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Original Research

The Role of Sugar Factory Lime on Compound Fertilizer Properties

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Abstract

The manufacturing of compound fertilizers enriched with calcium by solid component granulation using by-product of beet sugar industry – sugar factory lime (SFL) was investigated on laboratory scale.

Sugar factory lime was examined by chemical, differential scanning calorimetry – thermogravimetry (DSC-TG), infrared spectroscopy (IR) and X-ray diffraction (XRD) analysis.

The dependence of particle size and crushing strength on SFL content, fertilizers component ratio and recycling part of fertilizers in granulation mixture was obtained. The main physicochemical properties of fertilizers such as particle size distribution, moisture content, pH, and particle crushing strength are determined.

The results of investigations show, that waste from the beet sugar industry may be used in production of compound fertilizers as a calcium source. The results obtained are important for environmental protection and plant fertilization.

Keywords: sugar factory lime, fertilizers, granulation, physicochemical properties, environment

Introduction

Calcium is one of the main secondary nutrients necessary for healthy plant growth. Important sources of calcium are various fertilizers such as a single and a triple superphosphate, a nitrophoska, a precipitate, a calcium nitrate, etc. The other way for enriching soils by calcium is liming. For this aim a lime, a dolomite, a magnesite and various calcium carbonate minerals are used.

Sugar factory lime (SFL) is obtained from the beet sugar industry at the stage of purification of raw juice by milk of lime and CO_2 gases and the main part of this by-product consists of calcium carbonate containing up to 50% of CaO. By-product is sugar industry waste, – for example, 120,000 t of SFL is cumulated in the dump of the Marijampolė (Lithuania) sugar factory and it is unimproved. To determine the methods of utilization of sugar factory lime from the dump is a very important environmental and technical problem. SFL is interesting as a calcium compound for fertilizer production or liming of soils.

Data on sugar factory lime used for liming of soils are found in [1-4].

Data concerning the use of sugar factory lime as calcium compound for production of compound fertilizers are lacking. Nitrogen, phosphorus, natrium, magnesium and other elements used for plant fertilization are an advantage of SFL chemical composition.

This work is a continuation of our previous research [5-7] on the enriching fertilizers by secondary elements and microelements. The results of the granulation process of compound fertilizers using by-products of sugar industry and physicochemical properties of product are presented.

The aim of this study was to analyze the usability for manufacturing granulated fertilizers containing calcium by

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using waste of beet sugar industry – a sugar factory lime. To achieve this objective, it was necessary to study some physicochemical properties of SFL to determine the optimum condition of the granulation process for manufacturing compound fertilizers using SFL, as well as to examine the main physicochemical properties of granulated product.

Materials and Methods

The industrial fertilizers used in our investigations included ammonium sulphate (20–0–0), superphosphate (0–20–0), diammonium phosphate (18–46–0), monoammonium phosphate (12–52–0), microelemental mixture (manganese oxide, zinc oxide, cupric sulphate, boron acid), and sugar factory lime – waste from Marijampolė beet sugar plant with water content approximately 30%, and phosphoric acid water solution (0.1%) to moisten of granulating mixture.

Clay was used as a binder material for granulation because some pure salts have little plasticity and are very difficult to granulate.

The rotary drum is the most popular method for granulation of compound fertilizers starting with all dry materials. The granulation of compound fertilizers was performed in the laboratory rotary drum equipment making possible to determine the process parameters. Granulator diameter is equal 11 cm and length 45 cm. A constant rotation rate was 26 rpm. Granulator axis was inclined 3° to the horizontal. A granulating mixture was heated up to 70°C.

The characteristics of granulated product such as moisture content, crushing strength of granules, particle size, screen analysis and pH of 10% concentration of fertilizer solution were determined by standart methods [8].

The calcium analysis was carried out by complexometric titration [8], nitrogen by volumetric methods [9], phosphorus by photocolorimetry [10, 11], potassium by flame spectrometry [12]. Concentrations of phosphorus and potassium were calculated as oxide.

Concentration of microelements was estimated by atomic absorption spectrometry (AAS) using AAnalyst 400 (Perkin Elmer) instrument.

IR spectra has been recorded with the help of the spectrometer Perkin Elmer FTIR system Spectrum GX. Specimens were prepared by mixing 1 mg of the sample in 200 mg of KBr. Spectral analysis was performed in the range 4000–400 cm^{-1} with spectral resolution of 1 cm^{-1}.

Differential scanning calorimetry-thermogravimetry (DSC-TG) was used to analyze the thermal effect occurring in a sample during heat treatment. DSC-TG analysis was performed with a NETZCH STA 409 PC Luxx (Germany) calorimeter under air atmosphere up to 1000°C with a rate of heating of 10°C·min^{-1}.

Samples were characterized by X-ray diffraction (XRD) analysis. XRD patterns are obtained at room temperature with DRON 6 diffractometer using Ni-filtered CuKα radiation.

Table 1. Chemical composition of sugar factory lime in dry material (DM).

