PARTICLE SIZE DISTRIBUTION OF SOME CHOPPED MEDICINAL PLANTS

Augustina Pruteanu[1], Ladislau David [2], Mihai Matache[1], Nitu Mihaela[1]
[1]National Institute of Research-Development for Machines and Installations Designed to Agriculture and Food Industry, Romania; [2]University Politehnica of Bucharest, Romania
pruteanu_augustina@yahoo.com, david.ladislau@yahoo.com, gabimatache@yahoo.com, rosumihaelan@yahoo.com

Abstract. Medicinal plants contain biologically active substances with therapeutic effect in different affections treatment. In order to cultivate medicinal plants, establishing organic or even ecological crops is very important, because medicinal plant species owe their phyto-therapeutic action to some bioactive components. Medicinal plant cultivation and capitalization by different processing operations are important for ensuring an enhanced quantity of raw material and preserving or increasing their valuable constituents. The primary processing implies all the technical operations of conditioning, harvesting, drying, grinding by chopping, transport, sorting, performed by specialized equipment through which the raw material is successively transformed, quantitative and qualitative, from the initial state to a state of finished product. Particle size distribution of some chopped medicinal plants (nettle, thyme, wormwood) was made using three commonly used methods of mathematical models by Rosin-Rammler, Gaudin-Schumann and by Gauss. On the basis of the network analysis, the distribution fraction was obtained. Experimental data were evaluated using the function models, which were compared and the best performing model function was identified, which leads to a more accurate separation of the different particle sizes in order to obtain a better industrial profit of the medicinal plants. The primary processing line and the bioactive substances extraction from medicinal and aromatic plants can be used to obtain tea (sachets or bags), volatile oils, juices, tinctures, syrups, tablets, food dyes, cosmetics, natural fertilizers, bio-insecticides, etc.

Keywords: chopped medicinal plants, particle size distribution, modelling.

Introduction

Cultivation and capitalization of these plants through different processing operations are important for ensuring an increased amount of raw material and for preserving or increasing valuable constituents in these plants. It is possible to achieve quality and accessible phyto-therapeutic products only by using advanced technical equipment, adapted to each plant [1].

Medicinal plants primary and advanced processing leads to obtaining volatile oils, macerated tea, vegetable extracts, tinctures, syrups, tablets, food colourings, cosmetics, natural fertilizers, bio-insecticides etc [2].

In terms of structure, technological processing includes all operations and interrelated phases, necessary for preparing and managing the acquired harvested plant material in an appropriate manner of storage, packaging or processing within a production unit [1; 3].

Plant products sieving is influenced by several factors, among which the most important are: particle size and shape, type of particle relative movement on the sieve surface, constructive characteristics and sieves disposal manner, intensity of working regime, material quantity arrived on the sieve [1; 3-7].

Particle size distribution is one of the most important physical properties of solids, which are used in medicinal plant processing. For determining particle size distribution of plants chopped sieving is used. There are three mathematical models widely used for studying the solid particles' distribution, namely the Rosin-Rammler model, Gaudin-Schumann model and Gauss model that have given excellent results and correct sieving [8].

The dimensional distribution of particles was studied by comparing the experimental results to mathematical modelling using the law Rosin-Rammler on switchgrass [9], the Rosin-Rammler and Gaudin-Schumann models on agglomerated cork [10], on sawdust and wood shaving mixtures [11].

Testing mathematical models for simulating the seed separation process on the sieves of a cleaning system are presented in papers [12; 13].

In papers [14; 15] the results of several experimental researches are presented regarding the separation of a mixture of dried and chopped nettle fragments [14] and chicory fragments [15]. For the separation process description on sieves for chopped vegetal material, the experimental results have been tested by the Rosin-Rammler distribution law.

The present paper presents the results of particle size distribution for chopped nettle, thyme, wormwood using the Rosin-Rammler, Gaudin-Schumann and Gauss mathematical models applied to data obtained by network analysis.

