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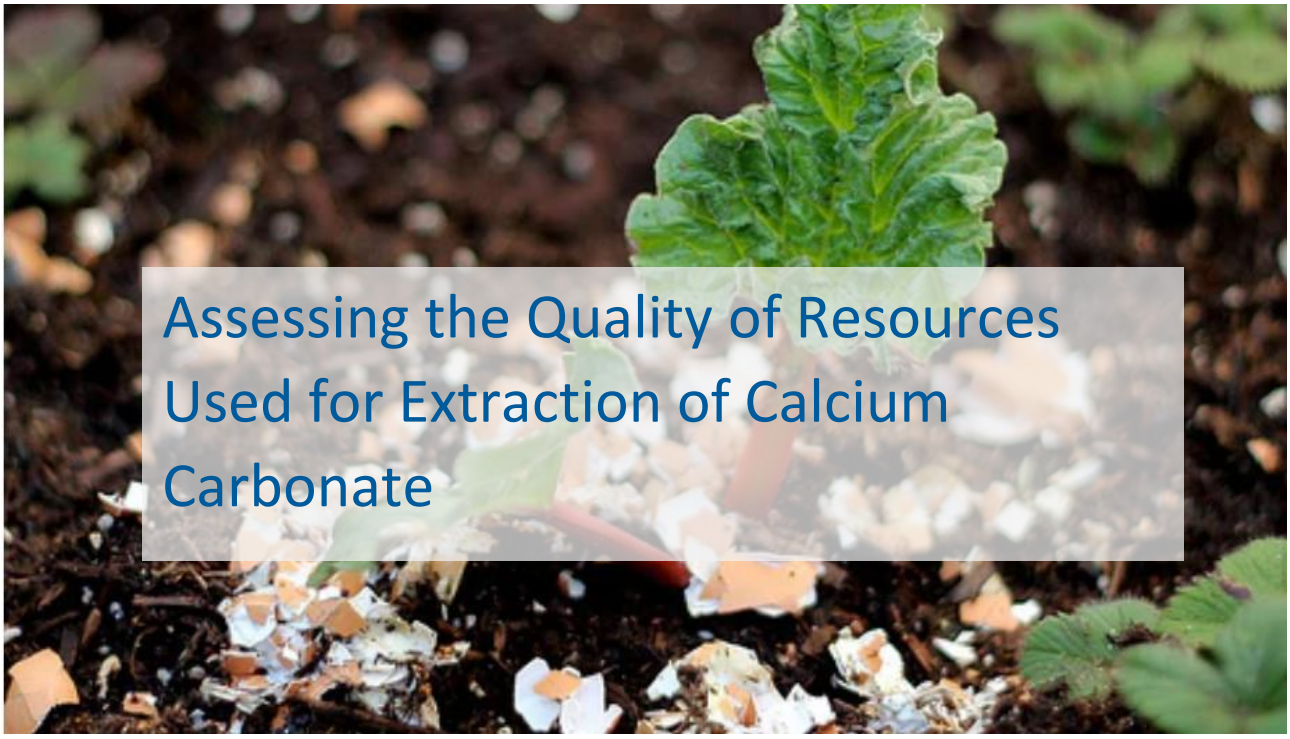

Assessing the Quality of Resources Used for Extraction of Calcium Carbonate

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General Introduction

Since the consumption of calcium carbonate does not exceed the amount of this mineral stored in natural deposits, it is not considered a non-renewable resource, however, water is consumed and carbon dioxide is released during its production and processing. Meanwhile, several million tonnes of waste are produced each year, including eggshells, which along with other types of waste could be used to extract calcium carbonate.

This lab exercise is intended for students aged 16 and above with previous laboratory experience (working with acids, boiling, filtering, titration, and preparing solutions of precise molarity).

Keywords:

Calcium carbonate, biological waste, eggshells, complexometric titration

Additional Background Information

Between 118 and 138 million tons of biological waste are produced in European countries each year. From 2024, sorting of such waste will be mandatory across the EU. It is an opportunity to make good compost, produce energy and create other products, however, there are also negative effects. Many EU countries struggle to find a place to degrade this waste in the long term. It is worth mentioning that some of the bio-waste degrades very slowly (e.g. oak leaves, thuja branches, eggshells), so it is cumbersome to recycle it in landfills. An alternative would be waste incineration, in fact, around 70 million tonnes of waste are incinerated in European countries every year, however, it produces around 52 million tonnes of CO_2, which significantly affects the climate.

Calcium carbonate ($CaCO_3$) accounts for ~4% of the Earth's outer layer. It is found in many rocks, such as calcite, chalk, and limestone. So far, calcium carbonate has not been categorised as a non-renewable resource, but due to the rising consumerism and high demand for products (it is used as an antacid (a neutralising agent), food colouring, and fertilizer), the market for this raw material is growing every year. It was worth ~50 billion US dollars in 2022 and is projected to reach ~73 billion US dollars by 2030.

A solution that could tackle both the issue of bio-waste and the need to obtain sustainable calcium carbonate would be using eggshells for the extraction of calcium carbonate.

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Learning Outcomes

Upon completion of this activity, the students will be able to:

- determine the content of calcium ions in eggshells using complexometric titration;
- calculate the calcium carbonate content of the sample based on the chemical reactions that have occurred;
- compare the content of calcium carbonate in eggshells of different origins.

