EXPERIMENTAL RESEARCH ON THE SEPARATION PROCESS OF SEEDS AND PULP, FROM THE FRUITS OF SEA BUCKTHORN
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CERCETARI EXPERIMENTALE ASUPRA PROCESULUI DE SEPARARE A SEMINTELOR ŞI A PULPEI, DIN FRUCTELE DE CATINĂ

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ABSTRACT

In the last period, a sector that has seen an important development in fruit growing is the one dedicated to sea buckthorn crops, respectively the technologies for the valorisation of fruits and food by-products deriving from the technological processes dedicated to these fruits with high human and animal nutritional value. In this paper, the aim is to present the results obtained by implementing innovative technologies for the integrated management of works in agricultural farms, vineyards and orchards, particularly intended for the cultivation of sea buckthorn, through which were tracked the technological parameters achieved by an equipment for the separation of sea buckthorn seeds from the pulp of the fruit, respectively the distribution of the separation fractions from the raw material depending on the working regime (the rotation frequencies of the functional systems) and the sizes of the holes of the separation sieve as well as the energy indices of the equipment. From the analysis of the obtained results, it was concluded that, in order to increase the performance of the experimental equipment, the site sections must include a wider range of hole sizes, it should be equipped with a brush system for their cleaning and improve the box system for collecting the material separated on fractions in order to reduce losses.

REZUMAT

În ultima perioadă, un sector ce cunoaște o dezvoltare importantă în pomicultură este cel destinat culturilor de cătină, respectiv a tehnologiilor de valorificare a fructelor și a subproduselor alimentare ce derivă din procesele tehnologice dedicate acestor fructe cu valoare nutrițională umană și animală ridicată. În cadrul acestei lucrări se urmărește prezentarea rezultatelor obţinute prin implementarea unor tehnologii inovative de management integrat al lucrărilor din ferme agricole, viticole și pomicole, în mod particular destinat culturii de cătină, prin care s-au urmărit parametrii tehnologici realizați de un echipament de separare a semințelor de cătină de pulpa fructului, respectiv distribuția fracțiilor de separare din materia prima în funcție de regimul de lucru (frecvențele de rotaţie ale sistemelor funcţionale) şi dimensiunile găurilor sitei de separare precum şi indicii energetici ai echipamentului. Din analiza rezultatelor obţinute, s-a desprins concluzia că, pentru creşterea performanțelor echipamentului experimentat, trebuie ca secțiunile de site să includă gamă mai largă de dimensiuni ale găurilor, dotarea cu un sistem de perii pentru curățarea acestora şi îmbunătățirea sistemului de cuve pentru colectarea materialului separat pe fracții, în vederea reducerii pierderilor.

INTRODUCTION

Sea buckthorn (*Hippophae rhamnoides* L.) is a unique and valuable multipurpose species currently being cultivated in various parts of the world, Asia: (*Li H, et. al.,2020*), Europa (*Kauppinen S. and Petruneva E., 2014*) and America de Nord (*Li S.C.T. and Schroeder W.R., 1996*).

Buckthorn fruits have a high nutritional level and important medicinal values for human health (*Li S.C.T. and Schroeder W.R., 1996*). Sea buckthorn is also a deciduous shrub considered useful for soil erosion control, reclaiming degraded land, improving wildlife habitat, and protecting farms.

In Europe, sea buckthorn is still a young fruit species, the number of sea buckthorn varieties for the European climate being too low (Finland and Sweden), although it is relatively easy to cultivate. There are many countries where the development of new varieties is sought (Germany).

A common problem is the susceptibility to frost of the male varieties of sea buckthorn, developing well on sandy clay and being a water lover, the effect of irrigation on the growth yield of the plant can be significant (*Höhne Friedrich, 2015*). However, it is exposed to the attack of diseases and pests, the most widespread being fungi and flies that can attack sea buckthorn fruits.

