size on percent of dry matter content at different days after storage of potato tuber

Combinations	Dry matter (%) at			
	0 DAS	20 DAS	40 DAS	60 DAS
Vm_1T_1	17.11 k	16.16 p	15.21 s	11.29 m
Vm_1T_2	17.19 k	16.22 p	15.29 r	11.37 lm
Vm_1T_3	17.34 j	16.37 o	15.44 q	11.52 kl
Vm_1T_4	17.41 j	16.44 n	15.51 p	11.59 k
Vm_1T_5	17.71 i	16.74 m	15.81 o	11.56 kl
Vm_2T_1	17.69 i	16.93 l	16.19 n	12.48 j
Vm_2T_2	17.89 h	17.12 k	16.39 m	12.67 j
Vm_2T_3	18.29 g	17.53 j	16.79 l	13.08 i
Vm_2T_4	18.94 f	18.17 h	17.44 j	13.72 h
Vm_2T_5	19.46 e	18.69 f	17.96 h	14.24 f
Vm_3T_1	18.43 g	17.76 i	17.13 k	13.52 h
Vm_3T_2	18.86 f	18.19 h	17.56 i	13.94 g
Vm_3T_3	19.81 d	19.14 e	18.51 f	14.89 e
Vm_3T_4	22.81 a	22.16 b	20.73 c	17.41 b
Vm_3T_5	22.87 a	22.29 a	21.26 b	17.53 b
Vm_4T_1	18.92 f	18.49 g	18.08 g	14.73 e
Vm_4T_2	19.52 e	19.09 e	18.68 e	15.33 d
Vm_4T_3	20.89 c	20.46 d	20.05 d	16.71 c
Vm_4T_4	22.55 b	21.81 c	21.51 a	17.92 a
Vm_4T_5	22.77 a	22.24 a	21.52 a	17.95 a
CV (%)	0.43	0.18	0.14	0.86
$LSD_{0.05}$	0.1395	0.0607	0.0494	0.2058
Level of significance	**	**	**	**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

*** = Significant at 1% level of probability; Vm_1 – Control, Vm_2 – 3 t ha^{-1}, Vm_3 – 6 t ha^{-1}, Vm_4 – 9 t ha^{-1}*

T_1 5-10 g, T_2 – 10-20g, T_3 – 20-30 g, T_4 – 30-40 g, T_5 - >40 g

Table 6. Effect of vermicompost on flesh color at different days after storage of potato tuber

Vermicompost levels	Flesh color at								
	20 DAS			40 DAS			60 DAS		
	L*	a*	b*	L*	a*	b*	L*	a*	b*
Vm_1	69.39 d	2.50 d	13.94 d	63.25 d	0.486 d	10.68 d	54.28 d	0.280 d	8.88 d
Vm_2	71.23 c	4.09 c	18.64 c	67.36 c	1.173 c	17.86 c	62.47 c	0.942 c	16.80 c
Vm_3	72.79 b	8.24 b	20.61 b	71.02 b	1.753 b	21.32 b	66.74 b	1.494 b	18.92 b
Vm_4	74.49 a	11.13 a	23.91 a	73.06 a	2.733 a	22.97 a	68.90 a	2.304 a	21.13 a
CV (%)	1.35	1.77	1.07	0.49	1.28	0.31	0.54	1.95	1.40
$LSD_{0.05}$	0.8704	0.1029	0.1838	0.3027	0.0175	0.0511	0.3048	0.0218	0.2057
Level of significance	**	**	**	**	**	**	**	**	**

*In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly. ** = Significant at 1% level of probability.*

Vm_1 – Control, Vm_2 – 3 t ha^{-1}, Vm_3 – 6 t ha^{-1}, Vm_4 – 9 t ha^{-1}

Table 7. Response of tuber size on flesh color at different days after storage of potato tuber

