Annals of Warsaw University of Life Sciences – SGGW
Agriculture No 63 (Agricultural and Forest Engineering) 2014: 105–112
(Ann. Warsaw Univ. Life Sci. – SGGW, Agricult. 63, 2014)

Analysis of water absorption process in the cones of common pine (*Pinus sylvestris* L.)

MONIKA ANISZEWSKA, BEATA BEREZA
Department of Agricultural and Forest Machinery,
Warsaw University of Life Science – SGGW

Abstract: *Analysis of water absorption process in the cones of common pine* (*Pinus sylvestris* L.). The process of water absorption in the cones of common pine of the same origin (Forest Inspectorate Osusznica) is described. The open cones were brought to dry mass state and placed in water for soaking. During investigations the changes in cone mass were measured and recorded, initially every 1 minute; then, the time was increased. Basing on measurements the moisture content and speed of water absorption were determined. The carried out investigations proved that at the beginning the cones rapidly changed their mass and reached the highest speed of water absorption. After 30 days of investigations, the changes in mass and speed of water absorption were close to zero. In the case of dividing cones according to their length, the highest increase in moisture content was found in long cones; the time of two-stage soaking for the cones of this origin should not exceed 5 minutes.

Key words: moisture content, change in mass, speed of water absorption, seed extraction

INTRODUCTION

In modern seed extraction plants in Poland a one-stage seed extraction from the cones of common pine and spruce has been carried out. Recently, a two-stage seed extraction is introduced for the cones of some origin, especially for common pine cones; it consists in interruption of seed extraction, when the cone scales are partially open, and their moistening to change their moisture content [Aniszewska 2008]. The created conditions cause movement of scales in two directions (seed extraction – opening, moistening – closing), that enables to obtain the higher number of seeds. To achieve the expected results of seed extraction, the moistening should be executed for certain time under determined temperature – moisture content conditions. Too long water absorption time may cause closing of scales and substantial increase in their moisture content, thus, prolongation of seed extraction process. Too short time will not allow for the scale movement in opposite direction (towards stem) and for their fast and full opening [Aniszewska 2012].

Evaluation of optimal water absorption time calls for describing of the process itself for the cones, from their dry mass to the maximal water absorption.

The presented investigations describe a change in dynamics of water absorption process in cones; it enables to determine the optimal duration of inter-stage soaking of cones depending on their size.

MATERIAL AND METHODS

The investigations on water absorption were carried out in laboratory of Department of Agricultural and Forest Machinery Warsaw University of Life Sciences

– SGGW (previously Warsaw Agricultural University – WAU). There were randomly selected 32 cones taken from the local seed extraction plant in Białogard (RDPL Szczecinek) and originated from Forest Inspectorate Osusznica, situated in the region 302 of Wielkopolska-Pomerania province.

The investigated cones were marked with identification numbers and their length was measured with a slide caliper with accuracy up to 0.1 mm. Then, they were placed in a dryer (Heraeus UT 6120) at temperature 105 ±2°C for 10 hours, to dry them to a dry mass state; it was measured with accuracy up to 0.01 g with the use of a laboratory scales WPS 210S.

After drying the cones were in turn immersed in open plastic containers filled with distilled water of temperature 22 ±2°C.

After the first minute the cones were taken out, carefully dried with a blotting-paper and weighed on a laboratory scales with accuracy 0.01 g; they were then placed again in the containers with water. The subsequent measurements were executed after 2, 3, 4, 5, 8, 10, 15, 20, 25, 30 minutes and through the next 6 hours every 1 hour. Time was determined with a stop-watch with accuracy 0.1 s. The next changes in mass were recorded through the following 10 days every 24 hours. The measurements were executed also on 20th and 30th days of soaking.

To analyze in details the process of water absorption, the cones were divided according to their length into three groups of cones: short (up to 4 cm), medium (from 4.1 to 5 cm) and long (over 5 cm).

The obtained results enabled to determine the changes in mass (g), water content (g H_2O per g d.m.), moisture content related to dry mass (%) and speed of water absorption (g H_2O/g d.m. per 1 min).

