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EVALUATION OF GRAPE POMACE COMPOSTING PROCESS

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Abstract

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The paper deals with the problems of composting of grape pomace in strip compost piles. The three variants of compost piles formed from grape pomace and vegetables waste, wood chips and mature in varying proportions were tested. Turning of piles was performed using windrow turner PKS 2.8, in which the achieved performance was monitored. On the performance of windrow turner has a significant influence also cross section or width and height of turning piles and the bulk density of ingredients including their moisture. In evaluating, attention has been paid to assessment of selected parameters (temperature, moisture content) of the composting process. From the viewpoint of temperature course, the highest temperature reached at the piles in Var. I (64.1 °C) and Var. II (55.3 °C). Moisture of compost piles in the individual variants did not differ significantly and ranged between 25–35%.

Keywords: compost, composting, grape pomace, compost piles, windrow turner

INTRODUCTION

Composting is a common treatment of biodegradable waste. Composting is a suitable treatment option for biological waste in developed countries. A range of technologies is in operation worldwide, from unmanaged static piles to highly engineered systems with automatic turning and treatment of the released gases in biofilters. The finished compost can be used on agricultural land. The benefit is that the use of inorganic fertilizers is avoided, carbon is bound to soil and simultaneously is maintained stable humus content (Bertran *et al.*, 2004).

Extensive research has demonstrated that many biodegradable organic wastes can be composted in a convenient and economical way. Composting of organic matter is a simple and efficient manner of transforming agro-industrial wastes into the products suitable for use as soil conditioners (Ferrer *et al.*, 1993).

Grape is one of the most grown fruit crops in the world with more than 60 million tons of production annually. Viniculture is an important agricultural activity in the World and produces huge amounts of organic wastes. Currently are sought and tested methods for their further use (Ferrer *et al.*, 2001).

The main organic wastes include grape pomace (63%), lees (13%), stalk (12%) and dewatered sludge (12%). Some of these wastes are being used as by-products (grape pomace and lees) whereas the rest of organic wastes (stalk and wastewater sludge) has been traditionally incinerated or disposed in landfill (Nerantzis, Tataridis, 2006).

Grape pomace has a humidity of about 50–70% and makes up for 11–15% of grapes crushed. Pomace itself has a granular structure and it has a good suction ability. Bulk density ranges between 450–600 $kg.m^{-3}$. One ton of pomace is composed of 249 kg of stalks, 225 kg of grape seeds and 425 kg of grape pellicles. The grape pomace is high in N–P–K–Ca (2.0–0.5–2.0–2.0). Pomace alone composts slowly and has low pH (3.5–3.8), but the compost microbes prefer a pH of 6.2 to become active (Bertran, 2004). The ratio of carbon and nitrogen in fresh pomace ranges appropriate for composting between ration 17–30:1. The feedstock added to pomace should also have C:N ratio appropriate for composting. Composting of grape pomace is a 5 to 8 month process, dependent upon turning frequency, moisture, and temperature of piles or windrows.

Annually, the wine industry is using big amounts of chemical fertilizers and organic matter. In this sense, the possibility of recovering organic wastes from the wine industry to vineyards may be presented as a sustainable strategy for the waste management. Exclusive addition of chemical fertilisers is no longer considered the best method to feed the plant and keep the plant pathogens under control. Growers understand that they must add some type of organic material to the soil, whether it is compost or another type of organic amendment (Inbar *et al*., 1986). This organic matter increases microbial biomass and helps maintain these beneficial bacterial and fungi populations. Ribererau–Gayon, Peybaud (1982) represent that the application of compost from winery wastes increases the percentages of organic matter, nutrient levels (providing a slow fertilisation action over a long-period time), microbial biomass and improves the soils physical properties (aeration, water-holding capacity, etc.). Diaz *et al*. (2002) report, that the grape pomace, a primary waste of wine production, could be recycled as a soil conditioner in view of its organic and nutrient contents. Moreover, a comparison of the best compost obtained from winery wastes with those from other organic wastes showed that its chemical values fell within the same range in most cases.