Tuber size	Flesh color at								
	20 DAS			40 DAS			60 DAS		
	L*	a*	b*	L*	a*	b*	L*	a*	b*
T_1	70.91 d	5.35 e	18.19 e	67.98 c	1.27 e	17.83 e	62.50 c	1.06 e	16.09 c
T_2	71.63 c	5.51 d	18.66 d	68.14 c	1.42 d	17.96 d	62.65 c	1.15 d	16.24 bc
T_3	72.08 b	6.76 c	19.16 c	68.83 b	1.55 c	18.21 c	63.19 b	1.25 c	16.42 b
T_4	72.42 ab	7.35 b	19.87 b	69.10 a	1.65 b	18.38 b	63.40 b	1.37 b	16.65 a
T_5	72.83 a	7.48 a	20.49 a	69.31 a	1.77 a	18.65 a	63.74 a	1.44 a	16.78 a
CV (%)	0.69	0.24	1.02	0.46	1.33	0.35	0.51	1.06	1.36
$LSD_{0.05}$	0.4102	0.0128	0.1640	0.2650	0.0170	0.0527	0.2657	0.0111	0.1856
Level of significance	**	**	**	**	**	**	**	**	**

*In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly. ** = Significant at 1% level of probability.*
T_1 – 5-10 g, T_2 – 10-20 g, T_3 – 20-30 g, T_4 – 30-40 g, T_5 - >40 g

Table 8. Combined effect of vermicompost and tuber size on flesh color at different days after storage of potato tuber

Combinations	Flesh color at								
	20 DAS			40 DAS			60 DAS		
	L*	a*	b*	L*	a*	b*	L*	a*	b*
Vm_1T_1	66.98 k	1.91 p	12.31 o	62.55 l	0.390 s	10.44 q	53.77 k	0.136 t	8.55
Vm_1T_2	69.19 j	1.93 p	13.15 n	62.53 l	0.423 s	10.46 q	53.82 k	0.246 s	8.66
Vm_1T_3	70.05 i	2.66 o	13.53 m	63.63 k	0.473 r	10.69 p	54.93 i	0.280 r	8.84
Vm_1T_4	70.26 hi	2.99 n	14.57 l	63.25 k	0.553 q	10.85 o	54.21 jk	0.346 q	9.13
Vm_1T_5	70.49 hi	3.01 n	16.12 k	64.29 j	0.593 p	10.94 o	54.66 ij	0.393 p	9.24
Vm_2T_1	70.71 hi	3.28 m	18.19 j	66.39 i	0.943 o	17.27 n	61.650 h	0.836 o	16.41
Vm_2T_2	70.90 hi	3.34 l	18.32 j	66.53 i	1.08 n	17.50 m	61.79 h	0.903 n	16.67
Vm_2T_3	71.15 hi	3.73 k	18.51 j	67.89 h	1.16 m	17.87 l	62.49 g	0.953 m	16.80
Vm_2T_4	71.38 gh	4.82 j	18.92 i	67.92 h	1.24 l	18.15 k	63.13 f	0.980 l	16.95
Vm_2T_5	72.03 fg	5.28 i	19.25 h	68.09 h	1.42 k	18.52 j	63.29 f	1.04 k	17.16
Vm_3T_1	72.43 e-g	6.05 h	19.40 h	70.44 g	1.61 j	21.02 i	66.24 e	1.24 j	18.52
Vm_3T_2	72.53 ef	6.15 g	20.07 g	70.68 fg	1.67 i	21.13 h	66.39 e	1.31 i	18.66
Vm_3T_3	72.75 ef	9.29 f	20.79 f	70.97 ef	1.75 h	21.37 g	66.55 e	1.46 h	18.94
Vm_3T_4	73.03 d-f	9.87 e	21.18 e	71.50 de	1.82 g	21.44 g	67.15 d	1.67 g	19.20
Vm_3T_5	73.19 de	9.88 e	21.63 d	71.51 d	1.90 f	21.63 f	67.38 d	1.76 f	19.30
Vm_4T_1	73.54 de	10.18 d	22.86 c	72.57 c	2.13 e	22.59 e	68.37 c	2.02 e	20.86
Vm_4T_2	73.91 cd	10.63 c	23.11 c	72.81 c	2.52 d	22.75 d	68.61 bc	2.14 d	20.97
Vm_4T_3	74.38 bc	11.37 b	23.80 b	72.84 bc	2.84 c	22.90 c	68.78 bc	2.31 c	21.09
Vm_4T_4	75.01 ab	11.74 a	24.80 a	73.75 a	2.98 b	23.10 b	69.10 b	2.48 b	21.33
Vm_4T_5	75.60 a	11.76 a	24.96 a	73.36 ab	3.19 a	23.50 a	69.64 a	2.57 a	21.44
CV (%)	0.69	0.24	1.02	0.46	1.33	0.35	0.51	1.06	1.36
$LSD_{0.05}$	1.1337	0.1053	0.3451	0.5607	0.0350	0.1070	0.5628	0.0293	0.3894
Level of significance	**	**	**	**	**	**	*	**	NS

