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The rate of respiration of potato tubers during storage. 2. Results of experiments in 1972 and 1973[1,2]

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Zusammenfassung, Résumé p. 204

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Summary

The rates of respiration of potato tubers in storage were determined with a number of commercial cultivars and breeding lines in 1972 and, in a more systematical way, with six commercial cultivars in 1973. The ranges of respiration rates in mg CO_2 kg^{-1} h^{-1} during the main storage period were 1.5–4.0 at 2.5°C, 1.5–2.5 at 5.0°C, 1.0–2.0 at 7.5°C, 1.0–3.0 at 10.0°C, 1.5–5.5 at 12.5°C and 2.5–12.5 at 15.0°C. At the start of the storage season, the rates, particularly at 2.5 and 5.0°C, were higher than during the main storage period. During late winter and early spring the rate of respiration of the tubers stored at the highest temperatures increased considerably. The minimum rates of respiration were found in December, except at 2.5°C when the minimum was in February. The rate of respiration was a clear characteristic of the cultivar, independent form both earliness in the field and length of dormant period. The rate of respiration increased noticeably when sprouts were at least 1 cm long.

Introduction

In a previous paper (Schippers, 1977) many factors were discussed which have been reported to influence the rate of respiration of potato tubers during storage. In the present publication results of experiments carried out to elucidate the influence of some of these factors will be reported.

Method of respiration measurement

For the determination of rate of respiration, samples of potato tubers, which were stored in crates, were held in closed containers for a certain duration after which an air sample was taken and analysed for percentage carbon dioxide. The containers were wide mouth brown bottles with a measured air volume of 4350 ml. As many

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tubers as possible were placed in each bottle which meant that the air volume was reduced to approximately half. The bottles were closed with a No 14 rubber stopper provided with a plastic sampling tube long enough to reach nearly to the bottom of the bottle. The other end of the tube, protruding through the stopper, was closed with a clip. After several hours a 50-ml all-glass syringe was connected with the sampling tube, the clip was opened, the air inside the bottle was mixed by 'pumping' the syringe 20 or 30 times vigorously, and an air sample was withdrawn. The air sample was transferred to a Lloyd Gas Analyzer, which is an adaptation by Lloyd (1958) of the Haldane gas analyzer (Haldane & Graham, 1935), and carbon dioxide content of the air was measured. The rate of respiration in mg CO_2 per kg fresh weight per hour was calculated by the formula:

$$\frac{\%\,CO_2 \times 0.01 \times (4250 - \text{volume of tubers in ml}) \times 1.85}{\text{numbers of hours} \times \text{kg of tubers}}$$

The factor 1.85 in the formula is to convert the milliliters carbon dioxide into milligrams. The volume of tubers was determined by subtracting the weight of the tubers in water from the weight in air (both in g). This was repeatedly done during the storage season after respiration measurements.

1972. Preliminary experiments of a methodological nature

1. At what concentration does carbon dioxide in the bottles start to have an inhibiting effect on the rate of respiration to such a degree that the experimental results would be affected seriously? In order to investigate this, a sample of tubers of the cultivar Katahdin was placed in a bottle, the bottle was closed and kept at 20 °C. The percentage of carbon dioxide was determined in air samples taken periodically from the bottle, and in the calculations the necessary corrections were applied for the replacement of bottle air by laboratory air. The results are represented by line a in Fig. 1. If all data points are considered, the linear as well as the quadratic influences are significant, which means that there was a certain degree of inhibition in the rate of respiration. If only the first three data points are considered, it seems that the increase in carbon dioxide content was fairly linear. However, this cannot be proved statistically because of the small number of observations. Therefore, the experiment was repeated at a later date with one sample of each of six varieties. These samples had been stored at 15°C and the experiment was done at the same temperature. The tubers showed sprouts of a length of 2 to 5 cm. The results, averaged over all varieties, are represented by line b in Fig. 1. In this case the quadratic component of the time effect was non-significant.

On the basis of these results, it seems fair to assume that is is safe to allow the carbon dioxide concentration to accumulate until reaching 3 to 4%. Therefore, in the following experiments, the duration of the carbon dioxide accumulation was chosen in such a way that the concentration stayed below 3%. Usually, however, the concentration did not exceed 2.5%.

Fig. 1. Accumulation of carbon dioxide in closed bottles filled with potato tubers. Line a: results for cv. Katahdin stored at 20°C; Line b: average results for six cultivars stored at 15°C.

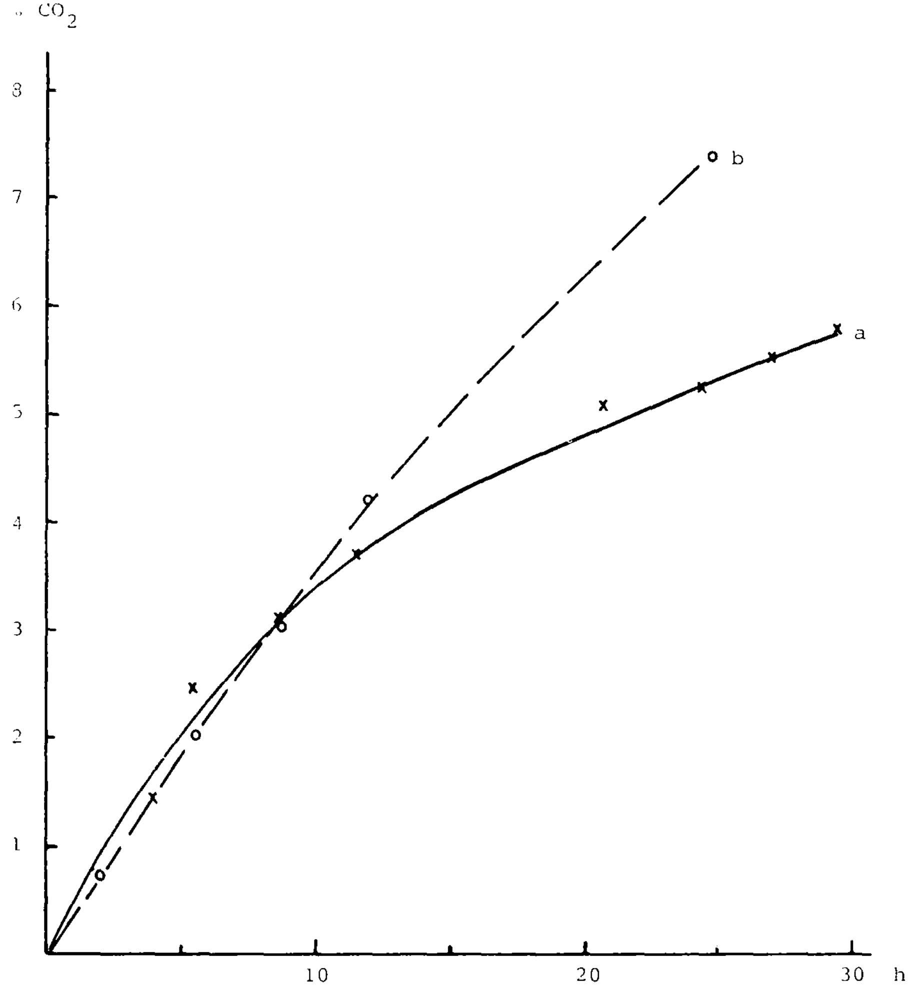


Fig. 1. Anhäufung von Kohlendioxid in geschlossenen, mit Kartoffeln gefüllten, Behältern. a: Ergebnisse der Sorte Katahdin, gelagert bei 20°C; b: Mittelwerte der Ergebnisse von 6 Sorten, gelagert bei 15°C.

