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AN IMPROVED METHOD FOR DETERMINING THE MASS FRACTION OF CALCIUM CARBONATE IN THE CARBONATE BEDROCK

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ABSTRACT

In the article it is offered to enter in the technological audit of the lime department of sugar factory the adjusted technique of the definition of the maintenance of calcium carbonate in carbonate breed. For this purpose, a complete chemical analysis of limestone was performed, which includes determination of moisture content, impurities insoluble in hydrochloric acid, the amount of one and a half oxides of aluminum and iron, calcium carbonate (advanced method), and magnesium carbonate, calcium sulfate, alkali metal oxides, potassium, and sodium. The obtained experimental data are summarized in one table and the material balance of all components of carbonate bedrock is summarized. The proposed method made it possible to obtain objective data on the component composition of the carbonate material. This, in turn, avoids many technological problems, namely to reduce the formation of melts in the lime kiln, improve the filtration of juices, increase the ability of lime to chemically interact with water, reduce the volume of water on the juicer etc. Thus, the use of the recommended method for determining calcium carbonate ($CaCO_3$), as part of the technological audit, will allow early adjustment of the process, which will give maximum energy and resource savings, as well as increase the level of environmental friendliness of the enterprise.

Keywords: limestone; carbonate bedrock; calcium carbonate; lime separation; sugar industry

INTRODUCTION

In the sugar industry of Ukraine, calcium hydroxide [$Ca(OH)_2$] and carbon dioxide (CO_2) are mainly used to purify diffusion juice from non-sugars **(Zheplinska et al., 2020)**. These components can be obtained by firing carbonate rocks and subsequent quenching of lime (CaO), obtained by dissociation of calcium carbonate ($CaCO_3$). Limestone is a sedimentary rock consisting mainly of calcite and impurities **(Zheplinska et al., 2019)**. The chemical composition of pure limestone is close to calcite, where CaO – 56% and CO_2 – 44%. As is known, limestone is an exhaustible resource, its deposits are limited and make up 19 – 22% of the total mass of sedimentary rocks **(Sheiko et al., 2019)**.

In Ukraine, limestones with a $CaCO_3$ content of 93.00% and impurities with a mass fraction are allowed for use in sugar production:

- substances that are insoluble in hydrochloric acid not more than 3.00%;
- oxides of aluminum and iron in the amount not exceeding 1.50%;
- magnesium carbonate not more than 2.50%;
- calcium sulfate not more than 0.40%;
- alkali metal oxides of potassium and sodium in the amount not exceeding 0.25%;
- impurities (clay, etc.) not more than 3.00% **DSTU 1451-96 (1997)**.

Despite the seemingly high condition of limestone, many problems often arise in practice: the formation of melts in the lime kiln, which is the irreversible loss of lime; formation of sediments on the heating surface of the evaporator; saturating juices are poorly filtered; the stability of the furnace lining is reduced; the rate of chemical interaction of CaO with water decreases, so the quenching process is significantly slowed down; the volume of molasses increases; the volume of water on the juicer increases, etc **(Alves et al., 2017)**. All the above technological problems lead to an increase in the cost of lime on the machine juicer and its irreversible losses in the lime department **(Palamarchuk et al., 2019)**. To provide the required amount of CaO, it is necessary to increase the use of limestone, which will increase the amount of fuel used for its firing and increase carbon dioxide emissions into the atmosphere, which worsens the ecological situation of the planet.

One of the primary causes of the above problems is the lack of a correct technological audit of the lime department, which includes the use of correct methods of control of technological parameters **(Mushtruk et al., 2020)**. One of these methods, which is part of the audit of the limestone department, namely the method of determining the mass

fraction of calcium carbonate in the carbonate rock, will be presented in this article **(Bhatia et al., 2016)**.

Each technique currently used in practice in the technological flow implies that it should be as accurate as possible, easy to use, and affordable. Often researchers omit some of the points of the above requirements and to date, there is very little research in this area. In particular, there is a method of determining the mass fraction of calcium carbonate in the carbonate rock **DSTU 1451-96 (1997)**, which is based on the acidimetric determination of the mass fraction of calcium carbonate in the carbonate rock by calculating the percentage of Trilon B solution, which went to titrate the calcium content. Other authors presented a method **(Zheplinska et al., 2021)**, which involves analysis by a complexometric method. At the same time, the proposed methods do not provide the high accuracy of the results of determinations.

There are modern techniques that can be used to simultaneously determine the isotopic ratios of calcium and magnesium from a single aliquot of biological and geological samples **(Somaratne et al., 2019)**. However, for the needs of a sugar factory, it is necessary to know the concentration of $CaCO_3$ in the carbonate rock, and not the isotopes of calcium and magnesium separately. As in the carbonate rock, there are impurities of calcium sulfate, which negatively affect the technological process, the isotopes of calcium from this component will give an error in estimating the content of $CaCO_3$. Also, this method is highly costly for ongoing control.

Therefore, the audit of the lime department, which includes the use of an adjusted method for the determination of calcium carbonate in limestone, will lead to the fact that the technologist will be able to choose in advance the most effective way to conduct the process. In turn, this will not only ensure energy and resource savings in sugar production but also reduce emissions.

The task of our research was to improve the method of determining the mass fraction of calcium carbonate in the carbonate rock, which will increase the accuracy of the results and reduce its cost.

Scientific hypothesis

To increase the accuracy of experimental data, the improved method should be based on the material balance of all components of the carbonate rock. This will make it possible to self-check the accuracy of the results obtained, as having summed up the balance of all components of limestone, approximately we should get a result of 100%. Given this fact and improving the method of determining the content of calcium carbonate in the carbonate rock and entering the results into the material balance, we hope to get the sum of all components approximately 100%, which will indicate the accuracy of the data.

