jotaf
Journal of TekirdagAgriculturalFaculty
Tekirdağ Ziraat Fakültesi Dergisi

Ocak/January 2021, 18(1)
Başvuru/Received: 24/04/20
Kabul/Accepted: 12/11/20
DOI: 10.33462/jotaf.726165

http://dergipark.gov.tr/jotaf
http://jotaf.nku.edu.tr/

ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Use of Solar Panel System in Vermicompost (Worm Manure) Production Facilities as Source of Energy

Vermikompost (Solucan Gübresi) Üretim Tesislerinin Enerji İhtiyacının Güneş Panelleri Sistemi ile Karşılanması

Elif YÜKSEL TÜRKBOYLARI[1*], Ahmet Nedim YÜKSEL[2]

Abstract

Agro-chemicals significantly improve quality and crop yield in agriculture and plant production however excessive use of these agro-chemicals will cause severe environmental problems and health conditions in the following years. Furthermore, solid organic wastes and residues have become environmental concerns due to rapid development of industry and population growth. Therefore, vermicompost (worm manure) manure might have a key position among organic-based alternative products that might improve sustainable and organic agriculture models and replace chemical fertilizers as well as pesticides. Production and use of vermicompost (worm manure) might be an effective option for solving this problem.

Electric energy is the most commonly used for production of vermicompost. The location of vermicompost production facility must be illuminated at all times. In dark places, the worms move on top of the organic substance and the worms dry and die there. Thus, the production facility must have electricity at all times. This energy might be supplied with solar panel systems. This method will make production of manures more cost-effective.

In order for a four-unit vermicompost production facility with 15.9 m length to operate effectively, a solar panel such as 4 kWh, which is larger than the calculated 3.23 kWh, is needed. Sufficient amount of energy cannot be generated with the system due to reasons such as dirty panel glasses, adverse weather conditions such as cloudiness and rain, indirect sunrays in the morning and evening and losses. This is why an energy system greater than the energy demand must be preferred. Energy remaining from the system can be stored in batteries and used later. Furthermore, remaining energy might be used for covering other needs of the vermicompost facility and this will reduce energy costs of the facility.

In Turkey, solar panels might be used in every region to supply sufficient electric power. Vermicompost facilities established for this purpose must be lighted at all times and this shows that use of solar panel system will be suitable for production. A material portion of electricity demand in the production facility can be supplied with green energy and fertilizer production will be more cost effective.

Keywords: Vermicompost (worm manure), Vermicompost (worm manure) production facility, Solar panel, Solar energy, Electric energy

[1]***Sorumlu Yazar/Corresponding Author:** Vocational School of Technical Sciences, Department of Plant and Animal Production, Greenhousing Programme, Tekirdağ Namık Kemal University, 59030 Tekirdağ/TURKEY. E-mail: eyuksel@nku.edu.tr OrcID: 0000-0003-4658-8068.

[2] Department of Agricultural Faculty Biosystem Engineering, Tekirdağ Namık Kemal University, 59030 Tekirdağ/TURKEY. E-mail: anyuksel@nku.edu.tr OrcID: 0000-0002-0278-7498.

Atıf/Citation: Elif YÜKSEL TÜRKBOYLARI, Ahmet Nedim YÜKSEL. Use of Solar Panel System in Vermicompost (Worm Manure) Production Facilities as Source of Energy.*Tekirdağ Ziraat Fakültesi Dergisi,* 18 (1), 91-97.