Fig. 1. Accumulation de gaz carbonique dans des bouteilles fermées contenant des tubercules. a: variété Katahdin conservée à 20°C; b: moyenne de 6 variétés conservées à 15°C.

2. Is the reported influence of tuber size on the rate of respiration of such a magnitude that the tuber size would have to be taken into consideration during sampling if the range sizes would be much smaller than employed by Meinl (1967) and Weber-Dahlmann (1957)?

This was studied in eleven varieties. The number of small tubers in each variety ranged from 21 to 29 (average tuber weight 70–100 g), medium tubers from 18 to 22 (100–130 g) and large tubers from 9 to 13 (160–250 g). The storage temperature was 7.5°C.

The average rate of respiration at 7.5°C of the small tubers of the varieties was 1.86, of the medium tubers 1.91 and of the large tubers 1.83 mg CO_2 kg^{-1} h^{-1}. The differences were statistically non-significant. There was no significant interaction between size and storage duration. It seems that under our conditions the tubers for a sample can be chosen at random, at least in the range of tuber sizes used in this case.

1972 Main experiments

Materials and methods

Cultivars and storage temperatures. The number of available tubers did not permit testing of all cultivars at all temperatures. Six cultivars were tested at 2.5, 22 at 5.0, 30 at 7.5, 13 at 10.0, 10 at 12.5 and 9 at 15.0°C. Storage started 12 October 1972, after the tubers had been cured at 15–20°C since harvest (14 September).
Size of samples. The weights of the samples varied from 1950 tot 2100 g, the number of tubers from 18 to 22.
Dates of measurements. Since there were 36 bottles available for more than 150 samples, the measurements were spread out over five days during each period of measurement. These periods wer 20–24 October (after 2 weeks of storage), 22–26 January (after 15 weeks), 4–8 March (21 weeks) and 6–9 May (30 weeks). Since most samples at 12.5 and 15.0°C sprouted strongly, these were discarded after the measurements in January.

Results: effects of cultivar, storage temperature and storage duration

Tubers of 21 cultivars were available, but there were only enough to store them at one temperature (7.5°C). Table 1 gives the rates of respiration of the commercial cultivars only. The unnamed breeding lines covered the same range of rates.

The rate of respiration increased slowly in the beginning of the storage season and somewhat faster later on. The increase was mainly linear ($F = 379.5$, d.f. 1:60), although the quadratic component was also highly significant ($F = 52.4$, d.f. 1:60).

The highly significant interaction between storage duration and cultivar, apparent in the table, was in part due to some irregularities in the results for cv. Hudson (October being much higher and January being much lower than the average figures) and in part by the increase in respiration during the storage season being faster than the average for some cultivars (e.g. Caribou and Superior) and slower for others (e.g. Katahdin). In most cultivars, however, the increase in rate of respiration ran reasonably parallel to the average. This increase did not show any relationship to the degree of sprouting which at that temperature was very slight. At the last date of measure-

Table 1. Rate of respiration of potato tubers stored at 7.5°C in 1972 (in mg CO_2 kg^{-1} h^{-1}).

Cultivar[1]	Dates of measurement[2]				
	20-24 Oct.	22-26 Jan.	4-8 Mar.	6-9 May	Average
Caribou	1.60	2.10	2.29	2.75	2.18
Alamo	1.85	1.83	2.00	2.63	2.05
Cascade	1.62	1.90	2.03	2.11	1.91
Hudson	2.02	1.42	1.80	2.17	1.85
Wauseon	1.63	1.68	1.87	1.98	1.79
Raritan	1.64	1.73	1.77	1.94	1.77
Superior	1.42	1.47	1.75	2.37	1.75
Katahdin	1.69	1.59	1.58	1.76	1.65
Abnaki	1.30	1.30	1.48	1.93	1.50
Average[4]	1.62	1.67	1.81	2.10	
Average of 21 cultivars[3]	1.67	1.69	1.85	2.13	
Least significant difference[5]					0.19

[1] *Sorte – Variété*; [2] *Datum der Messung – Dates des mesures*; [3] *Mittelwert von 21 Sorten – Moyenne de 21 variétés*; [4] *Mittelwert – Moyenne*; [5] *Geringste signifikante Differenz – Plus petite différence significative*

Tabelle 1. Atmung von Kartoffelknollen gelagert bei 7.5°C (in mg CO_2 kg^{-1} h^{-1}).
Tableau 1. Intensité respiratoire de tubercules conservés à 7.5°C (en mg CO_1 kg^{-1} h^{-1}).

ment the average sprout length for cultivars with the shortest dormant period was not more than approximately 1 cm.

Tubers of 13 cultivars were stored at 5.0, 7.5 and 10.0°C and their rates of respiration were measured four times. Table 2 gives the results for the commercial cultivars. Although the influence of cultivar was highly significant, the actual differences among the commercial cultivars in Table 2 were, according to the Keuls-Hartley (Keuls, 1952; Snedecor, 1956) sequential test, not significant. The significant differences were among some breeding lines which represented the extremes in rate of respiration. The interaction between cultivar and storage duration was significant at $P < 0.05$. The lower portion of Table 2 shows that the October result for cv. Hudson is an important factor in this (there were two breeding lines with a relatively high rate of respiration in October, comparable to Hudson). Also, the March result for cv. Reliance contributed to the interaction. Of more importance is the highly significant interaction between storage temperature and storage duration. This interaction has been caused primarily by the very high rate of respiration of the 5°C samples in October, and to a lesser degree by the relatively low rate of respiration of the 10°C samples in the same month. Since the samples which were measured in October had been placed at the various temperatures 10 to 12 days previously, it is

Table 2. Rate of respiration of potato tubers in storage in 1972 (in mg CO_2 kg^{-1} h^{-1}).

