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EFFECT OF SUBSTRATES ON THE YIELD, YIELD ATTRIBUTE AND DIETARY VALUES OF OYSTER MUSHROOM (*PLEUROTUS OSTREATUS*) IN THE PASTORAL REGIONS OF NORTHERN ETHIOPIA

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ABSTRACT

Dry areas are vulnerable to climate change and are commonly hit by drought, which makes the inhabitants to rely on food aid. Mushroom cultivation is a profitable agribusiness that can improve the economic and food status of farmers in dry areas as an alternative technology. Research on the effect of substrates on the yield, yield attributes and dietary values of oyster mushroom (*Pleurotus ostreatus*) was conducted to identify the best substrates. The experiment included 23 treatments with three replications. The substrates were sawdust, rice straw, cottonseed hull & maize cob with 100%, 75%, 50% and 25% combination ratios. The substrates were chopped, moisturized and filled into 40 cm X 60 cm polyethylene bags and sterilized for one hour at 100 ^{o}C. The substrates were cooled and inoculated with 75g mushroom spawn, and were kept in a dark place to enhance mycelium growth. The substrates were transferred to a growing room, with full light, lower temperature and higher relative humidity for fructification after mycelium growth was completed. Data on yield attributes, fresh yield and dietary values were collected and analyzed. The fruiting bodies were picked after 22 - 35 days of inoculation. The treatments had significant effect on the number of days for mushroom growth, stalk length, pileus diameter and number of fruiting body, fresh yield, biological efficiency and dietary values ($P < 0.05$). All consumers significantly preferred mushroom grown on 100% maize cob substrate. The 100% cottonseed hull substrate gave the highest profit (133.25US$ 100kg^{-1} substrate). The study concluded that 100% cottonseed hull substrate was the best substrate for oyster mushroom production at small-scale level. It was also the best nutritive source of substrate for oyster mushroom growth. Mushroom grown on a 100% maize cob substrate was a tasty and protein rich mushroom. Therefore, producers should be encouraged to use this substrate for maximizing the yield, for changing the agricultural wastes into food in the form of mushroom and for improving their livelihood. Oyster mushroom could play a pivotal role in supporting the food self-sufficiency, hence it should be included as a component of food security assurance strategy for the country.

Key words: mushroom, substrates, yield, pastoral, dietary value, agricultural waste, livelihood

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INTRODUCTION

There is a strong desire in Ethiopia to see the people come out of long lasting food insecurity and poverty. Despite this desire and willingness, there is a need for innovative ideas and concerted efforts as the problems are deep rooted and complex. One might suggest that intensification of the agricultural system in combination with soil conservation could be one of the solutions for increasing productivity and assuring food security even though it takes a long time. In Afar region, changes in natural environmental conditions have constantly influenced the pastoral livelihoods [1]. Recurrent droughts are challenges to food security in the region and during acute drought, all socio-economic activities are seriously affected. These factors have led to the degradation of natural resources and growing vulnerability of different agro-pastoral groups to ecological and economic stress, often resulting in poverty [2]. High malnutrition rates are common in the pastoral regions in different parts of the world. In order to solve this complex problem, simple alternative solutions that contribute considerably to immediate food self-sufficiency are required. Mushroom cultivation could be one of the options for alleviating household food shortage and poverty [3]. Mushrooms are nutritious and have a high content of protein that in some cases exceeds the protein content of beans; it is also rich in vitamins and minerals [4]. Besides, mushroom is said to have medicinal and other values [5].

Many people have a wrong perception with regard to mushroom in Ethiopia [5]. In spite of this wrong perception that mushrooms are food for the rich and need sophisticated technology for their production, it is observed in some countries of Africa that it can also be a food for the poor [6]. Nowadays, the demand for mushroom in Ethiopian cities is increasing [5]. The techniques used in the production system can also be handled by the poor, the disabled people and women [6]. Currently biotechnology performs all the activities of selecting the edible mushrooms from the poisonous ones and breeding the wild types to develop desirable commercial mushrooms [7, 8]. What is expected from the agro-pastoralist is to prepare substrates from any agricultural waste materials such as Teff straw, rice straw, wheat straw, poultry manure and other locally available agricultural wastes [9, 10, 11]. Construction of growing room is expected from the farmers; the room could be constructed from simple materials like thatches or other locally available materials [5].

The majority of Afar people are pastoralists and the livelihood of inhabitants in the study area is predominantly livestock husbandry [2]. Livestock is a source of income, food and a mode of transportation. Charcoal production, traditional mat making locally known as '*gadeta*', petty-trade and employment in local government and non-governmental organization also constitute the means of livelihood mainly for urban dwellers. Livestock are highly affected due to lack of feed at the time of drought. To alleviate this problem, the pastoralists are forced to move to distant places with their animals to search for water and grazing land. This movement, especially to the neighboring regions is the cause of conflicts. Moreover, inhabitants of the district are vulnerable to major hazards such as flooding, *Prosopis juliflora* invasion [2], livestock disease as well as intra and inter-tribal conflicts making the district to rely significantly on food aid.

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Afar is a low land region in northern Ethiopia with a suitable climatic condition for production of maize, sorghum, ground nuts, cotton, vegetables and fruit crops but unsuitable for pulses and oil seeds. Huge amounts of dry matter are produced yearly, which can be used for mushroom production. Therefore, the agricultural waste can support the production of mushroom with low investment costs and on small land in every household, but with a relatively high benefit in food supply and money return [6, 12]. This research was undertaken with the aim of investigating whether oyster mushroom can be grown well with easily available substrates, so that the agro pastoral community can benefit from mushroom production. Specifically, the study was conducted to evaluate the effect of different locally available substrates on the yield attributes and fresh yield of oyster mushroom; to appraise the effect of substrates on the biological efficiency; to investigate the effect of substrates on the dietary values of oyster mushroom and finally assess consumers' preferences and financial return from oyster mushroom production that was grown on different substrates.