MATERIAL AND METHODOLOGY

Samples

Carbonate rocks of ten different deposits were used for experiments, namely with (Bogdanivsky, Hlynsko-Rozbyshivsky, Malodivytsky, Milkivsky, Kybyntsivsky, Pryluky, Rybalsky, Pivdenno-Panasivsky, Velykobubnivsky, Sukhodolivsky).

Chemicals

Distilled water (producer «Inter-Synthesis» Limited Liability Company, Ukraine).

Hydrochloric acid (HCl, producer «Inter-Synthesis» Limited Liability Company, Ukraine, chemically pure for analysis).

Sulfuric acid (H_2SO_4, producer «Inter-Synthesis» Limited Liability Company, Ukraine, chemically pure for analysis).

Nitric acid (HNO_3, producer «Inter-Synthesis» Limited Liability Company, Ukraine, chemically pure for analysis).

Ammonia (NH_3, producer «Inter-Synthesis» Limited Liability Company, Ukraine, chemically pure for analysis).

Sodium (Na, producer «Inter-Synthesis» Limited Liability Company, Ukraine, chemically pure for analysis).

Ethyl alcohol (C_2H_5OH, producer «Inter-Synthesis» Limited Liability Company, Ukraine, chemically pure for analysis).

Indicator acid chromium dark blue ($C_{16}H_9ClN_2Na_2O_9S_2$, producer «Inter-Synthesis» Limited Liability Company, Ukraine, chemically pure for analysis).

Dry murexide indicator ($C_8H_8N_6O_6$, producer «Inter-Synthesis» Limited Liability Company, Ukraine, chemically pure for analysis).

Trilon B ($C_{10}H_{14}N_2Na_2O_8$, producer «Inter-Synthesis» Limited Liability Company, Ukraine, chemically pure for analysis).

Ammonium carbonate ($(NH_4)_2CO_3$, producer «Inter-Synthesis» Limited Liability Company, Ukraine, chemically pure for analysis).

Instruments

Analytical scales (BTHE-6-H1K-1, producer "Inter-Synthesis" Limited Liability Company, Ukraine).

Drying cabinet (DC-300, producer "Laboratory equipment" Limited Liability Company, Ukraine).

Desiccator (EximLab 150, producer "Laboratory equipment" Limited Liability Company, Ukraine).

Chemical cups (CC-100, CC-150, CC-200, CC-250, CC-500, producer "Laboratory equipment" Limited Liability Company, Ukraine).

Petri dish (producer "Inter-Synthesis" Limited Liability Company, Ukraine).

Measuring flasks (MF-100, MF-150, MF-200, MF -250, MF-500, producer "Laboratory equipment" Limited Liability Company, Ukraine).

Muffle furnace (SNOL 8,2/1100, producer "Laboratory equipment" Limited Liability Company, Ukraine).

Measuring pipettes (MP-0,001, MP-0,002, MP-0,005, MP-0,01, MP-0,015, producer "Inter-Synthesis" Limited Liability Company, Ukraine).

Conical flask (CF-100, CF-150, CF-200, CF-250, CF -500, producer "Laboratory equipment" Limited Liability Company, Ukraine).

Burette for titration (producer "Laboratory equipment" Limited Liability Company, Ukraine).

Filters (producer "Laboratory equipment" Limited Liability Company, Ukraine).

Photometer (eXact® Micro 20, producer "Inter-Synthesis" Limited Liability Company, Ukraine).

Laboratory Methods

For technological evaluation of carbonate rocks, their complete chemical analysis was performed, which includes the determination of mass fractions of calcium carbonate ($CaCO_3$); impurities insoluble in hydrochloric acid (SiO_2);

sums of one and a half oxides of aluminum and iron ($Fe_2O_3 + AI_2O_3$); magnesium carbonate ($MgCO_3$); calcium sulfate ($CaSO_4$); alkali metal oxides of potassium and sodium ($K_2O + Na_2O$); moisture content.

The content of impurities insoluble in hydrochloric acid, the amount of one and a half oxides of aluminum and iron, and calcium sulfate were determined by weight. Calcium and magnesium carbonates – by the method of complexometric titration with Trilon B. The content of alkali metal oxides of potassium and sodium – by the photometric method.

Determination of moisture content was performed as follows: 5 g of limestone from the sample preparation for analysis was weighed on analytical balances in a dry pre-weighed beaker. Then the beaker with the sample, without closing the lid, was placed in an oven and kept for 3 hours at a temperature of 105 – 110 °C. The beaker was then capped, removed from the oven, and placed in a desiccator for 20 minutes to cool, then weighed. The portion was dried to constant weight until the difference between the results of the two weighings was not more than 0.001 g.

The ability of silicates to dissolve under the action of strong concentrated acids was used to determine the content of impurities insoluble in hydrochloric acid. The obtained precipitate of silicic acids was calcined at a temperature of 1000 °C to constant weight and weighed. At high temperatures, silicic acids lose water and turn into silicon dioxide.

One and a half oxides of aluminum and iron after separation of silicic acids were precipitated in the form of hydroxides with concentrated ammonia solution at pH = 5.5, which corresponds to the isoelectric point of colloidal solutions of $Al(OH)_3$ and $Fe(OH)_3$. Next, the resulting precipitate was calcined at a temperature of 900 °C and weighed. In the process of calcination, hydroxides lose water and turn into oxides.

After the separation of silicic acids, the content of calcium sulfate was determined by adding barium chloride to the solution. The precipitate was washed with cold water until a negative reaction to the chlorine ion. The resulting precipitate was burned to constant weight in a muffle furnace at a temperature of 850 – 900 °C and weighed.

The complexometric method for the determination of magnesium ions was carried out using the disodium salt of ethylenediaminetetraacetic acid (Trilon B), which forms with this ion strong colorless complex compounds. The content of magnesium ions was determined in the presence of an indicator of dark blue acid chromium in ammonia buffer.