Key Competences within the European Framework

Literacy competence
S1. Ability to understand and interpret concepts, feelings, facts or opinions in oral and written form.
S4. Ability to interact in an appropriate and creative way in any situation.
Multilingual competence
S1. Ability to understand and interpret concepts, feelings, facts or opinions in oral and written form.
S4. Ability to interact in an appropriate and creative way in any situation.
S5. Knowledge of vocabulary, grammar and language.
Mathematical competence and competence in science, technology and engineering
S1. Ability to use constructive thinking in order to solve a problem in every situation.
S5. Capacity for quantitative thinking.
S6. Ability to extract qualitative information from quantitative data.
S7. Ability to formulate problems mathematically and in symbolic form to facilitate their analysis and solution.
S8. Ability to design experimental and observational studies and analyse data resulting from them.
S9. Ability to formulate complex problems of optimisation and decision-making and to interpret the solutions in the original contexts of the problems.
Digital competence
S1. Critical use of information technology for work.
Personal, social and learning to learn competence
S1. Ability to pursue and persist in different kinds of learning.
S2. Identifying available opportunities.
Citizen competence
S1. Ability to effectively interact with other people.

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S3. Ability to work effectively and collaborate with other team members.
Cultural awareness and expression competence
S3. Ability to plan and manage tasks.

United Nations' Sustainable Development Goals

The Sustainable Development Goals are the blueprint to achieve a better and more sustainable future for all. They address the global challenges we face, including those related to poverty, inequality, climate change, environmental degradation, peace and justice.

	 Enable access to basic services		 Equal access to global expertise
	 Safe medical devices		 Sustainable urbanization
✓	 Access to education	✓	 Responsible consumption and production
	 Less hardship, more opportunities		 Strengthen resilience, reduce disaster impact
	 Safe and affordable water		 Reduce marine pollution
	 Energy – the golden thread	✓	 Sustainable use of terrestrial ecosystems
	 Safety of workers and economic growth		 Promote peaceful and inclusive societies
	 Resilient infrastructure and sustainable industrialization		 Better access to technology and innovation

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Contents – Theoretical principles

Studies have shown that the chemical composition of eggshells varies depending on the origin of the eggs. It is influenced by factors such as climate, feed, age of the animal, etc. The following table contains general chemical compositions of various eggshells (source: https://www.researchgate.net/figure/Chemical-compositions-of-egg-shells_tbl1_26469281).

Element	Weight (%)			
	Natural hen egg shell	Boiled hen egg shell	Natural duck egg shell	Boiled duck egg shell
$CaCO_3$	96.48	96.48	96.48	95.99
S	2.31	3.59	1.24	1.92
Mg	0.404	0.440	0.996	0.927
P	0.501	0.469	0.508	0.481
Al	-	-	-	0.309
K	-	-	0.0839	0.00957
Sr	0.0737	0.0734	0.118	0.093

To determine the content of calcium carbonate in eggshells, they are dissolved in a preponderance of hydrochloric acid solution:

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$$

Calcium chloride dissociates into ions:

$$CaCl_2 \rightleftharpoons Ca^{2+} + 2Cl^-$$

To quantify calcium ions the sample is titrated with EDTA (ethylenediaminetetraacetic acid) disodium salt. Since EDTA disodium salt is a fairly universal polydental complexometric titrant, to ensure direct identification of calcium ions, ammonium buffer solution and Eriochrome Black T are added to the titrant as an indicator. The colour changes from red to blue.

Lab Procedure

During the lab exercise, students compare the shells of chicken eggs of different origins, establishing the content of calcium carbonate to determine which of them is the best source of calcium carbonate. During the experiment, fresh eggshells are dissolved, and the resulting sample is complexometrically titrated with EDTA using ammonium buffer solution and Eriochrome Black T as an indicator.

Resources on this topic:

Module 1 – Objective: Determining the Amount of Calcium Carbonate in Eggshells of Various Origins

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Learning Pathway

Step 1 – 10 min. – the teacher reminds students of the specific safety rules pertaining to this lab exercise and the use of personal protective equipment.
Step 2 – 60 min. – students are divided into groups of 3 people each. Each group receives its own sample of eggshells and carries out the experiment based on the prepared lab procedure outline.
Step 3 – 30 min. – students work in groups to fill out the remaining protocol, answer the questions, search for information, discuss the obtained results, etc.

Evaluation

First, students work in groups, and then several groups collaborate to discuss and draw conclusions on how the origin of eggshells affects the calcium carbonate content.
Students may also create posters and/or presentations on the use of calcium carbonate (a lesser-known resource) in various fields as a part of a separately evaluated exercise. Here, the assessment criteria would be determined by each school individually, based on the adopted evaluation procedures.

Description of Student's Cards

Student's Card 1 – Determining the Amount of Calcium Carbonate in Eggshells of Various Origins

Sources

https://chem.libretexts.org/Ancillary_Materials/Demos_Techniques_and_Experiments/General_Lab_Techniques/Titration/Complexation_Titration
https://royalsocietypublishing.org/doi/10.1098/rsif.2021.0502
https://edis.ifas.ufl.edu/publication/VM013

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