Respiration Rate and Changes in Composition of Volatiles during Short-Term Storage of Minimally Processed Root Vegetables

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Abstract

Preliminary results on aroma profiles (GC-MS) related to storage conditions (temperature, time and packaging atmosphere) are presented. The vegetables used in the experiments were rutabaga, carrot and turnip, which were peeled and cut before packaging, and stored at two different temperatures. O_2 and CO_2 concentrations in the packaging atmosphere were measured during the storage period to calculate the respiration rate of the produce. Cubed carrot showed a higher respiration rate than cubed turnip and rutabaga. Samples for analysis of volatiles were taken after 0 and 7 or 10 days. This type of analysis could be used as a complement to sensory analysis.

INTRODUCTION

"Improved quality of Norwegian fruits, potatoes and vegetables after long- and short-term storage" is a newly started, Norwegian project. The main objective of the project is to increase the knowledge on management of long- and short-term storage of Norwegian grown fruits, potatoes and vegetables that will underpin an improved product quality and increased end product diversity. This will hopefully increase the consumption and production of vegetables in Norway.

The project is divided into two scientific parts. The first will mainly focus on long-term storage of potatoes, apples and carrots. The aim is to develop methods for prediction of storage performance based on pre-harvest factors. The second part will focus on packaging and short-term storage of minimally processed Norwegian grown vegetables, preferably vegetables that can easily be stored (root vegetables). The aim is to establish a knowledge base for the determination of which vegetables are most suitable for various end uses. One of the objectives is to find vegetables that can be used together as a "ready-to-eat" or "ready-to-cook" product accepted by the consumer.

Lowering the temperature and modifying the surrounding atmosphere during storage are two methods commonly used to reduce respiration rate and physiological changes of fresh produce. (Fonseca et al. 2002). To create a modified atmosphere beneficial for improving shelf life of minimally processed vegetables, respiration rate is an important consideration. Calculation of respiration rate can be based on O_2 consumption and/or CO_2 production (Zhang et al. 2011).

Volatile compounds related to sensory analysis have the potential of being used as quality markers in minimally processed vegetable products (Lonchamp et al. 2009).

The first objective of this preliminary study was to measure the respiration rate for rutabaga, turnip and carrot, and how these vegetables differ in respiration with a view to combining them as a minimally processed "ready-to-eat" or "ready-to-cook" product. The second objective was to detect changes in volatile compounds from packaged minimally processed rutabaga, turnip and carrot.

MATERIALS AND METHODS

Sample preparation

Fresh rutabaga (*Brassica napus* ssp. *rapifera*), carrot (*Daucus carota*) and turnip (*Brassica rapa* ssp. *rapa*) were peeled with knife and hand peeler, washed and cut with a sharp knife into 1 cm cubes. 200g of the cut vegetables were separately weighted into trays.

Measuring and calculation of respiration rate

The closed system method was used to measure and calculate the respiration rate (Zhang et al. 2011); (Larsen et al. 2011). Cut vegetable cubes were packed in a 1500 ml high density polyethylene (HDPE) tray from Promens (Kristiansand, Norway), sealed with a barrier film, with ethylene vinyl alcohol (EVOH) as the barrier layer, from Wipak (Nastola, Finland). A Polimoon 511VG tray sealing machine from Promens (Kristiansand, Norway) was used to seal the film to the tray. The total OTR (oxygen transmission rate) of tray and film was measured by the ambient oxygen ingress method (Larsen et al. 2000) and was 0, 4 ml O_2/pkg x day at 4 °C and approximately 75 % RH (Larsen et al. 2011). The initial atmosphere inside the packages was air, and they were stored at 5 ºC or 10 ºC. O_2 and CO_2 concentrations were measured at relatively constant intervals by using a CheckMateII O_2/CO_2 -analyser from PBI-Dansensor (Ringsted, Denmark). A needle connected to the gas analyser was used to collect the atmosphere sample, and the samples were withdrawn through a rubber septum placed on the film.

O_2 and CO_2 concentrations inside the packages were measured periodically for 7 days, but only the first 8 measurements within 30 hours after packing were used to calculate the respiration rate. For the calculations, equations 1 and 2 given by Zhang et al. (2011) and Larsen et al. (2011) where used. C is the volumetric concentration of O_2 or CO_2 (decimal), t is the elapsed time (hours), V_f is the headspace inside the package (ml) and W is the mass of the vegetable inside the package (kg)

$$RO_2 = -\frac{\partial C_{O2}}{\partial t}\frac{V_f}{W} \qquad (1)$$

$$RCO_2 = \frac{\partial C_{CO2}}{\partial t}\frac{V_f}{W} \qquad (2)$$

V_f can be calculated by formula in equation 3, where V is the total volume of the sealed tray and ρ is the density of rutabaga (1.00 kg/dm^3), turnip (0.87 kg/dm^3) and carrot (1.00 kg/dm^3).

$$V_f = V - \frac{W}{\rho} \qquad (3)$$

Dynamic Headspace/GC-MS Analysis of Volatile Compounds

Samples for analyzing volatiles were taken after 0 days and 7 days for rutabaga and turnip, and after 0 and 10 days for carrot.