Cultivar[1]	Dates of measurement[2]				
	20-24 Oct.	22-26 Jan.	4-8 Mar.	6-9 May	Average
Storage temperature[4] 5.0°C					
Hudson	5.02	1.83	1.77	1.57	2.55
Cascade	3.80	2.29	1.86	1.54	2.37
Reliance	3.44	1.53	1.86	1.49	2.08
Alamo	3.35	1.39	1.72	1.47	1.98
Katahdin	3.49	2.00	1.66	1.41	2.14
Average of 13 cultivars[3]	4.00	1.77	1.72	1.73	2.25
Storage temperature 7.5°C					
Hudson	2.21	1.48	1.84	2.40	1.98
Cascade	1.60	1.95	2.04	2.18	1.94
Reliance	1.21	1.92	2.97	2.19	2.07
Alamo	1.91	1.79	2.06	2.52	2.07
Katahdin	1.66	1.58	1.63	1.78	1.66
Average of 13 cultivars	1.74	1.70	1.90	2.05	1.85
Storage temperature 10.0°C					
Hudson	2.37	2.24	2.29	1.97	2.27
Cascade	1.84	2.57	2.33	2.24	2.25
Reliance	1.34	2.37	2.34	2.86	2.23
Alamo	1.79	2.27	2.31	1.74	2.03
Katahdin	1.49	2.02	2.01	2.30	1.96
Average of 13 cultivars	1.76	2.41	2.34	2.27	2.20
Average of three temperatures[5]					
Hudson	3.20	1.85	1.97	1.89	2.25
Cascade	2.41	2.27	2.08	1.99	2.19
Reliance	2.00	1.94	2.39	2.18	2.13
Alamo	2.35	1.82	2.03	1.91	2.03
Katahdin	2.21	1.87	1.77	1.83	1.92
Average of 13 cultivars	2.50	1.96	1.99	1.94	2.10

[1], [2], [3] *Siehe Tabelle 1 – Voir tableau 1*; [4] *Lagerungstemperatur – Température de conservation*; [5] *Mittelwert von 3 Temperaturen – Moyenne des trois températures*

Tabelle 2. Atmung von Kartoffelknollen während der Lagerung (in mg CO_2 kg^{-1} h^{-1}).
Tableau 2. Intensité respiratoire de tubercules en cours de conservation (en mg CO_2 kg^{-1} h^{-1}).

possible that the high rate of respiration was an after-effect of the temperature change from 15–20°C to 5°C rather than the effect of the storage temperature itself, although over the whole period the rate of respiration at 5.0°C was significantly higher than at 7.5°C. Table 2 shows that the minimum rate of respiration was at 7.5°C till January, but at 5°C thereafter.

Tubers of 6 cultivars were stored at all six temperatures. The influences of storage temperatures and storage duration on the rate of respiration are shown in Fig. 2. Because of sprouting, the samples stored at 12.5 and 15.0°C were discarded after the January measurement. It is evident that sprouting had a considerable effect on the rate of respiration as early as January. At that time the sprouts of the samples stored at 12.5°C varied from 0.5 to 2.0 cm in length, while those stored at 15.0°C ranged from 2 to 10 cm.

Taken over the whole storage period, the rate of respiration of the samples stored at 7.5°C was significantly lower than the rate of the others. However, the minimum rate of respiration during the later part of the storage period was 5.0°C instead of at 7.5°C. The rates of the samples stored at 2.5°C were significantly the highest.

Fig. 2. The rate of respiration of potato tubers stored at six temperatures in 1972. Results are averages for six cultivars.

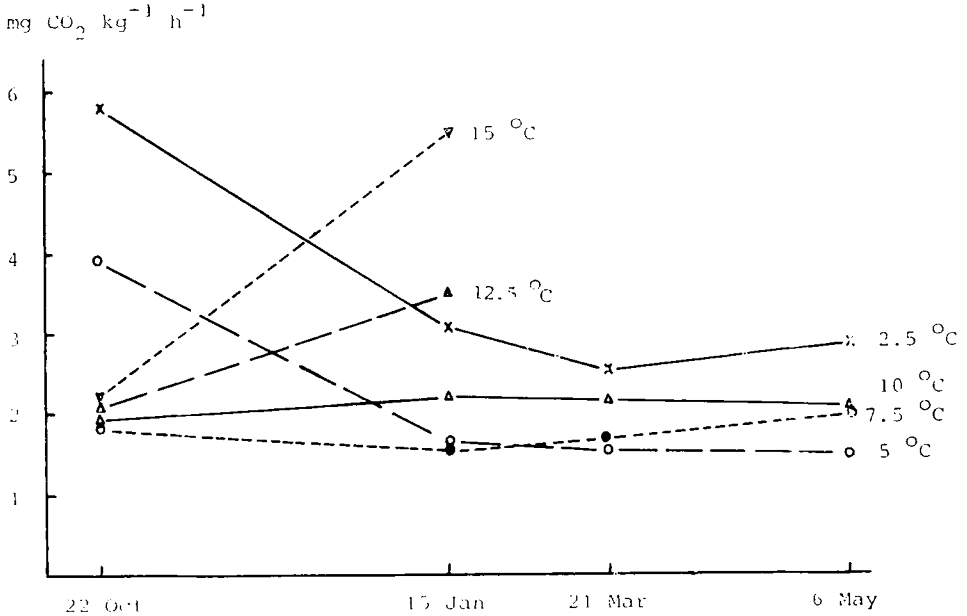
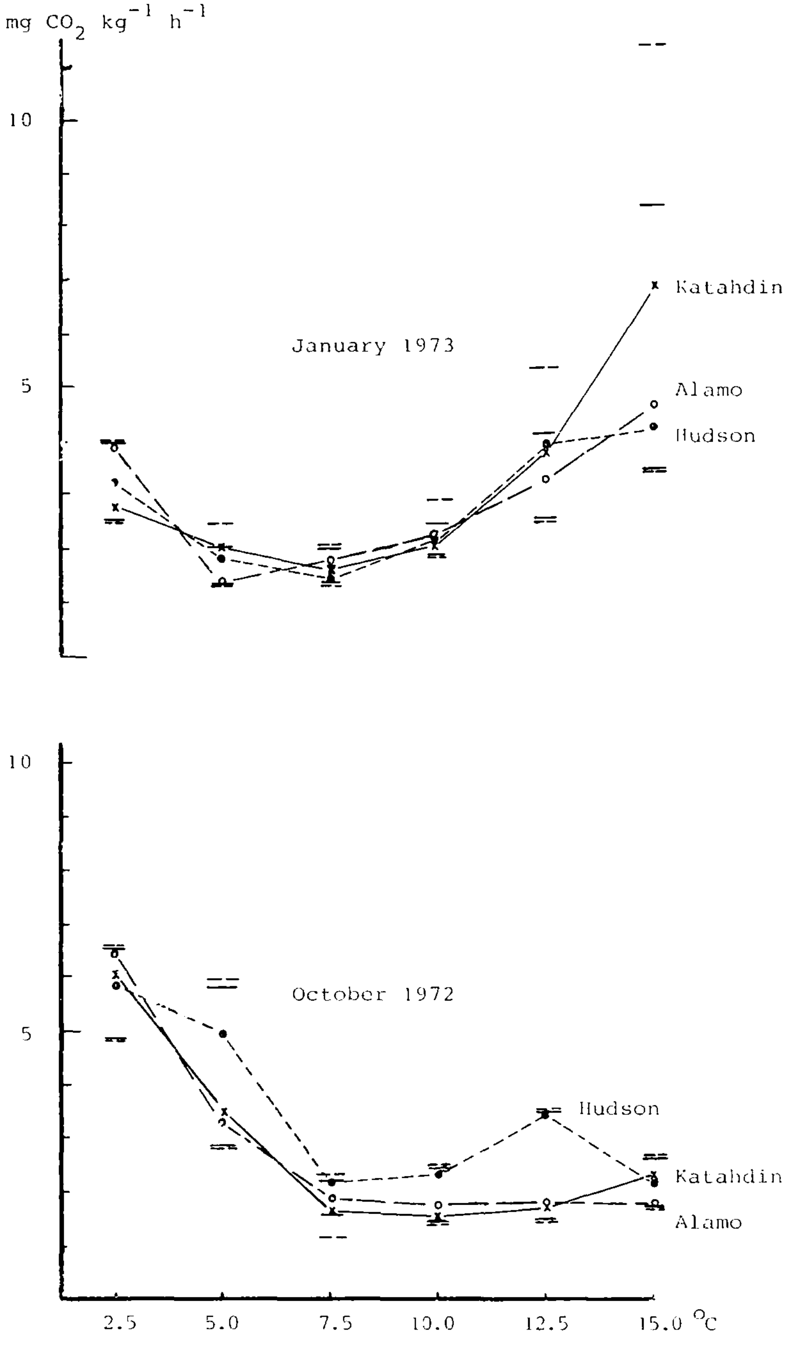


