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Results regarding behaviour of some small fruits under controlled atmosphere conditions

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Abstract

The marketing of excessively perishable small fruits is very important for all the actors on the market channel, but also for consumers. Raspberries, red and black currants, and blackberries are fruits with limited storage life. The preserving of fruits firmness, flavour, aroma, colour and brightness during the storage is given by the level of some biochemical components. The objective of this research was to study the response of small fruits from different cultivars of raspberry, currant, and blackberry after the storage period under controlled atmosphere conditions. The content of some biochemical components of fruits, respectively total solids, total sugar, and total acidity, were measured and compared at the moment of harvesting and after the storage period. For the organoleptic assessment of fruit quality, there have been analyzed fruits aroma, taste, and attractiveness. The storage period under the controlled atmosphere conditions determined: a decrease of total solids and total sugar at currant, raspberry and blackberry; a decrease of total acidity at cultivars of currant and blackberry, while at cultivars of raspberry it was increased; a decrease of aroma and taste characteristics.

Keywords: *raspberry, currant, blackberry, biochemical components, fruit quality.*

Introduction

Common cultivated small fruits include raspberries (*Rubus idaeus*), currants (*Ribes sativum*), blackberries (*Rubus* spp.), but also blueberries (*Vaccinium* spp.), strawberries (*Fragaria x ananassa*), kiwi (*Actinidia* spp.), and gooseberries (*Ribes* spp.). All these fruits species are precious due to their health properties and their unique flavour, taste, colour and appearance. Small fruits have a short postharvest life, but also a short shelf life. The ripening moment of the small fruits should be according to quality standards concerning fruit maturity stage, firmness, taste, aspect and size. The optimal level of quality components is the most important aspect in increasing shelf life in the process of storage.

The loss of small fruits on channel from harvest to the consumer's table is more than 45%. A percent of about 14% loss is registered from farmer to wholesaler, about 6% loss is registered from wholesaler to retailer, and about 22% is registered between retailer and consumer. Moreover, the losses are caused by the lack of good handling during the harvest process and also after the harvest process.

Producer’s difficulties associated with rapid postharvest deterioration of many small fruits, have demanded in the last 50 years researches and studies concerning the applicability of controlled atmosphere (CA) storage, but only over the last 20 years these researches were conducted more intensively (TERRY and JOYCE al. [1]).

The researches concerning CA or MAP (modified atmosphere package) of small fruits have shown that the shelf-life keeping biochemical and taste quality are significantly extended.

Small fruits express a relatively tolerance of increased concentration of carbon dioxide (CO_2) and decreased concentration of oxygen (O_2). CA storage of small fruits has shown an increasing of storage life caused by decreasing of respiration rate, inhibition of development for specific storage diseases like gray mold, and preserving of small fruits firmness. In reverse, erroneously control of CA storage parameters (duration, carbon dioxide concentration and decreased oxygen concentration), can induce negative effects in fruits quality (flavour, taste, texture, nutrient value).

The use of the CA for conservation of small fruits, increase the possibilities to extend the postharvest life and the shelf life, but also to preserve the nutritional value. Using CA properly, it can preserve small fruits quality by maintaining the concentration and integrity of flavour and taste (SIRO & al. [2]; ZHENG & al. [3]).

The demand of fresh small fruits on the fresh fruits market is increasing in the last few years. That is the reason why it will be useful to identify new solutions for extending postharvest life and also shelf life for fresh small fruits.

The researches concerning the storage of raspberry, currants, blackberry or gooseberry, in CA conditions, was relatively reduced compared to strawberry fruits. The results obtained on CA storage of small fruits was used for increasing postharvest life of blackberry and raspberry fruits in a similar way to strawberry fruit (JOLES & al. [4]; AGAR & al. [5]; HAFFNER & al. [6]; VAN DER STEEN & al. [7]).