Description of the Experiment

All measurements of instrument readings were performed 5 times. The number of repetitions of each experiment to determine one value was also 5 times.

Statistical Analysis

Mathematical and statistical processing of experimental data was carried out in determining the criteria of Cochran's C test, Fisher, and Student's *t*-test. The accuracy of the data was determined using the Cochrane criterion, and the adequacy of the mathematical model was checked using the Fisher and Student criteria.

Statistical processing was performed in Microsoft Excel 2019 values were estimated using mean and standard deviations.

RESULTS AND DISCUSSION

The results (Figure 1) obtained by repeating the experiment twice show that the moisture content in all samples was not significant. Only in sample no. 6 a jump in moisture, concentration was observed, which is explained by the fact that chalk-like limestone was analyzed. Cretaceous limestones are characterized by increased hygroscopicity. The authors of scientific works **(Buniowska et al., 2017; Verma et al., 2018; Shmyrin, Kanyugina and Kuznetsov, 2017)** engaged in similar research but obtained other scientific results. The presence of moisture in limestone has almost no effect on the firing process. However, if the moisture concentration significantly exceeds the norm, it will increase fuel consumption and reduce the concentration of CO_2 in the furnace gas. The last component (CO_2) is very important in the technological process of sugar production. The authors of scientific works **(Nadeem et al., 2018; Avalos-Llano, Molina and Sgroppo, 2020; Rahimi et al., 2020)** do not believe that the concentration (CO_2) is not an important factor in the technological process of sugar production.

Therefore, all samples of the studied limestones contained the normative concentration of moisture, which indicates that this indicator will not adversely affect the firing process of carbonate rocks. The next test component was impurities that are insoluble in hydrochloric acid. The standard concentration of these impurities in the carbonate rock for Ukrainian plants is not more than 3%. The authors of the following scientific papers **(Dalfré Filho, Assis and Genovez, 2015; Luo et al., 2019; Dhar et al., 2015)** other methods for determining impurities were used for similar scientific research. According to the results of experiments (Figure 2) we observe that samples no. 2, 3, and 7 have an inflated content of the investigated component of the carbonate rock.

Given that during the firing of limestone SiO_2 can form silicates of calcium and magnesium, which is an irreversible loss of limestone, the use of these samples in the process is not recommended. Besides, silicates contribute to the formation of sediment on the heating surface of the evaporator. The authors of scientific works **(Guo et al., 2018; Ozerov and Sapronov, 1985; Jiang, 2015; Almohammed et al., 2015)** recommend not to use such samples in the production process.

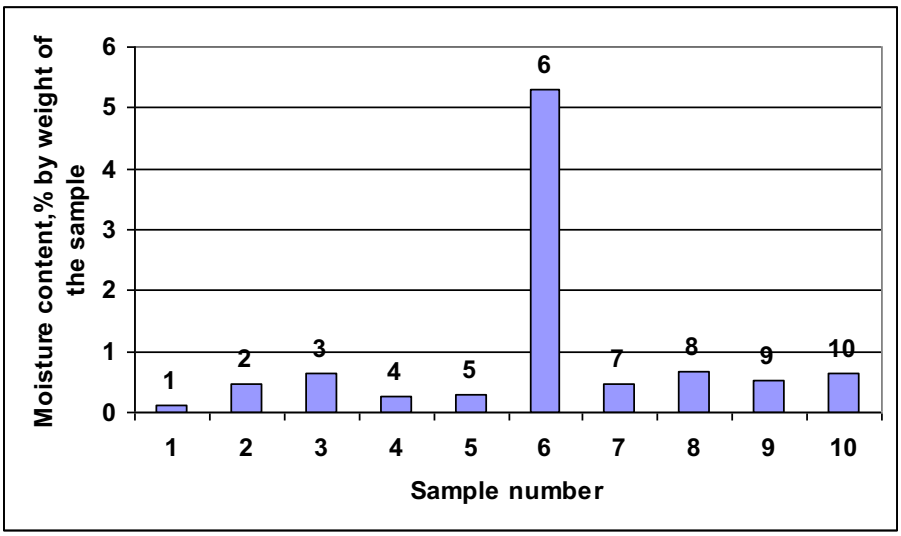

Figure 1 Moisture content in the studied samples of carbonate bedrocks.

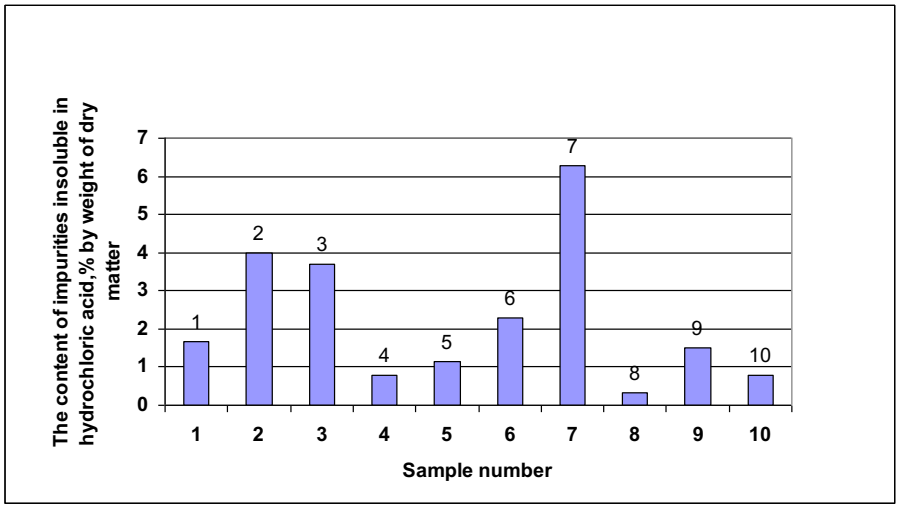

Figure 2 The content of impurities insoluble in hydrochloric acid in the studied samples of carbonate rocks.

