ARBORETUM KÓRNICKIE
Rocznik XXI — 1976

TADEUSZ TYLKOWSKI

Respiration of northern red oak (*Quercus borealis* Michx.) acorns*

INTRODUCTION

From the experiments conducted so far it appears that in natural conditions the viability of acorns can be maintained only until the first Spring after collection. Storage over several winters requires low temperatures (Holmes and Buszewicz 1956, Suszka 1971, 1972, 1973, 1974). The observed differences in the maintainance of viability by acorns kept in sealed and unsealed containers permit the conclusion that the reason for the rapid loss of germinability of acorns may be caused by changes in the gaseous composition within the containers.

It needs to be pointed out that stored acorns are characterized by a high water content and intensive respiration. High rate of respiration particularily under raised temperature conditions is indicated by the results of studies by Brown (1939), Zajtseva (1950) and Filimonova (1958) on the CO_2 production by the stored acorns.

Since data was lacking on the respiration of acorns in sealed and unsealed containers under controlled temperature conditions the following studies were planned and executed.

METHODS

For the studies on respiration we have used acorns of *Quercus borealis* collected in 1974 in Forest District Gromnik in Tarnów voivodship. After throwing away decayed acorns the viability of the remainder amounted to 98.0%. After partial drying the water content in the fresh weight was 38.4%. So prepared acorns were placed in 20 l metal containers on the 13th of December 1974. In each container there were about 700 acorns (about 2.1 liters).

The experiment was conducted at two temperatures: $-1°C$ and $20°C$ with a tolerance of $\pm 1°C$. At each temperature the acorns were in sealed

* This work has been partially supported by grant no. FG-Po-253 from the U.S. Department of Agriculture, under U.S. Public Law-480.

and unsealed containers. The former were sealed immediately after placing acorns into them and left for various lenghts of time. The latter were closed but not sealed for the same periods of time, and after that were sealed (Figs. 1, 2, 3).

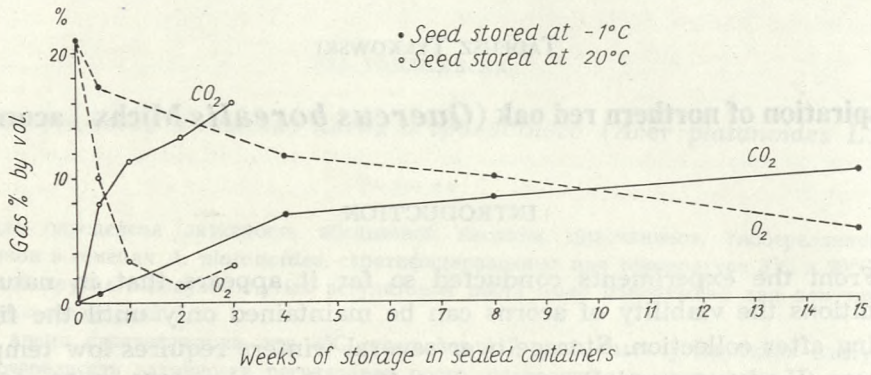

Fig. 1. Oxygen uptake and carbon dioxide emission by *Quercus borealis* acorns held in sealed containers at temperatures —1°C and 20°C

Studies on the respiration of acorns were conducted with the help of gas analysers: Infralyt for the measurement of CO_2, working on the principle of far red light absorption by this gas, and Permolyt for the mea-

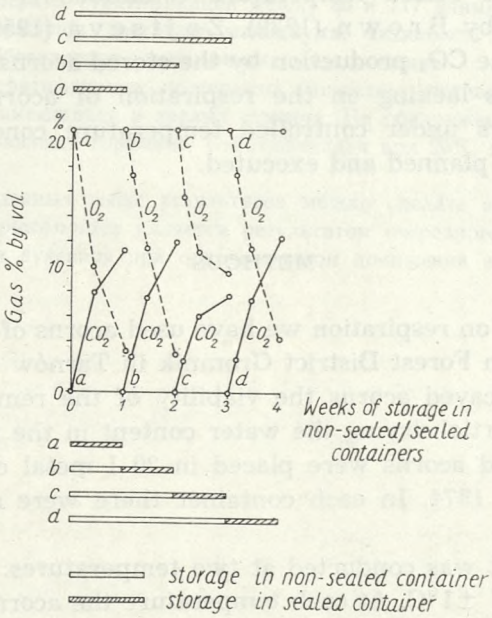

Fig. 2. Oxygen uptake and carbon dioxide emission by *Quercus borealis* acorns held in closed but not sealed containers at a temperature of 20° C for 1, 2 and 3 weeks, and then sealed for one week

surement of O_2, utilising the paramagnetic properties of oxygen. Gas analysers were equipped with recorders from which the results were read off.