Considerable research is currently being carried out on the properties of sea buckthorn fruits in the pharmaceutical, nutraceutical field (*Ciesarová, Z. et al., 2020; Ursache, F.M. et al., 2017; Suryakumar, G.et al., 2011),* food *(Madawala, S.R.P. et al., 2018; Zeb, A., 2004)* and cosmetic *(Smida, I. et al., 2019; Koskovac, M. et al., 2017*), but also for environmental protection (*Madawala, S.R.P. et al., 2018*).

Research carried out around the world has shown that the leaves, fruits and shoots of the plant contain a series of biologically active substances with an essential role in regulating metabolism (*Rati I. V. et al., 2018*). The main substances present in large quantities in the pulp of sea buckthorn fruits belong to the carotenoid class, the carotenoid content being one of the key characteristics by which sea buckthorn oil is marketed (*Ciesarová, Z. et al., 2020*).

Sea buckthorn seed oil is characterized by a high content of oleic acid (17%), omega-3 (alpha linolenic) and omega-6 (linoleic), important in the regulation of thousands of metabolic functions. In addition, sea buckthorn is a very good source of phytosterols, which play an important role in the prevention of cardiovascular diseases. Another important aspect of promoting sea buckthorn for human health is its high fibre content and the fact that it is considered a unique source of protein.

Sea buckthorn juice is rich in many free amino acids and vitamin C, a total of 18 of the 22 known amino acids found in sea buckthorn fruits, essential in various processes that take place in the human body (*Gâtlan A.-M. and Gutt G., 2021*). The most common product obtained from sea buckthorn is the juice derived from the pulp because it includes all the nutrients of the sea buckthorn, especially the flavonoids with antioxidant properties (*Wojtunik-Kulesza, K. A., et al., 2016; Liu R. et al., 2022*).

The phytochemical and nutritional composition of sea buckthorn fruits differs considerably depending on the species, analysed components, climatic and growing conditions, variations between years, degree of maturation, storage conditions, time of harvesting and last but not least, fruit processing method.

There are three main products that can be obtained through processing, namely: oil obtained from seeds, yellow pigment, and juice obtained from fruits and a secondary one which is the mixture of pulp and peel. Although the total number of publications available, describing the processing of sea buckthorn berries, is quite limited, the processing process of sea buckthorn berries is largely similar to that presented in Fig. 1.

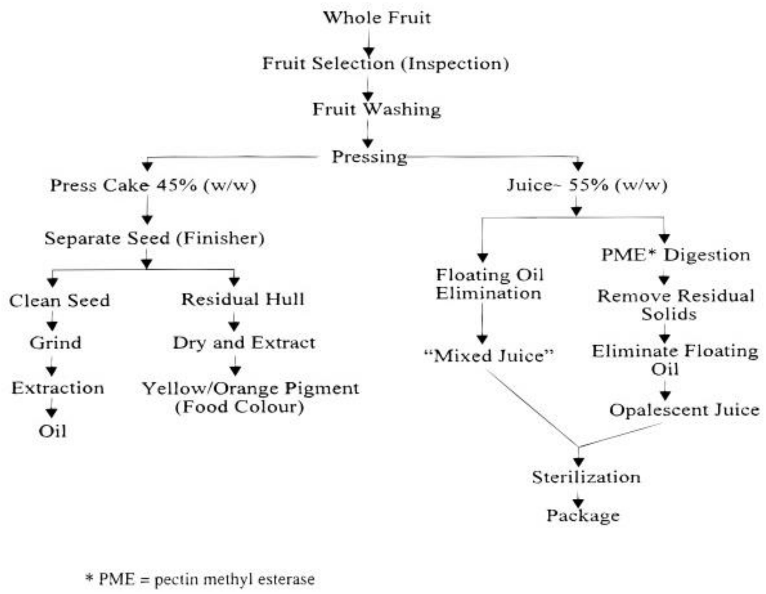

Fig. 1 - Processing of sea buckthorn berries
(*Beveridge T.et al., 1999*)

Tereshchuk L.V. et al., (2019), proposed a scheme of the complex technological flow of sea buckthorn processing is presented. After picking the fruits from the branches, they are washed, the impurities are separated, then they are ground with a disintegrator, the result being 88% pulp+juice and 12% seeds. Further, the seeds are dried, the final percentage being 7.2%, and the pulp+juice are subjected to the centrifugation process, the result being 24.5% juice and 53.5% pulp.