Özet

Tarımsal üretimin bitkisel üretim ile ilgili kısmında, kaliteli ve yeterli verim elde etmek amacıyla agro-kimyasal maddelerin aşırı kullanımı sonucunda zamanla önemli çevre ve sağlık sorunlarının meydana gelmesine neden olmuştur. Ayrıca hızlı endüstriyel gelişme ve nüfus artışı ile katı organik atık ve artıklarda çevre sorunu olarak ortaya çıkmıştır. Bu nedenle sürdürülebilir ve organik tarım modellerini geliştirerek, kimyasal gübre ve pestisitlerin yerini alabilecek, organik bazlı alternatif ürünler içerisinde vermikompost (solucan) gübresi önemli bir yer alabilir. Bu sorunların çözümünde vermikompost (solucan) gübresinin üretimi ve kullanımı etkili olabilir.
Vermikompost gübresinin üretimi sırasında, elektrik enerjisi kullanılmaktadır. Vermikompost üretim tesisinin bulunduğu ortamının sürekli olarak aydınlatılması gerekmektedir. Zira karanlık ortamda solucanlar, organik maddenin üstüne çıkmakta ve burada kuruyarak ölmektedirler. Bu nedenle, üretim tesisinde elektrik hiç kesilmemelidir. Bu üretim maliyetlerini arttırmaktadır. Bunu azaltmanın yollarından biri elektrik enerjisi yerine güneş panel sistemlerinin kullanılmasıdır.
Her bir gübre üretim ünitesinin uzunluğu 15.9 m olan, dört üniteli bir vermikompost üretim tesisinin verimli bir şekilde çalışabilmesi için, hesaplanan 3.23 kWh'ten daha büyük 4 kWh gibi bir güneş paneli sistemine ihtiyaç vardır. Panel camlarının kirlenmesi, bulutluluk ve yağış gibi olumsuz hava koşulları, güneş ışınlarının sabah ve akşam dik gelmemesi ve kayıplar gibi nedenlerle, sistemde yeteri kadar enerji üretilmez. Bu nedenle, ihtiyaçtan daha büyük bir enerji sistemi tercih edilmelidir. Sistemden artan enerji daha sonra kullanılmak üzere, akülerde depo edilebilir. Aynı zamanda fazla enerji vermikompost işletmesinin diğer ihtiyaçlarında kullanılarak, işletmenin enerji giderlerini azaltır.
Güneş panelleri, Türkiye koşullarında her bölgede kullanılarak yeterli elektrik enerjisi üretebilir. Bu amaçla kurulan vermikompost tesislerinde özellikle aydınlatmanın sürekli olması zorunluluğu, üretimde güneş paneli sisteminin kullanımının uygun olacağını göstermektedir. Üretim tesisinin elektrik ihtiyacının önemli bir kısmının, yeşil enerji ile karşılanması ile gübrenin üretimi daha ekonomik olur.

Anahtar Kelimeler: Vermikompost (solucan gübresi), Vermikompost (solucan gübresi) üretim tesisi, Güneş paneli, Güneş enerjisi, Elektrik enerjisi

1. Introduction

Use of chemical fertilizers and pesticides for agricultural production after the World War II increased product quality and crop yield in a short time and this increase is known as the "Green Revolution" (Schman and Simpson, 1977). Extensive use of the agro-chemicals caused certain environmental problems and health conditions. We started to experience these effects in the 1970s. Residues of chemical fertilizers found in underground and surface waters and contamination of drinking and tap waters became alarming problems in those years (Barier-Anderson and Anderson, 2000).

Residues and accumulations on the products produced with excessive use of chemicals in agriculture are considered as problematic by consumers and for export of vegetables. Thus, use of chemicals in agricultural production must be restricted; healthier and safer food production must be ensured. In this way, we should prevent return of these toxic substances back to the humans and other living creatures through the food chain (Saber, 2001; Broun and Supkoff, 1994; Çakmakçı et al., 2005; Kitiş, 2012).

This is why the agro-chemicals must be used today responsibly and according to the suggestions so that we can assure sustainable agricultural production and protect human health and environment. Related actions must be taken and use of agro-chemicals must be restricted as much as possible (Özkan et al., 2003; Delen et al., 2005).

Our focus shifted to design of sustainable and organic agricultural models and development of organic-based alternative products that can replace chemical fertilizers and pesticides. Besides plant nutrition aspect of aerobic compost products, namely their capacity to repress soil-based plant pathogens, was discovered (Hoitink et al., 1975; Hadar, 1991).

Studies on compost concluded that vermicompost, worm (mesophilic) compost method, has properties superior to aerobic compost in terms of collecting urban and industrial organic wastes and in terms of product and processing (Dominguez et al., 1997).

The production process of vermicompost fertilizer confirmed that worms have the capacity to transform organic wastes and residues into high quality and valuable products in a very short time. Thus, it led to the emergence of a new form of agricultural production called vermiculture in many countries. Vermiculture can be defined as lumbricus terrestris culture made for a number of purposes (Şimşek-Erşahin, 2007; Eker, 2016).