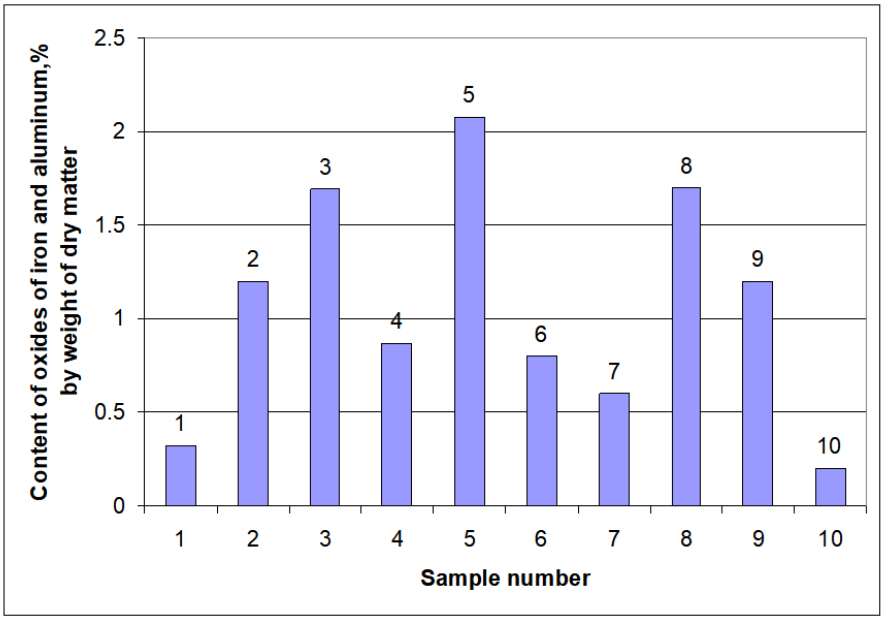

Figure 3 The content of iron oxide and aluminum oxide in the studied samples of carbonate rocks.

Carbonate rocks were analyzed for their content of iron and aluminum oxides. Since this component (both AI_2O_3 and Fe_2O_3) harms the filtration rates of saturating juices, and iron compounds reduce the stability of the lining and slow down the process of slaking lime, control over its content is necessary. The content of the sum of oxides of aluminum and iron in the carbonate rock according to **DSTU 1451-96 (1997)** should not exceed 1.5%. As the results of research (Figure 3) show, samples no. 3, 5, and 8 exceed the recommended norms, so their use in the technological process will lead to a number of the above negative consequences. The authors of the following scientific works **(Johnson, Zhou, and Wangersky, 1986; Lee et al., 2012; Lebovka et al., 2007)** recommend not to use such samples in the production process.

Control of the content of calcium sulfate in the carbonate rock should be carried out to prevent the formation of scale on the surface of the evaporator and slow down the hydration of lime. The mass fraction of calcium sulfate according to the recommendations **DSTU 1451-96 (1997)** should not exceed 0.4%. Figure 4 shows that samples no. 2, 7 and 8 cannot be recommended for use in the sugar industry. In subsequent scientific works **(Katariya, Arya and Pandit, 2020; Kim et al., 2016; Kozelová et al., 2011; Krasulya et al., 2016)** such studies were not conducted.

Determination of calcium carbonate content in the carbonate rock was carried out as follows. Pipette 0.15 m^3 of solution into a 2.50 m^3 porcelain cup or conical flask, add 1 m^3 of distilled water and 0.25 m^3 of sodium hydroxide solution with a mass fraction of 20% from a volumetric flask containing the filtrate obtained after precipitation of iron and aluminum oxides. After 1 – 2 minutes on the tip of a spatula made from 0.1 to 0.2 kg of murexide in a mixture with potassium chloride. The solution was stirred and titrated with 0.1 M solution of Trilon B until the transition from red to purple color, observed on a black background. Water was monitored by titration of the blank. The authors of scientific works **(Dehghannya et al., 2018; Moser et al., 2017; Zhu et al., 2016; Zdziennicka et al., 2017)** used other standardized methods to conduct similar studies.

Our proposed method **(Noguiera Felix et al., 2019)** differs from the method presented in **DSTU 1451-96 (1997)** in that the filtrate after precipitation of iron and aluminum oxides was additionally introduced murexide in a mixture with potassium chloride and then titrated with 0.1 M solution of Trilon B to the transition from red to violet color, and the mass fraction of calcium carbonate in the carbonate rock was calculated with a factor of 0.005008.

Thus, the mass fraction of calcium carbonate ($CaCO_3$) in the carbonate rock (based on the dry matter) (X) in percent was calculated by the formula (1):

$$X = \left(\frac{B \cdot K \cdot 0.005008 \cdot 100}{m} - 0.735 \cdot a \right) \cdot \frac{100}{100 - W} \quad (1)$$

Where:

B – is the volume of 0.1 M solution of Trilon B, which went to the titration of calcium, m^3;

K – is the correction factor for the solution of Trilon B;

0.005008 – the mass of calcium carbonate corresponding to 0.01 m^3 of a solution of Trilon B with a concentration of 0.1 $mol.m^{-3}$, kg;

a – is the mass fraction of calcium sulfate in limestone,%;

0.735 – conversion factor of calcium sulfate to calcium carbonate;

m – is a sample of limestone in the amount of 0.15 kg;

W – it is the mass fraction of moisture in percent.

The results of determining the mass fraction of calcium carbonate in the carbonate rock are shown in Table 1 and Figure 5.

Based on Table 1 and Table 2, all analyzed samples, which were carried out according to the method **DSTU 1451-96 (1997)**, have slightly inflated results. Therefore, an adjusted technique was proposed that gives more accurate results.

According to Figure 5, we see that the concentration of calcium carbonate in samples no. 2, 3, 5, 6, and 7 does not reach the recommended **DSTU 1451-96 (1997)**. Therefore, the use of such limestones is economically and technologically unprofitable.