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.
*** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Non-significant.*
Vm_1 – Control, Vm_2 – 3 t ha^{-1}, Vm_3 – 6 t ha^{-1}, Vm_4 – 9 t $ha^{-1;}$ T_1 5-10 g, T_2 – 10-20 g, T_3 – 20-30 g, T_4 – 30-40 g, T_5 - >40 g

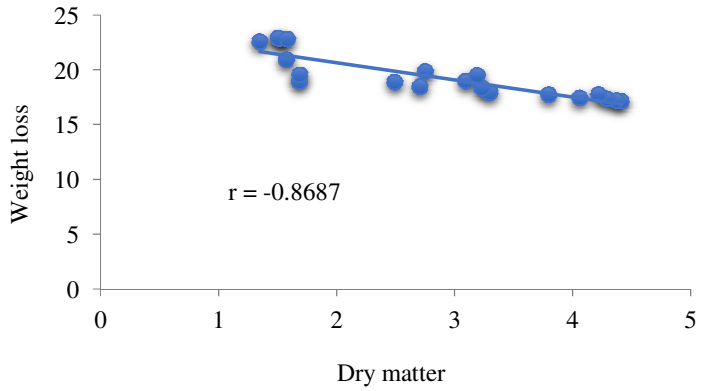

Fig. 9. A relationship between weight loss and dry matter of potato tuber at storage

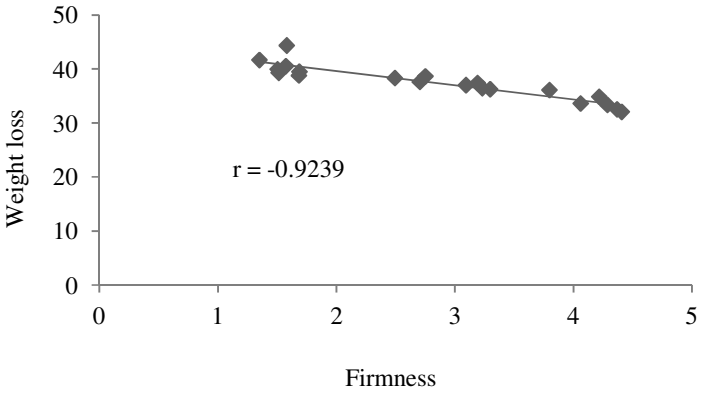

Fig. 10. A relationship between weight loss and firmness of potato tuber at storage