Therefore, sea buckthorn is a valuable plant, with many biologically active compounds with therapeutic functions, which, integrated in the diet, can bring important benefits to human health.

From the point of view of the existing installations and equipment for separating the seeds from the pulp, it can be stated that the offer is not very generous, however, there are several types used for the operation of separating the seeds, either from the raw material in a wet state either after a process of drying it.

Worldwide, there are companies producing complex equipment for separating the seed from the fruit pulp, installations intended especially for processing units with large and very large capacities, which include different separation systems, or individual equipment intended for reduced production.

At the current stage of development of the technique, there are several types of equipment for separating the seeds from the pulp of the buckthorn fruit, made by manufacturers, such as: Milani Estasi ABEVE – Italy; Bucher Industries AG -Switzerland; Diemme S.P.A.- Italy, Murlark-USA; Aslan Machinery – China; ANDGAR FOOD PROCESSING – Canada.

In this scientific paper, it is presented experimental research on the process of separating the pulp from the sea buckthorn seeds, carried out with an equipment designed and manufactured at INMA Bucharest, named: Equipment for separating the pulp from the sea buckthorn seed, symbol: ESSC.

MATERIALS AND METHODS

The determination of the working parameters was carried out using the following measuring and control devices: digital multimeter, electronic thermometer with surface transducer, centrifugal tachometer, electronic balance, vibrating separation device, wattmeter kit.

Three types of functional systems are interconnected within the ESSC composition, such as: Raw material decompaction system - 1; Pulp seed detachment system - 2; Separation system - 3, as shown in the functional scheme, Fig. 3. In addition to the three functional systems, the equipment also includes a frame, item 4, transmission, item 5, vats for the discharge of separated fractions, item 6, access ladder to the feed hopper, item 7, doors visit and access to the separation system, item 8 and the electrical installation, item 9, these components are shown in Fig. 4. Each of these systems performs distinct technological operations that are interconnected to separate the pulp, peels and other impurities from the sea buckthorn seeds, evacuated with the help of the evacuation funnels (B, C, D) of the products resulting from the separation process.

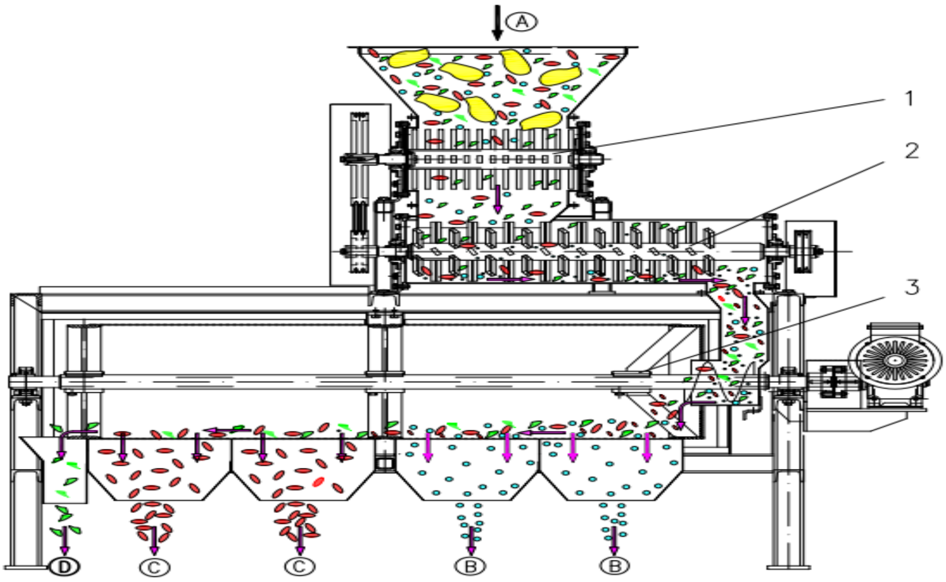

Fig. 3 – The functional scheme and the working principle of the experimentalmodel, ESSC