The share of magnesium carbonate in carbonate rocks should not exceed 2.5%. Since the excess of this impurity contributes to the deterioration of the filtration rates of juices. From Figure 6 we observe that samples no. 2, 3, 5, 6, and 8 do not meet the recommended standards. It is also observed that the indicators obtained by the method **DSTU 1451-96 (1997)** are slightly inflated (Table 2). Therefore, this method of determining magnesium carbonate in carbonate rocks requires clarification, which will be discussed in the next article. The author of **(Sasikumar, Chutia and Deka, 2019)** used other standardized methods to conduct similar studies.

Alkali metal oxides of potassium and sodium also attract a lot of attention and should not exceed 0.25% **DSTU 1451-96 (1997)**. K + and Na + ions are active molasses-forming agents. Therefore, control over their concentration must be carried out. From Figure 7 it is seen that all samples corresponded to the normative concentration.

To provide an objective assessment of limestones, in terms of their technological condition, it is not enough to consider their individual components. It is necessary to consider a comprehensive complete chemical composition of carbonate rocks and only then provide certain technological characteristics of limestone. For this purpose, all the obtained data were summarized (Table 2) and the balance of all components of carbonate rocks was summed up. When determining the chemical composition of the carbonate rock, the sum of the mass fractions of impurities and calcium carbonate in the rock should be approximately 100%. According to the results of the final calculations, the total sum of the components of carbonate rocks in all samples according to the method **DSTU 1451-96 (1997)** gives slightly inflated results, the data obtained by the proposed method are almost close to 100%. Therefore, our proposed method for determining the mass fraction of calcium carbonate in the carbonate rock **(Cervantes-Elizarrarás et al., 2017)** which is based on the material balance makes it possible to most accurately assess the chemical composition of the carbonate rock.

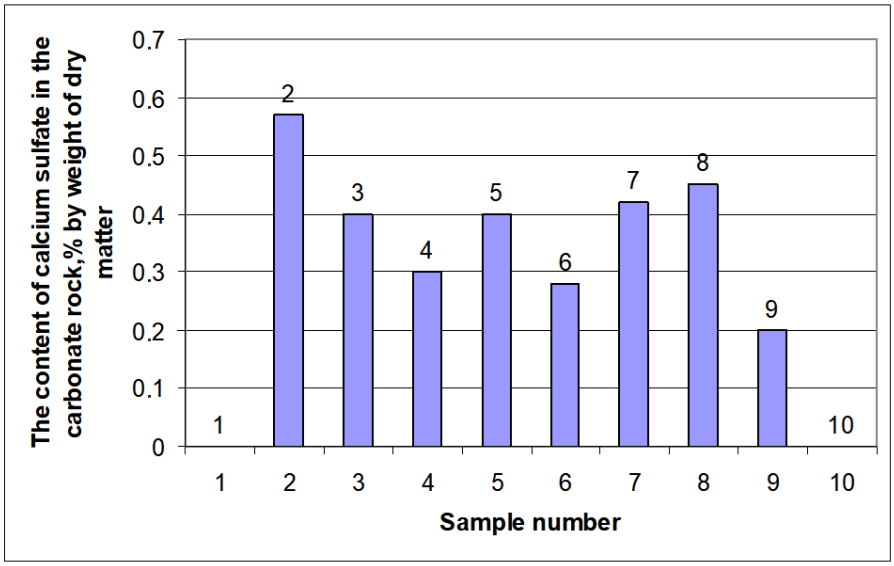

Figure 4 The content of calcium sulfate in the studied samples of carbonate rocks.

Table 1 The content of calcium sulfate in samples.

Sample number	Following method DSTU 1451-96 (1997)		Following the newly introduced method	
	% to probe mass	% to dry matter mass	% to probe mass	% to dry matter mass
Sample no. 1	193.22	193.41	96.70	96.78
Sample no. 2	179.16	180.06	89.42	89.87
Sample no. 3	178.18	179.25	89.02	89.56
Sample no. 4	193.80	194.29	96.88	97.12
Sample no. 5	183.99	184.54	91.92	91.20
Sample no. 6	173.4	183.11	86.66	91.51
Sample no. 7	179.37	180.27	89.60	90.05
Sample no. 8	186.12	187.36	92.95	93.57
Sample no. 9	190.0	190.25	94.83	95.30
Sample no. 10	195.16	196.33	97.61	98.20

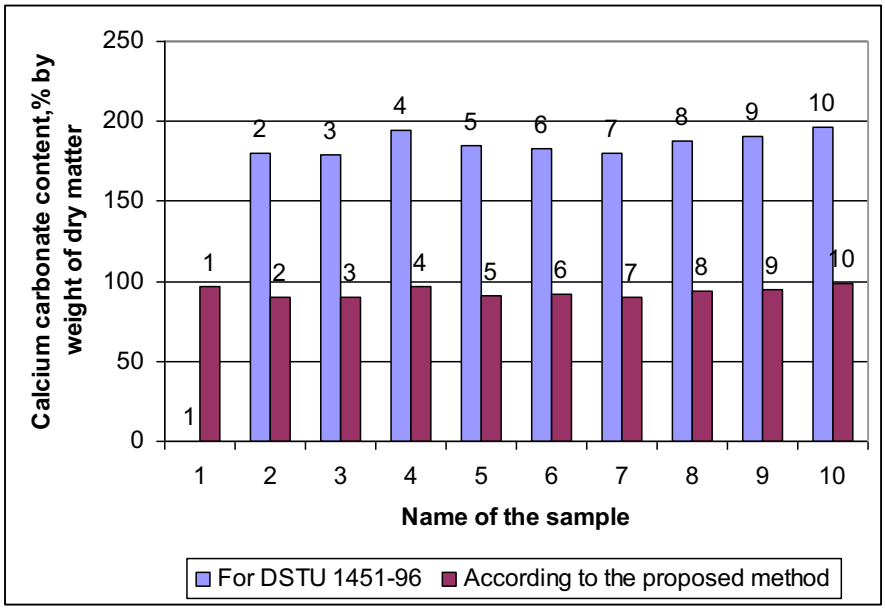

Figure 5 The content of calcium carbonate in the studied samples of carbonate rocks.

