A method for seed extraction process in the common pine (Pinus sylvestris L.) subjected to mechanical processing by removal of stem

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Abstract: A method for seed extraction process in the common pine (Pinus sylvestris L.) subjected to mechanical processing by removal of stem. The course of seed extraction process in the common pine cones originated from Forest Inspectorate Żednia (RDPL Białystok) is described. The investigated cones were subjected to mechanical processing consisted in removal of the cone stem. The operation of changing the cone state aimed at shortening of seed extraction process and quicker obtaining of vital seeds. There is no unequivocal answer whether the process yielded the expected result. The investigations with the use of described method should be carried out on two samples of the same origin to compare the samples.

Key words: seed extraction, cone, seeds, processing.

INTRODUCTION

Mechanism of cone opening consists in reduction of water content. It can be achieved by an increase in temperature and the intense exchange of air (the moist air into dry air) in the chamber of seed extraction or by separation of the cone part that does not contain seeds. Thus, its mass and the amount of heat needed to carry off moisture decrease. The change in temperature-moisture conditions is commonly used, although no operations are performed that influence the change in state (external dimensions) of cones subjected to seed extraction. In spite of this, the research attempts were undertaken at describing such process of seed extraction, with the use of cones with removed base where vital seeds do not exist [Aniszewska 2004]. It was proved that due to such operation the time of cone opening can be reduced by about 10% and more seeds (about 5%) can be obtained, when compared to whole cones subjected to seed extraction under the same conditions. Additional advantage of this method was less heat supplied to the cones that was essential to achieve the open state [Powicka 2003; Kurkiewicz 2007]. The promising results of these investigations induced the author to further searching for mechanical operations that could shorten the process and help to obtain bigger number of vital seeds.

At initial stage of seed extraction process, the heat flowing round the cone can not enter its inside, since the scales closely adhere to each other and can not open. To accelerate the heat penetration inside the cone, thus to shorten the open-
ing process and to obtain more seeds, an attempt of changing the cone state by removal of its stem was undertaken. Due to this operation the warm air could penetrate the cone inside from the beginning, causing water loss from the scales at stem-side part, where strong shrinkage of cone cells occur causing their full opening.

AIM AND SCOPE OF INVESTIGATIONS

The investigations aimed at analysis of seed extraction from common pine cones subjected to mechanical treatment of stem removal. As a result, the substantial amount of warm air can penetrate the cone inside, allowing for quicker opening of cones and obtaining seeds.

The scope of work presents: specification of external parameters of cones, analysis of changes in water content and drying speed in investigated cones, number and percentage of seeds obtained depending on time, and evaluation of seed vitality.

METHODICS OF INVESTIGATIONS

There were investigated the common pine cones originated from Forest Inspectorate Żdoria in RDLP Białystok, delivered to the kiln in Czarna Białostocka. From a large portion of cones designed for seed extraction there were randomly selected 50 cones; they were marked and measured. The following parameters that determine the external properties of cones were distinguished: length \((h)\), thickness \((d)\), initial mass \((m_i)\) and shape of shields that determine the form of cones. The size measurements of the cone and shields were performed with the use of slide calipers of accuracy up to 0.1 cm, while in mass measurements a laboratory scale of accuracy 0.01 g was applied.

The mechanical treatment of cones subjected to seed extraction consisted in removal of stem to a depth of 20–30 mm, depending on the cone height. This operation was performed with the use of drill with the bit diameter equal to 4 mm, selected upon analysis of dimensions (length and diameter) of cone stems measured by Gawart [2000].

The designated cones were placed in a laboratory drier under conditions safe for vital seeds. During drying there were recorded temperatures of wet and dry air and moisture content inside the drier.

During drying process the cones were taken off the drier and weighed to determine the changes in their mass; the released seeds were gradually shaken out and divided into two groups different in respect of the mass and colour, then they were counted and the wings were taken off.

Upon completion of the process the seeds were sown on the Jacobsen germinating apparatus according to methodology used in seed evaluation applied in State Forests (at constant temperature of 24 ±1°C at day and night and with additional 8-hour lighting of seeds during day) in order to evaluate the germination energy after 7 days and germination capacity after 14 and 21 days.

The drying process was stopped, when after subsequent measurement it was impossible to obtain seeds from the investigated cones.
The open and closed scales were counted after removal of cones from the drier. At the end of measurements the cones were dried at temperature 105 ±2°C for 6 hours to achieve the dry mass ($m_d$). This value was used in calculations of water content at the process beginning ($u_o$) and in the subsequent measurements ($u_k$).

