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EXPERIMENTAL RESEARCHES ON ENERGY CONSUMPTION FOR OBTAINING ROSEHIP POWDER USING A MILL FOR HARD PRODUCTS

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Abstract: This paper addresses the measurement of the energy consumption required for the disintegration of dry rosehip to obtain powder with cohesive and fine particles. The equipment used for grinding was the FRITSCH PULVERISETTE 19 Universal Mill for hard materials. The experimental studies were conducted using the same amount of sample, and the energy consumption was evaluated based on different grinding times, namely 30, 60, 90, 120, and 150 seconds, using four sieves with perforations of different shapes and sizes: 4 mm, 1 mm, 0.5 mm, and 0.2 mm. It was observed that the highest energy consumption was recorded when using the sieve with perforation size of 0.2 mm, followed by the use of sieves with perforation sizes of 0.5 mm, 1 mm, and 4 mm, respectively. Accordingly, the higher the desired level of fineness, the greater the electrical energy consumed by the equipment. There were also several instances of losses. It was found that the relatively short grinding time of 30 seconds resulted in significant amounts of material being lost using all four sieves. The smallest losses were observed after grinding the material using the 4 mm sieve, precisely due to its square–shaped perforations. Therefore, both the trapezoidal and square perforations of the sieves play a decisive role in the energy consumption required for grinding, as well as in the material losses incurred.
Keywords: rosehips powder, grinding, energy consumption, grinding time, sieve perforations

1. INTRODUCTION

The pseudo–fruits of Rosa *canina*, often referred to as rosehips, have been recognised as essential constituents for food and medicine due to their high concentration of flavonoids, carotenoids, galactolipids, triterpenoic acids, and vitamins *(Vartolomei et Turtoi., 2023; Salgın et al., 2016)*. However, they are perishable, just like regular fruits, produced seasonally, and difficult to consume due to the pseudo–fruit's physiology.

The shell, the fleshy red pulp, which is not a part of the botanical fruit, and the achenes, which are tiny membranes that enclose the individual rosehip seeds, are the main components of a rosehip. *(Winther et al., 2016)*. Studies have shown that the most valuable part of the pseudo–fruit is the pulp due to its antioxidant power, followed by the seeds due to their rich content of essential fatty acids. *(Ghendov–Mosanu et al., 2020*). Rosehips can have many uses, not just in jams and infusions; one of the greatest solutions would be to dry the fruits first, followed by grinding them to produce a powder. Manufacturing a powdered product would expand its applications as rehydrated juice or infusion, or to be incorporated to bakery products, sweets, dairy products, porridge, ice cream, smoothies, shakes, salads, snacks, among other things, and even for enriching directly any food in bioactive components (*Igual et al., 2022; Marstrand, & Campbell–Tofte, 2016*). Converting dried rosehips to powder is helpful in minimize packaging, storage and transportation costs by reducing ingredient volume. Food powders are complex systems that play a significant role in the food industry for obtaining foods due to the heterogeneity of their chemical composition and the variability of native structures. *(Singh et al., 2022; Erenturk et al., 2005)*.

Grinding is a common requirement for many raw material processing operations and is achieved by using a variety of forces to produce particles of specific sizes and shapes. In the food industry, grinding is considered one of the most energy–intensive processes where only 1% of the total energy input is used to reduce particle size and the rest of the energy is dissipated as heat. As a result, the temperature of the ground product, surrounding air, and the grinding mill all significantly increase during the grinding process. Measuring the energy required for grinding rosehips could be very useful in developing strategies to reduce the input energy in factories producing such food powders. *(Jung et al., 2018).*

In order to minimize the generation of heat and the loss of product quality induced by the temperature, which must not be higher than 40 °C, it is considered that the grinding time has a crucial importance in this regard. *(Aradwad et al., 2021; Ghodki & Goswami 2016)*.

Rosehips are ground using a variety of techniques and procedures, including standard grinding (hammer, plate, and pin mill), superfine grinding (ball and roller mill), and enhanced grinding (dry ice, cryogenics, chilled air and stage grindings). The mechanism of grinding, the degree of grinding the

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energy consumed, and the characteristics of the final product are all influenced by the type of equipment *(Aradwad, et al., 2021)*. Even though hammer mills and ball mills are the most commonly used to obtain food powders, precisely because they are more energy efficient than a knife mill and produce finer particles, we particularly wanted to highlight the efficiency of such a mill, based of the scissor cutting principle between the cutting edges of the rotor and the fixed knives in the grinding chamber until the desired final fineness is achieved.