The aim of this experiment was a semi industrial evaluation of composting process of grape pomace in strip piles with emphasis on the operating characteristics of windrow turner.

MATERIALS AND METHODS

Three variants of compost piles with different proportion of grape pomace were prepared as indicated in the Tab. I. The ratios of the individual ingredients are based on experiments performed in the previous period.

Composition of the compost piles primarily met the requirements of different structural properties of the resulting mixture and their availability at location of experiment. During experiment establishment, volumes of individual types of raw materials as well as density of components were monitored.

When individual components of compost piles were heaped up, final shapes of piles were provided by loader UNC–060 to desired width of the base 2.4 m and top width of 1.5 m. Piles had trapezoidal profile with slightly varying heights ranging from 1.0 to 1.1 m and the total length of 15 m. This length was in monitoring windrow turner divided in three repetitions, each of length 5.0 m.

Basic operation, e.g. turning, was done by modified windrow turner PKS 2.8 (trailed version), which was aggregated with the tractor Zetor 7211, equipped with a creeping speed (up to 300 $m.h^{-1}$). The time needed for turning of evaluated compost piles was monitored.

An approximate cross–sectional surface of the section (from the width of the pile and layer height) was calculated. Capacity of windrow turner in the monitored section, was calculated by the following formula (1):

$$W_{02} = 3600 \times v_p \times S \ (m^3.h^{-1}), \quad (1)$$

where

W_{02} .. capacity of windrow turner ($m^3.h^{-1}$),
v_p...... operating speed of turning machinery, calculated from measured time of turning ($m.s^{-1}$),
S .... profile surface of turning pile (m^2).

Theoretical value of density for each variant was calculated according to the following formula (2):

$$\rho_S = \frac{V_1 \times \rho_1 + V_2 \times \rho_2 + \ldots + V_i \times \rho_i}{V_C} \ (kg.m^{-3}), \quad (2)$$

where

ρ_S ...... theoretical value of density ($kg.m^{-3}$),
V_i...... volume of the raw material of individual component (m^3),
ρ_i....... density of the raw material of individual component ($kg.m^{-3}$),
V_c ..... total volume of material (m^3).

The actual density of the mixture was measured before the first turning and then after the turning. Bulkage coefficient for each variant was calculated from the measured values of density.

I: *The ratio of raw materials for experimental compost piles*

Experimental variant	The ratio of raw materials			
	Pomace	Vegetable waste	Wood chips	Livestock manure
Var. I	8	10	6	2
Var. II	10	7	2	2
Var. III	12	10	4	2

Bulkage coefficient was calculated according to the following formula (3):

$$k_N = \frac{\rho_{v1}}{\rho_{v2}} \ (-), \quad (3)$$

where

k_N ..... bulkage coefficient (–),

ρ_{V1} .... density of the mixture before turning (kg.m⁻³),

ρ_{V2} .... density of the mixture after turning (kg.m⁻³).

Temperature was measured by thermometer SANDBERGER GTH 1150 always in the same place. Temperature measurements were taken weekly in the centre of profile, in the depths of 0.25, 0.50 and 0.75 m from the top.

Parameters of the SANDBERGER GTH 1150 thermometer are as follows:

- type: GTH 1150;
- measuring range: from –50 to 1150 °C;
- measurement accuracy: from –20 to 550 °C < 1% ± 1;
- length of probe 800 mm.

Humidity of compost was scanned at a depth of 0.5 m from the top of the pile by sensor VIRRIB. Sensors, located in each pile were connected to the recording device VIRRIBLOGGER. When moisture dropped under 40%, moisture was increased by watering.

Parameters of the VIRRIB are as follows:

- power: 5.5–18 V=;
- output: 0–5 mA, 0–2.5 V, (or other, on request);
- measuring range: 5–50% volumetric of moisture;
- measuring accuracy: less than 0.01 $m^3.m^{-3}$.