In case of worm manure or vermicompost, composting process of organic wastes or residues is completed by worms. In this process, organic wastes and residues are fermented by the microorganisms present in the environment. When passing through the digestive system of worms, an accelerated humidification and detoxification process takes place. Coelom fluid in the digestive tract of worms has the capacity to transform all inorganic materials into organic forms (Tutar, 2013).

Worm manure significantly increases aggregate stability in loamy soils (Aktaş and Yüksel, 2020). Microbial activity of worm manure is 10 to 20 times more than the soil. This high level of microbial diversity enables production of chemicals that improve plant growth (hormones and other compounds) as well as enzymes and a range of compounds that suppress growth of harmful plant pathogens (Logsdon, 1994).

Nutritional elements wrapped with worn mucus and contained in vermicompost fertilizer are dissolved slowly and they are in a form ready to be used by the plants instantly. Since these nutritional elements are dissolved slowly, they will not be washed out in the soil and nutritional value will not be lost. Furthermore, worm manure has a porous structure and this makes it a great soil improver thanks to its high air balancing and water retention capacity. If used as mulch in the soil, nutritional elements will directly reach to the plant roots through irrigation (Anonymous, 1992).

Today, vermicompost offers the highest economic benefits out of all methods supporting sustainable agriculture. This method might be extensively used for repurposing solid organic wastes and residues which have become alarming environment concerns due to rapid development of industry and population growth. The vermicompost fertilizer, if produced correctly and properly, will be a bio-fertilizer and bio-pesticide with very high commercial value (Şimşek-Erşahin, 2007).

The purpose of this study is to focus on the use of renewable energy sources in agriculture. Especially it is of interest to us to examine the energy needs of a vermicompost production facility from renewable energy sources (generating electrical energy with solar panels).

2. Materials and Methods

2.1. Vermicompost production facility

In this study, vermicompost production facility was used for tests (Figure 1). Length of a worm manure production facility starts with 15.9 meters and it is available in any desired length; 20-30-50 meters (Figure 1). Its width and height are around 1.30 m. After produced by the worms, the manure will be cut from the bottom with the knife placed 10 to 15 cm high and poured on the conveyor band. The knife will repeat this process a few times. Then, the manure will be collected in one section of the machine when the conveyor band is operated. An electric motor with a capacity of 2.2 kWh is required for operating the knife and 1 kWh is required for operating the conveyor band.

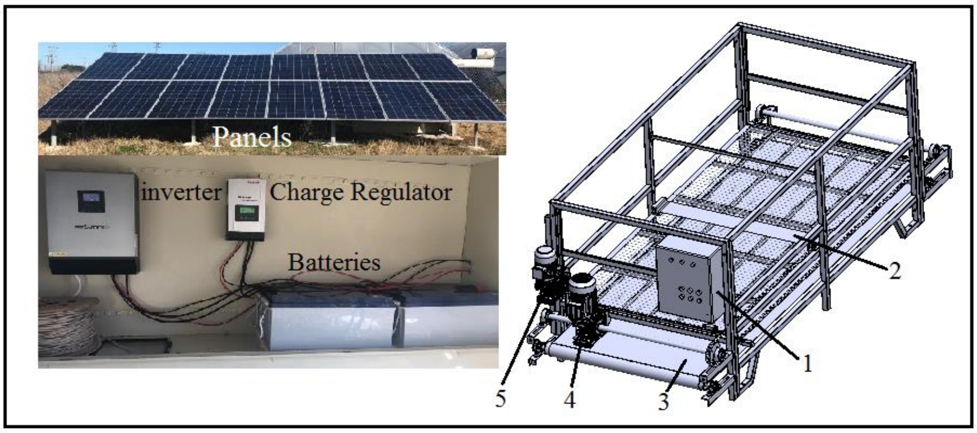

Figure 1. Vermicompost production facility 1. Control Panel 2. Double bladed harvesting knife 3. Conveyor band 4. Electric motor operating the knife 5. Electric motor operating the conveyor band

2.2. Drying vermicompost

Water content of the vermicompost produced at the production facility is around 80 %. According to the vermicompost regulation, the maximum level of moisture content in fertilizer must be 35 %. Thus, the fertilizer will be dried. Purpose of drying process is to reduce the product moisture content down to the allowed level as soon as possible and by consuming minimum energy however the product quality should not be impaired in any way (Polatçı and Tarhan, 2009). Another purpose of the drying process is to reduce the product volume and thus increase operational efficiency for transportation and storage of the fertilizer (Güngör et al., 2014).