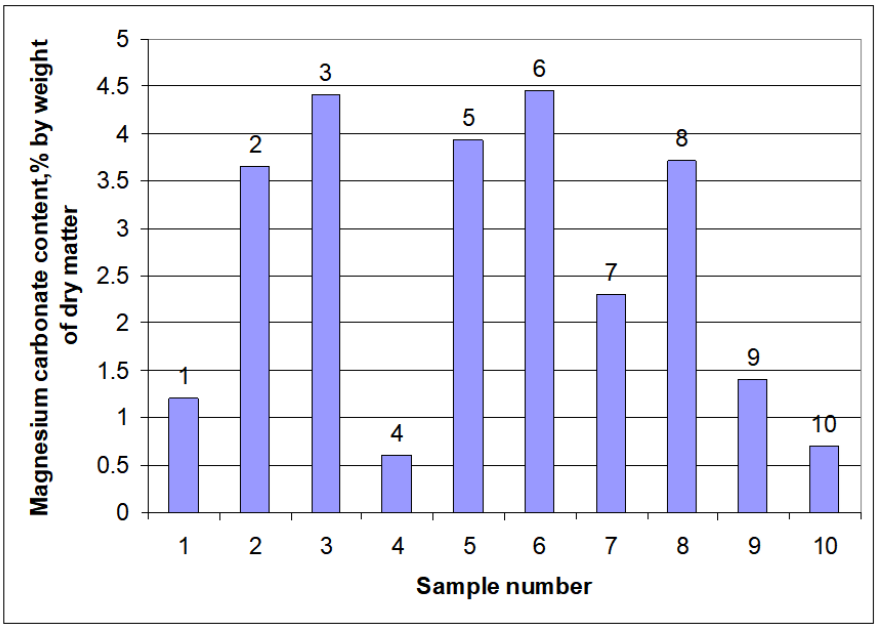

Figure 6 The content of magnesium carbonate in the studied samples of carbonate rocks.

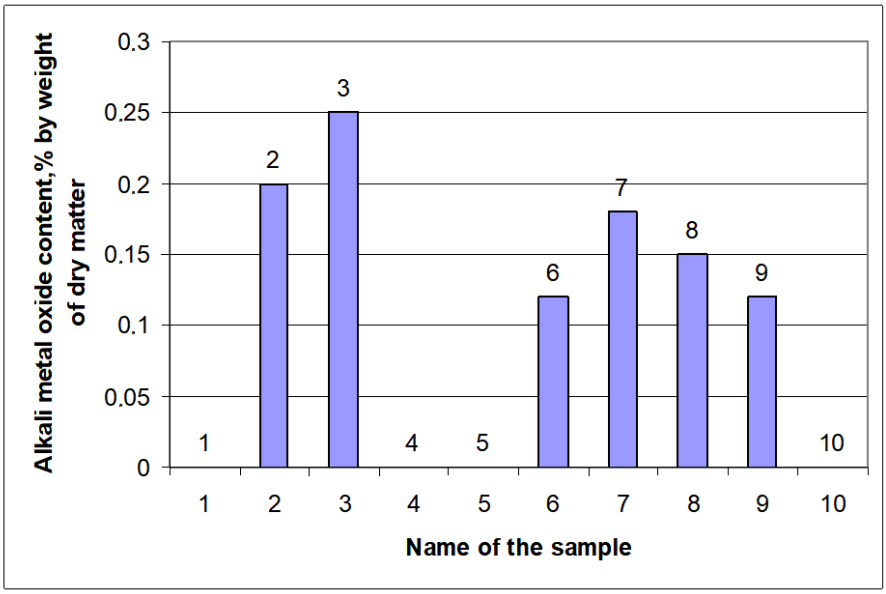

Figure 7 The content of alkali metal potassium oxide and sodium in the studied samples of carbonate rocks.

Table 2 Chemical composition of carbon bedrock.

	Carbon bedrock component	Sample no. 1				Sample no. 2			
		Following method DSTU 1451-96 (1997)		Following the newly introduced method		Following method DSTU 1451-96 (1997)		Following the newly introduced method	
		% to probe mass	% to dry matter mass	% to probe mass	% to dry matter mass	% to probe mass	% to dry matter mass	% to probe mass	% to dry matter mass
1	2	3	4	5	6	7	8	9	10
1.	Moisture	0.13		0.13		0.46		0.46	
		0.13		0.13		0.46		0.46	
	Moderate	0.13	-	0.13	-	0.46	-	0.46	-
2.	Impurities insoluble in hydrochloric acid, (SiO_2)	1.66	1.66	1.66	1.66	3.96	3.98	3.96	3.98
		1.66	1.66	1.66	1.66	3.95	3.97	3.95	3.97
	Moderate	1.66	1.66	1.66	1.66	3.96	3.98	3.96	3.98
3.	Oxides (AI_2O_3+Fe_2O_3)	0.32	0.32	0.32	0.32	1.20	1.20	1.20	1.20
		0.32	0.32	0.32	0.32	1.20	1.20	1.20	1.20
	Moderate	0.32	0.32	0.32	0.32	1.20	1.20	1.20	1.20
4.	Calcium carbonate ($CaCO_3$)	193.21	193.40	96.69	96.77	179.17	180.07	89.43	89.88
		193.23	193.42	96.71	96.79	179.16	180.06	89.42	89.87
	Moderate	193.22	193.41	96.70	96.78	179.16	180.06	89.42	89.87
5.	Magnesium carbonate ($MgCO_3$)	2.25	2.25	1.2	1.2	6.79	6.82	3.63	3.65
		2.25	2.25	1.2	1.2	6.81	6.84	3.64	3.66
	Moderate	2.25	2.25	1.2	1.2	6.80	6.83	3.63	3.65
6.	Calcium sulfate ($CaSO_4$)	-	-	-	-	0.57	0.57	0.57	0.57
		-	-	-	-	0.57	0.57	0.57	0.57
	Moderate	-	-	-	-	0.57	0.57	0.57	0.57
7.	Alkali metal oxides (K_2O+Na_2O)	-	-	-	-		0.20	0.20	0.20
		-	-	-	-	0.20	0.20	0.20	0.20
	Moderate	-	-	-	-	0.20	0.20	0.20	0.20
	Summary of the carbon bedrock component		197.64		99.96		192.84		99.47