The energy requirements depend on the kinematic and geometric characteristics of the grinding machine and the physical characteristics of the material being ground. The majority of the energy utilized in grinding is used to break down the material and reduce friction between the material and the grinder's parts *(Singh et al., 2022)*. When the size of the sieve perforations changes from coarse to fine and when the moisture content of the rosehips increases, more energy is required to obtain the powder with the desired particle sizes *(Dabbour et al., 2015)*.

The solubility, dispersion, and release of the powder's active components have been demonstrated in studies to be significantly influenced by particle size (*Zhang et al., 2021*). A powder with too small of a particle size limits easy absorption in the human digestive system, while a powder with a big particle size limits the bioavailability of certain ground particle components *(Singh et al., 2022)*. Moisture content is a critical factor in the manufacturing of food powders, since it is associated with better cohesiveness, in part because liquid bridges exist between the particles *(Zhang et al., 2021; Wu et al., 2022)*.

Rosehips with a higher moisture content are difficult to grind because during grinding the water content acts as a plasticizer along with the sticky nature of the oils found in the seeds. Therefore, it is essential to check the moisture content before and after the grinding process to obtain higher energy efficiencies in the food sector *(Jung et al., 2018)*. Grinding characteristics, such as energy consumption, specific energy requirements during grinding, are also necessary to design energy efficient and best yielding rosehips powder mills. There is also a lack of studies on empirical modeling of dried rosehip fruit milling *(Singh et al., 2022)*.

The objectives of this work were: to measure the specific energy consumption for grinding dry rosehips using a hard products mill based osn the cutting principle equipped with four sieve sizes, and evaluating it according to different grinding times, comparing the experimental data regarding the amounts of crushed material, respectively remained in the grinding chamber depending on the grinding time, thus observing the efficiency of the mill, monitoring the moisture content of the final powder, which varies according to the grinding time.

2. MATERIALS AND METHODS

Rosehip fruits of the variety *Rosa canina* were hand–picked from a forested area in Argeș County, at the beginning of September, being fully ripe, light red in color, free of mold and other impurities, and then washed and dried in the laboratory under 40°C until a moisture content of 4.53% was reached. The samples were maintained in moisture–proof polyethylene bags in a refrigerator at 5 °C to maintain the moisture content of rosehip fruits for further studies. A quantity of 800 g of dried rose hips was required for the experimental tests. The sample size selected for each experiment was 40 g. Whole fruits with peel, pulp and seeds were subjected to the grinding process so that the obtained powder has full nutritional value, each component part of the fruit having a profile of individual natural compounds.

The equipment used for grinding was a FRITSCH PULVERISETTE 19 mill for hard products based on the cutting principle between the cutting edges of the rotor and the fixed knives in the grinding chamber. It features a maximum feed size of 70 x 80 mm, a flow rate of up to 60 l/h and a rotor speed of 2800 rpm. Special geometry of the grinding chamber, with smooth inner walls, does not allow the existence of dead spaces and ensures easy, quick cleaning of all grinding tools. Rotor and sieve cassette can be easily removed when cleaning is desired. The rotor used is made of hardened stainless steel with four straight edges parallel to the fixed knives. The knives have 2 cutting edges and can be easily reversed to double the life of the rotor. Mill motor is a three–phase 2.8 kW maintenance–free motor equipped with a frequency converter.

Mill was first run empty and the energy consumption was determined. The material was introduced into the grinding chamber and was allowed to flow freely and was shredded between the rotor edges and

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counter–fixed edges. The final degree of grinding was regulated by four sieve cassettes with insert cells of different sizes, namely 4 mm, 1 mm, 0.5 mm and 0.2 mm, respectively, as show in Figure 2.
As soon as the material in the grinding chamber reached the required size, the particles fell through the holes in the cassette into the collecting vessel. The sieve cassettes had trapezoidal perforations, those with sizes of 0.2 mm, 0.5 mm and 1 mm, and the one with 4 mm size had square perforations. Sieve cassettes with trapezoidal perforations have an additional shredding effect due to the additional shear load compared to a screen cassette with square perforations.