Fig. 2. Atmungsrate von bei 6 Temperaturen gelagerten Kartoffelknollen im Jahr 1972. Die Ergebnisse sind Mittelwerte von 6 Sorten.

Fig. 2. Intensité respiratoire de tubercules conservés à 6 températures en 1972 moyenne de 6 variétés.


mg CO2 kg-1 h-1
10
5
January 1973
Katahdin
Alamo
Hudson
10
5
October 1972
Hudson
Katahdin
Alamo
2.5
5.0
7.5
10.0
12.5
15.0 °C

The relationship between the six temperatures and the rate of respiration is shown in greater detail in Fig. 3. The average results for the three commercial cultivars which were stored at all six temperatures are given, as well as the ranges covered by the six cultivars at all temperatures. Also given are the ranges for all cultivars present at each temperature. It is clear that the spread at each temperature was relatively small in October, but much greater in January, particularly at the higher temperatures. The main reason for this is the difference in degree of sprouting between cultivars.

It is also evident that the relationship between temperature and rate of respiration in October was quite different from this relationship in January. At the former date the highest rate of respiration was found at the lowest temperatures. In January the respiration rate was greater at the higher temperatures.

1973 Experiment

Materials and methods

Cultivars and storage temperatures. Tubers of the cultivars Cascade, Green Mountain, Hudson, Katahdin, Reliance and Russet Burbank, all grown on the Long Island Vegetable Research Farm, were stored in four replications at 2.5, 5.0, 7.5, 10.0, 12.5, and 15.0°C. Storage started 11–14 November, after curing at 15–20°C since harvest (second half of September).
Size of samples. The weights of the samples varied from 2050 to 2250 g. The numbers of tubers per sample were: Cascade 21, Green Mountain 17, Hudson 20, Katahdin 19, Reliance 16 and Russet Burbank 18.
Dates of measurement. Periods of measurements were 18–20 November (after one week storage), 16–19 December (5 weeks), 20–23 January (10 weeks), 17–20 February (14 weeks), 17–20 March (18 weeks). After the last measurement of respiration, the samples stored at 12.5 and 15°C were discarded because of sprouting. The rate of respiration of the other samples was again determined on 21–23 April (23 weeks) and 28–30 July (37 weeks).

Fig. 3. Relationship between storage temperature and rate of respiration at two dates during the storage period 1972.
——: range of the same six cultivars stored at each temperature; – –: range of all cultivars present at each temperature.
Fig. 3. Beziehung zwischen Lagerungstemperatur und Atmung an 2 Terminen während der Lagerperiode 1972.
——: Schwankungsbereich der selben 6 Sorten, die bei jeder Temperatur lagerten; – –: Schwankungsbereich aller Sorten, die bei jeder Temperatur vorhanden waren.
Fig. 3. Relation entre température stockage et intensité respiratoire à deux dates durant la période de conservation 1972.
——: gamme des six variétés conservées à chaque température; – –: gamme de toutes les variétés présentes à chaque température.

Table 3. Rate of respiration of potatoes in storage in 1973 (in mg CO_2 kg^{-1} h^{-1}). Main effects of the analysis of variance.

Cultivars		Storage temperatures[4] (°C)		Dates of measurement[2]	
Cascade	2.60	2.5	2.07	18-20 November	2.25
Green Mountain	2.14	5.0	1.93	16-19 December	1.72
Hudson	2.43	7.5	1.45	20-23 January	2.02
Katahdin	2.26	10.0	1.67	17-20 February	2.40
Reliance	2.41	12.5	2.40	17-20 March	3.03
Russet Burbank	1.87	15.0	4.19		
LSD[5]	0.13		0.13		0.05

[1], [2], [5] *Siehe Tabelle 1 – Voir tableau 1;* [4] *Siehe Tabelle 2 – Voir tableau 2*

Tabelle 3. Atmung von Kartoffelknollen während der Lagerung (in mg CO_2 kg^{-1} h^{-1}). Ergebnisse der Varianzanalyse.
Tableau 3. Intensité respiratoire de tubercules en cours de conservation (en mg CO_2 kg^{-1} h^{-1}). Analyse de variance.

Results

An analysis of variance was carried out with the results of the five dates of measurement when all samples were still present. All three main effects on the rate of respiration (cultivar, storage temperature and storage duration) were highly significant. Although the fact that both first and second order interactions were highly significant makes a simple explanation of the results impossible, some general conclusions can be drawn (Table 3).

The first conclusion is that the rate of respiration is definitely a characteristic of the cultivar. Over the period from November till March, only two differences in rate of respiration were non-significant, those between Green Mountain and Katahdin and between Hudson and Reliance.

The second is that, as in 1972, there was a minimum rate of respiration at 7.5°C.

The third is that, at normal storage temperatures, the rate of respiration changed slowly over the course of the storage period. A decrease in respiration at the start of the storage season led to a minimum in December, after which the rate of respiration increased slowly. At higher storage temperatures the rate of respiration increased considerably after December. There are variations on these general themes which are mainly caused by specific cultivar reactions on the many different combinations of storage temperature and storage duration.