Change in the water content in cones was described with equation (1), while drying speed (water loss in time) with equation (2):

$$u = (u_o - u_k) \cdot e^{-b\tau} + u_k$$

$$\frac{du}{d\tau} = -b \cdot (u_0 - u_k) \cdot e^{-b\tau}$$

where:

- $u$ – instantaneous water content,
- $u_o$ – initial water content,
- $u_k$ – final water content,
- $b$ – coefficient determined for every cone on the basis of real course of moisture content changes,
- $e$ – Napierian base.

The change in water content during drying was described for every investigated cone.

There was determined the time of opening ($t_0$), equal to time of obtaining the last seed; the water content in the cone at the moment of opening ($u_{_o}$) was determined also.

Additionally, for the entire set there was determined the average number of seeds obtained in time. Drying of cones after seed extraction at temperature 105°C enabled to find out amount of seeds not extracted during the process.

RESULTS AND THEIR ANALYSIS

Basic parameters of cones

The investigated cones of common pine from Forest Inspectorate Żdzieńia differed in dimensional parameters and mass. Average length was equal to 44.52 mm (from 32.60 to 61.00 mm), thickness – 21.01 mm (from 17.00 to 28.90 mm) and initial mass – 7.11 g (from 3.75 to 16.75 g). The standard deviation amounted to 6.48, 2.68 and 2.66, respectively.

Measurement results proved that the cones are included in ranges determined by researchers [Bialobok et al. 1993]. A significant difference between length and thickness of investigated cones was found, with $R = 0.8066 (> 0.325)$.

The volume of particular cones measured according to Gawart [2000] amounted on the average to 9,697.65 mm$^3$ (from 4,437.48 to 23,996.42 mm$^3$), while the volume of removed stem ranged from 251.3 to 377.0 mm$^3$; on the average it was 3% of the cone volume.

Process conditions and course

During experiment there were recorded inside drier the constant dry-bulb and wet-bulb temperature of 50 and 22.5°C and air humidity – 7.3%.

The total duration of process was equal to 12 hours.

The average, minimal and maximal values of process parameters for the cones of investigated set are presented in Table 1.

Basing on the values of changes in water content during process the drying curves were drawn for every cone, presented in Figure 1 for selected cones of...
various initial water content \( (u_o = 0.26 \text{ kg H}_2\text{O/kg d.m.} \text{ and } 0.32 \text{ kg H}_2\text{O/kg d.m.}) \). The regression equations for the presented cones are given below.

\[
\begin{align*}
    u &= 0.237 \cdot e^{-0.24 \cdot t} + 0.038 \quad (3) \\
    u &= 0.271 \cdot e^{-0.40 \cdot t} + 0.050 \quad (4)
\end{align*}
\]

On the curves describing the real course of changes in water content there are marked the point of obtaining the last seed from these cones (this is 5th and 6th hour of process, respectively).

The recorded time of cone opening was below average calculated for the entire set. The minimal and maximal values of opening time and obtaining the last vital seed during process are given in Table 1. One can find that average opening time amounts to 7 hours at cone moisture content about 7.5\% \( (u_{ot} = 0.075 \text{ kg H}_2\text{O/kg d.m.}) \). In the investigated lot there were cones that opened at moisture content 5\%, but from some cones the seeds were obtained already at moisture content of 11\%.

### TABLE 1. Parameters of process curves

<table>
<thead>
<tr>
<th>Item</th>
<th>Initial water content ( u_o ) [kg\text{H}_2\text{O/kg d.m.}]</th>
<th>Final water content ( u_k ) [kg\text{H}_2\text{O/kg d.m.}]</th>
<th>Coefficient ( b ) [1/h]</th>
<th>Real opening time ( u_{ot} ) [h]</th>
<th>Water content at the moment of opening ( u_{ot} ) [kg\text{H}_2\text{O/kg d.m.}]</th>
<th>Water content at the moment of model ( u_{ot} ) [kg\text{H}_2\text{O/kg d.m.}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.285</td>
<td>0.050</td>
<td>0.28</td>
<td>7.0</td>
<td>0.074</td>
<td>0.089</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.028</td>
<td>0.010</td>
<td>0.075</td>
<td>2.36</td>
<td>0.015</td>
<td>0.013</td>
</tr>
<tr>
<td>Min.</td>
<td>0.216</td>
<td>0.028</td>
<td>0.19</td>
<td>4.0</td>
<td>0.050</td>
<td>0.063</td>
</tr>
<tr>
<td>Max.</td>
<td>0.356</td>
<td>0.076</td>
<td>0.47</td>
<td>11.0</td>
<td>0.111</td>
<td>0.114</td>
</tr>
</tbody>
</table>

FIGURE 1. Diagrams for exemplary cones: a – changes in water content with marked time of their opening, b – drying speed of cones
However, no dependence of opening time on initial water content was found.