Basic statistical indicators i. e. arithmetic average, standard deviation, construction of confidence intervals around the arithmetic mean were used. Computer software Unistat 4.53 for Excel and MS Excel were applied for above mentioned methods of statistical evaluation.

RESULTS AND DISCUSSION

Tabs. II–IV shows the composition of the compost piles for each variant. Percentage share of raw materials in the tables express volume percent in piles, as the volume of materials was observed during trial establishment. Coefficient of bulkage for variant reached values from 1.12 to 1.21. This coefficient expresses tendency of mixture in compost pile to settle down and at the same time serves as an informative indicator of turning process efficiency (capacity).

Performance of the tractor windrow turner PKS 2.8 aggregated with the tractor Z 7211 was monitored during the first turning. Measured efficiency values are presented in Tab.V–VII. Efficiency of turner varies between 227–255 $m^3.h^{-1}$, in relation to pile composition. During this initial phase, machinery is working in the worst condition because it works with unexpanded components of raw material of different character. Statistically significant differences in efficiency were found only in the Var. I.

Differences in the machine efficiency during the second and third turning were not observed.

II: *Quantity of raw materials–Var. I*

Material	Share (vol.%)	Density ρ_v (kg.m⁻³)	Quantity in variant (m³)
Pomace	31	440	9.3
Vegetable waste	38	248	11.4
Wood chips	23	305	6.9
Livestock manure	8	890	2.4
Total m³			30
Mixture before turning	–	435	k_N = 1.21
Mixture after turning	–	360	
Theoretically calculated value for the mixture		372	

III: *Quantity of raw materials–Var. II*

Material	Share (vol.%)	Density ρ_v (kg.m⁻³)	Quantity in variant (m³)
Pomace	48	440	14.3
Vegetable waste	33	248	9.9
Wood chips	9.5	305	2.9
Livestock manure	9.5	890	2.9
Total m³			30
Mixture before turning	–	440	k_N = 1.12
Mixture after turning	–	391	
Theoretically calculated value for the mixture		407	

IV: *Quantity of raw materials–Var.III*

Material	Share (vol.%)	Density ρ_v (kg.m^{-3})	Quantity in variant (m^3)
Pomace	43	440	12.9
Vegetable waste	36	248	10.8
Wood chips	14	305	4.2
Livestock manure	7	890	2.1
Total			30
Mixture before turning	–	423	k_N = 1.17
Mixture after turning	–	363	
Theoretically calculated value for the mixture		383	

Efficiency of the windrow turner PKS 2.8 was significantly influenced by piles cross the profile. Monitored difference in working speed indicate that the input raw material of different properties (graininess, density) causes different resistance to turning rotor leading often to machine halt. The results show, that the highest efficiency of machine performance was achieved in the piles with a higher proportion of wood chips (Var.I). This fact is also illustrated by the value of bulkage coefficient k_N = 1.21. Michel (2002) state that the efficiency of windrow turners performance depends on compost piles composition, its size and technical parameters of machine. It is necessary to choose the frequency of turning in relation to the moisture and homogeneity of mixture. Komilis, Ham (2004) state that higher performance efficiency can be achieved when turning structural granular material than turning inhomogeneous settled material.

In accordance with Paredes *et al.* (2000), frequency of compost turning can significantly reduce the total time of raw materials decomposition. Tiquia *et al.* (2000) state that the frequency of turning equal to 1 x per week can lead to the time shortening by 20%. In addition, more frequent turning also increases the bulk density of compost Breitenbeck *et al.* (2004).