Materials and methods

For the experimental determinations nettle, thyme and wormwood plants were used, identified and harvested within the spontaneous flora of Romania, in respect to their morphological characteristics and according to specialty guides [16; 17].

The herb was dried naturally in the shade, until it reached the humidity 13 %, cleaned of foreign bodies (inorganic materials or other plants, injured plants) under the provisions of [18; 19], and then it was chopped in bulk using the TIMATIC grinder for medicinal plants, adjusted to the size of 4 mm for each plant. The images of dry bulk plants are shown in Figure 1.

Nettle *(Urtica dioica)* is a herbaceous perennial species of 20-50 (70) cm height, with aerial erect or ascendant stems of Lamium type, Lamiaceae class; it is spread in hilly areas up to the mountain level [16]. Herb of nettle contains the following active substances: rosmarinus acid, tannins (12-14 %), essential oil, flavonoids, mucilage [17].

Thyme *(Thymus vulgaris)* is a species of herbaceous perennial with semi-wooden base, of Thymus type, Lamiaceae class; it is spread in hills, meadows and pastures [16]. Thymol is the main active substance contained by thyme, being a natural antiseptic, very helpful against viruses [17].

Wormwood *(Artemisia absinthium)* is a herbaceous perennial plant in the Asteraceae family, 60-120 cm high; spread from the lowlands up to the hilly ones [16]. Wormwood contains the following active substances: bitter substances – temisina, about 3-12 % volatile oils composed of thujone and tuiol, azulenes, flavones, organic acids (palmitic) linoleic, oleic, lauric, stearic, nicotinic, arachidic [17].

Nettle **Thyme** **Wormwood**

Fig. 1. **Images of dry bulk plants**

In this work, the granulometric analysis of each initial mixture of fragments was carried out, corresponding to each species of medicinal plant. For all three medicinal plants five samples were performed, each sample of the analysed plant material from the mass of the mixture of fragments had 300 g. The plant material was sieved using the vibratory sieve shaker (Figure 2), at the amplitude of 50 mm, for 10 minutes. The accuracy of such analyses is, among other factors, strongly dependent on the sieving time. Decisive for the accuracy and reliability of the measurement result is, in addition to the reproducible operating Vibratory Sieve Shaker, the quality of the sieve used for tests [20].

The Vibratory Sieve Shaker of the Retsch GmbH type is successfully used in almost all areas of industry and research within the scope of quality control, especially where there are high demands regarding easy operability, speed, precision and reproducibility [20].

On each sieve a quantity of plant material was found that represented the totality of the fragments with sizes smaller than those of the openings of the sieve above of the one considered and larger than the mesh of the sieve below it.

Fig. 2 **Vibratory sieve shaker Retsch AS 200 [20]**

For sorting the medicinal fragments, sieves with meshes of 1.0 mm, 1.4 mm, 2.0 mm, 2.8 mm, 4.0 mm, 5.6 mm and 8.0 mm were used, images with the sorting plants are shown in Figure 3. The dimensions for the meshes of the shaker's sieves were chosen so that they form the terms of geometrical progression with a ratio of 1.414. [4; 6; 7; 9].

Fig. 3. **Sorting medicinal plants**

Mathematical models for determining particle size distributions are:

- Model Rosin-Rammler:

$$p_x = 100 \cdot \left(1 - e^{-\lambda \cdot x^{\delta}}\right), \quad (1)$$

- Model Gaudin-Schuman:

$$p_x = 100 \cdot \left(\frac{x}{\lambda}\right)^{\delta}, \quad (2)$$

- Model Gauss:

$$p_x = 100 \cdot \left(1 - \lambda \cdot e^{-\delta \cdot x^2}\right), \quad (3)$$

where p_x – cumulative retained at a size x, %;
x – particle size, mm;
λ – mean particle size, mm;
δ – measure of the particle size distribution.

For processing the experimental data, the average of the five experimental samples was used, the equations of mathematical models being solved in Mathcad. For the regression analysis, the method of least squares is also frequently used, which can convert curves to data points. The correlation coefficient is used as a parameter indicating the relevance of the measured data set in the equations.