Volatile compounds were analyzed using a dynamic headspace method. Five g of the cubes were placed in a closable erlenmeyer flask (250 ml). Ethyl heptanoate (Sigma-Aldrich, Chemie GmbH, Steinheim, Germany) in methanol was injected into the flask as an internal standard. The flasks were placed in a water bath at 70 ºC, and purged with purified nitrogen at 100 mL/min for 20 min. Before injection, water was removed from the adsorber by N_2 flushing (100 mL/min) for 5 min in the opposite direction of sampling. Volatiles were trapped on an adsorbeer (Tenax GR), desorbed at 280 ºC for 5 minutes in a Markes Thermal Desorber and transferred to an Agilent 6890 GC with an Agilent 5973 Mass Selective Detector (El, 70eV). Volatile compounds were separated on a DB-WAXetr column (30 m, 0.25 mm i.d., 0.5 μm film) with a temperature program starting at 30 ºC for 10 min, increasing 1/min to 40 ºC, 3/min to 70 ºC, and 6.5/min to 230 ºC, hold time 5 min. The peaks were integrated and compounds tentatively identified with HP Chemstation software, NIST Mass Spectral Library. System performance was checked with blank samples before and after analysis.

RESULTS AND DISCUSSION

The change of O_2 concentration with time in the atmosphere inside the sealed trays containing cubed rutabaga, carrot or turnip is presented in Figure 1. It shows that carrot has a higher consumption rate of O_2 than turnip and rutabaga when stored at both 5 ºC and 10 ºC. A total depletion of O_2 in the tray containing carrot at 10 ºC can be seen after 90 hours.

The results from calculation of respiration rate, using O_2 and CO_2 concentrations inside the sealed trays, are presented in figure 2 and 3 respectively. It is shown in both Figure 2 and 3 that carrot has a higher respiration rate than turnip and rutabaga. Iqbal et al. (2008) examined respiration rate for whole, sliced, baton and shredded carrots. The respiration rate for the cubes in the present study was comparable and between sliced and baton carrots. The difference in respiration rates between rutabaga, carrot and turnip (Figs. 2 and 3) should be considered if combining these vegetables in a minimally processed product.

The changes in concentration of some selected volatile compounds from cubed rutabaga, carrot and turnip are presented in Table 1. It shows that the concentration of terpenes in carrot, and sulphur containing compounds in rutabaga and turnip decrease during storage. Both of these compound classes are sensory active. Table 1 also shows that the concentration of ethanol is higher in cubed carrots stored at 10 ºC, compared to the carrots stored at 5 ºC. Terpenes and sulphur containing compounds are sensorially active and a change in these compound classes can lead to sensory changes during storage. The increased concentration of ethanol could be an indication of anaerobic respiration. This can be related to the low O_2 concentration at the end of storage in the trays containing cubed carrots stored at 10 ºC (Fig 1).

CONCLUSION

If minimally processed rutabaga, carrot and turnip are packed together, a difference in respiration rate should be considered when choosing packaging material.

Analysis of volatiles could be used as a complement to sensory analysis in the determination of quality of minimally processed vegetables and should be tested later on in the project.

Literature Cited

Fonseca, S. C., F. A. R. Oliveira and J. K. Brecht (2002). Modelling respiration rate of fresh fruits and vegetables for modified atmosphere packages: a review. Journal of Food Engineering 52(2): 99-119.

Iqbal, T., F. A. S. Rodrigues, P. V. Mahajan, J. P. Kerry, L. Gil, M. C. Manso and L. M. Cunha (2008). Effect of Minimal Processing Conditions on Respiration Rate of Carrots. Journal of Food Science 73(8): E396-E402.

Larsen, H., A. Kohler and E. M. Magnus (2000). Ambient oxygen ingress rate method - An alternative method to ox-tron for measuring oxygen transmission rate of whole packages. Packaging Technology and Science 13(6): 233-241.

Larsen, H., A. Leufvèn and M. Høy (2011). Respiration Rate of Cubed Carrots (Daucus Carota) In Relation To Gas Transmission Rate through the Packaging Material. 25th IAPRI Symposium Berlin.