Course of temperature measurements in trial piles with marked turning interference (3 times in each variant) is showed in the Figs. 1–3. To reach

V: *Determination of the efficiency of windrow turner–Var. I*

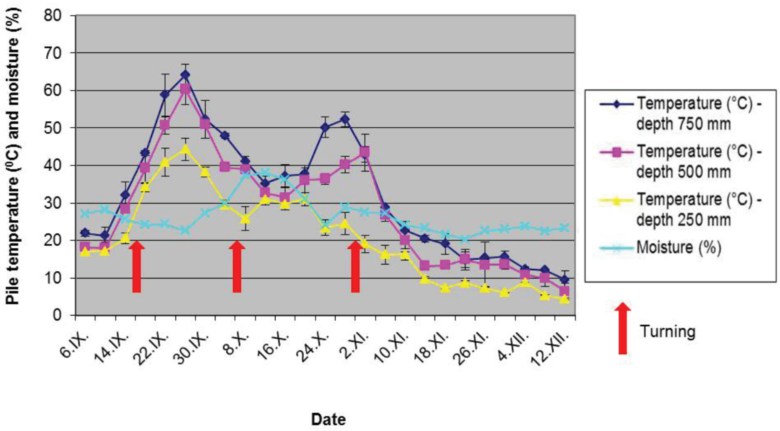
Stretch	Length of the stretch L (m)	Windrow turning time T_p (s)	Working speed v_p (m.s^{-1})	Layer height H (m)	Cross sectional area S (m^2)	Performance of machine set W_{02} Measured value (m^3.h^{-1})	Average value (m^3.h^{-1})	Standard deviation
1	5	136.8	0.037	1.07	2.09	278		
2	5	151.2	0.033	1.00	1.95	232	255	23.00
3	5	140.4	0.036	1.01	1.97	255		

VI: *Determination of the efficiency of windrow turner–Var. II*

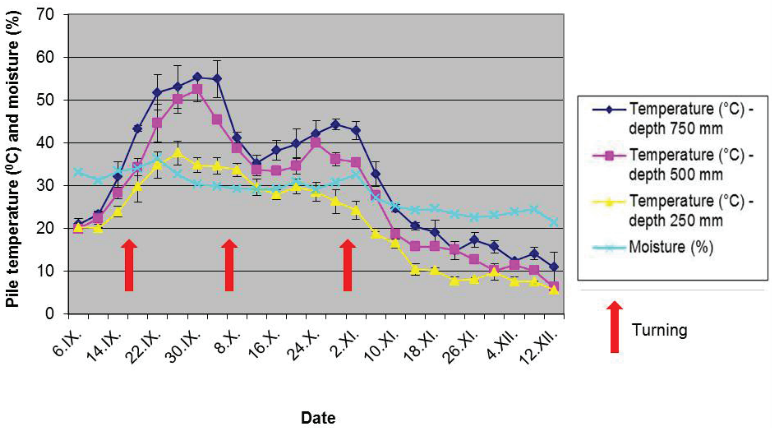
Stretch	Length of the stretch L (m)	Windrow turning time T_p (s)	Working speed v_p (m.s^{-1})	Layer height H (m)	Cross sectional area S (m^2)	Performance of machine set W_{02} Measured value (m^3.h^{-1})	Average value (m^3.h^{-1})	Standard deviation
1	5	162.0	0.031	1.05	2.05	228		
2	5	154.8	0.032	1.10	2.15	248	227	22.03
3	5	187.2	0.027	1.08	2.10	204		