Continuation of **Table 2**.

	Carbon bedrock component	Sample no. 1				Sample no. 2			
		Following method DSTU 1451-96 (1997)		Following the newly introduced method		Following method DSTU 1451-96 (1997)		Following method DSTU 1451-96 (1997)	
		% to probe mass	% to dry matter mass	% to probe mass	% to dry matter mass	% to probe mass	% to dry matter mass	% to probe mass	% to dry matter mass
1	2	3	4	1	2	3	4	1	2
1.	Moisture	0.63		0.63		0.25		0.25	
		0.63		0.63		0.25		0.25	
	Moderate	0.63	-	0.63	-	0.25	-	0.25	-
2.	Impurities insoluble in hydrochloric acid, (SiO_2)	3.65	3.68	3.65	3.68	0.77	0.77	0.77	0.77
		3.64	3.67	3.64	3.67	0.77	0.77	0.77	0.77
	Moderate	3.65	3.68	3.65	3.68	0.77	0.77	0.77	0.77
3.	Oxides (AI_2O_3+Fe_2O_3)	1.68	1.69	1.68	1.69	0.87	0.87	0.87	0.87
		1.68	1.69	1.68	1.69	0.87	0.87	0.87	0.87
	Moderate	1.68	1.69	1.68	1.69	0.87	0.87	0.87	0.87
4.	Calcium carbonate ($CaCO_3$)	178.19	179.26	89.03	89.57	193.80	194.29	96.88	97.12
		178.17	179.24	89.02	89.56	193.79	194.28	96.88	97.12
	Moderate	178.18	179.25	89.02	89.56	193.80	194.29	96.88	97.12
5.	Magnesium carbonate ($MgCO_3$)	8.2	8.2	4.37	4.40	1.12	1.13	0.6	0.6
		8.2	8.2	4.39	4.42	1.12	1.13	0.6	0.6
	Moderate	8.2	8.2	4.38	4.41	1.12	1.13	0.6	0.6
6.	Calcium sulfate ($CaSO_4$)	0.40	0.40	0.40	0.40	0.3	0.3	0.3	0.3
		0.40	0.40	0.40	0.40	0.3	0.3	0.3	0.3
	Moderate	0.40	0.40	0.40	0.40	0.3	0.3	0.3	0.3
7.	Alkali metal oxides (K_2O+Na_2O)	0.25	0.25	0.25	0.25	-	-	-	-
		0.25	0.25	0.25	0.25	-	-	-	-
	Moderate	0.25	0.25	0.25	0.25	-	-	-	-
Summary of the carbon bedrock component			193.47		99.99		197.36		99.66

Continuation of **Table 2**.

	Carbon bedrock component	Sample no. 1				Sample no. 2			
		Following method DSTU 1451-96 (1997)		Following the newly introduced method		Following the newly introduced method		Following method DSTU 1451-96 (1997)	
		% to probe mass	% to dry matter mass	% to probe mass	% to dry matter mass	% to probe mass	% to dry matter mass	% to probe mass	% to dry matter mass
1	2	3	4	5	6	7	8	9	10
1.	Moisture	0.29		0.29		5.31		5.31	
		0.29		0.29		5.31		5.31	
	Moderate	0.29	-	0.29	-	5.31	-	5.31	-
2.	Impurities insoluble in hydrochloric acid, (SiO_2)	1.13	1.13	1.13	1.13	2.16	2.28	2.16	2.28
		1.13	1.13	1.13	1.13	2.16	2.28	2.16	2.28
	Moderate	1.13	1.13	1.13	1.13	2.16	2.28	2.16	2.28
3.	Oxides (AI_2O_3+Fe_2O_3)	2.07	2.08	2.07	2.08	0.76	0.80	0.76	0.80
		2.07	2.08	2.07	2.08	0.76	0.80	0.76	0.80
	Moderate	2.07	2.08	2.07	2.08	0.76	0.80	0.76	0.80
4.	Calcium carbonate ($CaCO_3$)	183.99	184.54	91.92	91.20	173.4	183.11	86.65	91.50
		184.00	184.55	91.92	91.20	173.4	183.11	86.67	91.52
	Moderate	183.99	184.54	91.92	91.20	173.4	183.11	86.66	91.51
5.	Magnesium carbonate ($MgCO_3$)	7.37	7.40	3.93	3.94	7.92	8.36	4.21	4.45
		7.35	7.38	3.94	3.95	7.94	8.38	4.23	4.47
	Moderate	7.36	7.39	3.93	3.94	7.93	8.37	4.22	4.46
6.	Calcium sulfate ($CaSO_4$)	0.4	0.4	0.4	0.4	0.27	0.28	0.27	0.28
		0.4	0.4	0.4	0.4	0.27	0.28	0.27	0.28
	Moderate	0.4	0.4	0.4	0.4	0.27	0.28	0.27	0.28
7.	Alkali metal oxides (K_2O+Na_2O)	-	-	-	-	0.11	0.12	0.11	0.12
		-	-	-	-	0.11	0.12	0.11	0.12
	Moderate	-	-	-	-	0.11	0.12	0.11	0.12
Summary of the carbon bedrock component			195.54		99.75		194.96		99.45

Continuation of **Table 2**.