MATERIALS AND METHODS

Study area

This study was conducted in Gewane District of Afar regional state of Ethiopia, which is located at 10^0 10, N and 40^0 32, E latitude and longitude, respectively. The study area lies at an altitude of about 626 meters above sea level. The area is characterized by a semi-arid climatic zone, with mean annual temperature of 32°C. The mean annual precipitation is about 400mm. The rainfall has a bimodal distribution pattern with the main rains, locally called *Karma*, accounting for above 60% of the annual total rainfall. The rains come between July and September followed by the grazing season of *Kayra* that occurs from September to November. *Sugum* (a minor rainy season) usually occurs in March and April and it accounts for 20% of the total rainfall. *Gilal* (a less severe dry season with relatively cool temperatures) occurs mainly between November and March. There is always uncertainty with the occurrence of rainfall, which makes conditions unsuitable for crop production [1, 2].

Methods

The experiment was carried out using a completely randomized design with 22 treatments and a control with 100% saw dust with three replications. Treatments were randomly assigned on shelves for mycelium running and fruiting body formation. The treatments included sawdust (SD), rice straw (RS), cottonseed hull (CSH) and maize cob (MC); these treatments were made with 100%, 75%, 50% and 25% combination ratios (Table 1).

Preparation of substrates

The rice straw and maize cob substrates were chopped by *machete* into 2 - 3 cm and 1 - 2 cm, respectively [13 , 14]. The cottonseed hull and saw dusts were procured in small pieces, therefore, did not need chopping. The substrates were weighed to desired proportions and mixed by hand on a clean cemented floor covered with a plastic sheet. After mixing, the substrates (except the maize cob) were soaked for 30 minute to allow for moisture absorption. The maize cob was soaked for 24 hours and composted for four days by covering with polyethylene sheet. The excess water was drained until it reached

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65% moisture level [13]. The moisture content of the substrates was determined by applying the squeeze test to determine whether the substrate is moist enough. A few drops of water (2 - 3 drops) were released with some pressure [8]. The substrates were filled in 40 cm X 60 cm polyethylene bags [15]. Each bag was tied loosely with strings. Finally, the heat resistant bags were sterilized using autoclaves for 60 minutes at 100 ^{o}C. The bags were allowed to cool for one day on clean shelves. The bags were inoculated aseptically with 75g of mushroom spawn and mixed thoroughly to ensure that the mushroom mycelium grew evenly throughout the substrate [8]. To allow aeration, 3 - 5 holes were made with a stainless steel knife on the bags. The bags were tagged properly on each substrate and arranged randomly on shelves in a dark place. The temperature and relative humidity of the growing room was recorded using a thermometer and hygrometer, respectively. The temperature range was 24 ^{o}C - 29 ^{o}C and 60 – 90% relative humidity (RH) for mycelium colonization [16]. The whole area of the plastic bag (including the bottom part) being covered by whitish mycelia was an indication for the bags to be opened for fruiting [8]. The compacted substrates were put on shelves, which was suitable for mushroom growth to different directions [5]. The growing room was at 19 - 24 ^{o}C, 80 – 95 % relative humidity and had adequate light for fructification. The floor was covered by carpets locally known as '*gadeta*' to sustain humidity and prevent dust from blowing. The compacted substrate was watered two to three times a day using a sprayer. The growing room was also sprinkled with water to increase the room's RH and the temperature was controlled using an air conditioner [15]. Picking of mushroom was done manually in the morning when the edges of the caps started to fold or curl upwards. The adhering substrate particles were removed manually and the fruiting body collected in baskets for further data collection.

Data collection and statistical analysis

The number of days for starting and completion of spawn running, pinhead and fruiting body formation was recorded taken every day after inoculation and the stalk (stipe) length, cap (pileus) diameter, fresh yield of mushroom were measured and the number of fruiting body was counted after harvesting. Sample mushrooms were obtained, one bunch (cluster) per 1kg of substrate randomly. From the selected bunch, three samples of fruiting body were selected. The stalk length (cm) and pileus diameter (cm) were measured from the sampled mushroom using a graduated ruler and number of fruiting bodies was determined by counting the total number of fruiting body per 1kg substrate at three replications and three flushes. The yield data were obtained by weighing the fresh mushroom harvested per unit production (plastic bag), which was expressed as gg^{-1} or weight of fresh yield dry $weight^{-1}$ of substrate [17]. The total number of mushroom samples was 69. They were collected from different substrates and replications separately, dried by cutting off at the basal part of the stalk, arranged in single layers on shelves and exposed to the sun for about three days under continuous sunshine [8]. They were then properly packed in plastic bags, labeled and submitted to Mekelle University Chemistry Laboratory for analysis of the protein, fiber, ash, phosphorous, fat, carbohydrate and moisture content. Moisture, ash and phosphorous were determined using standard methods of analysis [18]. The crude protein, total fat and crude fiber were estimated using automatic KEL PLUS, SOCUS PLUS and FIBRA PLUS equipment, respectively [18].

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The percentage of biological efficiency was calculated using the method of Mamiro and Mamiro [17]. Sixty consumers were chosen randomly from the pastoral community, half of them were women. Consumer preference was determined by tasting the roasted mushroom and collecting their responses about their favorite. The economic efficiency was done using the Net Present Value (NPV). The NPV is derived by subtracting the sum of the Present Value (PV) of a cash flow of costs from the sum of the PV of a cash flow of revenues.

The data were analyzed using SPSS version 20.0 software, modified in 2012. A one- way analysis of variance (ANOVA) was used to test for significance of variation in yield and yield attributes of substrates on different flushes. Means were compared using Tukey test, when F-test from ANOVA was significant at $p<0.05$.

RESULTS

Effect of substrates on yield attributes

The number of days to start and complete mycelium running in spawn bags ranged from 3 - 9 and 12 - 23 days, respectively (Table 2). The lowest days to start and complete mycelium running was recorded for T3, T4, T6, T14, T16, T18, T19 and T20, each taking three days to start; T3, T4 and T16 took 12 days for completion. The maximum number of days (nine) for the start of mycelium running was recorded for T1, T2, T11, T15 and T17, which was significantly different from T3, T4, T6, T14, T16, T18, T19 and T20 (Table 2). The maximum number of days for completion of mycelium running was 23, recorded for T19, which was significantly different from all substrates except T9, T10, T20 and T23 (Table 2).