The change in mass was the difference between subsequent masses measured, while the water content was calculated as the difference between the cone mass after certain time of water absorption and its dry mass [Kubiak and Laurow 1994, Kozakiewicz 2012]. Determination of water mass in the cone and its dry mass enabled to calculate the absolute humidity in percentage value.

The speed of water absorption was calculated with the following equation:

$$\upsilon = \frac{\mathrm{d}m_w}{\mathrm{d}\tau} \quad (1)$$

where:
m_w – mass of water;
τ – time.

RESULTS

The mean length of investigated cones amounted to 42.6 mm (from 31.5 to 59.8 mm). The mean dry mass was equal to 5.29 g (from 2.42 to 11.54 g). The mean mass of moist cone after 30 days amounted to 10.06 g (from 4.62 to 22.65 g), and mean change in mass from the dry mass to saturation with water was equal to 4.76 g (from 2.2 to 11.11 g). The set of cones consisted of: short cones – 14, medium cones – 13 and large cones – 5.

Mean values of change in mass for the cones divided according to their length are presented in Table 1, change in mass of the cones during water absorption is presented in Figure 1.

TABLE 1. Mean change in mass of cones with time [Bereza 2013]

Time [min]	Cones					
	short		medium		long	
	mass	mass increment	mass	mass increment	mass	mass increment
	g					
0	3.579	–	5.559	–	9.408	–
1	3.890	0.311	6.085	0.526	10.270	0.862
2	4.034	0.144	6.275	0.190	10.646	0.376
3	4.121	0.087	6.451	0.176	10.878	0.232
4	4.212	0.091	6.609	0.158	11.114	0.236
5	4.268	0.056	6.730	0.121	11.290	0.176
8	4.352	0.084	6.862	0.132	11.520	0.230
10	4.436	0.084	6.969	0.107	11.742	0.222
15	4.522	0.086	7.095	0.126	11.984	0.242
20	4.592	0.070	7.239	0.144	12.188	0.204
25	4.662	0.070	7.326	0.087	12.354	0.166
30	4.752	0.090	7.463	0.137	12.598	0.244
60	4.949	0.197	7.778	0.315	13.082	0.484
120	5.242	0.293	8.217	0.439	13.932	0.850
180	5.403	0.161	8.483	0.266	14.452	0.520
240	5.501	0.098	8.692	0.209	14.788	0.336
300	5.574	0.073	8.764	0.072	14.982	0.194
360	5.645	0.071	8.852	0.088	15.098	0.116
1,800	6.129	0.484	9.544	0.692	16.276	1.178
3,240	6.284	0.155	9.797	0.253	16.646	0.370
4,680	6.377	0.093	9.942	0.145	16.892	0.246
6,120	6.456	0.079	10.055	0.113	17.082	0.190
7,560	6.503	0.047	10.125	0.070	17.244	0.162
9,000	6.536	0.033	10.196	0.071	17.334	0.090
10,440	6.571	0.035	10.242	0.046	17.450	0.116
11,880	6.594	0.023	10.268	0.026	17.520	0.070
13,320	6.605	0.011	10.289	0.021	17.560	0.040
14,760	6.619	0.014	10.313	0.024	17.596	0.036
29,160	6.749	0.130	10.476	0.163	17.918	0.322
43,560	6.779	0.030	10.534	0.058	18.006	0.088

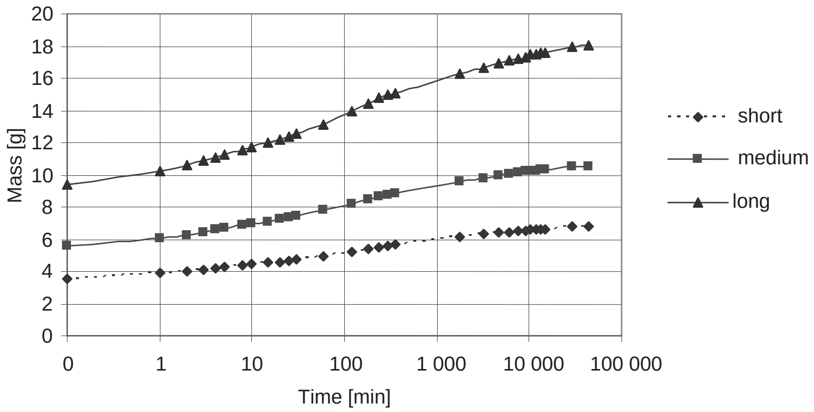

FIGURE 1. Mean change in mass of three groups of cones during water absorption process