Measurements of the CO_2 and O_2 concentration at 20°C were conducted after 1, 2 and 3 weeks of storage in sealed and unsealed containers. The concentration of both the gases in sealed containers in which the acorns were kept after their stay in unsealed ones was measured after 1, 3 and 7 days (Fig. 2).

Measurements of gas concentrations in the containers with acorns stored at −1°C were conducted in a analogous way as at 20°C temperature, except that the measurements of CO_2 and O_2 concentration were made at larger time intervals, namely after 4, 8 and 15 weeks. Acorns placed in containers with air access were sealed after 4, 8 or 15 weeks of storage and the measurements of CO_2 and O_2 concentration were conducted after further 4, 7 and 4 weeks of storage respectively (Fig. 3).

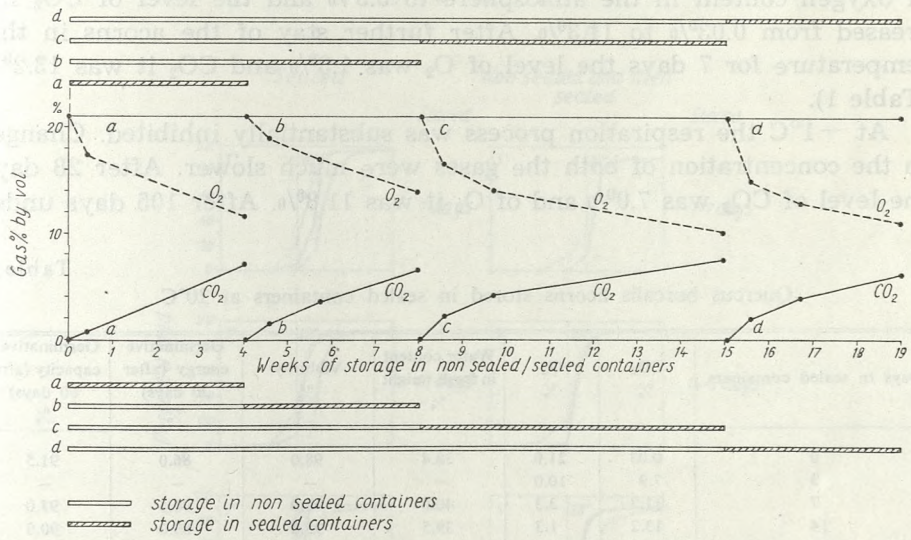

Fig. 3. Oxygen uptake and carbon dioxide emission by *Quercus borealis* acorns held in closed but not sealed containers at temperature of −1°C for 4, 8 and 15 weeks and then sealed respectively for 4, 7 and 4 weeks

After termination of acorn storage of each experimental variant the acorns were subjected to an evaluation of the viability by the cutting test, and of the water content in fresh weight by drying for 48 hours at a temperature of 105°C. Also the germinability was tested (4×50 acorns). The germination test was conducted in a peat-sand mixture (1 : 1 by vol.) initially at a temperature of 5°C in order to break dormancy characteristic for this species immediately after collection. After the first radicles

appeared the temperature was raised to 20°C. In all the duration of the test amounted to 70 days after storage at 20°C and to 60 days after storage at −1°C, in view of the differences in the course of germination.

Only those acorns were considered as germinated which have had besides a growing radicle also some epicotyl growth beyond the cotyledons.

RESULTS

The oxygen absorption and the emission of carbon dioxide by the acorns proved to be dependent on the storage temperature (Fig. 1).

At 20°C the respiration process was very intense. The greatest changes in the concentration of oxygen and exuded carbon dioxide were observed in the conditions of a tightly sealed container already after 7 days of storage. During that time the level of oxygen declined from the 21% of oxygen content in the atmosphere to 3.3% and the level of CO_2 increased from 0.03% to 11.3%. After further stay of the acorns in this temperature for 7 days the level of O_2 was 1.3% and CO_2 it was 13.2% (Table 1).