Although the rate of respiration is a characteristic of the cultivar, this does not mean that differences between cultivars were qualitatively and quantitatively constant at all times and at all storage temperatures. This certainly is not the case, but on the whole, the order of cultivars was more or less the same at all temperatures. In

Fig. 4. Rate of respiration during the storage period 1973 of potato tubers of the cv. Katahdin, stored at six temperatures.

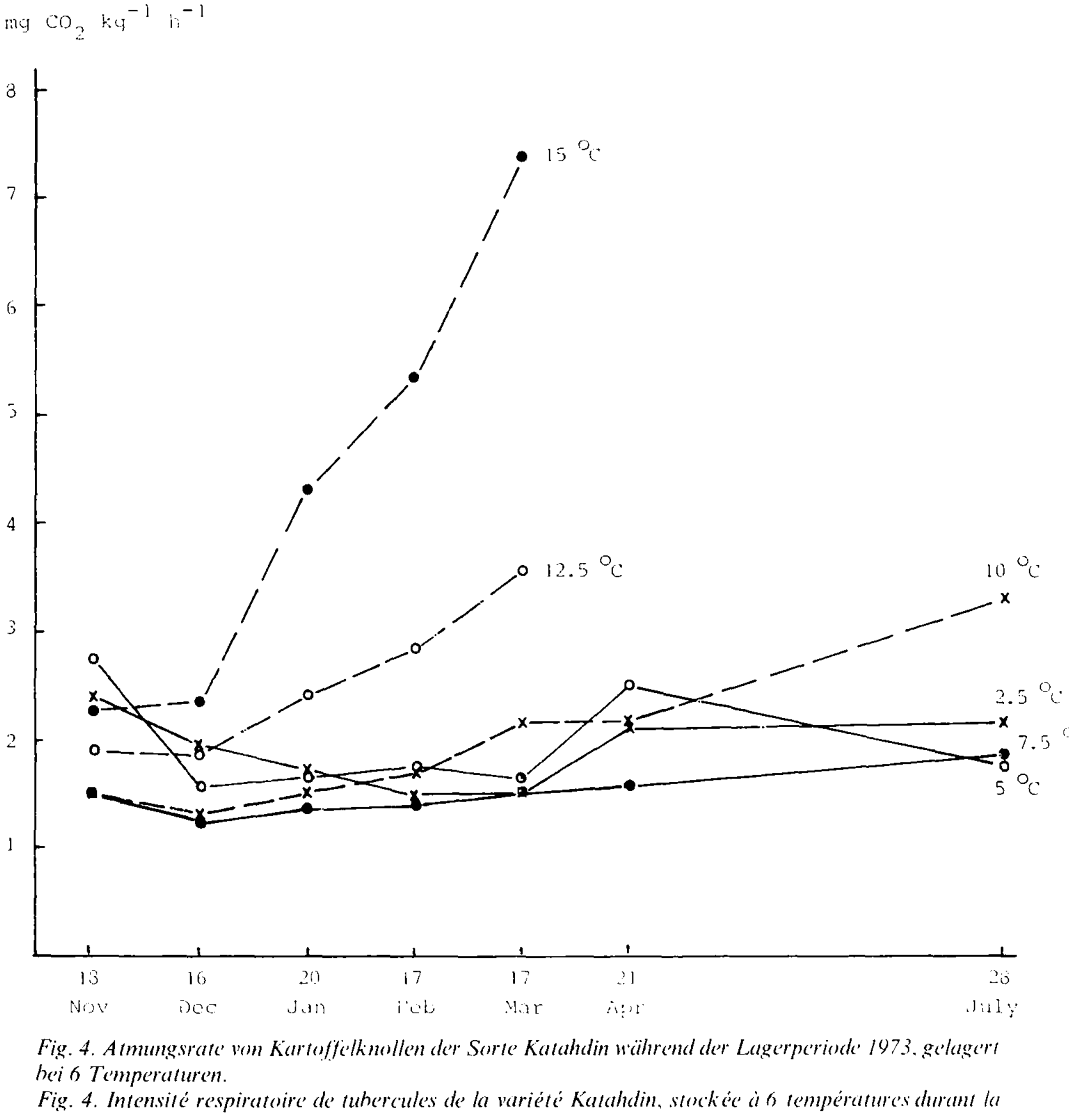


Fig. 4. Atmungsrate von Kartoffelknollen der Sorte Katahdin während der Lagerperiode 1973, gelagert bei 6 Temperaturen.

Fig. 4. Intensité respiratoire de tubercules de la variété Katahdin, stockée à 6 températures durant la période de conservation 1973.

Fig. 5. Rate of respiration during the storage period 1973 of potato tubers of the cv. Russet Burbank stored at six temperatures.