The number of days required for starting of pinhead formation ranged from 15 to 27 days and for pinhead completion from 19 to 31 days (Table 2). The minimum number of days (15) for pinhead formation was recorded for T4, which was significantly different from all substrates except T3, T13 and T16 (Table 2). The maximum number of days for starting of pinhead formation (27 days) was documented from T19 and T20, which was significantly different from all substrates except from T23 (Table 2). The lowest number of days for pinhead completion was 19, recorded for T3 and T13, and was significantly different from all substrates except for T4, T6, T7, T14, T16, T18 and T21 (Table 2). The longest number of days to complete pinhead formation was 31 days for T20, which was significantly different from all substrates except for T10, T19 and T23 (Table 2).

Fruiting bodies were completed within 22 - 35 days after inoculation (Table 2). The lowest number of days (22) for fruiting bodies completion was recorded on T4, T7, T13 and T21, which was significantly different from all substrates except T3, T6, T8, T14 and T16 (Table 2). The highest number of days (35) was recorded on T10, which was significantly different from all substrates except from T19 and T20 (Table 2).

The stalk length and pileus diameter were variable for different flushing stages. In the first flush, the highest stalk length 3.91 cm was recorded from T18 whereas the lowest stalk length 2.07 cm was recorded from T4 (Table 3). In the second flush, the maximum stalk length 3.56 cm was recorded from T6, which was significantly different from T8

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and T7 (Table 3). The minimum stalk length (1.56 cm) was recorded from T8 and T10, which was significantly different from T6, T20 and T22 (Table 3). In the third flush, the highest stalk length (3.83 cm) was recorded from T22, which was significantly different from T3, T7, T8, T12 and T13 (Table 3). The lowest stalk length (1.61cm) was recorded from T12, which was significantly different from T22 and T23 (Table 3). Among the three flushes the maximum stalk length (3.91cm) was found for the T18 during the first flush and the minimum (1.56 cm) was recorded from T8 and T10 during the second flush (Table 3). In the first flush, the highest pileus diameter (7.66 cm) was obtained from T9, which was significantly different from T11 and T13. The lowest pileus diameter (3.66 cm) was recorded from T13 which was significantly different from T9 and T14 (Table 3). In the second flush, the highest pileus diameter (9.78 cm) was recorded from T8 which was significantly different from all substrates except T7, T9, T15 and T23. The lowest pileus diameter (4.29 cm) was obtained from T19 which was significantly different from T7 and T8 (Table 3). In the third flush, the highest pileus diameter (9.78 cm) was documented from T8 which was significantly different from all substrates except T3, T6, T7, T9, T12, T15 and T23. The lowest pileus diameter (4.50 cm) was recorded from T19 which was significantly different from T3, T6, T7, T8, T9, T12 and T15 (Table 3). The maximum pileus diameter (9.78 cm) was documented from T8 on the second and the third flushes and the minimum pileus diameter (3.66 cm) was recorded from T13 during the first flush (Table 3).

The maximum number of fruiting body (164.33) was recorded on T3 and was significantly different from the control in the first flush. The minimum number of fruiting body (7) was counted on the control. In the second flush, the highest number of fruiting body 96.67 was recorded from T3, which was significantly different from all substrates and the lowest number of fruiting body (4.67) was recorded from the control. In the third flush, the maximum number of fruiting body (23.33) was obtained from T3 and the lowest number of fruiting body (2.67) was recorded from the control. The maximum number of fruiting body (164.33) was counted from T3 in the first flush and the minimum number of fruiting body (2.67) was counted from T1 in the third flush (Table 3).

Effect of substrates on fresh yield

The highest yield (610g kg^{-1} of substrate) was obtained from T3 in the first flush, which was significantly different from all the substrates except T12, T15 and T22. The minimum fresh yield (60g kg^{-1} of substrate) was obtained from T20 in the first flush, which was significantly different from T3 (Table 4). In the second flush, the highest fresh yield 150g kg^{-1} of substrate was acquired from T22 and the lowest fresh yield 20g kg^{-1} of substrate was recorded from T1 and T7, which was significantly different from T6 (Table 4). In the third flush, the highest fresh yield 86.67 g kg^{-1} of substrate was obtained from T22, which was significantly different from the control, T7, T8, T10, T11, T13, T19, T20, T21 and T23. The lowest fresh yield 5g was obtained from T10, which was significantly different from T3, T14 and T22 (Table 4). The maximum total yield (796.7g) was obtained from T3 followed by T6 (581.7g), T22 (573.3g) and T14 (501.7g).

Effect of substrates on biological efficiency

The biological efficiency varied significantly between the treatments (Table 4). The highest biological efficiency (61%) was obtained from T3 during the first flush, which

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was significantly different from all the substrates except T12, T15 and T22. The lowest biological efficiency (6%) was obtained from T20 during the first flush which was significantly different from T3 (Table 4). In the second flush, the maximum biological efficiency (15%) was obtained from T22. The lowest biological efficiency (2%) was obtained from the control, T20 and T10, which was significantly different from T6 (Table 4). In the third flush, the highest biological efficiency (8.67%) was obtained from T22, which was significantly different from the control, T7, T8, T10, T11, T13, T19, T20, T21 and T23. The lowest biological efficiency (0.50%) was obtained from T10, which was significantly different from T3, T14 and T22 (Table 4). The total biological efficiency of T3 was 79.7%, which proved this treatment to be the superior substrate followed by T6 (58.2%), T22 (57.3%) and T14 (50.2%).

Effect of substrates on dietary values

The maximum protein content (18.64 %) was recorded from treatment 4. The crude protein content varied from 10.27 to 18.64% (Table 4). T4 was significantly different from T6 (Table 5). The crude fiber content on dry weight basis ranged from 10.20 to 32.60% (Table 5). The highest crude fiber content was obtained from T10 and the lowest crude fiber was found in T11, which was significantly different from T9 and T10 (Table 5). The ash content ranged from 3.33 to 26.67g (Table 5). The highest ash content was found in T16 whereas the lowest was in the T20 (Table 5). The total fat content ranged from 3.50 to 9.40 % (Table 5). The lowest and the highest total fat content were obtained from T9 and T18, respectively. The substrate combination T9 was significantly different from T16, T17 and T23. The total phosphorous content ranged from 7.23 to 13.40 ppm (Table 5). The highest phosphorous content was obtained from T1 whereas the lowest was obtained from T8. T5 was significantly different from T8, T9, T12, T13, T14, T16, T17, T19, T20, T22 and T23 (Table 5). The moisture content ranged from 4 to 29% (Table 5). The highest moisture content was recorded from T23 and the lowest moisture content was obtained from T8. The substrate combination T8 was significantly different from T1, T9, T11 and T23 (Table 5). The carbohydrate content ranged from 26.87 to 58.38 % (Table 5). The highest carbohydrate content was obtained from T11 whereas the lowest was in T5 (Table 5). The substrate T5 was significantly different from T11 and T20 (Table 5).