Alternative controlled atmosphere treatments applied at strawberry fruits, like ozone (BARTH, [8]) or super atmospheric oxygen (SIRO & at. [2]; VAN DER STERN [7]) have been studied in order to inhibit postharvest diseases of small fruits (raspberry, other berries). If the small fruits samples were placed in CA conditions, at 20^{o}C for 2 days, fruits showed less decay. According to AGAR & al. ([9]), CA conditions were not adequate for some berry fruits species. CA determines some specific effects on ascorbic acid which tended to decrease at high level of CO_2. High levels of CO_2 may reduce total ascorbic acid content on blackberries and blackcurrant.

Therefore, the aim of researches that conducted to the elaboration of the present paper was to study the response of small fruits from different cultivars of raspberry, currant, and blackberry after the storage period under controlled atmosphere conditions, by determining and comparing some chemical (total sugar, total acidity and total solids) and organoleptic parameters (attractiveness, aroma, taste and transportability).

Material and Methods

Three species of small fruits and three cultivars for each species were the source of the experiment samples, respectively: raspberry with cultivars Glen Moy, Veten, and Willamette; black currant with the cultivar Geo and red currant with cultivars Roşu Timpuriu and Jonkheer van Tets; blackberry with cultivars Darrow, Lockness, and Arapaho. All the species and cultivars were cultivated in the experimental fields belonging to the Research Institute for Fruit Production Piteşti, Romania.

The small fruits were harvested in the summer of 2008 and 2009, at the commercial maturity stage for each species and cultivar. The maturity stage for fresh small fruits is generally appreciated by fruit colour, fruit gloss, fruits firmness, content of soluble solids, and acidity.

The right moment of harvesting the small fruits for fresh storage is one of the most important factors which can influence the postharvest life or shelf-life. Postharvest technologists appreciate that the maturity stage should be "that stage at which a product has reached a sufficient stage of development that after harvesting and postharvest handling (including ripening, where required), its quality will be at least the minimum acceptable to the ultimate consumer" (REID [10]).

The ripening stage of raspberry has a major effect on the fresh fruit quality concerning colour, sweetness, flavour and aroma. As the fruits firmness decrease with the maturity increasing, raspberry were harvested at the stage *earlier than ripe-red*, when the sugar content was higher and the acidity was lower (WANG and LIN [11]).

Red currants were harvested before the skin bright changed and when the content of soluble solids was of 7.4-11.0% and the acidity was approximately 2% (PANTELIDIS & al. [12]).

Black currants were harvested when the skin was very dark blue and the soluble solids were between 13.5 and 26.0% and acidity attains 3.0-4.8% (KIKAS & al. [13]; PLUTA and ZURAWICZ [14]). Fruits with uniform colour, size, ripeness and free from injury or defect were used for this study.

The blackberries fruits were harvested at the stage when they were pulled easily from the receptacle, being firm.

The small fruits from all species were harvested manually, directly in little plastic bags (250 g capacity). The samples were placed in mobile refrigerating boxes immediately after harvesting and transferred into the biochemical laboratory. The fruit samples were placed under controlled atmosphere conditions (4% CO_2), in their little plastic bags. The storage period was established according to species, respectively 13 days for raspberry varieties, 30 days for currant varieties, and 20 days for blackberry varieties.

The total solids content, total acidity and total sugar were determined at harvest moment and at the end of the storage period. In order to appreciate the fresh fruits quality before and after the storage period, there were made chemical analysis and sensorial assessments for each sample.

The total solids content of fresh perishable fruits after harvest and after the storage period, measured in percent, was made with ABBE refractometer.

The total acidity after harvest and after storage period for each sample was determined using volumetric method, and it was expressed in percent.

The total sugar content, measured in percent, was made using Bertrand’s method.

Organoleptic assessments concerning fruit quality on samples were realised in accordance with UPOV guidelines for raspberry, currant and blackberry (UPOV, [15][16][17]. Concerning the organoleptic evaluation in order to have the mean values of some qualitative parameters, there was used the method of sensory taste with positive points. The parameters which have been analyzed were the following: fruits taste and attractiveness (6 points maximal) and aroma (4 points maximal), as well as the transportability (pointed with 3-5-7 points where 3 means low transportability, 5 means medium transportability, and 7 means high transportability).