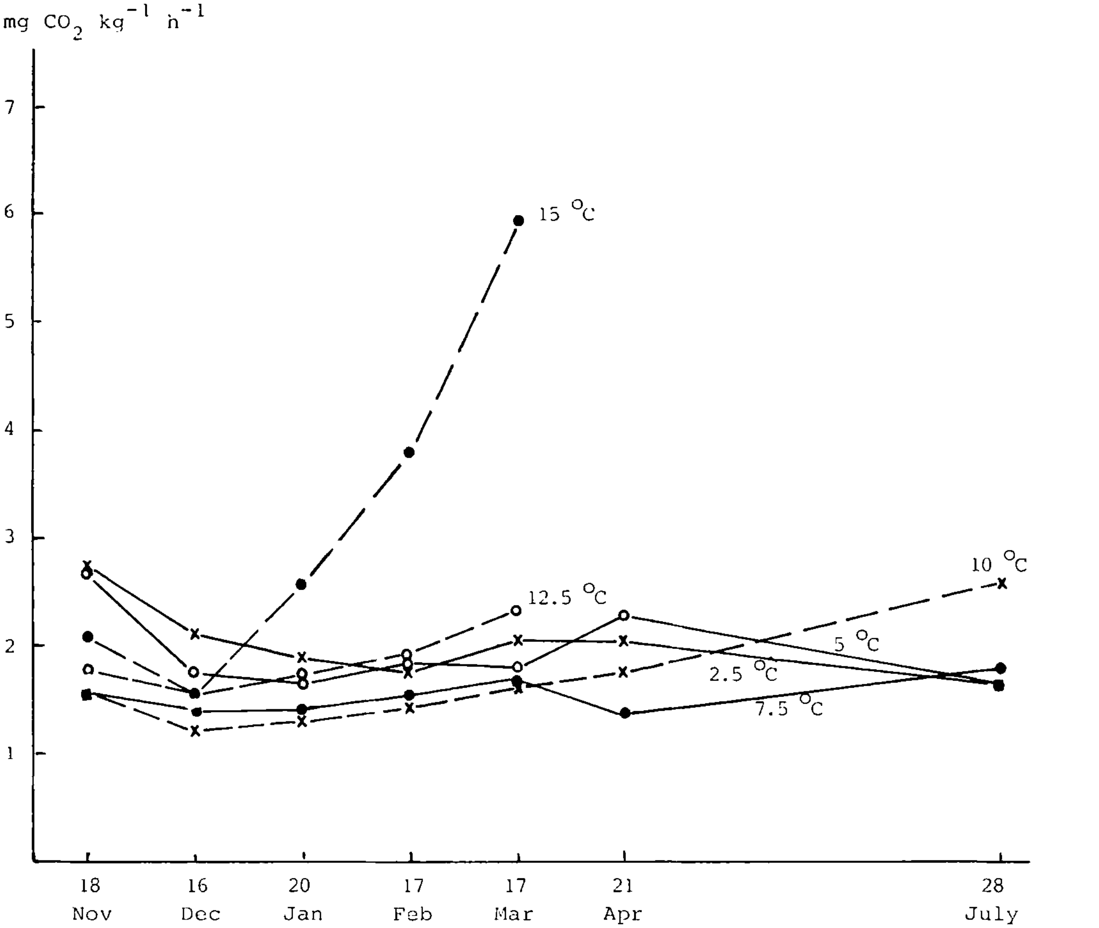


Fig. 5. Atmungsrate von Kartoffelknollen der Sorte Russet Burbank während der Lagerperiode 1973, gelagert bei 6 Temperaturen.
Fig. 5. Intensité respiratoire de tubercules de la variété Russet Burbank, stockée à 6 températures durant la période de conservation 1973.

Fig. 6. Rate of respiration during the storage period 1973 of potato tubers of six cultivars stored at three temperatures and the dates on which the average sprout length was 0.5 cm (→) and 1.0 cm (- - →).
Fig. 6. Atmung von Kartoffelknollen 6 verschiedener Sorten während der Lagerperiode 1973, die bei 3 Temperaturen gelagert waren und die Termine, an denen die durchschnittliche Keimlänge 0,5 cm (→) und 1 cm (- - →) betrug.
Fig. 6. Intensité respiratoire de tubercules de 6 variétés stockées à trois températures, à des dates où la longueur moyenne des germes est de 0,5 cm (→) et de 1,0 cm (- - →) (conservation 1973).

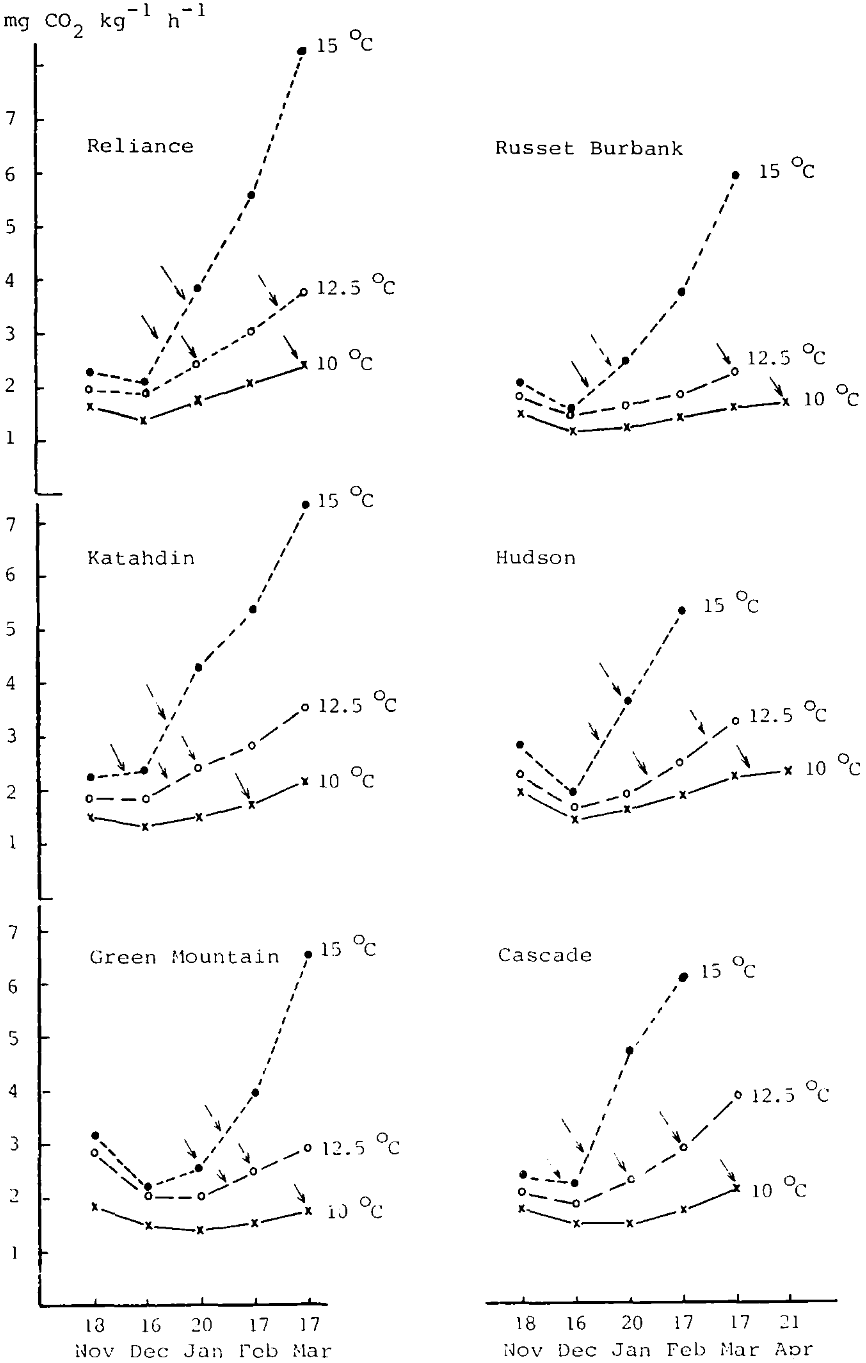

mg CO2 kg-1 h-1
Reliance
Russet Burbank
Katahdin
Hudson
Green Mountain
Cascade
15 °C
12.5 °C
10 °C
1
2
3
4
5
6
7
18 Nov
16 Dec
20 Jan
17 Feb
17 Mar
21 Apr

Fig. 7. Relationship between storage temperature and rate of respiration at various dates during the storage period 1973 (Average of six cultivars).