Consumers' preference and monetary value of mushroom

Mushroom grown on T4 was most preferred followed by the mushroom grown on T2. Mushroom grown on T3 ranked third. The mushroom with the highest protein content was preferred as the first choice by consumers. The mushroom with the second highest protein content ranked twelfth. The same was true for other dietary values examined in this study. The highest net present value was 133.26 US$ per 100kg of substrate obtained from T3 (100% CSH) followed by T6 (75%SD+ 25%CSH), T22 (25% RS +75% CSH), T17 (75% RS + 25% MC) and T14 (75% CSH+ 25% MC) (Table 6).

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DISCUSSION

The mycelium running was the first stage of mushroom cultivation. The mycelium running took 2-3 weeks after inoculation, which was in agreement with the findings of Shah *et al.* [15]. The length of days taken to complete mycelium running of oyster mushroom on different substrates might be due to a variation in the chemical composition and the C: N ratio of substrates [12]. The pinheads were formed after mycelium running was completed. This result was higher by four days from the study done by Ahmed and Syed [3] who reported that *Pleurotus ostreatus* completed spawn running in 17- 20 days on different substrates and the time for pinhead formation was found to be 23 - 27 days. The difference in the number of days taken to complete pinhead formation of oyster mushroom on different substrates might be due to a variation in the nutrient availability of substrates, the temperature and RH of cropping room during the transferring of the bags [12]. The nutrient availability and the C: N ratio of substrates affects the number of days taken by mushroom to produce pinheads and temperature and relative humidity have been considered to play a significant role [19].

Fruiting body formation was the final stage during the cultivation of mushroom. Fruiting bodies were completed in 3 - 4 weeks after inoculation of spawn [20]. The dissimilarity in fruiting body completion time might be due to the different types of substrates [21]. The first fruiting body occurred on different days depending on the type of substrate, which was in agreement with the findings of this study. Once the stalk length increased, the protein and ash content of mushroom decreased and the fat content of mushroom increased. This affects the quality of mushroom [22]. Mushrooms are expected to contain lower fat. Oyster mushroom quality depends on the length of stalk; the higher the stalk length, the poorer the quality of the mushroom [13].

The result of the pileus diameter from this study differed from that of Mondal *et al*. [13] in that the highest (7.8 cm) diameter was recorded on sawdust at first flush and the lowest (3.11 cm) was recorded on banana leaves and rice straw (1:3) of third flush. The pileus diameter affected the fresh yield. The increase of pileus diameter decreased the yield [13]. The fruiting body was the edible part of mushroom. The increase in the number of fruiting body significantly increased the yield of oyster mushroom. The yield of mushroom was dependent on number of fruiting body and more than 69 % of variation in the yield may be explained by variation in the number of fruiting body [13]. Temperature and relative humidity have been considered to play a significant role that affected production of fruit bodies of mushroom.

The difference in the yield might be due to the nutrient composition of the substrates. Varied substrate media for the cultivation of mushrooms affected the yield levels due to biological and chemical composition differences between the substrates and genotype of the cultured mushroom [23]. The yield performance of the *Pleurotus spp* mushroom affected C: N ratio of the substrates used for the cultivation [24]. The variations observed in the yield were related to the complexity of substrates in terms of their cellulose content resulting from the difference in the rate of degradation by the mushroom enzymes [5]. The highest level of nitrogen content in the substrates gives the highest yield [10]. In this

study the T3 (100% CSH) substrate was found to be the best substrate for production of *P. ostreatus* because it gave better yield per 1kg of substrate than the other substrates.

The variation in biological efficiency of substrates might be due to the characteristics of the substrates and the yield obtained from the substrates. These results were different from studies reporting that *Pleurotus ostreatus* gave maximum biological efficiency on sawdust [13]. Variation in biological efficiency of different substrates was due to low lignolytic and cellulonitic activity of the substrates used [25]. The protein content of *Pleurotus ostreatus* varied from 20.33% to 24.66%, which was different from those obtained by Shyam *et al.* [26]. The variation in protein content might be due to the source of substrate. The nature of protein in the substrate influences the protein content of the fruiting bodies [25]. Chitin nitrogen is responsible for high protein values derived with the usual 6.25 factor [27]. Dietary fiber content values were similar with 27.0 % with soybean stalk and 31.32 % with millet stalk medium [10]. The fiber content of *P. ostreatus* cultivated on wheat straw was 34.8% [28]. The crude fiber ranged from 11.72 to13.23% for oyster mushroom grown on banana leaves and paddy straw, respectively [29]. The variation in crude fiber content might be due to the part of mushroom used and the substrate degradability. The decrease in the fiber fractions could be due to the production of various enzymes during the vegetative and reproductive phases with cellulose degrading properties [11].

The ash content was lower than that of Bonatti *et al*. [30], found to be 5.58 and 6.13g of ash in *P. ostreatus* cultivated in banana leaves. The result agreed with that of Henock *et al*. [31] that substrates showed no differences in ash content. In this study, the fat amount obtained was higher than that of Bonatti *et al.* [30] with 5.97 and 6.32% in mushrooms cultivated in banana and rice straw, respectively. The variation in fat content might be due to the type of substrate [26]. Similarly, the variation in fat content of mushroom arises from biological and chemical differences of substrate media [10]. The variation in phosphorous content of mushroom might be due to the nutrient composition of the substrates. The mineral concentration of mushrooms can be influenced by a number of factors including mushroom species and strain types, age of the mushroom, part of the mushroom used, the composition of the growth substrate and the environment [9]. The variation in moisture content might be due to the water holding capacity of the substrates and the substrates used [29]. The moisture content varied with cropping, watering conditions of the substrate and type of substrate used. This result did not support the study of Shyam *et al*. [26] that the moisture content of mushroom is independent of substrate and is associated with mushroom species. The difference in carbohydrate content might be due to the effect of substrate. The nutritional value of mushroom largely depends on chemical the composition of the substrate, which causes variation in the composition of same species of mushroom [32].