Element	Concentration, % (DM)	Element	Concentration, mg/kg (DM)
Primary and secondary nutrients		Microelements	
N	0.22	Fe	3387.50
P_2O_5	0.30	Cu	84.48
K_2O	0.16	Zn	64.07
CaO	40.75	Mn	412.46
MgO	1.97	Co	124.44
Na_2O	0.05	Mo	1054.54

Results and Discussion

Technical sugar factory lime obtained on industrial scale by the Marijampolė (Lithuania) beets sugar factory was used for the fertilizer granulation investigation.

A chemical composition of sugar factory lime is given in Table 1.

Calcium is the main component of SFL, 40.75% of CaO respectively. The chemical composition of SFL was confirmed by XRD diffraction analysis. The XRD patterns are presented in Fig. 1. The XRD pattern showed that $CaCO_3$ was dominant in the sample [13]. The reflection intensities (*I*) and interplanar spacings (*d, nm*) for SFL almost completely coincide with published data for calcium carbonate [13].

The data of DSC–TG analysis of sugar factory lime are presented in Fig. 2. The endothermic peak at 117.7°C can be attributed to water removal. The endothermic effect at 800–900°C shows that destruction of calcium carbonate into CaO and CO_2 occurs. The curve of thermal analysis is similar to the curve of calcium carbonate [13].

TG curve shows two weight losses: 29% up to 120°C and 30% above 800°C. Total weight loss is equal to 59.55%.

IR studies have confirmed the results of X-ray diffraction analysis. IR spectra of the sample showed bands corresponding to $CaCO_3$ [14]. Bands in the regions 1400–700 cm^{-1} and 2500–1800 cm^{-1} can be attributed to the presence of CO_3^{2-} and CH(CO) groups, respectively. A broad band at ~3300 cm^{-1} can be related to water molecules.

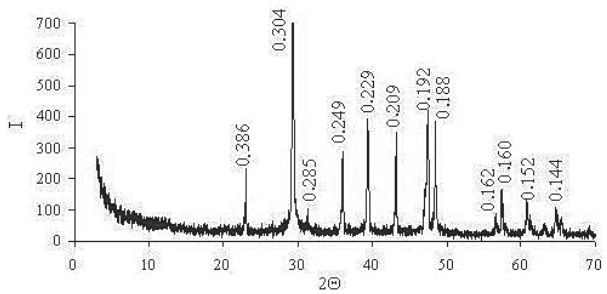

Fig.1. X-ray diffraction pattern of SFL.

Usability of sugar factory lime for production of granulated compound fertilizers containing primary elements such as nitrogen and phosphorus as well as microelements was investigated. The grade of compound fertilizers 5–31–0 was prepared. Superphosphate, ammonium phosphate, manganese oxide, zinc oxide, cupric sulphate, boron acid and clay as filler were used for laboratory scale manufacturing. Depending on calcium concentration in fertilizers, SFL amount in the range of ~2–10% was added.

Fertilizer granulation optimum parameters such as moisture content in mixture, ratio of fertilizers components, recycling amounts of small fraction to granulation

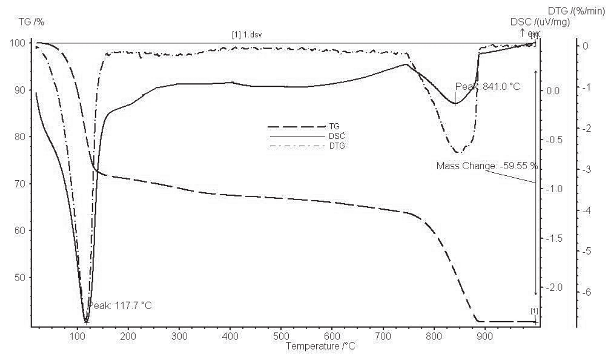

Fig.2. The data of DSC–TG analysis of sugar factory lime.

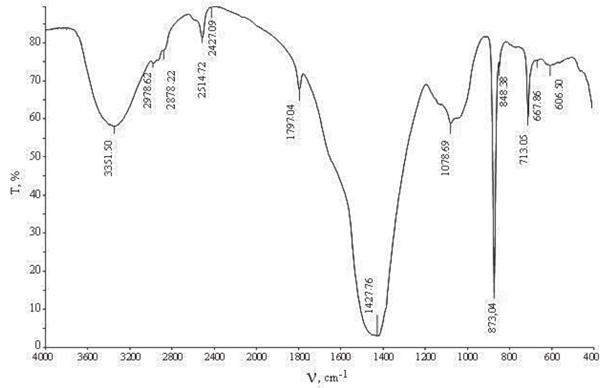

Fig.3. IR spectra of SFL.

Table 2. The parameters of granulation process 5–31–0 grade fertilizers and the main physico–chemical properties of the product.