At −1°C the respiration process was substantially inhibited. Changes in the concentration of both the gases were much slower. After 28 days the level of CO_2 was 7.0% and of O_2 it was 11.8%. After 105 days under

Table 1

Quercus borealis acorns stored in sealed containers at 20°C

Days in sealed containers	CO_2 %	O_2 %	Water content in fresh weight %	Viability %	Germinative energy (after 20 days) %	Germinative capacity (after 60 days) %
0	0.03	21.0	38.4	98.0	86.0	91.5
3	7.9	10.0	–	–	–	–
7	11.3	3.3	40.0	92.0	90.5	97.0
14	13.2	1.3	39.5	95.0	89.0	90.0
21	15.9	3.0	40.2	92.5	88.0	91.5

Table 2

Quercus borealis acorns stored in sealed containers at −1°C

Days in sealed containers	CO_2 %	O_2 %	Water content in fresh weight %	Viability %	Germinative energy (after 20 days) %	Germinative capacity (after 60 days) %
0	0.03	21.0	38.4	98.0	86.0	91.5
3	0.8	17.3	–	–	–	–
28	7.0	11.7	40.0	95.0	92.0	94.0
56	8.2	9.9	39.9	95.5	94.0	95.0
105	10.2	5.5	40.5	93.0	91.5	91.5

a tight seal at his temperature the CO_2 level amounted to 10.2% and of O_2 to 5.5% (Table 2, Fig. 1).

In a similar manner changes in the concentration of both the gases were observable under a tight seal following each period of storage in unsealed containers.

Besides the change in respiration intensity dependent on temperature it was also possible to observe differences in the course of acorn germination in the germination tests. These differences became manifest in the

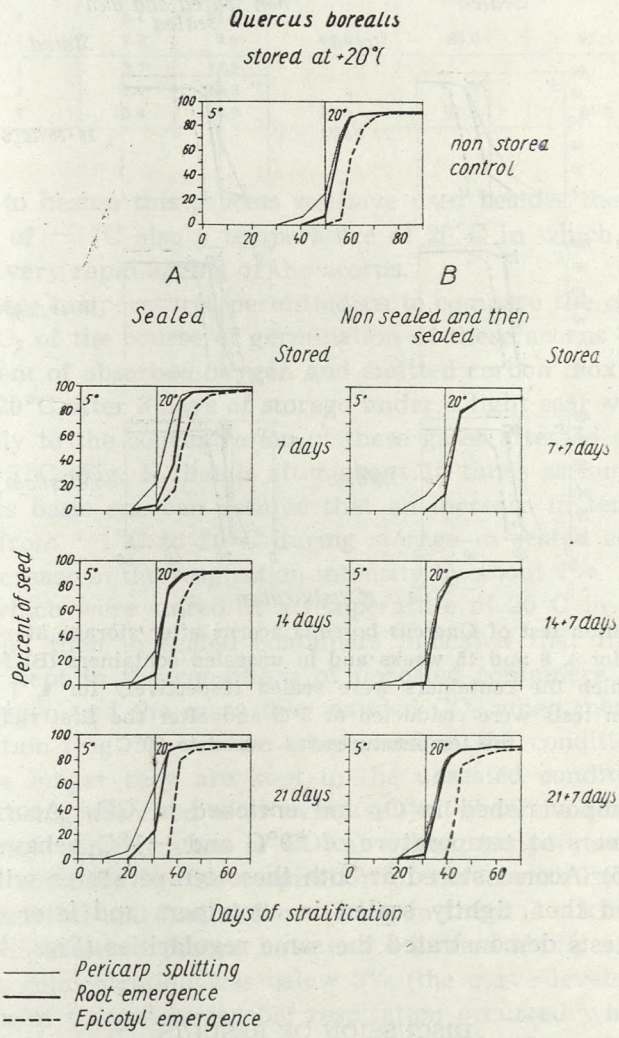

Fig. 4. Germination tests of *Quercus borealis* acorns after storage at 20°C in sealed containers (A) for 1, 2 and 3 weeks, and in unsealed containers (B) for the same periods of time after which the containers were sealed for another week. The germination tests were conducted at 5°C and after the first radicles appeared the temperature was raised to 20°C

hastening of the onset of radicle emergence in the initially low temperature of the test (5°C) and after transfer to the higher temperature (20°C) in the shortening of the germination time (including root and epicotyl growth) in the seeds stored in sealed containers, that is in an