Mushrooms have some unique color, taste, aroma and texture characteristics, which attract the attention of consumers [33]. The variation in preference of mushroom might be due to the taste of mushroom. The desirability of a food product does not necessarily bear any relationship to its nutritional value [33]. Instead, its appearance, taste and aroma may sometimes stimulate consumer behavior. Variation in the net present value of this study was observed due to the cost of substrates and the yield obtained from each

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substrate. The cost of production, productivity of substrates, growing system used and the scale of production are among the factors that affect the output and revenue considerably [34].

CONCLUSION

The fresh yield, yield attributes, dietary value, biological efficiency and consumer preference of mushrooms can be greatly affected by the type of substrates. Despite the difference in the dietary values of the mushrooms, the overall nutritional potential of the mushrooms was good. The agricultural wastes (saw dust, rice straw, cottonseed hull and maize cob) used in this study for cultivation of *P. ostreatus* are usually burnt or left in the field to rot. They can be effectively used for the cultivation of *P. ostreatus*. These substrates will provide an economic gain to the pastoralists and protect the environment, while providing a nutritious food source such as mushrooms. The 100% CSH substrate is found to be the most convenient substrate for the cultivation of *P. ostreatus* at small-scale level compared to the other substrates. The 100% CSH substrate is the best nutritive source of substrate for oyster mushroom growth. Therefore, producers should be encouraged to use this substrate for maximizing the yield in utilizing agricultural waste to produce food in the form of mushroom. Mushroom grown on a 100% MC substrate is tasty and protein rich. Oyster mushroom can play a pivotal role in promoting food self-sufficiency; therefore, it should be included as one component of food security assurance strategy of the country.

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Table 1: Substrate composition

Treatments	Substrates	Treatments	Substrates
T1	100%SD(control)	T13	25% SD + 75%MC
T2	100%RS	T14	75%CSH + 25% MC
T3	100%CSH	T15	50%CSH + 50% MC
T4	100%MC	T16	25%CSH + 75% MC
T5	75%SD + 25%RS	T17	75% RS + 25% MC
T6	75%SD + 25% CSH	T18	75%RS + 25% CSH
T7	75%SD + 25 % MC	T19	50% RS + 50% MC
T8	50% SD + 50% RS	T20	50% RS + 50% CSH
T9	50% SD + 50% CSH	T21	25% RS + 75% MC
T10	50% SD + 50% MC	T22	25% RS + 75% CSH
T11	25% SD + 75% RS	T23	25%MC+25% RS+25% CSH+25% SD
T12	25% SD + 75% CSH		

SD- sawdust; RS-Rice straw; CSH- Cottonseed hull; MC- Maize cob

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Table 2: Effect of different substrates and combination of substrates on mycelium running, pinhead and fruiting body formation

Treatments	Substrates	Mean number of days				
		Starting of mycelium running ± SD	Completion of mycelium running ±SD	Starting of pinheads formation ± SD	Completion of pinheads formation± SD	Completion of fruiting body formation ± SD
T1	100%SD (Control)	9.00±1.000b	19.33±0.577 c	23.00±1.000 c	25.00±1.000 c	26.00±1.000 b
T2	100 %RS	9.00±1.000 b	15.00±1.000 b	19.00±1.000 b	24.00±1.000 bc	26.00±1.000 b
T3	100 %CSH	3.00±1.000 a	12.00±1.000 a	16.00±1.000 a	19.00±1.000 a	23.00±1.000 a
T4	100 %MC	3.00±1.000 a	12.00±1.000 a	15.00±1.000 a	20.00 ±2.646 ab	22.00±1.000 a
T5	75% SD+25% RS	6.00±1.00ab	17.17±1.04bc	21.00±1.04def	23.00±0.00bcd	28.00±1.00c
T6	75%SD +25% CSH	3.00±1.00 a	15.00±1.00ab	19.00±1.00bcd	20.00±1.00ab	23.00±1.00 ab
T7	75%SD+25 % MC	6.00±1.00 ab	15.00±0.57b	19.00±1.00bcd	20.00±1.00ab	22.00±1.00 a
T8	50% SD+50% RS	6.00±1.00ab	17.50±1.50bc	21.00±1.04def	23.00±0.00bcd	26.00±1.00 abc
T9	50% SD+50% CSH	6.00±1.00 ab	21.00±1.00 de	23.00±1.00efg	25.00±1.00 de	27.00±1.00 bc
T10	50% SD+50% MC	6.00±1.00 ab	20.00±1.00cde	24.00±1.00fgh	28.00±1.00ef	35.00±1.00 f
T11	25% SD +75% RS	9.00±1.00b	17.17±1.04bc	22.17±1.04efg	24.00±1.00cd	29.33±4.93 cd
T12	25% SD+75% CSH	6.00±1.00ab	15.00±1.00 ab	20.00±1.00 cde	23.00±1.00bcd	27.00±1.00 bc
T13	25% SD+75 % MC	6.00±1.00ab	15.00±1.00ab	18.00±1.00abc	19.00±1.00a	22.00±1.00 a
T14	75%CSH+25% MC	3.00±1.00 a	15.00±1.00ab	19.00±1.00bcd	20.00±1.00ab	23.00±1.00 ab
T15	50%CSH+50% MC	9.00±1.00b	17.00±1.00bc	22.00±1.00defg	24.00±1.00cd	27.00±1.00 bc
T16	25%CSH+75% MC	3.00±1.00 a	12.00±1.00a	16.00±1.00ab	21.00±1.00abc	23.00±1.00 ab
T17	75% RS+25% MC	9.00±1.00b	17.17±1.04bc	22.17±1.04 efg	24.00±1.00cd	28.00±1.00 c
T18	75%RS +25% CSH	3.00±1.00a	15.00±1.00ab	19.00±1.00bcd	22.00±1.00abcd	27.00±1.00 bc
T19	50% RS+50% MC	3.00±1.00a	23.00±1.00e	27.00±1.00hi	30.00±1.00 f	34.00±1.00 ef
T20	50% RS+50% CSH	3.00±1.00 a	21.00±1.00de	27.00±0.57 i	31.00±1.00f	33.00±1.00 def
T21	25% RS +75% MC	7.00±1.00b	15.00±1.00 ab	19.00±1.00bcd	20.00±1.00 ab	22.00±1.00 a
T22	25% RS+75% CSH	6.00±1.00 ab	17.67±0.57bc	21.00±1.00cdef	25.00±1.00de	27.00±1.00 bc
T23	25%RS+25%MC+25%SD+25%CSH	6.00±1.00ab	21.00±1.00 de	24.67±0.57 ghi	28.00±1.00 ef	30.33±1.53 cde