Results and Discussions

Total solids as average values for the two experimental years (2008 and 2009), measured after harvesting (Table 1), varied according to variety between 9.75 and 11.20% for raspberry, with an average value for all the three cultivars and the two experimental years of 10.53%. For currant, the total solids varied between 13.22 and 18.29%, with an average value

for all the three cultivars and the two experimental years of 15.15%. For blackberry, the total solids varied between 11.00 and 16.11%, with an average value for all the three cultivars and the two experimental years of 13.8%. The highest values for total solids were registered at currant cultivar Geo (18.29% in average for the two experimental years), while the smallest values were registered at raspberry cultivar Veten (9.75% in average for the two experimental years). Among the three analysed species, the raspberry has the smallest content in total solids.

After the storage period under the controlled atmosphere conditions, the total solids registered smaller values for all the species and cultivars taken into analyse.

Thus, for raspberry, the total solids after 13 days of storage under controlled atmosphere conditions varied between 7.85 and 8.95%, with an average value for all the three cultivars and the two experimental years of 8.27%. Compared to the content of total solids after harvesting, the content of total solids after storage under controlled atmosphere conditions represented an average percentage of 78.54%.

For currant, the total solids after 30 days of storage under controlled atmosphere conditions varied between 11.39 and 17.85%, with an average value for all the three cultivars and the two experimental years of 13.9%. Compared to the content of total solids after harvesting, the content of total solids after storage under controlled atmosphere conditions represented an average percentage of 91.75%.

For blackberry, the total solids after 20 days of storage under controlled atmosphere conditions varied between 7.88 and 13.17%, with an average value for all the three cultivars and the two experimental years of 11.96%. Compared to the content of total solids after harvesting, the content of total solids after storage under controlled atmosphere conditions represented an average percentage of 78.88%.

Table 1. Results concerning the total solids at the analysed small fruits (average values for 2008 and 2009)

Species	Variety	Total solids after harvesting (%)	Total solids after storage* under the controlled atmosphere conditions (%)	Average percentage** after storage (%)
Raspberry	Glen Moy	*11.20*	*8.95*	*79.91*
	Veten	*9.75*	*7.85*	*80.51*
	Willamette	*10.65*	*8.00*	*75.12*
	Average	***10.53***	***8.27***	***78.54***
Currant	Roşu timpuriu	*13.95*	*12.47*	*89.39*
	Geo	*18.29*	*17.85*	*97.59*
	Jonkheer van Tets	*13.22*	*11.39*	*86.16*
	Average	***15.15***	***13.90***	***91.75***
Blackberry	Darrow	*11.00*	*7.88*	*71.64*
	Lochness	*14.28*	*11.89*	*83.26*
	Arapaho	*16.11*	*13,17*	*81,75*
	Average	***13.80***	***11.96***	***78.88***

* No of storage days was 13 for raspberry varieties, 30 for currant varieties, and 20 for blackberry varieties.
** Average percentage of total solids after storage under modified atmosphere conditions compared to the content of total solids after harvesting.

Total acidity as average values for the two experimental years (2008 and 2009), measured after harvesting (Table 2), varied according to variety between 0.34 and 0.61% for raspberry, with an average value for all the three cultivars and the two experimental years of 0.57%. For currant, the total acidity varied between 4.23 and 5.20%, with an average value for all the three cultivars and the two experimental years of 4.63%. For blackberry, the total acidity varied between 0.59 and 1.07%, with an average value for all the three cultivars and the two experimental years of 0.86%. The highest values for total acidity were registered at currant cultivars, while the smallest values were registered at raspberry cultivars. It has to be

underlined the fact that the high content in total solids at currant is associated with a high value for total acidity, while the small content in total solids at raspberry is associated with a small value for total acidity.

After the storage period under the controlled atmosphere conditions, the total acidity decreased at the cultivars of currant and blackberry and it increased at the cultivars of raspberry.

For raspberry, the total acidity after 13 days of storage under modified atmosphere conditions varied between 0.57 and 0.80%, with an average value for all the three cultivars and the two experimental years of 0.69%. Compared to the content of total acidity after harvesting, the content of total acidity after storage under controlled atmosphere conditions represented an average percentage of 135.29%.