1 – Raw material decompaction system; 2 – Pulp seeds detachment system; 3 – Separation system; A – feed with dry raw material (mixture of seeds, fruit peels, tails, pulp); B – exhaust fraction smaller than the seeds (fragments of pulp and peels, tails); C – evacuation of sea buckthorn seeds; D – evacuation of fraction larger than the seeds (fragments of pulp and peels)

The main functional characteristics of the ESSC are: total installed power of 2.95 kW; drum speed of raw material decompaction system can vary between 300–400 min^{-1}; the speed of the pulp seed removal system rotor varies between 500–700 min^{-1}.

Characteristics of the sieve separation system: diameter of the sieves, ϕ 400 mm; the active length of the two-section sieve, 2x575 = 1150 mm; sieve rotational speed, 23 min^{-1}; hole sizes for the first separation sieve (Lxl= 25x1.8 mm); hole dimensions for the second separation sieve (Lxl= 25x2.7 mm).

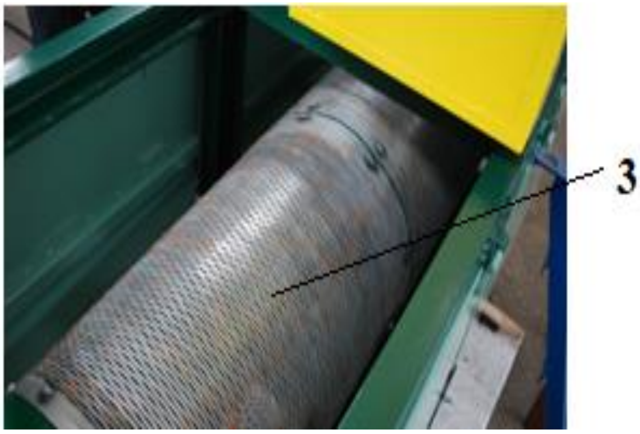

Fig. 4 – The ESSC experimental model tested in laboratory and operating conditions
1 - raw material decompaction system; 2 - pulp seed detachment system; 3 - separation system with circular sieves; 4 - support frame; 5 - transmissions with trapezoidal belts; 6 - exhaust funnels; 7- scale for technical assistance and supervision; 8 - side doors; 9 - electrical drive installation

After adjusting the working parameters, such as the distance between the impactors of the detachment system and its casing, to values between 1.5 -2.5 mm and their inclination angle of approx. 30 degrees, the ESSC equipment was put into operation and fed with raw material in order to separate the seeds from the hawthorn pulp.

During operation, the fractions from the discharge hoppers B, C, D were collected. The seeds, pulp and peels were weighed, the distribution of the separated size fractions being presented in table 2.

The method that is the basis of the process is separating the seeds from the pulp after the mixture has been dried, beforehand, to a humidity below 12%.

In order to evaluate the technological performance of the ESSC equipment and the quality of the separation operation performed on it, a series of stages were completed, based on an experimentation methodology, which includes:

• Stage 1. Extracting the juice from sea buckthorn fruits Fig. 2B, using a juicer Kuvings, model B 1700;

• Stage 2. Drying of the secondary product obtained, consisting of the secondary fraction (pulp + peel) and seeds (fig. 2C), using an oven Memmert, at the temperature of 105°C, for 4 hours;

• Stage 3. Determination of the moisture content of the raw material, Fig. 2D, was made using electronic scale MB 45, the moisture value being 10.8 %;

• Stage 4. Determination of the type dimensions from the dry raw material fractions component, as follows:

Step 1. Weigh a random sample of the by-product, Fig. 2E;