Basing on the obtained results it was found that during the first minute of water absorption, an increase in mass amounted to about 9% (short cones – 8.68%, medium cones – 9.46%, long cones – 9.16%). During the second minute an increment decreased to about 3–4%, and during subsequent minutes (up to 30th minute) it amounted to about 2% in every measurement. Between 30th and 180th minute the mass changed by about 3–6%, then by 2% per hour. The highest mass increment occurred between 6th and 30th hour of investigations, when the difference amounted to about 8% (short cones – 0.484 g, medium cones – 0.692 g, long cones – 1.178 g). In 24h-measurements the mass increment during first 4 days amounted to about 1–2%, it decreased to 0.2% on 10th day. The mass change between 10th and 20th day amounted to about 2%, while between 20th and 30th day it was equal on the average to about 0.55%.

The changes in water content, moisture content and speed of water absorption are presented in Table 2 and Figure 2.

The moisture content of cones at the end of water absorption process amounted to almost 90%. In short cones the moisture content increased to 89.4%, in short cones – 89.5% and in long cones – 91.4%.

The change in water content in the three cone groups during water absorption was described with the equation:

$$m_w = a + b \cdot \log \tau \quad \text{for } \tau \geq 1 \text{ min} \tag{2}$$

where:
a = 0.1 g/g;
b = 0.18 g/g;
R = 0.994.

The speed of water content for the model was expressed as time derivative of water content of the form:

$$\frac{\mathrm{d}m_w}{\mathrm{d}t} = 0.18 \cdot \frac{1}{\tau} \cdot \log \tau = \frac{0.0782}{\tau} \tag{3}$$

The speed of water content for the first measurement amounted to 0.079 g H_2O/g d.m. per 1 min, for the second measurement it was close to 0.039 g H_2O/g d.m. per 1 min, for the third measurement 0.026 g H_2O/g d.m. per 1 min.

TABLE 2. Water content, change in moisture content and speed of water absorption

Time [min]	Cones						Model of change in water content [g/g]	Speed of water absorption [g/g/min]
	short		medium		long			
	water content [g/g]	change in moisture content [%]	water content [g/g]	change in moisture content [%]	water content [g/g]	change in moisture content [%]		
1	0.087	8.7	0.095	9.5	0.092	9.2	0.1000	0.07820
2	0.127	4.0	0.129	3.4	0.132	4.0	0.1542	0.03910
3	0.151	2.4	0.160	3.1	0.156	2.4	0.1859	0.02607
4	0.177	2.6	0.189	2.9	0.181	2.5	0.2084	0.01955
5	0.193	1.6	0.211	2.2	0.200	1.9	0.2258	0.01564
8	0.216	2.3	0.234	2.3	0.224	2.4	0.2626	0.00978
10	0.239	2.3	0.254	2.0	0.248	2.4	0.2800	0.00782
15	0.263	2.4	0.276	2.2	0.274	2.6	0.3117	0.00521
20	0.283	2.0	0.302	2.6	0.295	2.1	0.3342	0.00391
25	0.303	2.0	0.318	1.6	0.313	1.8	0.3516	0.00313
30	0.328	2.5	0.343	2.5	0.339	2.6	0.3659	0.00261
60	0.383	5.5	0.399	5.6	0.391	5.2	0.4201	0.00130
120	0.465	8.2	0.478	7.9	0.481	9.0	0.4743	0.00065
180	0.510	4.5	0.526	4.8	0.536	5.5	0.5059	0.00043
240	0.537	2.7	0.564	3.8	0.572	3.6	0.5284	0.00033
300	0.557	2.0	0.577	1.3	0.592	2.0	0.5459	0.00026
360	0.577	2.0	0.592	1.5	0.605	1.3	0.5601	0.00022
1,800	0.712	13.5	0.717	12.5	0.730	12.5	0.6859	4.3444E-05
3,240	0.756	4.4	0.762	4.5	0.769	3.9	0.7319	2.4136E-05
4,680	0.782	2.6	0.788	2.6	0.795	2.6	0.7606	1.6709E-05
6,120	0.804	2.2	0.809	2.1	0.816	2.1	0.7816	1.2778E-05
7,560	0.817	1.3	0.821	1.2	0.833	1.7	0.7981	1.0344E-05
9,000	0.826	0.9	0.834	1.3	0.842	0.9	0.8118	8.6889E-06
10,440	0.836	1.0	0.842	0.8	0.855	1.3	0.8234	7.4904E-06
11,880	0.842	0.6	0.847	0.5	0.862	0.7	0.8335	6.5825E-06
13,320	0.845	0.3	0.851	0.4	0.866	0.4	0.8424	5.8709E-06
14,760	0.849	0.4	0.855	0.4	0.87	0.4	0.8504	5.2981E-06
29,160	0.886	3.7	0.885	3.0	0.905	3.5	0.9037	2.6818E-06
43,560	0.894	0.8	0.895	1.0	0.914	0.9	0.9350	1.7952E-06