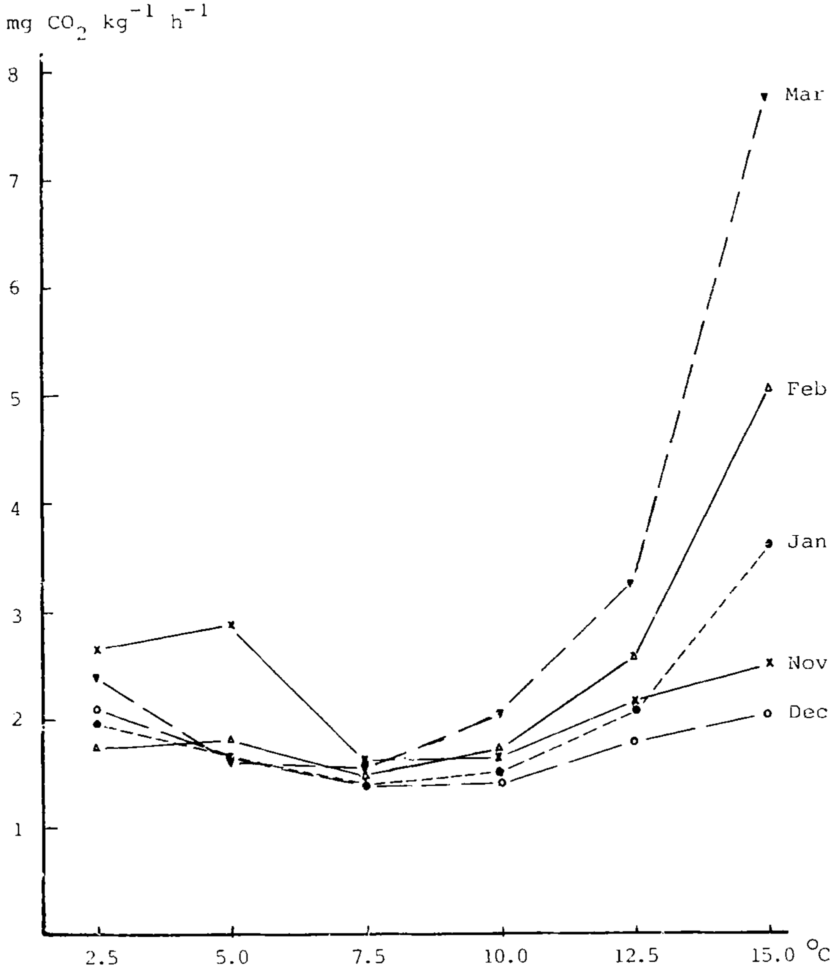


Fig. 7. Beziehung zwischen der Lagertemperatur und der Atmung an verschiedenen Terminen während der Lagerperiode 1973 (Mittelwerte von 6 Sorten).

Fig. 7. Relation entre température de stockage et intensité respiratoire à différentes dates durant la conservation de 1973 (moyenne de 6 variétés).

Fig. 4 and 5 the results for cvs. Katahdin and Russet Burbank are shown.

The increase in rate of respiration noted at higher storage temperatures after December was undoubtedly due, at least in part, to sprouting.

It seems, however, that the sprouts have to exceed a certain length for the influence on the rate of respiration to become measurable. This is shown in Fig. 6, in which arrows indicate the dates at which the average sprout lengths were 0.5 cm (at 10.0,

Table 4. Range in rate of respiration (in mg CO_2 $kg^{-1}h^{-1}$) in January of potato tubers stored at six temperatures.

Temperature (°C)	1972	1973
2.5	2.5– 3.0	1.5–2.5
5.0	1.5– 2.5	1.5–2.0
7.5	1.5– 2.0	1.0–1.5
10.0	2.0– 3.0	1.0–2.0
12.5	3.0– 5.5	1.5–2.5
15.0	5.0–12.5	2.5–5.5

Tabelle 4. Schwankungsbereich der Atmung (in mg CO_2 $kg^{-1}h^{-1}$) im Januar von Kartoffelknollen gelagert bei sechs Temperaturen.
Tableau 4. Gamme de l'intensité respiratoire (en mg CO_2 $kg^{-1}h^{-1}$) en Janvier de tubercules de la pomme de terre stockés à six températures.

12.5 and 15.0°C) or 1.0 cm (12.5 and 15.0°C only).

The relationship between rate of respiration and temperature at various stages during the storage period has been presented in Fig. 7. A minimum in respiration was reached in December, except for the samples at 2.5°C, which showed a continuous decline in rate of respiration till February. The rates of respiration at 2.5 and 5.0°C were much higher at the start of the storage period than later, confirming the results of 1972 (Fig. 3), but the initial values were not as high. Apart from this drop, the rates of respiration remained fairly constant for a considerable period at 5.0 and at 7.5°C and somewhat less so at 2.5 and 10.0°C.

Discussion

Considering the results of these experiments in relation to some points made in the previous publication in this series (Schippers, 1977), the following questions must be answered.

1. Is there a 'seasonal drift' in metabolism during the storage period as Huelin and Barker (1939) have reported and which is also apparent in Burton's (1974) results, or is the rate of respiration very nearly constant as has been suggested by others (Kimbrough, 1925, Barker, 1938, Singh & Mathur, 1938)? The results show that the rate of respiration during the main storage period was fairly constant at certain temperatures. Initially, when sudden changes in temperature might have had an after effect on the rate of respiration, respiration at the lower temperatures was higher than it was at the higher temperatures. However, the rate of respiration at the lower temperatures decreased to a more or less constant rate, whereas the rate of respiration at the higher temperatures increased clearly because of the sprouting of the tubers. The higher the storage temperature, the more one can refer to a 'seasonal drift'. In general, it seems that a minimum in respiration was reached in December, except for the tubers at 2.5°C which had a minimum in February. However, the constancy of the rate of respiration is also dependent on variety characteristics.

2. What is the influence of temperature on the rate of respiration in comparison to previous findings? It is difficult to establish a fixed relationship between the rate of respiration and the storage temperature since at some temperatures the rate of respiration was rather constant, whereas at others it was not. Therefore, a comparison with previously reported results in literature is difficult. Assuming that the January results give a good indication of the rate of respiration during the storage period, the ranges in rate of respiration found in 1972 and 1973 for that month have been tabulated in Table 4. In general, our results are lower than reported in most of the literature (see Schippers (1977, Table 1) for a summary of these data). It is clear that the season had a certain influence, while another important variable was the cultivar.
3. Is there a relationship between the rate of respiration during storage and the earliness of the cultivar as has been suggested by Schulz (1926/27) and by Schander et al. (1931/32 a, b)? There is not much evidence for the assumption that late cultivars have a higher rate of respiration than earlier ones. In 1972 the rates of respiration of the early commercial cvs. in March (average of the results for 5 and 7.5°C) were 1.77–1.84–1.89, of the mid-season cultivars 1.56–1.63–1.78–1.85–2.00–2.42 and of the only late cultivars 1.81 mg CO_2 kg^{-1} h^{-1}. In 1973 these results (averages of six temperatures in March) were: midseason 2.95–3.34–3.71 and late 2.35–2.61–3.23 mg CO_2 kg^{-1} h^{-1}. None of the differences were significant according to Wilcoxon's test (Wilcoxon, 1945; Wabeke & van Eden, 1955).