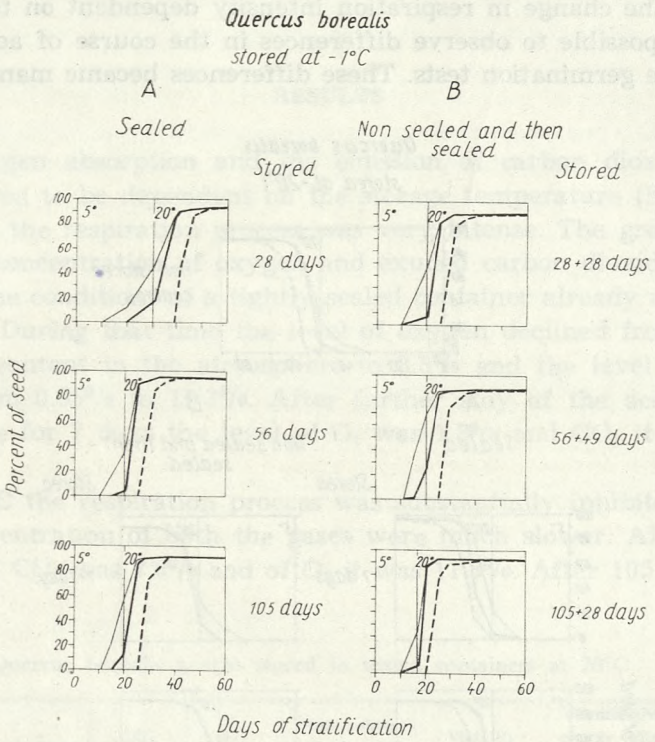

Fig. 5. Germination test of *Quercus borealis* acorns after storage at −1°C in sealed containers (A) for 4, 8 and 15 weeks and in unsealed containers (B) for 4, 8 and 15 weeks after which the containers were sealed respectively for 4, 7 and 4 weeks. The germination tests were conducted at 5°C and after the first radicles appeared the temperature was raised to 20°C

atmosphere impoverished in O_2 and enriched in CO_2. Acorns stored in sealed containers at temperature of 20°C and −1°C behaved similarily (Figs. 4 and 5). Acorns stored at both these temperatures with air access (unsealed) and then tightly sealed in containers and later subjected to germination tests demonstrated the same regularities (Figs. 4 and 5).

DISCUSSION OF RESULTS

It is known (Suszka 1971, 1972, 1973, 1974) that the storage of *Q. borealis* acorns and seed of other oak species in sealed containers leads to much more rapid loss of viability and consequently of the ability to germinate in each of the temperatures within the range 3° to −3°C.

Table 3

Quercus borealis acorns stored in unsealed/sealed containers at 20°C

Days in containers		CO_2 %	O_2 %	Water content in fresh weight %	Viability %	Germinative energy (after 20 days) %	Germinative capacity (after 60 days) %
unsealed	sealed						
0	0	0.03	21.0	38.4	98.0	86.0	91.5
7	1	2.8	17.3				
	3	7.5	11.5				
	7	12.0	3.0	38.7	92.0	86.5	89.5
14	1	2.5	15.6				
	3	6.1	11.2				
	7	7.7	9.6	40.1	89.0	85.5	92.5
21	1	2.7	17.5				
	3	7.4	11.3				
	7	12.4	4.3	38.6	87.0	81.0	89.5

In order to hasten this process we have used besides the best storage temperature of −1°C also a temperature of 20°C in which we expected to observe a very rapid ageing of the acorns.

Use of these temperatures permitted us to compare the concentrations of CO_2 and O_2 of the course of germination of these acorns in time.

The content of absorbed oxygen and emitted carbon dioxide at a temperature of 20°C after 3 days of storage under a tight seal was equivalent approximately to the concentration of these gases after 56 days of acorn storage at −1°C (Fig. 1) that is after about 15 times as long a period of time. On this basis one can assume that an increase in temperature by one degree from −1°C to 20°C during storage in sealed containers has caused an increase in the respiration intensity by about 7%.

Acorns which were stored at a temperature of 20°C in conditions of air access and then in sealed containers indicated that the longer the acorns were kept in the conditions of unsealed containers the less they absorbed oxygen and the more they exuded CO_2 when measured in the sealed condition (Fig. 2). On the other hand in the condition of storage at −1°C the longer they are kept in the unsealed condition the more oxygen was being absorbed after being subjected to the sealed condition (Fig. 3). A high concentration of CO_2 at a high temperature could have been caused not only by the respiration of the acorns but also by the numerous bacterial and fungal flora living in them (Łukomski 1970). Acorns kept in these conditions have had a limited ability to absorb oxygen when its concentration was below 3% (the curve levels off). At this concentration of oxygen anaerobic respiration occurred which in consequence leads to a rapid decomposition of the seeds (Suszka 1972). Storage of acorns in sealed containers, at temperature of −1°C has considerably hastened the epicotyl germination of seeds during stratification. The occurrence of epicotyls was even more abundant than after storage at +20°C (Fig. 5).