NB: Means with different letters in the same rows are significantly different (P<0.05) by Tukey multiple range test.SD: Saw dust RS: Rice straw CSH: Cottonseed hull MC: Maize cob at 100%, 75%, 50% & 25% treatment combinations

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Table 3: Effect of substrates and substrate combinations on yield attributes of oyster mushroom

Treatments	Substrates	Stalk length (cm)			Pileus diameter (cm)			Number of fruiting body		
		1st flush	2nd flush	3rd flush	1st flush	2nd flush	3rd flush	1st flush	2nd flush	3rd flush
T1	100%SD(Control)	2.83±.44 a	2.44±.10ab	2.39±.26abcd	6.33±1.21ab	6.44±.10abc	6.50±.17abc	7.00±2.00 a	4.67±.58 a	2.67±.58 a
T2	100%RS	2.94±.82a	2.00±.44ab	3.39±.54bcd	5.61±.26ab	6.00±1.02ab	6.66±.58abc	34.67±15.95ab	25.33±13.05 a	9.00±5.29a
T3	100%CSH	2.99±.91a	1.94±.20ab	1.89±.35abc	6.30±.38ab	6.16±3.18ab	7.61±1.62bcd	164.33±83.63b	96.67±53.16 b	23.33±20.50a
T4	100%MC	2.07±.323a	2.07±.40ab	2.11±.10abcd	6.00±.60ab	6.84±.29abc	6.56±.20abc	26.00±13.08ab	21.33±14.01 a	8.00±4.58 a
T5	75% SD+25% RS	2.95±.63 a	2.61±1.01ab	2.72±.25abcd	5.78±.58ab	6.89±.96abc	6.78±1.07abc	44.67±38.48ab	14.33±3.79 a	7.67±2.52 a
T6	75%SD +25% CSH	3.71±.17a	3.56±.92 b	2.33±.93abcd	7.49±1.37ab	6.28±1.50ab	7.45±2.34bcd	84.67±36.02ab	35.67±12.50 a	17.67±2.08 a
T7	75%SD+25 % MC	2.22±.42a	1.94±.10ab	2.00±.17abc	6.75±1.32ab	9.22±.39cd	9.28±.25cd	40.67±22.59ab	8.33±4.16 a	5.33±1.156a
T8	50% SD+50% RS	3.11±.35a	1.56±.10a	1.78±.25ab	7.00±1.61ab	9.78±.39 d	9.78±.39d	21.67±23.71ab	18.33±15.31a	9.00±7.00a
T9	50% SD+50% CSH	3.46±.61a	2.78±.09ab	3.24±.78abcd	7.66±1.76b	7.50±.40bcd	7.50±.60bcd	59.33±7.77ab	28.67±10.97a	16.67±7.64 a
T10	50% SD+50% MC	2.83±.93a	1.56±.10 a	2.33±1.17abcd	6.72±.92ab	6.89±.38abc	6.55±1.07abc	21.67±9.87ab	13.00±1.73 a	6.33±1.53 a
T11	25% SD +75% RS	2.83±1.01a	1.94±.42ab	2.17±.17abcd	6.03±1.77 a	5.89±.96ab	5.89±.96ab	66.67±44.16ab	13.33±8.51 a	6.00±3.00 a
T12	25% SD+75% CSH	2.75±.52a	2.55±1.11ab	1.61±.10 a	5.22±1.23ab	6.89±.38abc	7.39±.98bcd	150.3±155.26ab	33.00±28.58 a	16.00±8.72 a
T13	25% SD+75 % MC	2.11±.19 a	2.08±.09ab	2.06±.34abc	3.66±.89 a	6.67±.00abc	6.67±.00abc	82.67±18.93ab	20.33±10.41 a	6.33±3.22a
T14	75%CSH+25% MC	2.50±.72a	2.56±1.40ab	2.39±.54abcd	7.58±2.71b	6.33±.54ab	6.72±.48abc	69.00±47.51ab	32.33±13.05 a	21.00±12.53a
T15	50%CSH+50% MC	2.98±.37a	3.06±.10ab	3.06±.10abcd	6.39±.35ab	7.39±.26bcd	7.61±.63bcd	88.33±88.05ab	28.67±16.77 a	15.33±18.01 a
T16	25%CSH+75% MC	3.00±.577 a	2.28±.25ab	2.11±.10abcd	5.91±.88ab	6.94±.68abc	6.72±.42abc	75.67±38.07ab	36.33±30.37 a	11.33±3.056 a
T17	75% RS+25% MC	2.72±1.30a	3.04±.57ab	2.17±.17abcd	5.53±.90ab	6.55±1.19abc	6.51±1.06abc	42.00±22.61ab	25.00±12.77 a	12.67±6.66 a
T18	75%RS +25% CSH	3.91±1.25 a	2.11±.67ab	2.67±.60abcd	6.82±.86ab	5.07±.90ab	5.06±.92ab	102.67±42.40ab	16.67±5.69 a	11.67±4.73a
T19	50% RS+:50% MC	3.03±.50a	2.53±.28ab	2.83±.58abcd	6.52±1.21ab	4.29±.24ab	4.50±.17 a	84.67±4.16ab	20.33±16.65 a	10.67±7.02 a
T20	50% RS+50% CSH	3.56±.10a	3.39±.35 b	3.11±.82abcd	6.95±.25ab	6.55±.25abc	6.56±.534abc	19.33±8.33ab	10.33±5.13 a	4.33±1.53 a
T21	25% RS +75% MC	2.67±.17a	2.44±.10ab	2.67±.17abcd	5.50±1.74ab	6.11±.19ab	6.22±.54ab	90.33±41.36ab	24.33±4.04 a	10.00±8.72 a
T22	25% RS+75% CSH	3.33±.60 a	3.55±.63b	3.83±.29 d	6.52±1.34ab	6.11±.19ab	6.67±1.16abc	127.67±48.52ab	21.00±6.08 a	13.33±6.11a
T23	25%RS+25%MC+25 %SD+25%CSH	3.36±1.56a	2.44±.10ab	3.56±1.29cd	6.45±1.25ab	7.22±.25bcd	7.06±.42abcd	48.67±31.01ab	14.67±7.51 a	5.67±3.06 a