Lonchamp, J., C. Barry-Ryan and M. Devereux (2009). Identification of volatile quality markers of ready-to-use lettuce and cabbage. Food Research International 42(8): 1077-1086.

Zhang, Y., Q. Liu and C. Rempel (2011) Mathematical Modeling of Modified Atmosphere Packaging. p. 11-29 In A. L. Brody, H. Zhuang and J. H. Han (Eds.) Modified atmosphere packaging for fresh-cut fruits and vegetables. Wiley-Blackwell, Chichester.

Tables

Table 1. Changes of chosen volatiles in rutabaga, carrot and turnip stored at 5 ºC and 10 ºC, after 7 or 10 days.

Volatile compounds	Amount of volatiles (ng/ml headspace) from 5g of vegetable cubes				
	Day 0	Day 7, 5 ºC	Day 7 , 10 ºC	Day 10, 5 ºC	Day 10, 10 ºC
Carrot					
Ethanol	458	-	-	374	1106
Limonene	405	-	-	116	84
γ-terpinene	1789	-	-	739	699
Carene	2000	-	-	1034	644
Rutabaga					
Dimethyl disulfide	1266	334	427	-	-
Butyl isothiocyanate	603	260	175	-	-
Turnip					
Butyl isothiocyanate	1479	173	284	-	-
Ethyl methylthiazole	809	42	72	-	-

Figures

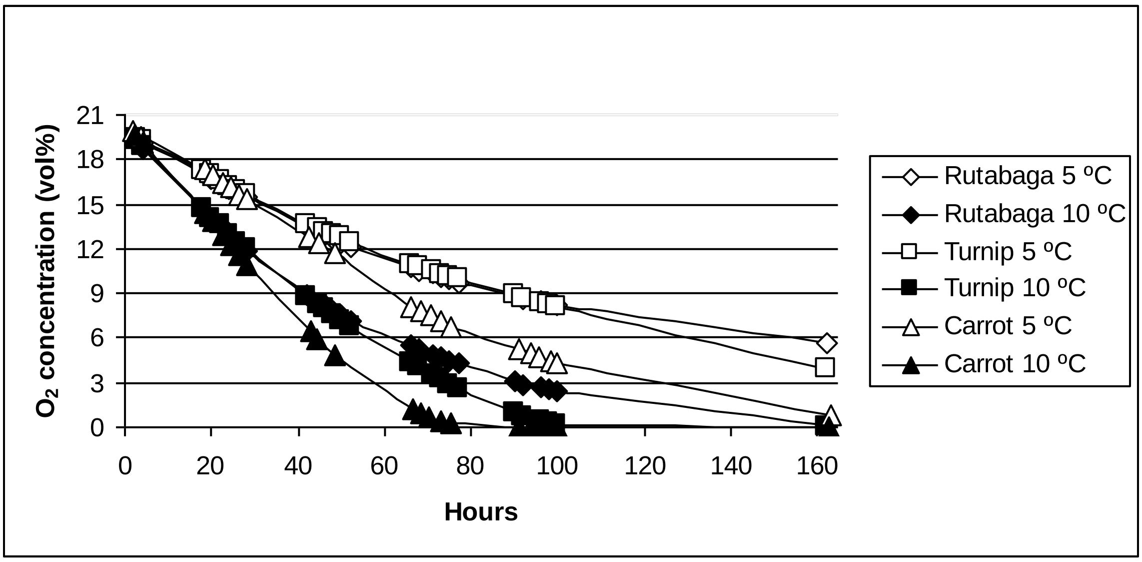

Fig. 1. Changes in O_2 concentration in the atmosphere of sealed trays containing cubed rutabaga, turnip or carrot stored at 5 ºC or 10 ºC.