For currant, the total acidity after 30 days of storage under controlled atmosphere conditions varied between 2.10 and 3.36%, with an average value for all the three cultivars and the two experimental years of 2.55%. Compared to the content of total acidity after harvesting, the content of total acidity after storage under controlled atmosphere conditions represented an average percentage of 55.07%.

For blackberry, the total acidity after 20 days of storage under controlled atmosphere conditions varied between 0.51 and 0.83%, with an average value for all the three cultivars and the two experimental years of 0.65%. Compared to the content of total acidity after harvesting, the content of total acidity after storage under controlled atmosphere conditions represented an average percentage of 75.58%.

Table 2. Results concerning the total acidity at the analysed small fruits (average values for 2008 and 2009)

Species	Variety	Total acidity after harvesting (%)	Total acidity after storage* under the controlled atmosphere conditions (%)	Average percentage** after storage (%)
Raspberry	Glen Moy	*0.34*	*0.57*	*167.65*
	Veten	*0.61*	*0.80*	*131.15*
	Willamette	*0.60*	*0.70*	*116.67*
	Average	***0.57***	***0.69***	***135.29***
Currant	Roşu timpuriu	*4.23*	*2.10*	*49.64*
	Geo	*5.20*	*3.36*	*64.61*
	Jonkheer van Tets	*4.45*	*2.19*	*49.21*
	Average	***4.63***	***2.55***	***55.07***
Blackberry	Darrow	*0.91*	*0.62*	*68.13*
	Lochness	*1.07*	*0.83*	*77.57*
	Arapaho	*0.59*	*0.51*	*86.44*
	Average	***0.86***	***0.65***	***75.58***

* No of storage days was 13 for raspberry varieties, 30 for currant varieties, and 20 for blackberry varieties.

** Average percentage of total acidity after storage under modified atmosphere conditions compared to the content of total solids after harvesting.

Total sugar as average values for the two experimental years (2008 and 2009), measured after harvesting (Table 3), varied according to variety between 3.97 and 4.80% for raspberry, with an average value for all the three cultivars and the two experimental years of 4.51%. For currant, the total sugar varied between 5.07 and 6.00%, with an average value for all the three cultivars and the two experimental years of 5.63%. For blackberry, the total sugar varied between 4.56 and 11.64%, with an average value for all the three cultivars and the two experimental years of 8.75%. The highest values for total sugar were registered at blackberry cultivars, while the smallest values were registered at raspberry cultivars. It has to be underlined the fact that the high content in total solids is associated with a high value for total sugar, while the small content in total solids is associated with a small value for total sugar.

After the storage period under the controlled atmosphere conditions, the total sugar registered smaller values for all the species and cultivars taken into analyse.

For raspberry, the total sugar after 13 days of storage under controlled atmosphere conditions varied between 2.30 and 4.21%, with an average value for all the three cultivars and the two experimental years of 3.31%. Compared to the content of total sugar after harvesting, the content of total sugar after storage under controlled atmosphere conditions represented an average percentage of 73.39%.

For currant, the total sugar after 30 days of storage under controlled atmosphere conditions varied between 4.27 and 5.43%, with an average value for all the three cultivars and the two experimental years of 4.70%. Compared to the content of total sugar after harvesting, the content of total sugar after storage under controlled atmosphere conditions represented an average percentage of 83.48%.

For blackberry, the total sugar after 20 days of storage under controlled atmosphere conditions varied between 4.01 and 7.11%, with an average value for all the three cultivars and the two experimental years of 5.36%. Compared to the content of total sugar after harvesting, the content of total sugar after storage under controlled atmosphere conditions represented an average percentage of 61.26%.