NB: Means with different letters in the same rows are significantly different (P<0.05) by Tukey multiple range test. SD: Saw dust RS: Rice straw CSH: Cottonseed hull MC: Maize cob at 100%, 75%, 50% & 25% treatment combinations

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Table 4: Effect of substrates and substrate combinations on the yield and biological efficiency of oyster mushroom

Treatments	Substrates	Weight of yield(g)			Biological efficiency (%)		
		1st flush	2nd flush	3rd flush	1st flush	2nd flush	3rd flush
T1	100%SD(Control)	70.00±72.11a	20.00±26.458a	6.67±5.77 a	7.00±7.211 a	2.00±2.65 a	.67±.577 a
T2	100%RS	106.67±11.55a	100.00±.00ab	46.67±5.77abcd	10.67±1.155 a	10.00±.00ab	4.67±.577abcd
T3	100%CSH	610.00±105.36b	116.67±76.376ab	70.00±26.47bcd	61.00±10.536 b	11.67±7.64ab	7.00±2.646bcd
T4	100%MC	186.67±32.15 a	53.33±15.275 a	30.00±10.00abcd	18.67±3.215 a	5.33±1.53 a	3.00±1.00abcd
T5	75% SD+25% RS	150.00±50.00a	83.33±28.868 a	26.67±11.55abcd	15.00±5.00 a	8.33±2.89 a	2.67±1.155abcd
T6	75%SD +25% CSH	301.67±23.63a	233.33±57.74b	46.67±15.275abcd	30.17±2.363 a	23.33±5.77 b	4.67±1.528abcd
T7	75%SD+25 % MC	116.67±76.38a	66.67±28.868 a	13.33±5.774ab	11.67±7.638 a	6.67±2.89 a	1.33±.577ab
T8	50% SD+50% RS	136.67±32.15a	83.33±28.868 a	16.67±5.774ab	13.67±3.215 a	8.33±2.89 a	1.67±.577ab
T9	50% SD+50% CSH	270.00±72.11 a	120.00±75.498ab	30.00±20.00abcd	27.00±7.211 a	12.00±7.55ab	3.00±2.00abcd
T10	50% SD+50% MC	86.67±32.15 a	20.00±10.000 a	5.00±5.00 a	8.67±3.215 a	2.00±1.00 a	.50±.500 a
T11	25% SD +75% RS	176.67±68.07 a	56.67±40.415 a	11.67±7.638ab	17.67±6.807 a	5.67±4.04 a	1.17±.764ab
T12	25% SD+75% CSH	333.33±152.75ab	70.00±72.111 a	56.67±40.415abcd	33.33±15.275ab	7.00±7.21 a	5.67±4.041abcd
T13	25% SD+75 % MC	140.00±52.92 a	70.00±26.458 a	20.00±10.00abc	14.00±5.292 a	7.00±2.65 a	2.00±1.00abc
T14	75%CSH+25% MC	301.67±97.51 a	120.00±72.11ab	80.00±62.450cd	30.17±9.751 a	12.00±7.21ab	8.00±6.245cd
T15	50%CSH+50% MC	333.33±144.34ab	66.67±28.868 a	26.67±20.207abcd	33.33±14.434ab	6.67±2.89 a	2.67±2.021abcd
T16	25%CSH+75% MC	256.67±174.74 a	56.67±5.774 a	40.00±10.00abcd	25.67±17.474 a	5.67±.58 a	4.00±1.00abcd
T17	75% RS+25% MC	270.00±60.83 a	133.33±57.735ab	46.67±15.275abcd	27.00±6.083 a	13.33±5.77ab	4.67±1.528abcd
T18	75%RS +25% CSH	300.00±100.00 a	63.33±32.146 a	25.00±5.00abcd	30.00±10.000a	6.33±3.22 a	2.50±.500abc
T19	50% RS+:50% MC	83.33±28.87 a	83.33±57.735 a	23.33±5.77abc	8.33±2.887 a	8.33±5.774 a	2.33±.577abc
T20	50% RS+50% CSH	60.00±36.06 a	26.67±20.817 a	8.33±2.89ab	6.00±3.606 a	2.67±2.08 a	.83±.289ab
T21	25% RS +75% MC	283.33±189.30 a	100.00±50.000ab	18.33±10.408abc	28.33±18.93 a	10.00±5.00ab	1.83±1.04abc
T22	25% RS+75% CSH	336.67±158.22ab	150.00±50.00ab	86.67±23.094d	33.67±15.822ab	15.00±5.00ab	8.67±2.309d
T23	25%RS+25%MC+25%SD+25%CSH	186.67±77.68 a	63.33±32.146 a	20.00±10.00abc	18.67±7.767 a	6.33±3.22 a	2.00±1.00abc

NB: Means with different letters in the same rows are significantly different (P<0.05) by Tukey multiple range test. SD: Saw dust RS: Rice straw CSH: Cottonseed hull MC: Maize cob at 100%, 75%, 50% & 25% treatment combinations

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Table 5: Effect of substrates and substrate combinations on dietary value of mushroom