Results and discussion

The values of the weights of different particle sizes of chopped nettle, thyme and wormwood obtained by the network analysis are shown in Table 1.

Table 1

Experimental data with plant fragments separated on sieve

Particle size, mm	< 1	1.0-1.4	1.4-2.0	2.0-2.8	2.8-4.0	4.0-5.6	5.6-8.0	Fraction, g
Nettle	5.48	23.43	29.42	33.86	45.61	63.16	99.04	300.00
Thyme	3.86	3.59	9.46	11.95	24.90	86.38	159.87	300.00
Wormwood	8.92	9.04	17.30	22.21	33.88	82.87	125.78	300.00

From the processing of the experimental data using the three mathematical functions, the graphs in Figure 4 resulted.

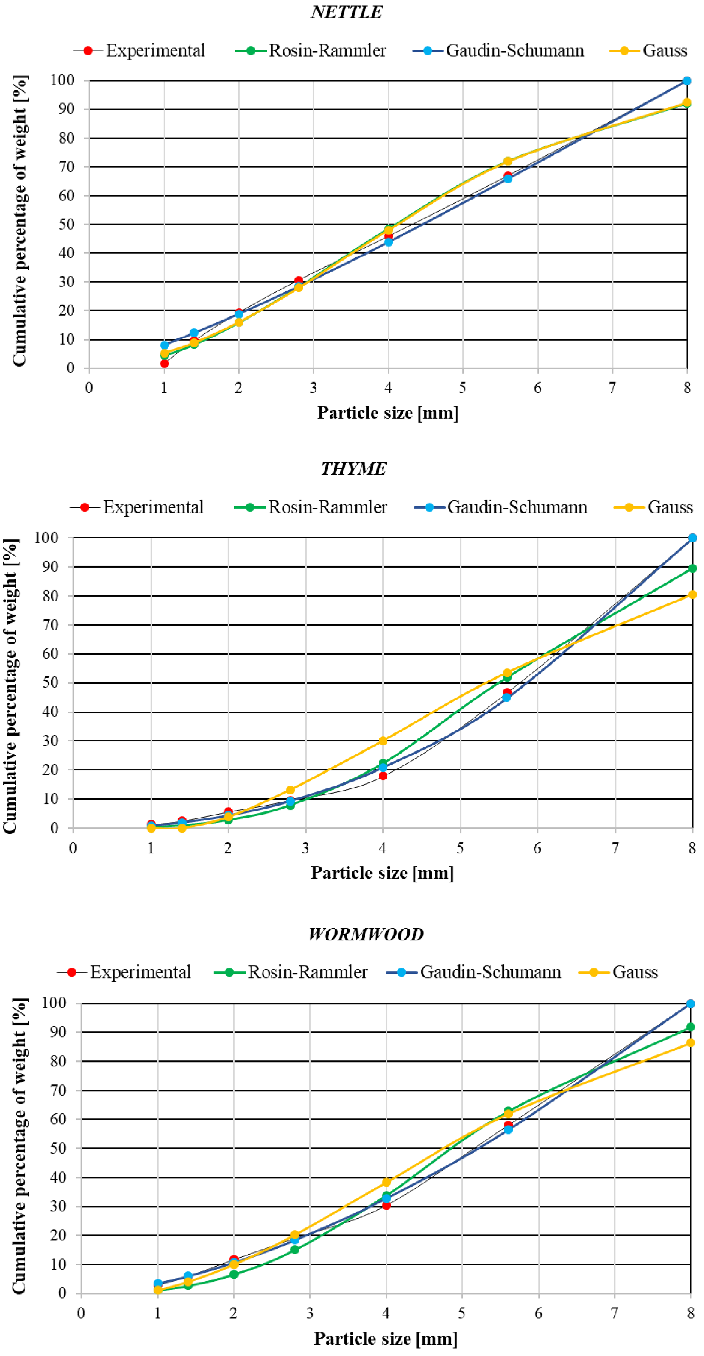

Fig. 4. **Particle size distribution obtained by sieving**

From observation of Figure 4 and the corresponding linear correlation coefficient, one deduces that the Gaudin – Schuman model provides a better fit to the experimental particle size distribution curve than Rosin – Rammler does. However, when testing other materials, the Rosin – Rammler model usually fits better to the experimental curve. Values of coefficients λ and δ for experimental data correlated to Rosin-Rammler, Gaudin-Schuman and Gauss models (eq. 1, eq. 2, eq. 3), and values of the correlation coefficient R^2 and standard deviation (σ) are shown in Table 2.