Fertilizer can be dried under natural and controlled conditions. Drying fertilizer under natural conditions might expose the fertilizer to environmental conditions that change continuously and this might have negative impact on product quality. Drying fertilizer under controlled conditions shortens the drying time and improves product quality as well as other properties (Kara et al., 2014).

2.3. Vermicompost production facility and photovoltaic battery design

Our country has many advantages in terms of solar energy. In our country, insolation times are different each season. The duration will be 5 hours, in average, during winter but around 7 hours in autumn and spring and around 11 hours during summer (Anonymous, 2019a).

It is concluded that average insolation time in Turkey is 2628 hours per year (7.2 hours per day in average) and average total radiation capacity is 1311 kWh m^{-2} $year^{-1}$ (3.6 kWh m^{-2} per day in average) (Küsek et al., 2016).

Radiation capacity in the location of this study, namely in Tekirdağ province, this is about 1281.2 kWh m^{-2} $year^{-1}$ (3.51 kWh m^{-2} day^{-1}) and this value is very close to the average radiation capacity in Turkey (Yüksel and Yüksel-Türkboyları, 2018).

If the location of vermicompost production does not have electricity, if there are blackouts or if the establishment intends to lower operation costs, solar panels might be used to generate electricity. Consequently, use of solar energy systems in agricultural production facilities and amount of electricity generated increase (Yüksel and Yüksel-Türkboyları, 2018).

A solar panel is a photovoltaic tool that has solar cells and that directly converts sunrays into electric current. Photovoltaic cells might be organic and inorganic based. Generally, inorganic based photovoltaic cells are used more commonly because they have output around 15 to 20 % and they are highly efficient (Grätzel, 2009).

Depending on the application, in photovoltaic cell systems, there are photovoltaic cells have photovoltaic (solar cell) battery group, battery charging regulator, inverter and auxiliary electronic circuits (Anonymous, 2019a; Köroğlu et al., 2010). In this system, a predetermined number of photovoltaic cells are used as source of energy. In case of overcast weather or insufficient sunrays, the batteries shall provide energy to the system. This system generally uses GEL (gelled electrolyte sealed lead acid) batteries. Maximum 70 % of the stored energy must be used in order to prevent battery malfunctions in the short run. Charge regulator is used for preventing overcharge or discharge of the batteries. Depending on the battery condition, it interrupts the current coming from the solar panels or current of the system providing the load. If the system will use 220 V and 50 Hz alternating current or current is to be provided to mains supply, the system must have an inverter (Köroğlu et al., 2010). A 15.9-meter long vermicompost production system with a height and width of 1.3-meter produces 3 to 3.5 tons of manure per month. The moisture content of the product is 80 % but it must be dries and the moisture content must be reduced down to 35 %. When this product is dried, the product weight shall be between 1.2 and 1.4 tons.

3. Results and Discussion

3.1. Energy demand of system

Electricity need of each production unit in the vermicompost production facility is for 2.2 kWh electric motor used for cutting the fertilizer with a knife. Also, a 1.1 kWh electric motor is used for pouring the fertilizer onto the conveyor after cutting and for collecting the fertilizer from conveyor. Location of vermicompost production facilities must be illuminated with dim light. Two or three 10 W LED bulbs will be sufficient for this lighting. The location of vermicompost production facility must be illuminated at all times. In dark places, the worms move on top of the organic substance and the worms dry and die there. Thus, the production facility must have electricity at all times.

The drying process should not be performed under natural conditions and outdoors. The drying environment must be ventilated for drying the product under controlled conditions and indoors.

The facility to be established will be economical if 3 or 4 production machines are used. For drying the products under controlled conditions, an indoor space of 150 to 200 m^2 is required. Greenhouse cultivation structures might be used in greenhouses for this purpose. Drying can be done in a shorter time by heating the greenhouse soil with a different method such as using solar collectors (Yüksel-Türkboyları, 2018).