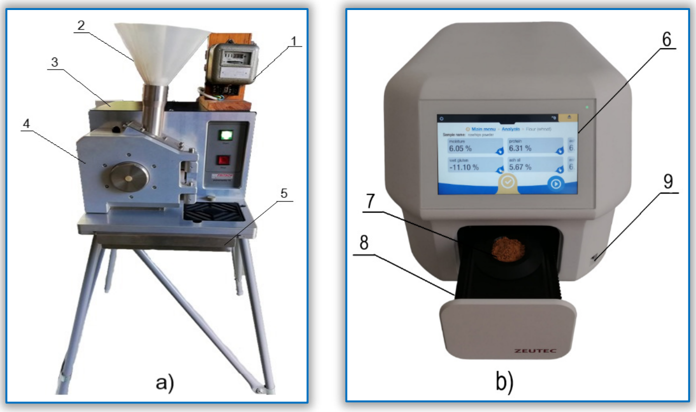

Figure 1 – Equipment used in experimental determinations
a) FRITSCH PULVERISETTE 19 mill for hard products used and the energy meter to measure the energy consumed during the grinding process; b) ZEUTEC SpectraAlyzer FOOD used for moisture determination. 1. Energy meter; 2. Standard funnel; 3. Motor cover; 4. Grinding chamber; 5. Collecting vessel; 6. Capacitive glass touch graphical user interface; 7. Open cup with sample (rosehips powder); 8. Sample drawer; 9.USB port;

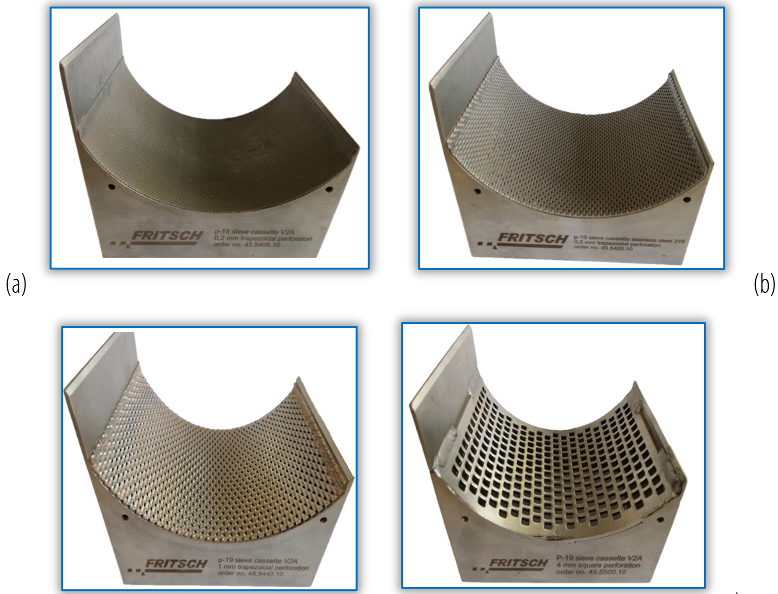

Figure 2 – The sieves used in the grinding process
a), b), c) sieve with trapezoidal perforations; d) sieve with square perforations

The same amount of rose hips of 40 g was ground in different time intervals, namely 30 seconds, 60 seconds, 90 seconds, 120 seconds and 150 seconds, using each sieve.
Throughout all the grinding processes, the mill was connected to an electromechanical induction type energy meter with the help of which the average total power consumed by the equipment was determined throughout the five grinding periods.
The energy meter was built in the laboratory, having as component parts: current coil, voltage coil, rotating aluminum disc, breaking system, counting mechanism. After recording each energy consumption value, both the material present in the collecting vessel and the one remaining on the sieve were weighed. After recording each energy consumption value, both the material present in the collection vessel and that remaining in the grinding chamber were weighed. Fig. 1a) shows the experimental setup to measure the energy consumed during the grinding process.
To determine the moisture content, a very important factor in maintaining the physical quality of the product during storage, a near infrared (NIR) spectrometer named ZEUTEC SpectraAlyzer FOOD, designed for the compositional analysis of samples using the near infrared reflectance characteristics of sample spectra, was used.
There was no need to condition the sample, and this analyzer provided the moisture result in just 45 seconds, working optimally even in a space with temperature fluctuations. Spectral range of this equipment is between 1400–2400 nm and the wavelength accuracy is <0.05 nm. The main components of the analyzer are illustrated in Fig.1b).

3. RESULTS

The results obtained from the experimental determinations were structured in Table 1. The energy consumption, the amount of sample found in the collection vessel, the amount of sample left on the

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sieve, the material losses and the humidity of each sample were obtained, all of which are related to the different grinding times, namely: 30, 60, 90, 120, 150 seconds.