Sample	Mixing materials,%			Distribution,%					Moisture of the product,%	pH	Crushing strength, N/gran.
	SFL	Recycling content	Moisture	Particle size, mm							
				>5	3-5	2-3	1-2	<1			
1	1.97	–	17.15	9.18	15.14	11.83	22.16	41.70	4.25	4.7	10.8
		20	17.05	5.18	13.80	14.18	30.09	36.75	4.06	4.5	17.2
		40	15.19	3.97	11.97	13.24	28.89	41.93	2.44	4.6	26.5
		60	13.24	1.94	8.74	14.27	46.53	28.51	2.31	4.6	23.4
		80	13.14	0.63	2.27	9.83	68.44	18.83	4.43	4.7	14.7
2	5.80	–	16.34	4.30	9.76	16.49	44.99	24.46	3.24	5.1	12.4
		20	17.80	0.97	7.19	21.34	55.96	14.55	3.49	5.1	18.9
		40	13.17	1.67	8.22	26.77	52.68	10.66	4.03	4.9	25.5
		60	16.54	0.85	10.03	26.15	55.65	7.33	3.41	4.7	21.2
		80	16.25	0.09	1.70	26.00	61.73	10.48	4.88	4.8	16.1
3	7.46	–	14.94	7.76	17.07	29.92	37.43	7.82	6.49	4.8	10.2
		20	16.02	3.18	21.57	41.23	31.29	2.72	5.17	4.8	17.6
		40	16.36	2.65	13.01	35.24	44.81	4.29	5.05	4.7	24.4
		60	14.43	0.24	3.31	37.54	54.34	4.57	1.58	4.8	22.2
		80	16.34	0.00	1.09	7.23	79.54	12.14	3.18	4.9	13.2
4	9.96	–	15.58	3.04	13.56	23.10	41.96	18.33	5.46	5.0	9.7
		20	15.07	2.28	12.27	24.29	50.48	10.68	5.06	5.1	15.1
		40	18.12	2.15	13.63	35.75	43.74	4.73	6.35	5.0	19.5
		60	15.53	1.47	7.00	26.72	59.52	5.29	2.34	5.0	16.4
		80	15.03	1.12	7.18	26.69	62.45	2.57	4.35	5.1	11.9

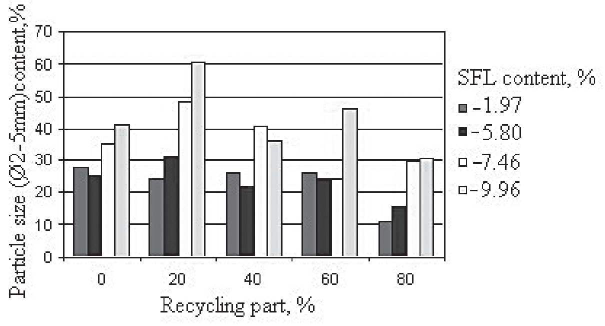

Fig. 4. Dependence of commercial particle size (∅2–5 mm) content on recycling part and SFL content.

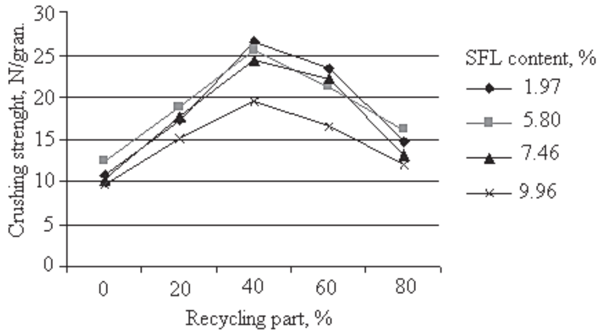

Fig. 5. Dependence of granule (∅ 3 mm) crushing strength on recycling part and SFL content.

as well as the main characteristic of the product such as particle size, crushing strength of granules, moisture content, and pH value of 10% water solution of the product were measured. The results are given in Table 2.

A particle size is one of the main properties for handling and using granular fertilizers. The general size range of 2.0 to 5.0 mm is commercially sufficient. Small-sized (less that 2.0 mm) particles are used for recycling into granulator in a primary mixture to form nuclei for the granules and is very important for final particle size distribution in the product.

Dependence of commercial particle size content on the recycling part and SFL content in product is shown in Fig.4. The commercial particle size in the range of 2.0–5.0 mm was calculated. The results show that the highest commercial size content of fertilizers is obtained when recycling contains 20% of granular mixture.

As fertilizers are handled, abrasion between granules can cause degradation and dust formation. Crushing strength value characterizes the stability of granular fertilizers in this regard. Granules of 3 mm diameter were used for measurements. Dependence of crushing strength granules size range 3 mm from recycling part and SFL content in product is shown in Fig.5.

As shown in Fig. 5, crushing strength value is highest when approximatly 40% of the recycling part is added to granulating mixture and mixture contains from 1.97% up to 7.46% of SFL. When fertilizer contains 9.96% of SFL, the crushing strength of granules is weakest.

Evaluation of crushing strength and particle size value shows that optimum content of the recycling part is equal to 20–40% of granular mixture.

The results show that it is possible to obtain 5–31–0 grade fertilizers, containing microelements and calcium up to 2.15% CaO (7.46% of SFL) with sufficient physicochemical properties of compound fertilizers.

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