Ventilation need might be calculated according to the base area of the facility. Accordingly, the ventilation need per 1 m^2 of base area is 0.033-0.042 m^3 s^{-1} or 120-150 m^3 h^{-1} (Anonymous, 1993; Yüksel and Yüksel, 2012). Considering the base area, ventilation need in a 150 m^2 drying facility will vary between:

$$150 \times 120 = 18000 m^3 h^{-1} \text{ or } 150 \times 150 = 22500 m^3 h^{-1} \qquad \text{Eq. (1)}$$

Average value is around 20250 m^3h^{-1} (Eq.1).

The number of mono-phase, 1300 rpm (dd^{-1}), 0.55 kWh aspirator with 60 cm diameter to be used for ensuring air exchange of 9500 m^3h^{-1} might be calculated as follows. The system needs:

$$20250/9500 = 2.1pcs \quad \text{Eq. (2)}$$

In order words, the number of aspirators needed is approximately 2 (Eq.2).

3.2. Energy demand of vermicompost system

$$2.2 + 0.55 \times 2 + 0.01 \times 3 = 3.23kWh \quad \text{Eq. (3)}$$

For efficiently operating this system, a solar panel system that is greater than the demand calculated, namely greater than 3.23 kWh, such as 4 kWh because panels can reach their optimum powers only under the optimum conditions (Eq.3). Sufficient amount of energy cannot be generated with the system due to reasons such as dirty panel glasses, adverse weather conditions such as cloudiness and rain, indirect sunrays in the morning and evening and losses (Anonymous, 2019b) This is why an energy system greater than the energy demand must be preferred. Energy remaining from the system can be stored in batteries and used later. Furthermore, remaining energy might be used for covering other needs of the vermicompost facility and this will reduce energy costs of the facility.

4. Conclusions

Excessive use of agro-chemicals in agriculture over an extended period of time caused some environmental issues and health concerns. Therefore, vermicompost (worm) manure might have a key position among organic-based alternative products that might improve sustainable and organic agriculture models and replace chemical fertilizers as well as pesticides. It is concluded that worms have the capacity transform organic waste and residues into a high quality and valuable product within a short period of time.

In Turkey, solar panels might be used in every region to supply sufficient electric power. Vermicompost facilities established for this purpose must be lighted at all times and this shows that use of solar panel system will be suitable for production. A material portion of electricity demand in the production facility can be supplied with green energy and fertilizer production will be more cost effective.

References

Aktaş, T., Yüksel, O., (2020). Effects of vermicompost on aggregate stability, bulk density and some chemical characteristics of soils with different textures. *Journal of Tekirdag Agricultural Faculty (Jotaf)*, 17(1): 1-11.

Anonymous, (2019a). www.elektrikport.com, (accessed date: 15.10.2019)

Anonymous, (2019b). www.gunesenerjisipanelleri.net, (accessed date: 18.07.2019)

Anonymous, (2019c). www.rhs.com.tr, (accessed date: 28.11.2019)

Anonymous, (1993). The Greenhouse climate handbook. ACME Engineering and Manufacturing Corp. Box 978. Muskagee, OK 74402.

Anonymous, (1992). Vermigro premium earthworm soil product, sold by canyon recyling, San Diego, Ca. worm watch, Education Department of South Australia.

Baier-Anderson, C., Anderson, R.S. (2000). The effects of chlorothalonil on oyster hemocyte activation: phagocytosis, reduced pyridine nucleotides, and reactive oxygen species production. *Environmental Research*, 83(1):72-78.

Broun, A.L., Supkoff, D.M. (1994). Options to methyl bromide for the control of soil-borne diseases and pests in California with reference to the Netherlands. Pest Management Analysis and Planning Program. State of California, Environmental Monitoring and Pest Management Branch. California

Çakmakçı, R., Dönmez, M.F., Canpolat, M., Şahin, F. (2005). In Greenhouse and Different Field Conditions, The Effect Of The Plant Growth Promoting Bacteria On Plant Growth and SoilPproperties. *6th Turkish Field Crops Congress*, P.45-50 Antalya, Turkey.

Delen, N., Durmuşoğlu, E., Güncan, A., Güngör, N., Turgut, C., Burçak, A. (2005). Türkiye'de Pestisit Kullanımı Kalıntı ve Organizmalarda Duyarlılık Azalışı Sorunları. *Turkey Agricultural Engineering Sixth Technical Congress*, 3-7 January, P.629-648, Ankara, Turkey.