There was no clear relationship between the rate of respiration during dormancy and the length of the dormant period.

Zusammenfassung

Atmung von Kartoffelknollen während der Lagerung. 2. Ergebnisse der Versuche in den Jahren 1972 und 1973

Die Atmungsrate von Kartoffeln, die bei verschiedenen Temperaturen gelagert waren, wurde gemessen, indem Kartoffelproben von ungefähr 2 kg mehrere Stunden in verschlossenen Weithalsflaschen lagen und der CO_2-Gehalt (in %) in einer Luftprobe mit einem Lloyd Gasanalysator bestimmt wurde. Wenn die Versuchszeit so gewählt wurde, dass die CO_2-Konzentration 3% nicht überschritt, hatte es keinen hemmenden Einfluss auf die Atmungsrate (Abbildung 1).

Im bereich des Knollengewichtes, (70–250 g), der in einem Vorversuch gewählt wurde, zeigte die Knollengrösse keine Beziehung zur Atmungsrate. In den Hauptversuchen war der Bereich viel kleiner.

1972 wurden die Atmungsraten von vielen Handelssorten und Zuchstämmen im Oktober, Januar, März und Mai während der Lagerung bei 2,5, 5,0, 7,5, 10,0, 12,5 und 15°C gemessen, mit Ausnahme der Proben, die bei 12,5 und 15°C gelagert waren und die nach der Messung im Januar wegen Keimung verworfen wurden. Tabelle 1 zeigt signifikante Unterschiede in der Atmung zwischen den bei 7,5°C gelagerten Sorten. Eine hoch signifikante Interaktion bestand zwischen der Lagertemperatur (5,0, 7,5, 10°C) und der Lagerungsdauer, verursacht durch eine sehr hohe Atmungsrate bei 5,0°C im Oktober (Tabelle 2).

Abb. 2 zeigt den beträchtlichen Einfluss der Keimung auf die Atmung während der Lagerung bei 12,5 und 15°C. Die Beziehung zwischen der Temperatur und der Atmungsrate im Januar 1973 war sehr verscheiden von der im Oktober 1972 (Abb. 3).

1973 wurden bei gleichen Lagertemperaturen nur 6 Handelssorten verwendet. Die Atmungsraten wurden von November bis März monatlich gemessen. Im April und Juni wurden nur die bei 10°C und tiefer gelagerten Proben gemessen.

Tabelle 3 zeigt die Varianzanalyse der Ergebnisse von November bis März. Die Veränderungen, die aus Tabelle 3 ersichtlich sind, wurden hauptsächlich durch sortenspezifische Reaktionen auf die vielen unterschiedlichen Kombinationen zwischen Lagertemperatur und -dauer verursacht. Die Abb. 4 und 5 zeigen die Ergebnisse für die Sorten Katahdin und Russet Burbank.

Um eine durch die Keimung verursachte Steigerung der Atmung messen zu können, mussen die Keime 1 cm oder länger sein (Abb. 6). Die Beziehung zwischen der Lagertemperatur und der Atmungsrate änderte sich in der Lagerperiode kontinuierlich, vor allem bei Temperaturen von 10°C oder höher (Abb. 7).

Wie 1972 lag das Minimum der Atmungsrate bei 7,5°C. Im Dezember war bei fast allen Temperaturen die geringste Atmungsrate erreicht, bei 2,5°C jedoch erst einen oder 2 Monate später. Keine Beziehung ergab sich zwischen der Atmung und der Frühreife einer Sorte oder der Länge ihrer Keimruhe.

Résumé

L'intensité respiratoire des tubercules pendant la conservation. 2. Résultats des expérimentations 1972–1973

L'intensité respiratoire des tubercules conservés à différentes températures a été mesurée sur des échantillons de 2 kg environ, enfermés pendant plusieurs heures dans des bouteilles à large goulot, en déterminant le pourcentage de gaz carbonique de l'air à l'aide d'un analyseur de gaz Lloyd. Si la durée de l'expérience est telle que la concentration en gaz carbonique ne dépasse pas 3%, il n'y a pas d'effet inhibiteur sur l'intensité respiratoire (fig. 1).

Au cours d'une expérience préliminaire effectuée sur une gamme de poids de tubercules (70 à 250 g), aucune relation entre le calibre et l'intensité respiratoire n'a pu être mise en évidence. Dans l'expérimentation principale, la gamme de poids était beaucoup plus petite.

En 1972, l'intensité respiratoire de nombreuses variétés a été mesurée en octobre, janvier, mars et mai après une conservation à 2,5°C, 5,0°C, 7,5°C, 10,0°C, 12,5°C, et 15,0°C, à l'exception des échantillons stockés à 12,5°C et 15,0°C qui avaient été éliminés après la mesure de janvier à cause de leur germination.

Des différences significatives ont été enregistrées entre les variétés stockées à 7,5°C (tableau 1).

Une interaction hautement significative a été constatée entre la température (5,0, 7,5 et 10,0°C) et la durée de conservation, provoqué principalement par une intensité respiratoire très élevée à 5,0°C en octobre (tableau 2).

A 12,5 et 15,0°C la germination a un effet considérable sur l'intensité respiratoire. La relation entre température et intensité respiratoire en janvier 1973 était très différente de celle d'octobre 1972 (figure 3).

En 1973, les mêmes températures furent étudiées mais avec seulement 6 variétés. L'intensité respiratoire a été déterminée chaque mois, de novembre à mars. Les mesures ont aussi été effectuées en avril et juillet, mais uniquement sur des échantillons conservées à 10°C et moins de 10°C. L'analyse de variance des résultats obtenus de novembre à mars est présentée dans le tableau 3. Les variations enregistrées sont dûes principalement à la réaction spécifique des variétés aux différentes combinaisons température-durée de conservation.

Les figures 4 et 5 donnent les résultats obtenus avec les variétés Katahdin et Russet Burbank.

Les germes doivent avoir 1 cm de long pour qu'une élévation de l'intensité respiratoire provoquée par la germination soit mesurable (figure 6).

La relation entre température et durée de conservation évolue continuellement au cours du stockage particulièrement à 10°C et au-dessus de 10°C (figure 7).

Comme en 1972, une intensité respiratoire minimale a été constatée à 7,5°C. Les intensités

respiratoires les plus basses ont été observées en décembre, sauf pour la température de 2,5 C (un ou deux mois plus tard).

Aucune relation n'a été trouvée entre l'intensité respiratoire et la précocité ou la durée du repos végétatif des variétés.

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