Kale (*Brassica oleracea* L. var. *acephala* DC) leaf water loss as affected by genotype and bagging

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Abstract

The aim of this study was to determine the effect of enclosing kale leaves in PE-bags on leaf weight loss, water loss rate and chlorophyll index in two kale genotypes (cv. ‘Red Russian’ and ‘Konavle 2’ which is a Croatian local population). The experiment was consisted of six replications with three leaves per treatment at room temperature (22°C; 50% RH) for five days. Non-bagged leaves of both genotypes, after 5 days, had more than 50%, while bagged leaves had only 17% of water loss. Water loss rate was higher in ‘Red Russian’ than in “Konavle 2” only in non-bagged leaves. Enclosing leaves in plastic bags reduced the rate of leaf water loss resulting in increased shelf life of kale leaves.

Key words: chlorophyll index, leaf gas exchange, room temperature

Introduction

Kale is a native of the eastern Mediterranean, where it has been grown and used in the diet for more than 2,000 years (Balkaya and Yanmaz, 2005; Lešić et. al., 2004). Although a somewhat forgotten vegetable, in recent years kale has had increasing popularity as a result its high nutritional properties (Batelja et. al., 2009). Health benefits of kale can be compared to those of cabbage and savoy (Lešić et. al., 2004). Kale has the second strongest antioxidant activity against peroxyl radicals among 22 common vegetables, including spinach, broccoli, carrot and potato (Cao et. al., 1996). Kale leaf contains more than 85% of water (Lešić et. al., 2004). It is highly perishable after harvest and cannot be kept for more than a few days under ambient conditions of 20-25°C (Imungi, 1992). Retention of leaf colour, freshness and turgidity are factors that determine market value of kale. Methods used to reduce postharvest losses include cooling, waxing and packaging (Elkashif et. al., 1983). Tulio et. al. (2002) reported that jute leaves stored in polyethylene bags can be stored for extended periods. The aim of this study was to determine the effect of bagging on leaf weight loss, water loss rate and chlorophyll index of two kale genotypes stored at room temperature.

Materials and methods

Greenhouse grown seedlings of two kale genotypes ['Red Russian’ (Johnny’s Selected Seeds, Winslow, Maine. USA) and Croatian local population ‘Konavle 2’] were planted in the field on 13 March 2011 at the Horticulture Farm, Univ. of Georgia, Tifton (31°28’N; 83°31’E), GA, USA.

Preharvest leaf gas exchange. Leaf gas exchange was measured in the field the day before harvest with a photosynthesis system (LI-6400, Li-Cor, Lincoln, NE, USA).

Postharvest leaf weight loss, water loss rate, and chlorophyll index. Six marketable leaves (fully expanded and free from damage) per each replication were harvested on 2 June 2011 between 8:00 and 8:30am, kept in an ice chest, and immediately transported to the laboratory.
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[Vegetable Growing Research Lab (VORL), Tifton, GA]. We used Clarke and McCaig (1982) procedure, with the following modifications. Leaf petioles were recut to have leaf petioles of about the same size. The experiment consisted of six replications with three leaves per treatment [(treatment = genotype (‘Konavle 2’ or ‘Red Russian’) x bagging (bagged or non-bagged)]. For the bagging, leaves were enclosed inside a 15 L volume polyethylene (PE) bag (Berry plastics corporation – Evansville, Indiana). Both bagged and non-bagged leaves were kept at room temperature (22°C; 50% RH) for five days. Leaf weight loss (WL) and water loss rate (WLR) were calculated by measuring daily changes in leaf fresh weight for five days, as follows:

\[
WL (%) = \frac{(W_0 - W_n)(W_0 \times 100)}{
WLR (%/day) = \frac{(W_0-W_n)((t)(W_0))*100}{(t_1)(W_0)}
\]

where \(W_0\)-initial weight, \(W_n\)-weight at period \(n\), \(t_n\)-time between two measurements.

Leaves were weighed at 0 (immediately after arrival to the laboratory), 5, 24, 48, 72, 96 and 120 h after harvest. On each weighing period, immediately after leaf weight determination, leaf chlorophyll index (an estimator of leaf greenness) was determined at four points on the upper one third of each leaf with a handheld chlorophyll meter (SPAD 502, Konica Minolta, Minolta Corp, Ramsey, N.J.). After the 5 day period, leaves were oven-dried at 75°C for 48 h to determine leaf dry weight.

**Statistical Analysis**

Data were analyzed by analysis of variance (ANOVA), using StatView statistical software (StatView for Windows; SAS Institute Inc. Copyright© 1992-1998; Version 5.0). Following a significant F-test, means were separated using the LSD-test at \(P \leq 0.05\).