VII: *Determining the efficiency of windrow turner – Var. III*

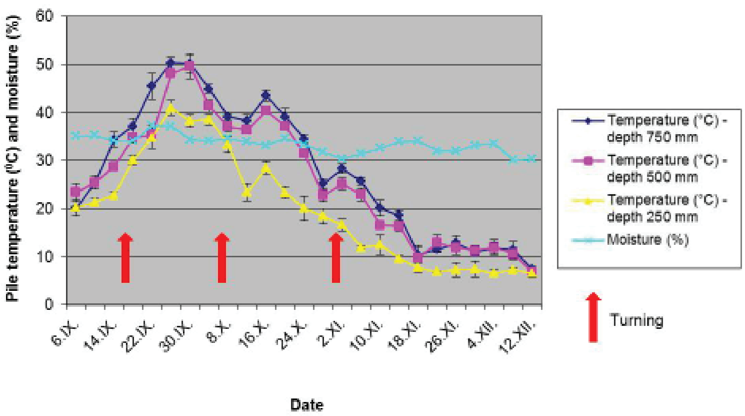
Stretch	Length of the stretch L (m)	Windrow turning time T_p (s)	Working speed v_p (m.s^{-1})	Layer height H (m)	Cross sectional area S (m^2)	Performance of machine set W_{02} Measured value (m^3.h^{-1})	Average value (m^3.h^{-1})	Standard deviation
1	5	144.2	0.035	1.01	1.97	245		
2	5	132.4	0.038	1.05	2.05	279	242	37.55
3	5	169.6	0.029	0.99	1.93	204		



1: *Temperature, moisture and turning interventions for Var. I*



2: *Temperature, moisture and turning interventions for Var. II*



3: *Temperature, moisture and turning interventions for Var. III*

the maximum of temperature is important especially for the compost hygienic parameters (sanitation). Measured values indicate that a rapid temperature rise up to the maximum temperature in the range of 55–64 °C occurs during the first three weeks in the compost piles of Var. I a Var. II.

Experimental trial of the Var. III with the highest proportion pomace and vegetable waste shows relatively slow start of decomposition process, which even after turning interventions remains less intensity and is relatively slow. This finding is in accordance with general knowledge of slow disintegration of some materials with the high moisture content in compost Kokkora *et al.*, 2006. Measured moisture values in compost piles show that pomace is a material with high moisture content.

A larger proportion of grape pomace in the compost mixture has a positive effect on maintaining the required moisture. Hansen *et al.* (2007) evaluated absorption capacity of different types of raw materials suitable for composting and they come to the same conclusions. Too high proportion of grape pomace in compost mixture may contribute to the creation of anaerobic conditions and to impede the progress of the composting process.

CONCLUSION

The paper deals with the problems of composting of grape pomace in strip compost piles. The three variants of compost piles formed from grape pomace and vegetables waste, wood chips and mature in varying proportions were tested. Turning of piles was performed using windrow turner PKS 2.8, in which the achieved performance was monitored. Efficiency of turner varies between 227–255 $m^3.h^{-1}$, in relation to pile composition. Measurement results shows that the greatest performance of values were obtained for piles in Var. I and Var. III with a higher proportion of structural materials (grape pomace, wood chips). On the performance of windrow turner has a significant influence also cross section or width and height of turning piles and the bulk density of ingredients including their moisture. From an operational point of view may occur the complications during turning while maintaining turners in an upright position against the piles. In evaluating, attention has been paid to assessment of selected parameters of the composting process. From the viewpoint of temperature course, the highest temperature reached at the piles in Var. I (64.1 °C) and Var. II (55.3 °C). According to the standards for compost production was for all variants of compost piles secure the necessary sanitisation. The standard prescribes the temperature of 45 °C for at least 5 days. Moisture of compost piles in the individual variants did not differ significantly and ranged between 25–35%. Obtained results confirm the possibility of effective removal and effective use of grape pomace for the compost production and producing of high quality organic fertilizer.

SUMMARY

Composting process represents an effective use of grape pomace. The compost made from grape pomace is regarded as the high quality organic fertilizer. Introduced experiment deals with monitoring of the composting process of grape pomace. It was provided by 3 variants of different compost piles. Obtained results indicate that dynamics of this process is affected by the share of raw materials. According to the temperature curve characteristics, the temperature above 45 °C for at least 5 days was necessary for compost sanitation. Such temperature was achieved in all piles with different pomace content. Monitoring also showed the influence of compost piles composition expressed by structure and density of composted materials on performance efficiency of machines for turning. Performance capacity the windrow turners ranged, depending on the composition of the pile, between 227–255 $m^3.h^{-1}$.

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