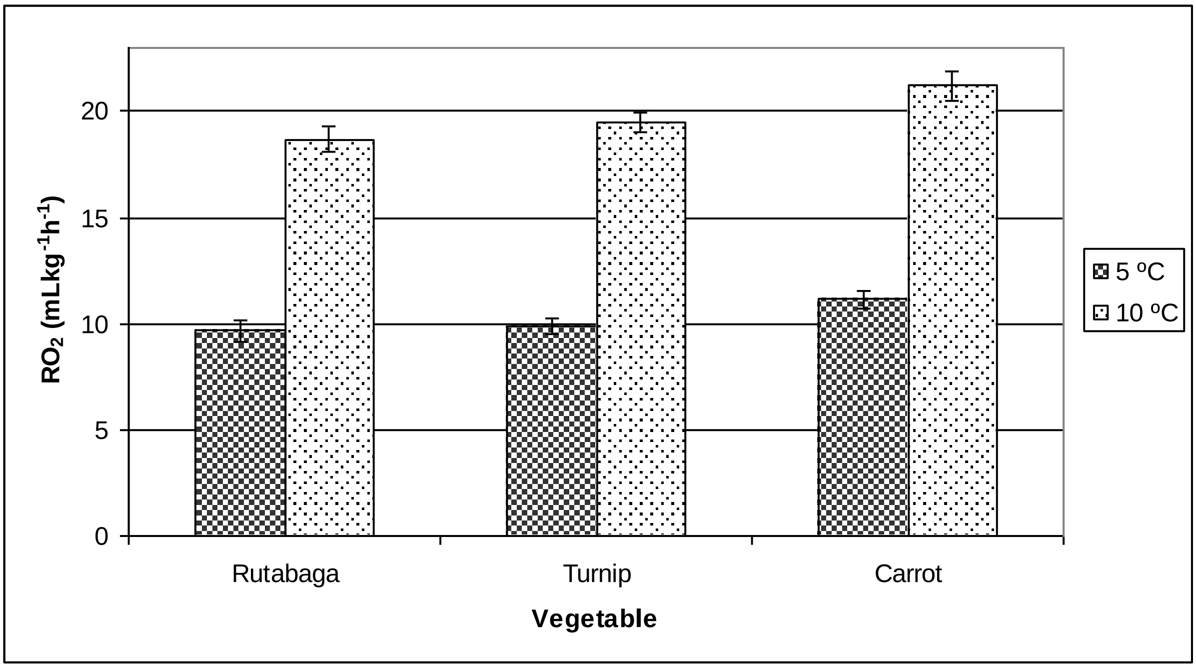

Fig. 2. O_2 consumption rate for cubed rutabaga, turnip and carrot stored at 5 ºC and 10 ºC in air.

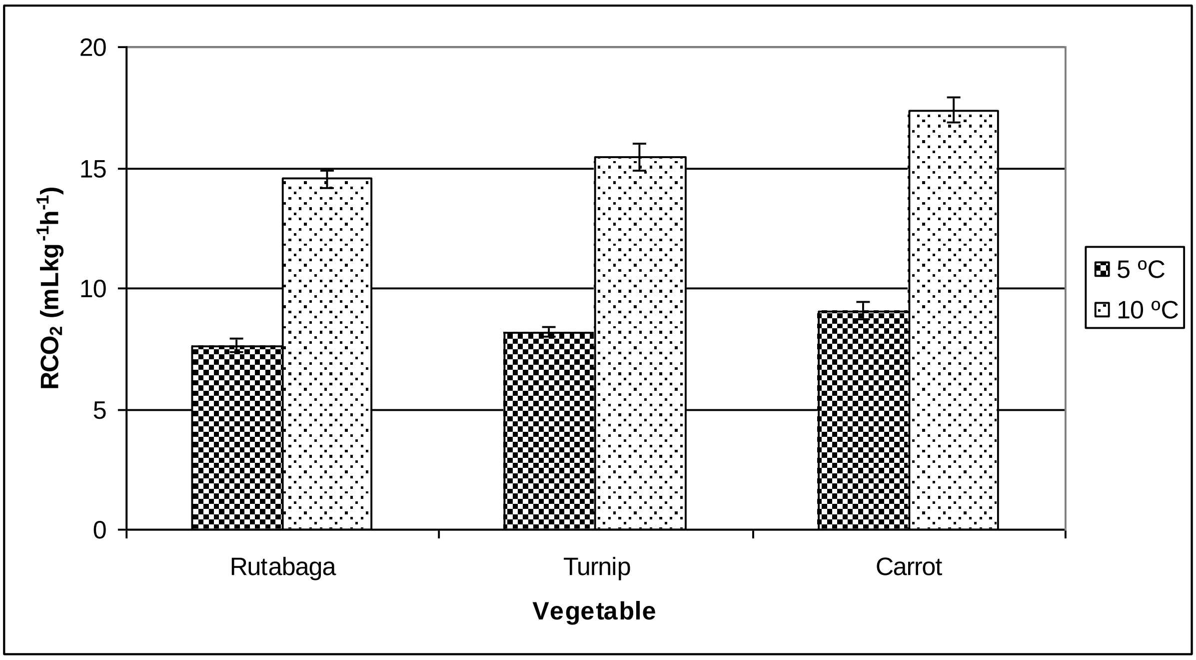

Fig. 3. CO_2 production rate in air for cubed rutabaga, turnip and carrot stored at 5 ºC and 10 ºC.