**Results and discussion**

**Preharvest leaf gas exchange.** All leaf gas exchange factors: photosynthetic rate, stomatal conductance, intercellular CO₂ and transpiration were significantly higher in ‘Konavle 2’ than in ‘Red Russian’ (Table 1), probably because ‘Konavle 2’ is more tolerant to heat stress conditions compared to ‘Red Russian’. ‘Konavle 2’ has been selected by farmers for its tolerance to drought and poor soil conditions. On cabbage seedlings, Sato et al. (2004) were reported by that photosynthetic rate was lower in stressed than in non-stressed plants.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>A (μmol m⁻²s⁻¹)</th>
<th>gₛₜ (mol m⁻²s⁻¹)</th>
<th>Ci (μmol mol⁻¹)</th>
<th>E (mmol H₂O m⁻²s⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Konavle 2</td>
<td>33.6±1.55a</td>
<td>0.49±0.02</td>
<td>241.9±4.77</td>
<td>13.58±0.47</td>
</tr>
<tr>
<td>Red Russian</td>
<td>27.2±1.91</td>
<td>0.33±0.03</td>
<td>222.6±5.20</td>
<td>10.06±0.63</td>
</tr>
</tbody>
</table>

\(^a\) Values are presented as mean value ±SD (n =6).

**Postharvest leaf weight loss, water loss rate, and chlorophyll index.** Leaf weight loss was higher in unbagged than in bagged leaves (Fig. 1). By day 5, non-bagged leaves of both genotypes had more than 50% WL, while bagged leaves had only 17% WL. Leaf weight loss in non-bagged leaves was higher in 'Red Russian' than in 'Konavle 2'. There was no difference in WL between genotypes of bagged leaves. Our results are consistent with those of Elkashif et.al. (1983) showing that polyethylene film significantly reduced WL in broccoli.
Water loss rate declined with time after harvest (Fig. 2). This decline, however, was more accentuated in unbagged compared to bagged leaves, irrespective of genotype. A decreased WLR with increased time after harvest has also been reported in bell pepper (Díaz-Pérez et al., 2007). Water loss rate showed significant genotype x bagging interaction. WLR was higher in ‘Red Russian’ than in ‘Konavle 2’ only in non-bagged leaves. Although ‘Red Russian’ leaves had significantly lower stomatal conductance and transpiration than ‘Konavle 2’, ‘Konavle 2’ probably acclimated better to suboptimal conditions. Denna (1970) found that most of water loss in cabbage leaves in daytime experiments was through stomatal transpiration. Increased WLR of ‘Red Russian’ might be result of poor adaptation traits including slower closing of stomata in the first 24 h after harvest. Dahanda and Sethi (1998) report that genotype-environment interactions significantly affected excised-leaf water loss in bread wheat. The increased WLR of ‘Red Russian’ may also be attributed to an increased leaf cuticular conductance.

Chlorophyll index remained about constant for the first 48 h after harvest and then decreased with time after harvest in all treatments (Fig. 3), which is consistent with the observed decreased leaf greenness (increased yellowing) with time after harvest. A similar decreased greenness after 48 h was reported by Pogson and Morris (1997) in broccoli. In unbagged leaves, CI was higher for ‘Red Russian’ than for ‘Konavle 2’. In contrast, in bagged leaves, ‘Red Russian’ showed a decreased CI compared to all the other treatments. This decreased CI in unbagged leaves of ‘Red Russian’ was possibly caused by an increased ethylene concentration inside the bag and suggests that the two genotypes differ in sensitivity to ethylene.
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Graph 2. Postharvest leaf water loss rate (% day\(^{-1}\)) of kale genotypes Konavle 2 and Red Russian as affected by leaf bagging at room temperature (temperature = 22°C; RH 50%). Vertical bar indicates mean ±1 SE.

Graph 3. Chlorophyll index concentration of kale genotypes Konavle 2 and Red Russian as affected by bagging at room temperature (temperature = 22°C; RH 50%) in Tifton GA. Vertical bar indicates mean ±1 SE.

Conclusions

Kale showed a high water loss rate and loss of greenness at room temperature. Kale genotypes differed in rates of leaf water loss and greenness after harvest. Enclosing leaves in plastic bags reduced the rate of leaf water loss resulting in increased shelf life of kale leaves.
Acknowledgements

This paper was done as part of the project "Croatia Agriculture Research and Education Exchange" funded by the USDA ISE (Grant: 2009-51160-05465).

References