Table 4

Quercus borealis acorns stored in unsealed/sealed containers at −1°C

Days in containers		CO_2 %	O_2 %	Water content in fresh weight %	Viability %	Germinative energy (after 20 days) %	Germinative capacity (after 60 days) %
unsealed	sealed						
0	0	0.03	21.0	38.4	98.0	86.0	91.5
	4	1.6	18.9				
28	12	3.6	17.0				
	28	6.5	13.9	39.5	96.5	90.0	91.0
	4	2.2	16.5				
56	12	4.2	14.1				
	49	7.5	10.2	40.3	87.0	87.5	88.0
	4	2.0	15.0				
105	12	4.0	13.0				
	28	6.1	11.0	40.8	89.5	90.0	91.0

The duration of the germination test at 5°C until dormancy breaking was 31 days after storage at 20°C for 1, 2 and 3 weeks and also for 4 weeks after storage at −1°C, while it was reduced to 20 days after storage at −1°C for 8 and 15 weeks (Figs. 4 and 5).

The germination of acorns stored before the germination test in an environment with air access and only later sealed, both at 20°C and at −1°C did not differ in any way from the germination after storage in sealed conditions. It was only found that there was an increased tendency to decay among the acorns stored with air access (unsealed) at both the temperatures and a mould covered them when stored at 20°C (Table 2 and 4).

The duration of the experiment was too short to be able to notice the differences in viability known from the long-term storage experiments.

SUMMARY

Studies on the oxygen absorption and carbon dioxide emission by stored acorns of northern red oak (*Q. borealis*) collected in 1974 have been conducted during storage at two temperatures, 20° and −1°C. At each of these temperatures the acorns were stored in both sealed and unsealed containers. The former were sealed immediately after the acorns were placed in them for various periods of time (7, 14 and 21 days in 20°C and 28, 56 and 105 days in −1°C) while the latter were closed but unsealed for the same period of time and only after that were sealed for 7 days at 20°C and for 28 - 49 days in −1°C.

In sealed containers at 20°C respiration was very intensive. After the first week of storage oxygen content declined from 21% to 3.3% and the level of CO_2 increased from 0.03 to 11.3%.

At −1°C, a temperature optimal for storage, the intensity of respiration process was substantially reduced. After 15 weeks at this temperature the atmosphere in the sealed containers included 5.5% of oxygen and 10.2% of CO_2. It was found that during storage in the sealed conditions the intensity of acorn respiration was about 15 times lower at −1°C than at 20°C.

Acorns stored in the unsealed condition both at 20°C and at −1°C were characterized by a uniform intensity of respiration, regardless of the duration of the storage period prior to measurement. It was found that after storing in sealed containers in the atmosphere rich in CO_2 and poor in oxygen acorn germination was more early the longer was the storage period. This is of particular interest since after collection the acorns of *Q. borealis* are in a dormant condition.

Institute of Dendrology
Kórnik nr. Poznań

LITERATURE

1. Brown J. W. — 1939. Respiration of acorns as related to temperature and after-ripening. Plant Physiol. 14 : 621 - 645.
2. Filimonova W. D. — 1958. Biologicheskie osnovy khraneniya zheludej v zimnij period. Trudy Inst. Lesa Akad. Nauk SSSR, XXXIX (I) : 83 - 132.
3. Holmes G. D., Buszewicz G. — 1956. Longevity of acorns with several storage methods. Rep. For. Res., For. Comm. London 1954/55, 88 - 94.
4. Łukomski S. — 1970. Investigations on the protection of acorns against diseases under storage conditions. For. Res. Inst. Warszawa, FG-PO-253, E21--FS-48.
5. Suszka B. — 1971, 1972, 1973, 1974. Studies on the long-term storage of acorns. Polish Acad. of Sciences, Inst. of Dendrology Kórnik near Poznań, FG-PO-253, E21-FS-44.
6. Zajtseva A. A. — 1950. Zimnee khranenie semennykh zheludej. Lesn. Khoz. 3 (10) : 63 - 72.