Table 3. Results concerning the total sugar, at the analysed small fruits (average values for 2008 and 2009)

Species	Variety	Total sugar after harvesting (%)	Total sugar after storage* under the controlled atmosphere conditions (%)	Average percentage** after storage (%)
Raspberry	Glen Moy	*4.80*	*4.21*	*87.71*
	Veten	*4.75*	*2.30*	*48.42*
	Willamette	*3.97*	*3.43*	*86.40*
	Average	***4.51***	***3.31***	***73.39***
Currant	Roşu timpuriu	*6.00*	*4.27*	*71.17*
	Geo	*5.81*	*5.43*	*93.46*
	Jonkheer van Tets	*5.07*	*4.40*	*86.78*
	Average	***5.63***	***4.70***	***83.48***
Blackberry	Darrow	*4.56*	*4.01*	*87.94*
	Lochness	*11.04*	*7.11*	*64.40*
	Arapaho	*10.64*	*4.95*	*46.52*
	Average	***8.75***	***5.36***	***61.26***

* No of storage days was 13 for raspberry varieties, 30 for currant varieties, and 20 for blackberry varieties.
** Average percentage of total sugar after storage under modified atmosphere conditions compared to the content of total solids after harvesting.

The most important decrease in the content of total sugar after the period of storage under controlled atmosphere conditions was registered at blackberry cultivars, while at currant cultivars was register the less important decrease in the content of total sugar.

Fruits quality parameters (Table 4), as average values for the two experimental years (2008 and 2009), determined after the storage period under the controlled atmosphere conditions registered the following values: the attractiveness was in average of 4.2 points at raspberry, 4.3 points at currant, and 4.8 points at blackberry; the aroma was in average of 2.8 points at raspberry, 2.2 points at currant, and 2.8 points at blackberry; the taste was in average of 4.0 points at raspberry, 4.0 points at currant, and 4.5 points at blackberry.

After the storage period under the controlled atmosphere conditions, the transportability (Table 5) was in average of 5.0 points at raspberry, 4.8 points at currant, and 5.2 points at blackberry.

Table 4. Results concerning the fruit quality parameters determined after the storage period* under the controlled atmosphere conditions, at the analysed small fruits (average values for 2008 and 2009)

Species	Variety	Attractiveness (1-6)	Aroma (1-4)	Taste (1-6)
Raspberry	Glen Moy	*4.5*	*3.0*	*4.5*
	Veten	*3.5*	*3.0*	*4.0*
	Willamette	*4.5*	*2.5*	*3.5*
	Average	***4.2***	***2.8***	***4.0***
Currant	Roşu timpuriu	*3.5*	*2.0*	*3.5*
	Geo	*5.0*	*2.0*	*4.5*
	Jonkheer van Tets	*4.5*	*2.5*	*4.0*
	Average	***4.3***	***2.2***	***4.0***
Blackberry	Darrow	*4.5*	*3.0*	*4.5*
	Lochness	*5.5*	*2.0*	*4.5*
	Arapaho	*4.5*	*3.5*	*4.5*
	Average	***4.8***	***2.8***	***4.5***

* No of storage days was 13 for raspberry varieties, 30 for currant varieties, and 20 for blackberry varieties.

Table 5. Results concerning the fruit transportability after the storage period under the controlled atmosphere conditions at the analysed small fruits (average values for 2008 and 2009)

Species	Variety	Transportability (3-5-7)
Raspberry	Glen Moy	*5.5*
	Veten	*5.0*
	Willamette	*4.5*
	Average	***5.0***
Currant	Roşu timpuriu	*4.5*
	Geo	*5.0*
	Jonkheer van Tets	*5.0*
	Average	***4.8***
Blackberry	Darrow	*5.5*
	Lochness	*4.5*
	Arapaho	*5.5*
	Average	***5.2***

Conclusions

The storage period under the controlled atmosphere conditions determined a decreasing of the total solids and total sugar at currant, raspberry and blackberry, while the total acidity decreased at the cultivars of currant and blackberry and increased at the cultivars of raspberry.

The high content in total solids is associated with a high value for total sugar, while the small content in total solids is associated with a small value for total sugar.

Compared to raspberry and blackberry, currant registered the highest values for total acidity. The high content in total solids at currant is associated with a high value for total acidity.

The storage period under the controlled atmosphere conditions (4% CO_2) affected the most aroma and taste, and then attractiveness.

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