Step 2. Separate the component fractions of the extracted sample into 7 sorts, using 6 sieve sizes, respectively 10; 6.3; 4; 2.8; 2 and 1 [mm], placed on a vibratory separator with a Retsch circular sieve, operating mode: amplitude 50 mm, for 10 minutes, Fig. 2F;

Step 3. Weigh the packaging of the fractions = 5.2 grams, Fig. 2G;

Step 4. Weigh each fraction obtained at each sieve on a Kern model electronic balance, measurement precision of 0.001 g, from which the mass of plastic foil was subtracted, Fig. 2H;

Step 5. Centralise the data obtained according to table 1;

Step 6. Determine the fraction of seeds from the dry raw material mass at 10.8% moisture: pulp+shells = 69.79%; seed = approx. 30.21%, fig. 2 I.

A - Stage 1.
Sea buckthorn
fruits to be processed

B – Stage 2.
Extracting the juice
from sea buckthorn fruits

C - Stage 3.
Drying the
secondary product
(pulp+seeds)

D - Stage 4.
Determining the moisture
content of the by-product

E – Determination of the mass of the sample

F – Separation of the component fractions from the extracted sample

G– Determining the mass of the package

H- Determination of the mass of the by-product fractions

I–Determination of the percentage of seeds in the pulp

Fig. 2 - Aspects during the preparation of the raw material for experiments

Table 1

Dimensional distribution of fractions from the raw material - Step 5

The amount of raw material separated [g]	Separation sieve hole dimensions [mm]	Distribution of material fractions	
		[g]	[%]
56.7	< 1	0.4	0.705
	1	0.8	1.412
	2	4.2	7.407
	2.8	5.8	10.229
	4	17.9	31.569
	6.3	17.1	30.158
	10	10.5	18.52
TOTAL		**56.7**	**100**

RESULTS

The separation tests were performed for three values of the rotation frequency of the decompaction rotor, respectively detachment rotor. The separation performances of the experimental model were determined by measuring the dimensional distribution of the fractions from the raw material both at the feed (pulp, peels, impurities) and at the exit from the ESSC, respectively of the seed fraction, the values being presented in table 2.

Table 2

Separation parameters of ESSC

Distribution of dimensional fractions in matter before separation [%]	The dimensions of the holes of the separation sieve [mm]	The working rotation frequencies of the decompaction rotor, respectively detachment rotor [min^{-1}]		
		241, respectively 552	402, respectively 920	562, respectively 1288
		Distribution of pulp size fractions, after separation, [%]		
0	**1**	**2**	**3**	**4**
0.705	< 1	3	5	10
1.412	1	5	8	15
7.407	2	12	15	25
10.229	2.8	30	35	35
31.569	4	10	20	7
30.158	6.3	25	10	5
18.52	10	15	7	3

From Table 1, it can be seen that for the sizes of the sieve holes between 0.1…2.8 mm, the distribution of the material before separation is smaller compared to the average distribution of the material after separation. Then, at the sizes of the sieve openings larger than 4 mm to 10 mm, the weight of the distributions is higher before separation and lower after separation.

It is also observed that the distribution of the fractions differs as follows:

- in the material before separation, the distribution is maximum (≈32%), at sieve sizes of 4.0 mm and minimum (≈0.5%) at sizes smaller than 1 mm.

- in the material after separation, the distribution is maximum (≈34%), for sieve sizes of 2.8 mm and minimum (≈6%) for sizes smaller than 1 mm.

Regarding the comparative dimensional distribution of the material fractions after the separation operation depending on the rotation frequencies, table 2, it can be noticed that at small sizes of the sieve holes (1…2.8 mm), the distribution of the material on the fractions increases from the low speed up to high speed. At the larger sizes of the sieve holes (4…10 mm), the distribution of the material into fractions depending on the working rotation frequencies of the decompaction/detachment rotors is different and varies from high percentages of separation to low rotation frequencies at low percentages in the case of high rotation frequencies.

Although the percentage of the last fraction is relatively high, which means that the raw material was not crushed enough, still the seeds were separated from the pulp in a percentage between 85 and 92%.