	Carbon bedrock component	Sample no. 1				Sample no. 2			
		Following method DSTU 1451-96 (1997)		Following the newly introduced method		Following method DSTU 1451-96 (1997)		Following the newly introduced method	
		% to probe mass	% to dry matter mass	% to probe mass	% to dry matter mass	% to probe mass	% to dry matter mass	% to probe mass	% to dry matter mass
1	2	3	4	1	2	3	4	1	2
1.	Moisture	0.47 0.47		0.47 0.47		0.67 0.67		0.67 0.67	
	Moderate	0.47	-	0.47	-	0.67	-	0.67	-
2.	Impurities insoluble in hydrochloric acid, (SiO_2)	6.24 6.24	6.27 6.27	6.24 6.23	6.27 6.26	0.32 0.32	0.32 0.32	0.32 0.32	0.32 0.32
	Moderate	6.24	6.27	6.24	6.27	0.32	0.32	0.32	0.32
3.	Oxides (AI_2O_3+Fe_2O_3)	0.60 0.60	0.60 0.60	0.60 0.60	0.60 0.60	1.7 1.7	1.7 1.7	1.7 1.7	1.7 1.7
	Moderate	0.60	0.60	0.60	0.60	1.7	1.7	1.7	1.7
4.	Calcium carbonate ($CaCO_3$)	179.36 179.38	180.26 180.28	89.60 89.60	90.05 90.05	186.13 186.11	187.37 187.35	92.95 92.95	93.57 93.57
	Moderate	179.37	180.27	89.60	90.05	186.12	187.36	92.95	93.57
5.	Magnesium carbonate ($MgCO_3$)	4.26 4.27	4.28 4.29	2.3 2.3	2.3 2.3	6.91 6.91	6.95 6.96	3.69 3.69	3.72 3.72
	Moderate	4.27	4.29	2.3	2.3	6.91	6.96	3.69	3.72
6.	Calcium sulfate ($CaSO_4$)	0.42 0.42	0.42 0.42	0.42 0.42	0.42 0.42	0.45 0.45	0.45 0.45	0.45 0.45	0.45 0.45
	Moderate	0.42	0.42	0.42	0.42	0.45	0.45	0.45	0.45
7.	Alkali metal oxides (K_2O+Na_2O)	0.18 0.18	0.18 0.18	0.18 0.18	0.18 0.18	0.15 0.15	0.15 0.15	0.15 0.15	0.15 0.15
	Moderate	0.18	0.18	0.18	0.18	0.15	0.15	0.15	0.15
Summary of the carbon bedrock component			192.03		99.82		196.94		99.91

Continuation of **Table 2**.

	Carbon bedrock component	Sample no. 1				Sample no. 2			
		Following method DSTU 1451-96 (1997)		Following the newly introduced method		Following method DSTU 1451-96 (1997)		Following the newly introduced method	
		% to probe mass	% to dry matter mass	% to probe mass	% to dry matter mass	% to probe mass	% to dry matter mass	% to probe mass	% to dry matter mass
1	2	3	4	5	6	7	8	9	10
1.	Moisture	0.53		0.53		0.63		0.63	
		0.53		0.53		0.63		0.63	
	Moderate	0.53	-	0.53	-	0.63	-	0.63	-
2.	Impurities insoluble in hydrochloric acid, (SiO_2)	1.49	1.5	1.49	1.5	0.79	0.8	0.79	0.8
		1.49	1.5	1.49	1.5	0.79	0.8	0.79	0.8
	Moderate	1.49	1.5	1.49	1.5	0.79	0.8	0.79	0.8
3.	Oxides (AI_2O_3+Fe_2O_3)	1.19	1.20	1.19	1.20	0.19	0.20	0.19	0.20
		1.19	1.20	1.19	1.20	0.19	0.20	0.19	0.20
	Moderate	1.19	1.20	1.19	1.20	0.19	0.20	0.19	0.20
4.	Calcium carbonate ($CaCO_3$)	190.0	190.25	94.83	95.30	195.15	196.32	97.61	98.20
		190.0	190.25	94.83	95.30	195.17	196.34	97.62	98.21
	Moderate	190.0	190.25	94.83	95.30	195.16	196.33	97.61	98.20
5.	Magnesium carbonate ($MgCO_3$)	2.81	2.82	1.39	1.4	4.22	4.24	0.69	0.7
		2.81	2.82	1.39	1.4	4.22	4.24	0.69	0.7
	Moderate	2.81	2.82	1.39	1.4	4.22	4.24	0.69	0.7
6.	Calcium sulfate ($CaSO_4$)	0.2	0.2	0.2	0.2	-	-	-	-
		0.2	0.2	0.2	0.2	-	-	-	-
	Moderate	0.2	0.2	0.2	0.2	-	-	-	-
7.	Alkali metal oxides (K_2O+Na_2O)	0.12	0.12	0.12	0.12	-	-	-	-
		0.12	0.12	0.12	0.12	-	-	-	-
	Moderate	0.12	0.12	0.12	0.12	-	-	-	-
Summary of the carbon bedrock component			196.72		99.72		201.57		99.9

CONCLUSION

The obtained data indicate that the use of the proposed method for determining the mass fraction of calcium carbonate in the carbonate rock makes it possible to obtain more accurate indicators of its concentration and, accordingly, the chemical composition of limestone.

Thus, the inclusion of the proposed improved method for determining the content of calcium carbonate in the carbonate rock, as one of the elements of the technological audit of the lime department will allow to give an objective assessment of the processes of the sugar plant and their early correction, which will lead to economic and environmental efficiency.

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