TADEUSZ TYLKOWSKI

Oddychanie żołędzi dębu czerwonego (Quercus borealis Michx.)

Streszczenie

Badania nad pobieraniem tlenu i wydzielaniem dwutlenku węgla przez przechowywane żołędzie dębu czerwonego (*Q. borealis*) zebrane w 1974 r. prowadzono podczas ich przechowywania w dwóch temperaturach: 20°C i −1°C. W każdej z temperatur żołędzie przechowywano zarówno w pojemnikach szczelnie, jak i nieszczelnie zamkniętych. Pojemniki szczelnego przechowywania zamykano zaraz po umieszczeniu w nich żołędzi na coraz dłuższe okresy czasu (7, 14 i 21 dni w 20°C; 28, 56 i 105 dni w −1°C), w pozostałych pojemnikach żołędzie przechowywano przy nieszczelnym zamknięciu przez takie same okresy czasu, a dopiero po tym pojemniki zamykano szczelnie (na 7 dni w 20°C i na 28 - 49 dni w −1°C).

W zamkniętych szczelnie pojemnikach oddychanie żołędzi przebiegało w 20°C bardzo intensywnie. Po pierwszym tygodniu takiego przechowywania zawartość tlenu obniżyła się z 21% do 3,3%, a poziom CO_2 wzrósł z 0,03% do 11,3%.

W korzystnej dla przechowywania żołędzi temperaturze —1°C intensywność procesu oddychania uległa znacznemu zahamowaniu. Po 15 tygodniach pobytu żołędzi w tej temperaturze atmosfera zamkniętych pojemników zawierała 5,5% tlenu i 10,2% CO_2. Okazało się że intensywność oddychania żołędzi była w temperaturze —1°C około 15 razy niższa niż w 20°C.

Żołędzie przechowywane przy dostępie powietrza zarówno w 20°C, jak i w —1°C charakteryzowały się bez względu na zastosowane okresy przechowywania niezmienioną intensywnością oddychania po umieszczeniu w zbiornikach szczelnych.

Stwierdzono również, że po przechowaniu w pojemnikach zamkniętych w atmosferze bogatej w CO_2, a ubogiej w tlen, kiełkowanie żołędzi przebiegało tym wcześniej, im dłużej je przechowywano. Zasługuje to tym bardziej na uwagę, że po zbiorze żołędzie *Q. borealis* znajdują się w stanie spoczynku.

ТАДЕУШ ТЫЛЬКОВСКИ

Дыхание желудей красного дуба (Quercus borealis Michx.)

Резюме

Исследования поглощения кислорода и выделения двуокиси углерода хранящимися желудями красного дуба (*Q. borealis* Michx.), собранными в 1974 году, проводились во время их хранения в двух температруах: 20°C и —1°C. При каждой из этих температур желуди хранились как в герматически закрытых, так и в неплотно закрытых контейнерах.

Герметические контейнеры закрывались сразу же после помещения в них желудей с каждым разом на более длительный период времени (7, 14 и 21 дней при 20°C; 28, 56 и 105 дней при —1°C), в остальных контейнерах желуди хранились при неплотном закрытии на такие самые периоды времени, и только после этого контейнеры закрывались герметически (на 7 дней при 20°C и на 28 - 49 дней при —1°C).

В герметичесикх контейнерах дыхание желудей при 20°C проходило очень интенсивно. После первой недели такого хранения содержание кислорода снижалось от 21% до 3,3% а уровень CO_2 возрастал от 0,03% да 11,3%.

В благоприятной для сохранения желудей температуре —1°C интенсивность процесса дыхания подвергалась значительному замедлению. Через 15 недель пребывания желудей в этой температуре атмосфера закыртых контейнеров содержала 5,5% кислорода и 10,2% CO_2. Оказалось, что интенсивность дыхания желудей в температуре —1°C была около 15 раз нише, чем при 20°C.

Желуди, хранящиеся при доступе воздуха как при 20°C, так и при —1°C, характеризовались, независимо от применяемых периодов хранения, неизменной интенсивностью дыханя после помещения их в герметических контейнерах.

Было обнаружено также, что после хранения в закрытых контейнерах в атмосфере богатой CO_2 и бедной кислородом прорастание желудей было тем раннее, чем более длительным было их хранение. Этот факт тем более заслуживает внимания в связи с тем, что желуди *Q. borealis* после сбора находятся в состоянии покоя.