The degree of separation of the seeds detached from the pulp was approx. 67%, the difference up to 92% being spread in the other fractions, collected by funnels B and C, Fig. 3, due to the fact that the seeds have very varied sizes.

The presence of pulp and peel fractions was also found in the seed collection sections. This fact is caused by the dimensional irregularity of the mentioned fractions, which leads to their separation on several areas of the sieves (B, C), see Fig. 3.

The degree of separation of seeds from the pulp achieved by the equipment can be increased by passing the resulting material through a cyclone with air currents. In this situation, the conclusion was drawn that the equipment must be improved so that the separation system is equipped with sections with sieves with a wider range of sizes at the openings, the differences between them being smaller compared to the existing situation.

It was also found that part of the holes of the sieves got clogged with material, which is why a cleaning brush should be provided. Also, part of the processed material fell outside the collection funnels, therefore some sealing panels will be provided around the sieves.

The values of the intensity and voltage of the electric current were read directly from the converter for different values of the frequency of the current, and the consumed power was calculated with relation 1.

$$P = \sqrt{3} \times U \times I \times cos\,\varphi, \text{ [kW]} \tag{1}$$

The characteristics of the electric motors for operating the raw material decompaction system and the seed detachment system are: n_{motor}=920 min^{-1}; P_n= 1.5 kW; I_n= 6.6/3.8 A; U_n= 230/400 V; $cos\,\varphi$ = 0.75.

Fig.5 shows some details during the experimental model testing phase in operating mode.

a) Raw material (by-product) supply system

b) By-product separation system

c)

d) Sorts obtained at evacuation

e) Details of the separation process by dimensional fractions

f) Detailed images of the separated fractions at the end of the process

Fig. 5 – Details from the experiments of the ESSC experimental model in operating mode

The values power consumption during the exploitation regime are presented in table 3.

Table 3

Values of ESSC power consumption during the exploitation regime

Work mode (rotational speed of active parts)	Frequency [Hz]	Measured parameter	The value of the measured parameter			
			Sample I	Sample II	Sample III	Average
- decompaction rotor n_1 =241 min^{-1} -detachment rotor n_2 =552 min^{-1}	30	Current intensity, I [A]	3.53	3.47	3.49	3.51
		Current voltage, U [V]	200	199	198	199
		Absorbed power, Pa [kW]	0.916	0.895	0.896	0.902
- decompaction rotor n_1 =402 min^{-1} - detachment rotor n_2 =920 min^{-1}	50	Current intensity, I [A]	2.43	2.44	2.42	2.43
		Current voltage, U[V]	397	398	399	398
		Absorbed power, Pa [kW]	1.27	1.26	1.25	1.16

Experiments were also carried out at speeds higher than 562min^{-1} at the decompaction rotor and 1288min^{-1} at the detachment rotor, but a high percentage of broken seeds was found, which were separated together with the smallest pulp fractions and peels from the separation system, therefore these speeds must be avoided. From the point of view of the energy consumption achieved at the working regimes used, it was found that the range of variation does not exceed 10%. Rotors and determined energy consumptions are not relevant.

However, the energy consumption can vary significantly with the increase in the flow rate of material supply and, implicitly, of separation.

CONCLUSIONS

After carrying out the experiments under operating conditions for the experimental model of the Technical Equipment for the separation of the pulp from the sea buckthorn seed, it was found that this performs the separation sea buckthorn seed pulp in an acceptable percentage and corresponds to the criteria for further processing of the obtained fractions.

The speeds of the decompaction and detachment rotors must be limited to values of approx. 562min^{-1} and at the decompaction rotor at approx. 1288min^{-1}.

In order to improve performance and create a prototype that can be used by processors in the food or phytopharmaceutical industry, the equipment can be improved, respectively the sieve system for separation, so that the sieve sections include a wider range large holes in terms of size (since the experimental model has a sieve of close dimensions), equipping with a system of brushes for cleaning them and a sealed exhaust system to reduce material losses but also better collection of the processed material on fractions.

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