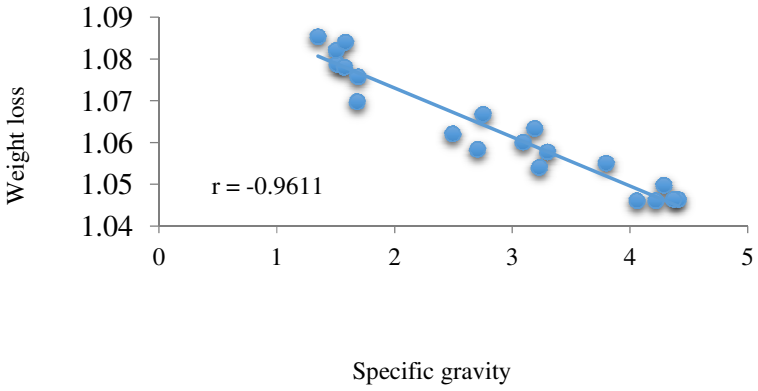

Fig. 11. A relationship between weight loss and specific gravity of potato tuber at storage

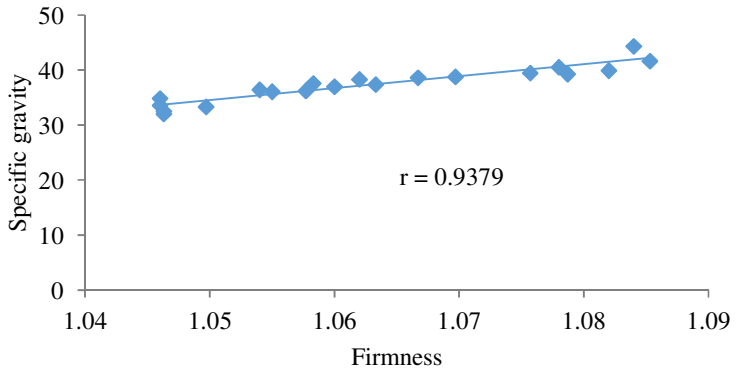

Fig. 12. A relationship between specific gravity and firmness of potato tuber at storage

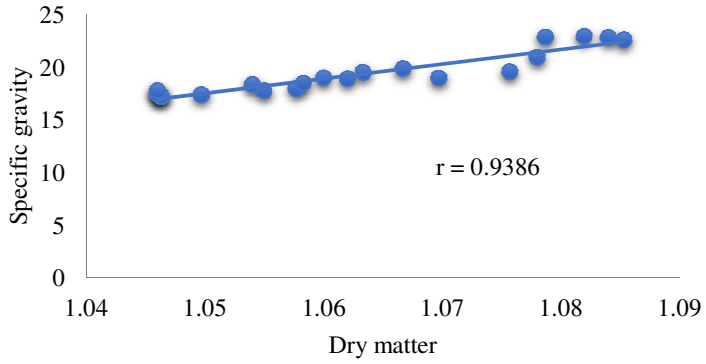

Fig. 13. A relationship between specific gravity and dry matter of potato tuber at storage

Higher Vermicompost rate was shown maximum tuber flesh color and sustained maximum storage time compared to control [44,45].

4.6 Correlation Coefficient (r)

The correlation was calculated on the basis of data from 0 days of storage condition *i.e.*, at harvesting day. In Fig. 9, a negative linear relation (r = -0.8687) presented between weight loss and dry matter percentage. In Fig. 10, a negative relation (r = -0.9239) presented between weight loss and firmness of potato tuber. In Fig. 11, a negative relation (r = -0.9611) presented between weight loss and specific gravity of tuber. In Fig. 12, a strong positive relation (r = 0.9379) presented between specific gravity and firmness. In Fig. 13, a strong positive relation (r = 0.9386) presented between specific gravity and dry matter content. A positive linear correlation between specific gravity and dry matter of tubers was observed earlier [46,47].

5. CONCLUSION

From this study, it may be concluded that vermicompost is good organic manure. It plays an important role in increasing tuber quality and ambient storage performance also. From the above discussion, it was observed that Vm_4T_5 that is vermicompost level 9 t ha^{-1} and tuber size >40 g showed the superior processing quality that is higher firmness, specific gravity, dry matter content, and flesh color compared to those of other treatments. However, the potato farmers of Bangladesh may be benefited for potato cultivation by using vermicompost, ultimately, they can produce high quality potato tuber and can store without decreasing processing quality at ambient storage condition up to 40 DAS.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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