Figure 1b presents the change in drying speed in time for exemplary cones and the equations describing their course:

\[
\frac{du}{d\tau} = -0.057 \cdot e^{(-0.24 \cdot \tau)}
\]

(5)

\[
\frac{du}{d\tau} = -0.108 \cdot e^{(-0.40 \cdot \tau)}
\]

(6)

One can find that the cone of higher initial water content is characterized at the beginning by faster loss of water (by about 0.05 l/h), than the cone of lower initial water content.

The analysis of changes in water content enabled to determine the final process water content \((u_f)\) and the \(b\) coefficient describing the course of real changes in water content. Average final water content was equal to 0.050 kg\(_{st,0}/kg_{d,m}\), while the \(b\) coefficient – 0.28.

The significant effect of external parameters on \(b\) value was found, but its dependence on initial and final water content was not fund.

The analysis of open and closed scales showed that the number of open scales averaged to 26 scales per one cone (from 16 to 37), while the number of closed scales amounted to 38 (from 30 to 49).

The closed scales are situated at the cone base and have smaller shields and the cone shank [Aniszewska 2004], than the scales from central and top part of cone. There is the lack of seeds on these scales, sometimes there are only wings on them.

The significant dependences were found: between the cone thickness and the number of open and closed scales, and between the length and the number of open scales. Longer and thicker cones have bigger number of open and closed scales.

Table 2 presents the average, minimal and maximal number of seeds in the investigated cones, divided into vital seeds (capable of germination) and not vital seeds. On the average 24 vital seeds per cone and 2 not vital seeds were found.

In Figure 2 there is presented in percent the number of seeds for the entire set obtained during process, divided into the vital and not vital seeds. One can find that obtaining of cone seeds starts from the second hour of process and ends at the ninth hour (almost 97% of all seeds are obtained, including 90% of vital seeds). Therefore, the process can be completed after 9 hours. After drying of cones at temperature 105°C, 1% of seeds were extracted (on the average).

### Table 2. Number of scales and obtained seeds in investigated cones

<table>
<thead>
<tr>
<th>Item</th>
<th>Scales</th>
<th>Seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Closed</td>
<td>Open</td>
</tr>
<tr>
<td></td>
<td>[pcs]</td>
<td>[pcs]</td>
</tr>
<tr>
<td>Mean</td>
<td>37.9</td>
<td>26.38</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>4.47</td>
<td>5.37</td>
</tr>
<tr>
<td>Min.</td>
<td>30</td>
<td>16</td>
</tr>
<tr>
<td>Max.</td>
<td>49</td>
<td>37</td>
</tr>
</tbody>
</table>
The total number of seeds obtained in particular measurements for the entire set were analyzed to determine the process duration needed to obtain the greatest seed number. It is evident from Figure 2b that it occurred in the fourth hour of process, when almost 30% of seeds were obtained.

**Evaluation of seed quality**

After removal of wings, the seeds were sown on the Jacobsen germinating apparatus in four repetitions. The obtained results of germination energy and capacity are presented in Table 3.

Basing on carried out investigations on seed vitality one can find that germination energy amounted on the average to 89% (quality class II), while after 21 days the germination capacity was equal to 93% (quality class I).

The obtained high values of seed evaluation proved correctness of the seed extraction process course.

**TABLE 3. Results of germination energy and capacity of seeds obtained during extraction process**

<table>
<thead>
<tr>
<th>Number of sample</th>
<th>Day of germination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7</td>
</tr>
<tr>
<td>1</td>
<td>92</td>
</tr>
<tr>
<td>2</td>
<td>90</td>
</tr>
<tr>
<td>3</td>
<td>86</td>
</tr>
<tr>
<td>4</td>
<td>88</td>
</tr>
<tr>
<td>Mean</td>
<td>89</td>
</tr>
</tbody>
</table>
CONCLUSIONS

1. The analysis of seed extraction process from the cones of Forest Inspectorate Żednia subjected to mechanical processing enables to conclude, that average duration of process amounts to 7 hours. During that time about 80% of vital seeds can be obtained; the further 10% of seeds can be extracted during next two hours.

2. The described processing treatment consisted in removal of stem of diameter 4 mm, aimed at faster heat penetration into the cone, did not yield the expected results of significant reduction in cone opening time. The investigations with the use of described methodologies should be carried out for the whole cones and the cones subjected to mechanical treatment; such experiment would allow for a real view on possible application of this cone processing method, e.g. in the forest gene banks, where usually small lots of cones are subjected to seed extraction for further storage.

3. High index of seed vitality of 93% proves the correctness of seed extraction process course.

REFERENCES


Przeprowadzone badania nie dały jednoznacznej odpowiedzi, czy proces wyluszczania przyniósł oczekiwany rezultat, bo badania opisaną metodą należy przeprowadzić dla dwóch partii jednego pochodzenia (całych i poddanych obróbce), które można ze sobą porównać.

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