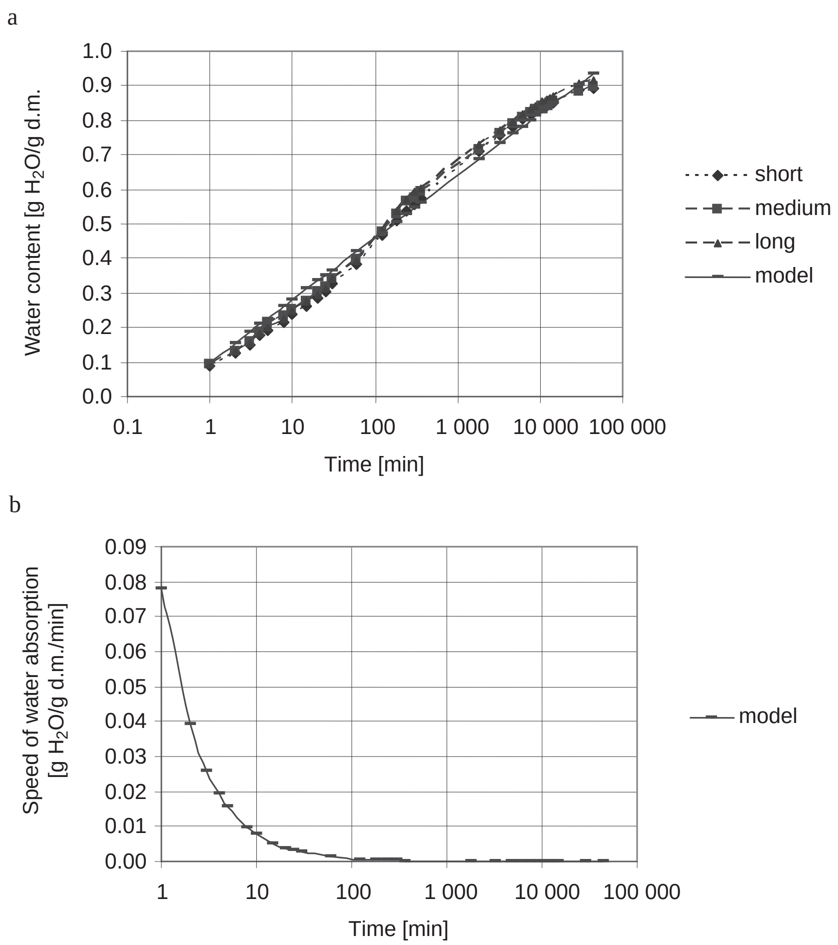

FIGURE 2. Mean change in: a – water content for dividing of cones according to their length, b – speed of water absorption with time for model of water content change

After 30 min it decreased to 0.0026 g H_2O/g d.m. per 1 min, while after 360 min to 0.00022 g H_2O/g d.m. per 1 min.

The speed of water absorption of cones from their dry mass to saturation is the highest during first 10 minutes of the process. During that time the cones reach about 28% of absolute humidity. In the two-stage process the cones after the first stage of seed extraction reach the moisture content from 12 to 15%, depending on duration of that stage (10–7 hours) and the initial water content in cones (over 35 kg H_2O/kg d.m.). The moisture content found at the end of first stage allows for partial deflection of scales from the stem. According to investigations, already after three minutes of water absorption (Fig. 2a) the cones increase their moisture content to 23%; that allows for the scales movement towards the stem and for their partial closing.