Dominguez, J., Edwards, C.A., Subler, S. (1997). A comparison of vermicomposting and composting. *Biocycle*, 38(4): 57-59.

Eker, M. (2016). *Vermikompost ve Diğer Bazı Organik Gübrelerin Farklı Dış Mekan Süs Bitkilerinin Gelişimine Etkisinin Araştırılması*. (MSc. Thesis) Namık Kemal University. Graduate School of Natural and Applied Science, Tekirdağ, Turkey

Grätzel, M. (2009). Recent advences in sensitized mesoscopic solar cell. *Accounts of Chemical Research*, 42(11): 1788-1798.

Güngör, A., Hepbaşlı, A., Günerhan, H. (2014). Gaz tahrikli ısı pompalarının kurutmada kullanımının deneysel incelenmesi. *Tesisat Mühendisliği Dergisi*, 142: 32-41

Hadar, Y. (1991). Control of soil-borne diseases using suppressive compost in container media. *Phytoparasitica*, 19(2):167.

Hoitink, H.A.J., Schmitthenner, A.F., Herr, L.J. (1975). Composted bark for control of root rot in ornamentals. *Ohio Reporter*, 60: 25-26.

Kara, N., Baydar, H., Kayaalp, Ö., Boyar, S. and Bayhan, A. (2014). Effects of drying in sun and shade on essential oil content and composition of hyssop (*Hyssopus officinalis* L.). *Süleyman Demirel University Journal of Natural and Applied Science*, 18(1): 85-90.

Kitiş, Y.E. (2012). Solarizasyon Nedir? Nasıl Uygulanır? *Tarım Günlüğü*, 10: 34-37.

Köroğlu, T., Teke, A., Bayındır, K.Ç., Tümay, M. (2010). Güneş paneli sistemlerinin tasarımı. *Elektrik Mühendisliği Dergisi*, 439:98-104.

Küsek, G., Öztürk, H.H., Akdemir, Ş. (2016). Tarım İşletmelerinde Güneş Enerjisinden Elektrik Üretiminin Tekno-Ekonomik Uygulabilirliği. *13.Ulusal Kültürteknik Kongresi*, 12-15 Nisan, P.127-136, Antalya, Turkey.

Logsdon, G. (1994). Worlwide progress in vermicomposting: earthworms and composting. *Biocycle*, 35: 63-65.

Özkan, B., Vuruş-Akçagöz, H., Karadeniz, C.F. (2003). Antalya ilinde turunçgil üretiminde tarımsal ilaç kullanımına yönelik üretici tutum ve davranışları. *Anadolu Journal of AARI*, 13(2): 103-116.

Polatçı, H., Tarhan, S. (2009). The effects of various drying methods on the drying time and quality of basil (ocimum basilicum). *Journal of Agricultural Faculty of Gaziosmanpaşa University*, 26(1): 61-70.

Saber, M.S.M. (2001). Clean biotechnology for sustainable farming. *Engineering in Life Sciences*, 1(6): 217-223.

Schuman, S.H., Simpson, W. (1997). A clinical historical overview of pesticide health issues. *Occup. Med-State of the Art Rev*., 12: 203-207.

Şimşek-Erşahin, Y. (2007). Obtaining vermicompost products, and alternatives for use in agricultural production. *Journal of Agricultural Faculty of Gaziosmanpaşa University*, 24(2): 99-107.

Tutar, U. (2013). Investigation of antimicrobial activity on some plant pathogens of obtained from the earthworm's vermicompost. *Cumhuriyet University Faculty of Science Journal (CSJ)*, 34(2): 1-12.

Yüksel, A.N., Yüksel, E. (2012). Sera Yapım Tekniği. Hasad Yayıncılık, İstanbul

Yüksel, A.N., Yüksel-Türkboyları, E. (2018). Using The Photovoltaic Cells for Ventilation and Cooling of The Animals Barns. *1st International 14th National Congress on Agricultural Structures on Irrigation (ICASI 2018),* 26-28 September, P.49-55. Antalya, Turkey.

Yüksel-Türkboyları, E. (2018). Tekirdağ koşullarında güneş kolektörlerinden elde edilen ısı enerjisi ile sera toprağının dezenfekte edilmesi. *Journal of Tekirdag Agricultural Faculty (Jotaf)*, 15(01): 123-128.