Table 1. Data obtained from experimental studies

Sieve 1 (0.2 mm)					
Grinding time (seconds)	30	60	90	120	150
Energy consumption (kJ)	23400	41400	52560	71280	93240
Quantity of sample in collection vessel (g)	1.3	1.9	4.8	6.4	7.1
Quantity of sample remained on the sieve (g)	37.6	37.1	34.6	33.1	32.6
Quantity of sample milled (g)	38.9	39	39.4	39.5	39.7
Loss of material (g)	1.1	1	0.6	0.5	0.3
Moisture of the powder	4.93	4.6	3.96	3.88	3.45
Sieve 2 (0.5 mm)					
Grinding time (seconds)	30	60	90	120	150
Energy consumption (kJ)	18000	37440	50400	66960	90000
Quantity of sample in collection vessel (g)	7.6	11.1	14.8	19.4	19.8
Quantity of sample remained on the sieve (g)	30.4	27.6	24.6	20.3	20
Quantity of sample milled (g)	38	38.7	39.4	39.7	39.8
Loss of material (g)	2	1.3	0.6	0.3	0.2
Moisture of the powder	4.73	4.62	4.56	3.8	3.21
Sieve 3 (1 mm)					
Grinding time (seconds)	30	60	90	120	150
Energy consumption (kJ)	21240	33120	45720	58320	69120
Quantity of sample in collection vessel (g)	24.2	32.9	33.9	36.4	37.1
Quantity of sample remained on the sieve (g)	12.9	5.3	4.6	3.2	2.7
Quantity of sample milled (g)	37.1	38.2	38.5	39.6	39.8
Loss of material (g)	2.9	1.8	1.5	0.4	0.2
Moisture of the powder	4.6	4.36	4.24	4.08	4.02
Sieve 4 (4 mm)					
Grinding time (seconds)	30	60	90	120	150
Energy consumption (kJ)	21960	30240	41040	46800	60120
Quantity of sample in collection vessel (g)	1.3	1.9	4.8	6.4	7.1
Quantity of sample remained on the sieve (g)	37.6	37.1	34.6	33.1	32.6
Quantity of sample milled (g)	38.9	39	39.4	39.5	39.7
Loss of material (g)	1.1	1	0.6	0.5	0.3
Moisture of the powder	4.56	4.52	4.32	4.2	4.16

As can be seen from the table, the highest energy consumption was recorded using the sieve with 0.2 mm perforations, followed by the use of sieves with 0.5 mm, 1 mm and 4 mm perforations. In this way, it has been proven that the higher the degree of fineness desired, the higher the energy consumption, as shown in the graph in Figure 3. Also, the energy consumed increases linearly with increasing grinding time.

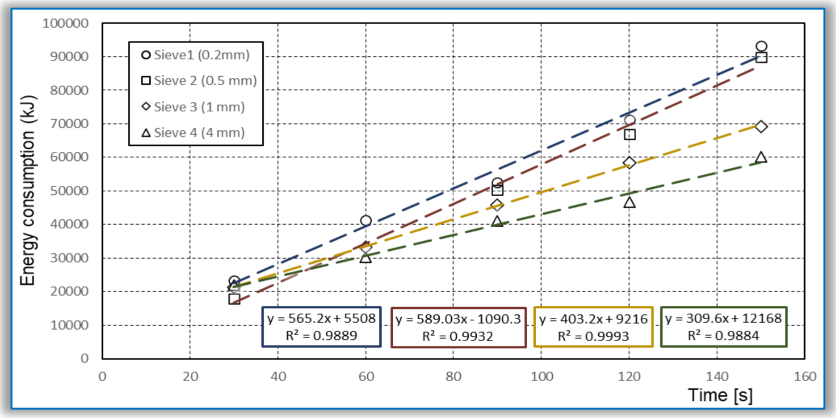

Figure 3 – Energy consumption as a function of the time

Regarding the amount of ground material taken from the collection vessel, the largest amount was obtained using the sieve with perforations of 4 mm, followed by the sieve with perforations of 1 mm, 0.5 mm and 0.2 mm. In all these cases, the grinding time was 150 seconds. Thus, it was concluded that the longer the grinding time is, the more the amount of powder with the appropriate particle size is obtained in the collector vessel.

This dependence of the amount of sample reaching in the collection vessel according to the grinding time can be observed in Fig. 4. The amount of ground material decreases as the sieve perforations get smaller. Also noteworthy is the increasing linear trend in the variation of the amount of milled material with shredding time.