RECAPITULATION AND CONCLUSIONS

1. The highest increase in moisture content in groups resulted from dividing according to the length occurred in long cones – 91.4%; in short and medium cones it amounted to 89.4 and 89.5%, respectively, and no significant difference was found.
2. With respect to insignificant differences in the water content change during water absorption, for the cones of that origin and various length, the course of curve was described by the logarithmic function model of coefficients: a = 0.1 g H_2O/g d.m. and b = = 0.18 g H_2O/g d.m.
3. The highest speed of water absorption was found for the first 10 minutes of soaking cones in water.
4. In all groups the speed of water absorption after 30 days amounts to zero; therefore it can be assumed that during this time the cones reached the saturation state.
5. Assuming that the cones of the investigated origin reach moisture content of 12 to 15% after the first stage of two-stage seed extraction lasting from 7 to 10 hours, the cones moistening (soaking in water) not longer than 5 minutes is sufficient.

REFERENCES

ANISZEWSKA M. 2008: Charakterystyka wielofazowego procesu wyłuszczania nasion modrzewia europejskiego *Larix decidua* Mill. na przykładzie wyłuszczarni gospodarczej w Czarnej Białostockiej. Leśne Prace Badawcze 69 (2): 155–163.

ANISZEWSKA M. 2012: Dynamika procesu pozyskania nasion w jedno- i dwuetapowych procesach łuszczenia szyszek sosny zwyczajnej *Pinus sylvestris* L. Rozprawy Naukowe i Monografie. Wydawnictwo SGGW, Warszawa: 120.

BEREZA B. 2013: Analiza procesu nasiąkania szyszek sosny zwyczajnej (*Pinus sylvestris* L.). Praca inżynierska, Katedra Maszyn Rolniczych i Leśnych SGGW: 45.

KOZAKIEWICZ P. 2012: Fizyka drewna w teorii i zadaniach. Wydawnictwo SGGW, Warszawa: 152.

KUBIAK M., LAUROW Z. 1994: Surowiec drzewny. Fundacja „Rozwój SGGW", Warszawa: 493.

Streszczenie: *Analiza procesu nasiąkania szyszek sosny zwyczajnej* (*Pinus sylvestris* L.). W artykule opisano proces nasiąkania szyszek sosny zwyczajnej jednego pochodzenia (Nadleśnictwo Osusznica). Przedstawione badania opisują zmianę dynamiki procesu nasiąkania szyszek, co może umożliwić określenie optymalnego czasu trwania moczenia międzyetapowego szyszek w zależności od ich wielkości (długości). W badaniu szyszki poddano procesowi łuszczenia. Otwarte szyszki doprowadzono do suchej masy i umieszczono w wodzie w celu nasiąkania. Pomiar masy wykonano początkowo co 1 min, a później zwiększono odstęp czasu. Czas trwania całego badania wynosił 30 dni. Podczas badań rejestrowano zmianę masy. Na jej podstawie obliczono zmiany zawartości wody i prędkości nasiąkania w czasie. Obie wielkości opisano modelami matematycznymi. Wykonane badania potwierdziły, że szyszki na początku próby gwałtownie zwiększają masę oraz osiągają największą prędkość nasiąkania. Po 30 dniach badań zmiana masy i prędkości nasiąkania bliska jest zeru. Wykazano, że w przypadku podziału szyszek względem długości, wzrost wilgotności dla szyszek długich był największy, choć nieistotny statystycznie w porównaniu z szyszkami krótkimi i średnimi. Analiza procesu nasiąkania pierwszych dziesięciu minut badania wykazała, że szyszki tego pochodzenia, aby uzyskać stan częściowego zamknięcia podczas przerwy międzyetapowej w dwuetapowym procesie łuszczenia, powinny być moczone nie dłużej jak 5 minut.

MS. received September 2013

Authors' address:
Monika Aniszewska
Wydział Inżynierii Produkcji SGGW
Katedra Maszyn Rolniczych i Leśnych
02-787 Warszawa
ul. Nowoursynowska 164
Poland
e-mail: monika_aniszewska @sggw.pl