Table2

Values for experimental data correlated with Rosin-Rammler, Gaudin-Schuman and Gauss models, coefficient λ and δ, coefficient of correlation R^2 and standard deviation for nettle, thyme and wormwood

Coefficient	Model Rosin-Rammler			Model Gaudin-Schuman			Model Gauss		
	Nettle	Thyme	Worm-wood	Nettle	Thyme	Worm-wood	Nettle	Thyme	Worm-wood
λ	0.046	$3.146 \cdot 10^{-3}$	0.011	7.985	7.989	7.985	0.984	1.069	1.021
δ	1.933	3.163	2.602	1.209	2.259	1.61	0.04	0.027	0.031
R^2	0.984	0.982	0.982	0.992	0.998	0.998	0.984	0.925	0.968
Standard deviation, σ	0.047	0.083	0.064	0.033	0.025	0.016	0.046	0.16	0.085

It can be noticed that the mathematical model has been sufficiently well correlated to the experimental data values, being obtained by the high correlation coefficient $R^2 = 0.998$ for thyme and for wormwood using the Gaudin-Schuman model.

Standard deviation (σ) allows to estimate the accuracy of the experimental data compared to the theoretical ones obtained in the paper. As the value of standard deviation is smaller, the data are more precise, therefore the theoretical data obtained are closer to the experimental ones. When the standard deviation is bigger, it indicates that the theoretical data obtained are more dispersed compared to the data obtained experimentally.

The mathematical models presented in this paper constitute the research object of a variety of specialty papers. [8; 11-13]. Particle size distribution of sawdust and wood shaving mixtures is presented in paper [11], with better results of the Gaudin-Schuman model. In papers [8; 13] the authors presented particle size distribution of grist fraction with better results of the Rosin-Rammler model.

Conclusions

In the paper the manner was presented, in which the distribution models of plant fragment size are used for finding the dimensioned fragments depending on the size of meshes of a vibratory sieve shaker, leading to the following conclusions:

1. The chosen model Gaudin-Schuman is correlated well enough with the experimental data values, being obtained high correlation coefficients $R^2 = 0.998$ for thyme and for wormwood and $R^2 = 0.992$ for nettle.
2. The Rosin-Rammler model presents low correlation coefficients $R^2 = 0.982$ for thyme and wormwood and $R^2 = 0.984$ for nettle.
3. From the data obtained for standard deviation (σ) it is observed that in the case of the Gauss model for thyme, the value of standard deviation is the biggest ($\sigma = 0.16$), therefore the theoretical data obtained are more dispersed compared to the data obtained experimentally and the smallest standard deviation ($\sigma = 0.016$) was obtained with the Gaudin Schuman model for wormwood, therefore, the theoretical data obtained are closer to the data obtained in experiments, and consequently the data are more precise.
4. By analysing both experimental and theoretical data, it is appreciated that for all three medicinal plants the optimal distribution is obtained with the Gaudin-Schuman model, Gauss model and then the Rosin-Rammler model, a fact that has been proven by many researches and by practical applications.