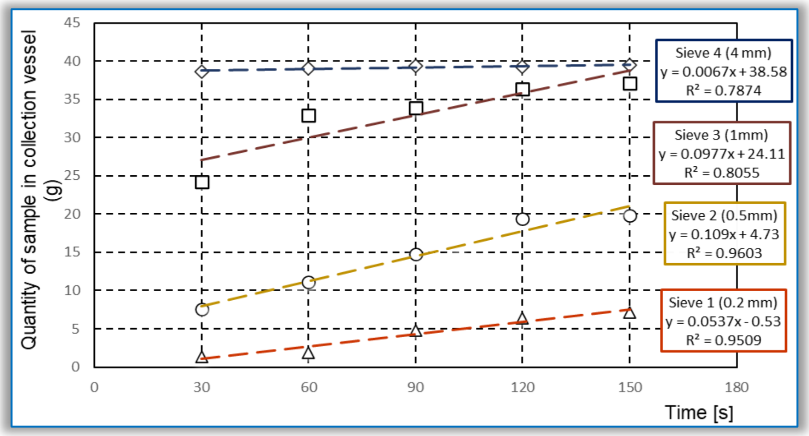

Figure 4 – Quantity of sample in collection vessel milled as a function of the time

The largest amount of remaining material in grinding chamber was observed on the sieve with the perforations of 0.2 mm. This was followed by sieves with dimensions of 0.5 mm, 1 mm and 4 mm. However, as the grinding time increased, this amount remaining in the grinding chamber decreased, which can be illustrated in Fig. 5, which also shows a decreasing linear variation.

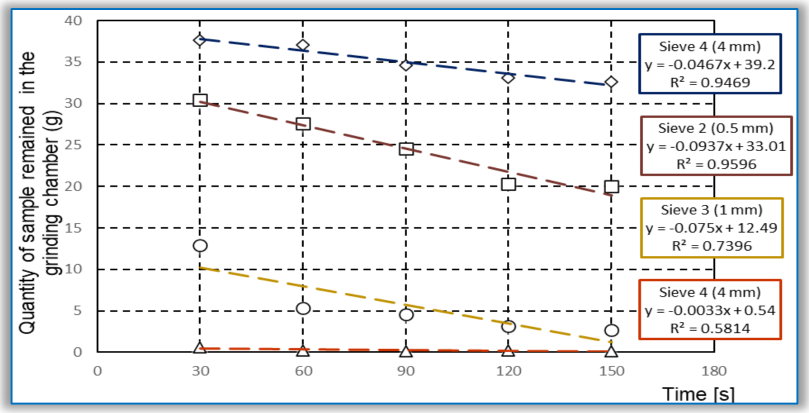

Figure 5 – Quantity of sample remained on the sieve as a function of the time

Losses due to many factors are encountered during milling processes, and effective management of these losses is essential to maximize powder production yield *(Ghodki & Goswami, 2016).* The main causes of grinding losses are mainly due to the short grinding time, dust emissions, but also the adhesion of the powder to the working organs of the machine, which has an important fat content due to the grinding of the seeds. It was found that material losses decrease with the increase in grinding time and, consequently, with the increase in energy consumption, precisely because the material no longer remains blocked in the feed hopper and no longer adheres to the working organs of the mill.
Also, the moisture, a very important parameter for ensuring the quality of the powders and the shelf life, varies with the grinding time. This decreases as the grinding period increases, precisely due to the temperature transmitted to the material by the working organs existing in the grinding chamber.

4. CONCLUSIONS

The energy efficiency of a cutting mill for hard products for the purpose of obtaining rosehips powder was evaluated in this work. The results showed that a higher energy consumption is required when a higher degree of fineness of the powder is desired, and the size of the sieve perforations is reduced and trapezoidal in shape.
Regarding the amount of ground material obtained, it decreases as the particle size reduction is desired. At the same time, the trend of linear growth of shredded material with shredding time was observed.

As in any technological process, there are losses in terms of sample quantity due to dust emissions and blockage of the material in the grinding chamber due to the short grinding time. As for moisture, it decreased with increasing grinding time and energy consumption.

It should be noted that such a mill is efficient in the production of rosehip powder precisely because there were no huge energy consumptions, the highest being 93240 kJ corresponding to grinding 40 g for 150 seconds using a screen with trapezoidal perforations, with dimensions of 0.2 mm.

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