Treatments.	Substrate rates	Parameters						
		Crude Protein (%) Mean ± SD	Crude fiber (%) Mean ± SD	Ash(g) Mean ± SD	Total fat (%) Mean ± SD	Phosphorous(ppm) Mean ± SD	Moisture (%) Mean ± SD	Total Carbohydrate (%) Mean ± SD
T1	100% SD(Control)	12.72±2.336ab	19.47 ±11.60 ab	17.89±2.589a	6.13± 2.409 cde	11.81±5.537 ab	28.00±6.928 c	43.80±12.147 abcd
T2	100%RS	14.85±4.05 ab	12.39±7.41 ab	18.56 ± 2.72 a	6.33 ± 1.10 cde	12.58±5.005 ab	17.33±3.06 abc	47.87±13.375 abcd
T3	100%CSH	14.27 ± 2.81 ab	26.53 ± 11.22 ab	3.56 ± 0.39 a	6.10 ±1.77 a	9.89 ± 1.18 ab	21.33 ±12.86 abc	49.54±15.657bcd
T4	100%MC	18.64 ±1.54 b	25.66 ±1.60ab	15.22 ± 9.75 a	6.40 ± 3.59 abcde	10.92 ± 6.18 ab	13.87 ± 2.01 abc	34.08±10.478 abc
T5	75% SD+25% RS	16.74±1.31ab	30.30±70 ab	19.33±.67 a	6.75±1.15cde	16.92±1.00 b	21.00±3.00abc	26.87±1.094a
T6	75%SD +25% CSH	10.27±.21 a	28.33±1.3 ab	15.00±1.67a	6.67±1.33 abcde	11.15±1.00 ab	15.50±.50 abc	39.73±1.881 abcd
T7	75%SD+25 % MC	11.65±1.46ab	24.00±1.00 ab	15.00±1.67 a	4.40±1.40abcde	9.61±1.00 ab	7.50±.50 ab	44.95±3.067 abcd
T8	50% SD+50% RS	15.29±3.06ab	27.01±13.22 ab	10.33±.33 a	5.40±.40 abcd	7.23 ±1.00 a	4.00±.00 a	41.96±9.424 abcd
T9	50% SD+50% CSH	15.00±3.35 ab	30.59±5.01 b	8.83±4.50 a	3.50±1.00 abc	7.23±1.00 a	23.50±3.50 bc	42.08±2.859 abcd
T10	50% SD+50% MC	17.04±.15 ab	32.60±3.00 b	12.00±5.33a	8.40±.50 abcd	9.75±1.00 ab	16.00±4.00 abc	29.96±2.979 abc
T11	25% SD +75% RS	14.71±2.77ab	10.20±3.40 a	11.67±8.33 a	5.05±2.55 abcd	11.15±1.00 ab	27.00±13.0 c	58.38±4.717d
T12	25% SD+75% CSH	14.56±1.46 ab	13.40±2.60ab	19.17±2.50 a	3.90±1.9cde	9.38±.80 a	13.00±3.00 abc	48.97±3.256bcd
T13	25% SD+75 % MC	16.30±2.63ab	13.20±1.60ab	17.00±2.00 a	8.30±.70bcde	9.15±1.00 a	20.00±2.00abc	45.20±1.531 abcd
T14	75%CSH+25% MC	15.00±3.35ab	19.36±6.64ab	13.67±3.67 a	6.75±2.25 abcd	7.82±1.00 a	23.00±7.00 a	45.23±4.708 abcd
T15	50%CSH+50% MC	16.31±1.75 ab	24.70±.70 ab	5.33±1.33 a	5.50±2.50 ab	10.26±2.22 ab	22.00±8.00 abc	48.16±2.214 abcd
T16	25%CSH+75% MC	16.60±.00 ab	18.70±7.10ab	26.67±3.33 a	5.30±2.30 e	9.25±.50 a	23.00±5.00a	32.73±6.067 abc
T17	75% RS+25% MC	15.14±2.91 ab	27.50±3.50 ab	21.67±1.67 a	7.30±1.70de	9.40±1.00 a	15.00±1.00abc	28.39±.621 ab
T18	75%RS +25% CSH	16.60±1.46ab	21.00±11.40 ab	8.33±5.00 a	9.40±3.60 abc	10.47±2.00 ab	20.00±4.00abc	44.67±1.344 abcd
T19	50% RS+50% MC	15.43±.87 ab	23.80±3.00 ab	12.67±6.00a	4.35±1.45 abcd	9.04±2.97 a	20.00±8.00 abc	43.75±9.576 abcd
T20	50% RS+50% CSH	14.12±1.02 ab	27.10±8.30 ab	3.33±.00 a	4.00±.50a	9.25±.50 a	17.00±1.00 abc	51.44±7.781cd
T21	25% RS +75% MC	13.25±3.06 ab	24.19±.61 ab	18.33±1.67 a	8.90±.00cde	9.82±1.00 ab	14.00±10.00abc	35.33±4.114 abc
T22	25% RS+75% CSH	16.74±2.18 ab	15.30 ±2.70ab	17.50±2.50 a	5.20±2.70 bcde	9.46±.50 a	18.00±6.00 abc	45.26±.716 abcd
T23	25%RS+25%MC+25%SD+25%CSH	15.00±1.31 ab	22.87±9.33ab	21.67±5.00a	4.95±3.95 de	8.53±.50a	29.00±5.00 c	35.52±6.970 abc

NB: Means with different letters in the same rows are significantly different (P<0.05) by Tukey multiple range test. SD: Saw dust RS: Rice straw CSH: Cottonseed hull MC: Maize cob at 100%, 75%, 50% & 25% treatment combinations

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Table 6: Financial analysis of substrates (SD- Sawdust; RS- Rice straw; CSH- Cottonseed hull; MC- Maize cob at 100%, 75%, 50% & 25% treatment combinations)

Item	Treatments				
	T3 (100%CSH)	T6 (75%SD+25% CSH)	T22 (25%RS + 75% CSH)	T17 (75% RS+ 25% MC)	T14 75%CSH+ 25%MC
Yield (kg)/100kg substrate	79.67	58.17	57.33	45	50.17
Price of 1kg yield (ETB)	60	60	60	60	60
Total revenue (ETB)	4780.2	3490.2	3439.8	2700	3010.2
Cost of land	-	-	-	-	-
Cost of Spawn	1250	1250	1250	1250	1250
Cost of water	Free	Free	Free	Free	Free
Cost of labor	-	-	-	-	-
Cost of substrate (100kg)	565	277	425	91	516
Polyethylene bags (100pieces)	300	300	300	300	300
Total cost (ETB)	2115	1827	1975	1641	2066
NPV	2665.2	1663.2	1464.8	1059	944.2

NB: The cost of air conditioner is not included in the analysis

ETB- Ethiopian Birr; NPV- Net Present Value

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