Acknowledgement

This work was supported by a grant of the MINISTRY OF RESEARCH AND INNOVATION, contract_18N/16.03.2018, Project code*: PN 18 30 02 31,* NUCLEU Project title – "Technology for establishing and superior capitalization of raw plant material obtained from medicinal plants", phase 2: *Implementation documentation for the Experimental model of multi-purpose equipment for establishing medicinal plant crops on small surfaces.*

References

[1] Oztekin S., Martinov M., Medicinal and aromatic crops: harvesting, drying and processing, Editura Haworth Press, United States and Canada, 2007, pp. 154-172.
[2] Păun G., Gheorghe O., Diaconu M., Guide of medicinal plants processing/Ghid de procesare a plantelor medicinale, MedPlaNet Project, 2012, pp. 5-11.
[3] Ţenu I., Technologies, machinery and equipment for products industrialization, part two: Cleaning, washing and conditioning, Junimea Publishing House, 1999, pp. 5,14,38.
[4] Allen T., Powder Sampling and Particle Size Determination, Particle size analysis by sieving, Ch. 4, Elsevier, Amsterdam, Netherlands, 2003, pp. 208-235.
[5] Căsăndroiu T., David L., Equipment for primary processing and preservation of agricultural products; Guidelines for laboratory work, ch.4, Ed. Politehnica University of Bucharest, Bucharest/Romania; 1994.
[6] Liu K.S. Some factors affecting sieving performance and efficiency, Powder Technology, Vol.193, Issue 2, , Elsevier Publishing House, London/U.K.; 2009, pp. 208-213
[7] Sullivan J. F., Screening theory and practice, Triple/S Dynamics, Vol.8, Issue 1, Faisalabad/Pakistan, 2012, pp. 90-95.
[8] Constantin G.A., Researches on the sifting and sorting process of grist fractions in a industrial milling plant, Phd. Thesis, Bucharest, 2014
[9] Bitra V., Womac A., Yang Y., Igathinathane C., Miu P., Chevanan N., Sokhansanj S., Knife mill operating factors effect on switchgrass particle size distributions, Bioresource Technology, issue 100, 2009, pp. 5176-5188.
[10] Macias-Garcia A., Cuerda-Correra Eduardo M., Diaz-Diez M.A., Application of the Rosin-Rammler and Gates-Gaudin-Schuhmann models to the particle size distribution analysis of agglomerated cork, Materials Characterization, 52, 2004, pp. 159-164
[11] Vítěz T., Trávníček P., Particle size distribution of sawdust and wood shavings mixtures, Res. Agr. Eng., Vol. 56, No. 4, 2010, pp. 154-158.
[12] Voicu Gh., Căsăndroiu T., Târcolea C., Testing stochastic models for simulating the seeds separation process on the sieves of a cleaning system, and a comparison with experimental data, Agriculturae Conspectus Scientificus, Vol. 73, No. 2, 2008, pp. 95-101.
[13] Constantin G.A., Voicu Gh., Ştefan M.E., Influence of cinematic regime and quantity of material on efficiency of sifting process, 3nd International Conference on Thermal Equipment, Renewable Energy and Rural Development, TE-RE-RD 2014, Mamaia, România, pp.199-204.
[14] Pruteanu A., Matache M., Sorică C., Muscalu A., Niţu M., 2016 – Separation of chopped nettle material on plane sieve length, Annals of the University of Craiova – Agriculture, Montanology, Cadastre Series), Vol. XLVI, 2016, pp.516-521
[15] Pruteanu A., Matache M., David L., Muscalu A., Niţu M., Rădulescu E. L., Bota M.S.O., Separation of chopped chicory material on flat sieve length, 6th International Conference on Thermal Equipment, Renewable Energy and Rural Development, TE-RE-RD, 8-10 iunie, Moieciu de Sus, 2017, pp. 435-440 .
[16] Ardelean A., Mohan Gh. Medicinal Flora of Romania, All Publishing, Bucharest, 2008.
[17] Bojor O. Guide of medicinal and aromatic plants from A to Z, Fiat Lux Publishing, 2003.
[18] European Pharmacopoeia, 8th edition, EDQM Council of Europe Publishing, Strassbourg, 2011
[19] Romanian Pharmacopoeia, 10th edition, Medical Publishing, 1993.
[20] RETSCH – Solutions in Milling & Sieving [online][19.03.2018] Available at: http://www.retsch.com